Enhance Your Learning

Michael R. Melloch
School of Electrical and Computer Engineering
Purdue University

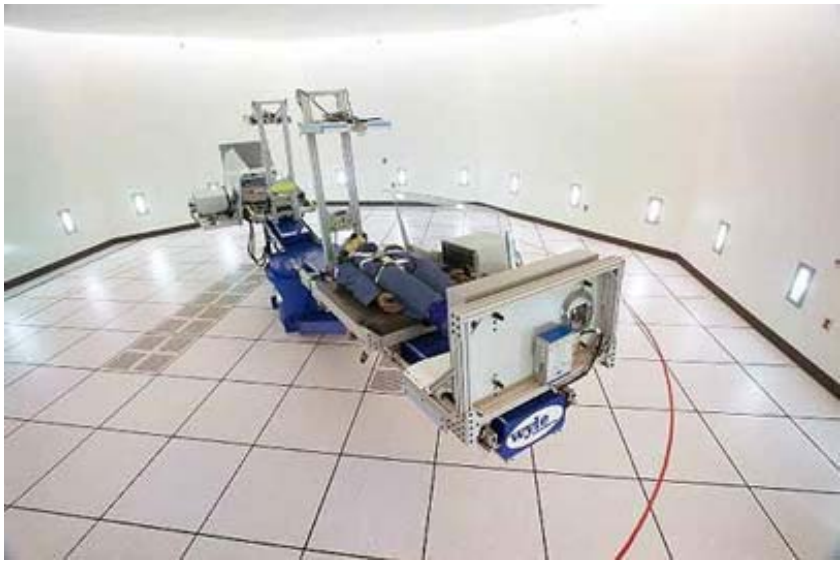
Office EE 122D
Email: melloch@purdue.edu
Phone: 49-43543

What is Learning?

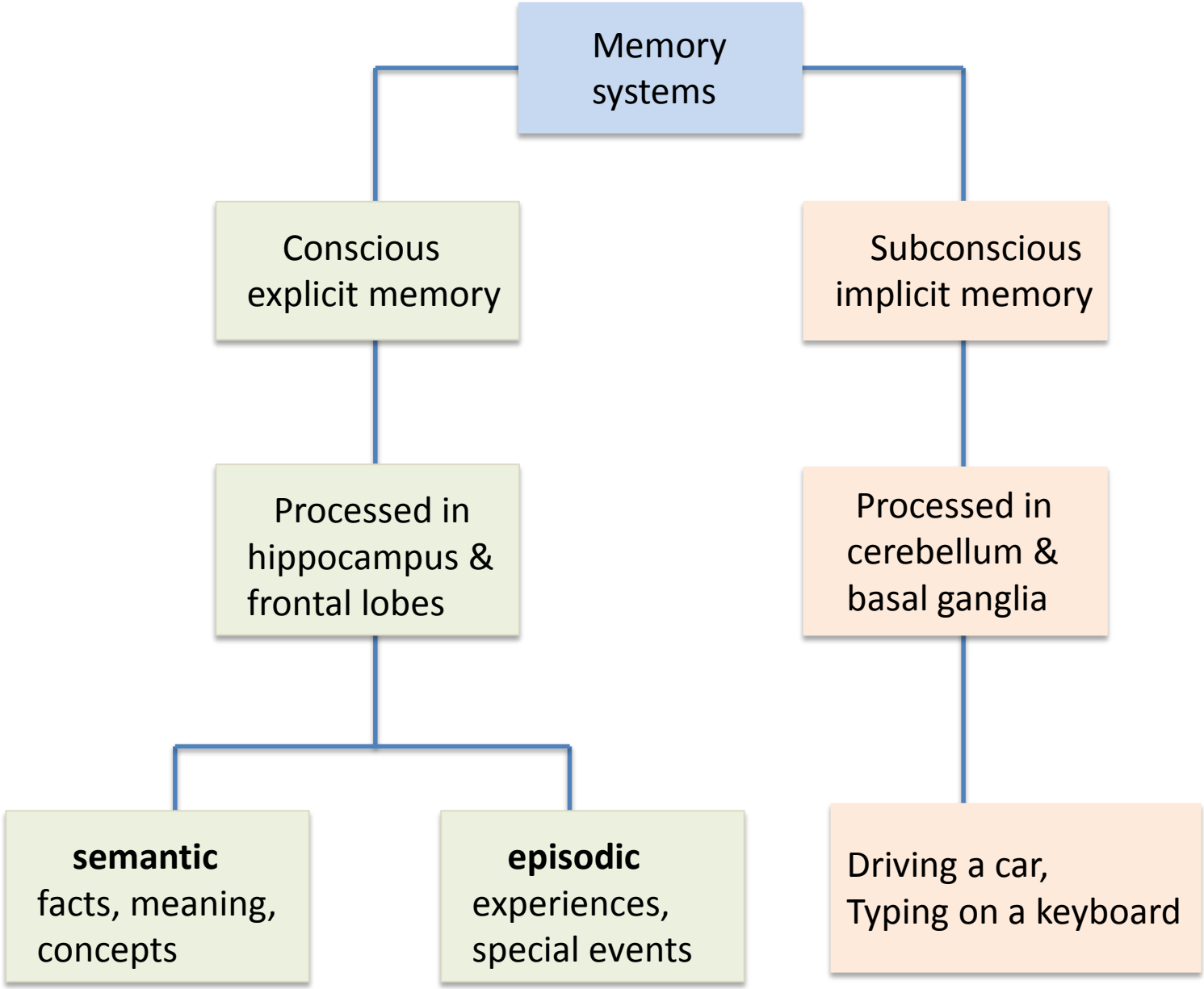
"Acquiring knowledge and skills and having them readily available from memory so you can make sense of future problems and opportunities," from *Make it Stick.*

Human Brain

- 2% of the body weight
- Uses 20% of the body's glucose & oxygen
  - 1/3 for cell health maintenance
  - 2/3 for neuron activity
- Cut off energy supply and the brain stops functioning in 10 seconds



Memory


Memory systems
Conscious explicit memory
Subconscious implicit memory
Processed in hippocampus & frontal lobes
Processed in cerebellum & basal ganglia
semantic facts, meaning, concepts
episodic experiences, special events
Driving a car, Typing on a keyboard

Patient H.M., Henry Molaison

Two Memory Systems in the Brain (Brenda Milner)

- Conscious, explicit memory

  Hippocampus is important for explicit memory and memory Consolidation. Remove the hippocampus and no more adding to long-term memory

- Subconscious, procedural memory

  how to ride a bike

Milner B. In: Physiologie de l'hippocampe. Passouant P, editor. Centre National de la Recherche Scientifique; Paris: 1962. pp. 257–272


WIDESCREEN SPECIAL EDITION
ADAM SANDLER
DREW BARRYMORE
50 FIRST DATES
The ultimate bachelor will face the ultimate challenge.
DVD

At Least Two Memory Systems in the Brain (Brenda Milner)

- Conscious, explicit memory

  Hippocampus is important for explicit memory and memory Consolidation. Remove the hippocampus and no more adding to long-term memory

- Subconscious, procedural memory

  how to ride a bike

Milner B. In: Physiologie de l'hippocampe. Passouant P, editor. Centre National de la Recherche Scientifique; Paris: 1962. pp. 257–272

Spaced versus Massed

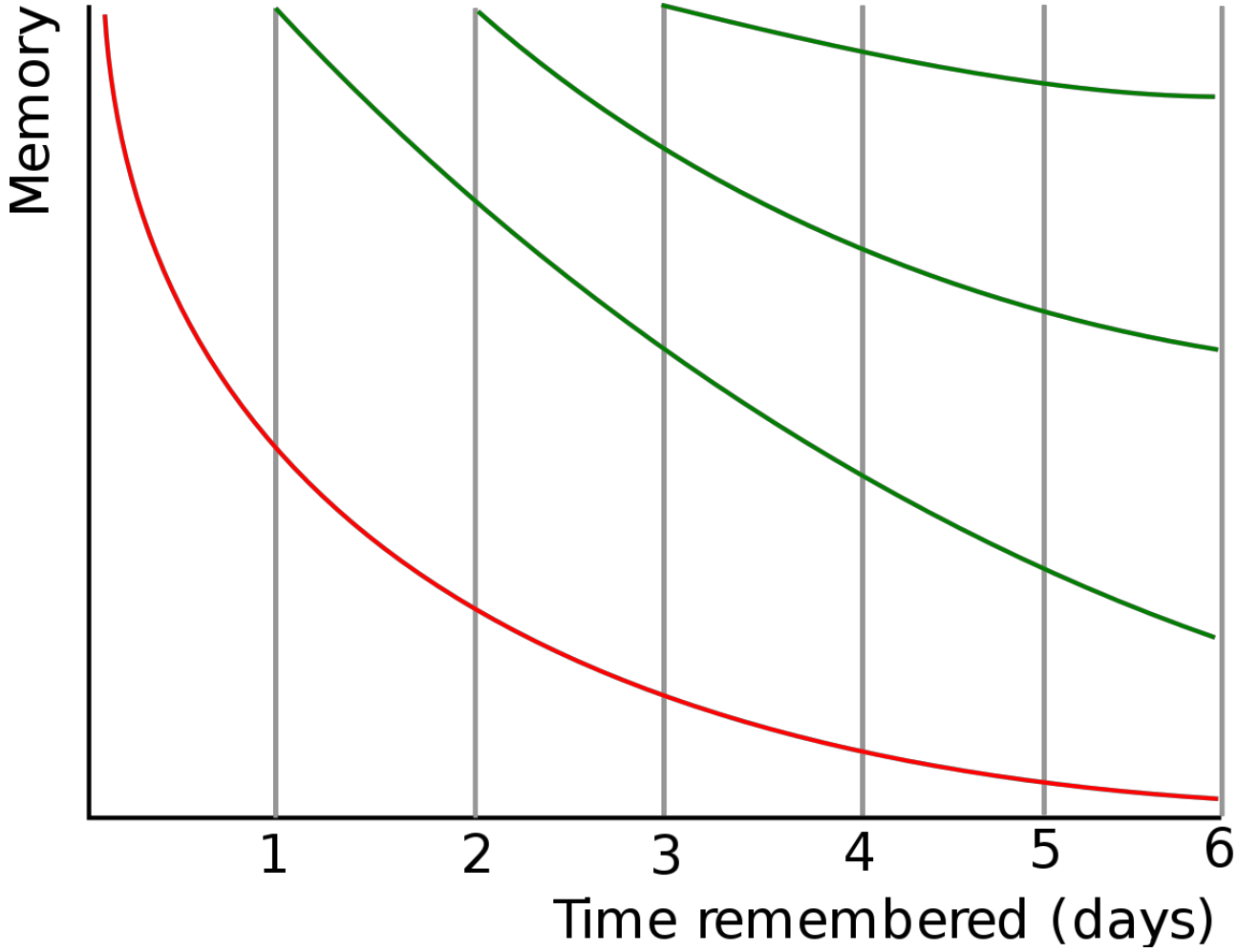
The Forgetting Curve

- Hermann Ebinghaus 1885
- Experiment

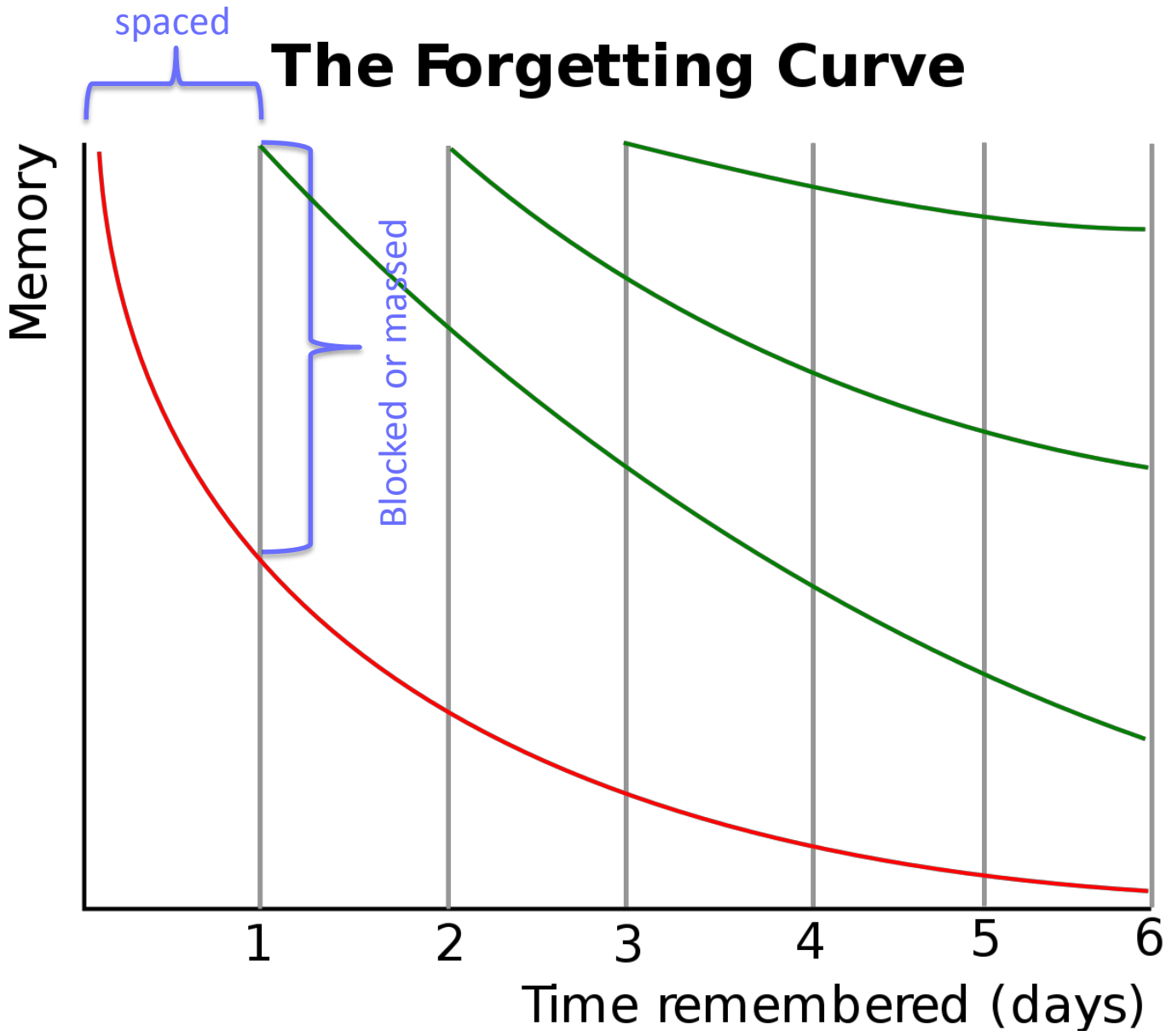
  Memorize a list of nonsense syllables

  “WID” “ZOF” “MOT”
- Check how many are remembered after 1-day, 2-days, 3-days, ….
- Retrievability = $e^{-t/\tau}$

The Forgetting Curve



Discovered by Hermann Ebbinghaus in 1885



Some forgetting makes the retrieval harder, which leads to stronger learning

What is forgetting?

Memory has disappeared

or

Memory is still there but retrieval is harder

New Theory of Disuse

- Unlimited storage capacity
- Once entrenched the memory remains there
- Retrieval capacity is severely limited
- Retrieval strength fades with disuse no matter how well learned/entrenched
- We need current info most assessible.

Bjork, R. A., & Bjork, E. L. (1992). A new theory of disuse and an old theory of stimulus fluctuation. In A. Healy, S. Kosslyn, & R. Shiffrin (Eds.), *From learning processes to cognitive processes: Essays in honor of William K. Estes.* (Vol. 2, pp. 35– 67). Hillsdale, NJ: Erlbaum

Easy to see memory is still there even if you cannot retrieve it

- Cannot recall your grade school friends name.
- Shown a list of four names you can pick it out.

- Memory, focus and will-power are functions of the brain like strength is a function of a muscle
- You don’t lift weights indefinitely till you are strong
- Some forgetting is like muscle breakdown
- Rapid gains from blocked practice is evident, but the rapid forgetting is not

“Cramming seems to stamp things in by intense application before the ordeal. But a thing thus learned can form few associations. On the other hand, the same thing recurring on different days in different contexts, read, recited, referred to again and again, related to other things and reviewed, gets well wrought into the mental structure.”

William James in his 1901 book, Talks to Teachers on Psychology and to Students on Some of Life’s Ideals

Determining the number of permutations

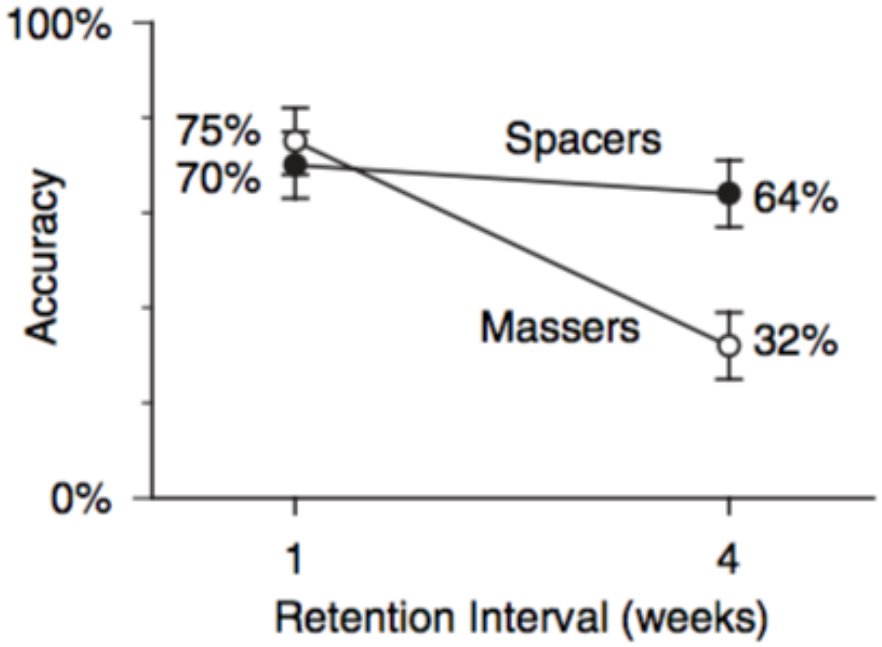
- abbbcc has 60 permutations, abbcbc, abcbcb, bbacbc, …..
- UGs would not know how to do this
- Each student was randomly assigned to one of four groups
- Spacers with 1-week and 4-week RIs (Retention intervals)
- Massers with 1-week and 4-week RIs

Spacers received a tutorial at start of session one and massers at start of session two

A Practice Schedule

	session one	1 week apart	session two
Spacers	5 problems		5 problems
Massers			10 problems

B Test Results



Doug Rohrer and Kelli Taylor, "The Effects of Overlearning and Distributed Practise on the Retention of Mathematics Knowledge," Appl. Cognit. Psychol. 20: 1209–1224 (2006)

38 Surgical Residents Learning Microsurgery

- Each randomly assigned to one of two groups
- Series of 4 short lessons in microsurgery
- Group 1 completed all 4 lessons in one day, common teaching practice
- Group 2 had each lesson spaced by a week

C-A. E. Moulton, A. Dubrowski, H. MacRae, B. Graham, E. Grober, & R. Reznick, Teaching surgical skills: What kind of practice makes perfect?, Annals of Surgery 244 (2006), 400–409.

Tested One Month After Last Lesson
Reattaching the pulsating, severed aortas of rats

- The blocked group scored lower on all measures than the spacers—elapsed time, number of hand movements, and overall surgery success
- 16% of blocked learners damaged the aortas beyond repair

Where you study

Recall More in Study Environment

- 18 scuba divers studied 36 words submerged at 20 feet
- One hour later they took a test

  9 on land

  9 submerged at 20 feet
- Those underwater remembered 30% more words

D.R. Godden and A.D. Baddeley, "Context-Dependent Memory in Two Natural Environments: On Land and Underwater," British Journal of Psychology, 1975 page 325.

- 54 PSYC 101 students studied 40 words
- They were divided into three groups

Group 1 studied in silence
Group 2 studied with a jazz piece playing
Group 3 studied with a Mozart piece playing

Steven M. Smith, “Background Music and ConteXt-Dependent Memory,” The American Journal of Psychology, Vol. 98, No. $, 591-603 (19850.

Two days Later their recall was tested

- Jazz-Jazz 21 words
- Mozart-Mozart 21 words
- Jazz-Mozart 11 words
- Jazz-Silence 11 words
- Silence-silence 11 words

Vary where you study

- Two groups studied forty four-letter words
- Two 10-minute sessions, a few hours apart
- Group 1 was split into two groups

  ½ studied in a cluttered basement

  ½ studied in a neat bright room
- Group 2 had one session in each setting
- Three hours after the last 10-minute session the groups were tested in a third room

Steven M. Smith, Arthur Glenberg, and Robert A. Bjork, "Environmental Context and Human Memory," Memory & Cognition, volume 6, 1978, page 342

- The one-room group recalled an average of 16 words

- The two-room group recalled an average of 24 words

“Strong recall improvements with variation of environmental context”

Vary Were You Study

- Your room
- Library
- Location of your test
- Coffee shop

Moderate, versus low, ambient noise increases arousal, cognitive disfluency, and enhances creativity

Ravi Mehta, Rui (Juliet) Zhu and Amar Cheema, Is Noise Always Bad? Exploring the Effects of Ambient Noise on Creative Cognition," *Journal of Consumer Research* Vol. 39, No. 4 (December 2012), pp. 784-799

coffitivity.com

Google Apple iCloud Yahoo Google AmazonSmile Wikipedia LinkedIn The Weather Channel Bing Yelp TripAdvisor

Coffitivity

Premium About Research Contact/Support Blog

Login

CAFE LIBRARY

Morning Murmur
A gentle hum gets the day going

Lunchtime Lounge
Busting chatter of the lunchtime rush

University Undertones
The scholarly sounds of a campus cafe

Paris Paradise
Energizing ambience from the City of Light

Brazil Bistro
The musical chatter of a Brazilian coffeehouse

Texas Teahouse
Hefty sounds from a big state

Welcome to Coffitivity!

Coffitivity recreates the ambient sounds of a cafe to boost your creativity and help you work better. Proven and peer reviewed, see the research to learn more.

Take Coffitivity Offline Today

Created by our friend Siwalik Mukherjee, this app lets you go anywhere your MacBook can—even without the internet. Listen to our three free tracks you know and love, straight from your desktop.

See It Now

The actual test was harder than the practice/previous tests!

The actual test was harder than the practice test!

What were the conditions when you took the practice test?

- In your quiet room
- No time limit
- Class material available
- Key readily available

Interleaving

Interleaving

- Different subjects
- Same subject mix topics (identifying artists) [1]
- Different skills (bean bag toss) [2]

[1] Kornell and Bjork, “Learning Concepts and Categories, Is Spacing the “Enemy of Induction”?.” Psychological Science, Vol. 19, page 585.

[2] Kerr and Booth, “Specific and Varied Practice of Motor Skills,” Perceptual Motor Skills, Vol. 46, page 395.

Interleave different skills (bean bag toss)

Kerr and Booth, “Specific and Varied Practice of Motor Skills,” Perceptual Motor Skills, Vol. 46, page 395, 1978.

Interleaving

Same subject mix topics (identifying artists) [1]

Van Gogh

Monet

[1] Kornell and Bjork, “Learning Concepts and Categories, Is Spacing the “Enemy of Induction”?.” Psychological Science, Vol. 19, page 585, 2008.

Interleaving

Same subject mix topics (identifying artists) [1]

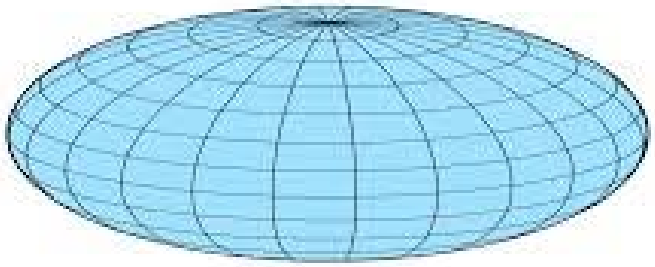
- 65% correct for those who used interleaving
- 50% correct for those who used blocking

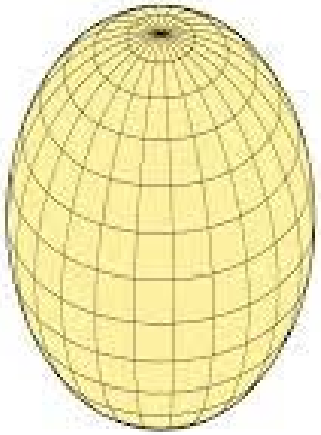
In a questionnaire after the final test 80% of participants rated block learning better than interleaving!

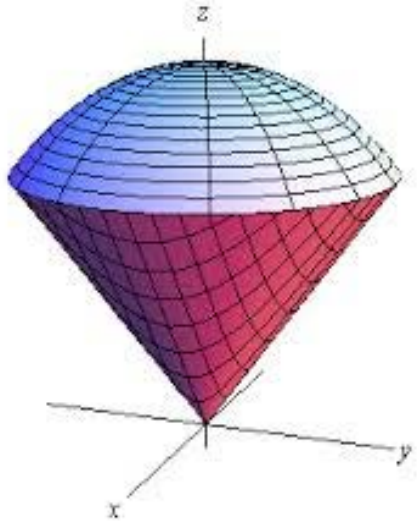
[1] Kornell and Bjork, “Learning Concepts and Categories, Is Spacing the “Enemy of Induction”?.” Psychological Science, Vol. 19, page 585, 2008.

Volume of wedge, spheroid, spherical cone, and half cone

- Group 1 practiced problems clustered by type
- Group 2 practiced the same problems, but the sequence was mixed (interleaved)



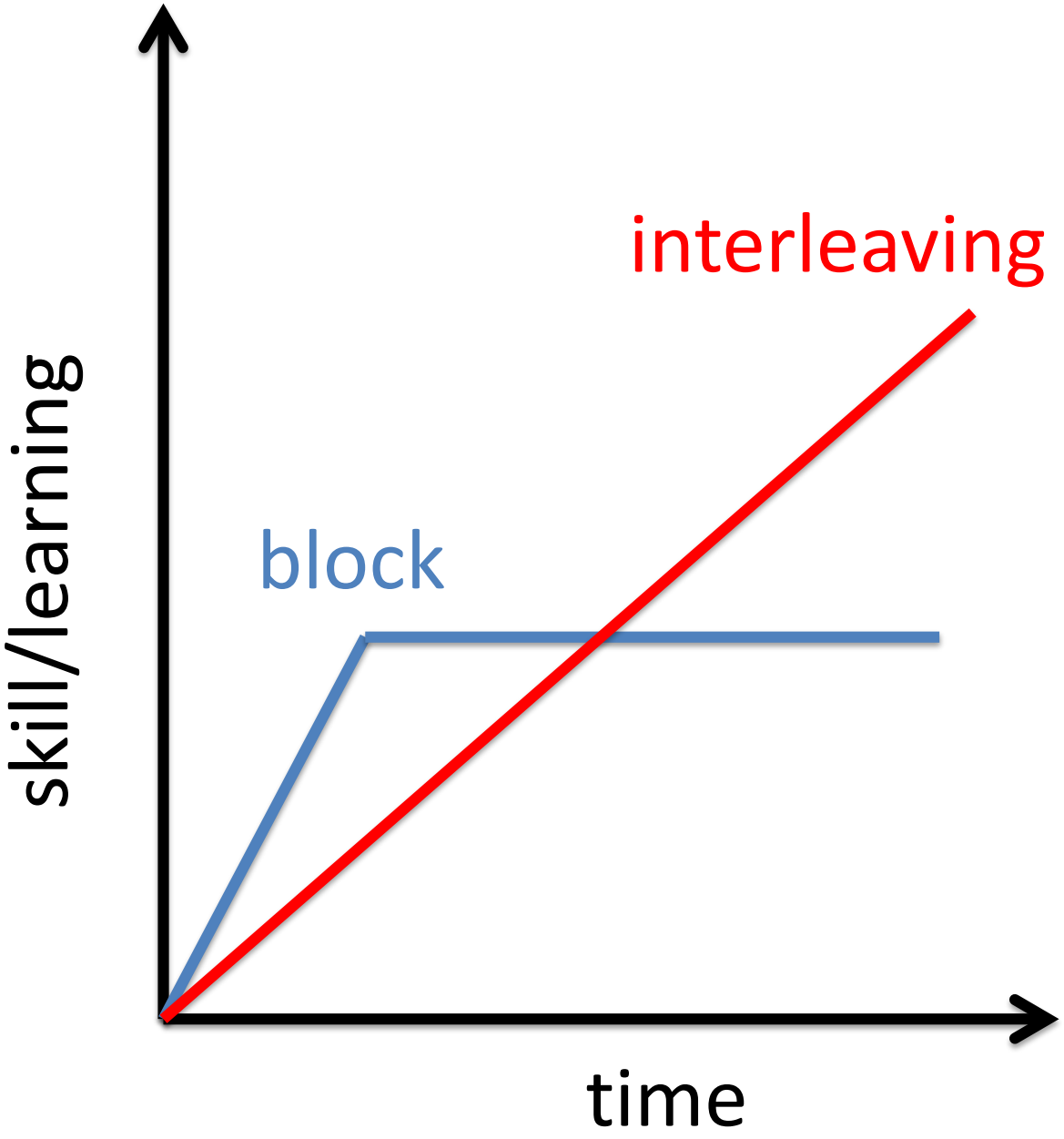




Volume of Wedge, Spheroid, Spherical Cone, and Half Cone

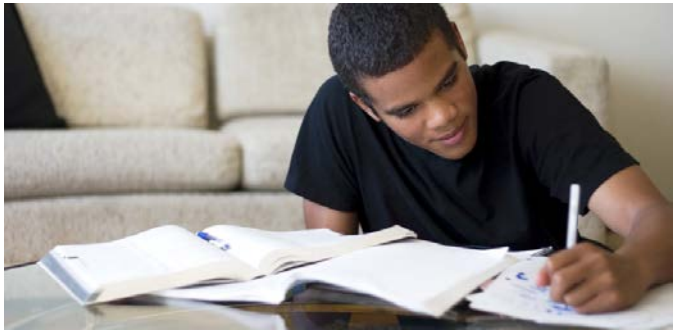
- On a test group 1 scored 60% and group 2 scored 89%
- A test a week later group 1 scored 20% and group 2 scored 63%

D. Rohrer and K. Taylor, “The Shuffling of Mathematical Problems Improves Learning,” Instructional Science 35(2007), 481-498.


interleaving
block
skill/learning
time

Preparation and Incubation

- **Preparation** is associated with the concentrating abilities of the brain's prefrontal cortex



- **Incubation** is what happens when you relax your attention and just let your mind wander

“Happy ideas come unexpectedly, without effort, like an inspiration. So far as I am concerned , they never come to me when my mind was fatigued, or when I was at my working table…they came particularly readily during the slow ascent of wooded hills on a sunny day,” Hermann von Helmholtz.

Made contributions in many scientific fields

Discovered the principle of the conservation of energy

Wallas' Stages of Control

- Preparation: time you spend at your desk working on a problem
- Incubation: when you put the problem aside

  walks, naps, playing a sport, cooking,

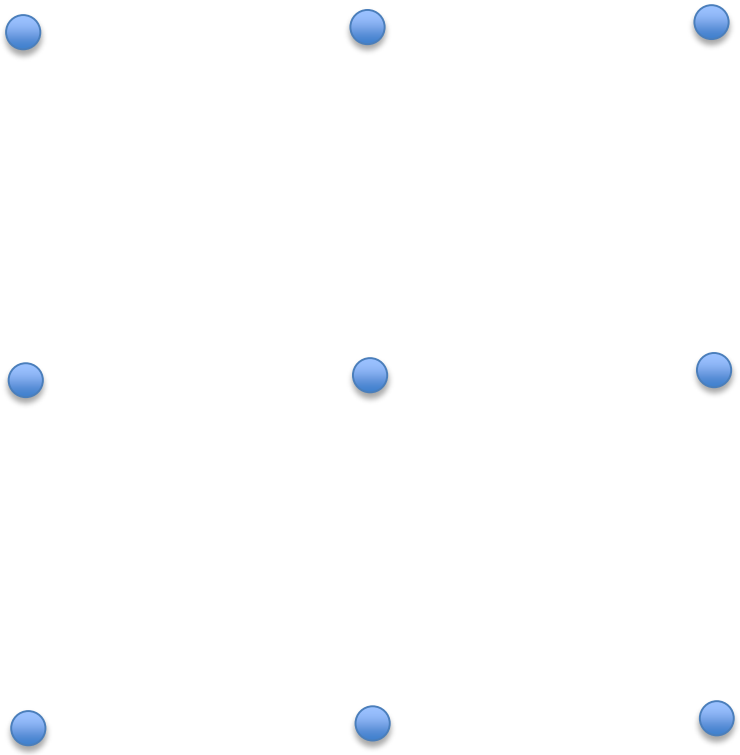
  change subjects you are studying, take a shower, etc.
- Illumination: the aha moment!
- Verification: finish solving the problem

Graham Wallas, The Art of Thought, 1926

Move three dimes to form a triangle pointing downward

Thiss equation contains three errrors.

Connect the dots with four continuous straight lines



Large Projects

- Start right away
- Do a little every day, or every other day
- Incubation for full duration of the project

Deliberate Practice

For over almost 40 years Anders Ericsson has studied the top athletes, musicians, chess players, doctors, salespeople, teachers, mathematicians, etc.

What is it that made them experts?

Peak: Secrets from the New Science of Expertise
by Anders Ericsson and Robert Pool

"Learning isn't a way of reaching one's potential but rather a way of developing it."

"The right sort of practice carried out over a sufficient period of time leads to improvement. Nothing else."

- Hired Steve Faloon, a Carnegie Mellon UG, to come in 3 times per week to try to remember a series of digits
- Generally people can only remember 6-7 digits
- Can practice increase this limit?
- Did Steve ever get beyond single digits?

Ericsson, K. A., Chase, W. G., & Faloon, S., “Acquisition of a memory skill,” Science, 208, 1181-1182 (1980)

Deliberate Practice Develops Effective Mental Representations

- National-level, mid-range, and novice chess players
- Shown a board for a few seconds
- The pieces were in an arrangement of a game or randomly
- What did they remember?

William Chase and Herbert Simon, “Perception in Chess,” Cognitive Psychology 4, 55-81 (1973)

	game	random
national	most	2
mid	half	2
novice	4	2

William Chase and Herbert Simon, “Perception in Chess,” Cognitive Psychology 4, 55-81 (1973)

training regular by leads to in the parts brain of that are training challenged the changes the

How many words do you remember?

Regular training leads to changes in the parts of the brain that are challenged by the training.

Now how many?

Regular training leads to changes in the parts of the brain that are challenged by the training.

Meaning aids memory

Approach studying as a way to learn the material, not to obtain a grade……the grades will come

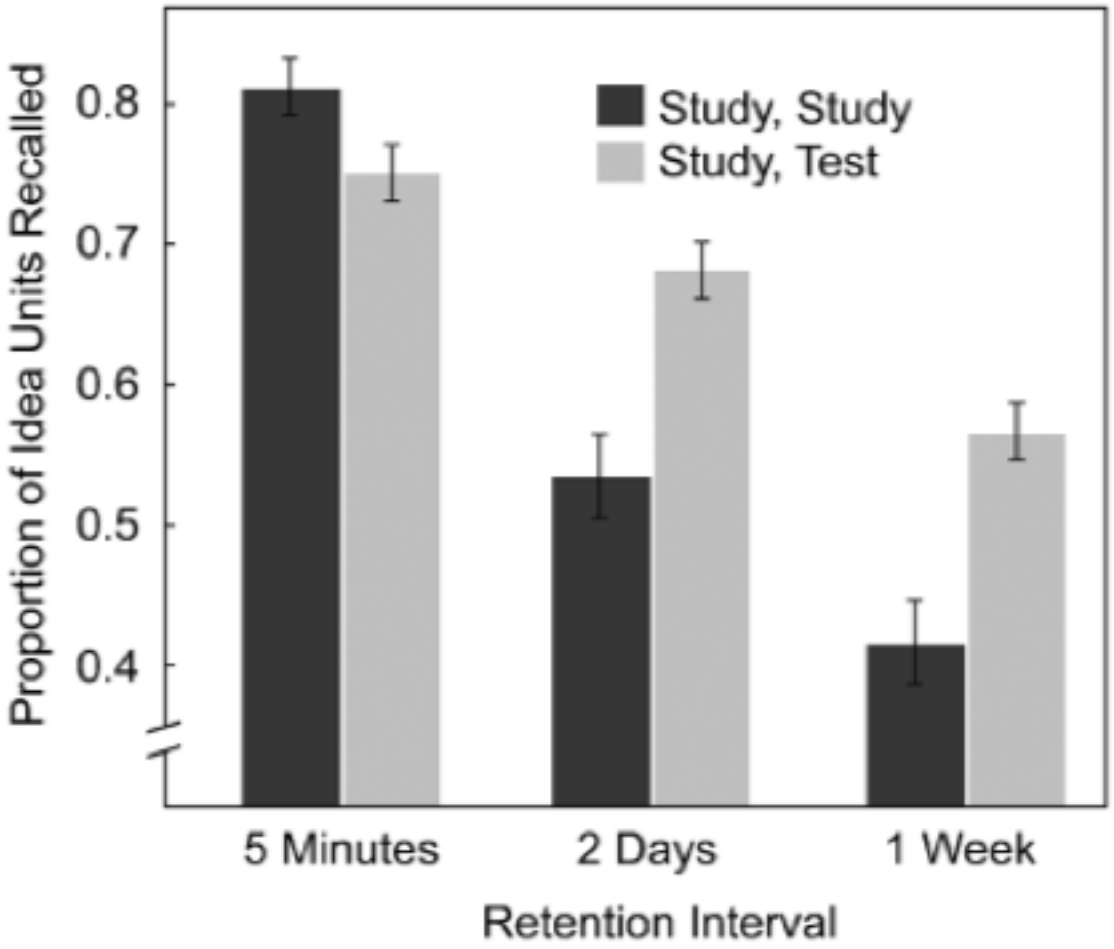
Testing Effect

Testing

- View testing as a means of assessment
- Many Learning Benefits, it is deliberate practice
  - Retrieval (recall) exercise that aids retention
  - Form connections
  - Frequent testing keep students on task and interrupts forgetting
  - Students discover gaps in their knowledge
  - Learn more from next study episode

Roediger and Karpicke, “Test-Enhanced Learning, Psychological Science, Vol 17, page 250

- 120 UG students studied two scientific passages (sun and sea otters)
- First group studied the two passages twice for 7 minutes
- Second group studied the two passages once for 7 minutes and in next 7-minute segment wrote down as much as they could recall from the two passages
- Split each group into three groups and tested—one group was tested 5 minutes, one group 2 days, and one group 1 week after last session



testing ≠ studying

testing > studying

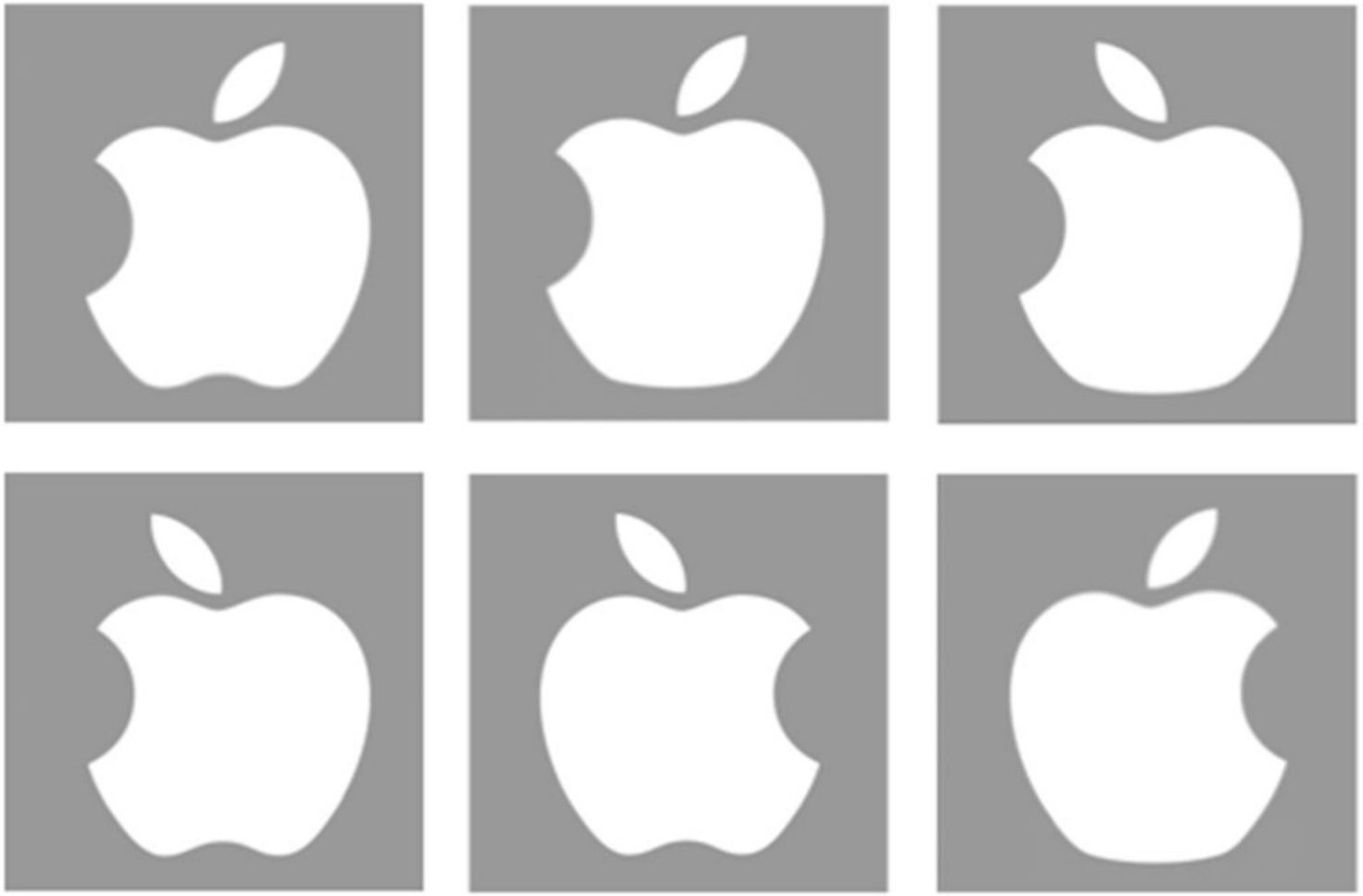
How to Study

How not to Study

- Reading the text and your notes over and over
- Highlighting
- Glancing at a solution to a problem
- Massed

Mistake familiarity with knowing the material

This is what Anders Ericsson calls naive practice



How to Study

Approach studying as a way to learn the material, not to obtain a grade……the grades will come.

- Read the text and you notes, just don't go over and over them (no more than 20-30% of your time)
- Spaced retrieval (recall) exercises
- Work problems—examples in text, problems in text that weren't assigned, homework, previous exams
- Explain the material to someone or explain it to yourself out loud

Testing is a Powerful Form of Studying

- Do a past exam as if you were actually taking it
- Wait a day and then look it over, see if you have figured out how to do the problems you had difficulty with. Only at this point look at solutions or ask for help.
- Do it again with another past exam
- Try to write an exam
- Eventually go back and retake the first exam

“Immediate recall in the form of a test is an effective method of aiding the retention of learning and should, therefore, be employed more frequently.”

“Achievement tests or examinations are learning devices and should not be considered only as tools for measuring achievement of pupils.”

Herbert F. Spitzer, “Studies in Retention,” Journal of Educational Psychology, December 1939, page 641.

177 UGs surveyed at Washington University

Study Strategies

Strategy	*Percent who list strategy*		*Percent who rank as #1 strategy*		*Mean rank*
1. Rereading notes or textbook	83.6	(148)	54.8	(97)	1.5
2. Do practice problems	42.9	(76)	12.4	(22)	2.1
3. Flashcards	40.1	(71)	6.2	(11)	2.6
4. Rewrite notes	29.9	(53)	12.4	(22)	1.8
5. Study with a group of students	26.5	(47)	0.5	(1)	2.9
6. "Memorise"	18.6	(33)	5.6	(10)	2.0
7. Mnemonics (acronyms, rhymes, etc)	13.5	(24)	2.8	(5)	2.4
8. Make outlines or review sheets	12.9	(23)	3.9	(7)	2.1
9. Practise recall (self-testing)	10.7	(19)	1.1	(2)	2.5
10. Highlight (in notes or book)	6.2	(11)	1.6	(3)	2.3
11. Think of real life examples	4.5	(8)	0.5	(1)	2.8

Karpicke, Jeffrey D., Butler, Andrew C. and Roediger III, Henry L.(2009) "Metacognitive strategies in student learning: Do students practice retrieval when they study on their own?," Memory,17:4,471 — 479

How to Read Your Text

As you read, look up and silently recall what you have been reading

A.I. Gates, “Recitation as a factor in memorizing,” Archives of Psychology 6 (1917)

Augment With Study Groups

- Catch errors in your thinking
- Opportunity to explain things out loud
- Become comfortable explaining to others
- Quick way to determine errors in credible sources
- Avoid it becoming a socializing session

You need to start your studying alone and the majority of your studying should be alone

Take Advantage of Office hours

- Both TAs and professors
- Goal: one professor a semester who knows who you are
- Go with a friend to office hours

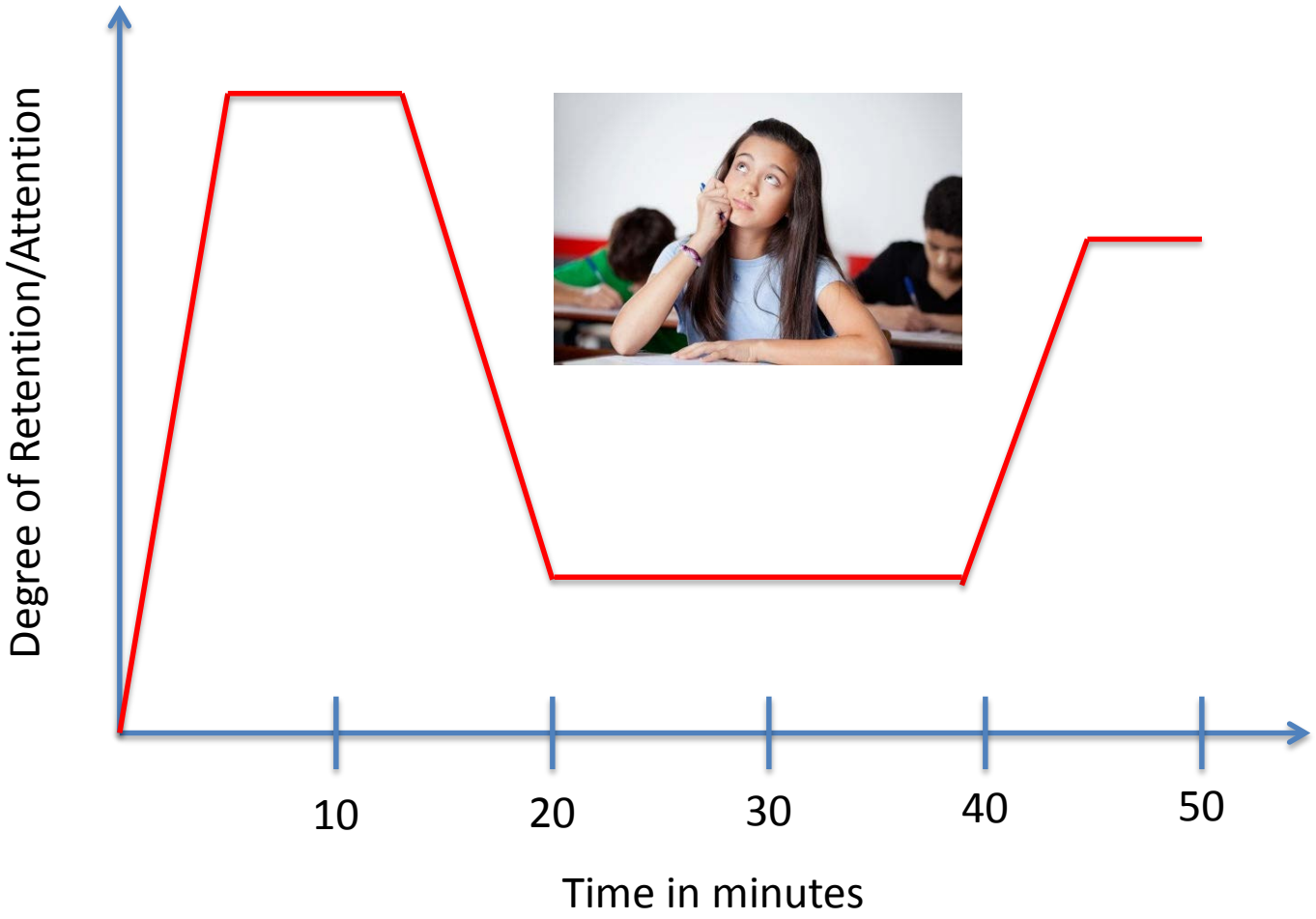
Learning Styles (visual, written text, or auditory) is a Myth

- People have learning preferences, but you do not learn better when the instruction fits those preferences.
- Best style sometimes depends on material
- The more senses you bring to bear—vision, hearing, touching, smelling—the more hooks (retrieval clues) to the material.

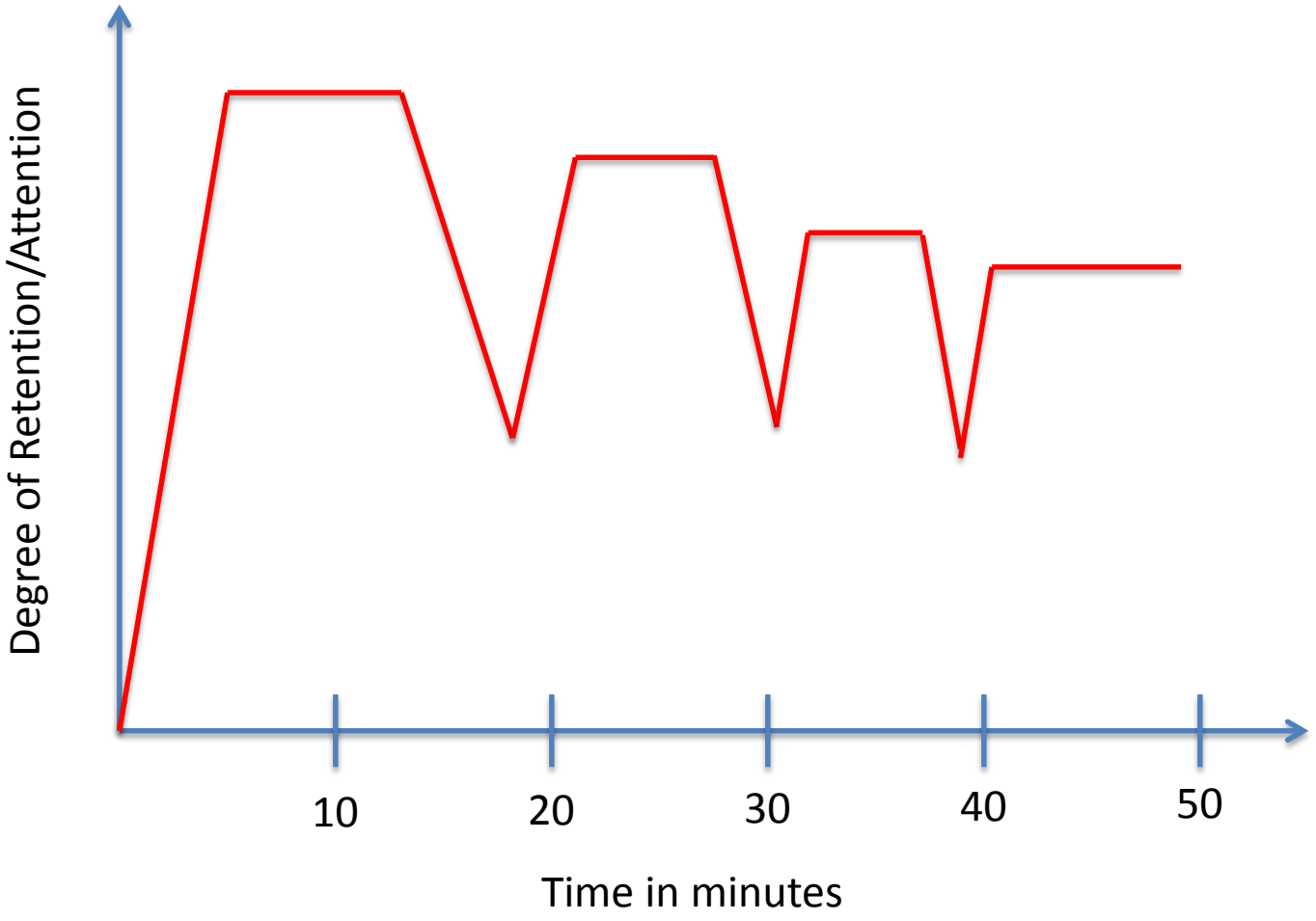
Class

Primacy-Recency Effect

We tend to remember best that which comes first, second best that which comes last, and least that which is in the middle.



Primacy-Recency Effect



The act of creating questions is a profound step toward understanding.

Constantly formulating and raising questions is a mind-opening habit that forces You to have a deeper engagement with the world and a different experience.

Getting in the habit of asking questions will transform you into an active, rather than passive, listener.

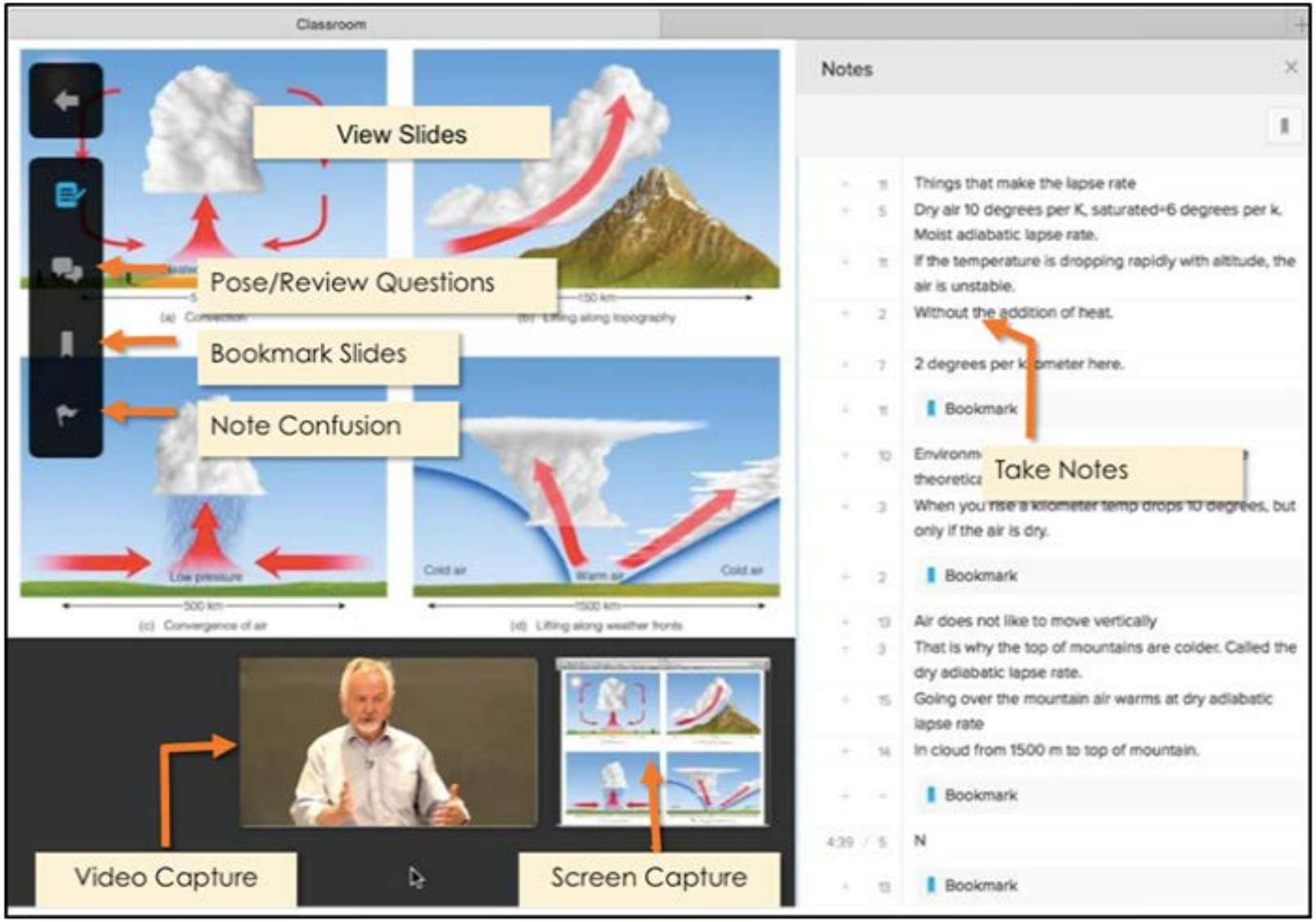
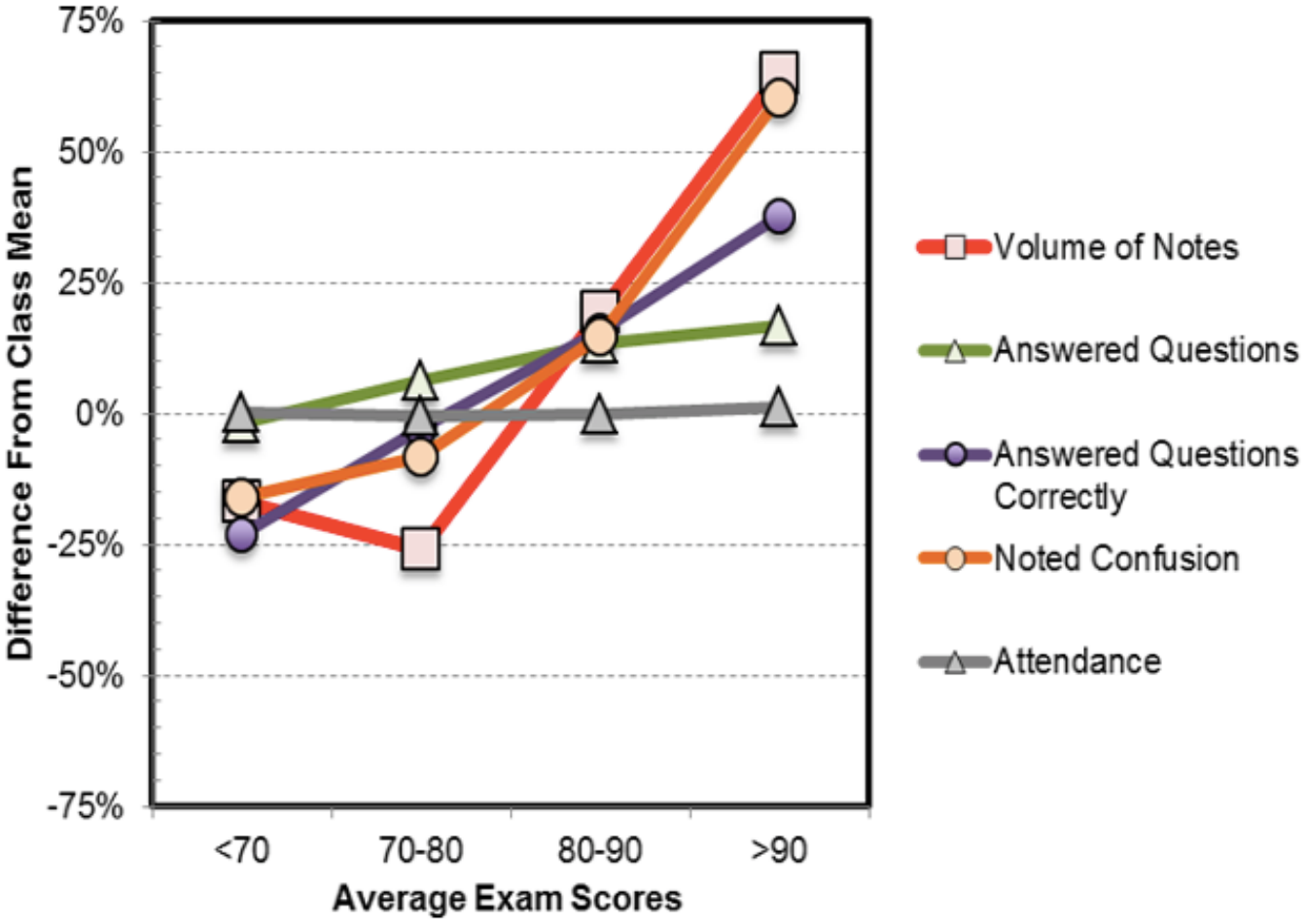


Figure 1. The Active Learning Platform student view allows students to view and bookmark slides and participate by taking notes, asking questions, and indicating confusion.



Students who encode information by actively taking notes perform better because they experience better conceptual understanding.

From Perry Sampson, University of Michigan
https://er.educause.edu/articles/2015/8/promoting-engagement-in-larger-classes

Student Behavior	Incoming GPA		
	>3.5	3.0–3.5	<3.0
Attendance	100%	99%	95%
Answered Questions	100%	97%	82%
Answered Questions Correctly	100%	88%	58%
Noted Confusion	100%	84%	33%
Volume of Notes	100%	59%	25%

Table 1. Differences in student behaviors relative to the behavior of students with an incoming GPA higher than 3.5

The Pen Is Mightier Than the Keyboard

Advantages of Longhand Over Laptop Note Taking

Pam A. Mueller1 and Daniel M. Oppenheimer2

1Princeton University and 2University of California, Los Angeles

"…we found that students who took notes on laptops performed worse on conceptual questions than students who took notes longhand. We show that whereas taking more notes can be beneficial, laptop note takers' tendency to transcribe lectures verbatim rather than processing information and reframing
it in their own words is detrimental to learning."

Hands Are Made for Learning

- Hunter-gathers

  touch plants to gauge edibility

  touch objects to determine weapon suitability
- Keyboards and smartphone screens are a sensory desert
- More the brain is tickled with sensory input the more it pays attention

Sleep