The Cognitive Science of Teaching and Learning

(or, How People Learn)

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Disclaimer: None
Disclosure: None

Caveats:

Due to time limitations this presentation:

will simplify some concepts

will not discuss many topics

Outline:

Knowledge acquisition

People learn more by using retrieval, spaced learning, hand-written notes, interpolated tests, delayed summarization and metacognition.

Understanding

People understand more deeply from constructivism and collaborative discourse. This requires learners to justify their understandings and educators to listen for misunderstandings and then correct them.

Severe limits exist within our cognitive systems

People possess severe constraints in working memory capacity and they have profound difficulty with analogical transfer.

Dealing with setbacks

A 'growth mindset' helps learners and educators deal with setbacks or challenges in learning.

Vignette

As a Program Director, I used to meet with residents twice a year. They **routinely** told me that they didn't remember what they read.

They would say things like: "I know I read it because my highlighter marks are on the page but it just didn't stick….I really thought I knew it when I read it…."

Is there anything that will help?

Knowledge Acquisition

Remembering more "stuff":

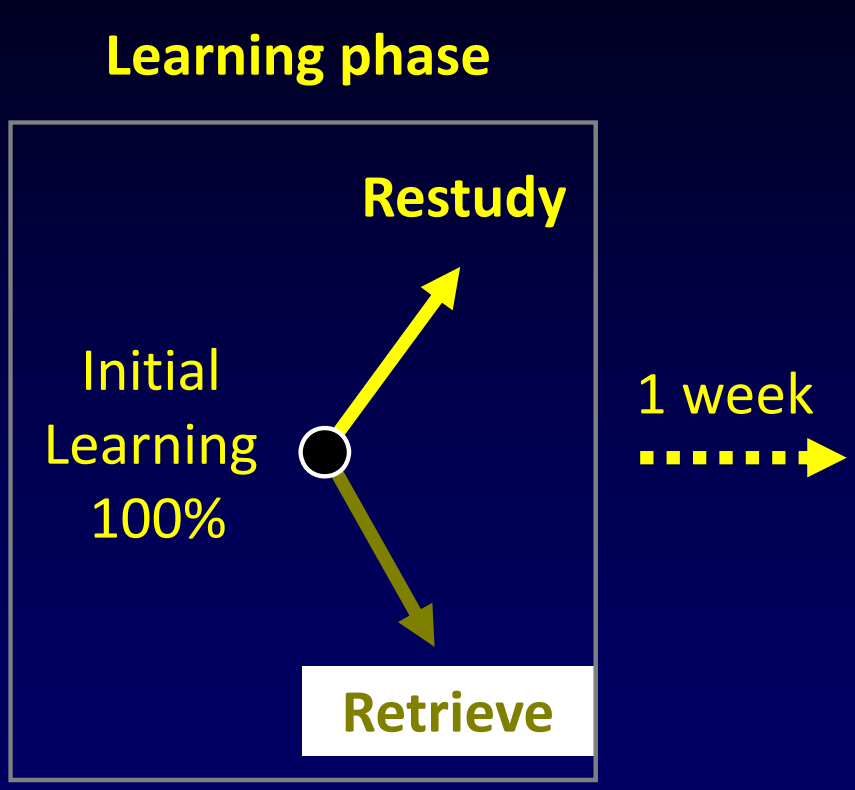
1) Retrieval
2) Spacing
3) Hand-written notes

Finding out if you actually know something:

Delayed summarization

Retrieval:

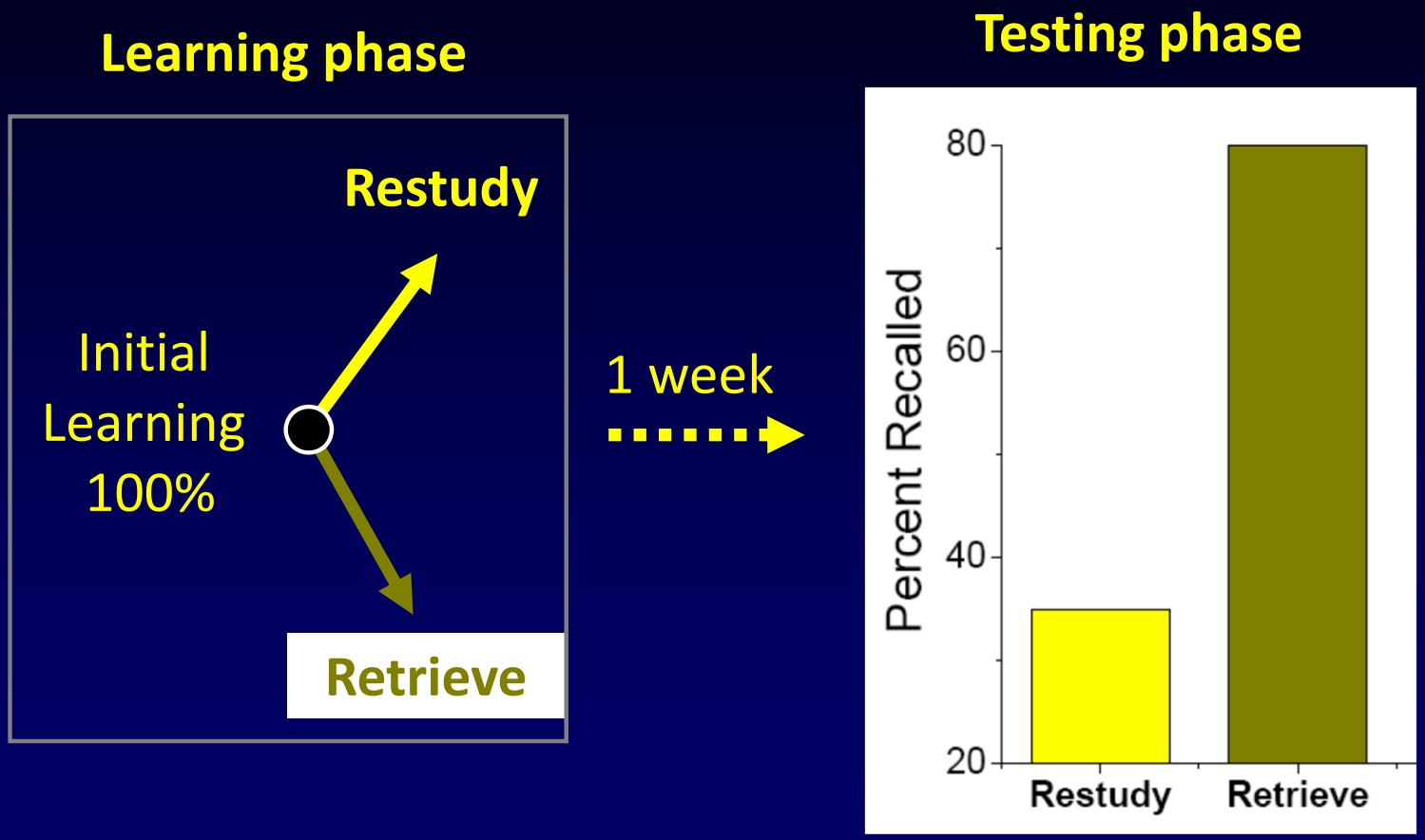
Learning words in a new language



Karpicke et al. Science **319** 966 (2008)

Retrieval:

Learning words in a new language



Karpicke et al. Science **319** 966 (2008)

d = 4; metacog = 0

Long term **retention** depends on the **processes** learners employ to "learn"

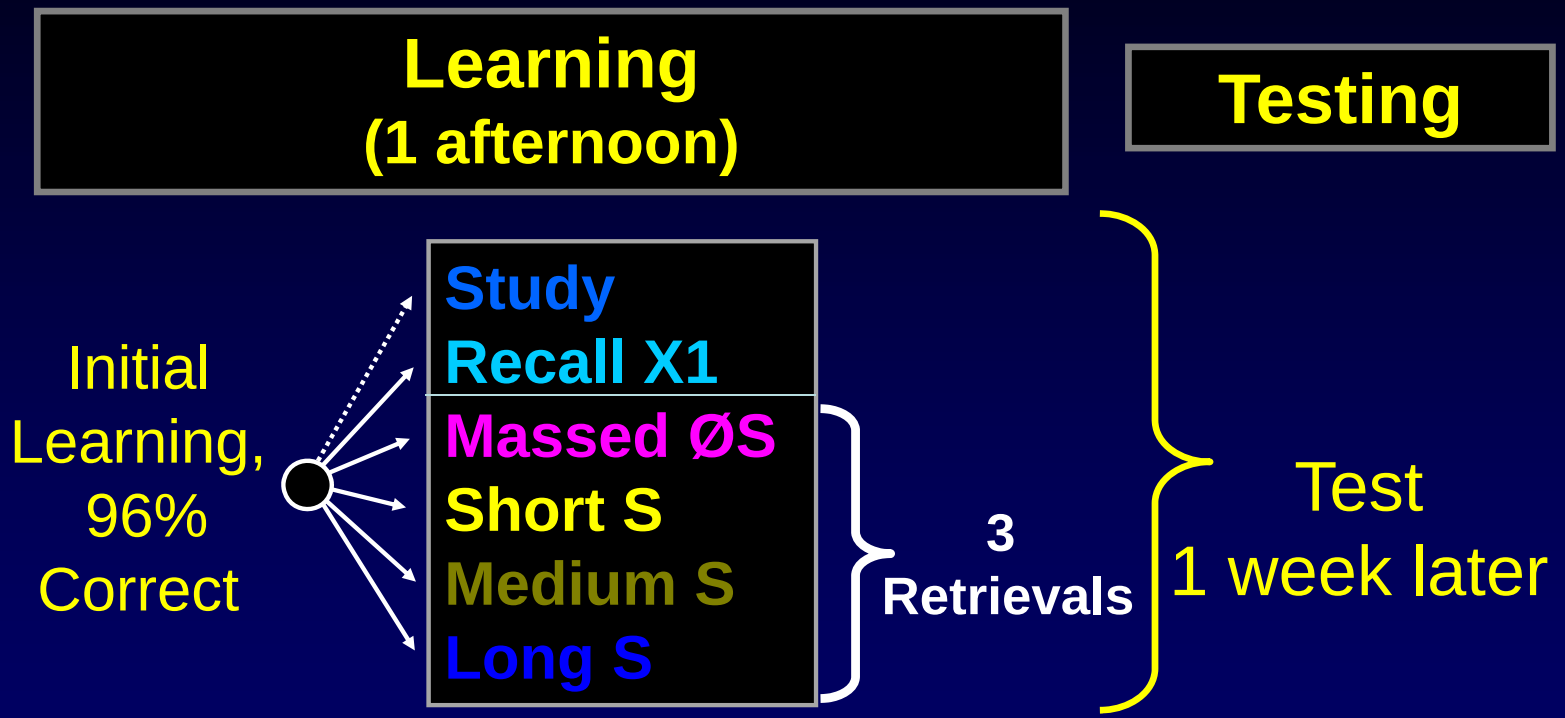
repeated encoding/rereading
→ low benefit

Repeated Retrieval
→ large benefits

*** Learners are ***completely unaware*** of this! ***

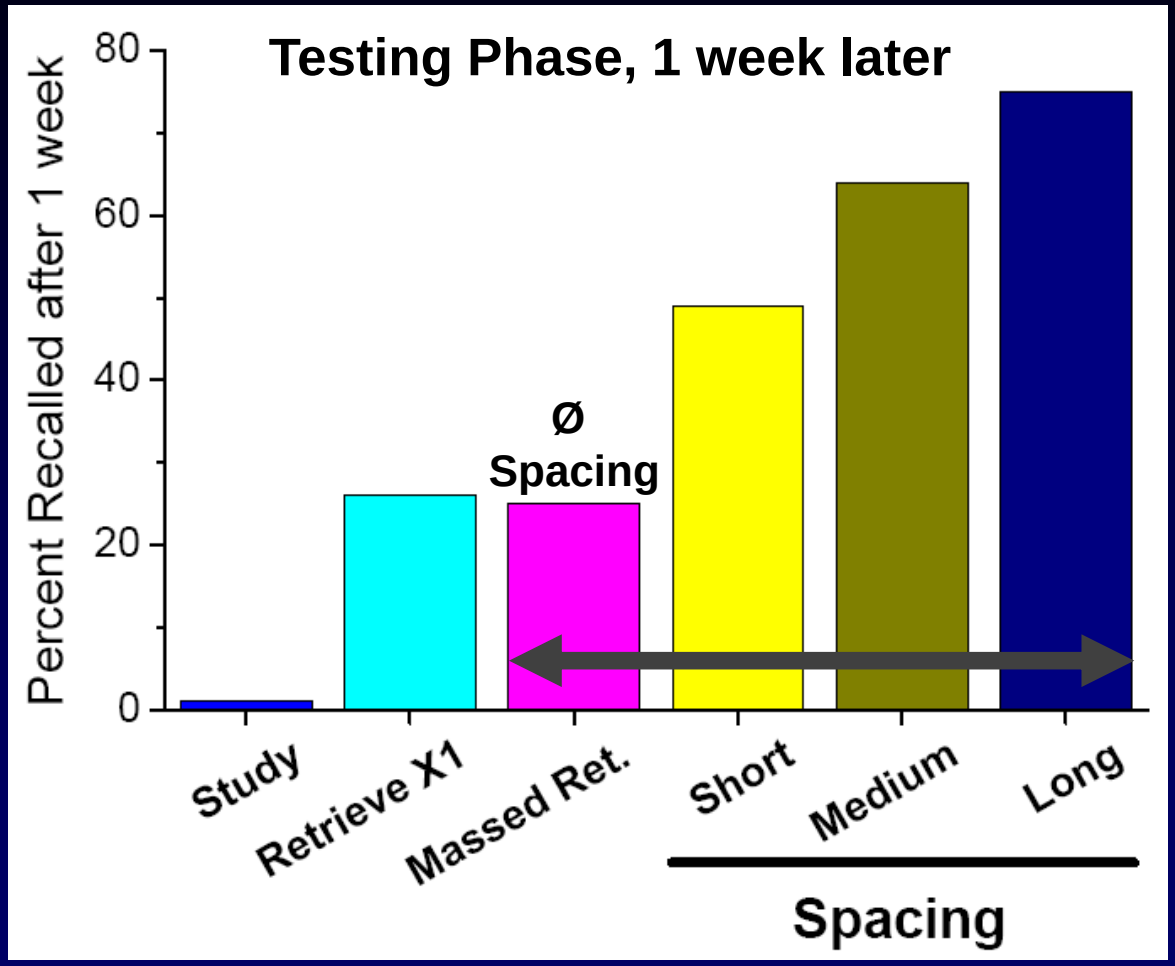
Karpicke et al. Science **319** 966 (2008)

Spacing



Karpicke et al. J. Exp. Psych. **37,** 1250 (2011) Undergrads, Swahili-English pairs

Spacing

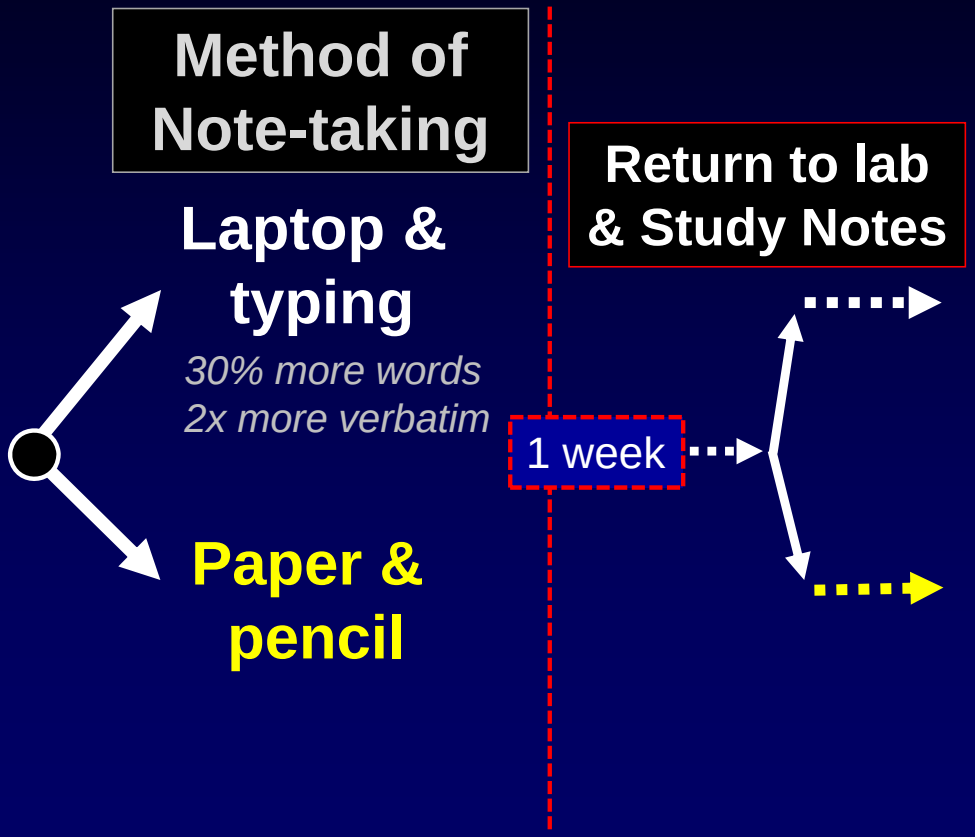


3
Retrievals

Karpicke et al. J. Exp. Psych. **37,** 1250 (2011) Undergrads, Swahili-English pairs, 1 week until test

Taking notes

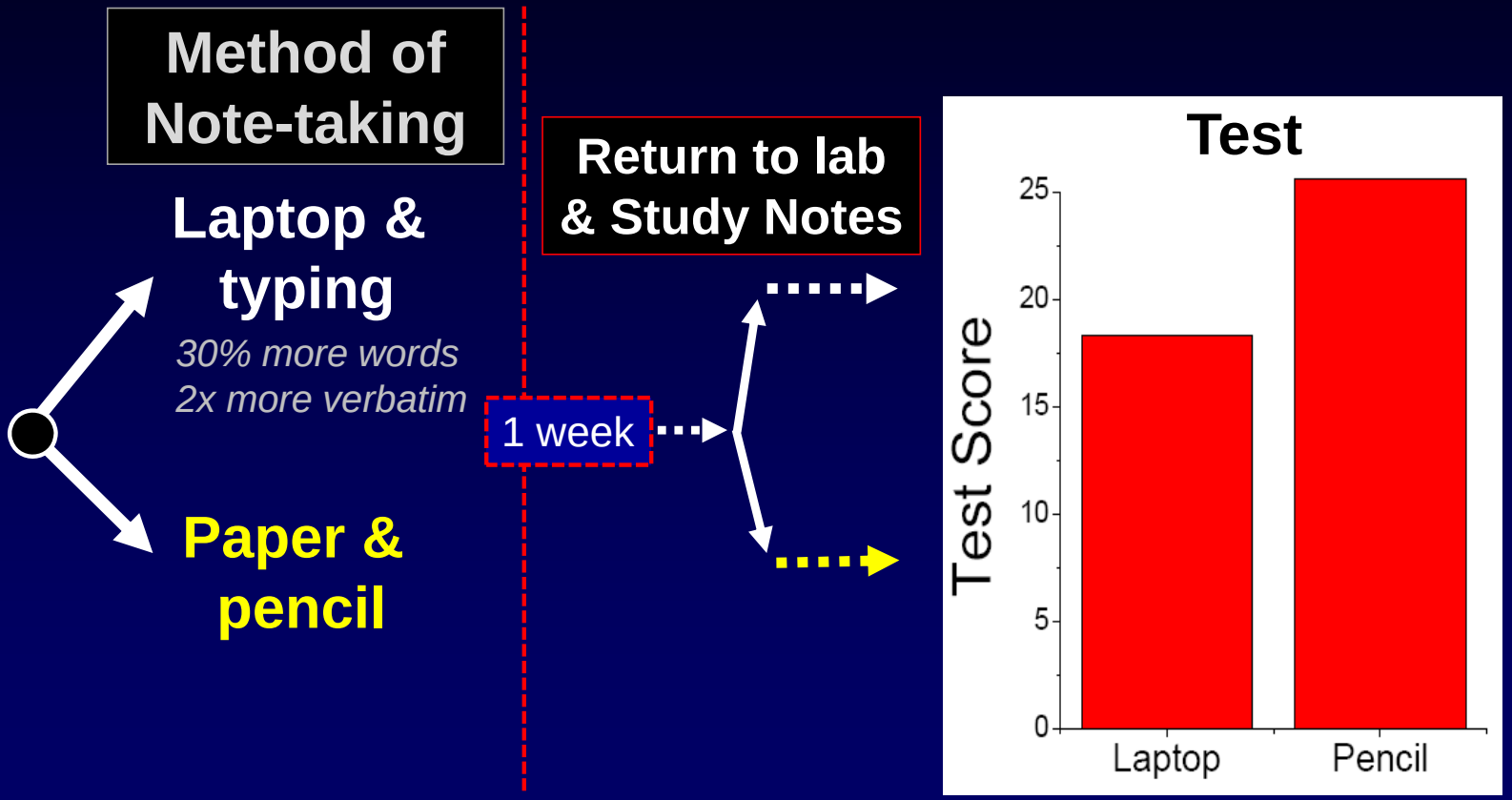
Laptop & typing *vs*. Pencil & paper



Mueller and Oppenheimer. Psych. Sci. **25** 1159 (2014) – college students

Taking notes

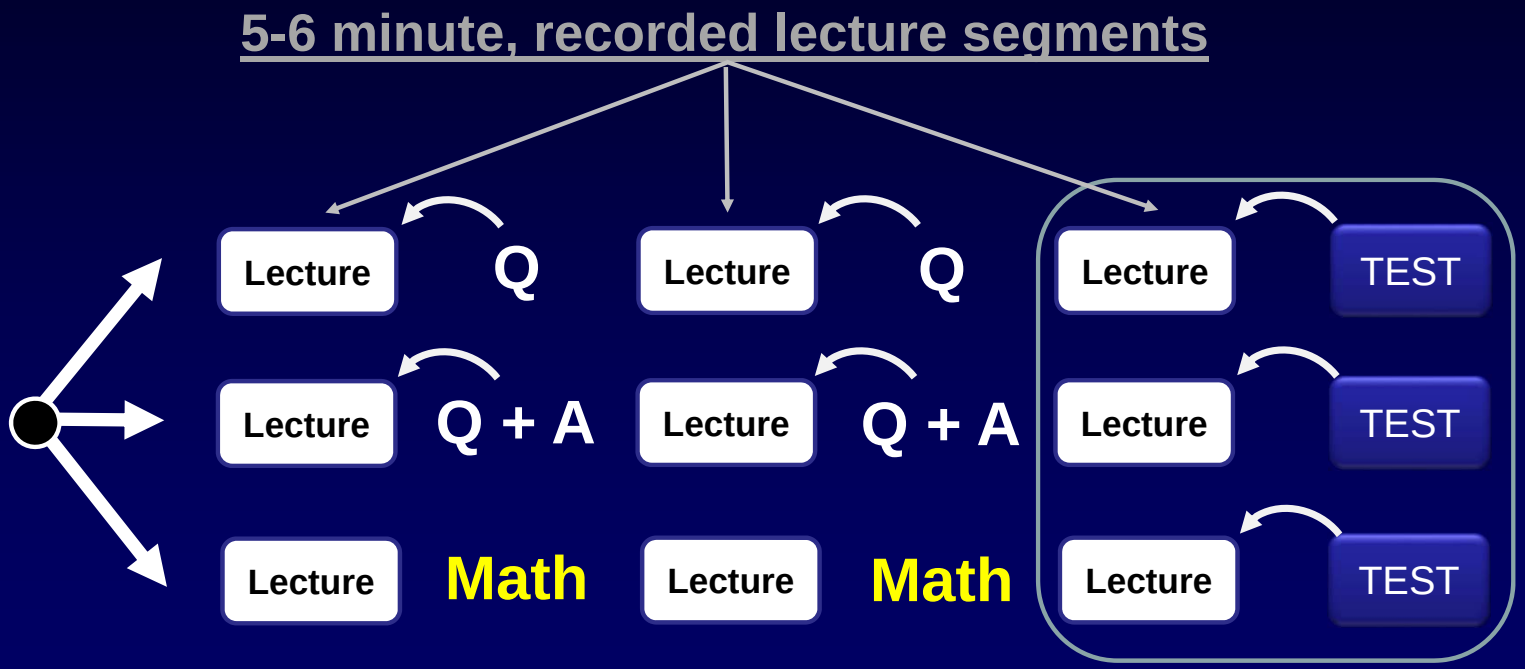
Laptop & typing *vs*. Pencil & paper



Mueller and Oppenheimer. Psych. Sci. **25** 1159 (2014) – college students

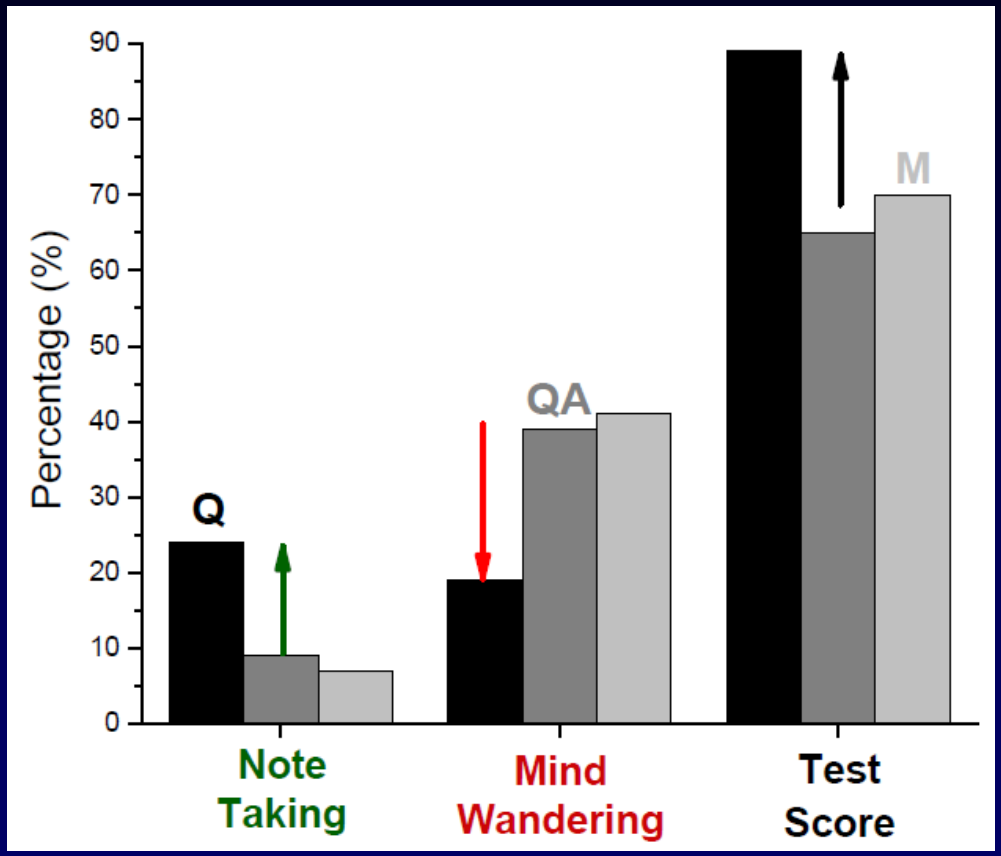
How do you get people to take more notes, pay attention and learn more when you speak?

(R_x = Q *vs.* Q + A *vs.* Math)



Szpunar. P.N.A.S. **110** 6313 (2013) – Harvard students, statistics

Interpolated tests result in:
More notes, More attention & More learning



Szpunar. P.N.A.S. **110** 6313 (2013) – Harvard, statistics: all Q $p < 0.03$, $d > 1.01$, else ns

Metacognition

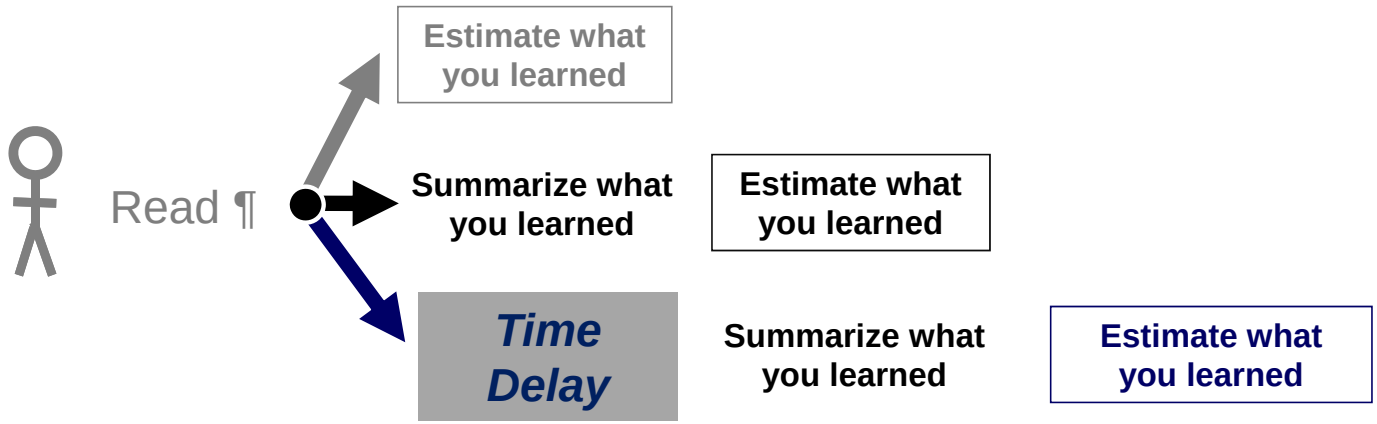
Essential cognitive activity for learning
('meta' – beyond or more than)

"Thinking about your thinking"
"Knowing about your knowing"

Metacognition is occurring when **you realize** that you do (or don't) know, or understand, something.

This information is used in the **"discrepancy-reduction model"** for self-regulated learning.

How accurate are people at predicting how much they learned after reading a paragraph?



Thiede. Cont. Ed. Psych. **28** 129 (2003) – college students

Summarizing, ***After a Delay***, improves **metacognitive** accuracy

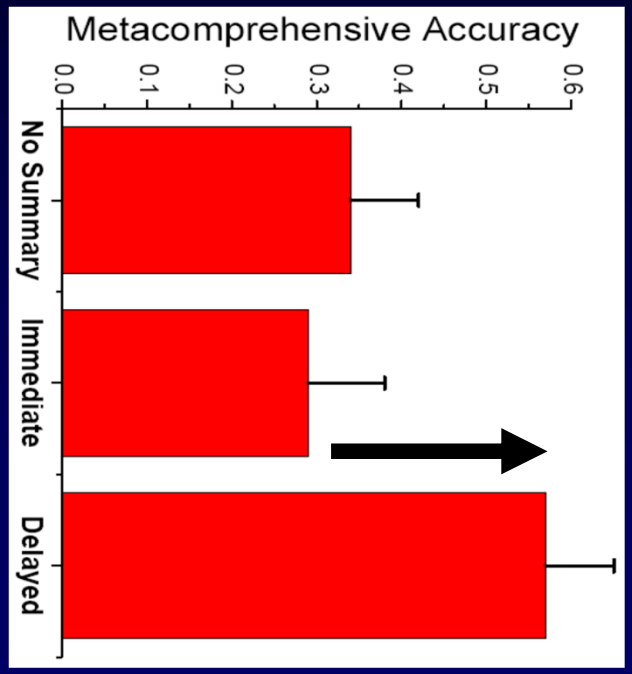
(improved realization of what you **do**, and **don't**, know)

Read → estimate

Read → Summarize → estimate

Read → **DELAY** → Summarize → estimate

Details *



Thiede. Cont. Ed. Psych. **28** 129 (2003) – college students, expt 2

* Similar results obtain when learning concepts

Short term memory (STM) is ***Fleeting*** (minutes).

The mechanism underlying the fleeting nature of STM is debated but **decay** and **replacement** by new information are leading contenders for the rapid failure of STM.

If you want to know if you **really learned something**, **try to recall what you learned** after a delay of at least 15 minutes.

For the person who reads but doesn't remember:

1) Take a break after reading (at least 15') and try to recall what was read. In the case of failure, review the material and repeat.

2) While reading, take handwritten notes (*not verbatim*). Review the notes after a break of at least 15'. Use the notes to help recall what was read. In the case of failure, review the material and repeat.

3) Repeat 1) or 2) the next day and on subsequent occasions until the material is retrieved more than once (10x rule).

Vignette

A faculty member corners me and tells me that a person just "doesn't seem to understand some key concepts". The faculty member admits that the person knows basic medical facts but they are not putting it together.

Is there anything that will help?

Understanding concepts and ideas:

Constructivism
Collaborative Discourse

When people get “taught” a new idea,
what happens inside their minds?

People come with preconceptions about how things work.
If their prior understandings are not engaged, they may fail to incorporate new concepts into their thinking.

Bransford et al. How People Learn. Nat. Res. Council. (1999)
Fish is Fish. Leo Lionni (1970)

"**Constructivism** maintains that **individuals** incorporate new information into **their** previous conception…. and that **they only change ideas when they realize that the new information conflicts with their previous understanding**, creating **cognitive dissonance.**

Constructivism defines the types of practice….exercises that challenge previous conceptions and require students to explain **their** thinking"

"Explaining" Creates Elaborated Knowledge

Haak et al. Science **332**, 1215 (2011)

Words/phrases that foster constructivism:

Why? Why not?

Explain that…

What other options exist?

What if … [change the scenario]

What evidence supports your point?
What evidence does not support your point?

Tips for helping the person who is not using medical knowledge in a sound or cogent manner:

1) When a learner makes a decision, ask them to explain how they made that decision *even if is a sound or good decision*. This will reveal their understanding *which can serve as a starting point for further discussion*.

2) Ask the learner to explain a concept to someone else and listen for appropriate understanding while they explain the concept. *Discuss any misunderstandings.*

Vignette

A faculty member corners me, again, and tells me that a junior resident just "doesn't seem to follow their instruction". The faculty member admits that the resident is smart and is trying hard but,

…they just can't seem to follow the faculty member's explicit instructions during a procedure.

Is there anything that can help?

Limits of our cognitive systems

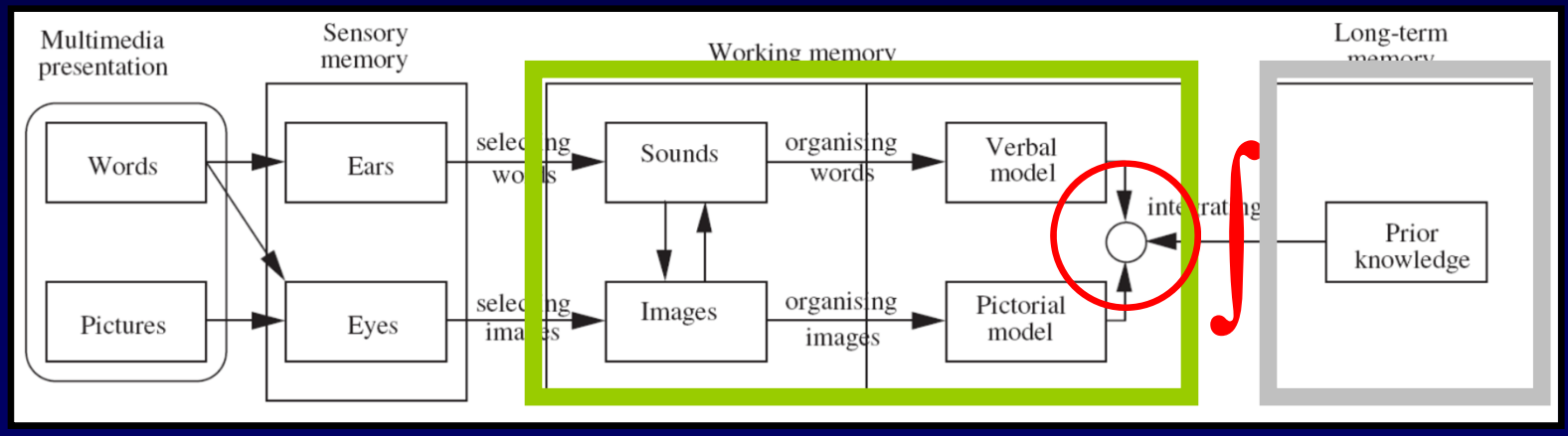
- Working memory capacity & cognitive load theory
- Analogical Transfer

Mayer's Cognitive Theory Model

WMC is *the Bottleneck*

Attention & Choice

Prior Knowledge



Mayer, Med Ed **44** 543 (2010)

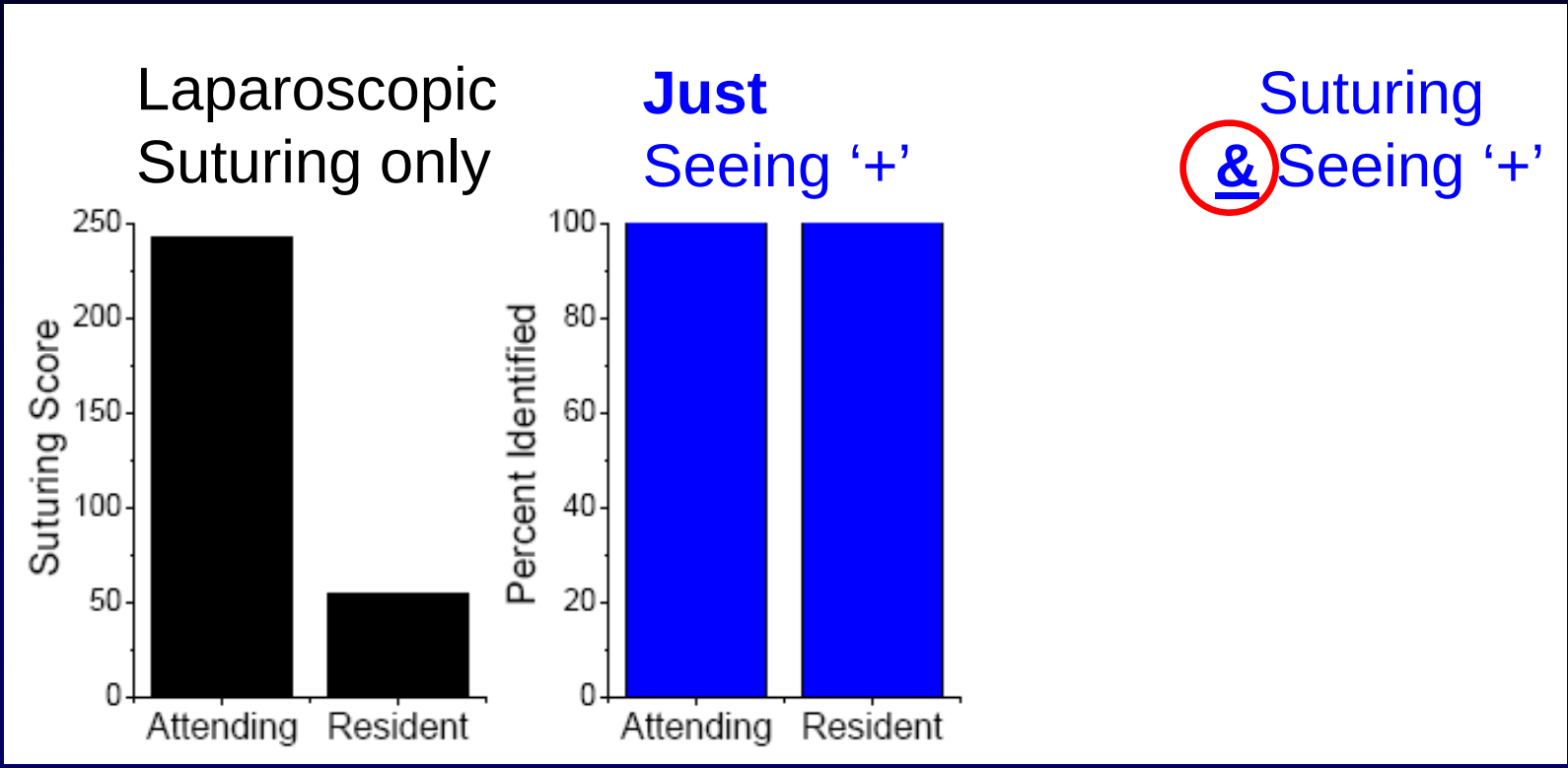
Principles of learning from a cognitive science perspective

Limited capacity principle: learners can only process a few elements at any one time (**WMC is limited = Bottleneck**).

Active learning principle: meaningful learning occurs when learners engage in appropriate cognitive processing during learning, including mentally organizing information into coherent cognitive representations and integrating (∫) it with prior knowledge activated from long-term memory.

Med Ed **44** 543 (2010)

Paying attention to complete a newly learned task (suturing) *can severely* reduce performance on an otherwise easy task (seeing '+' signs)



Stefanidis et al., Am J Surg **193**, 502 (2007)

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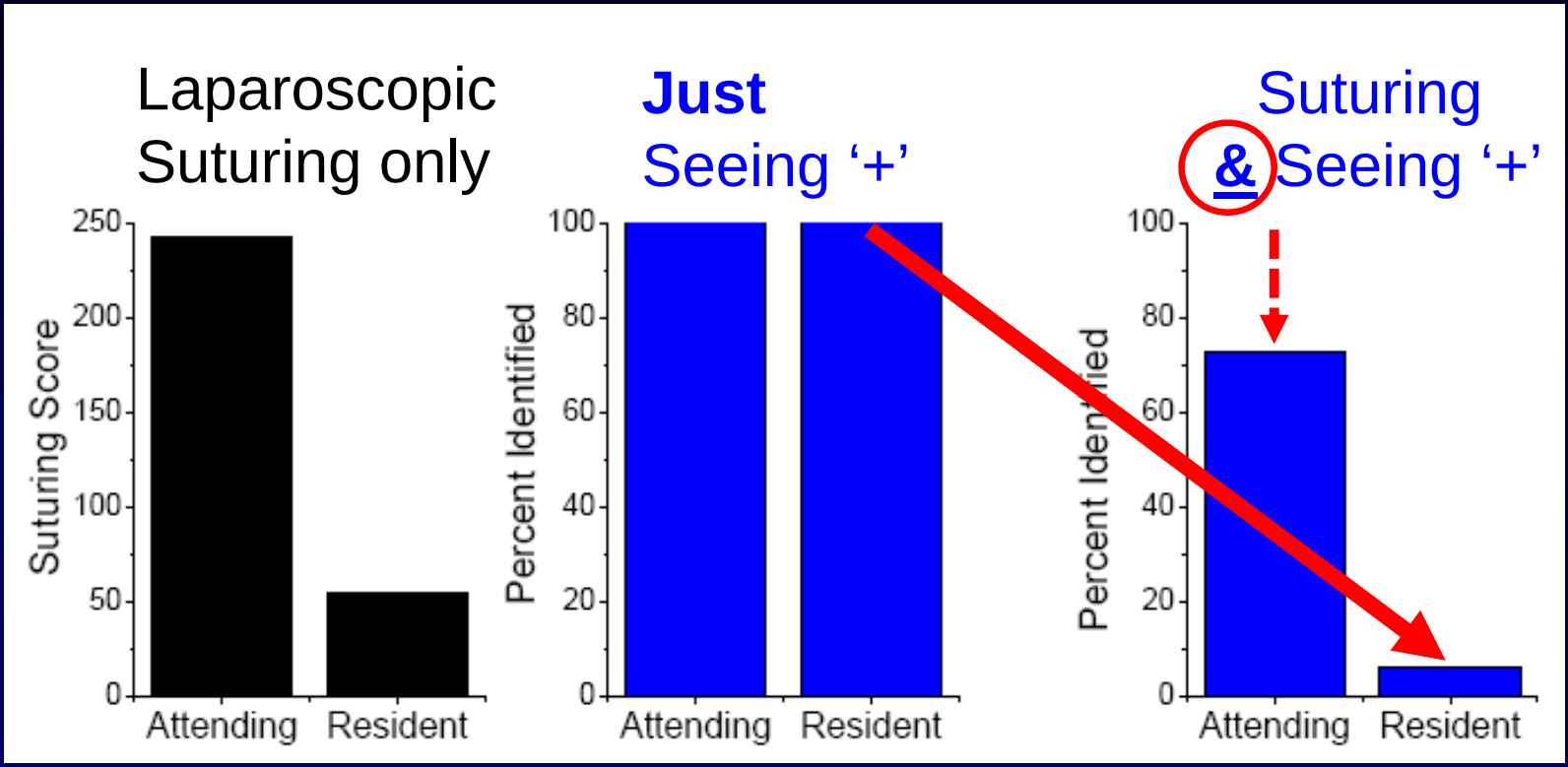
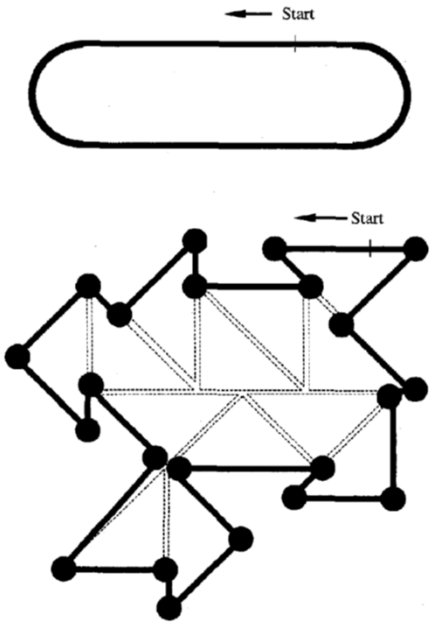
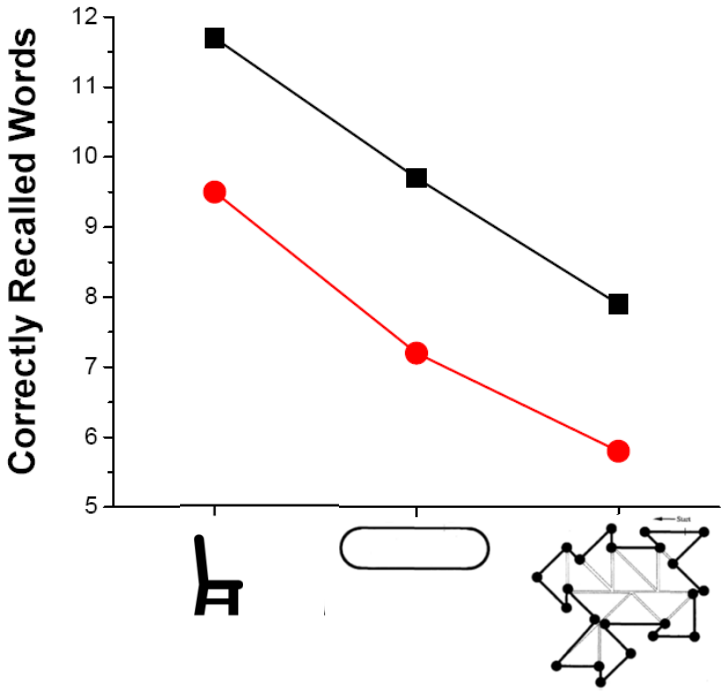


Stefanidis et al., Am J Surg **193**, 502 (2007)

How vulnerable is the learning process?

Do you think walking could interfere with learning?





Lindenberger et al. Psych Aging **15** 417 (2000) – Table 6

The Disruptive Potential of **Concurrent** Feedback

Learners use their entire WMC when learning new procedures and when trying to understand new ideas. This leaves no cognitive capacity for any other activities.

During task completion, feedback competes for working memory resources, ***forcing out*** information necessary for operator compilation.

(think of the slide on suturing and spotting the + signs)

Schooler and Anderson. Carnegie Mellon Univ. Res Showcase **27** 702 (2008)

Tips for the person who is not able to attend to direct instruction during learning

1) **Disengage the person** from the task that they are attempting. Once they are 'unlocked' from the task and are focused on you, provide instruction or feedback.

2) Ask the person to **mentally rehearse** the procedure on their own time so that the basic elements become a bit more automated and don't require as much active cognitive control (i.e. WMC).

   *Over time, people subordinate much (but not all) of what they do to **automatic processes**. They also develop '**scripts**' to know what to do. These processes reduce cognitive load and free up WMC to attend to other things.*

Analogical Transfer

The process of taking a principle and using it to solve **a new but related problem** (an analogous problem). This is what we typically mean by '**applying knowledge**' or '**problem solving**'.

Problems have:

Surface Structure: details that don't affect the solution

Deep Structure: the core features of the problem

Example: Google → **MIT grads light bulb**

Humans are STUNNINGLY POOR at AT!

Casale et al: Mem Cogn **40** 434 (2012)

Do you want learners to recognize something?
If yes, teach CONCRETE examples.

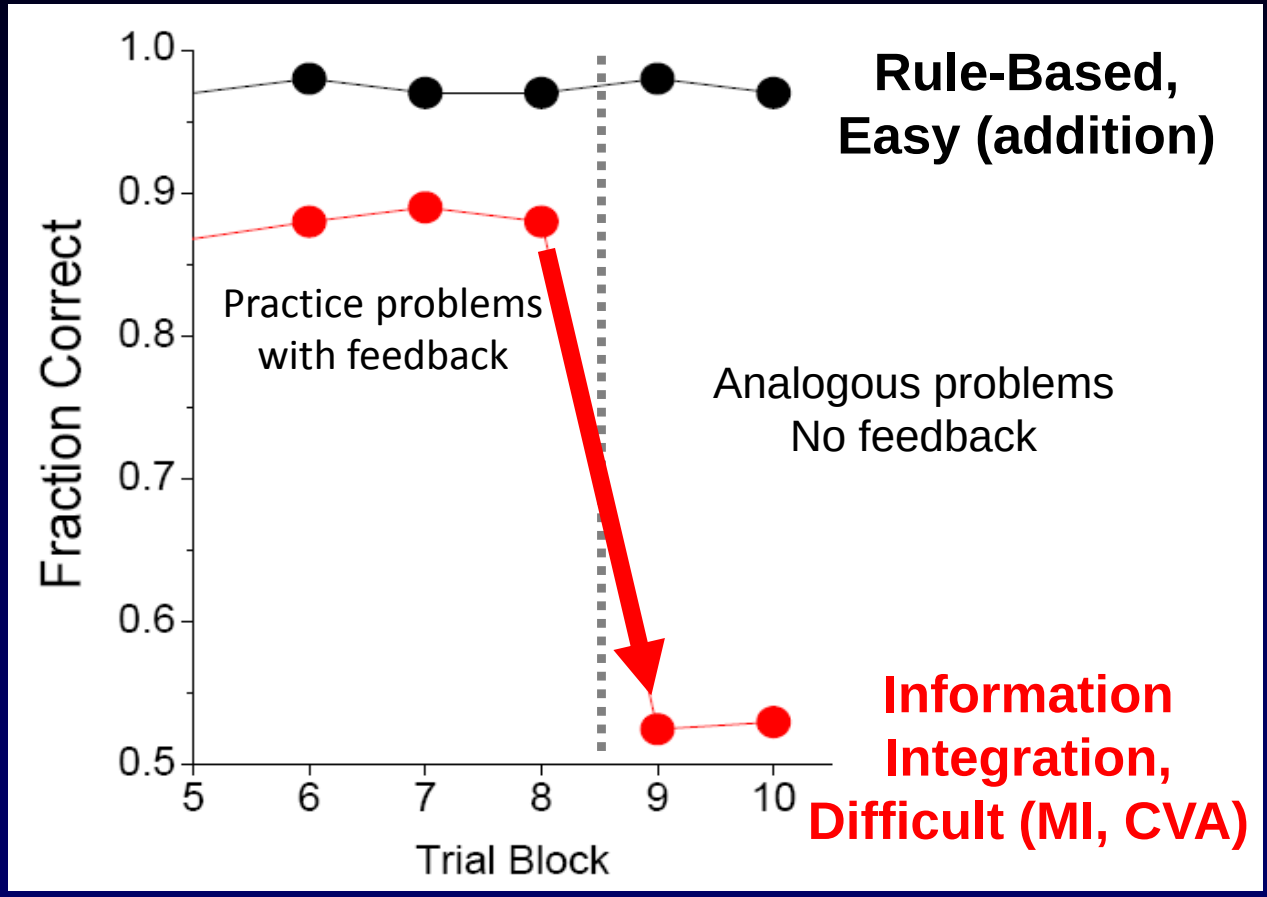
If you want the learner to become familiar with something clinical, for example how a patient may present with a myocardial infarction, then use MANY specific examples. This will help build a schema of how myocardial infarction presents so that **the next case is recognized** (**near transfer**).

Do you want learners to apply their knowledge?
If yes, teach principles or ABSTRACT concepts.

If you want the learner to have deeper understanding that they can **apply to a novel problem** (**far transfer**) then teach deep structure and principles (abstract concepts). Analogical transfer is remarkably difficult for most humans. Showing the problem solving process (scaffolding, tips) helps the learner "see" how the transfer was made.

Analogical Transfer?

Yes … & no…



Casale. Mem. Cog. **40** 434 (2012), expt 3

Cognitive limits exist in ALL of us.

There is no known simple way to make these limits go away.

I believe these limits require educators to have patience with learners and to show empathy towards them too.

Given these limits, it is most effective to approach the learner with a mindset of '**growing the learner**' past the difficulty.
Helping learners overcome the challenge of learning with the goal of improving performance takes something called a **growth mindset**.

Adopting a ‘growth mindset’

The goal is to functionally respond to challenging learning situations

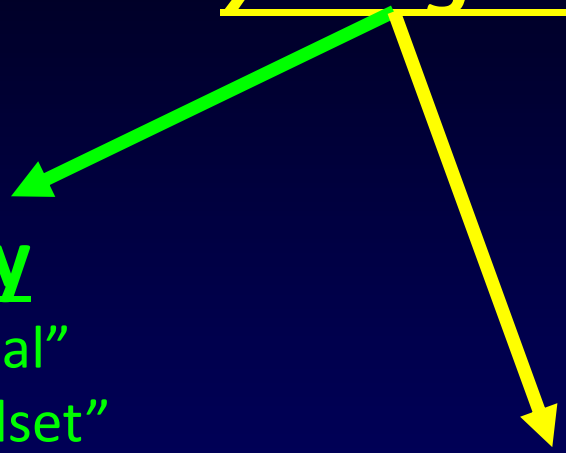
We **ALL** face Challenges

You…

- get a poor evaluation
- don’t understand something
- don’t know the answer
- get a low test score
- miss the diagnosis
- fail at a procedure
- get some negative feedback
- etc…

When ***you*** meet a challenge

what is ***your goal?***



Mastery

"Learning Goal"

"Growth Mindset"

"Learning Orientation"

Validate ability

"Validation Orientation"

"Performance Orientation"

Definitions:

Learning Goal Orientation

(Growth Mindset)

The active striving toward development and growth in competence

Validation Goal Orientation

Seeking to validate one's ability, gain favorable judgments of one's attributes and avoid negative judgments of one's self

Examples:

Learning Oriented individuals would say:

I felt very satisfied when:

… I learned something new

… I saw improvement in my work

… I was totally involved in something I was doing

… I worked hard

… I worked on a challenging task or assignment

Validation Oriented individuals would say :

I felt very satisfied when:

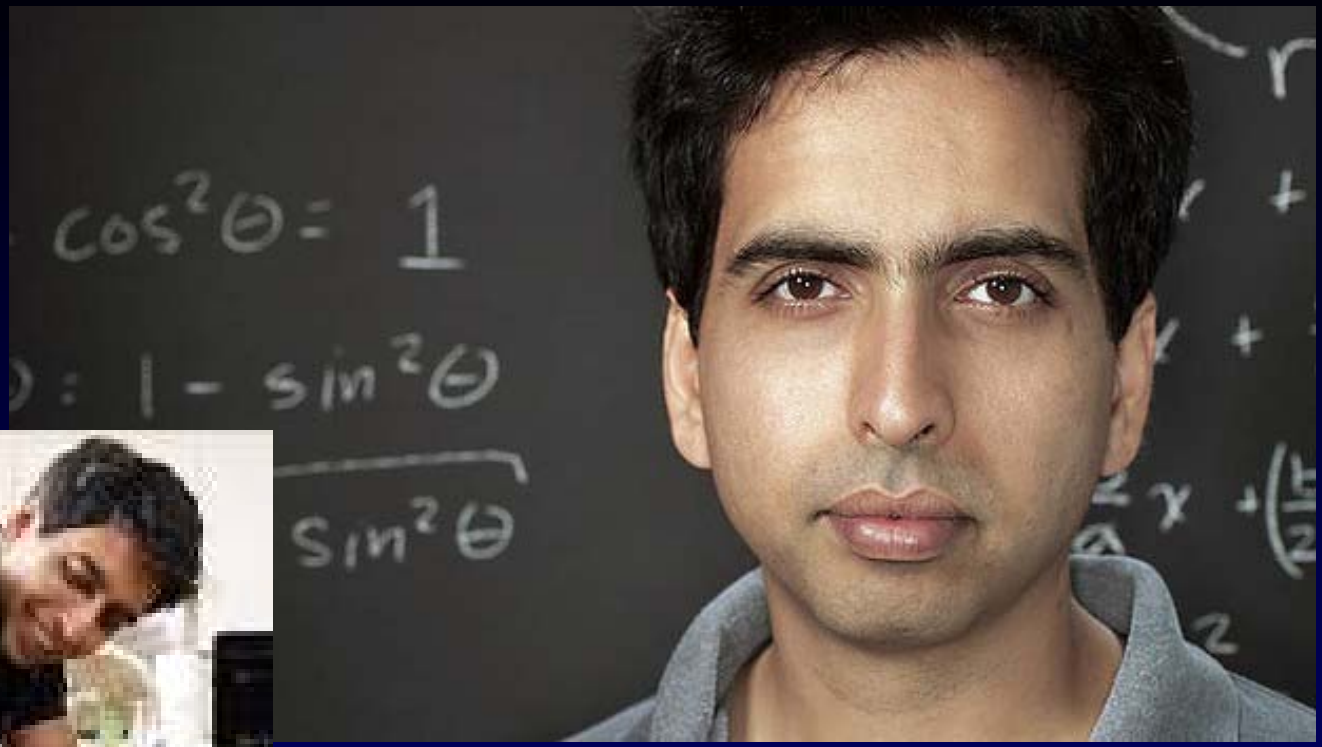
… I got a higher grade than the others

… I received recognition or prestige

… I was the only one in class who knew the answer

… all the tasks and assignments were easy

Perrot et al, Adv. Health Sci. Ed. **6** 193 (2001)



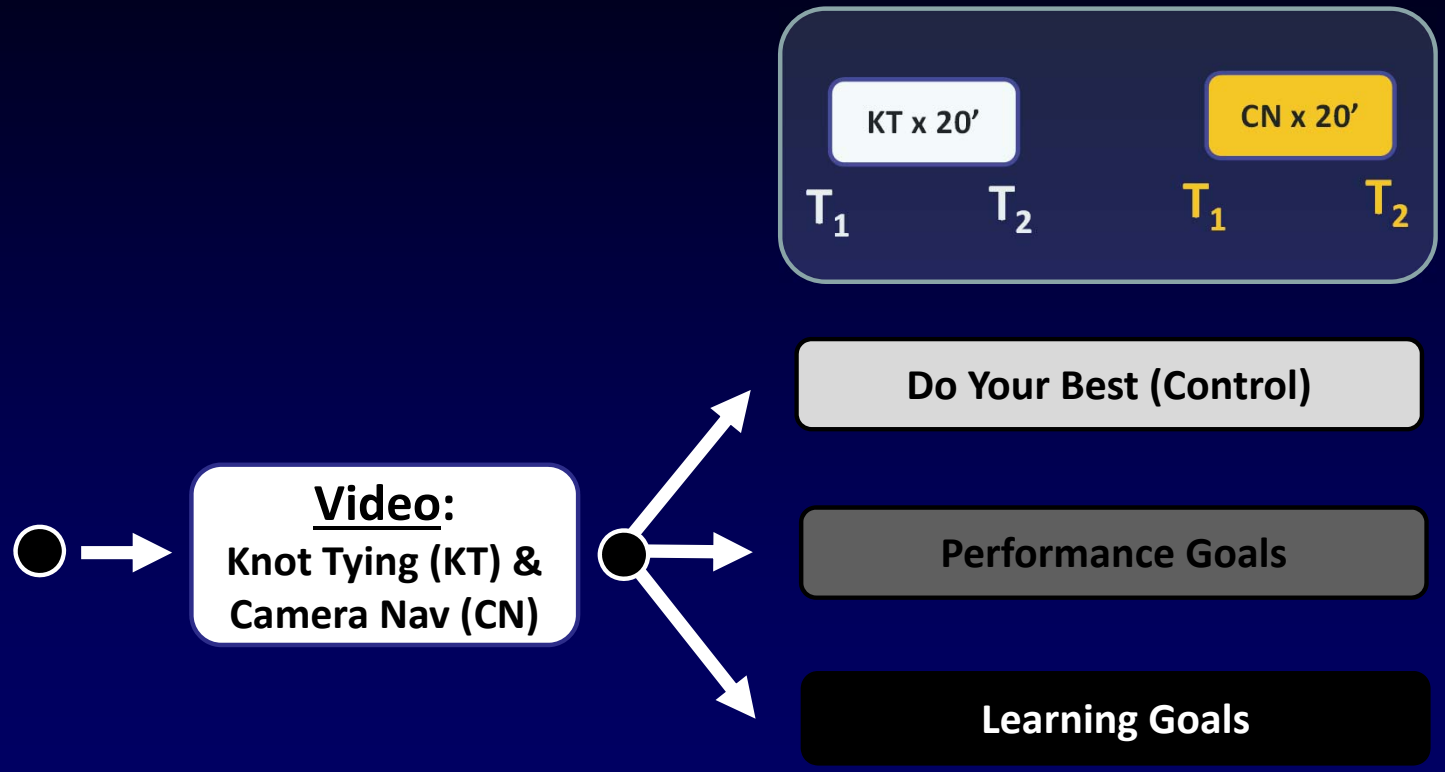
https://www.youtube.com/watch?feature=player_embedded&v=JC82Il2cjqA

https://www.khanacademy.org/about/blog/post/95208400815/the-learning-myth-why-ill-never-tell-my-son-hes

"I am more convinced than ever that mindsets toward learning could matter *more than anything else* we teach."

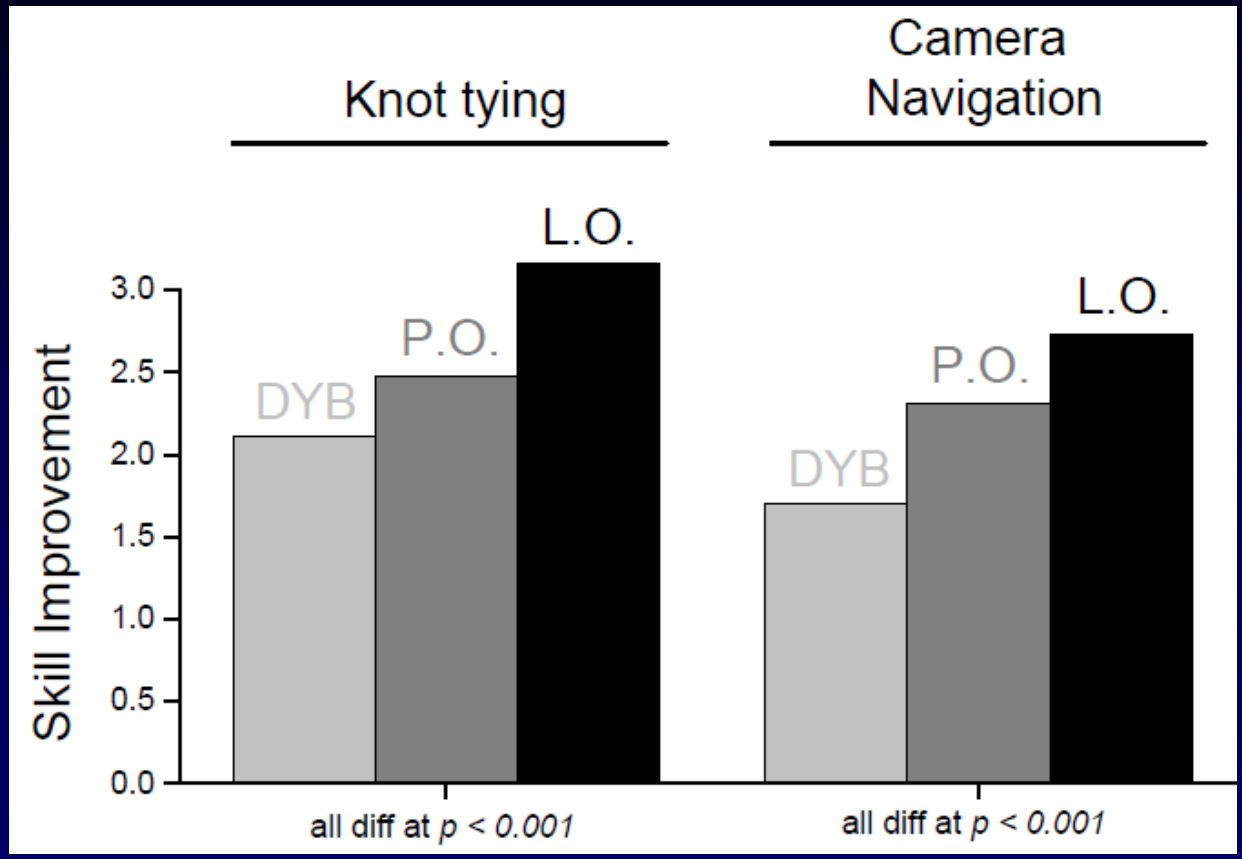
Sal Kahn, 2014

Do Goal Orientations Matter to Skill Acquisition?



Gardner et al, Am. J. Surg. **211** 321(2016) 3rd Yr Med Students

A Learning Orientation (LO) During Training Results in Better Skill Acquisition



Gardner et al, Am. J. Surg. **211** 321(2016)

Interactions between 'Person' and 'Environment' Favors a Learning Orientation Environment

		Environment		
		DYB	Performance	Learning
Person	Performance Oriented	-.92	ns	ns
	Learning Oriented	ns	-.62	+.85

Gardner et al, Am. J. Surg. **211** 321(2016)

Research findings on Learning Orientation (LO)

Response to a setback is more functional with a **LO** (1-4)
LO can be increased by primes and environment (5)
Medical student **LO** decreases during 1st year (6)
Teachers prefer students who have a **LO** (7)
Residents with a **LO** accept negative feedback better (8)
A **LO** increases information sharing with colleagues (9)
LO scientists engage in more collaborative research (10)
One's **LO** is unrelated to one's validation orientation (11)

1) Grant et al., J Pers Soc Psych **85**, 541 (2003)
2) Mueller et al., J Per Soc Psych **75**, 33 (1998)
3) Nussbaum et al., Pers Soc Psychol Bull **34**, 599 (2008)
4) Hong et al., J Pers Soc Psych **77**, 588 (1999)
5) Heslin et al., J App Psych **90** 842 (2005)
6) Madjar et al., Adv in Health Sci Educ **20**, 45 (2015)
7) Schraw et al., J Educ Res **91,** 215 (1998)
8) Teunissen et al., Acad Med **84**, 910 (2009)
9) Matzler et al., J Econ Psych 32 317 (2011)
10) Bateman et al., PNAS **112** 3653 (2015)
11) Attenweiler et al., Ed. Psych. Meas. **66** 342 (2006)

Thanks for your attention and participation

Questions?

khbaker@partners.org

Review : Weidman and Baker. Anesth Analg **121, 1**586 (2015)