

Learning in Science and Engineering: An overview

Roland Tormey

Teaching Support Centre / Centre d'appui à l'enseignement

Email: roland.tormey@epfl.ch

Introduction

- Where does evidence about learning come from?
- Key findings:
 - Working
 - Prior Knowledge
 - Feedback systems
 - Appropriate Challenge
 - Spread over time
 - Independence
 - Beliefs about self and material

Sources of Evidence

- American Psychological Association Review of Evidence on school reform (1997)
- US National Research Council review of Evidence on learning and teaching (2000)
- Best evidence synthesis on learning for diverse settings (2003)
- Meta-analysis of 800 meta-analyses on learning (2009)

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Learning is work

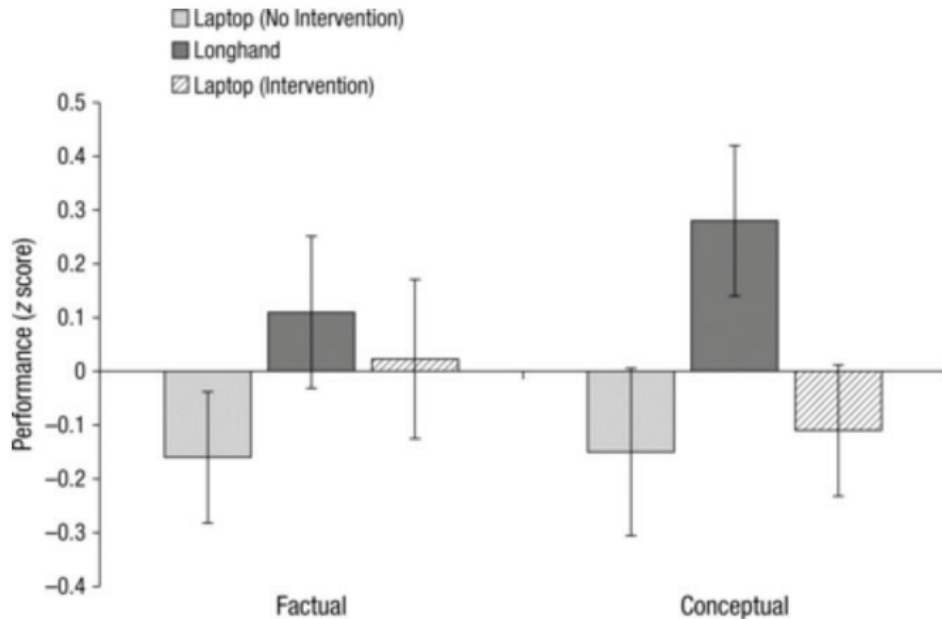


Fig. 4.

Mean z-scored performance on factual-recall and conceptual-application questions as a function of note-taking condition (Study 2). Error bars indicate standard errors of the mean.



- “...synthesizing and summarizing content rather than verbatim transcription can serve as a desirable difficulty...”

The Pen Is Mightier Than the Keyboard
Advantages of Longhand Over Laptop Note Taking
Mueller and Openheimer 2014 *Psychological Science*

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Our Knowledge is Connected (or not...)

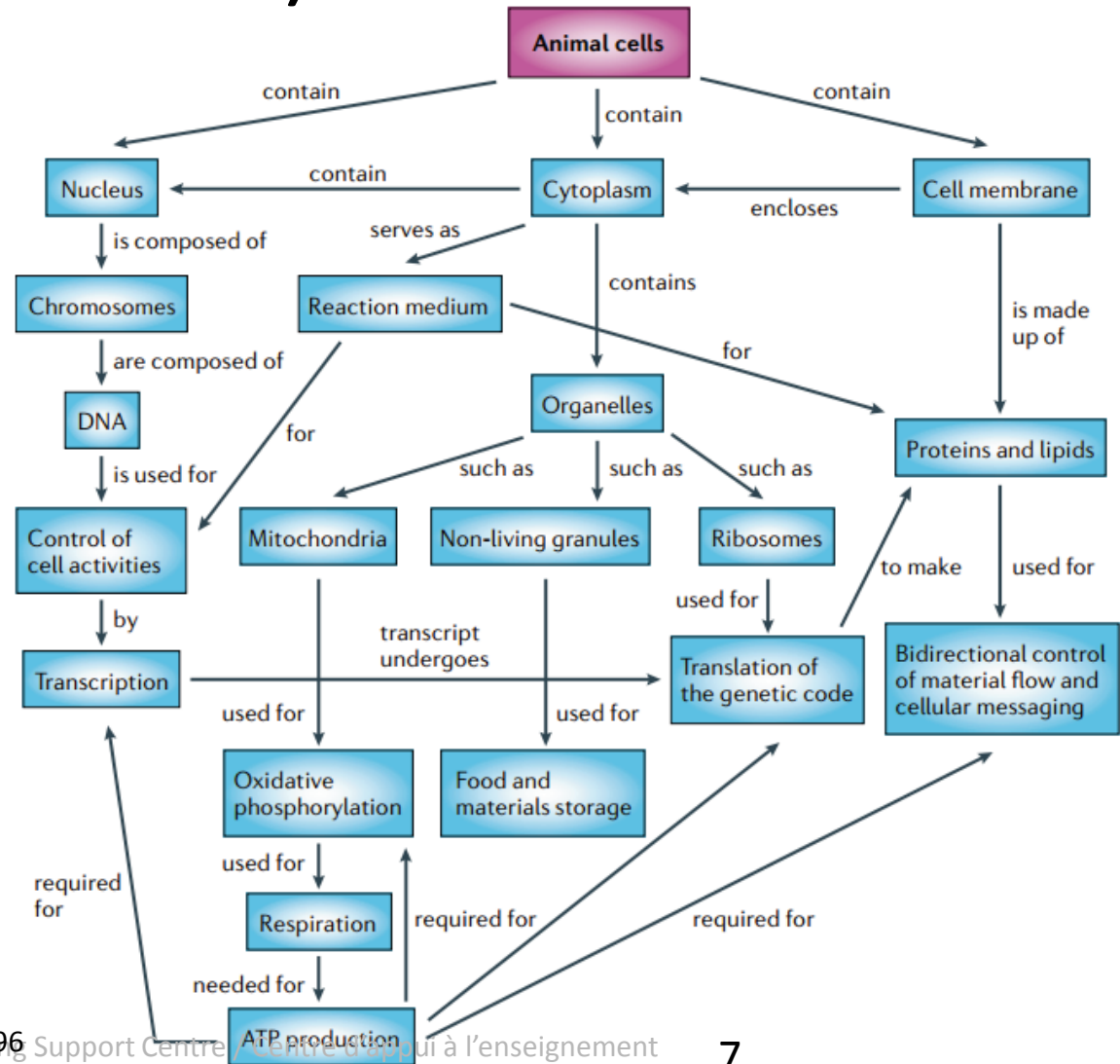
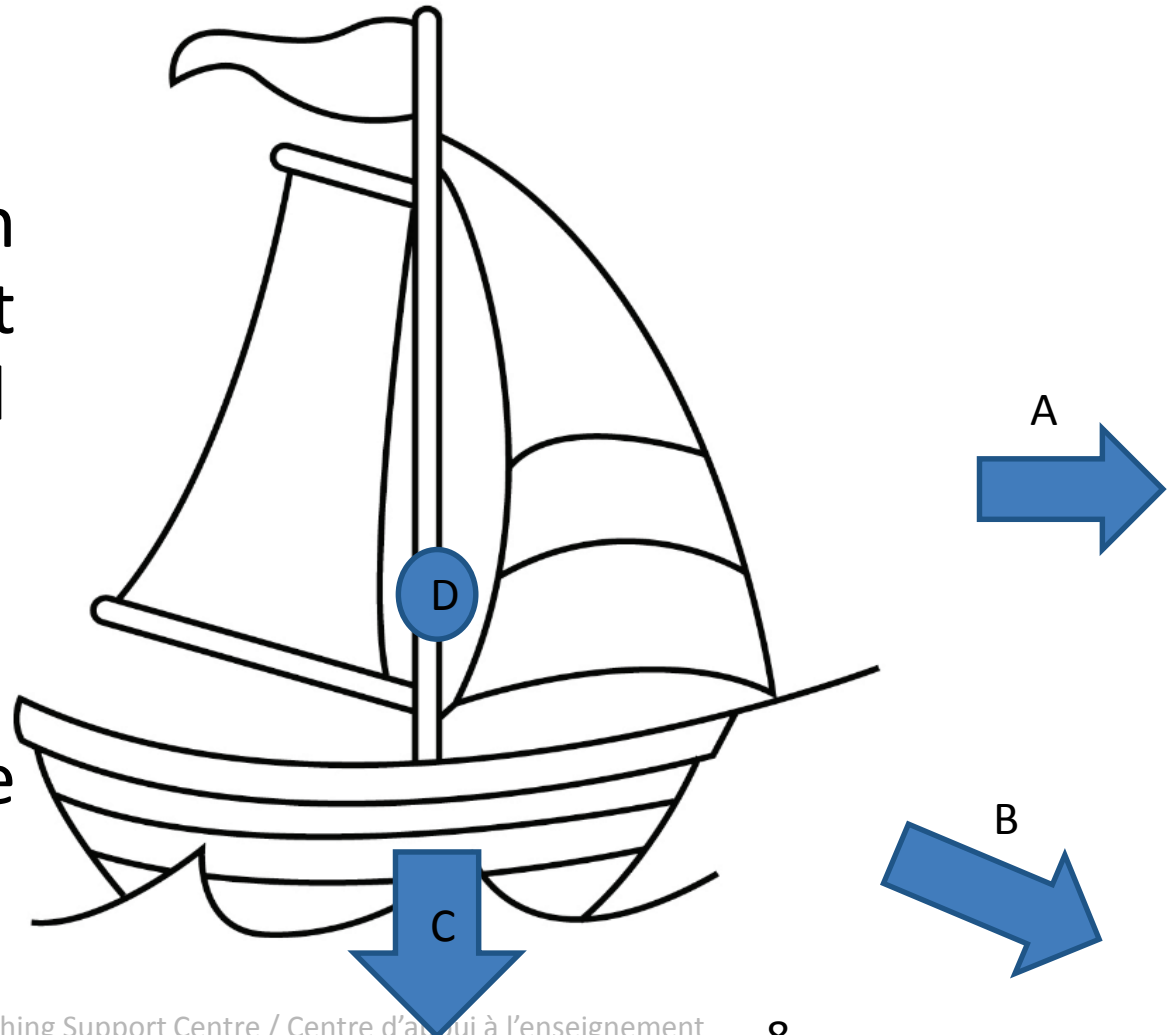
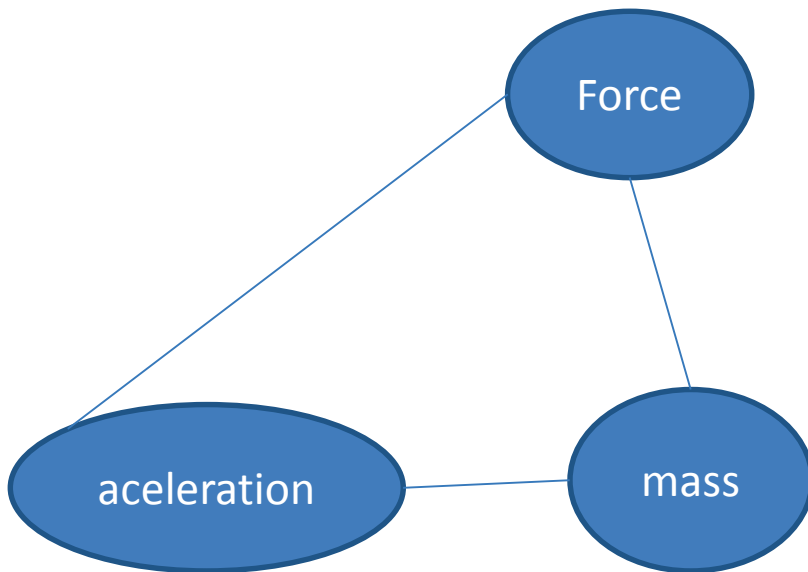


Image: Stephen Dicarlo (2006)

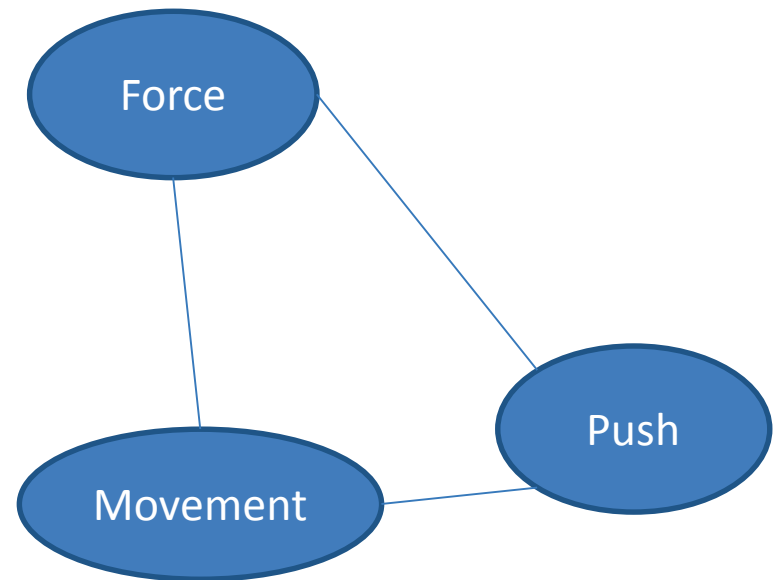
- Boat being driven by the wind straight in NE direction, at constant speed of 6 km/h.
- What is the direction of the net force?



Formal Model



Everyday thinking Model



Prior (Implicit) Misconceptions

About Forces:

- “If something is not moving there are no forces acting on it”

About thermodynamics:

- “Heating always results in an increase in temperature”
- “Materials like wool have the ability to warm things up”

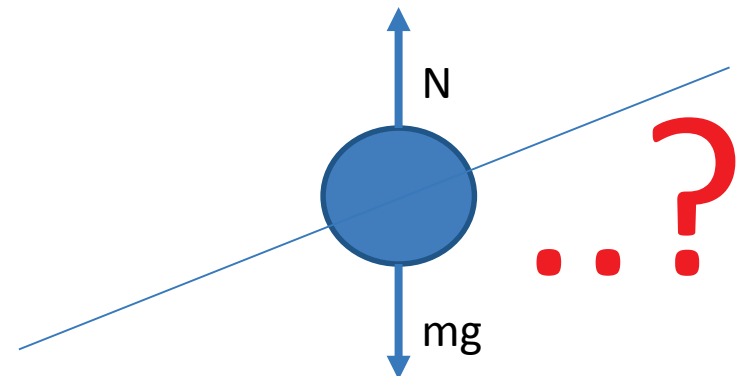
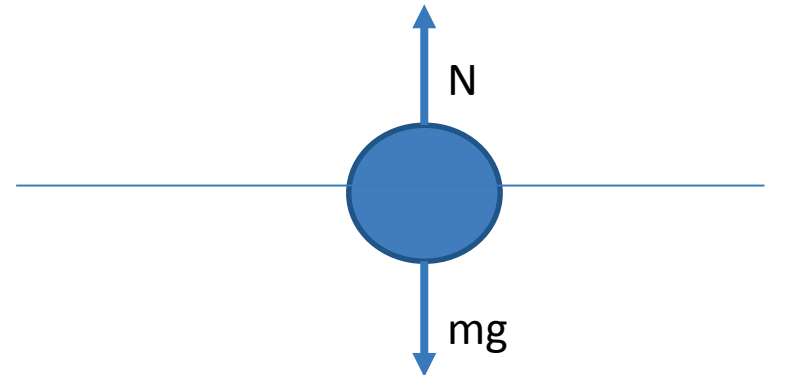
About oxidation:

“When metal rusts it gets lighter”

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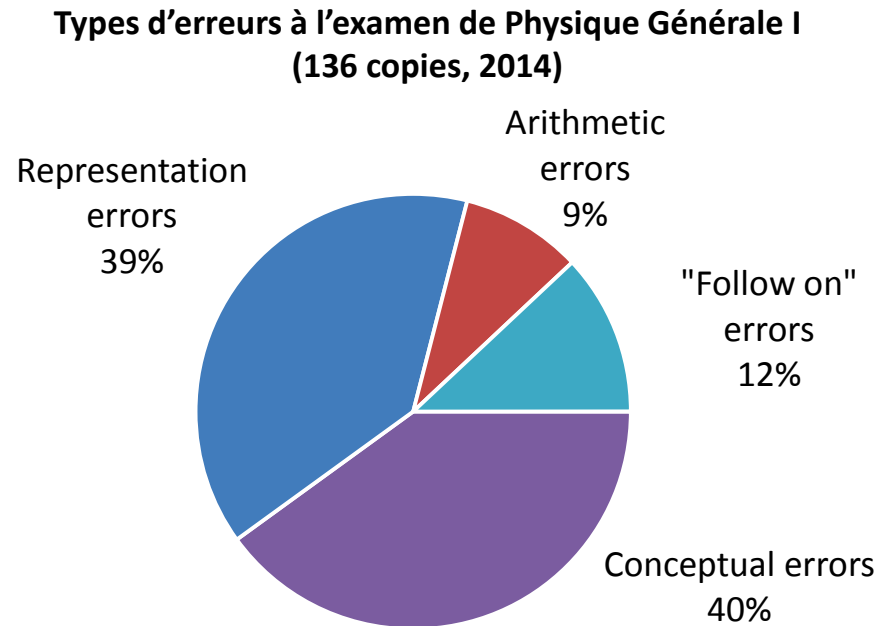
Feedback

- Learners make errors, then what?
 - feedback is “among the most powerful influences on achievement” (Hattie, 2009, p. 173)
 - Immediate feedback is preferable
 - Focus on goals, not the person
- What sources of feedback are typically available in college?



Errors in 1st Year Exams

- Representation errors were common in student exams
 - Project forces onto a coordinate system
- This type of activity was practiced in almost every exercise session!!
- Many students appear to not learn from mistakes



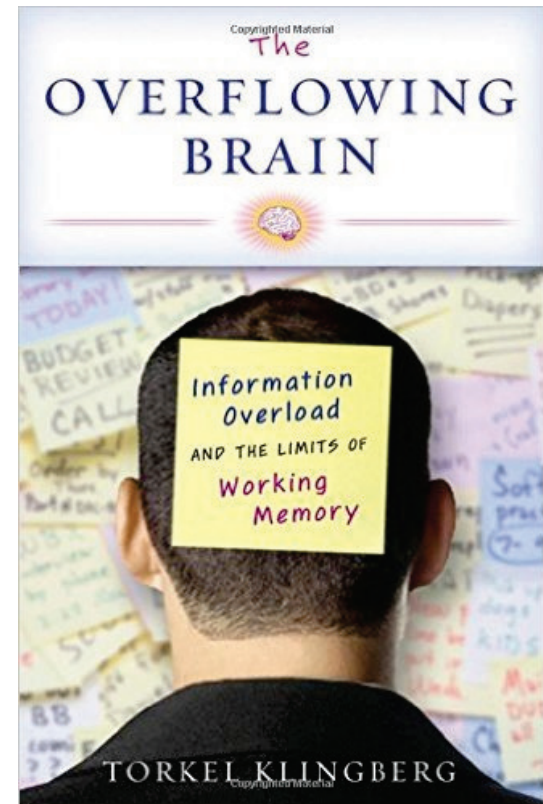
*P. Campiche, O. Chandran, D. Lombardo, and A. Trömel,
« Identification of common errors in learning classical mechanics »,
How People Learn Student Presentations, EPFL, Lausanne, 2015.*

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- In a calculus II class, a student is learning to integrate some ‘difficult to integrate’ functions, using trigonometric identities.
- In the exercise session, one of the questions is “What is the area under the curve of $f(x) = \cos^2(x)$ between $-\frac{\pi}{4}$ and $\frac{\pi}{4}$? “

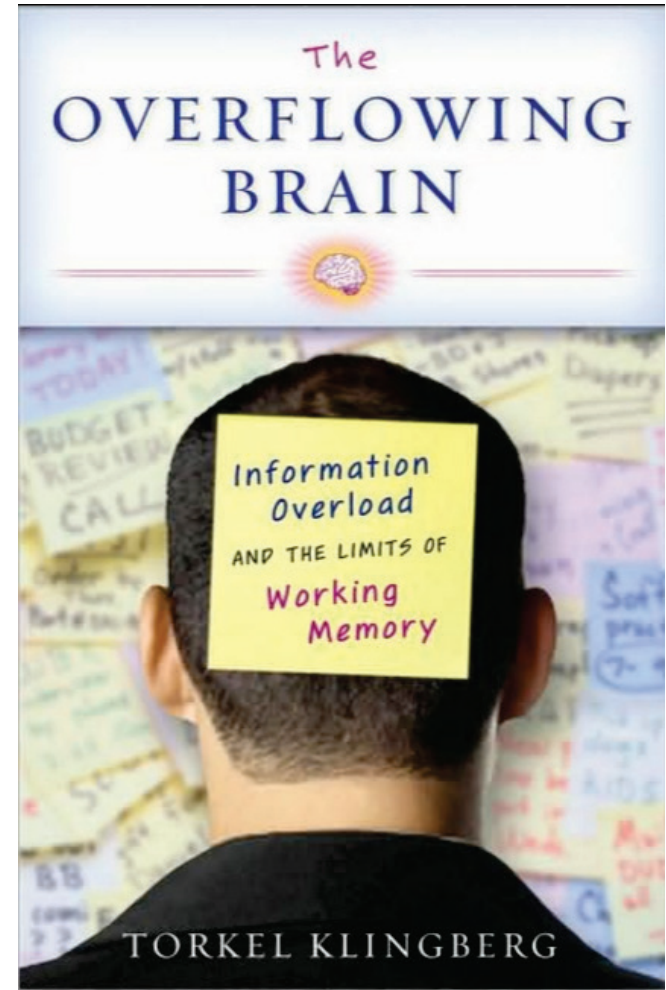
To solve the problem...

- Concepts from Calculus I (3 months ago)
 - How to find the signed area under the curve of a function
- Concepts seen in Calculus II but not in the last 4 weeks
 - What integrals they can assume are 'standard'
 - Integration by substitution (requiring the derivative as well as the integral of a function)
- Concepts seen in geometry (a year ago)
 - Uncommon trigonometric identities, like $\cos^2\theta = \frac{1}{2}(1 + \cos(2\theta))$
 - θ and x can be treated as interchangeable

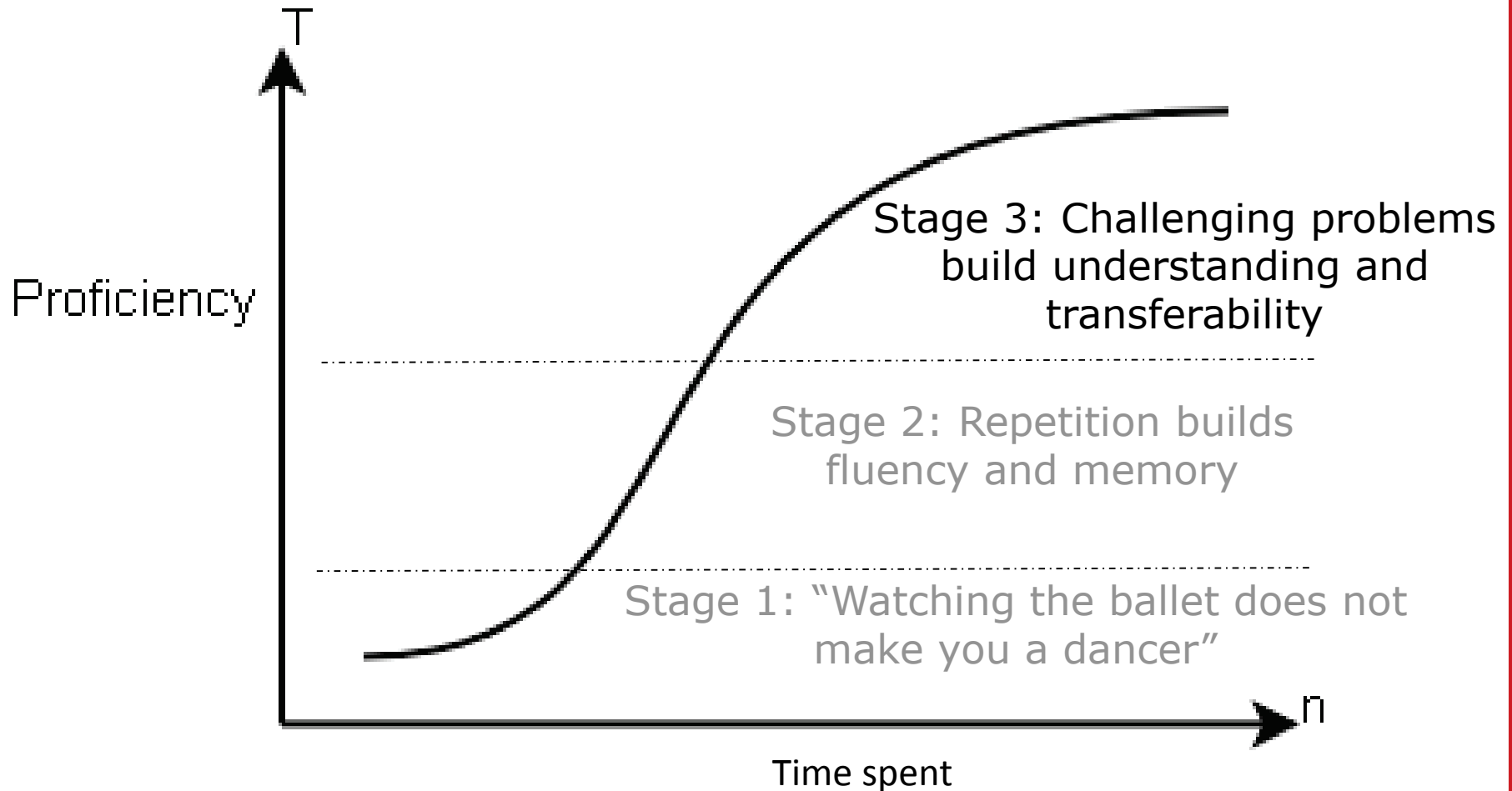


Limits to Processing Capacity

- The Magic Number 7(± 2)
- How do we cope?
 - Automatization of mental processes
 - Unlimited use of resources in LTM



Right challenge at the right time



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« Maintenance of Knowledge: Question of Memory We forget to Ask »

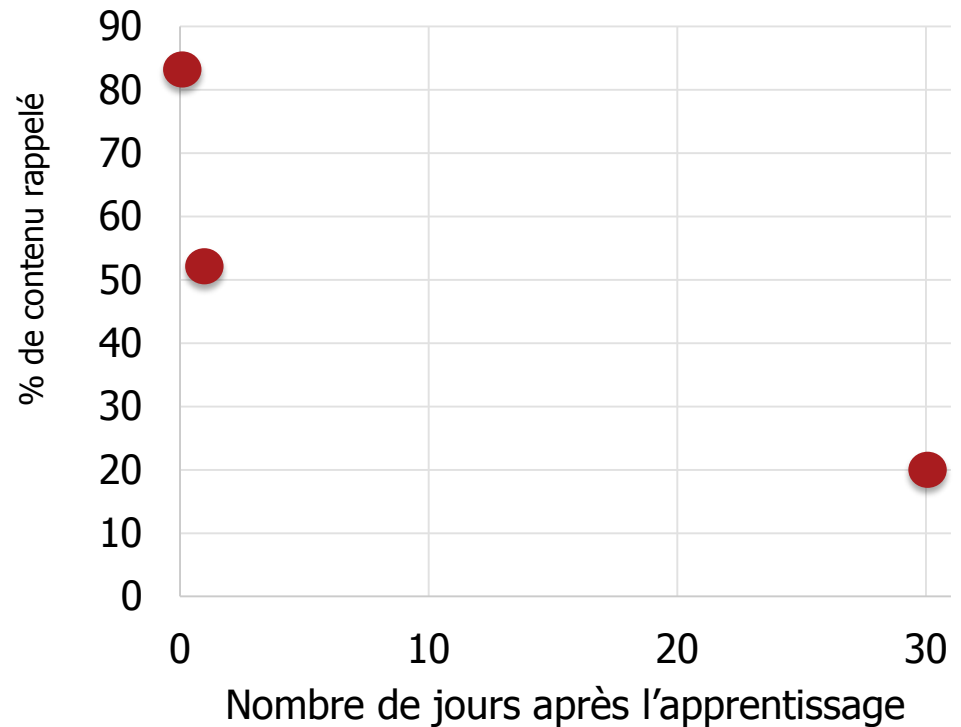
Harry Bahrick

Journal of Experimental
Psychology (1979)



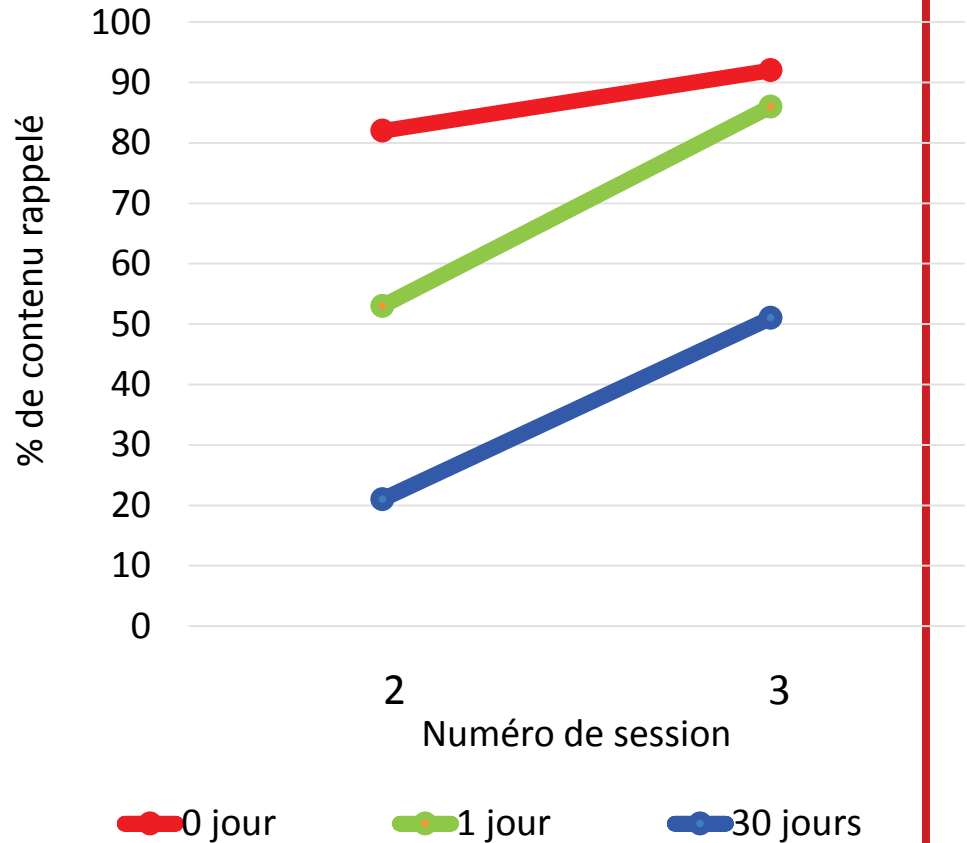
How much do we forget over time?

- Gap between tests:
 - Later same day
 - 1 day later
 - 30 days later
- We forget in an exponential way



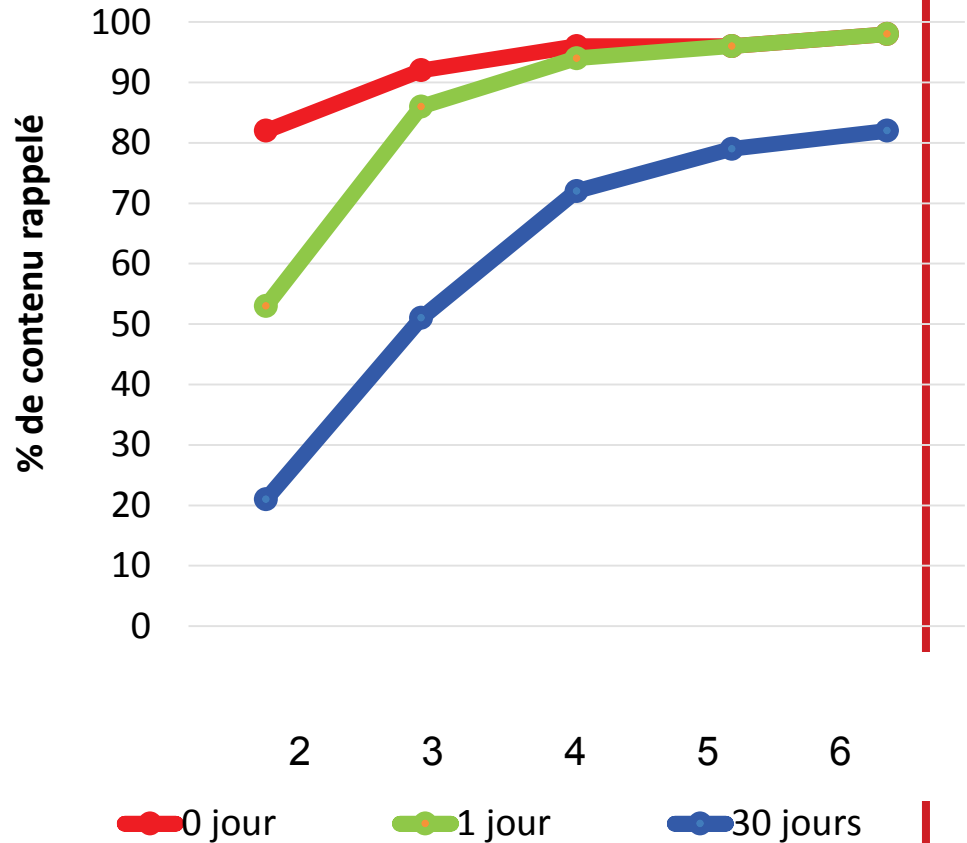
Does repetition help learning?

- Intervals between sessions:
 - **Later the same day**
 - **1 day later**
 - **30 days later**
- Longer intervals have a bigger effect on learning/retention



A quel point la répétition facilite-t-elle l'apprentissage ?

- Intervals between sessions:
 - **Later the same day**
 - **1 day later**
 - **30 days later**



Interval between training sessions	Score on final test
0 days	68
1 day	86
30 days	95

- Final test was 30 days after the last training session
- The group with the spaced training sessions performed best
- Spaced practice effectg

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Plan, Monitor, Debug, Review

Metacognition		
'thinking about thinking' across memorising, problem-solving and emotion regulation		
Meta-Knowing (Kuhn, 2000)		
Metacognitive knowledge (What to do, How to do it, When to do it)	Metacognitive Regulation	
	Regulation of Self and Executive Control (Planning, Monitoring, Debugging, Evaluating)	Metacognitive Feelings/ Judgements (Prospective, Concurrent and Retrospective)

Source: After Schraw and Dennison (1994) (shaded component), but informed by Schneider (2008), Schraw (2009) and Tarricone (2011)

Are students metacognitive?

- 169 2nd year students, **spring 2014**
- Test of whether they re-check results
- **60.4%** did not check all answers carefully.
- They were also asked to rate their skills at re-checking
- Self report was not correlated with objective score
- **...although many students are weak at monitoring their work, they are not particularly aware of this weakness**



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Beliefs about self

- Self-efficacy
 - I am good at this kind of thing
- Locus of Control
 - I can prepare better next time
 - Sometimes you are just unlucky

Conclusion

- Evidence exists
 - even if teachers and learners often don't use it
- Highlights key features
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