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**The Things We Know,  
The Things We Think We Know but Don't  
The Things We Don't Know but Should**

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There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know.

[Donald Rumsfeld](#)

# The Agenda

- 1) Some assertions about the nature of learning and teaching
- 2) A brief critique of some of the assertions
- 3) Science of learning – basic principles
- 4) Implications for educational research and practice

# 1) Admissions

Grades only predict grades. Performance on a multiple choice test has nothing to do with success as a doctor

## 2) Individual students

Individual students have different approaches to learning. An effective teacher must take individual learning styles into account

## 3) Self Assessment

It is essential that students learn self-assessment skills so they can become successful lifelong learners

## 4) Generation Y

Modern students are highly effective multi-taskers. “Children growing up now might have an associative genius we don’t– a sense of of the way ten projects all dovetail into something totally new”. (Anderson, 2009 in Kirshner, 2013)

## 5) Learning and Instruction

Learning in context assures transfer to the work situation. Successful simulations must closely resemble the real world (authenticity, high fidelity)



## 6) E-Learning

E-learning has clear and consistent advantages over alternative approaches. Today's students learn better in a virtual environment

## 7) Knowledge and Performance

Too much testing time is spent on knowledge tests. Knowledge tells us very little about how a student will perform. We should put more emphasis on performance measures like OSCEs.

## 8) Assessment and Learning

Multiple choice tests are overused. Too much testing interferes with learning.

## 9) Objectivity of assessment

Objective checklists are preferable to subjective ratings, because they are more reliable and valid.

# The Answers

According to Geoff, all the answers are wrong!

If you want the critical evidence, e-mail me at:

**[norman@mcmaster.ca](mailto:norman@mcmaster.ca)**

# Some of the Evidence

- Learning styles
- High vs. Low Fidelity
  - Comparison to nothing, alternative
- E-learning
  - Comparison to nothing, alternative
- Predictive Validity of Multiple Choice

# Are we really dealing with a new generation of multitaskers?

In conclusion, there is strong evidence that multitasking and task switching **impair** performance...

... there is overwhelming evidence that the “homo zappiens” and the multitasker do not exist,... and that they may actually suffer if education tries to play into these abilities to relate to, work with and control their own learning in multimedia and digitally pervasive environments.”

Kirschner & van Merriënboer, *Educ Psychol* 2013; 48: 169-183

# Learning styles

Do individual students have different learning approaches or styles?

Does matching teaching to learning result in enhanced learning?



“... our search of the learning-styles literature has revealed only *a few fragmentary and unconvincing pieces of evidence that meet this standard* [ that matching instruction to learning style enhances learning], and we therefore conclude *that the literature fails to provide adequate support for applying learning-style assessments in school settings*. Moreover, several studies that used appropriate research designs found evidence that contradicted the learning-styles hypothesis”.

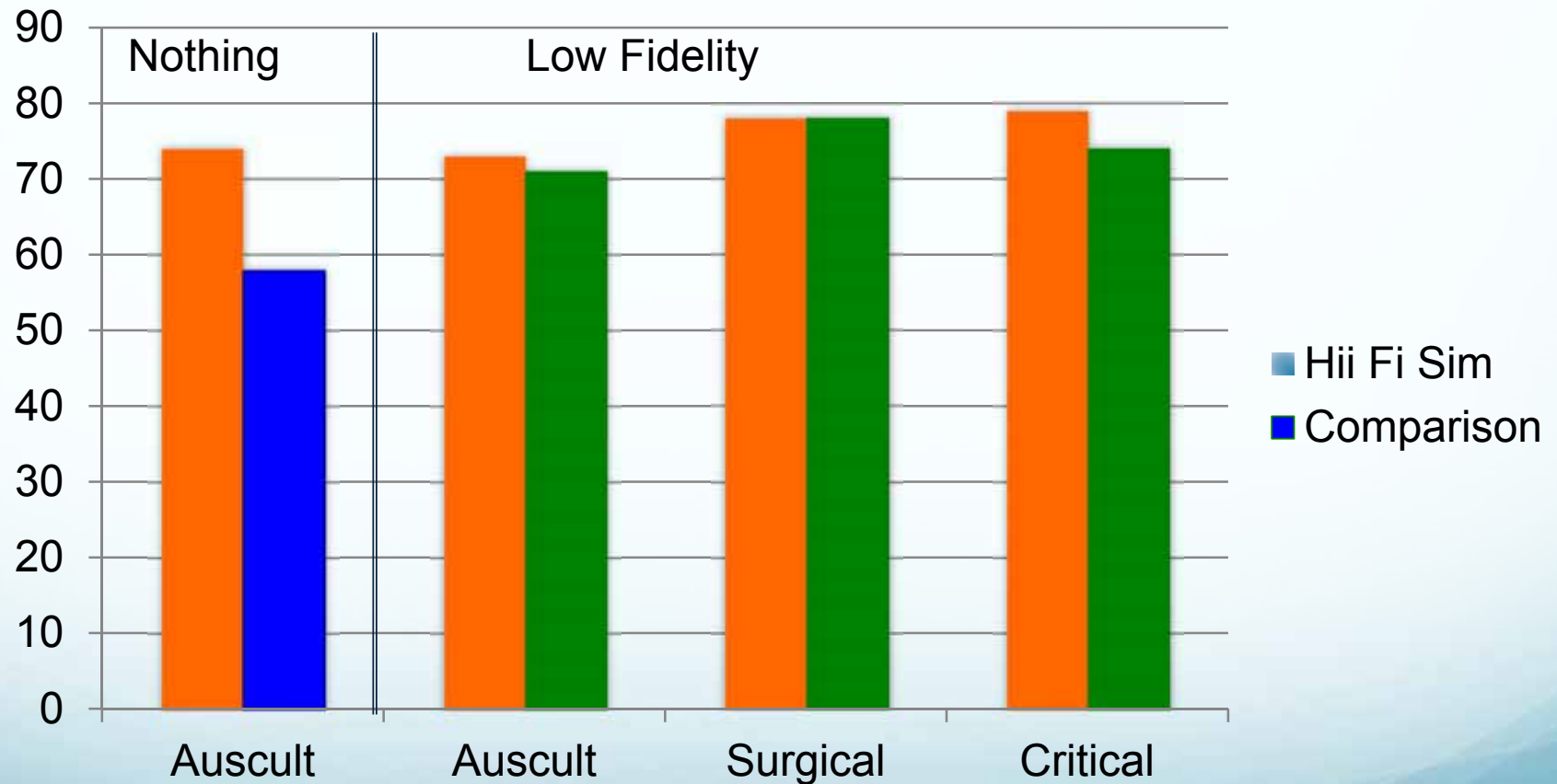
Pashler H, McDaniel M, Rohrer D, Bjork R. Learning styles: concepts and evidence. *Psychol Sci* 2009, 9, 105-119

# Simulation Fidelity and Performance

- Does high fidelity have advantages over low fidelity?
  - (Norman, Grierson, Dore, 2012)
- Review of studies comparing high and low fidelity in three areas
  - Auscultation skills (Harvey vs. CD)
  - Surgical skills
  - Critical care skills (Simulator vs. Didactic)

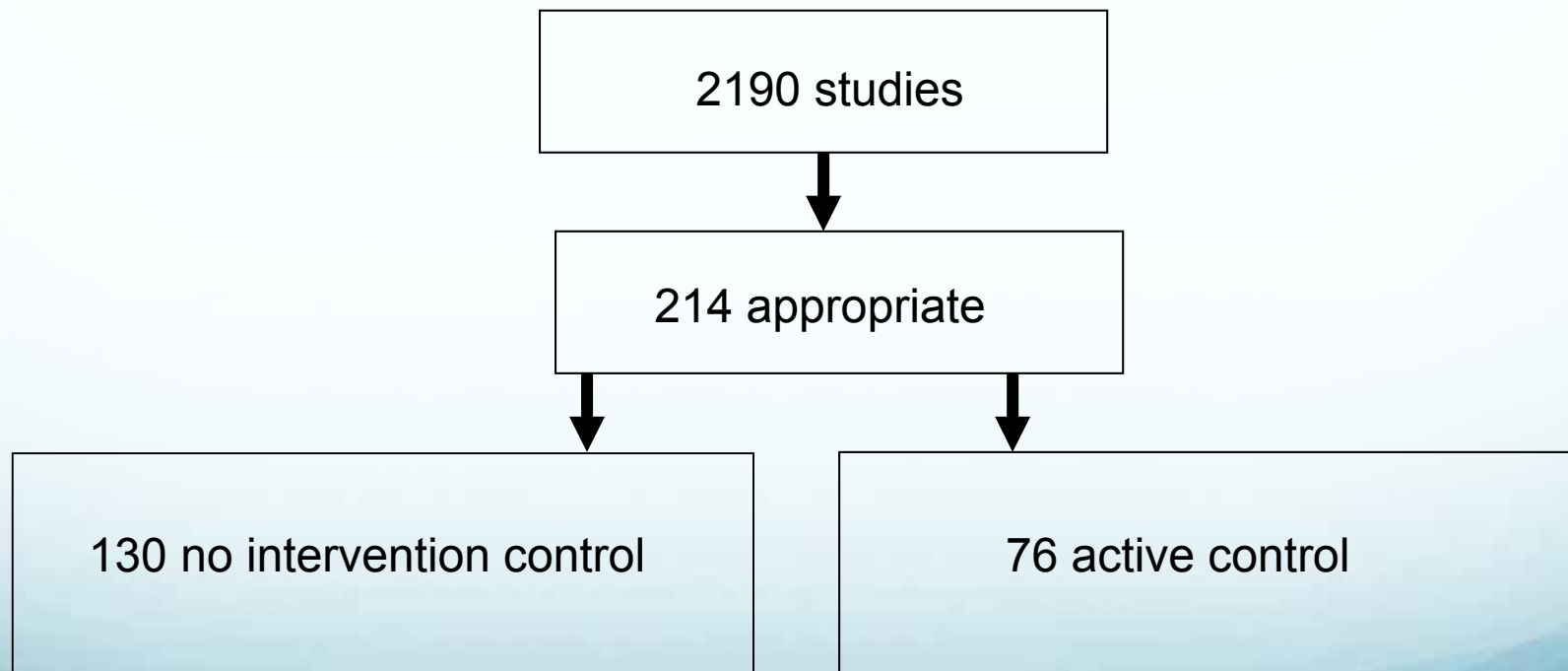
# Summary

## Comparison to nothing, active

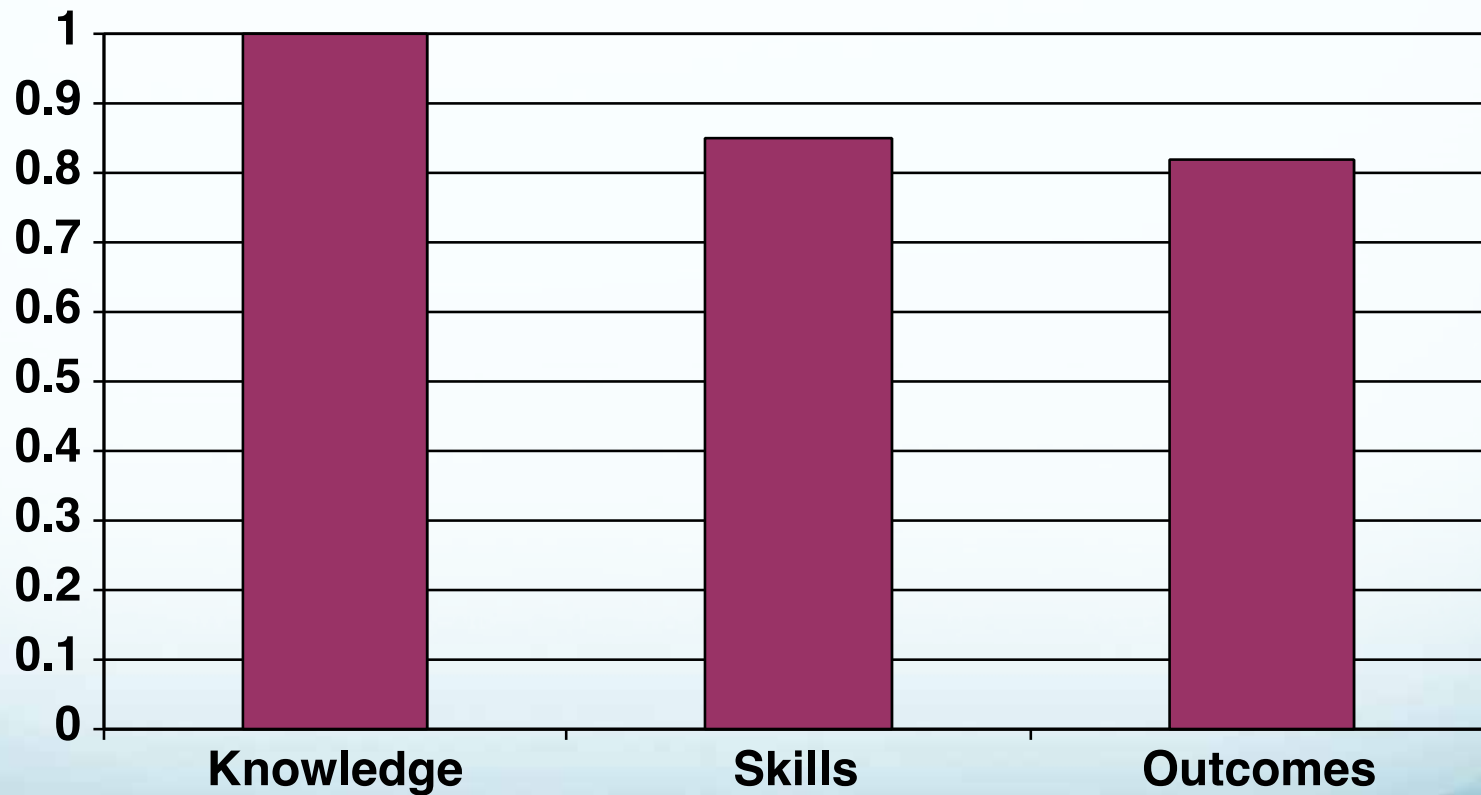


# Does e- learning work?

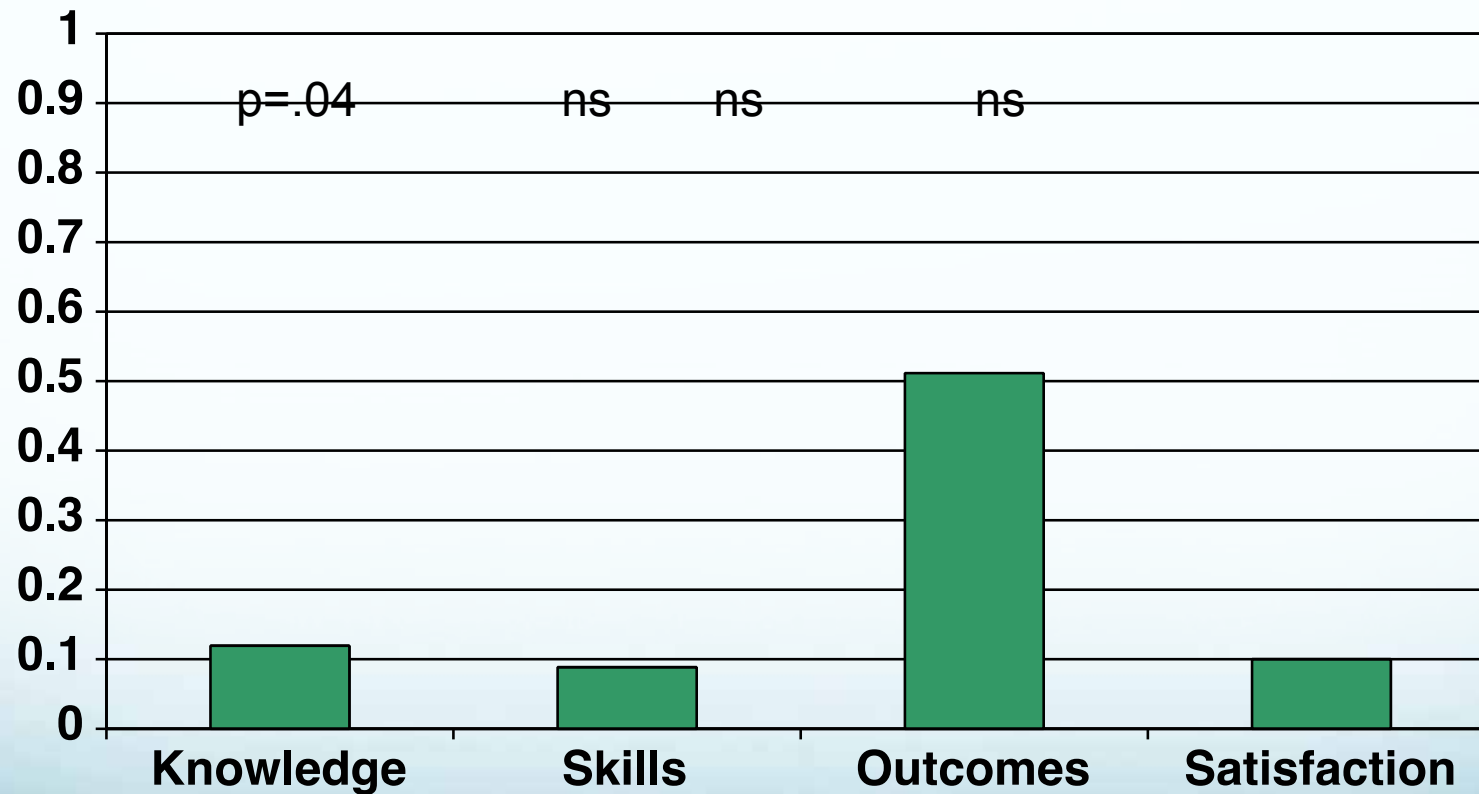
(Cook et al, JAMA 2008; 300: 1181-1196)



# Effect Size against No Intervention



# Effect Size against Alternative Intervention



# Predictive Validity of Multiple Choice

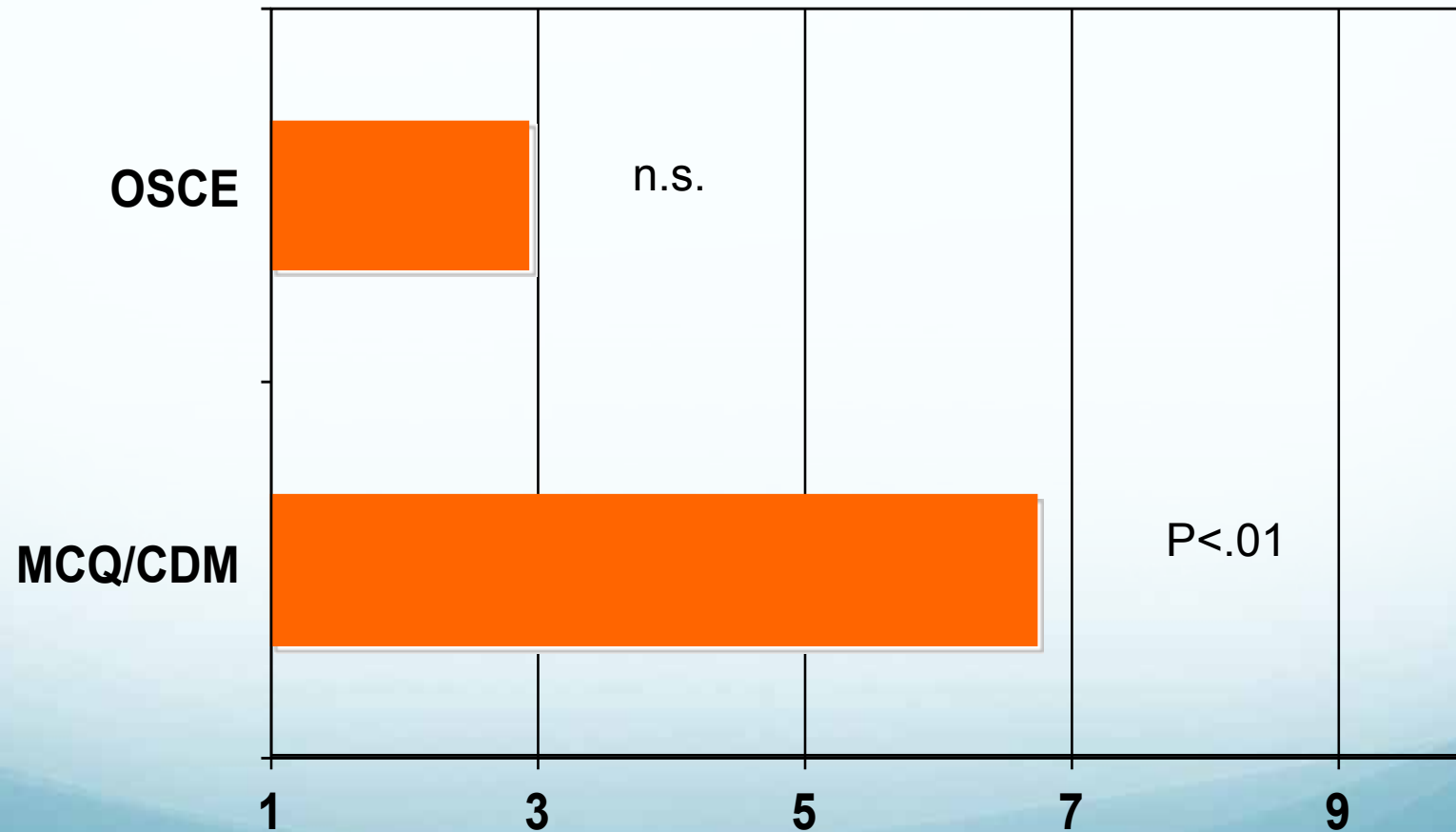
# Predictive Validity of Multiple Choice Test

( Wenghofer et al. et al., Med Educ 2009)

- 208 MDs, licensing exam 1993-1996
- practice in Ontario & Quebec
- Peer assessment , chart review



# O.R per 2 S.D. change in score



# Why are so many of our cherished beliefs so wrong?

- A) Rarely any theoretical or empirical basis
  - “Common sense”
  - “Folk wisdom”
- B) When theories do exist, often untested
  - “Adult learning theory”
  - “Situated cognition”

Most educators use theories the way a drunkard uses a lamppost

More for support than illumination

With apologies to Winifred Castle



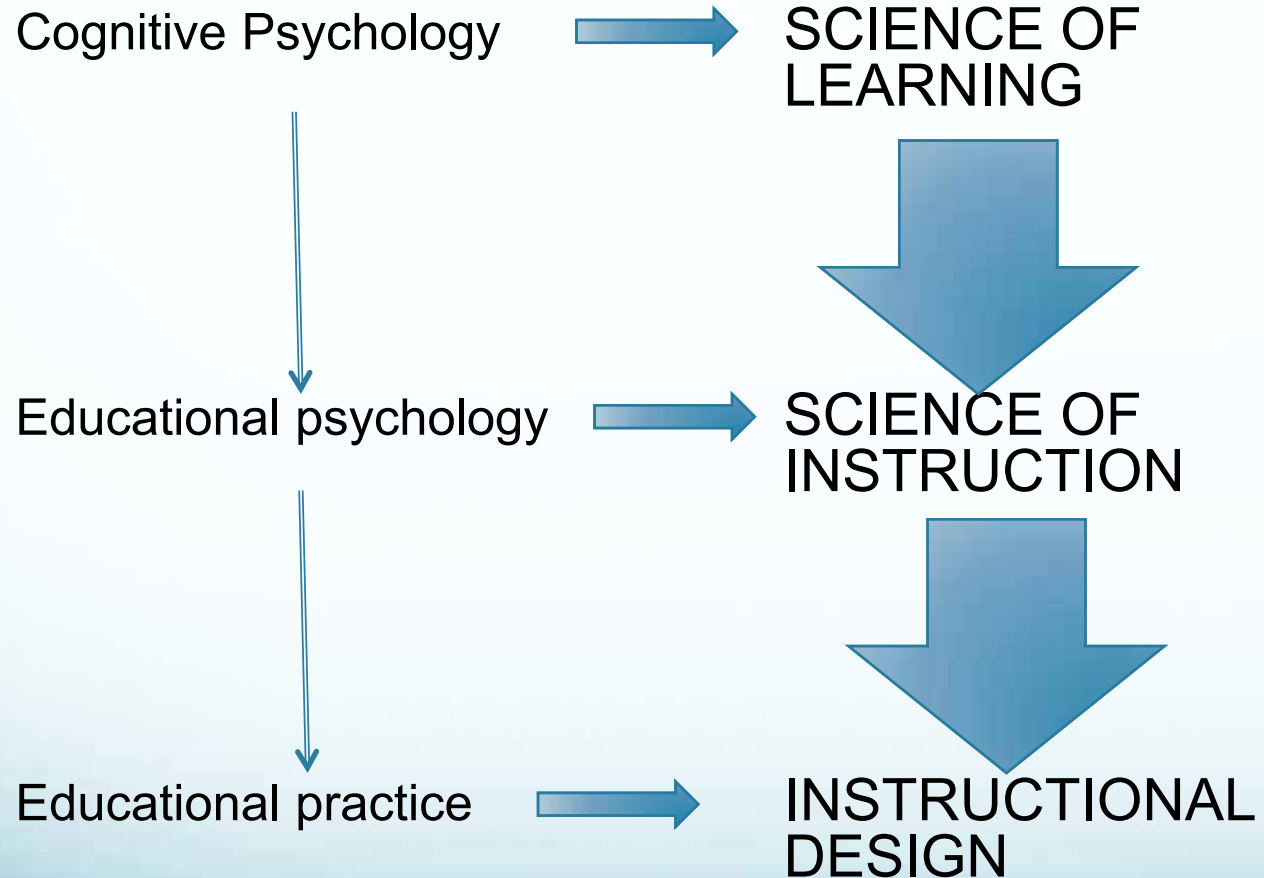
The field of education seems particularly susceptible to the allure of plausible but untested ideas and fads (especially ones that are lucrative for their inventors). One could write an interesting history of ideas based on either plausible theory or somewhat flimsy research that have come and gone over the years. And..... once an idea takes hold, it is hard to root out.

**H. Roediger, 2012**



Where do we go from here?

# A Quiet Revolution

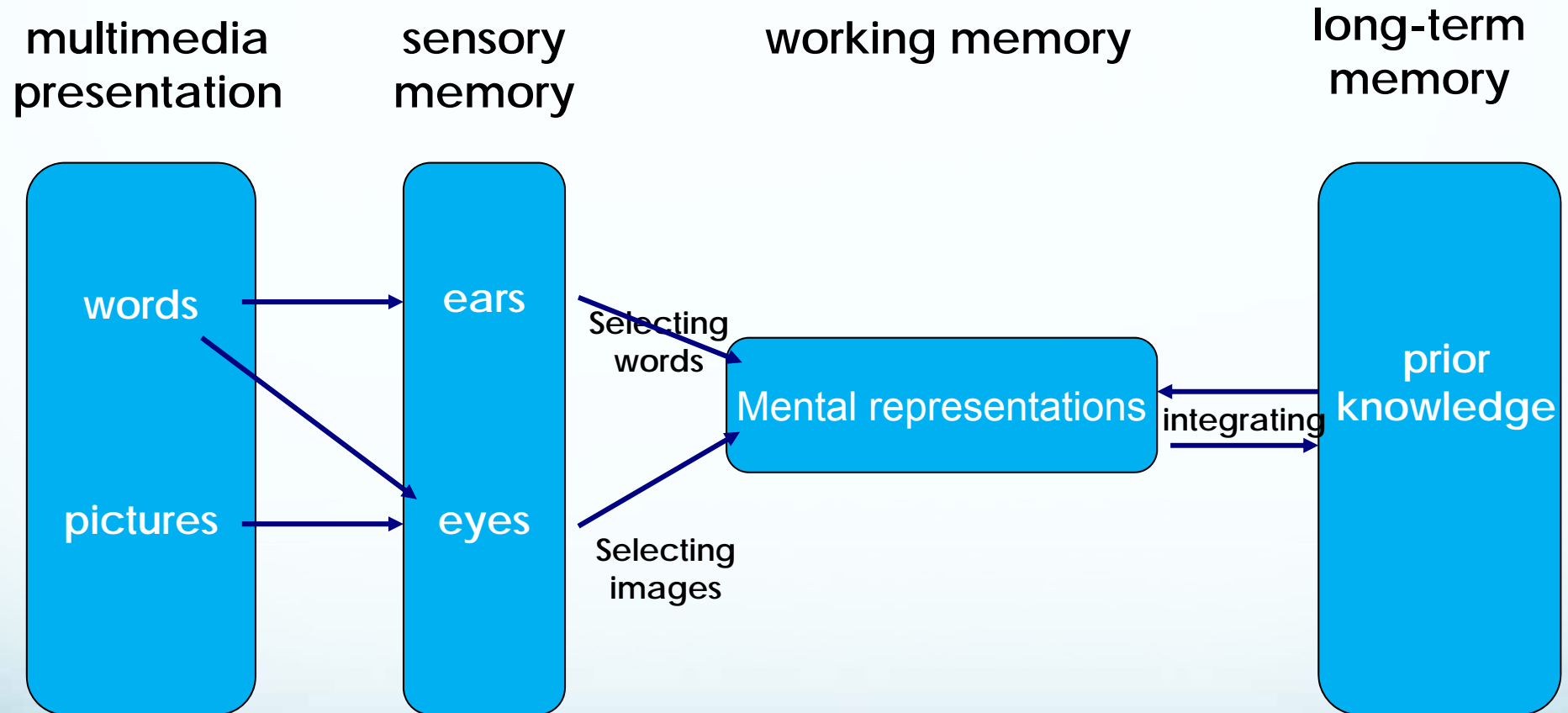


R.C. Mayer, 2010

# The Cast

- Hank Roediger
  - Former editor, J Exp Psychol
- Bob Bjork
  - Former editor, Psychol Review
- Richard Mayer
  - Chair, UC Santa Barbara
- Jeroen van Merriënboer
  - Professor, U of Maastricht
- And a number of supporting actors

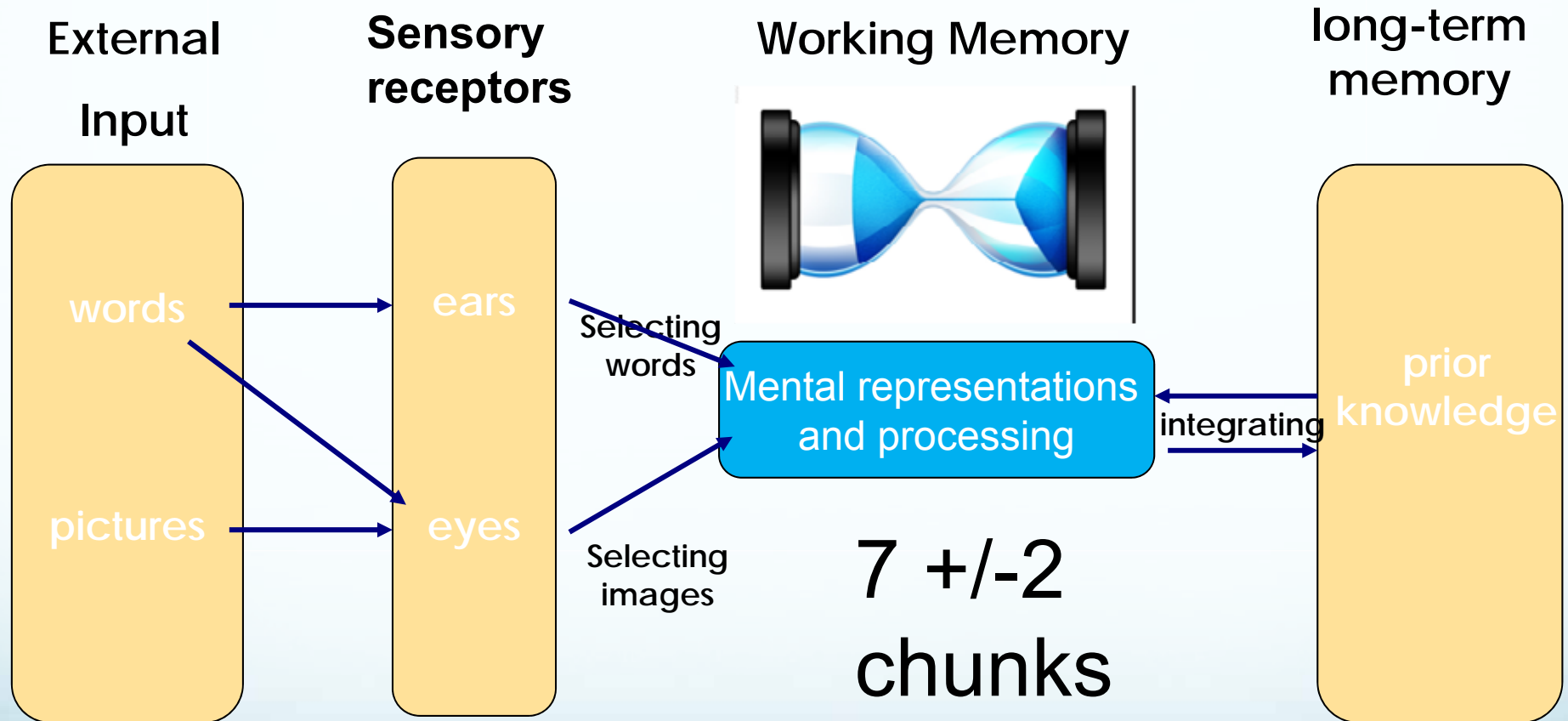
# A Model of Human Information Processing (Thinking)





# Short Term (Working) Memory

# Learning and Cognitive Load Theory



“When processing novel information, working memory is very limited in duration and in capacity”

# Learning, Cognitive Load and Working Memory

Any learning task can load WM in three ways

- Intrinsic Load – characteristics of the task
- Generative Load – additional effort related to learning (e.g. practice)
- Extraneous load

Effective instructional design should increase intrinsic and generative CL, decrease extrinsic CL

# Do specific strategies work?

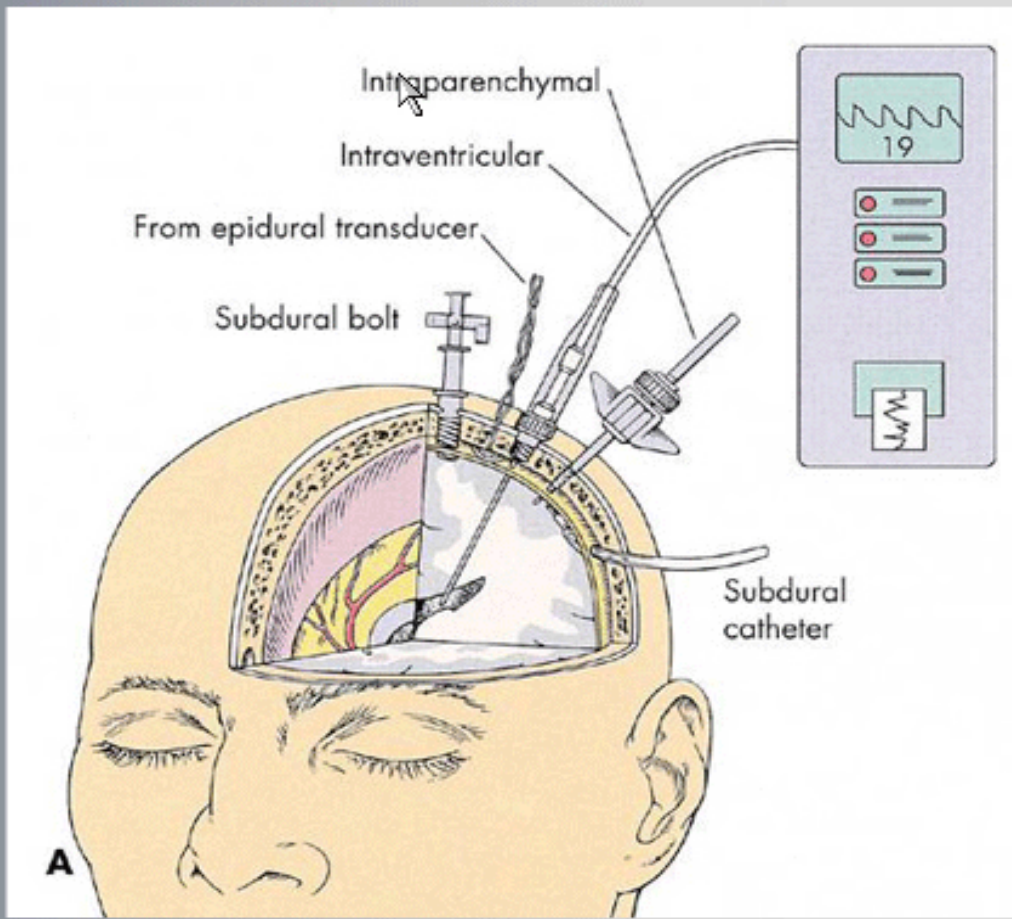
Mayer, RE. Med Educ 2010; 44: 543-549

- Reducing extraneous processing
  - Coherence, signalling, contiguity
- Managing essential processing
  - Pretraining, segmenting, modality
- Fostering generative processing
  - Multimedia, personalization, voice

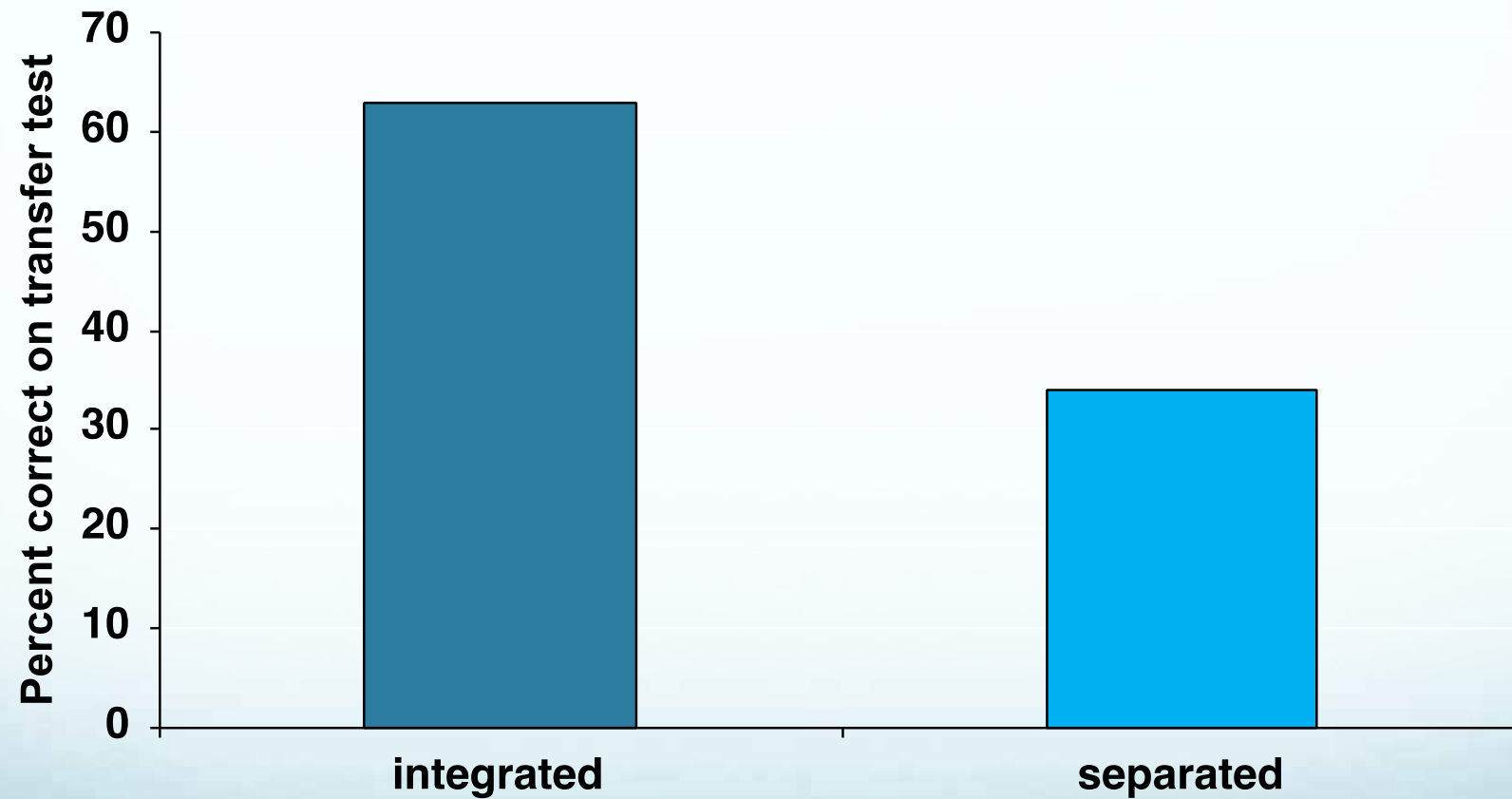
# Reducing extraneous processing

- Contiguity Principle
  - Place corresponding words and graphics near each other

### Intracranial pressure measurement : ICP



# Effect of Contiguity Outcomes



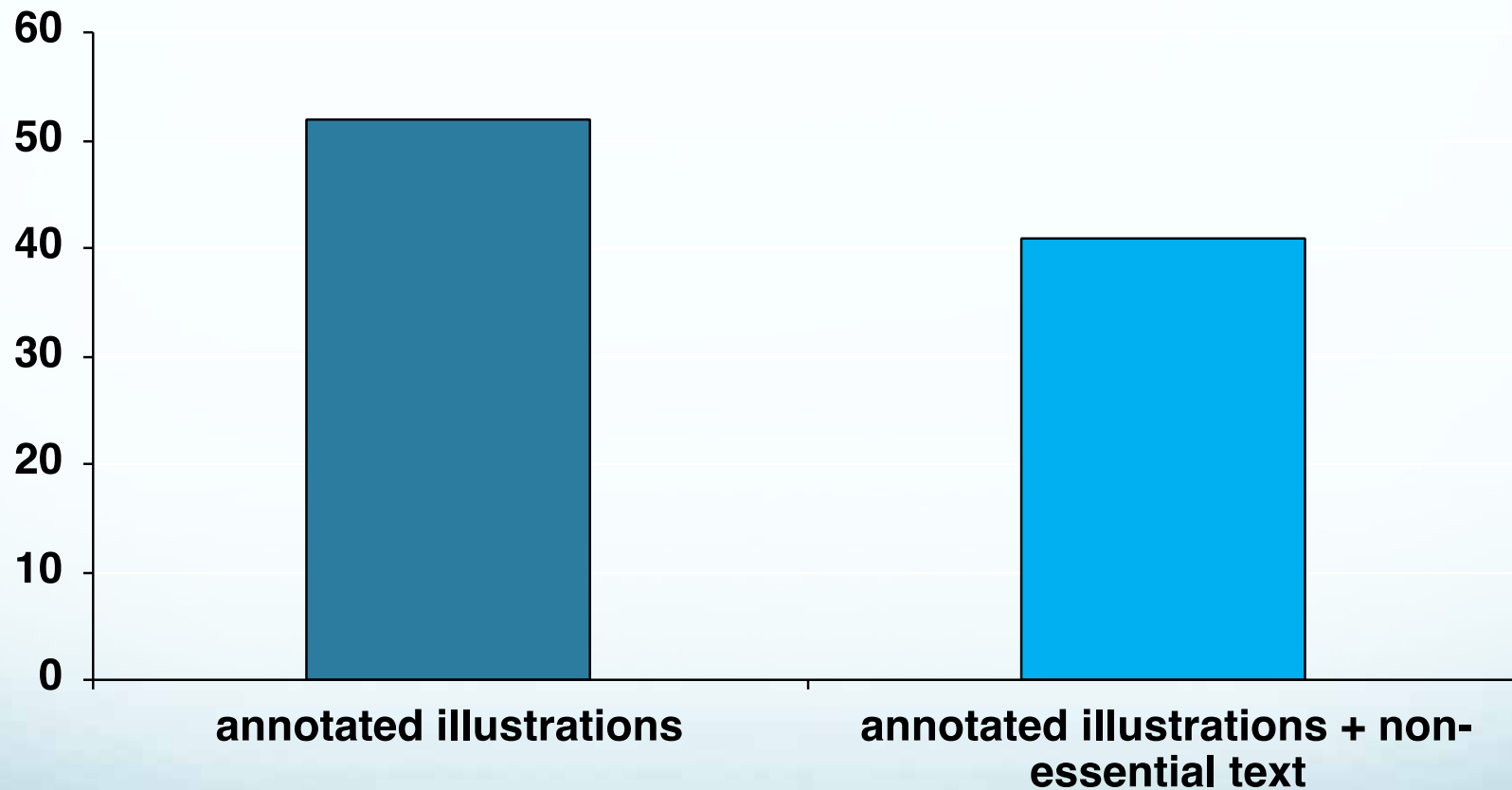
# Reducing extraneous processing

- Coherence Principle
  - Extraneous information reduces learning

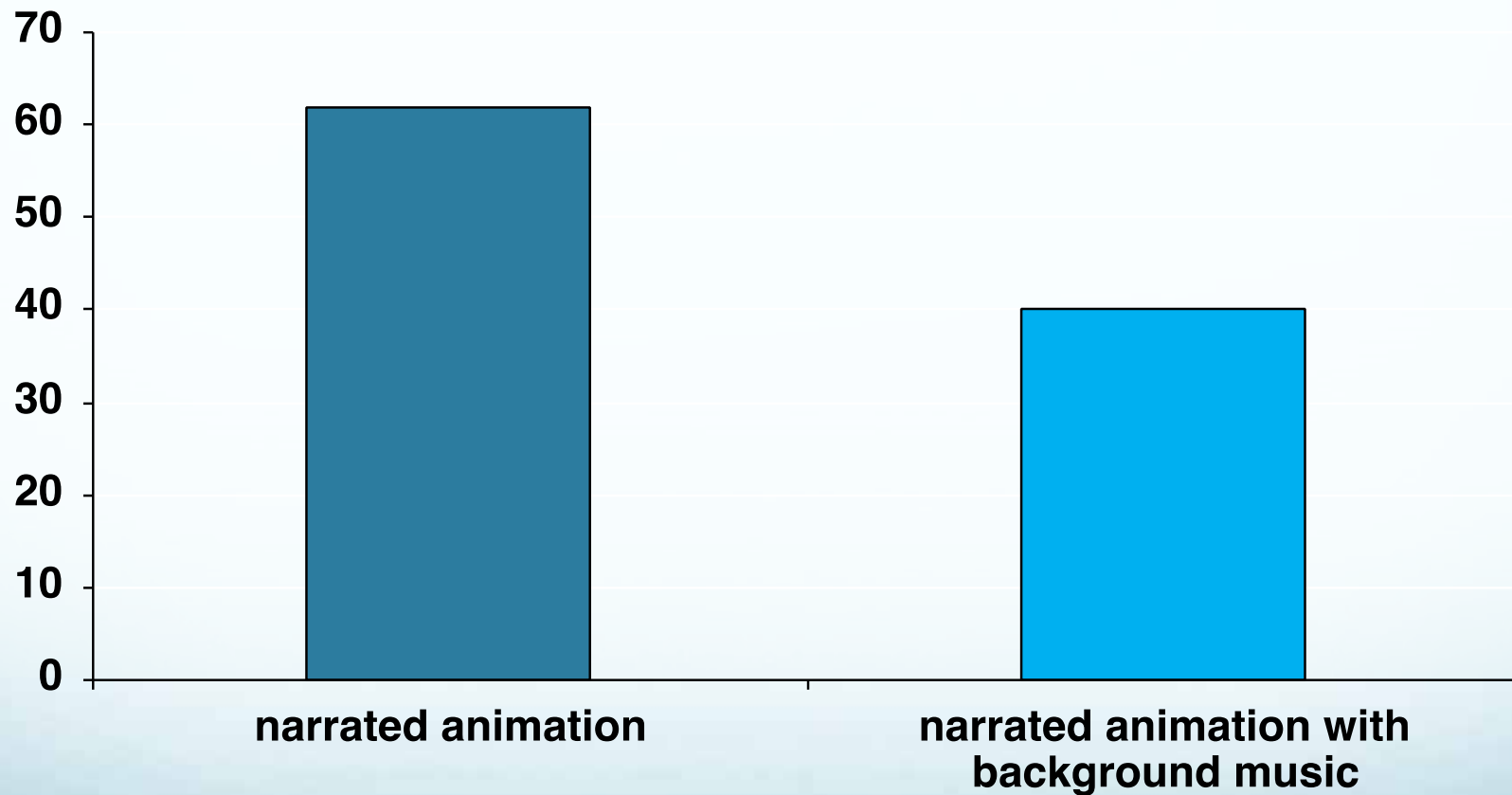




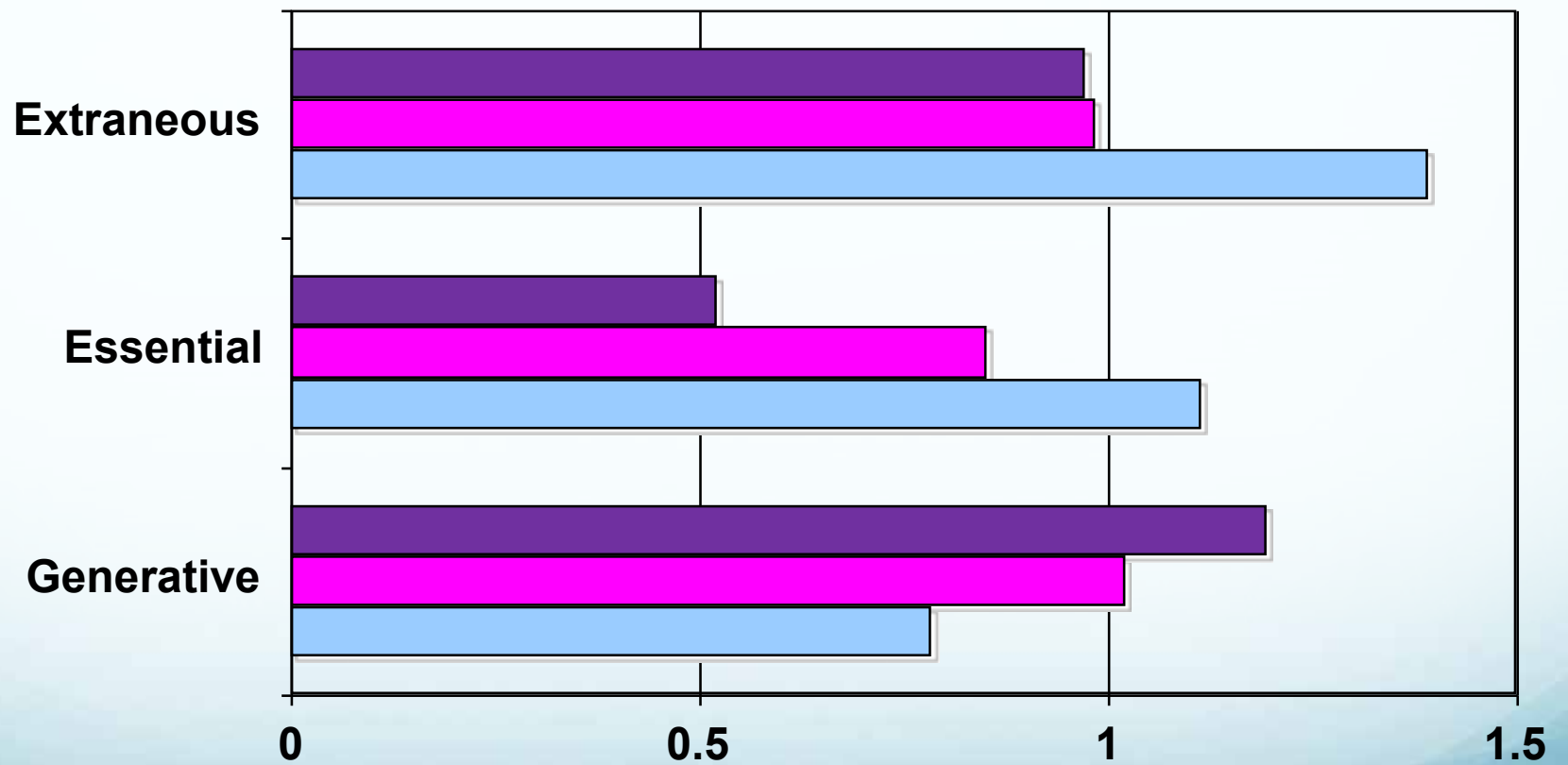
# Effect of Non-Essential Text



# Better Learning Without Background Music

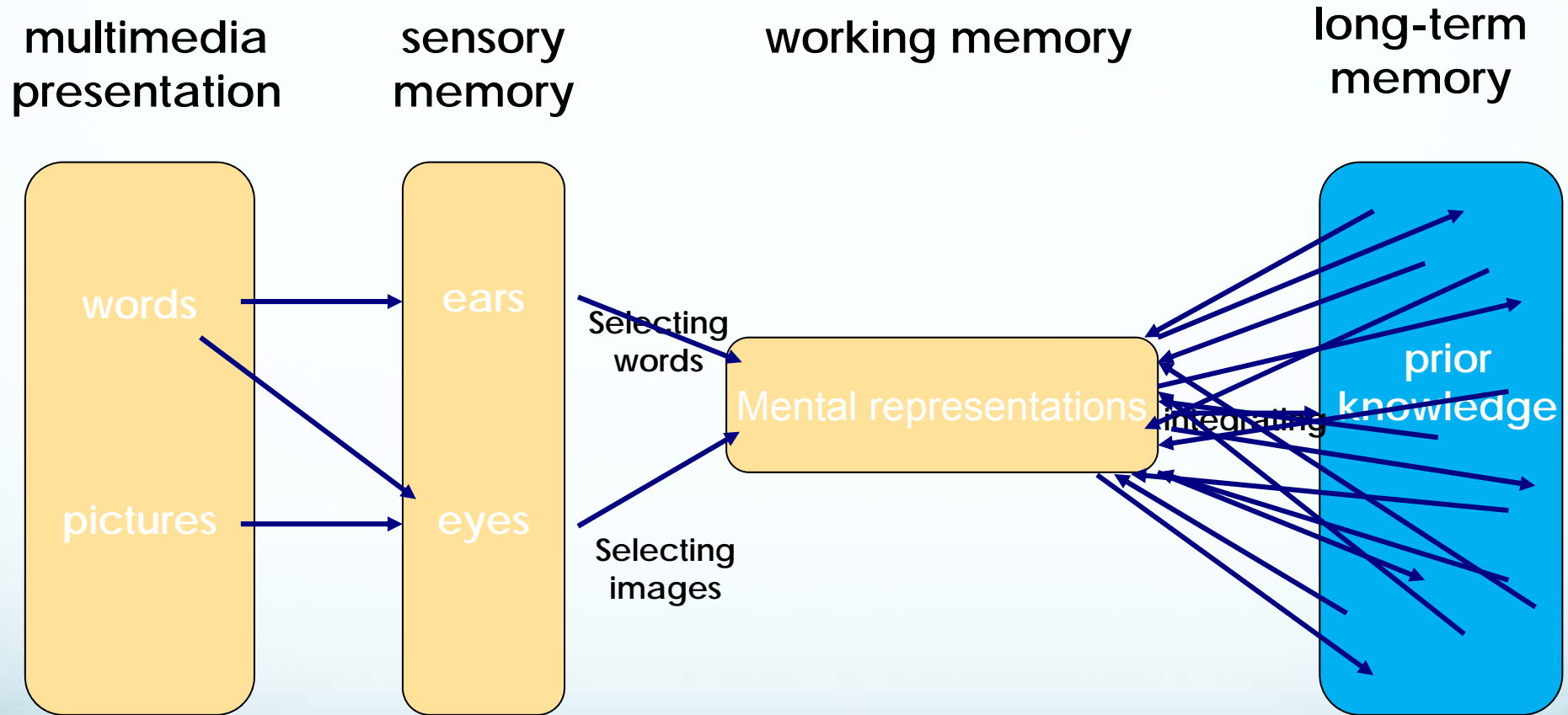


# Effect sizes



# Long Term (Associative) Memory

# Retrieval, Transfer and Associative Memory



Multiple associations  
To LTM

# The Jeopardy Challenge

**Watson is a workload optimized system designed for complex** analytics, made possible by integrating massively parallel POWER7 processors and the IBM DeepQA software to answer Jeopardy! questions in under three seconds. Watson is made up of a cluster of ninety IBM Power 750 servers (plus additional I/O, network and cluster controller nodes in 10 racks) with a total of 2880 POWER7 processor cores and 16 Terabytes of RAM. Each Power 750 server uses a 3.5 GHz POWER7 eight core processor, with four threads per core. The POWER7 processor's massively parallel processing capability is an ideal match for Watson's IBM DeepQA software which is embarrassingly parallel (that is a workload that is easily split up into multiple parallel tasks)

***Watson processes 500 gigabytes, a million pages, per second.***

***Watson contains ALL of Wikipedia***

***Watson won by a little bit!***



So Watson, reading a million pages a second,  
can beat Ken....just.

How can Ken be so gosh-darn good?



# Me and my iBook

CPU	1/5 sec.	1/2,000,000,000 sec.
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RAM bytes	1 byte	4,000,000,000
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ROM	?inf	250 Gb
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We should be less impressed that computers can do about as well as humans than that humans can do as well as computers, given the large architectural disadvantages they suffer from.

Paul Johnson , Medinfo 1977

How do we do it?

Our brains work different than  
computers

# Human Associative Memory

“..... we do not store information in our long-term memories by making any kind of literal recording of that information, but, instead, we do so **by relating new information to what we already know**. We store new information in terms of its **meaning** to us, as defined by its relationships and **semantic associations** to information that already exists in our memories.

Bjork, Dunlosky, Kornell, 2012

# North American Geography

- What is the capital of the United States?
- What is the capital of Canada?
- What is the capital of Saskatchewan?

- You know it
- You know that you know it
- You know when you ***don't*** know it



# Word Superiority Effect

brain 

crain 

rbaxn

# Stroop Effect

RED

RED

Associations with memory are happening simultaneously at the word and letter level (word superiority) or word and colour level (Stroop)

Different from sequential search of the computer

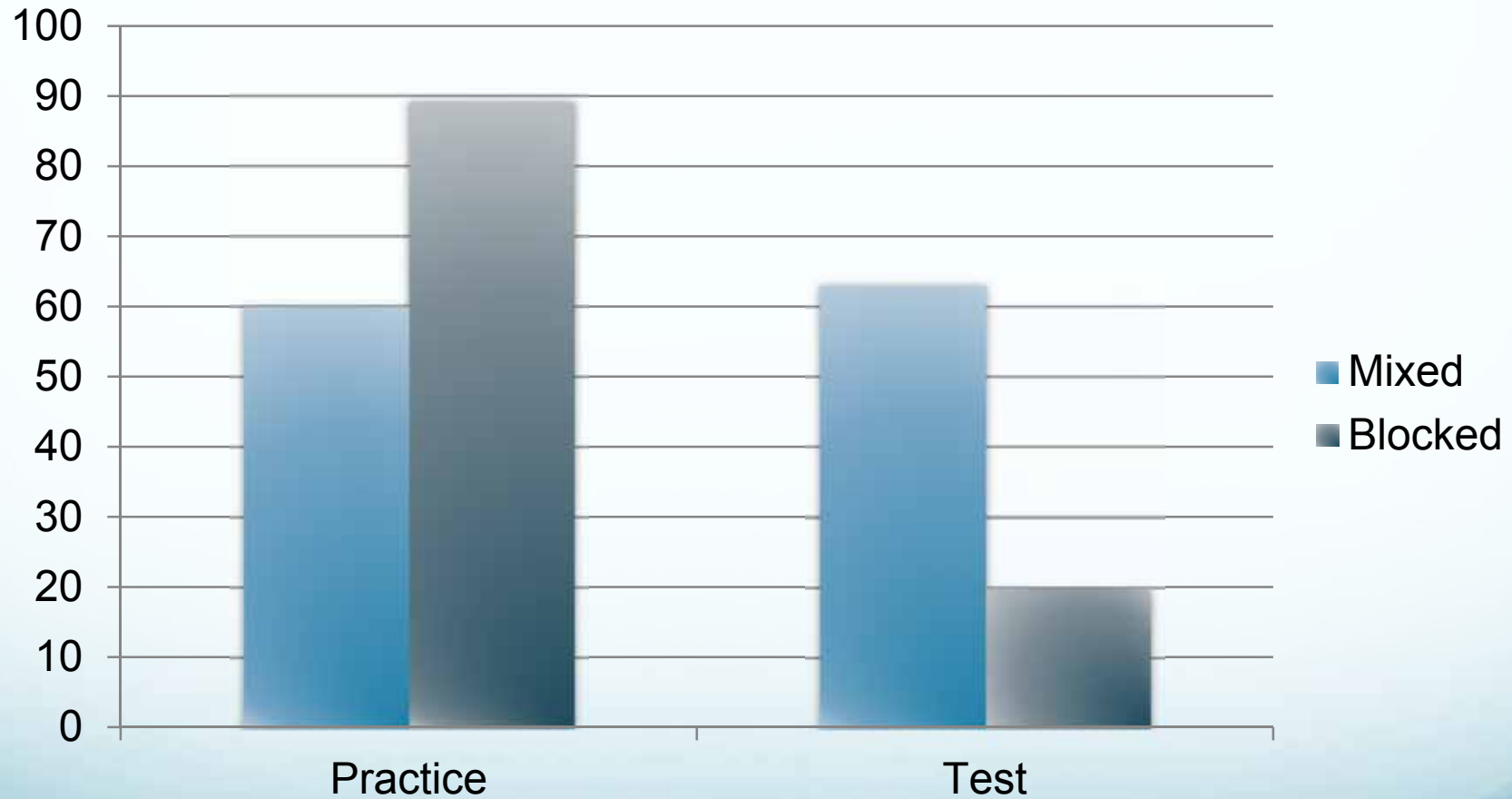
# The Science of Learning

- Learning amounts to enhancing associations in long term memory
- Enhanced by:
  - Mixed practice:
    - Learning to identify important associations
  - Distributed (spaced) practice:
    - Enhancing associations over repeated occasions
  - Test enhanced practice:
    - Enhancing associations by repeated recall

- **Mixed Practice**
  - Examples from multiple categories mixed up
- **Blocked practice**
  - Examples from each category practiced together
    - (end of the chapter)

Mixed practice a) Increases germane load, b)  
enhances relevant associations on LTM

# Mathematics learning



# Mixed vs. Blocked Practice

Hatala, 2000

- ECG Diagnosis -- 3 categories
- 6 examples / category

## Blocked

Review, then 6 examples/category

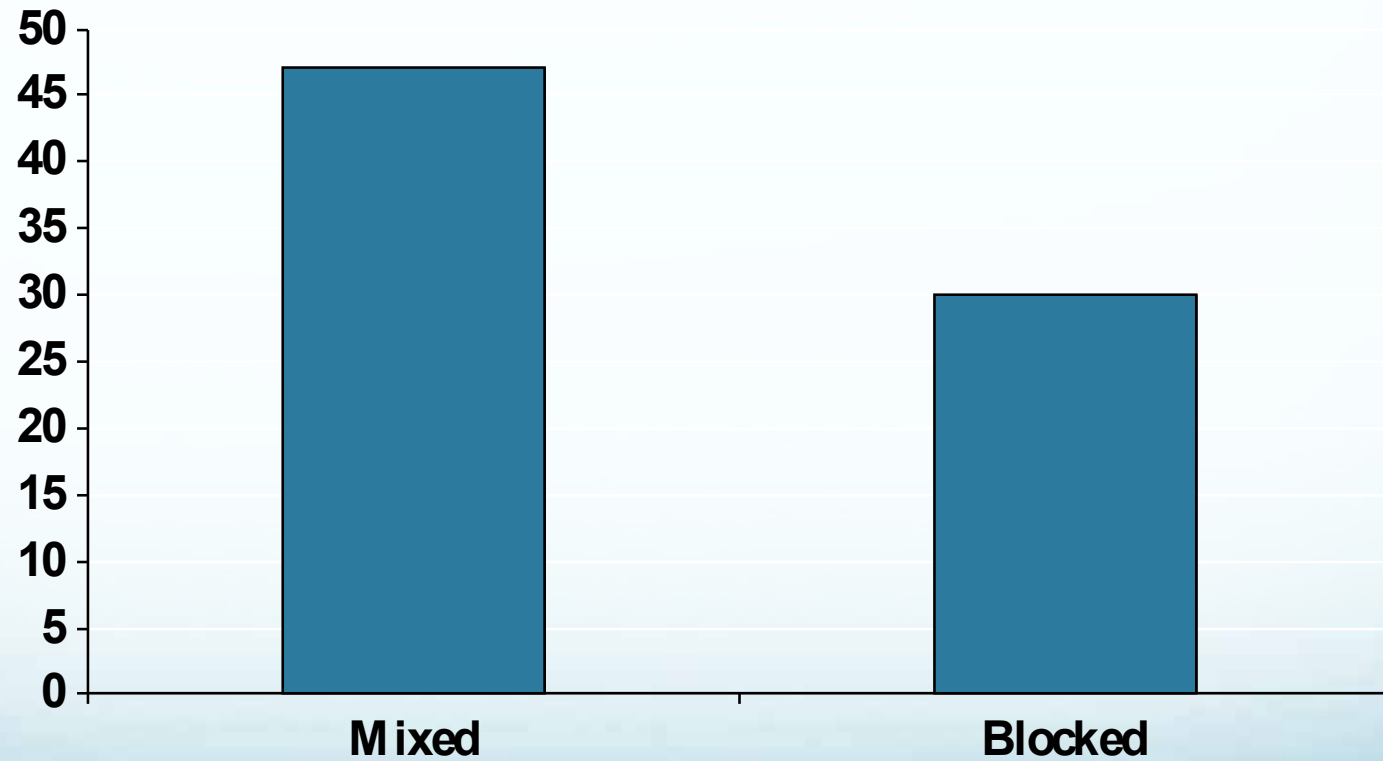
## Mixed

Review, 2/category, 12 (4 x 3) practice

## TEST

6 new ECGs

# Accuracy -- %



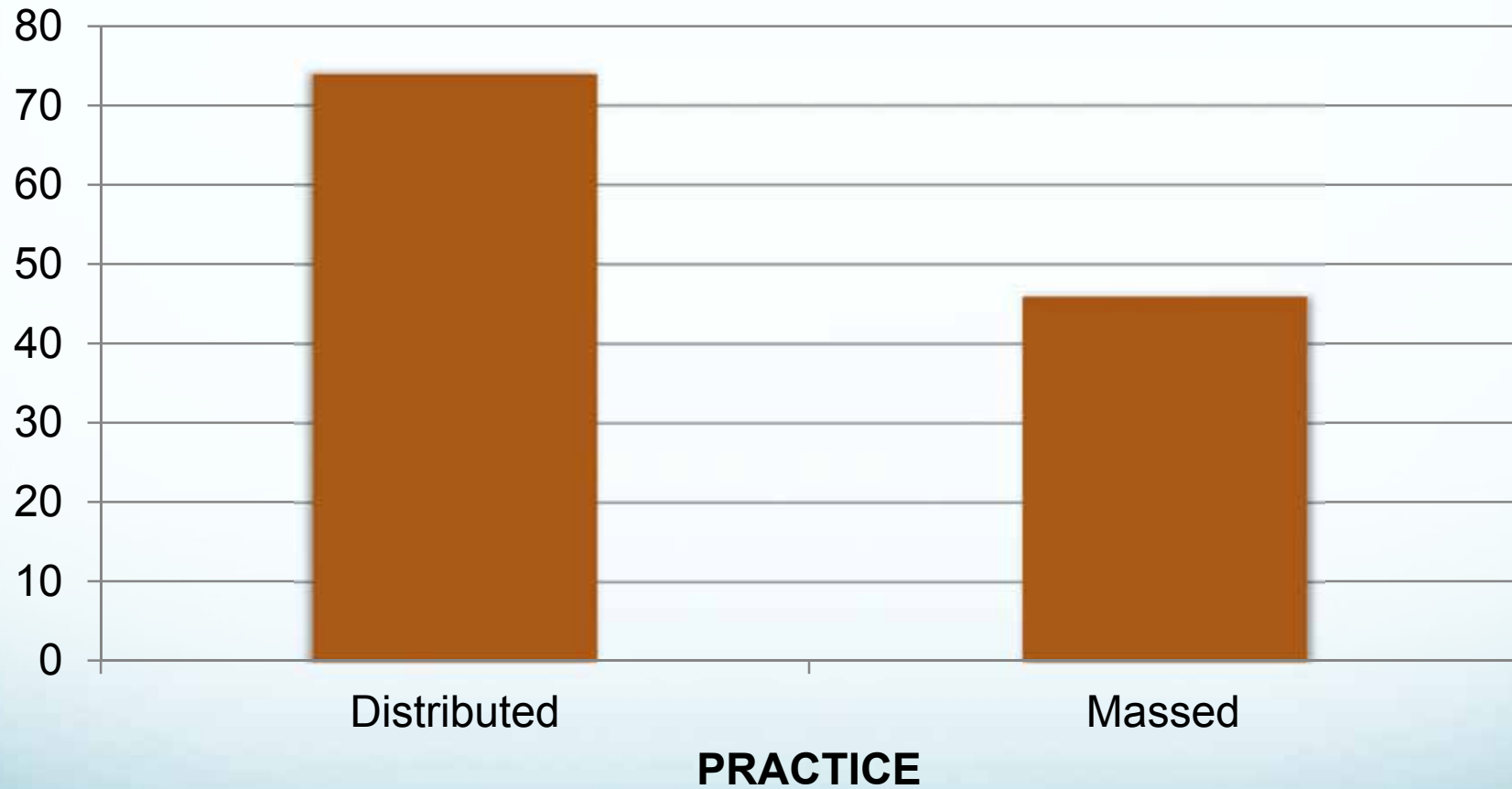


# Massed vs. Distributed Practice

- Massed
  - All learning takes place at one time
- Distributed
  - Learning takes place over multiple occasions

Distributed practice requires repeated retrieval,  
increases associations with LWTM

# Mathematics Learning



# Massed vs. Distributed

(Raman, McLaughlin, 2010)

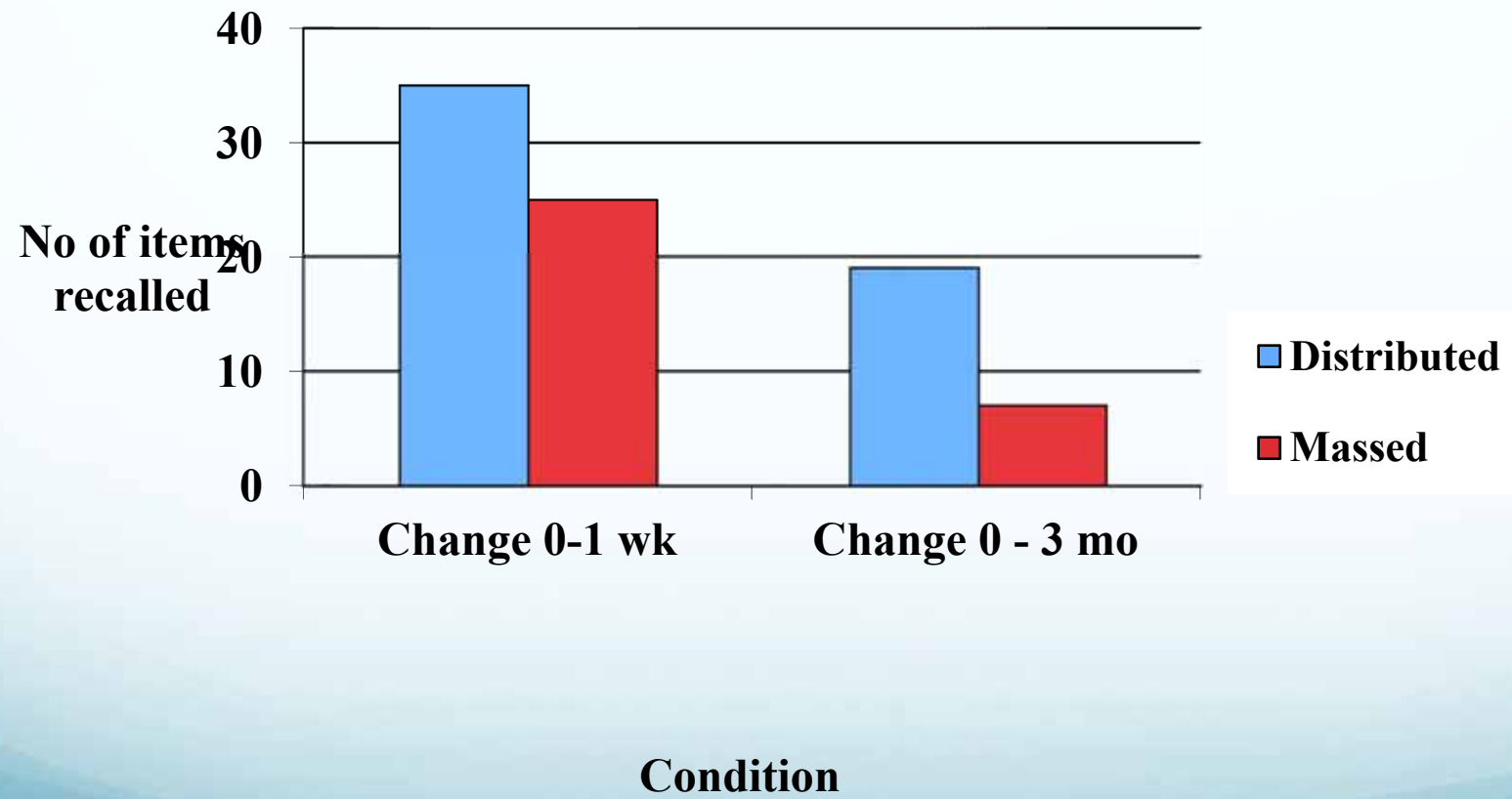
20 GI residents

Nutrition course

- 4 hr, one 1/2 day vs. 1 hr. 4 1/2 day

Multiple choice test, 0, + 1 wk., + 3 mo.

## Massed vs. Distributed



# Test enhanced learning

- Testing, requiring active recall, enhances associations with memory
- Self-generated explanations require elaboration, hence associations

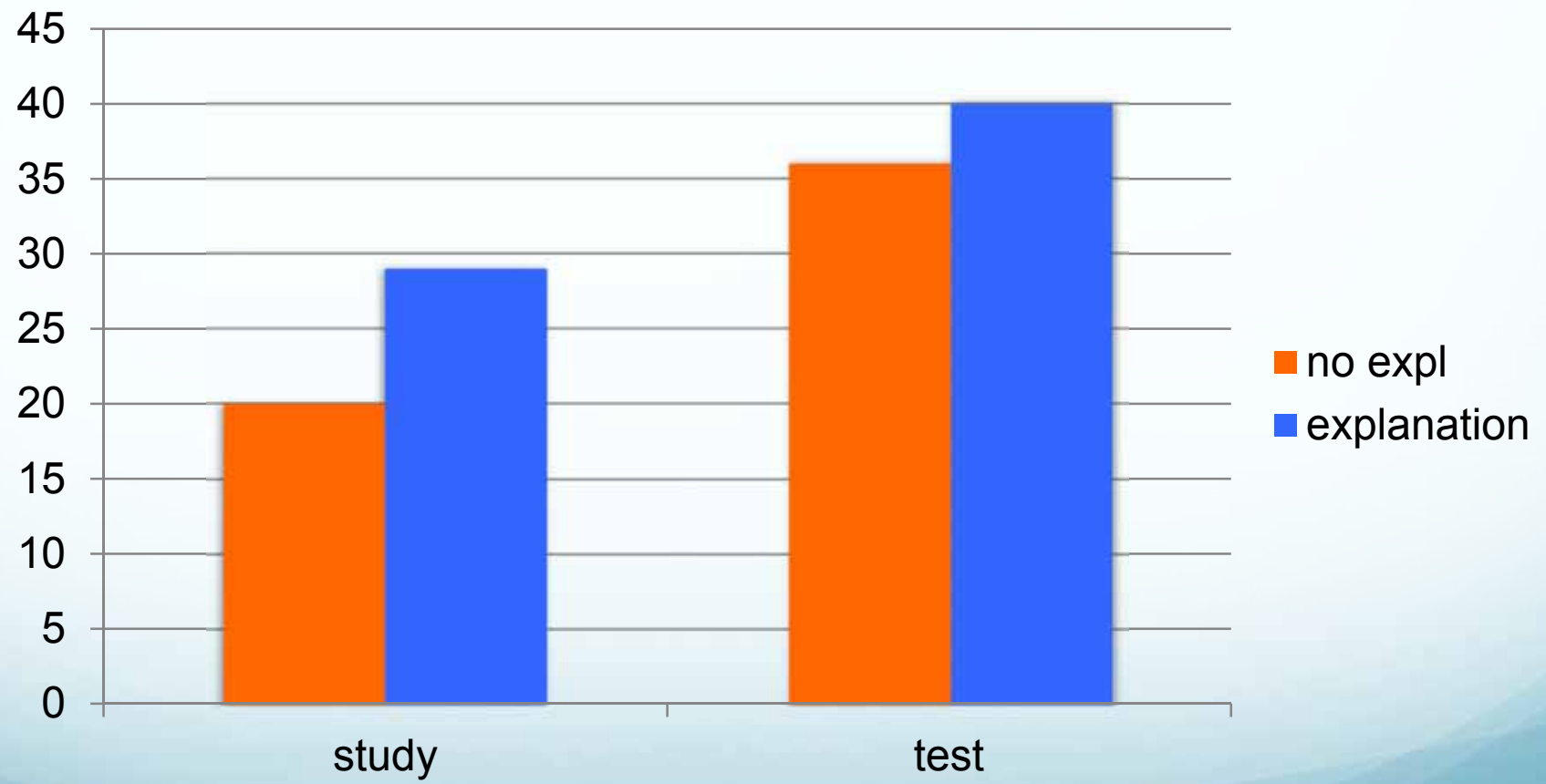
# Test Enhanced Learning

“repeated practice in retrieving information from memory seems to greatly enhance future recall.....the actual act of taking tests augments retention”.

“Studies... show that repeated testing produces superior retention relative to repeated study over time periods of 1-6 weeks”.

Larsen, Butler & Roediger, 2009

- Larsen et al. 2013
- 48 med students
- 4 groups
  - Testing with explanation
  - Testing w/o explanation
  - Studying with explanation
  - Studying w/o explanation
- 6 month delayed test





# Implications for Teaching

- Practice is critical for learning and transfer
  - to impose meaning on concepts
  - to overcome “context specificity”
  - to enhance transfer
  
- Some practice works better than others
  - Mixed >> blocked
  - Distributed >> Blocked
  - Test enhanced >> study time

# Science of Learning and Instruction

- A new paradigm in learning and instruction
  - Based on tested theories about nature of human learning
  - Based on substantial evidence of effectiveness
  - Creating testable hypotheses
  - With clear application to instruction