# Active Learning 101

## Why and How to Get Started

Michael S. Kirkpatrick

CFI New Faculty Orientation

August 20, 2018

# “Learning is…”

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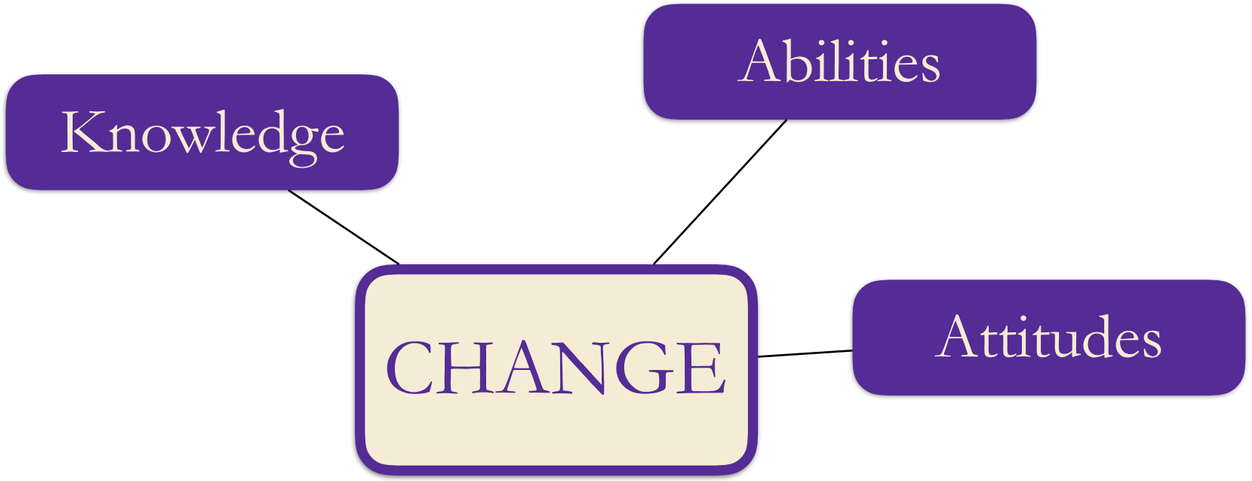

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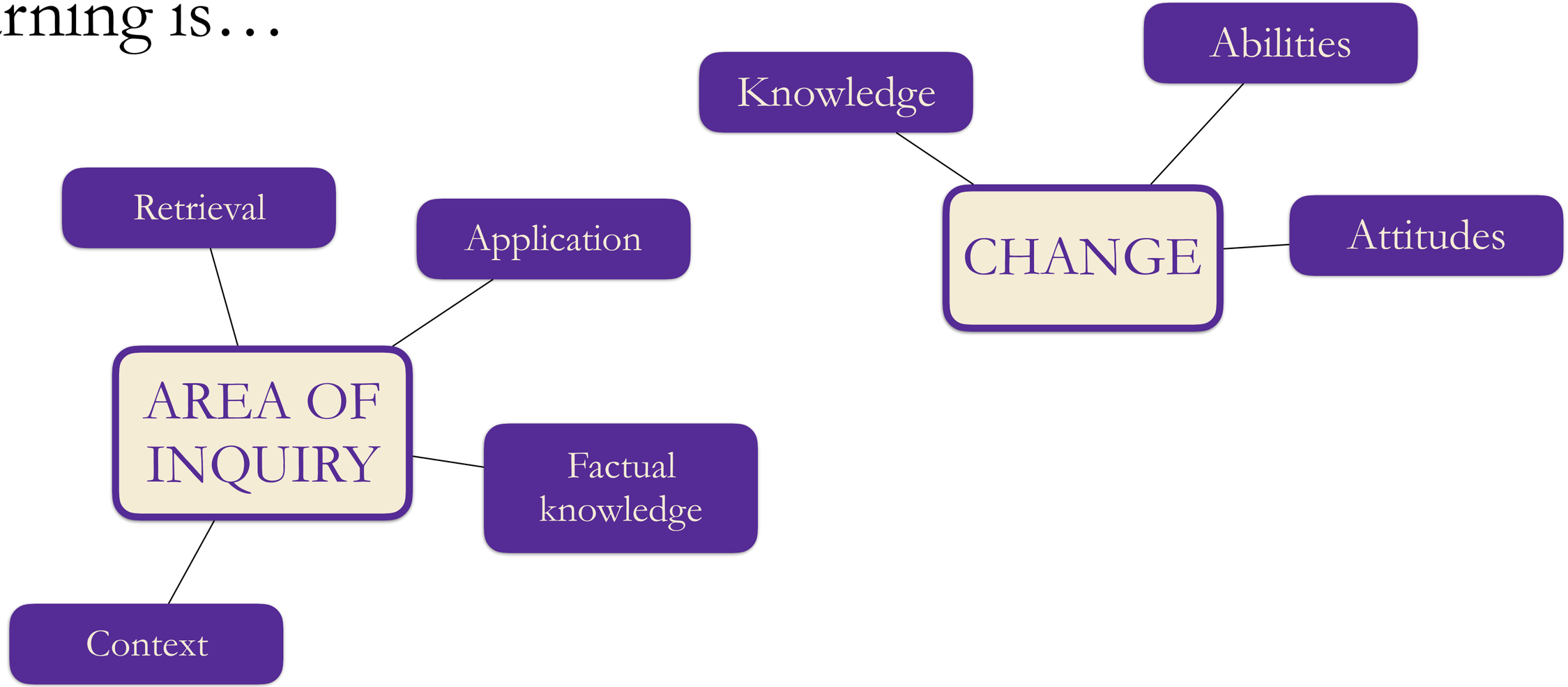
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Attitudes
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AREA OF INQUIRY
Factual knowledge
Context

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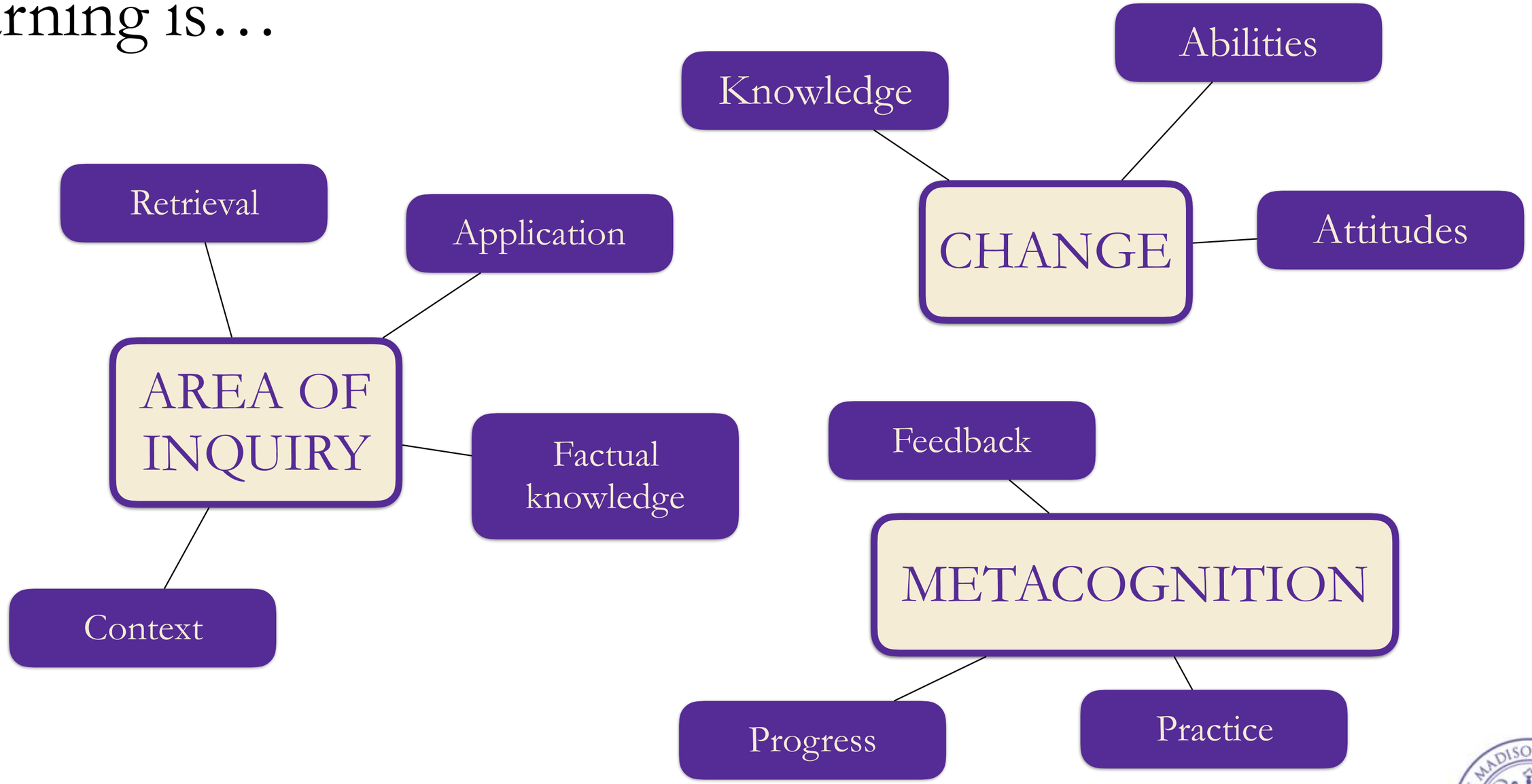
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AREA OF INQUIRY
Factual knowledge
Context
Feedback
METACOGNITION
Progress
Practice

# A short quiz

**True or False:**

1. Good learning makes us feel confident and clear.
2. Learning can occur without intentional effort.
3. You have to be interested and motivated to learn.
4. Intelligent people learn more easily.
5. Adapting instruction based on learning styles has no effect on learning.
6. Rereading textbooks efficiently reinforces concepts and leads to greater mastery.

M. Pasupathi, *How We Learn*. The Great Courses. Chantilly, VA, USA: The Teaching Company, 2012.
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–Michael Prince

ALL

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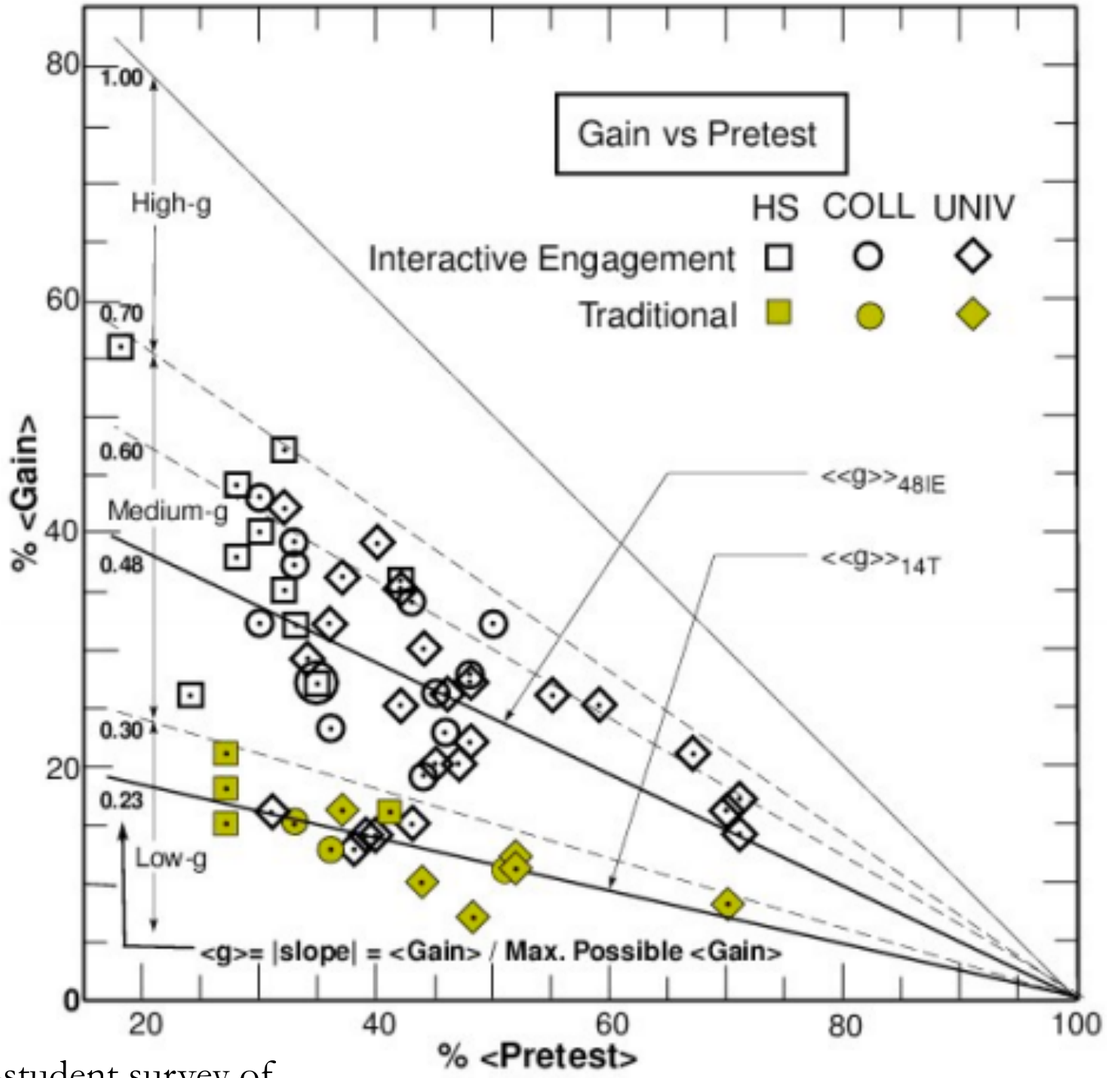
# Why active learning?

**Pre- vs. post- in physics**

- Mechanics Diagnostic
- Force Concept Inventory
- Multiple institutions
- 62 courses (14 trad.)
- 6542 students (2084)




R.R. Hake, "Interactive-engagement vs traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," Am. J. Phys. 66, 64- 74 (1998). http://www.physics.indiana.edu/~sdi/ajpv3i.pdf

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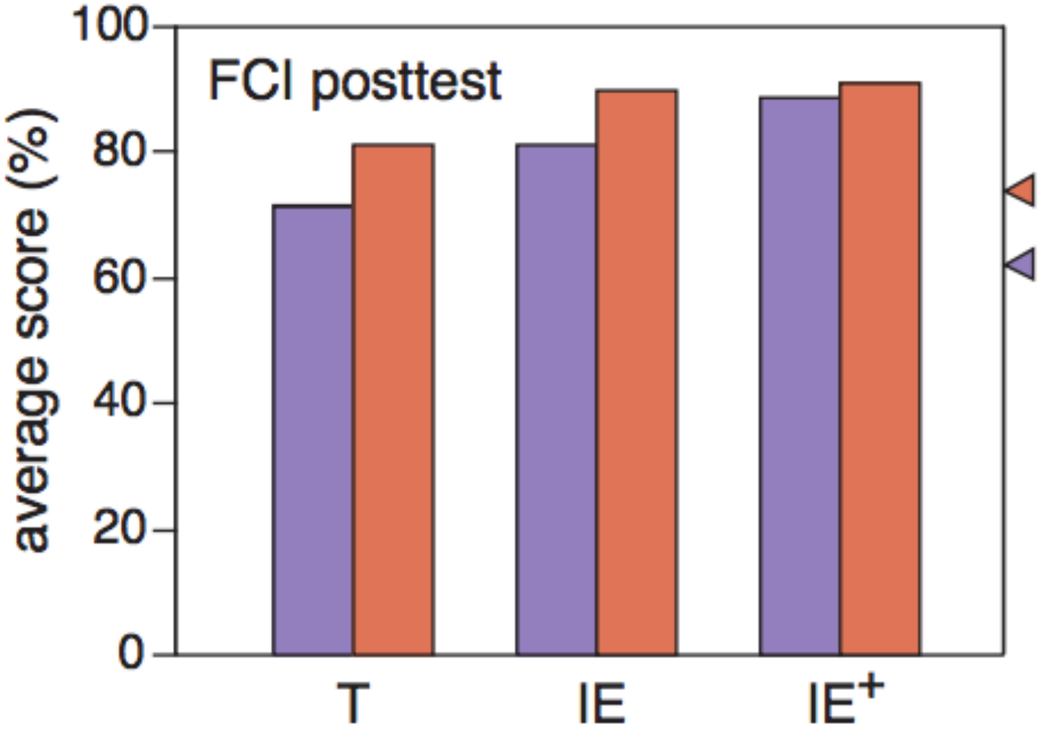


T: traditional lectures
IE: interactive lectures
IE+: interactive assignments, lectures, tutorials

## Closing the gender gap

- Pre-test scores different
- Gap persisted with lecture
- IE+ post-test equal

E. Mazur, "The scientific approach to teaching: Research as a basis for course design," keynote/plenary talk at the International Computing Education Research Conference (ICER), 2011. http://mazur.harvard.edu/search-talks.php?function=display&rowid=1712

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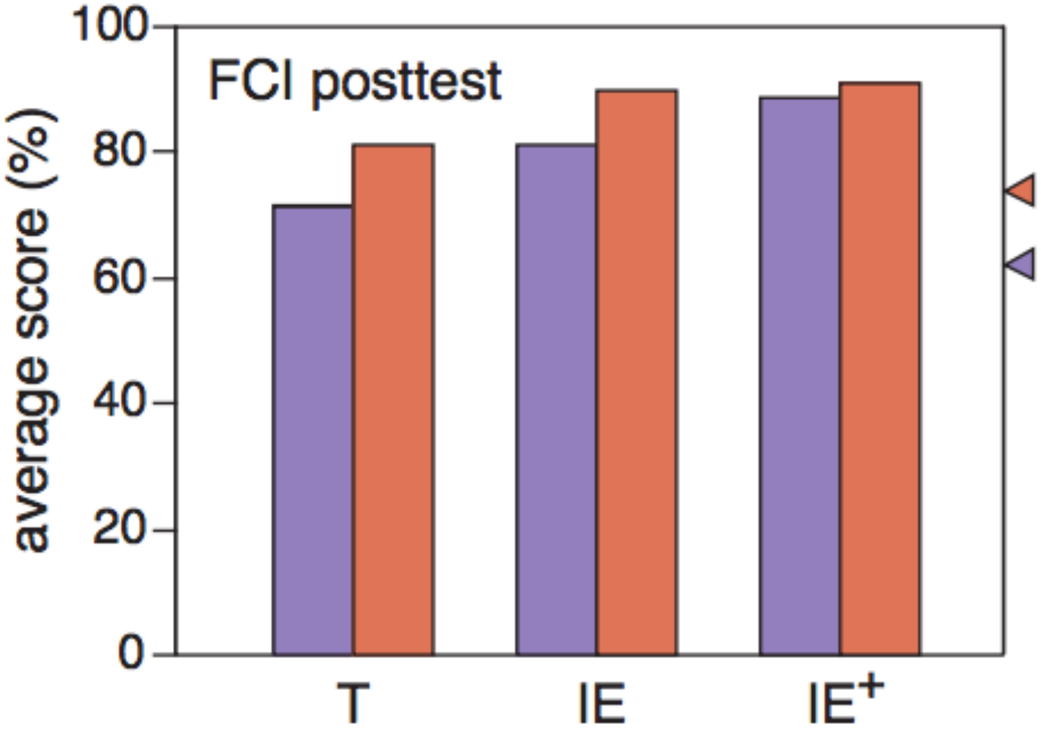


T: traditional lectures
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**Closing the gender gap**

- Pre-test scores different
- Gap persisted with lecture
- IE+ post-test equal
- Requires more than just interactive lecture

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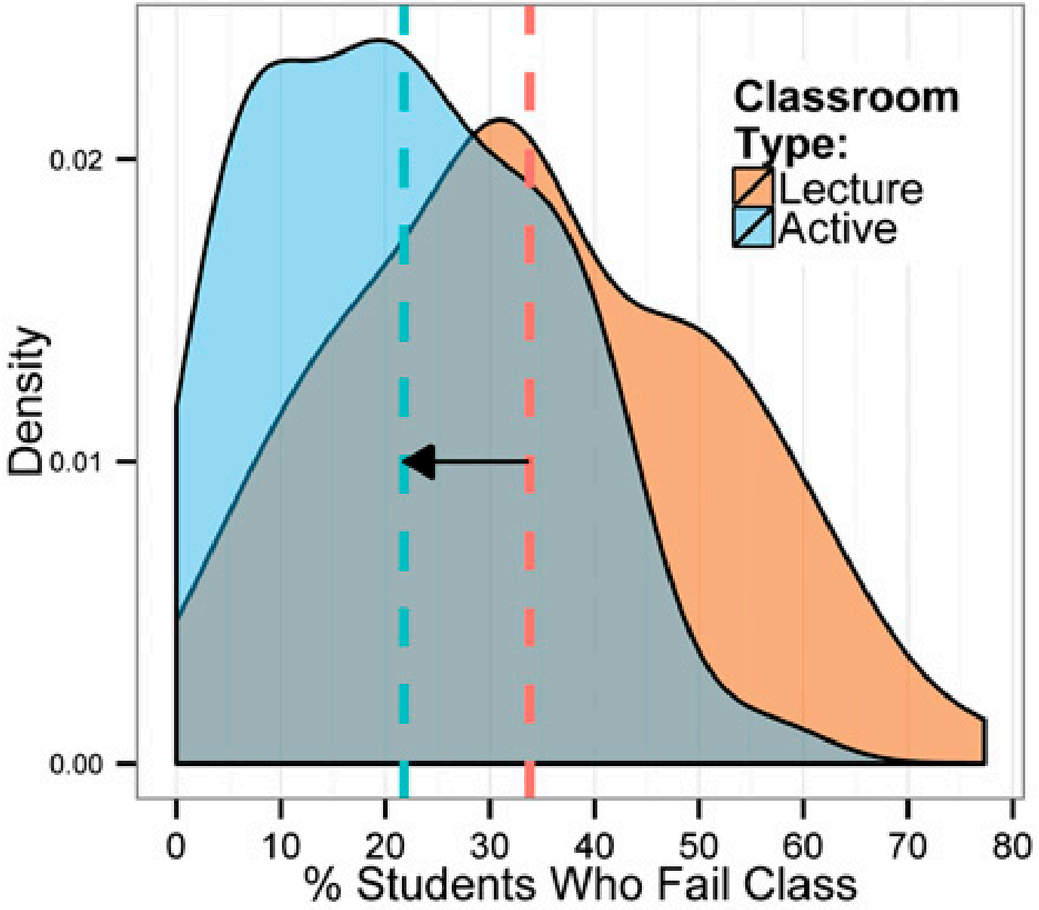



**Metaanalysis**

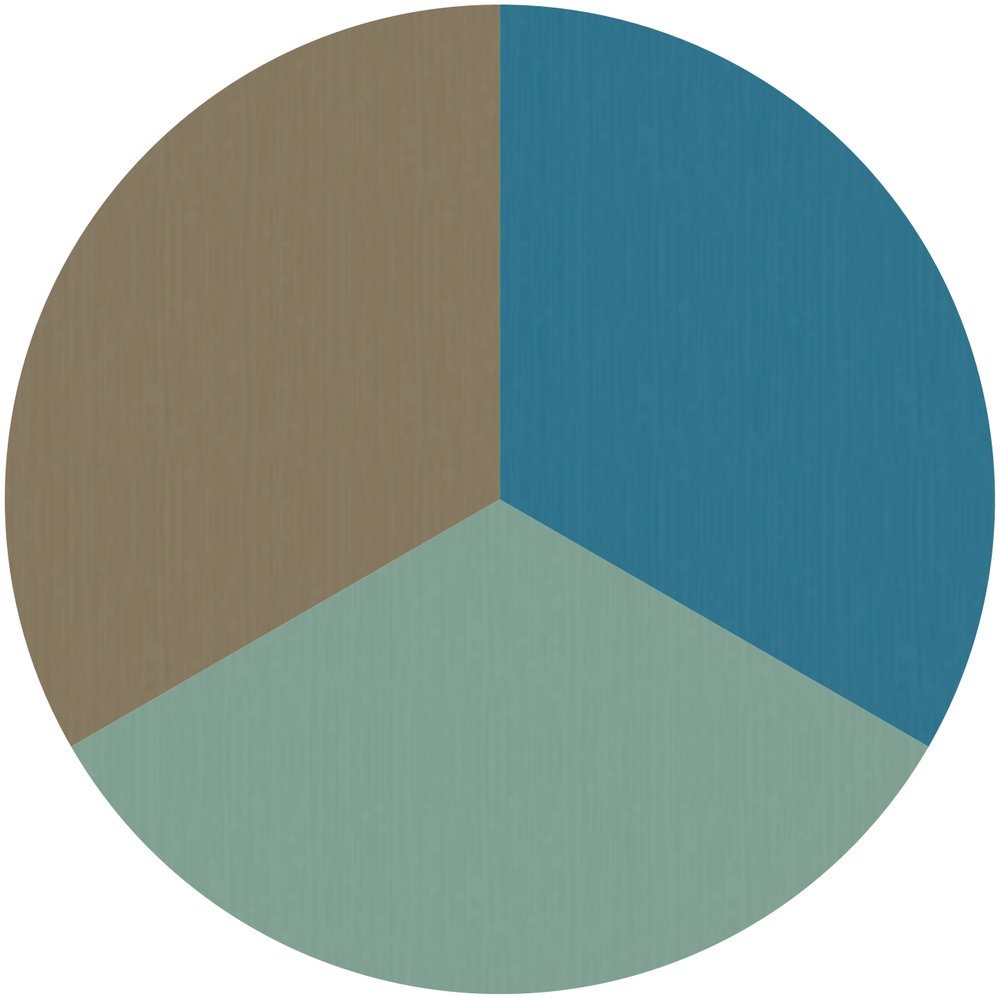
- 158 studies (exams/CIs)
  - 0.47 SDs on scores
  - 6% course grade
- 67 studies (failure rate)
  - 33.8% ⇒ 21.8%

S. Freeman et al., "Active learning increases student performance in science, engineering, and mathematics," Proceedings of the National Academy of Sciences 111(23), 8410- 8415, 2014.
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4060654/pdf/pnas.201319030.pdf

# Why active learning?

# But, um, aren't you…

# Human cognitive architecture



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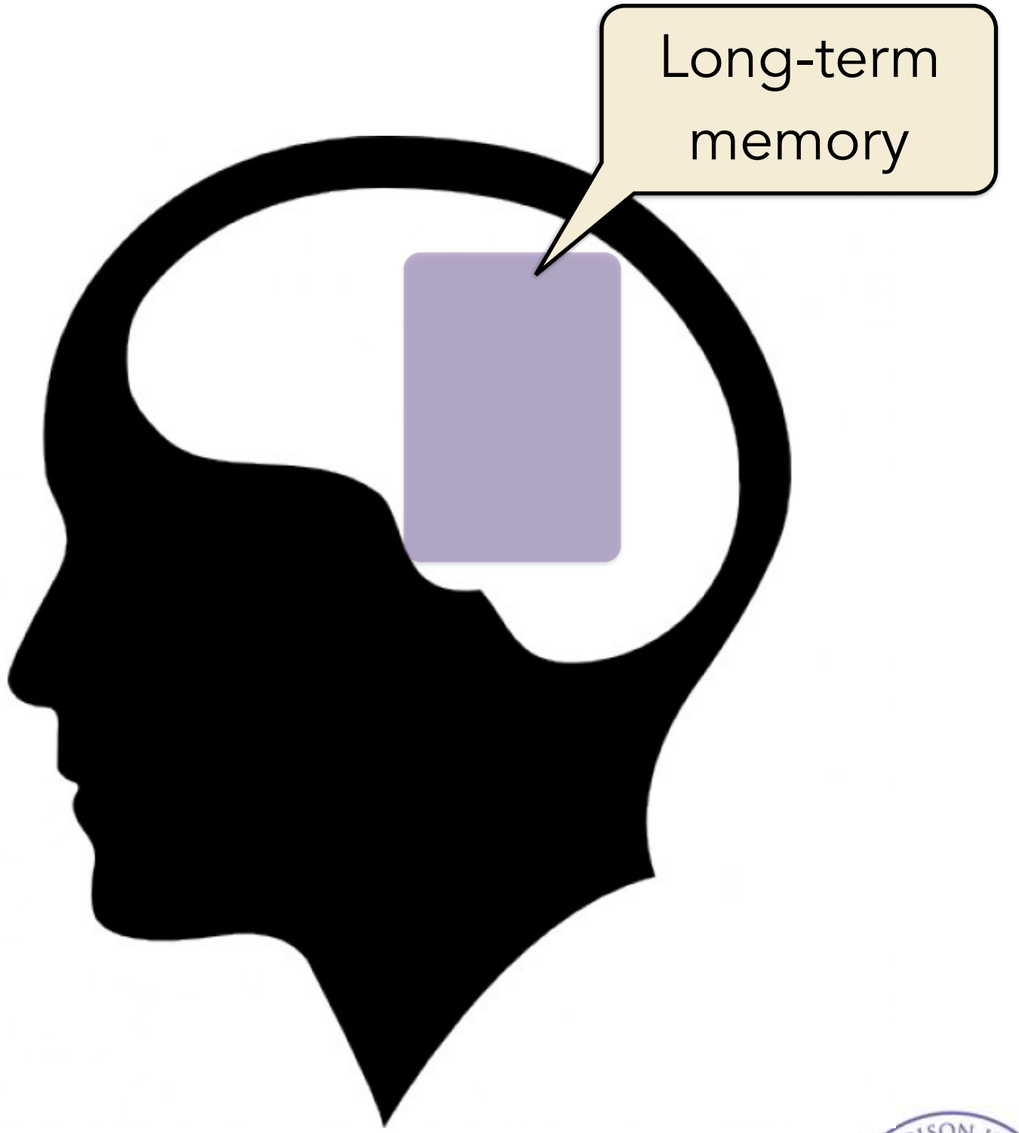

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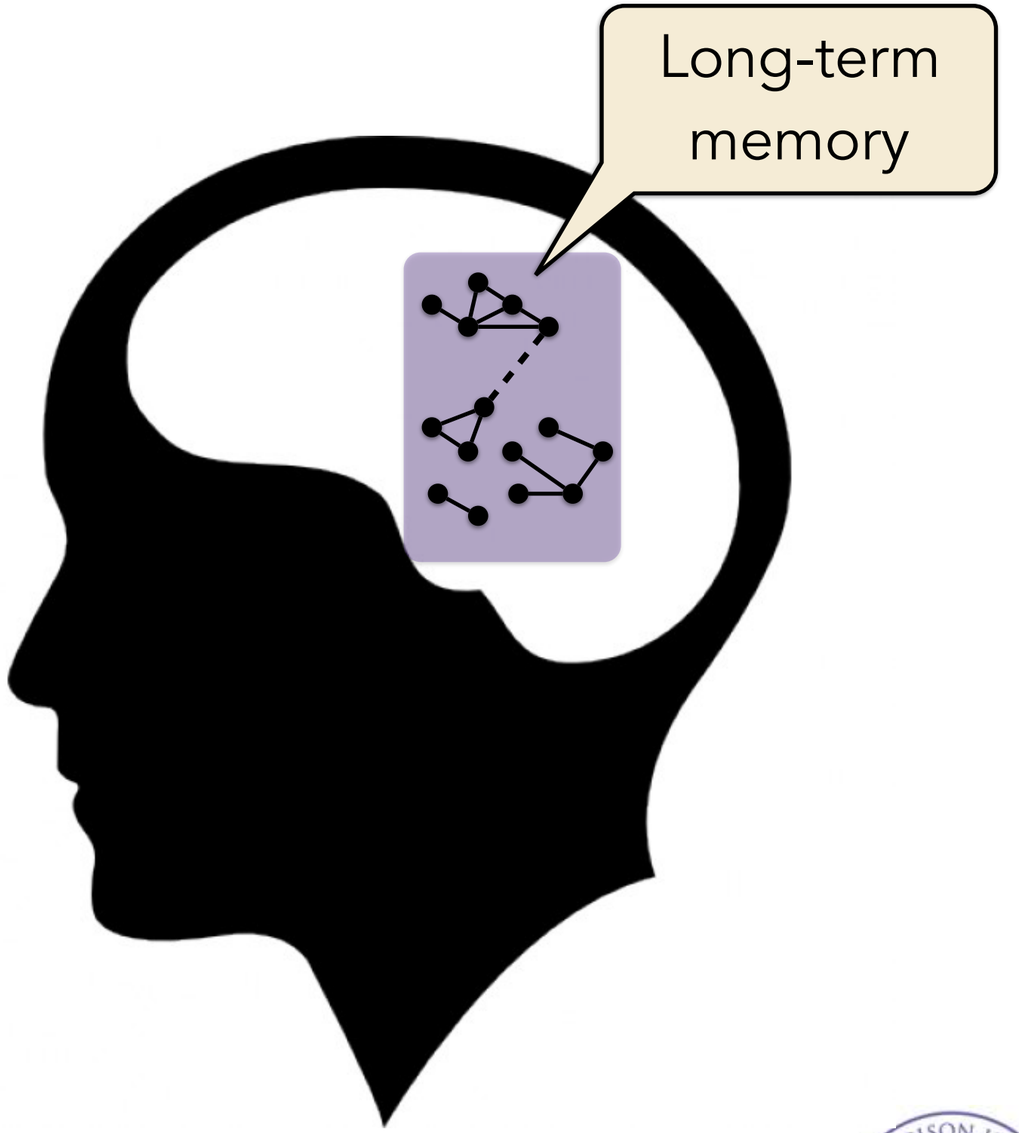

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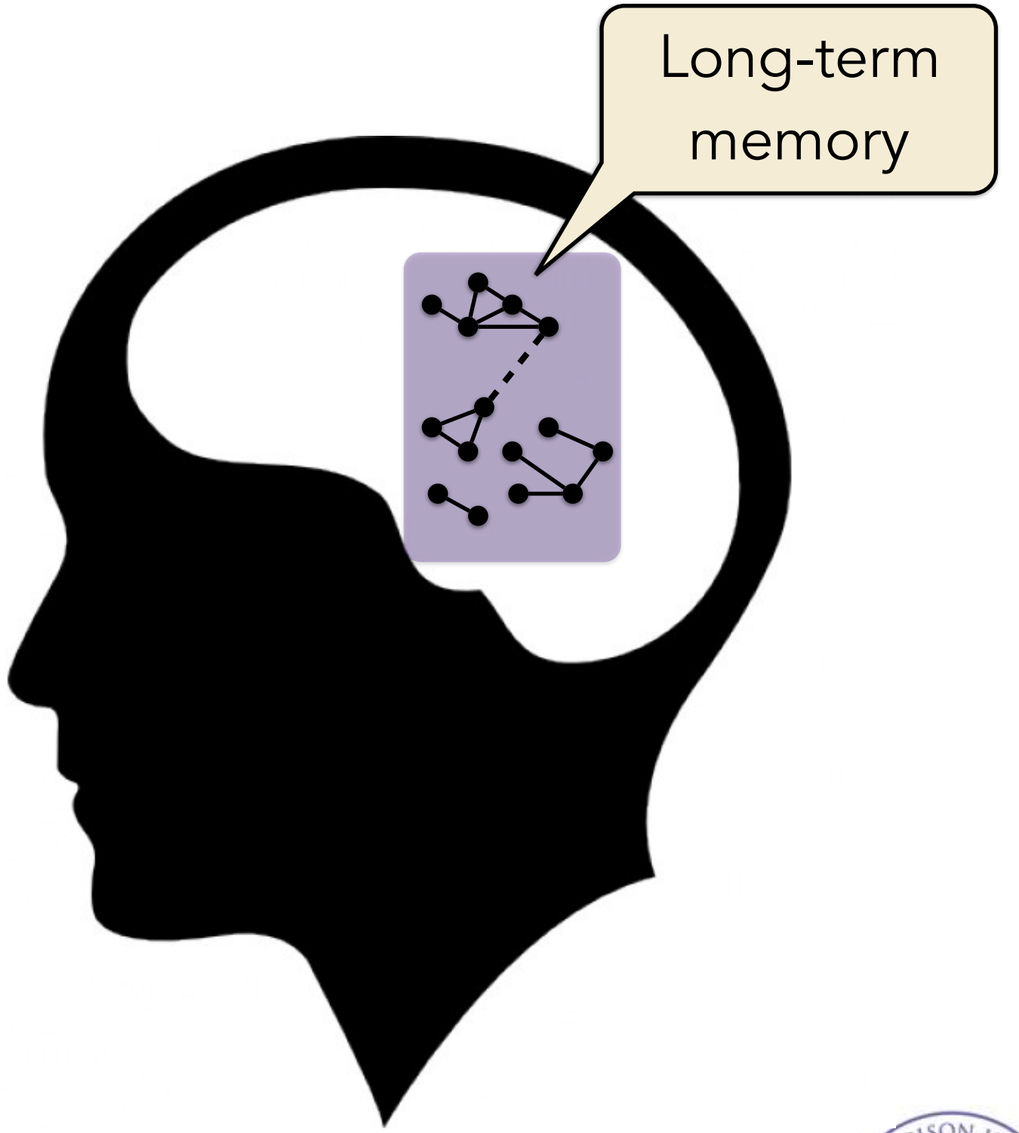

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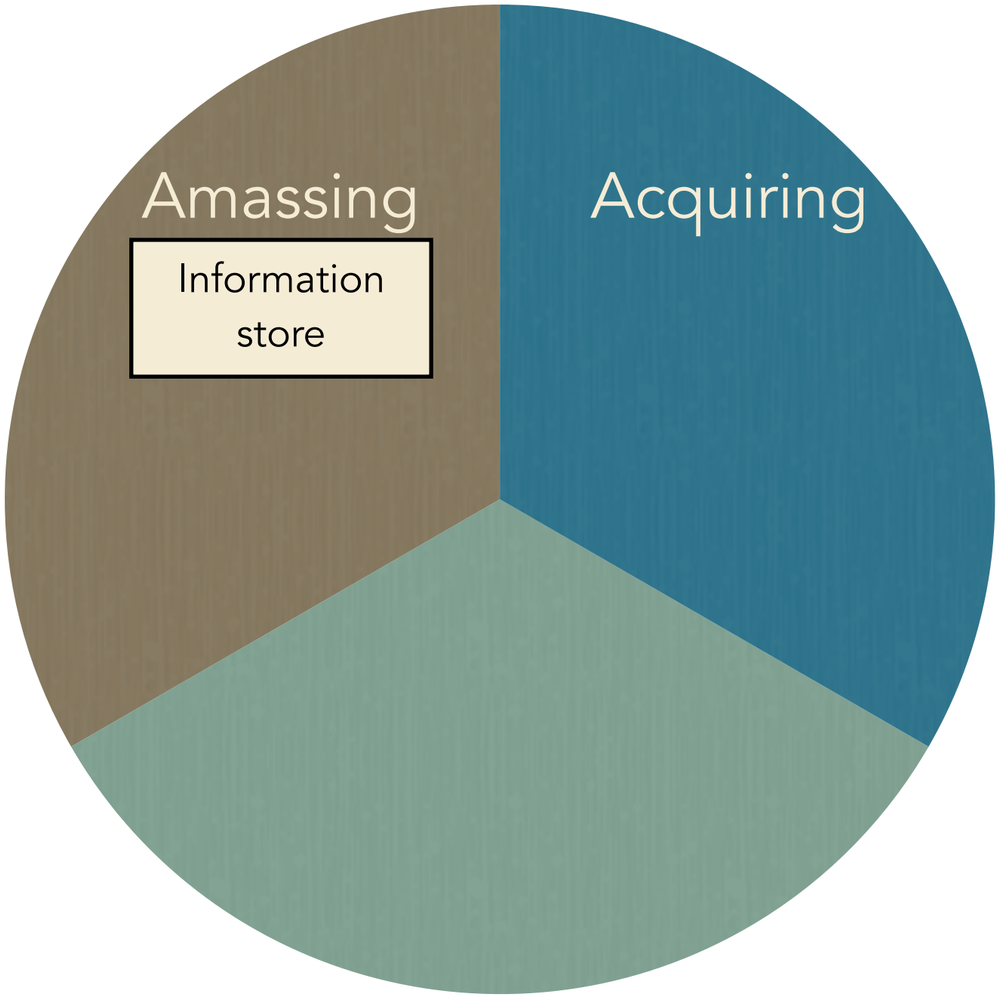


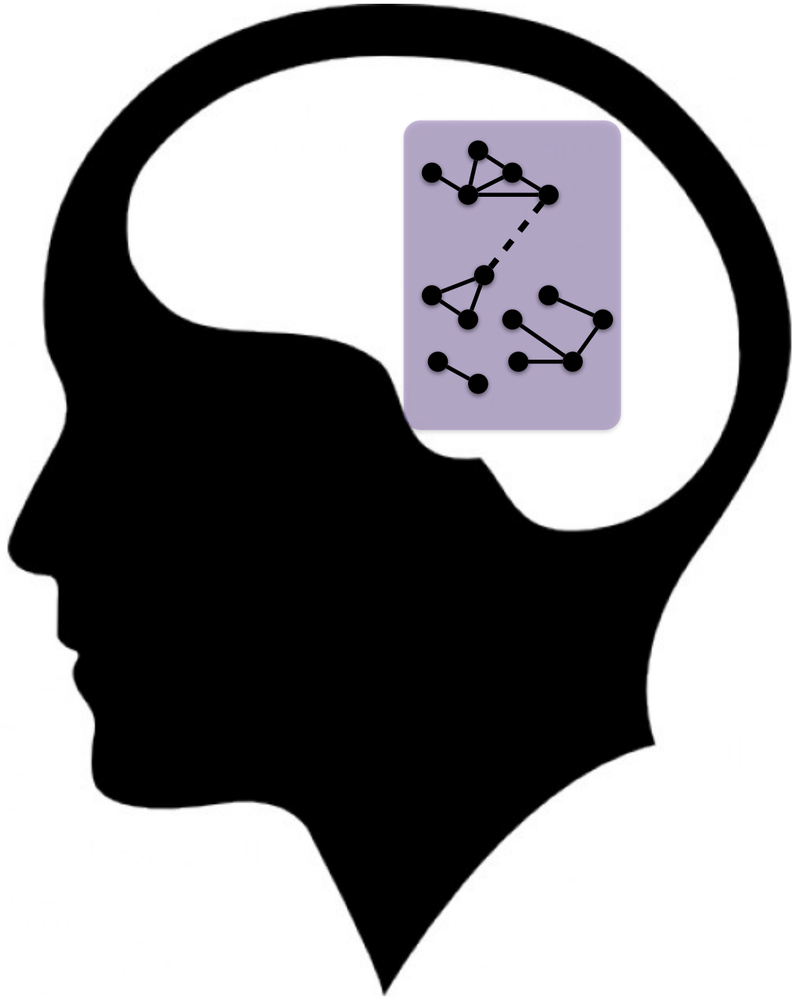

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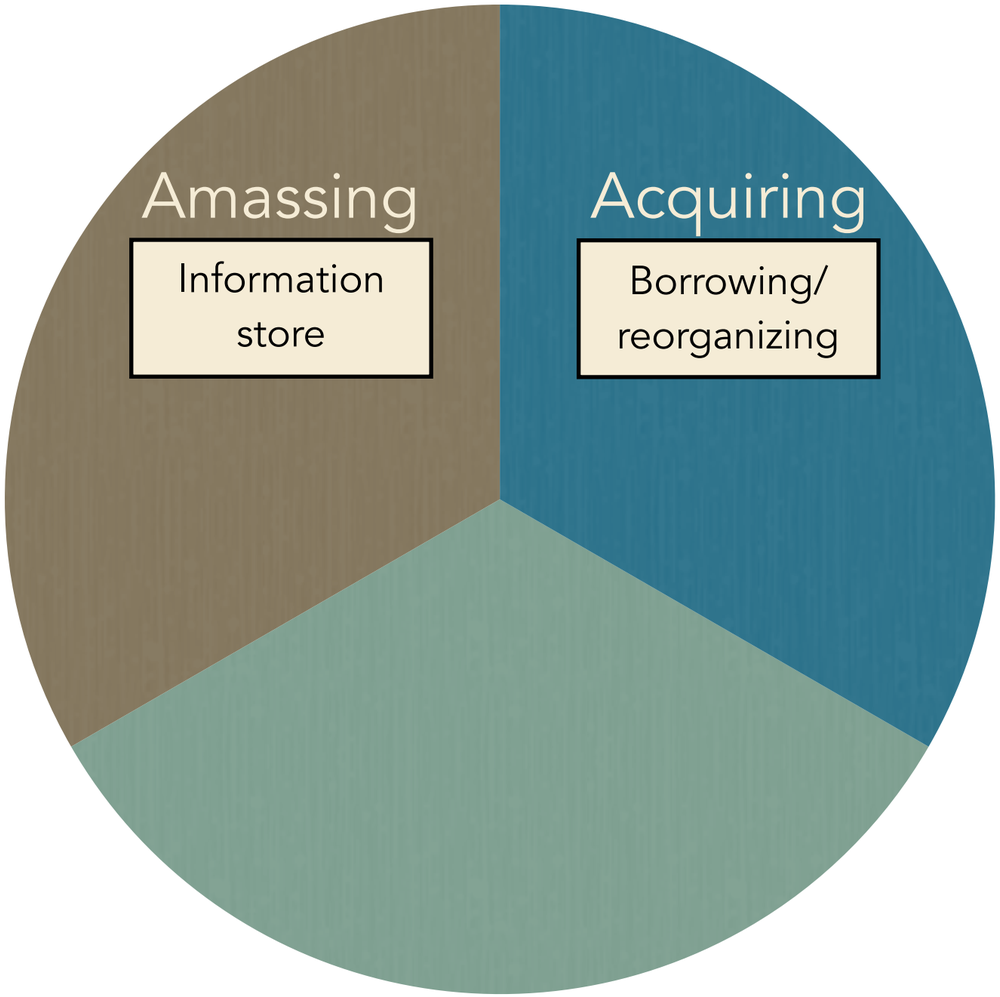


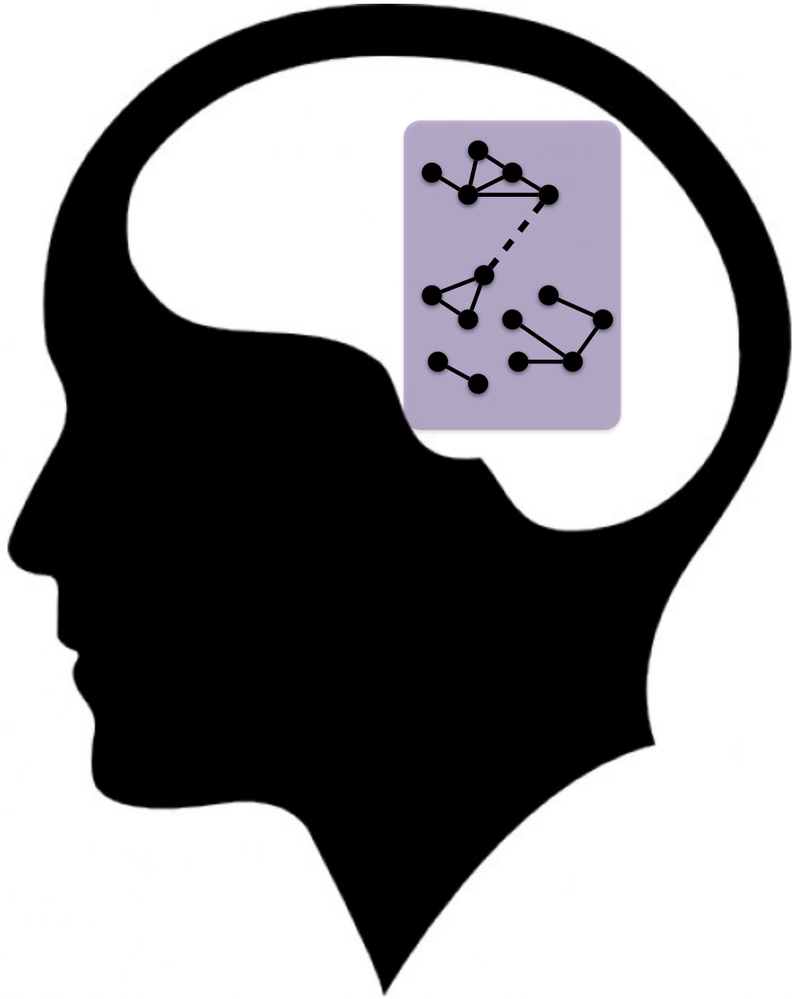

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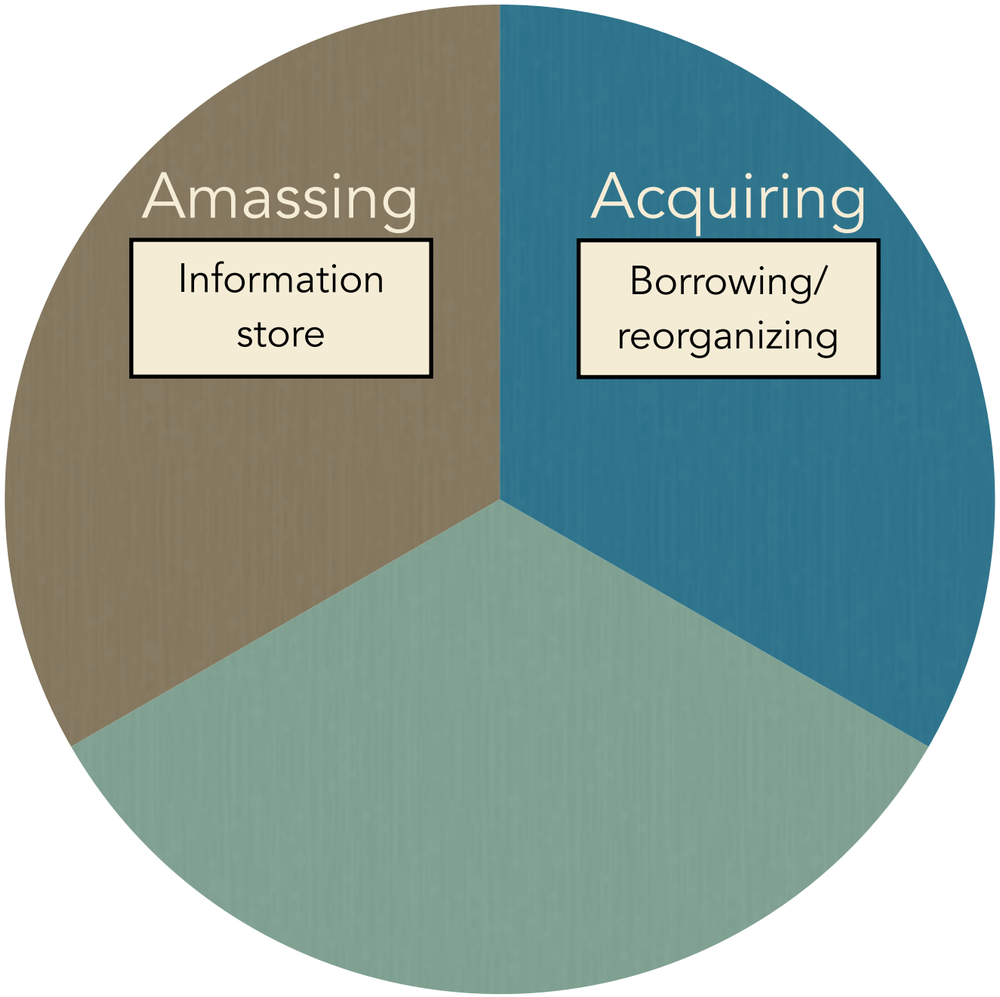


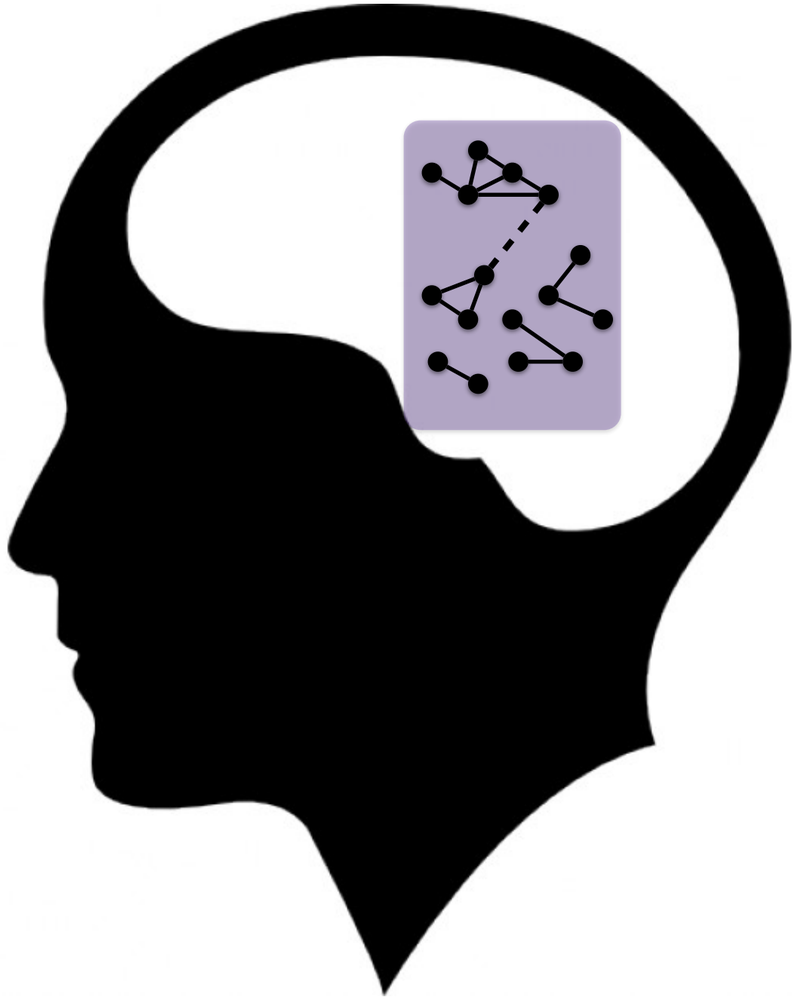

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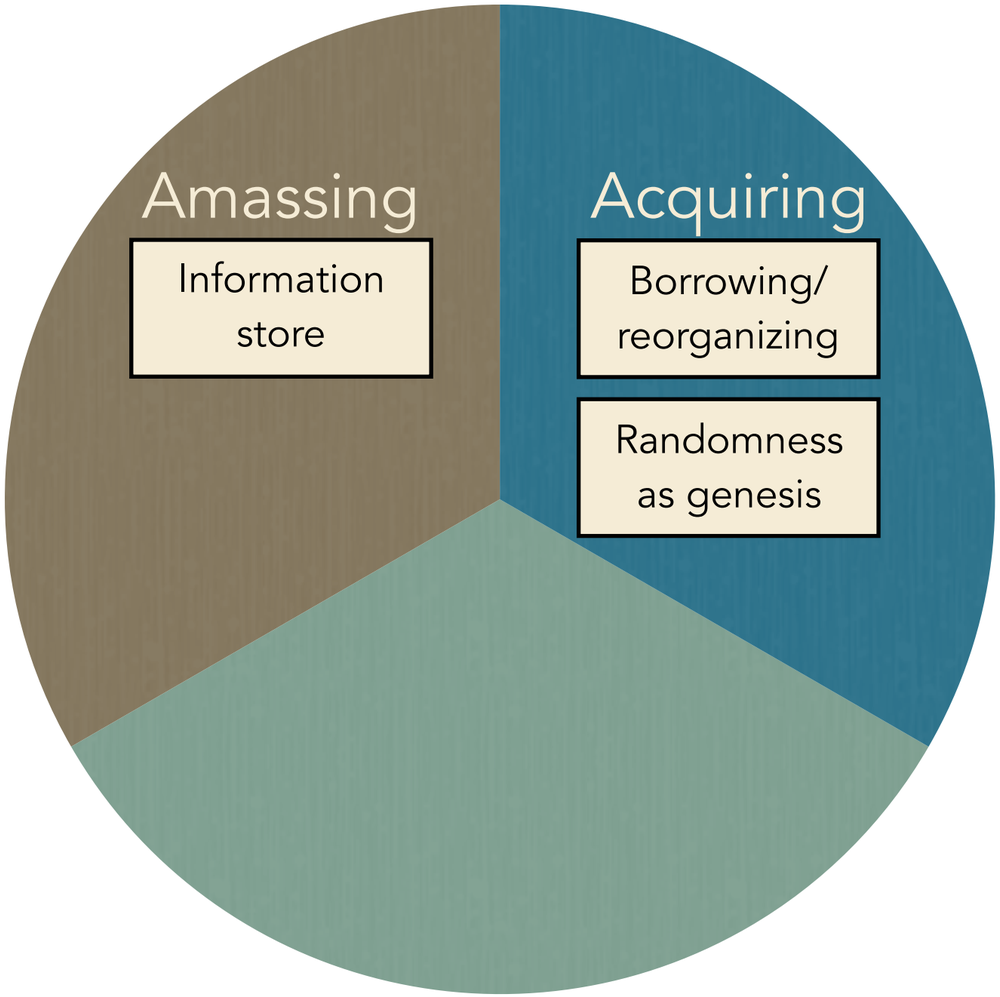


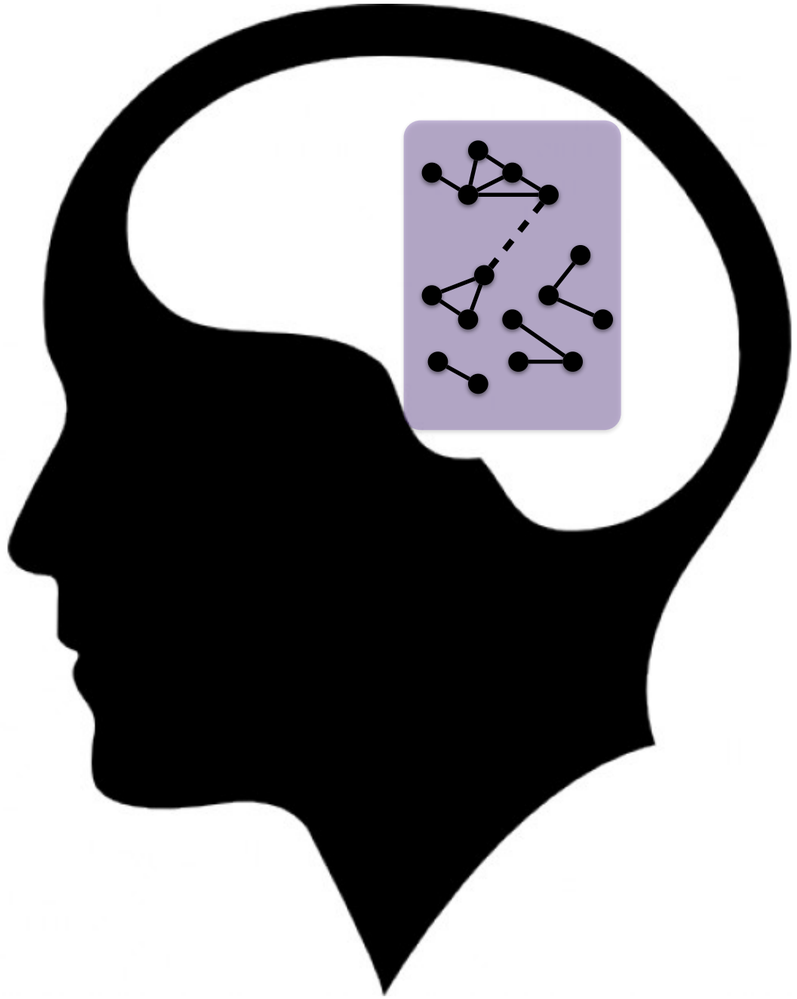

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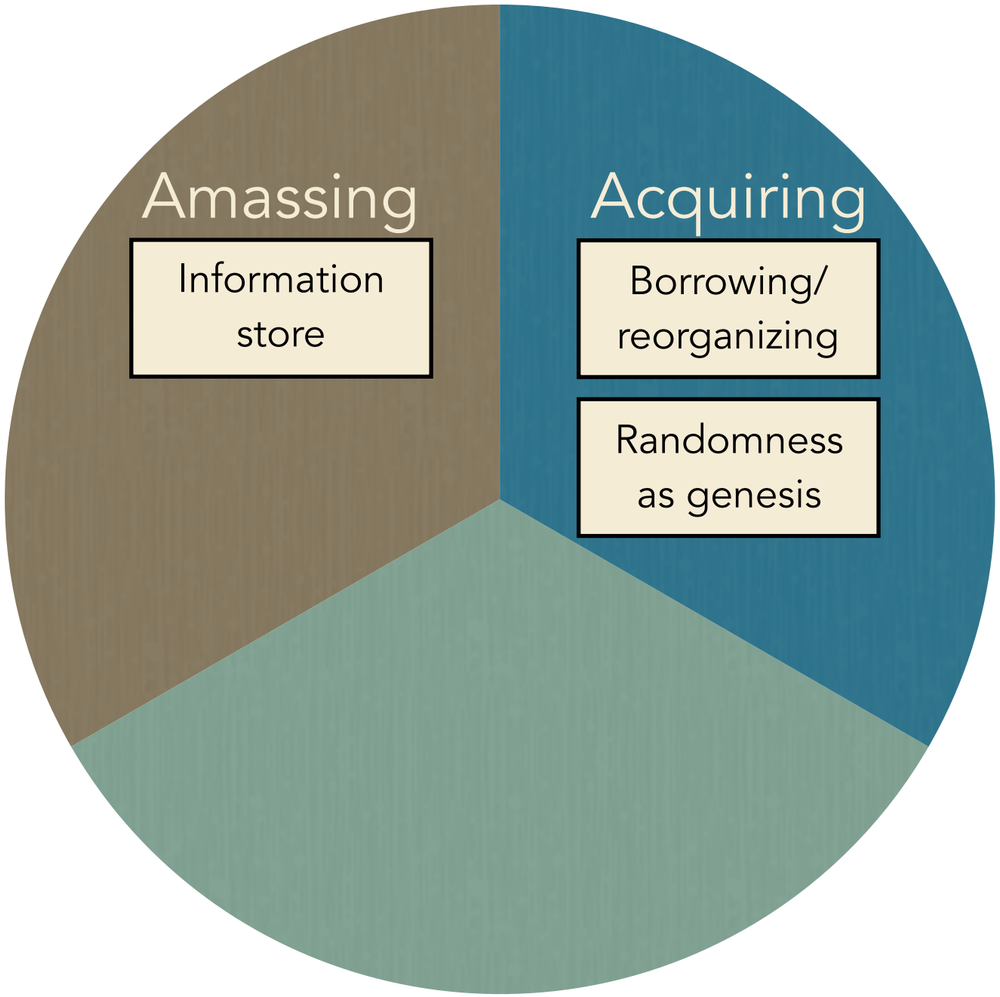


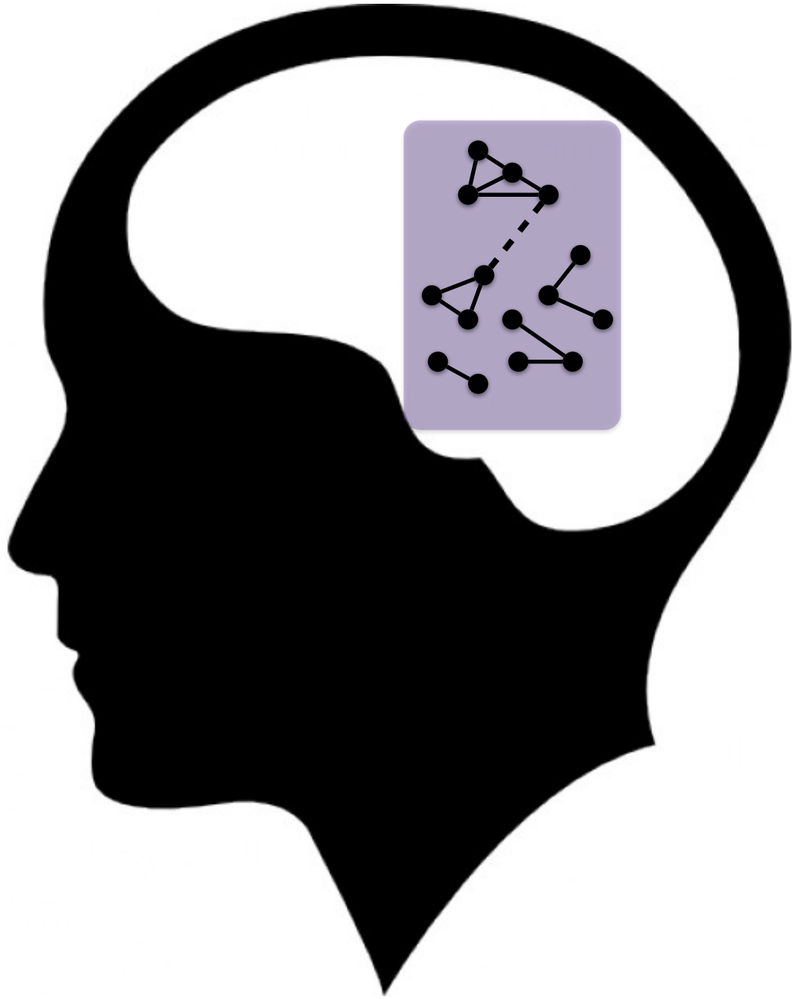

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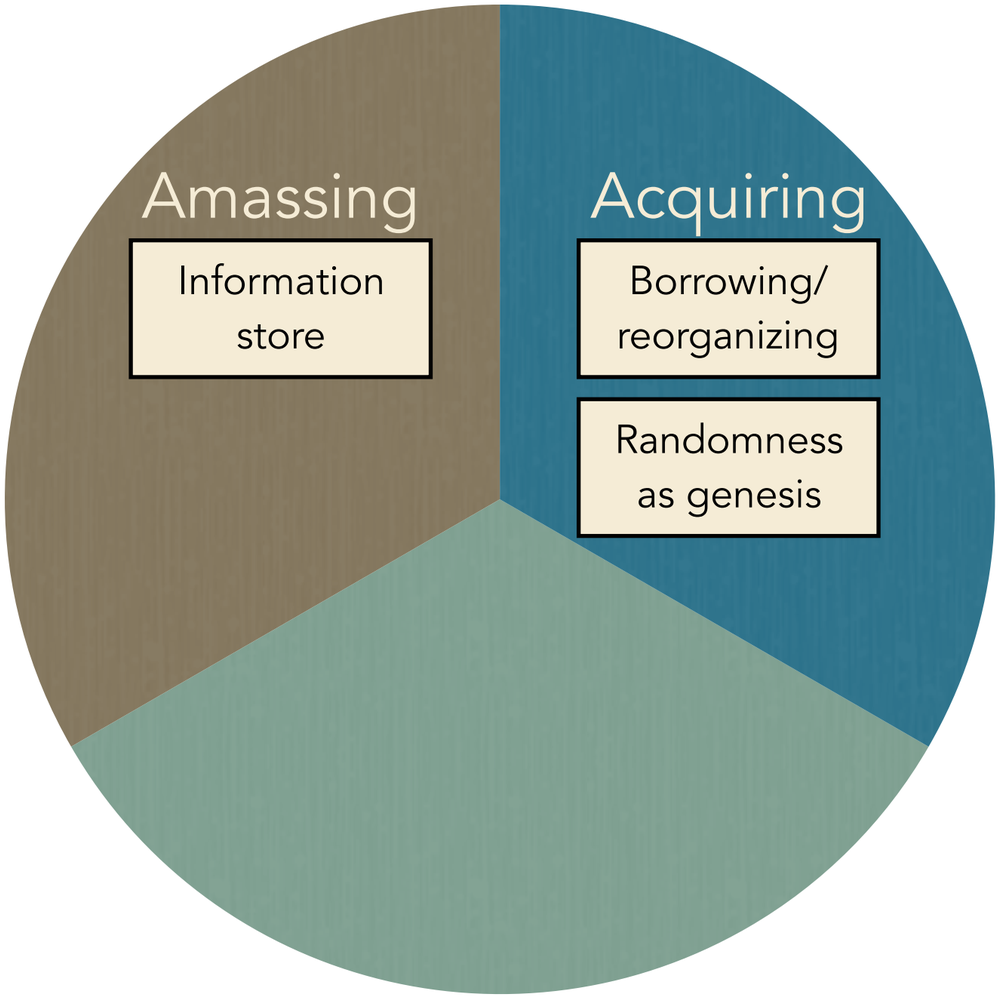


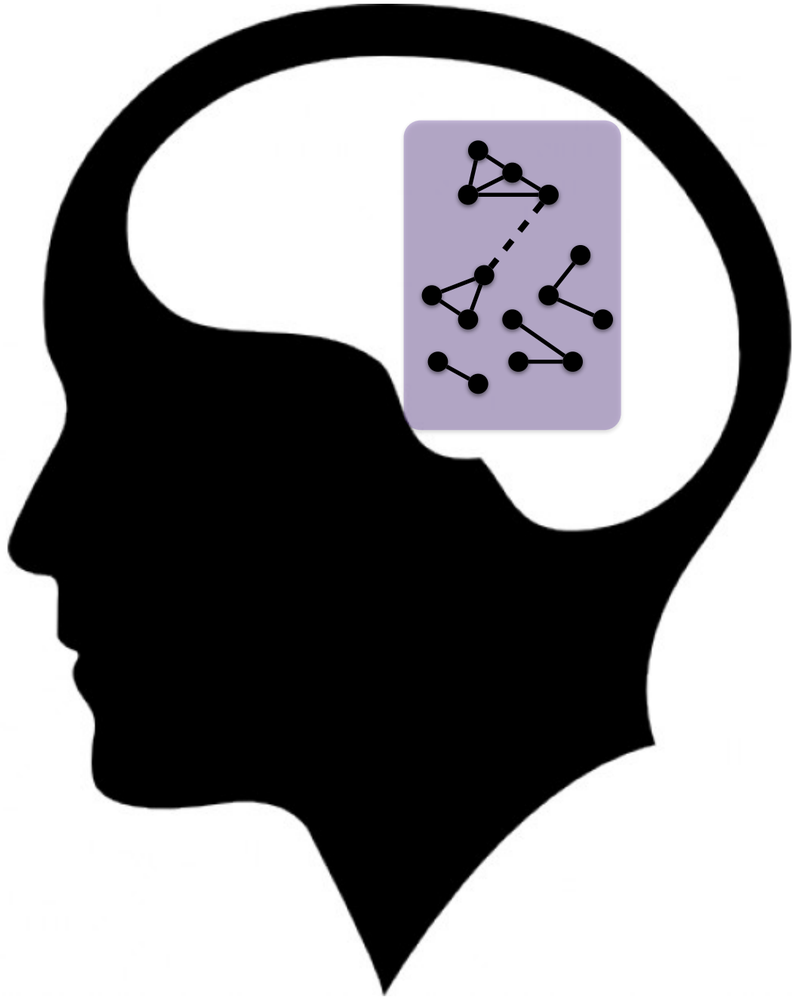

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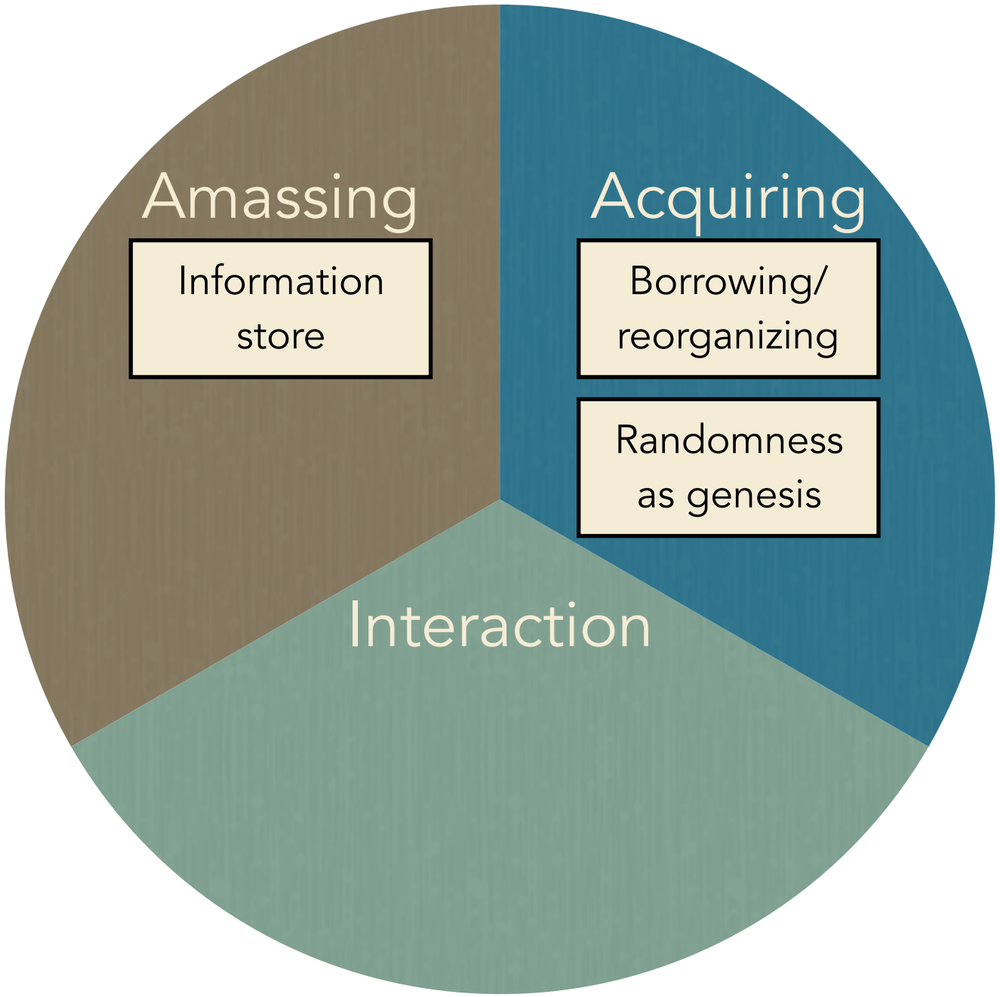


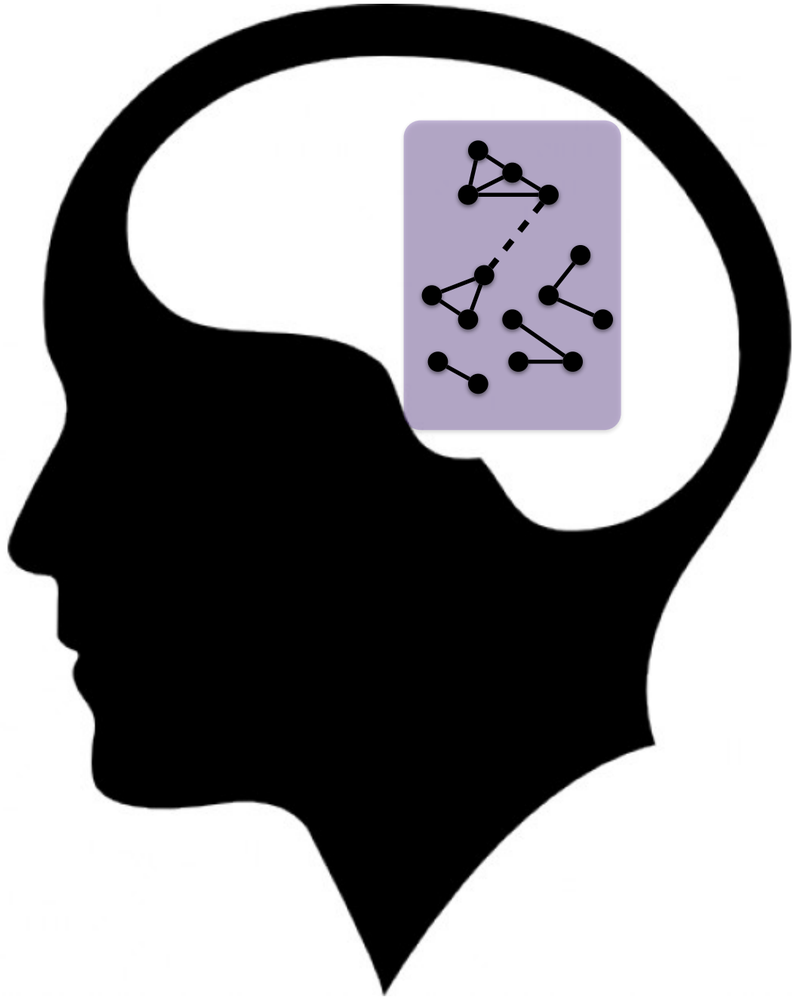

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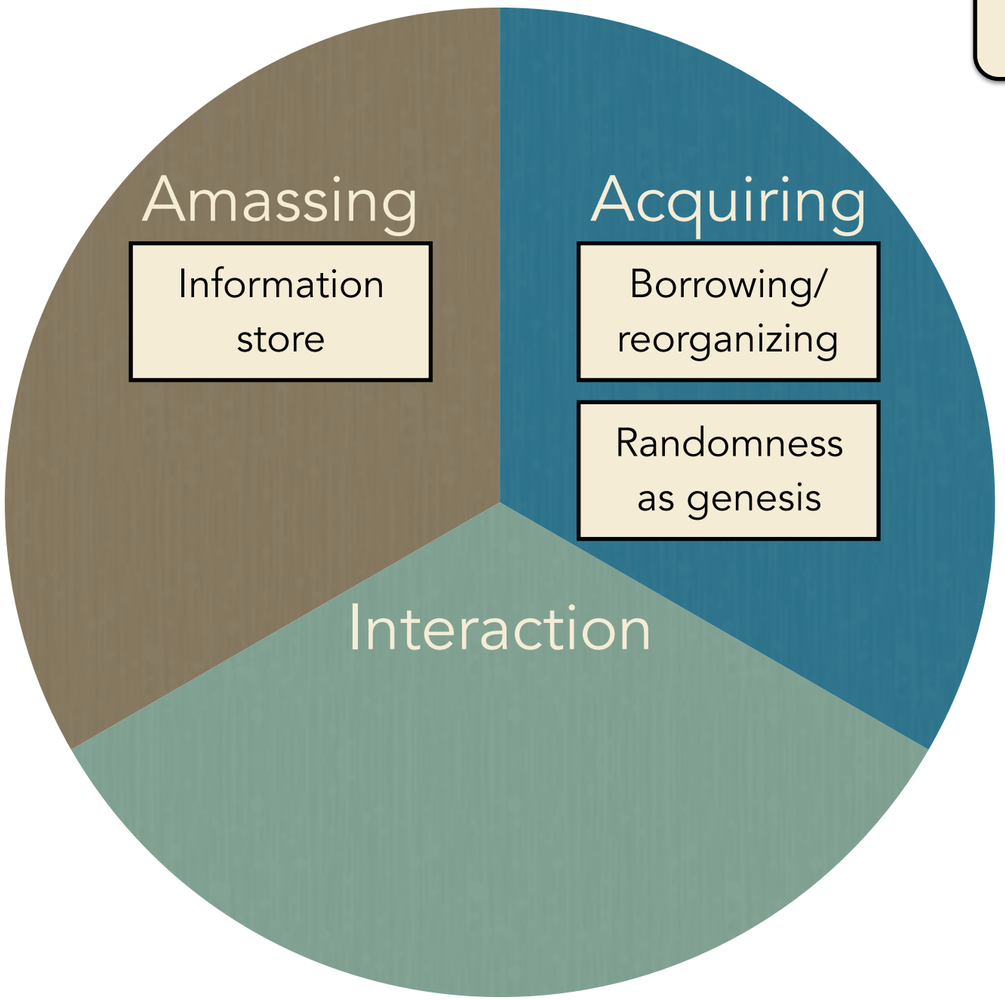


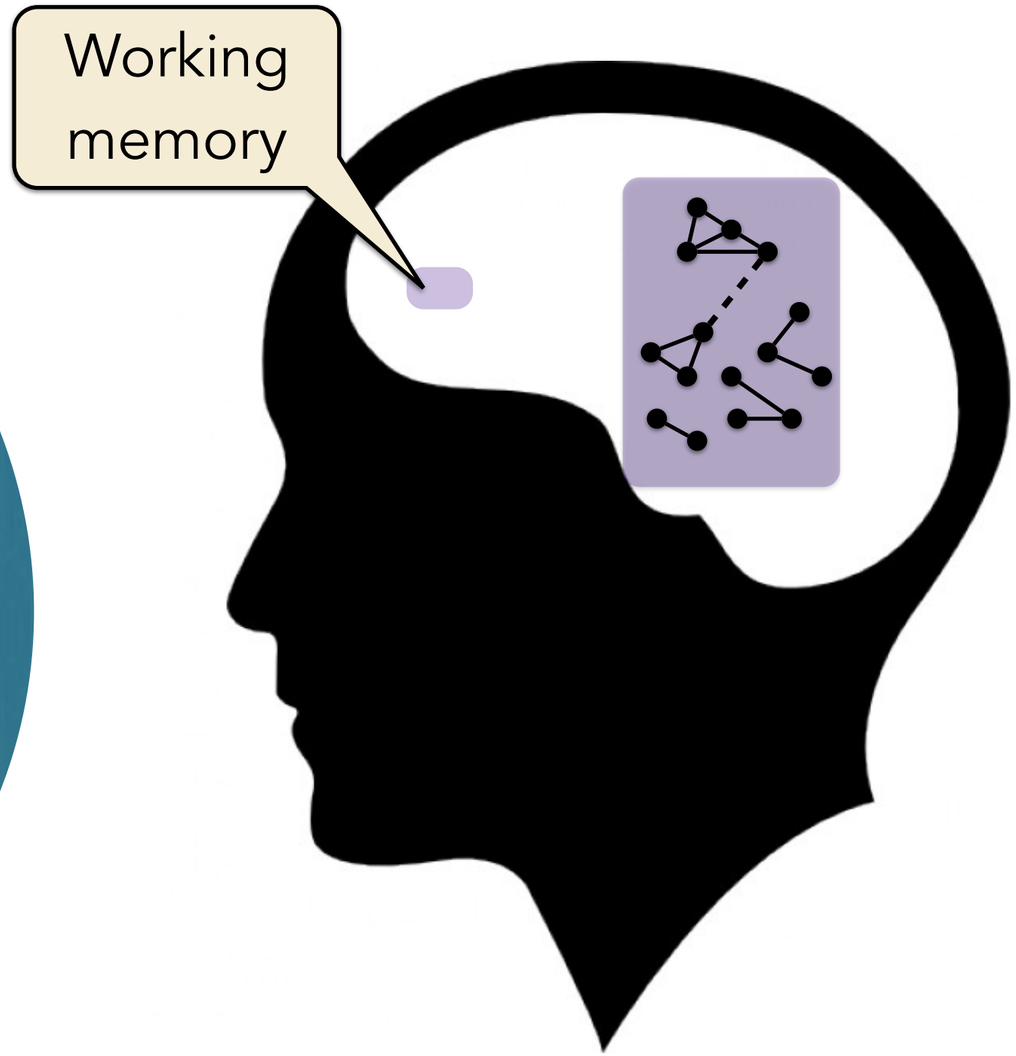

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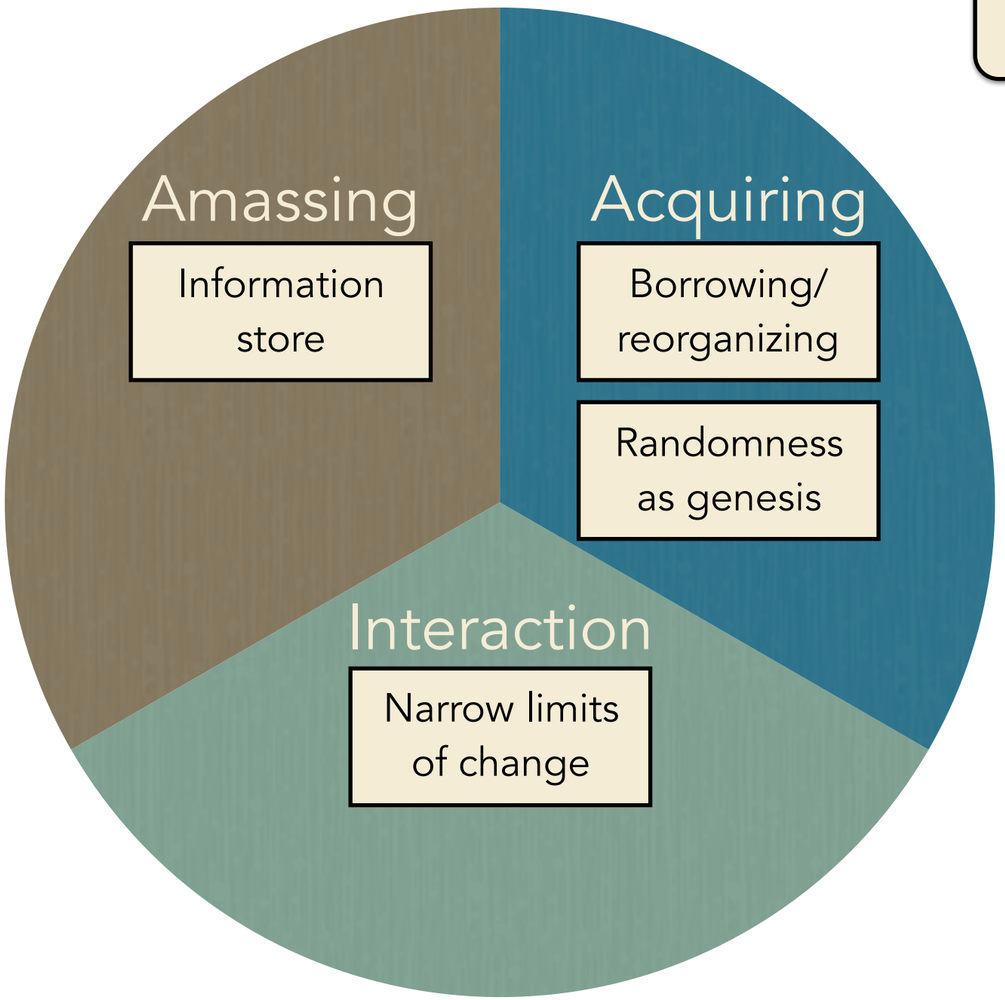


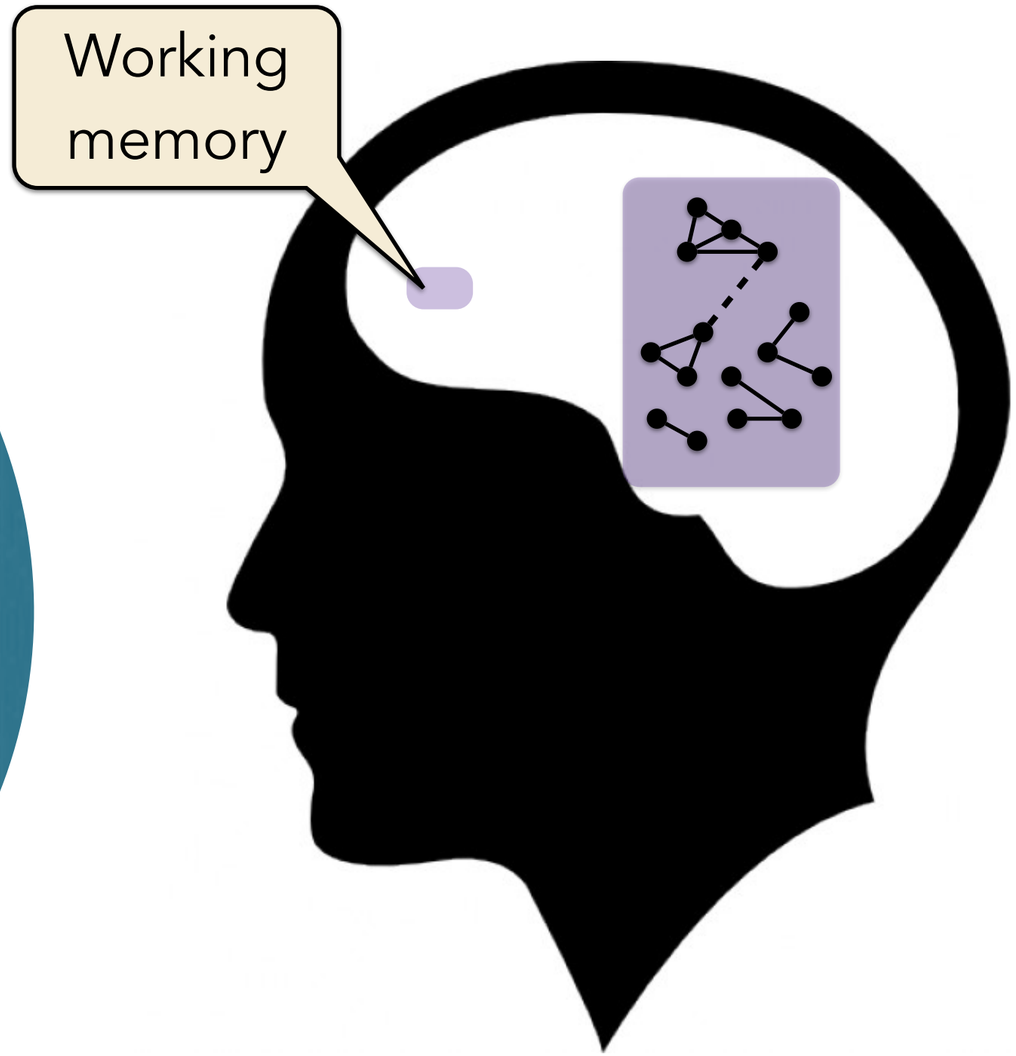

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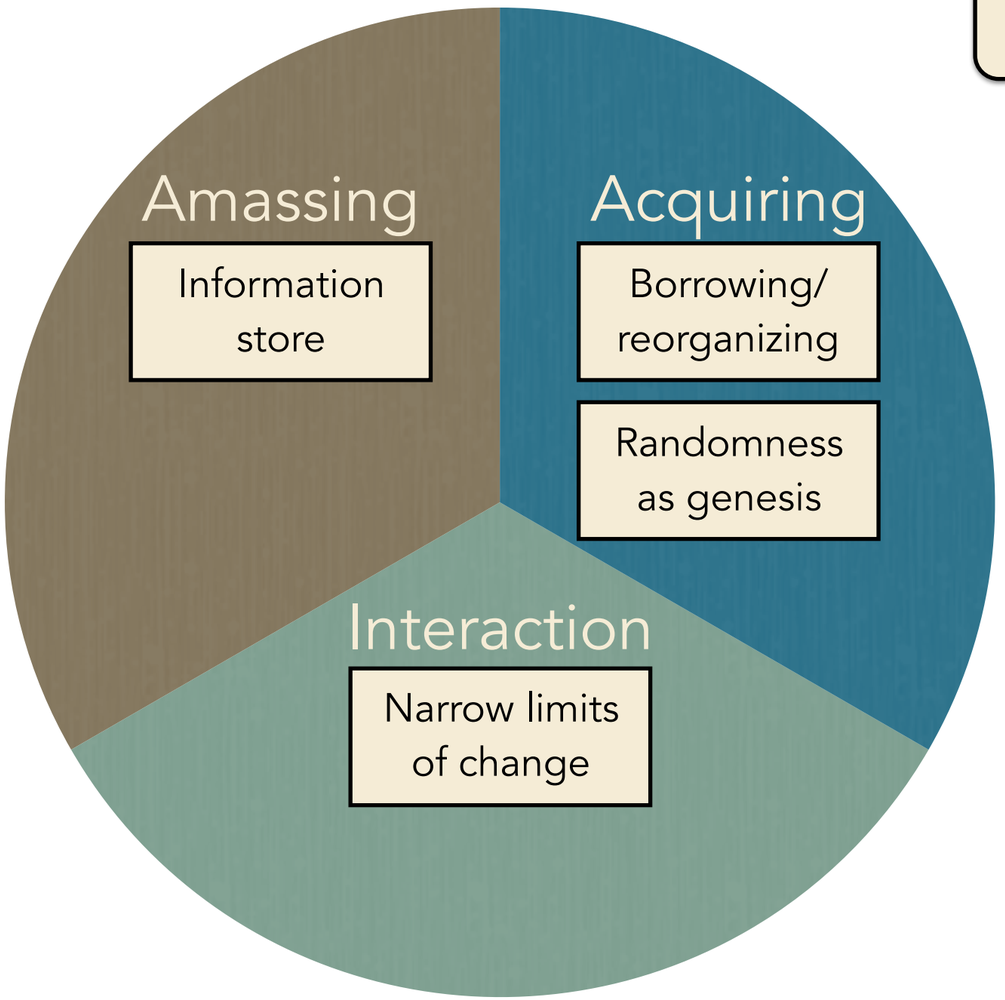


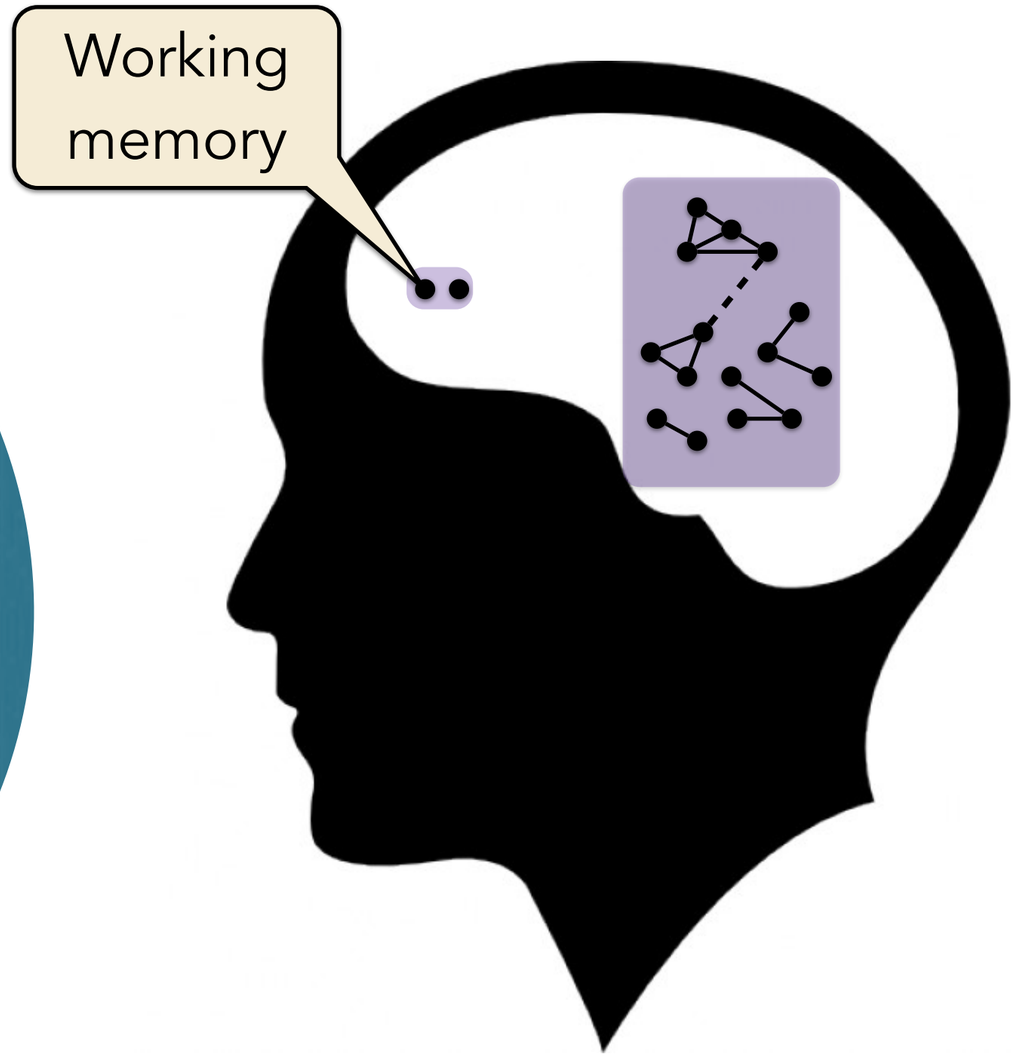

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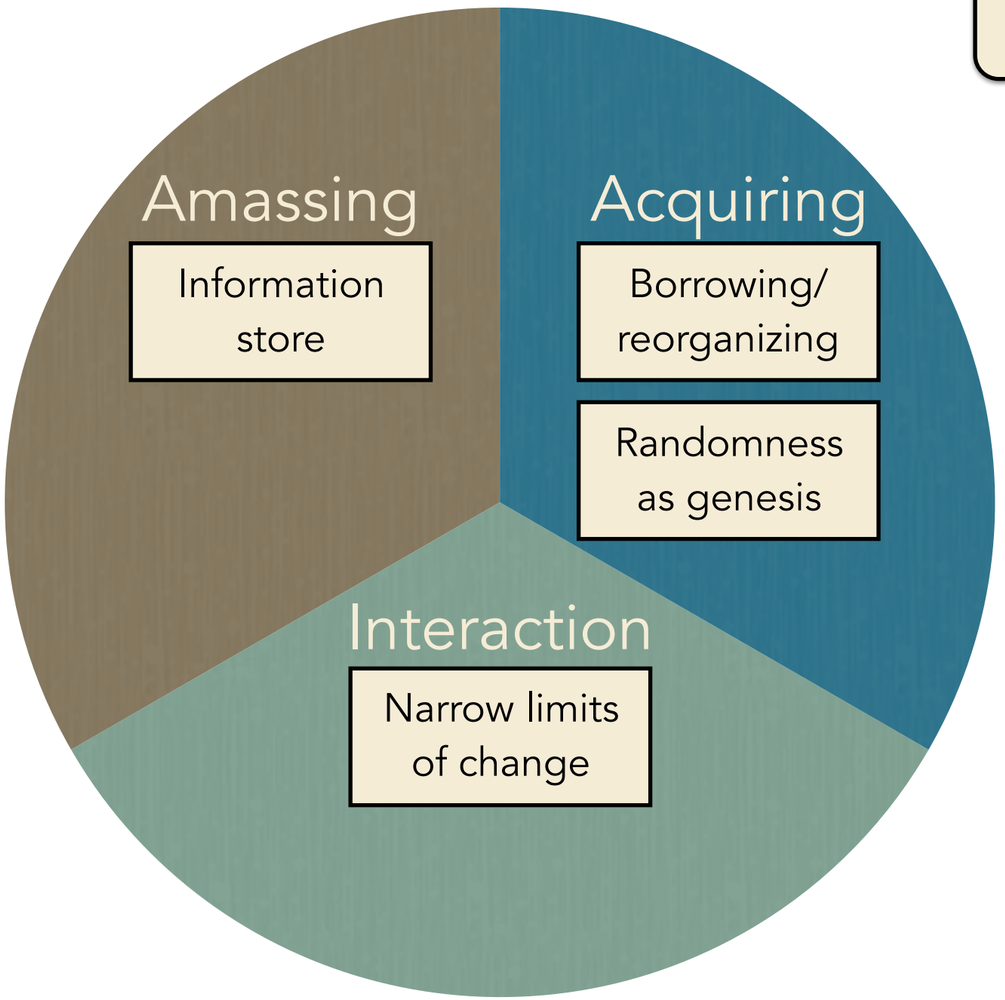


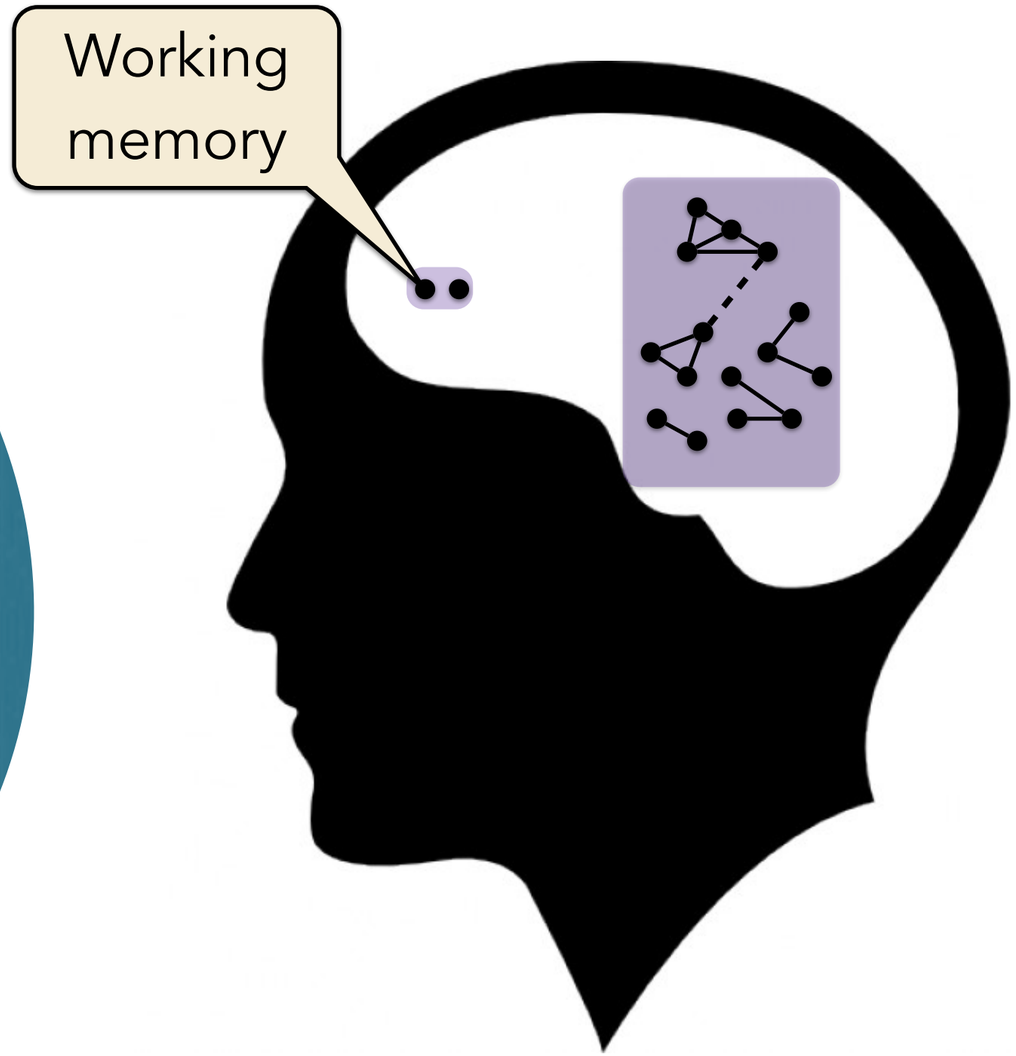

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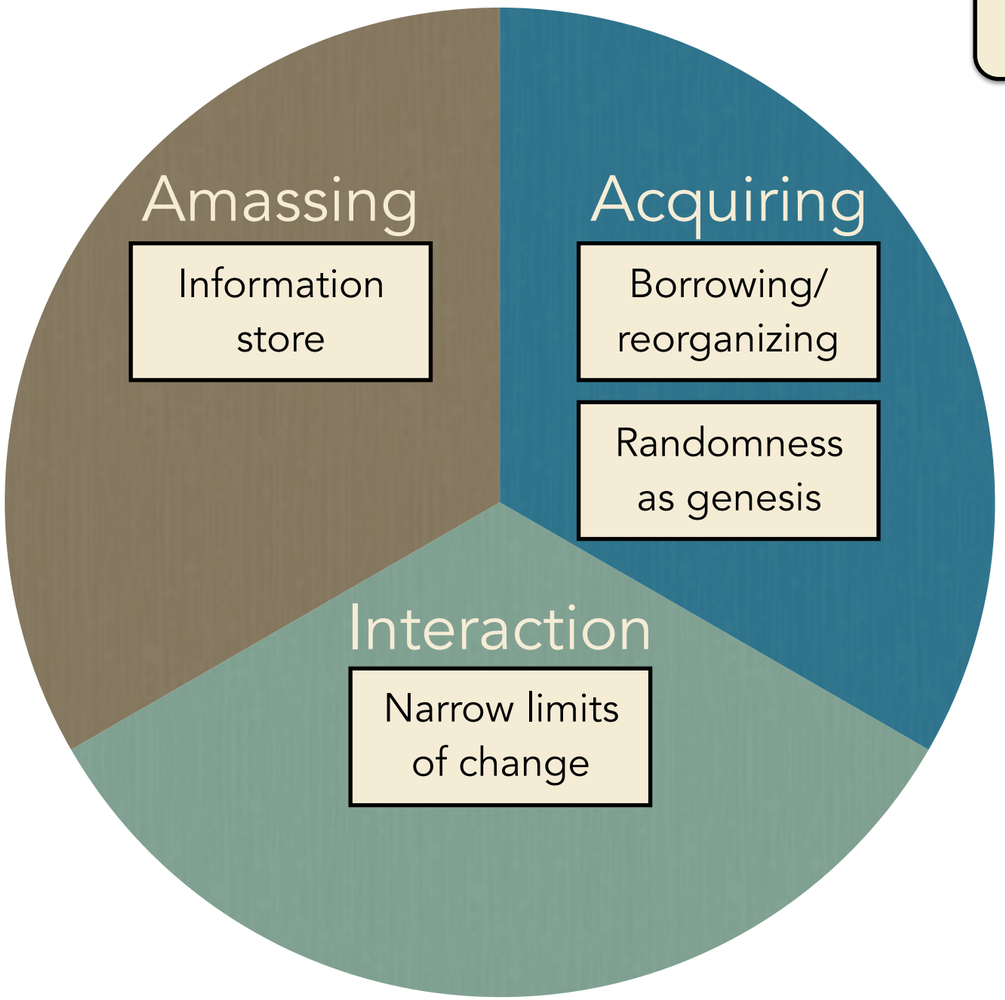


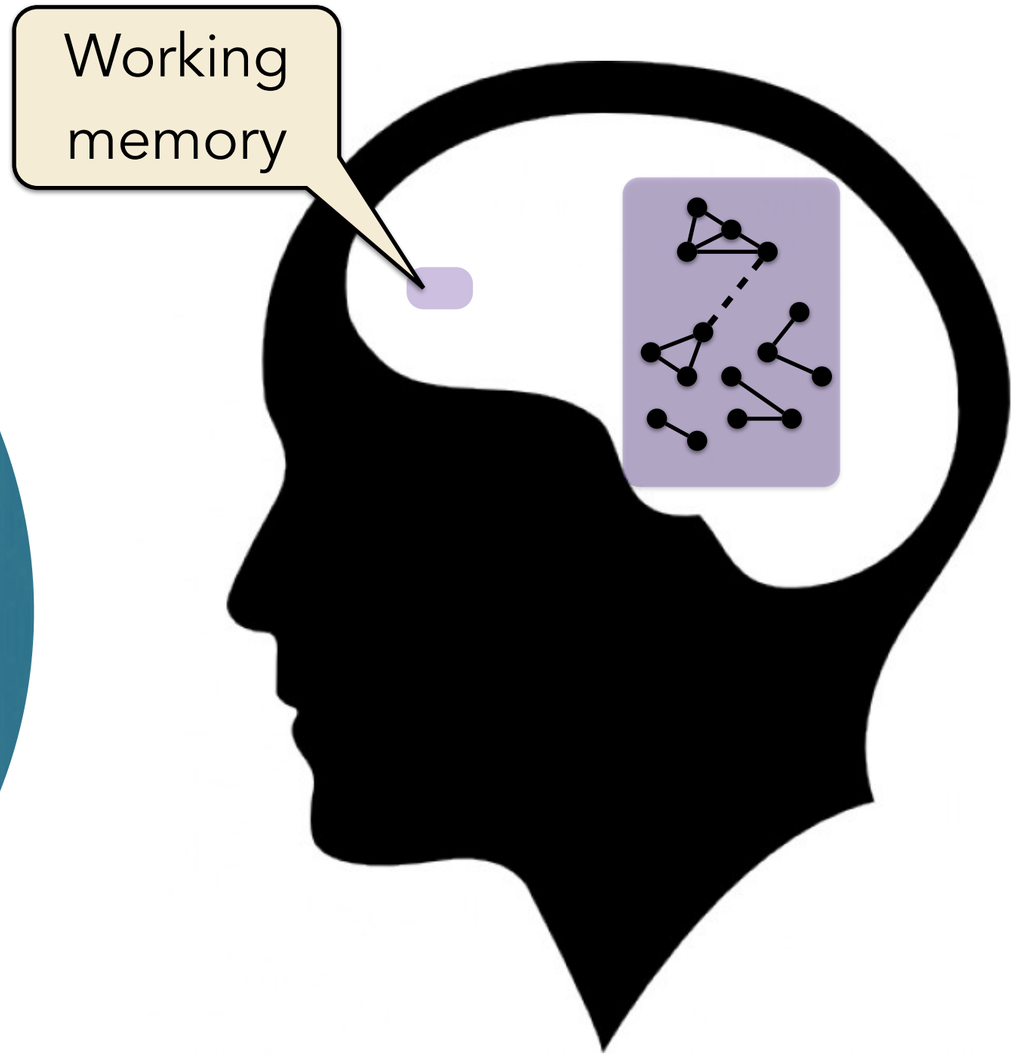

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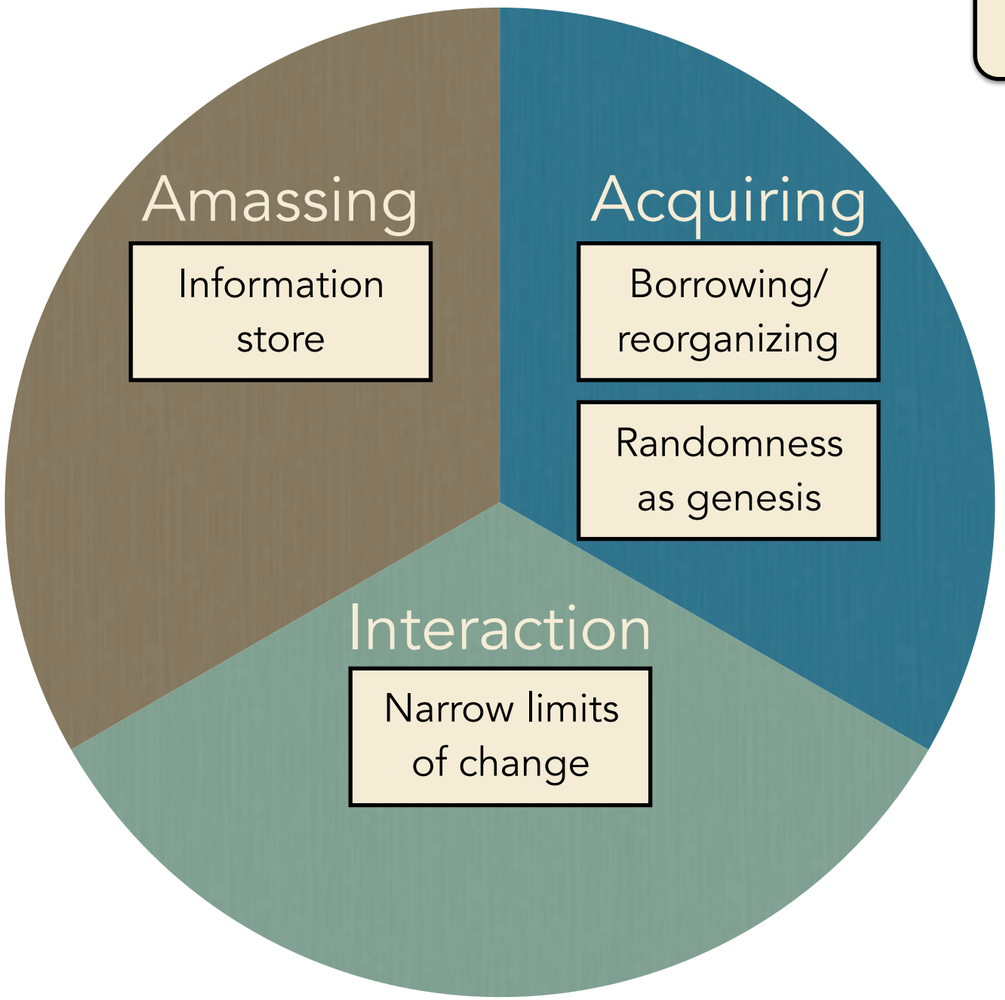


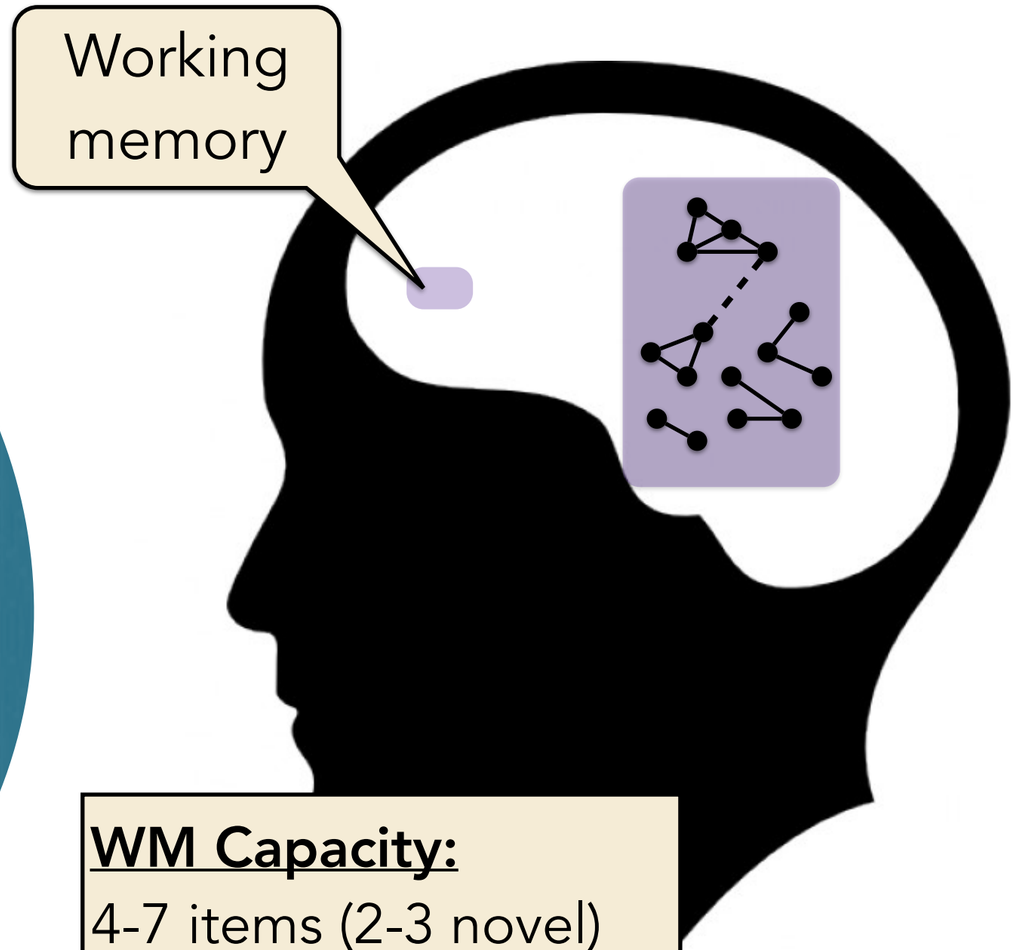


**WM Capacity:**
4-7 items (2-3 novel)
20 seconds maximum

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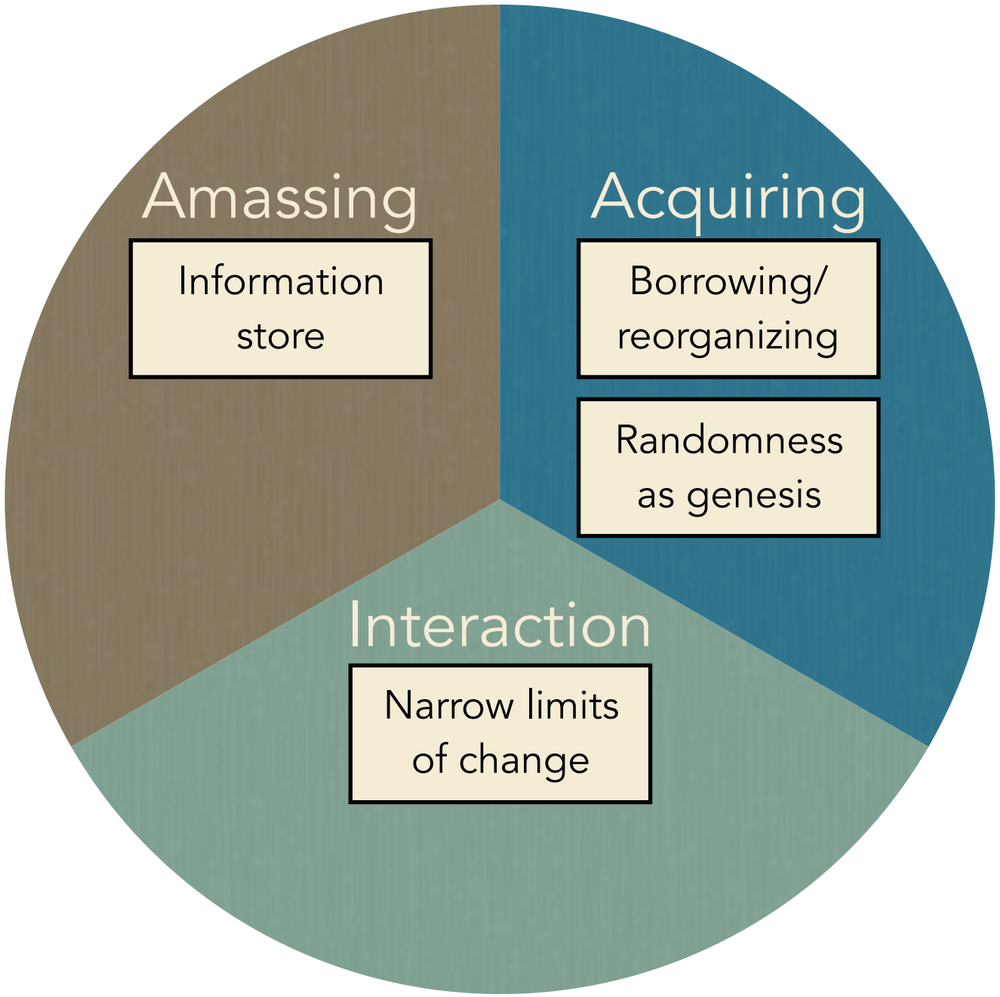


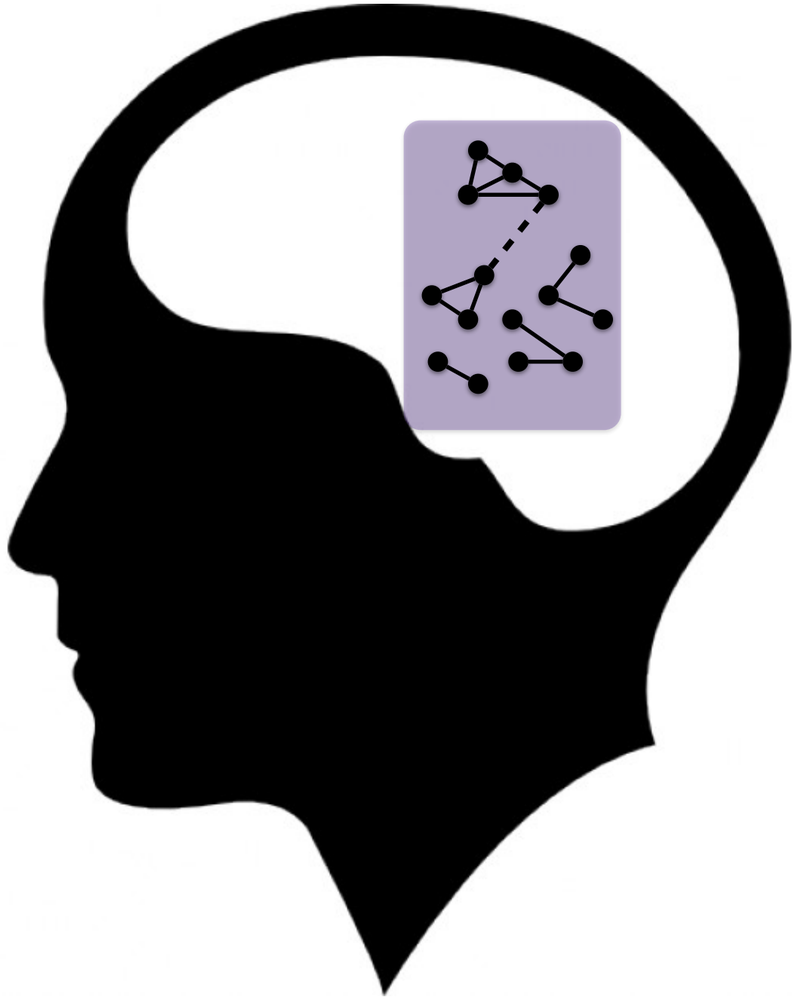

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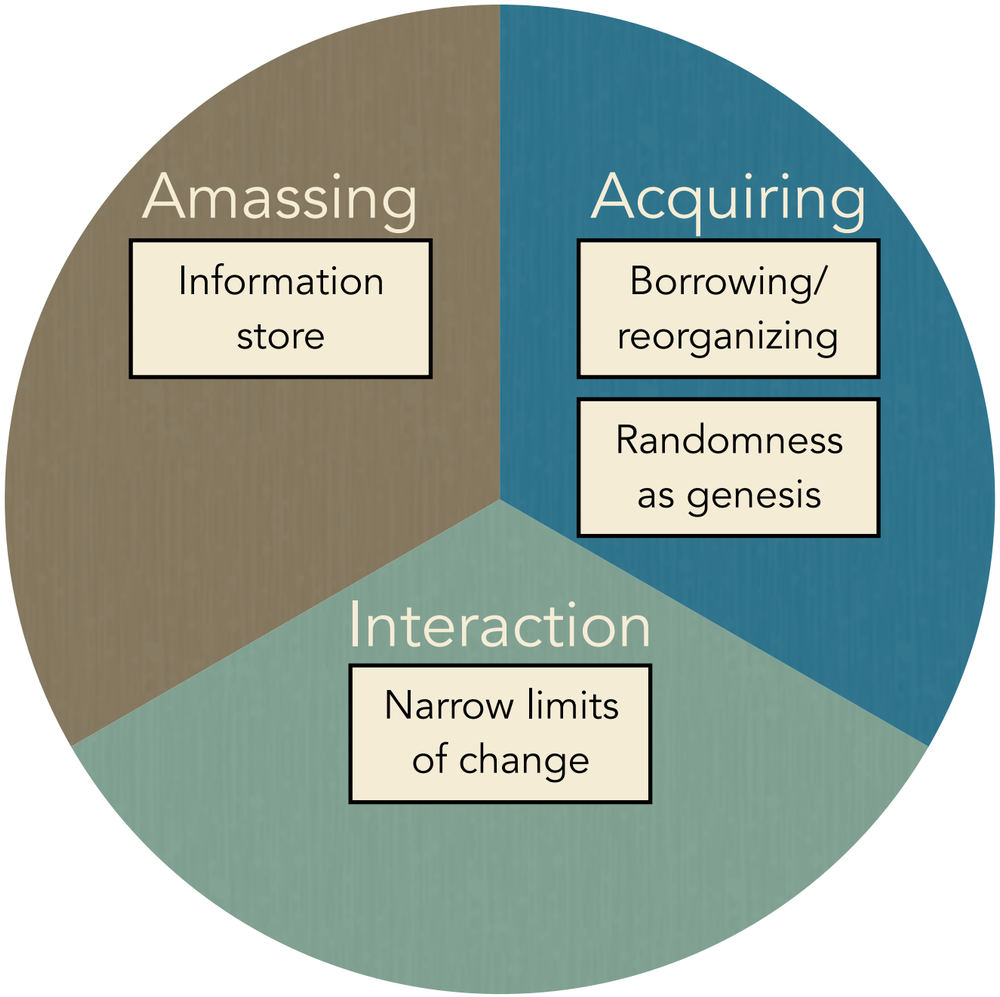


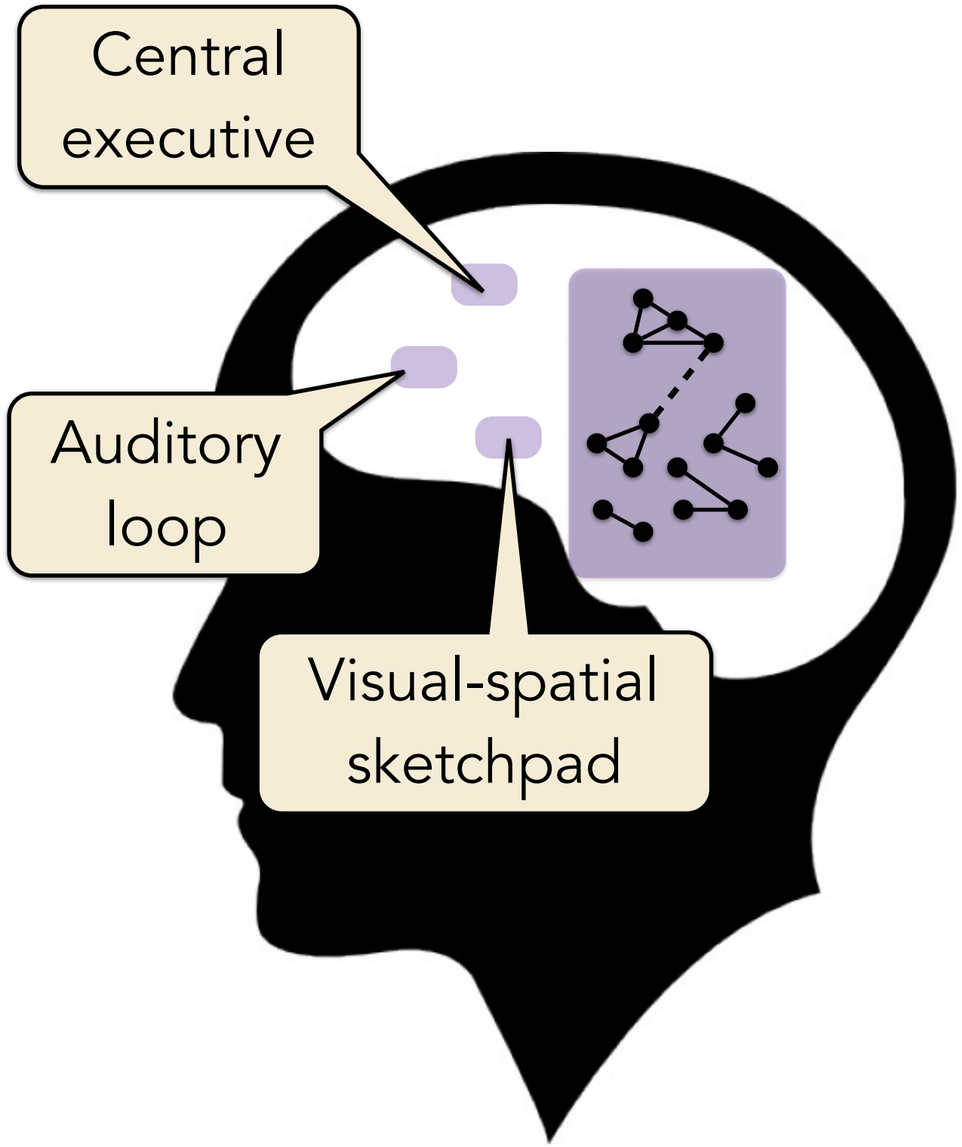

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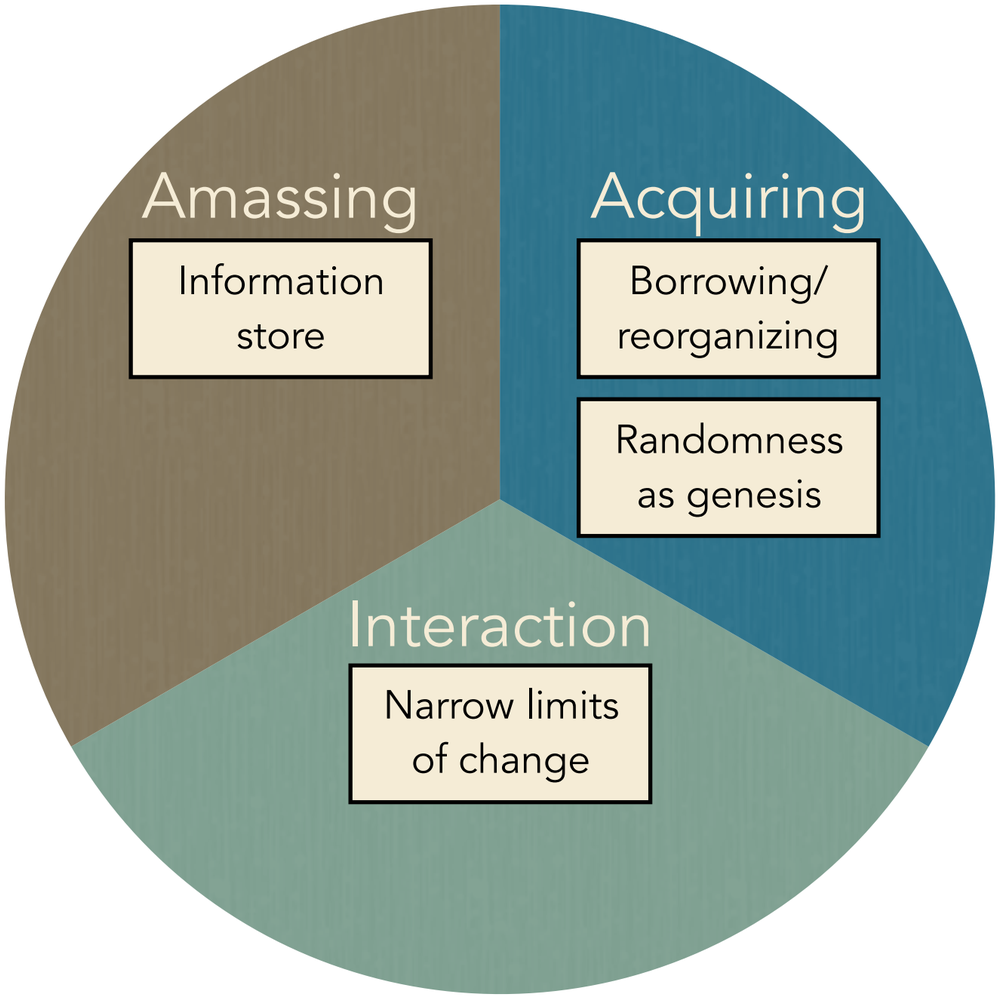


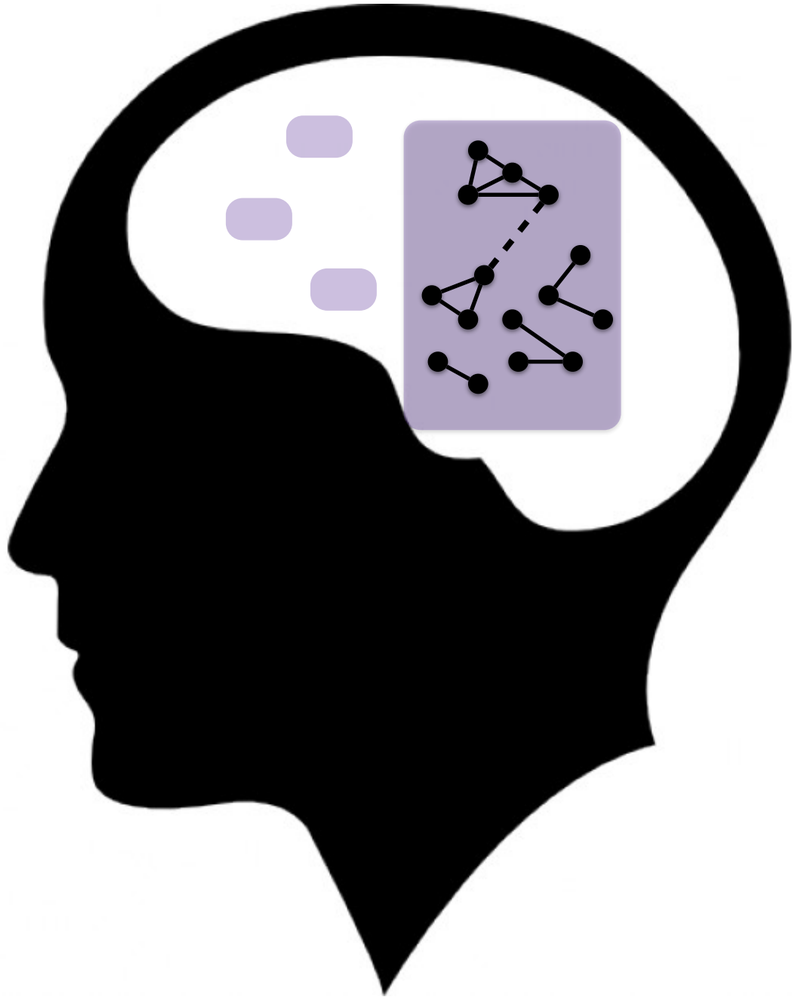

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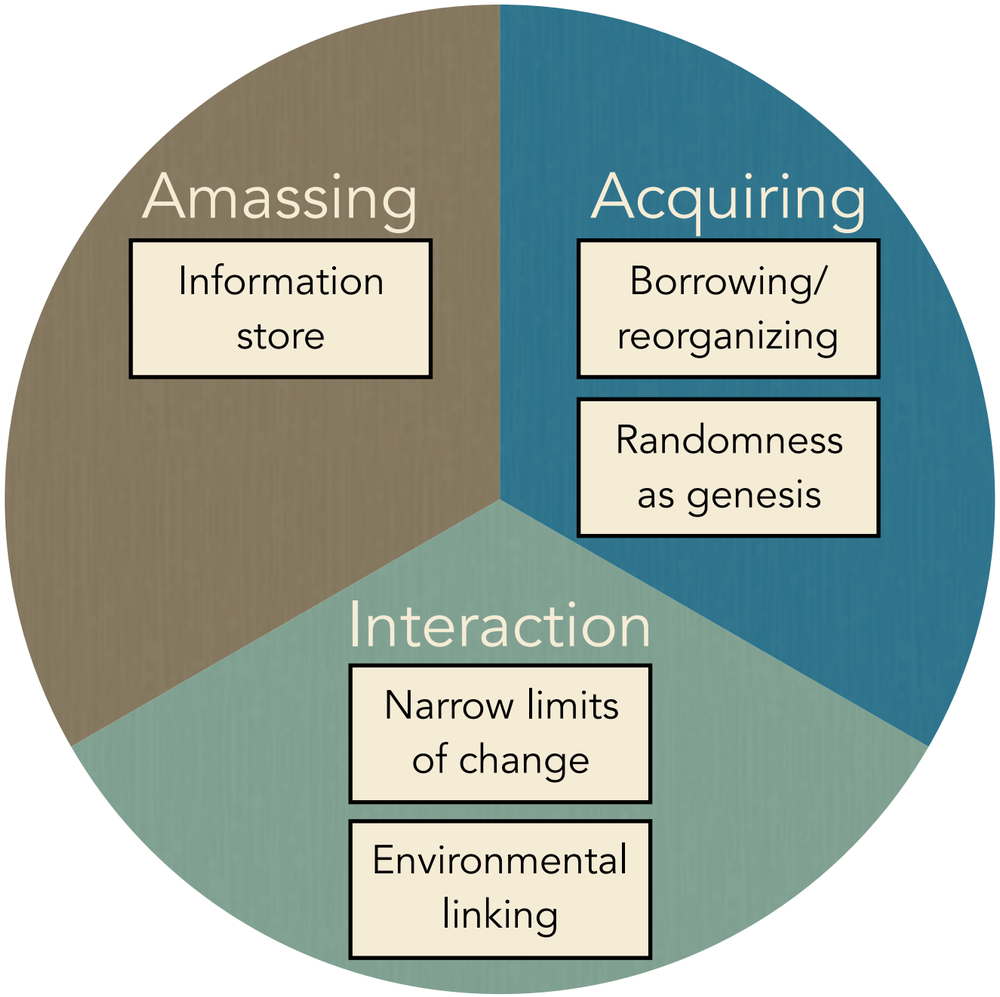


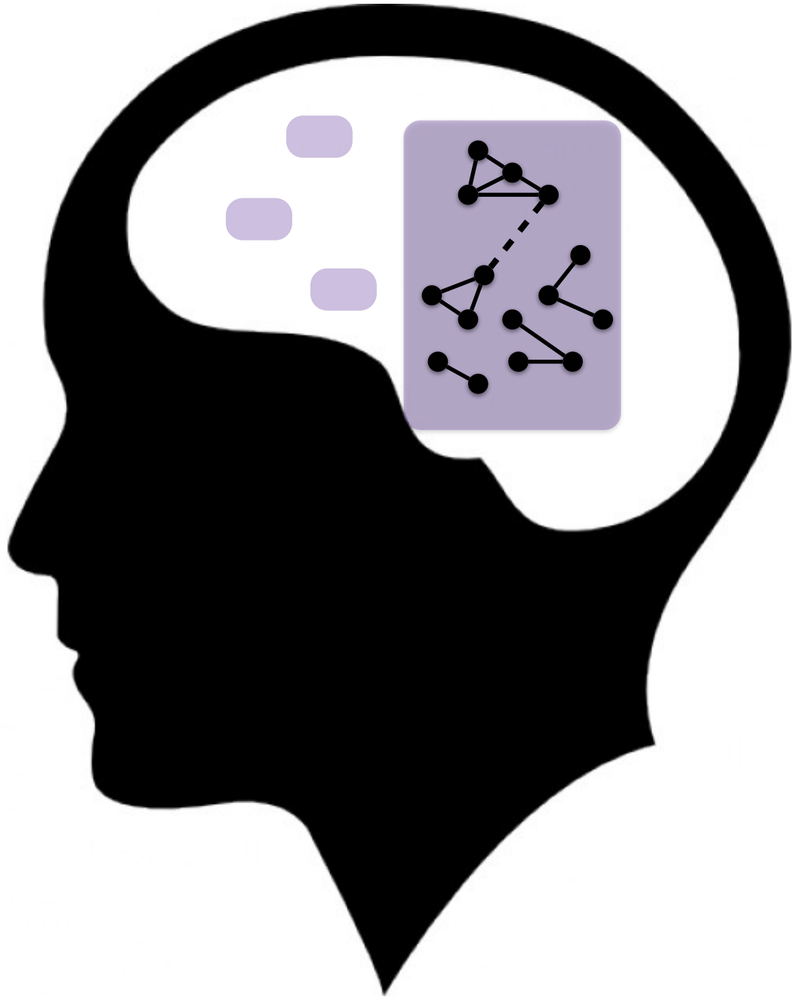

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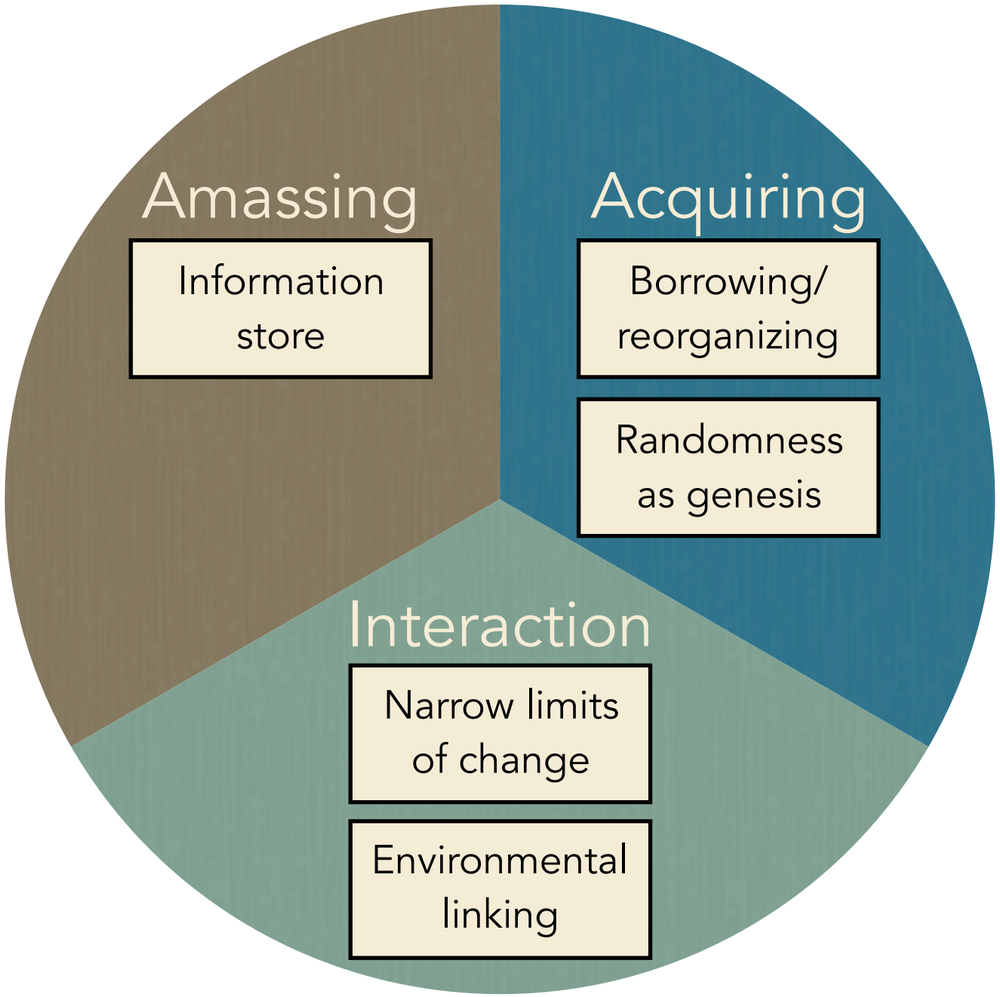


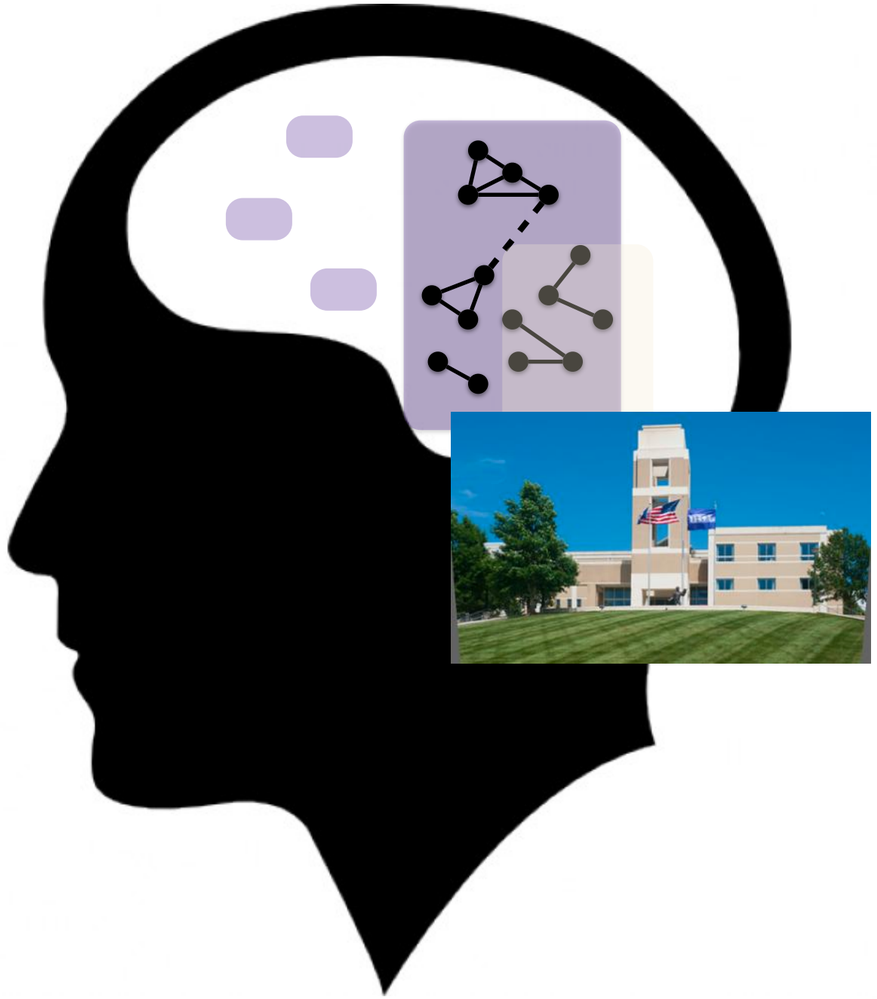

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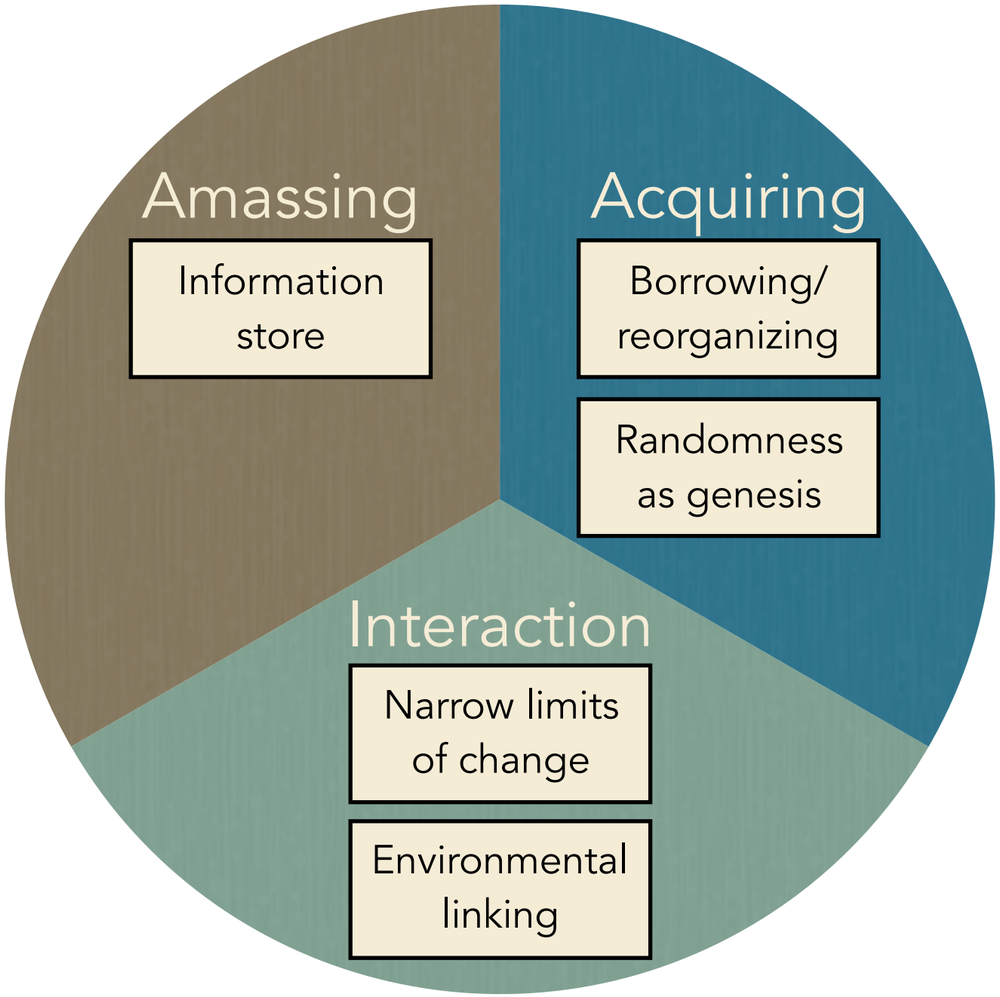
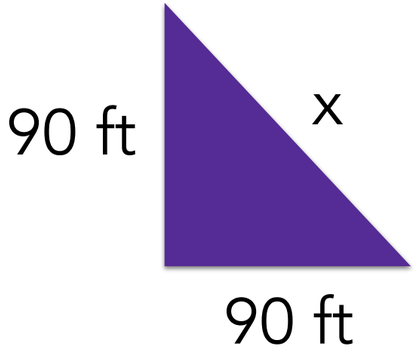
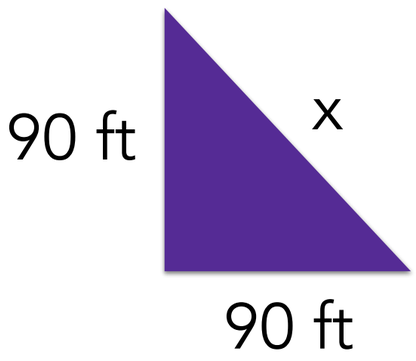



# Far transfer

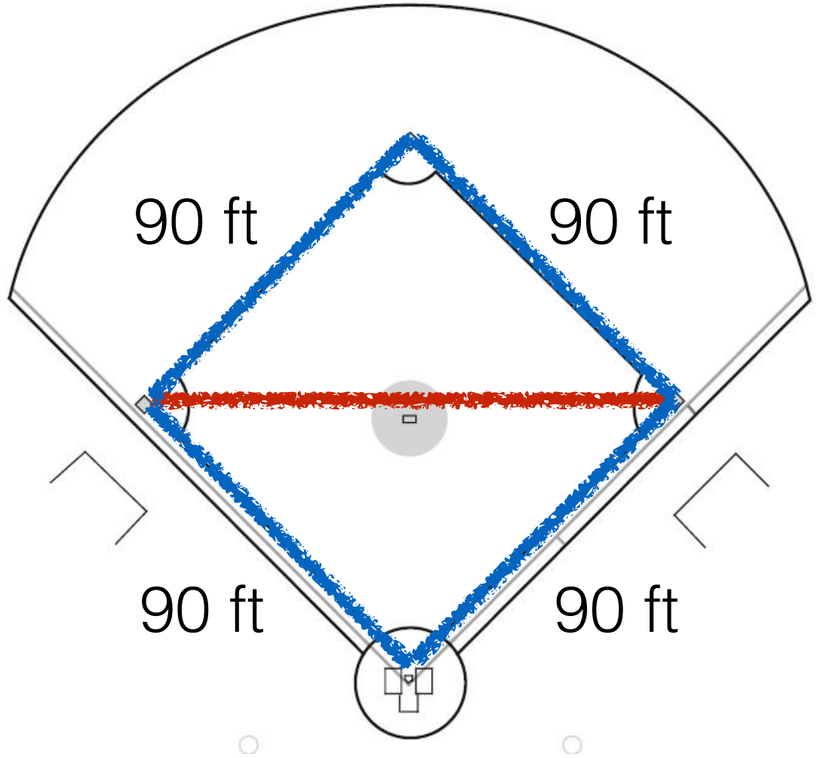



Apply the Pythagorean theorem to the above triangle to find the value of x.

# Far transfer




Apply the Pythagorean theorem to the above triangle to find the value of x.




In a baseball diamond, the distance between each base is 90 ft. Which of the following is true about the shortest distance between 1st and 3rd bases (the red line shown above)?

1. It is less than 90 ft.
2. It is between 90 and 120 ft.
3. It is greater than 120 ft.

Which of these principles of human cognition best explains why active learning is more effective than traditional lecture?

A. Information store
B. Borrowing and reorganizing
C. Randomness as genesis
D. Environmental linking

# Two systems of thinking

**System 1 - Automatic**

Quick

Effortless

Involuntary

Associative

# Two systems of thinking

**System 1 - Automatic**

Quick

Effortless

Involuntary

Associative

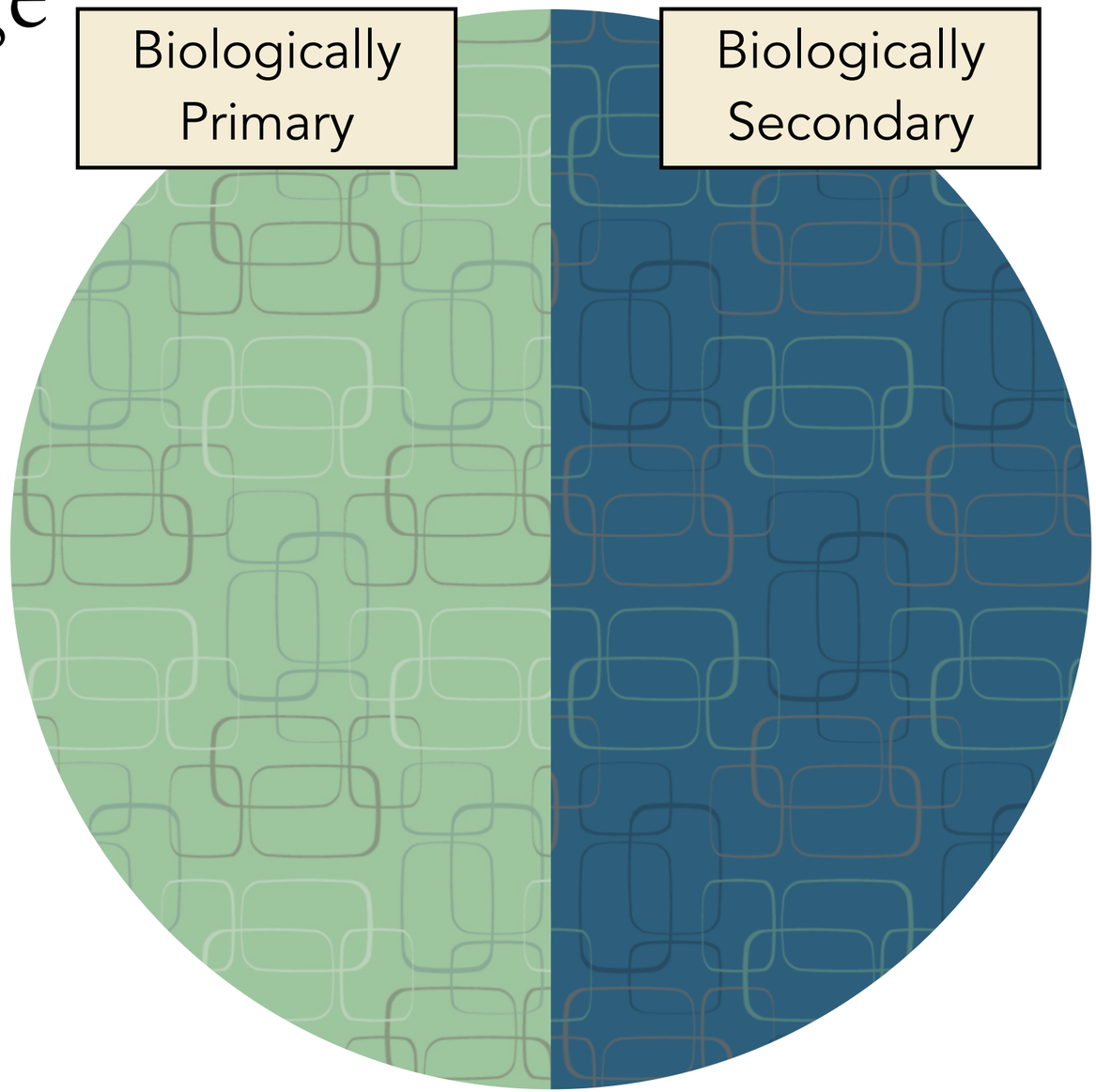
**System 2 - Effortful**

Lazy controller

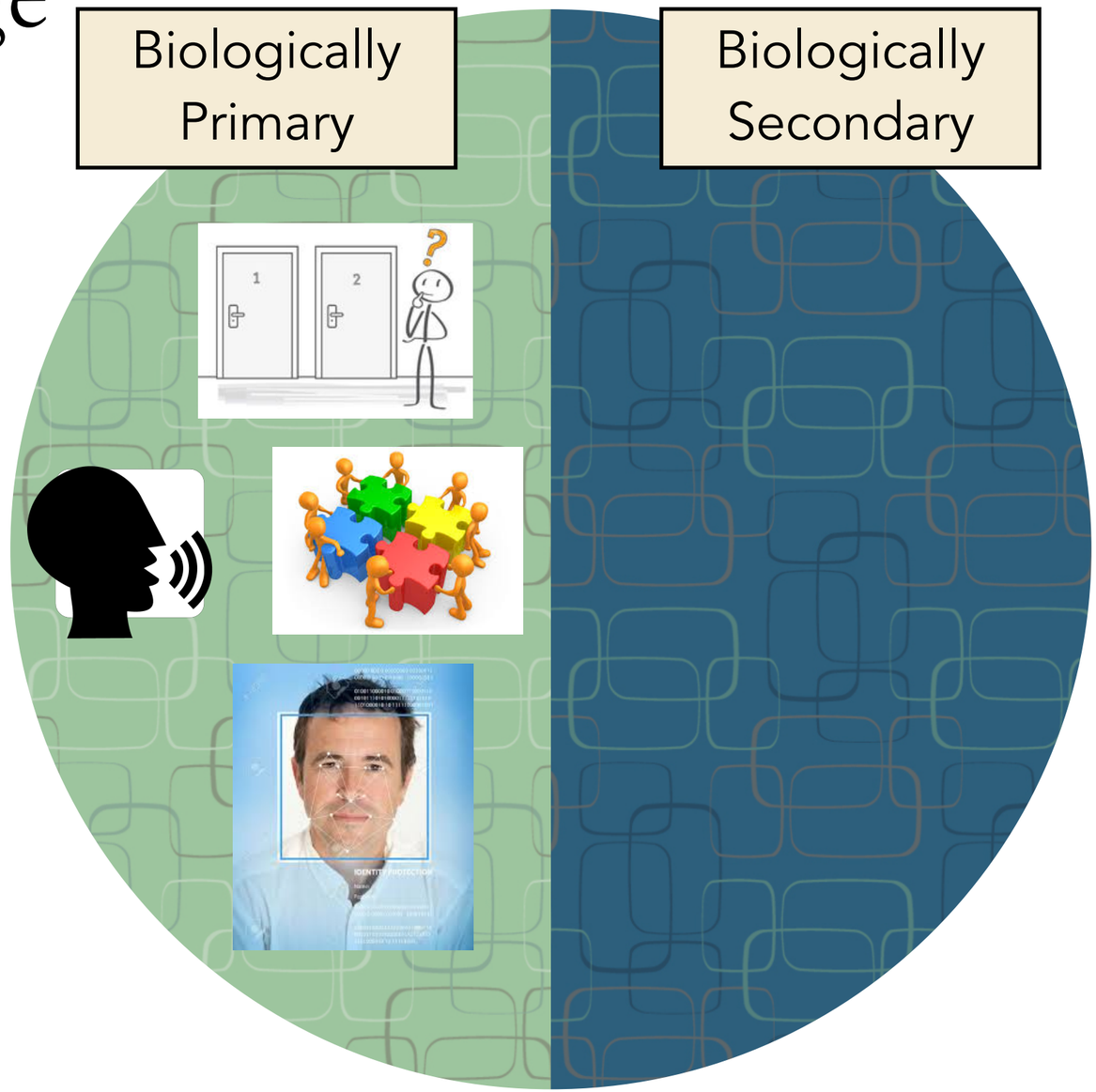
Calculations

Critical thinking

# Types of knowledge



# Types of knowledge



# Types of knowledge

## Biologically Primary


## Biologically Secondary

**Additive Rules**

$$\frac{}{\Delta, \mathbf{0} \vdash \Gamma}\ \mathbf{0}L \qquad \frac{}{\Delta \vdash \top, \Gamma}\ \top R$$

$$\frac{\Delta, B_i \vdash \Gamma}{\Delta, B_1 \,\&\, B_2 \vdash \Gamma}\ \&L\ (i = 1, 2) \qquad \frac{\Delta \vdash B, \Gamma \quad \Delta \vdash C, \Gamma}{\Delta \vdash B \,\&\, C, \Gamma}\ \&R$$

$$\frac{\Delta, B \vdash \Gamma \quad \Delta, C \vdash \Gamma}{\Delta, B \oplus C \vdash \Gamma}\ \oplus L \qquad \frac{\Delta \vdash B_i, \Gamma}{\Delta \vdash B_1 \oplus B_2, \Gamma}\ \oplus R\ (i = 1, 2)$$

**Quantifier Rules**

$$\frac{\Delta, B[t/x] \vdash \Gamma}{\Delta, \forall x.B \vdash \Gamma}\ \forall L \qquad \frac{\Delta \vdash B[y/x], \Gamma}{\Delta \vdash \forall x.B, \Gamma}\ \forall R$$

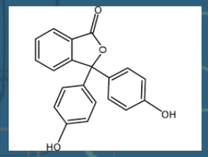
$$\frac{\Delta \vdash B[t/x], \Gamma}{\Delta \vdash \exists x.B \Gamma}\ \exists R \qquad \frac{\Delta, B[y/x] \vdash \Gamma}{\Delta, \exists x.B \vdash \Gamma}\ \exists L$$

**Exponential Rules**

$$\frac{!\Delta, B \vdash ?\Gamma}{!\Delta, ?B \vdash ?\Gamma}\ ?L \qquad \frac{!\Delta \vdash B, ?\Gamma}{!\Delta \vdash !B, ?\Gamma}\ !R$$

$$\frac{\Delta \vdash \Gamma}{\Delta, !B \vdash \Gamma}\ !W \qquad \frac{\Delta, !B, !B \vdash \Gamma}{\Delta, !B \vdash \Gamma}\ !C \qquad \frac{\Delta, B \vdash \Gamma}{\Delta, !B \vdash \Gamma}\ !D$$

$$\frac{\Delta \vdash \Gamma}{\Delta \vdash ?B, \Gamma}\ ?W \qquad \frac{\Delta \vdash ?B, ?B, \Gamma}{\Delta \vdash ?B, \Gamma}\ ?C \qquad \frac{\Delta \vdash B, \Gamma}{\Delta \vdash ?B, \Gamma}\ ?D$$




# Retrieval fluency

J.D. Bransford et al., How People Learn: Brain, Mind, Experience, and School. National Academy Press. 2000.
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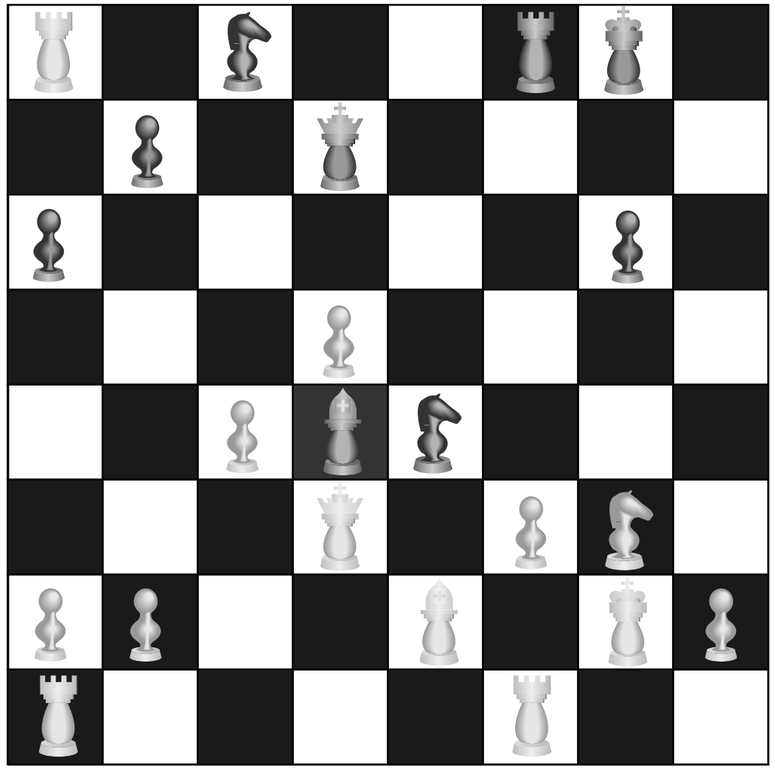

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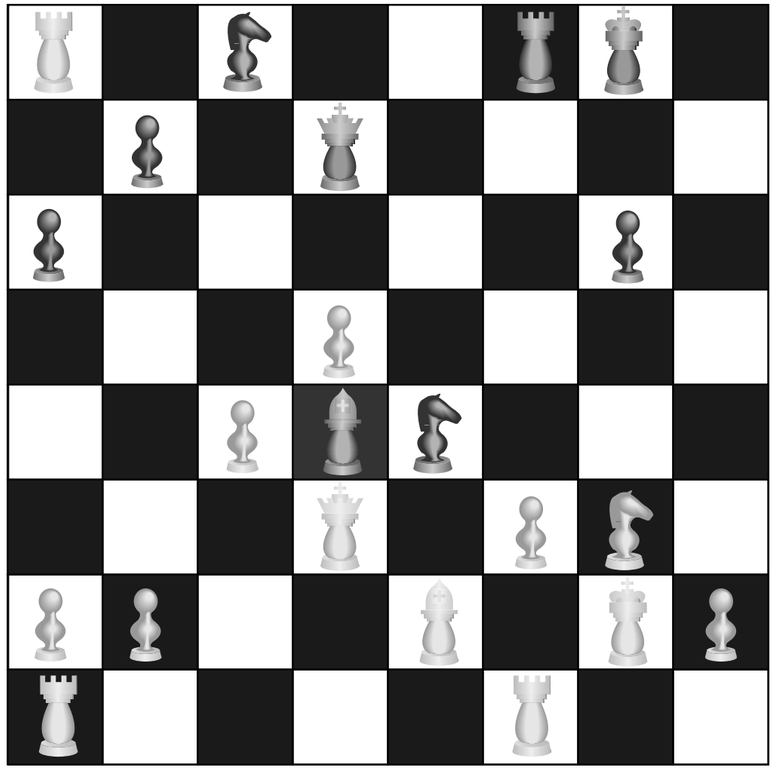

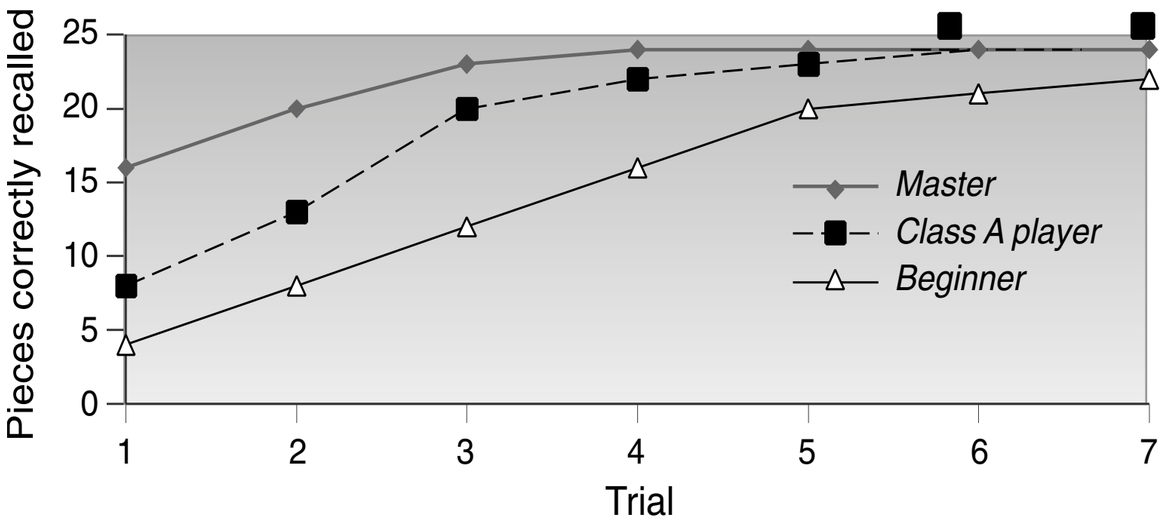


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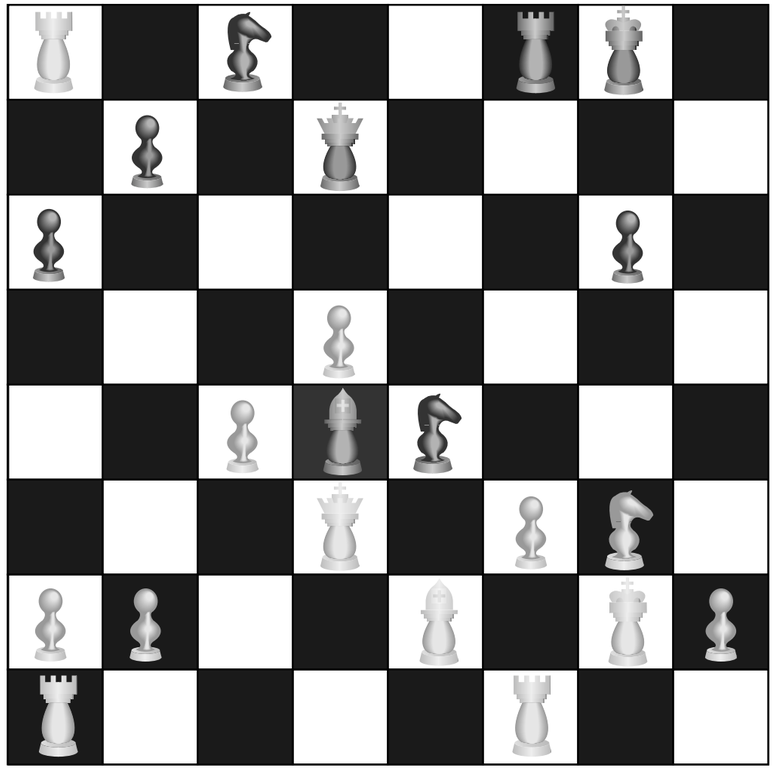

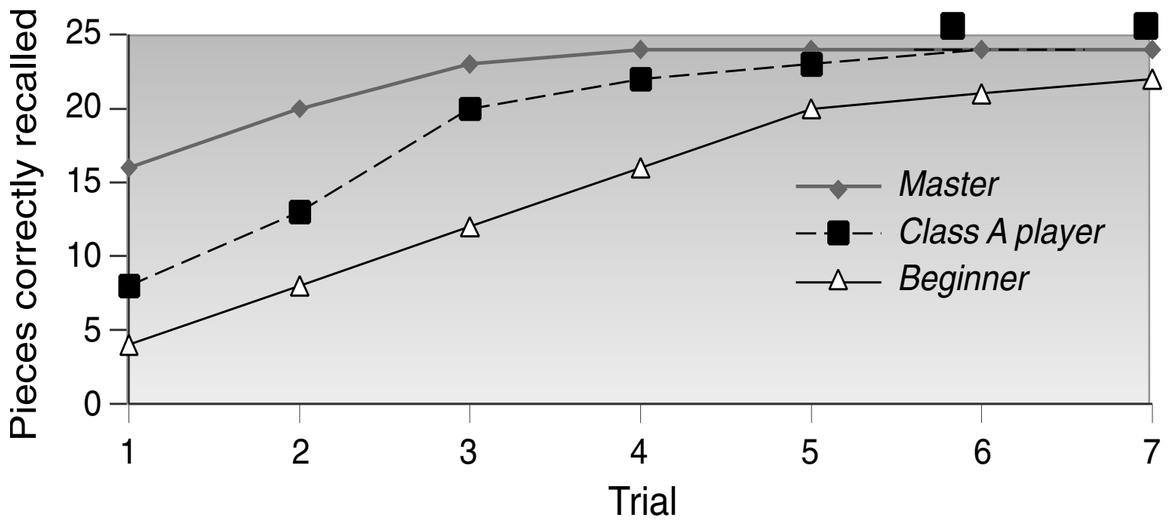


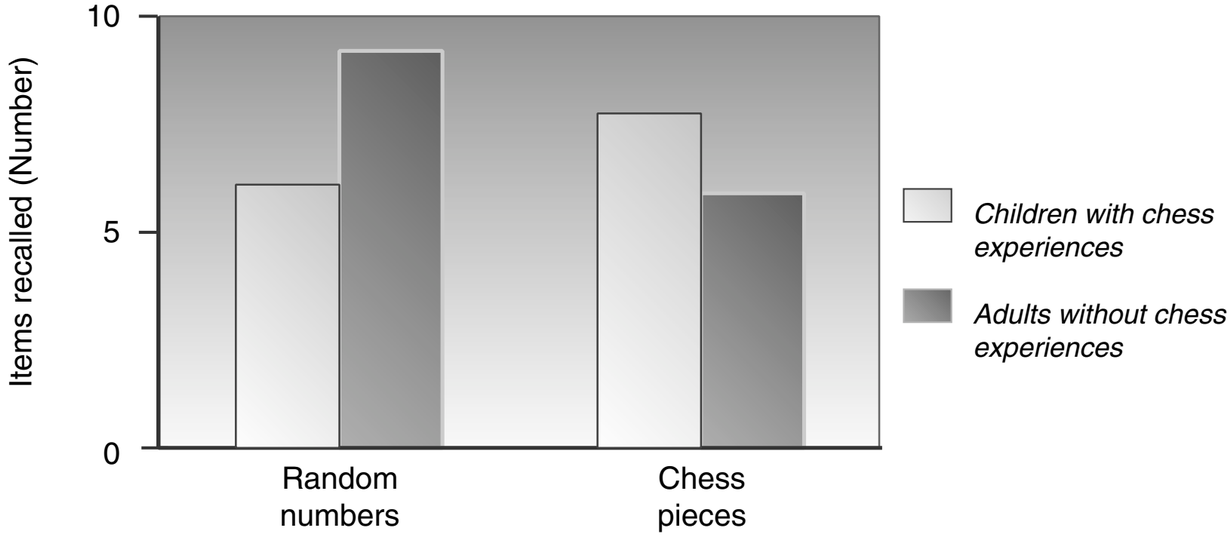


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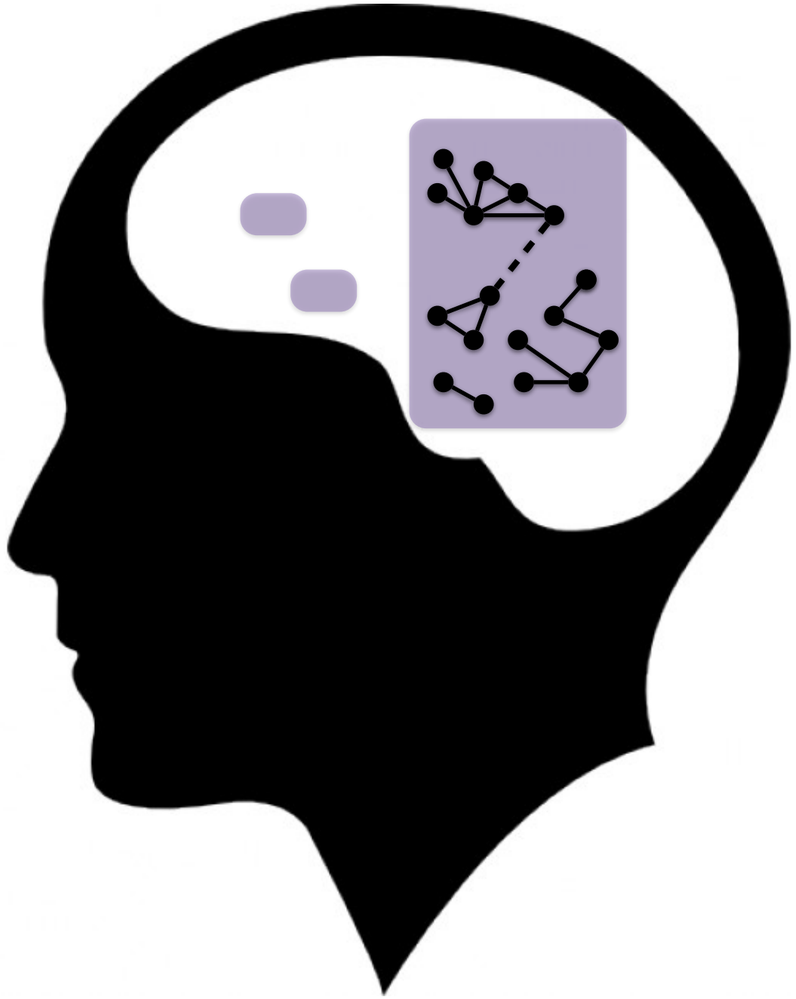

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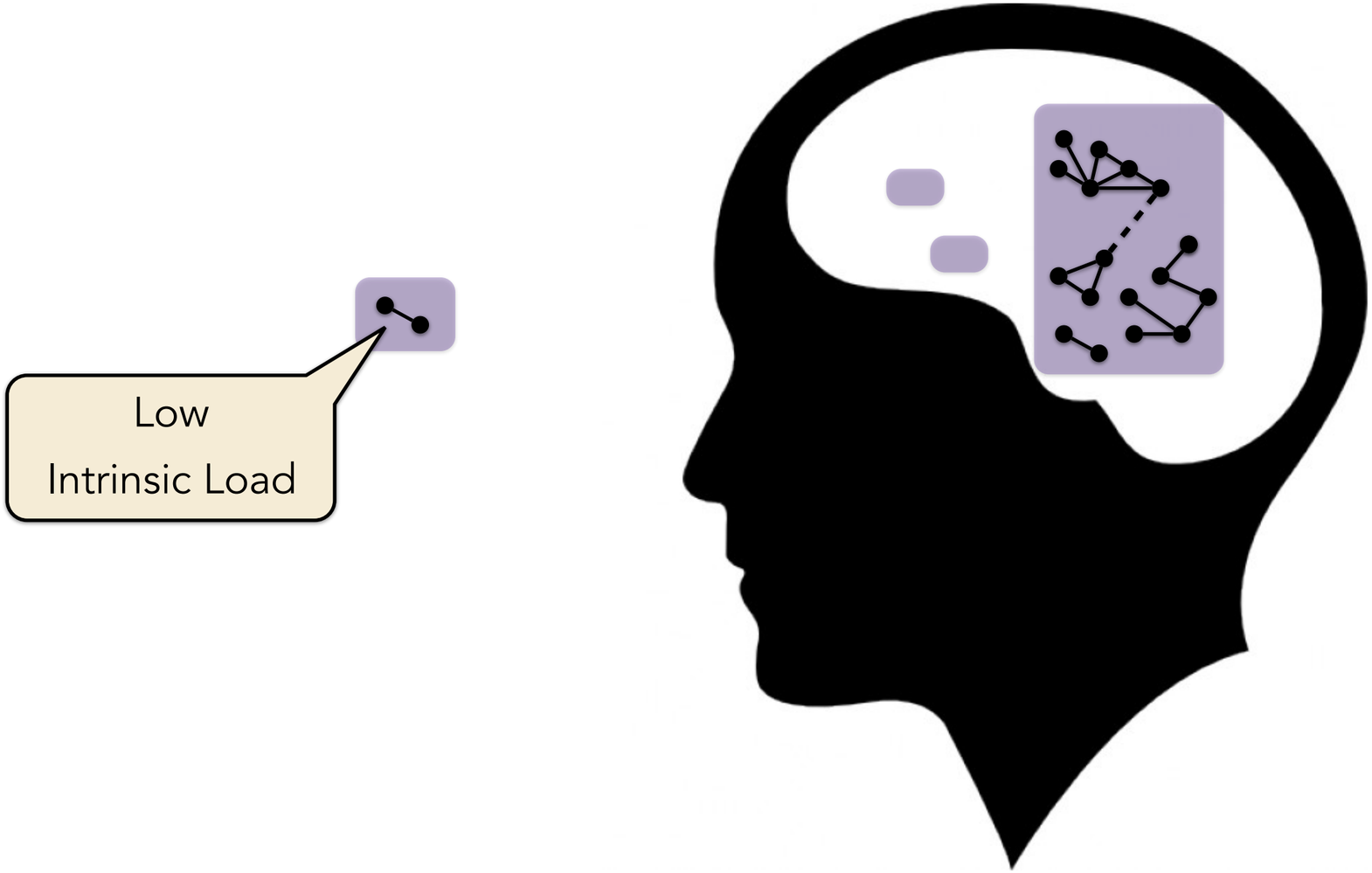

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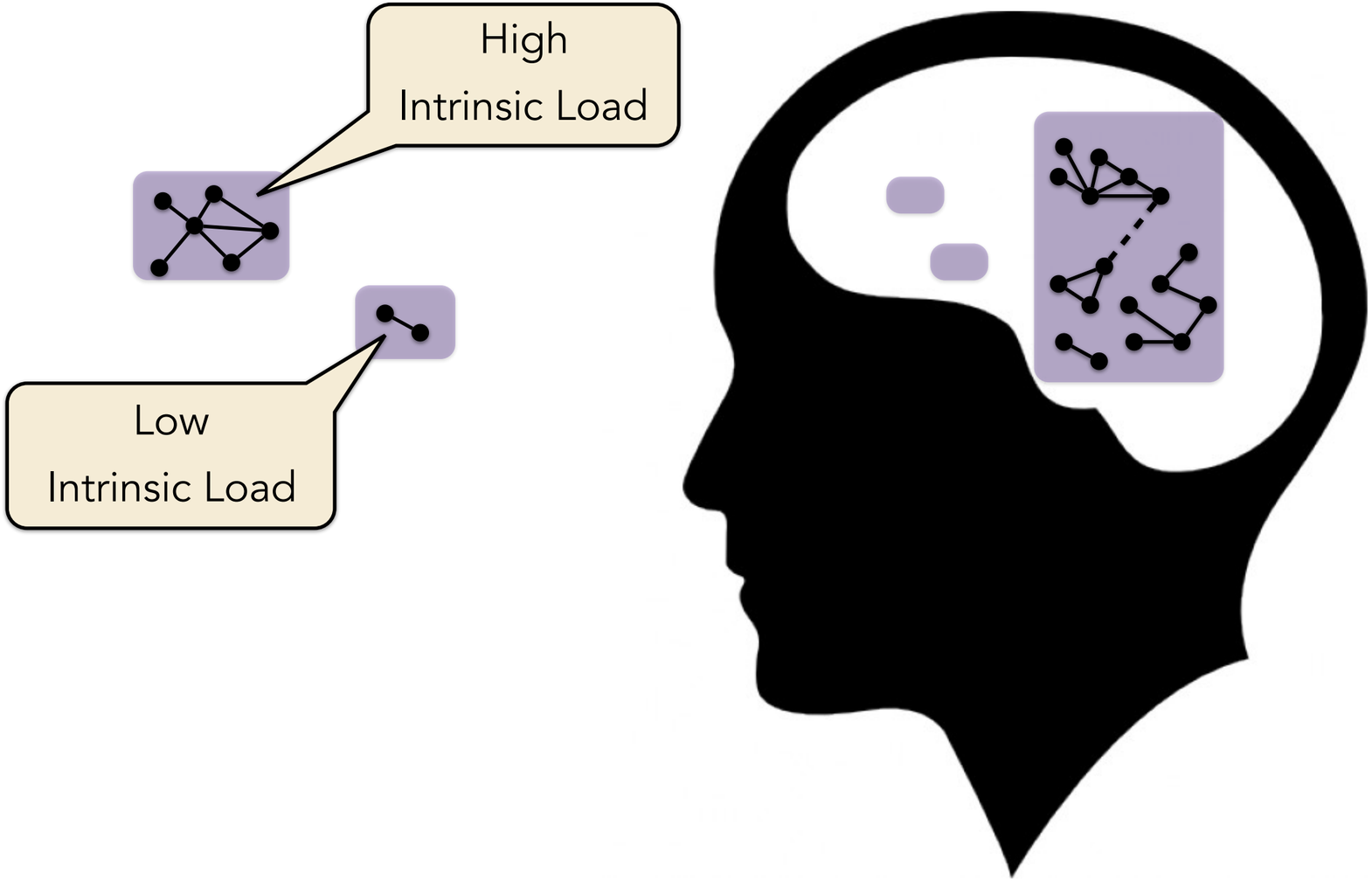

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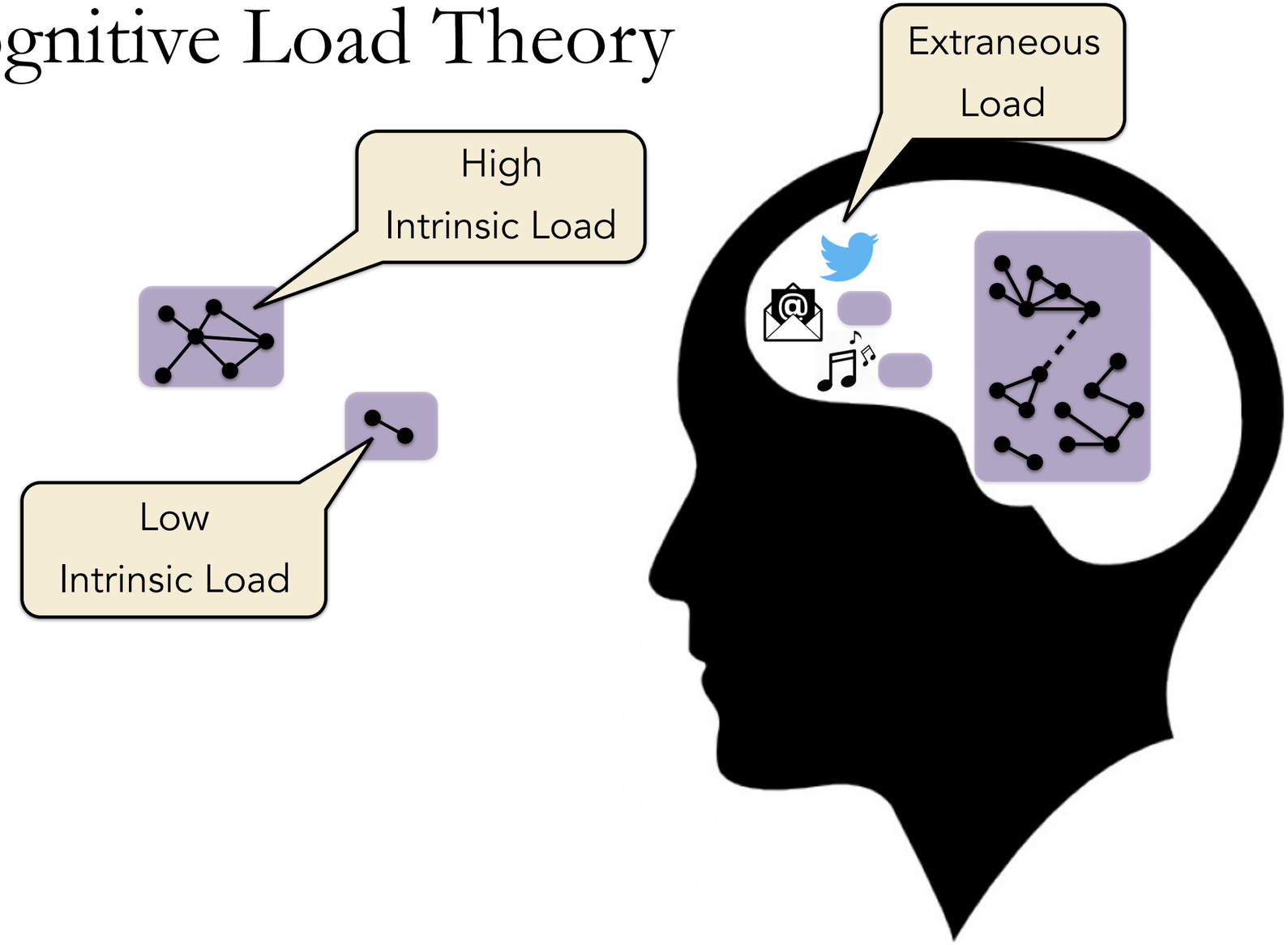

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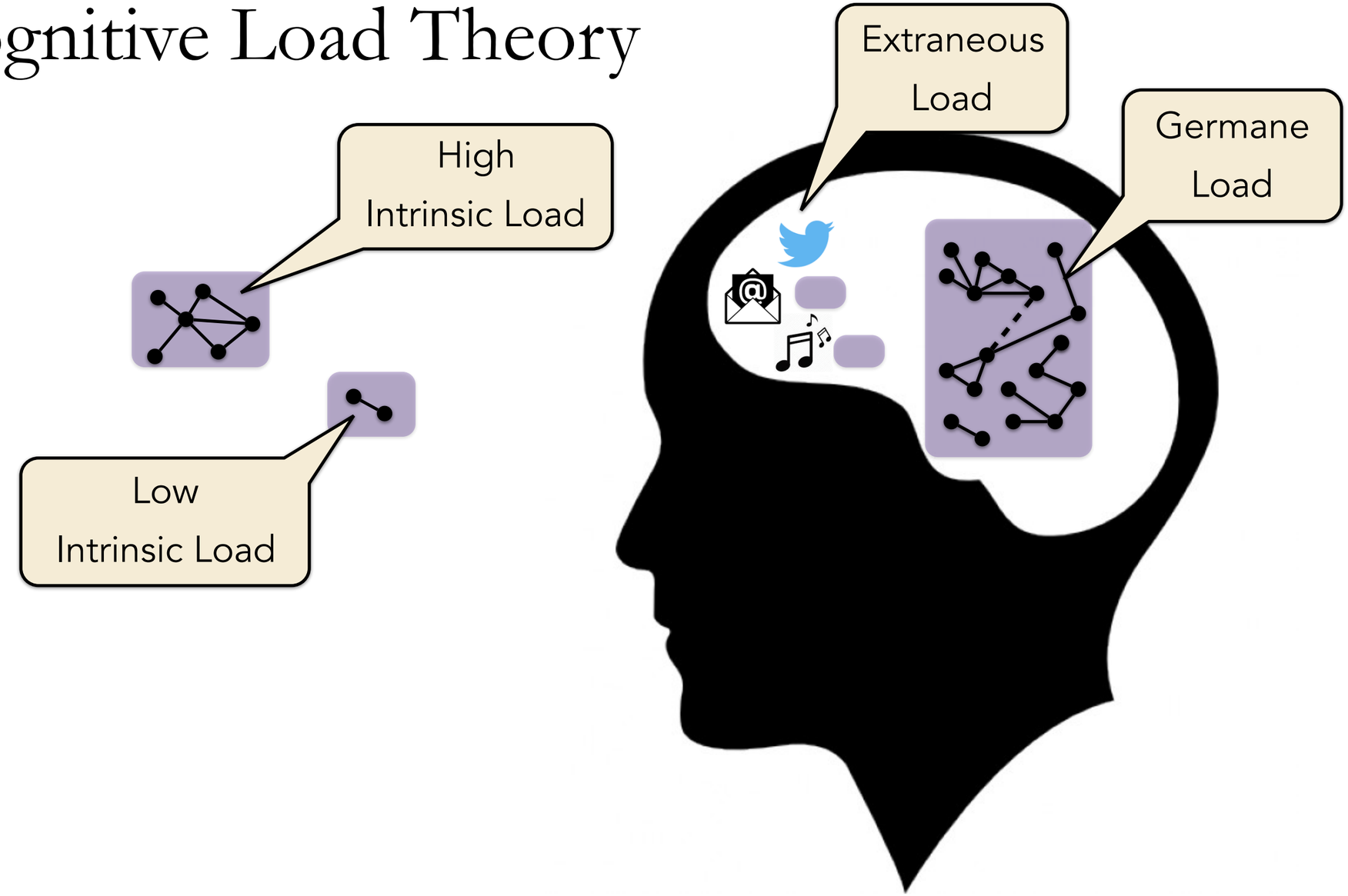

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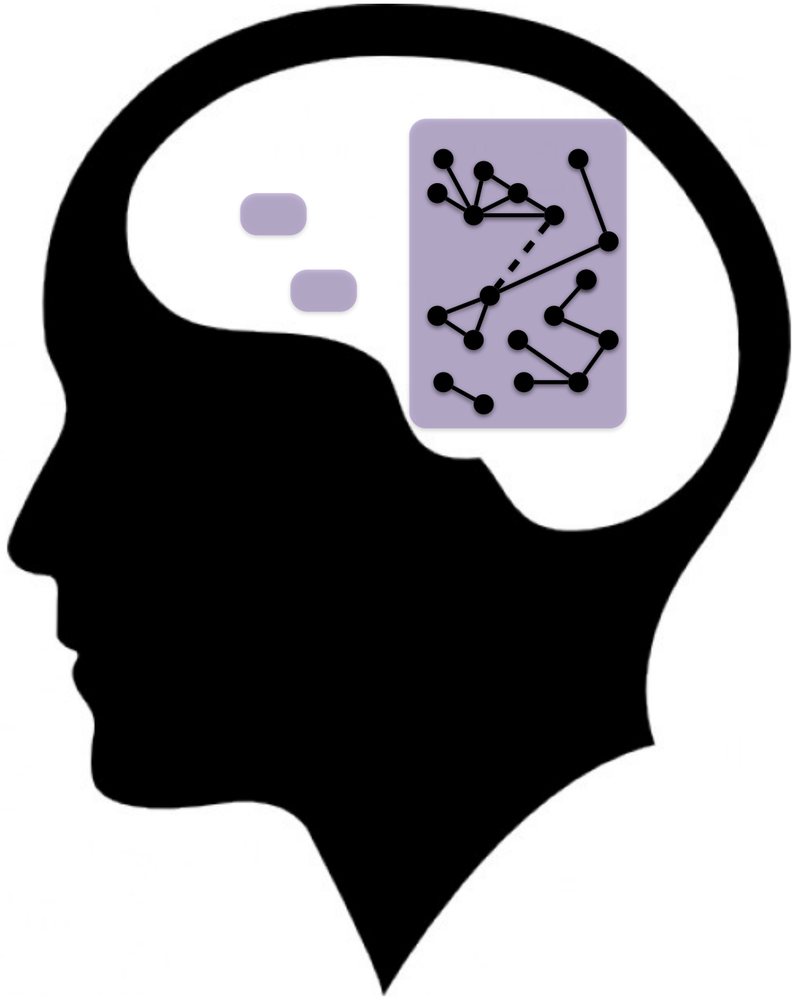

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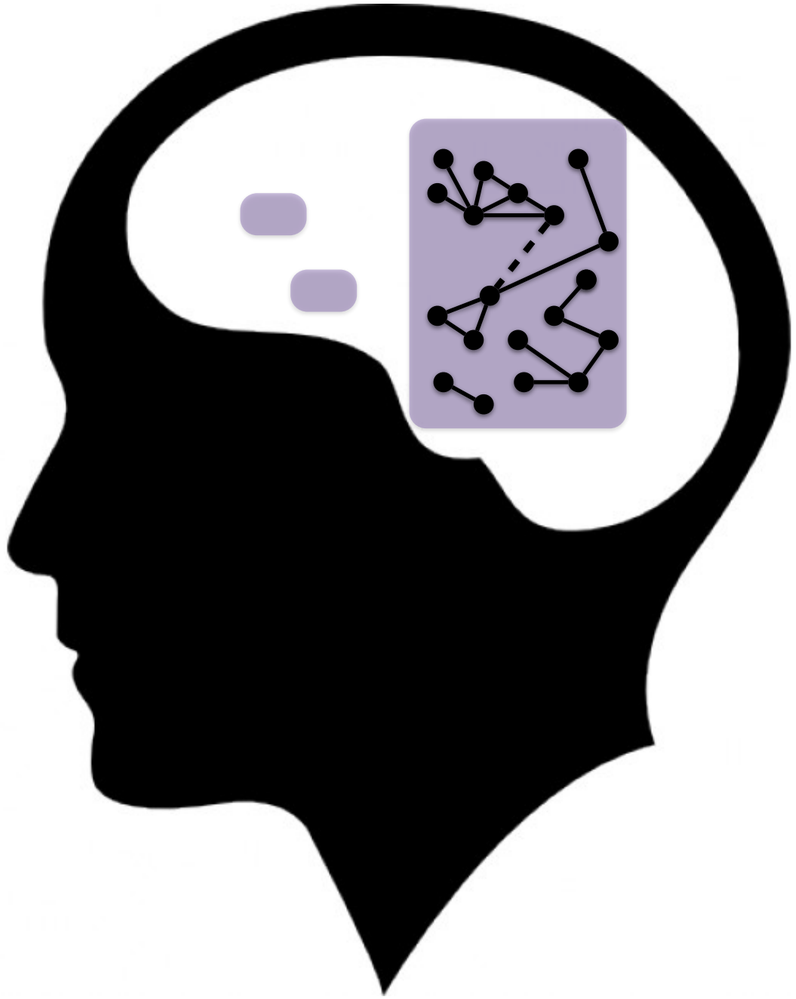
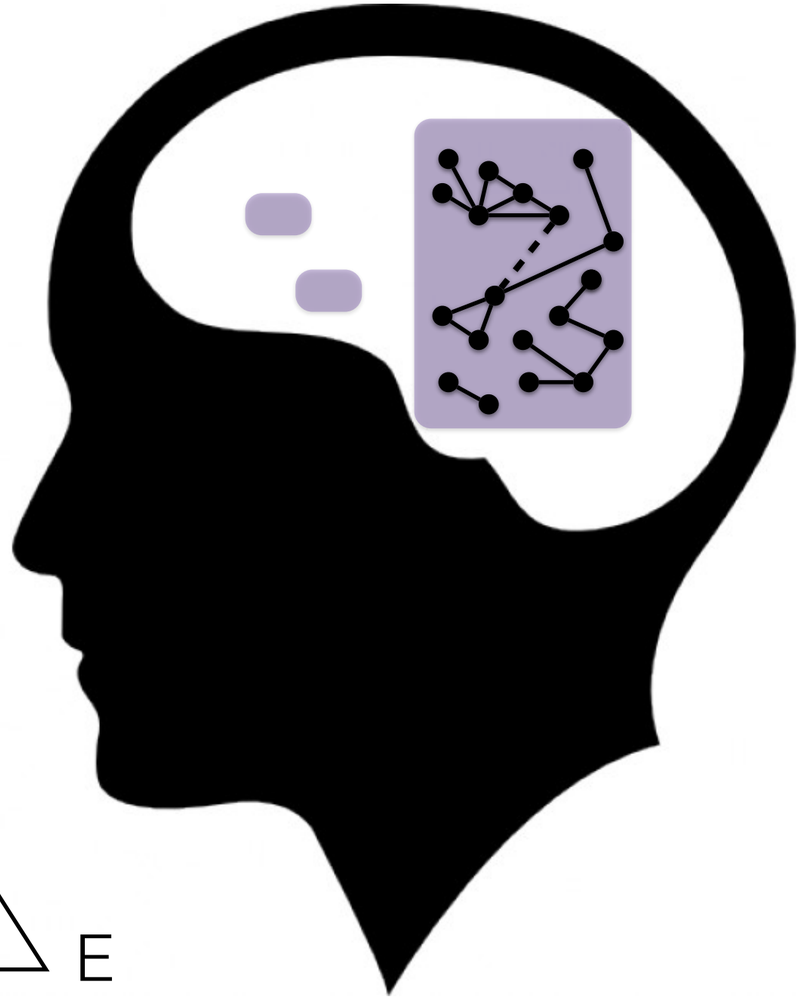
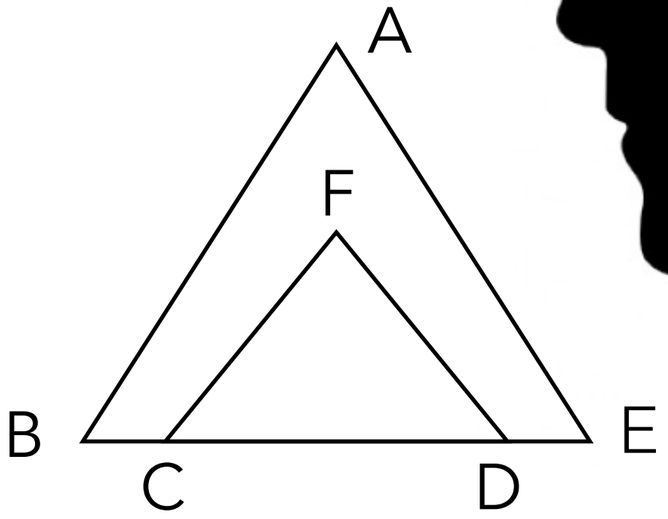


Goal-free effect

# Cognitive Load Theory

Goal-free effect





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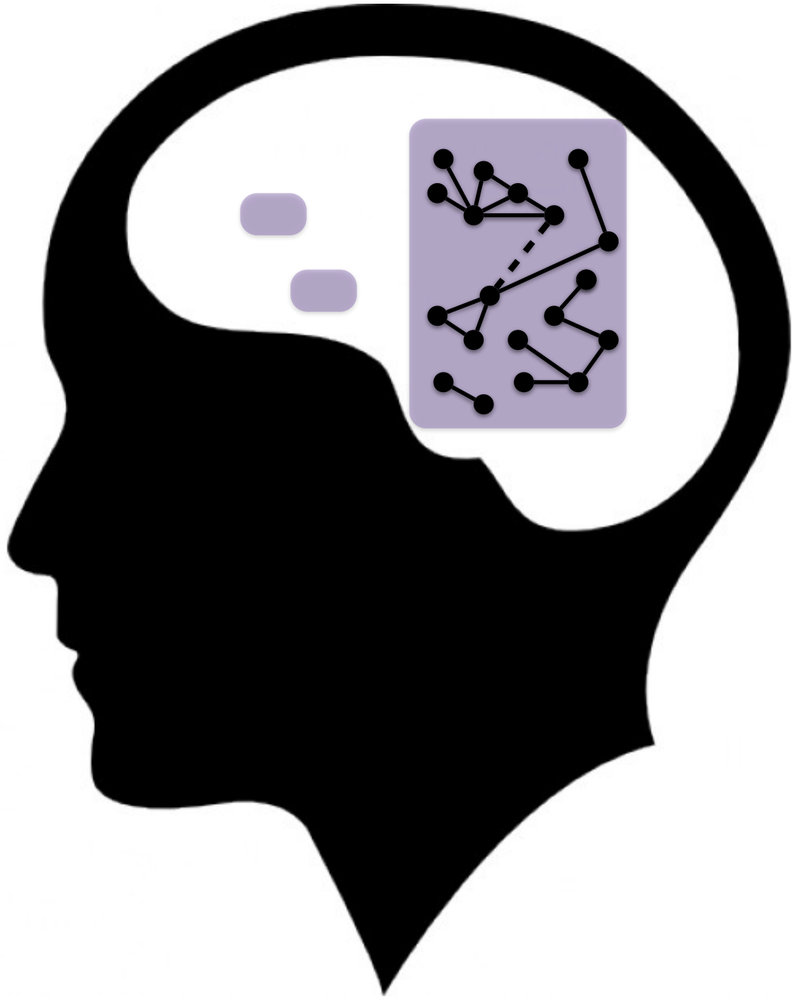
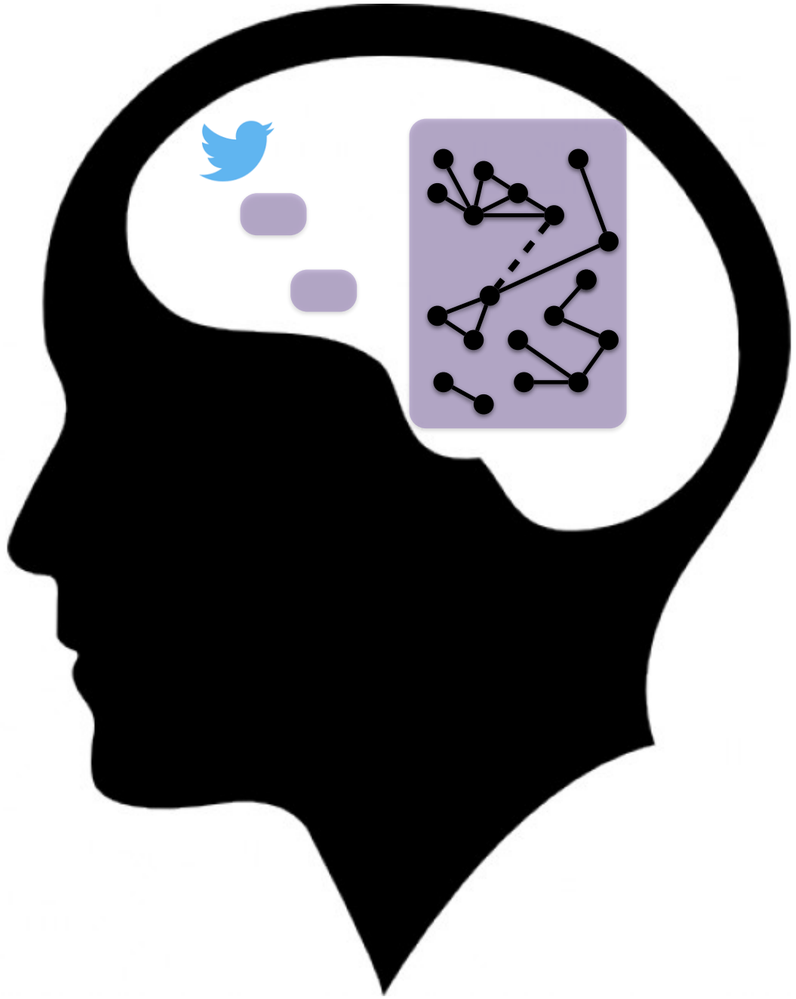


Goal-free effect

Modality effect

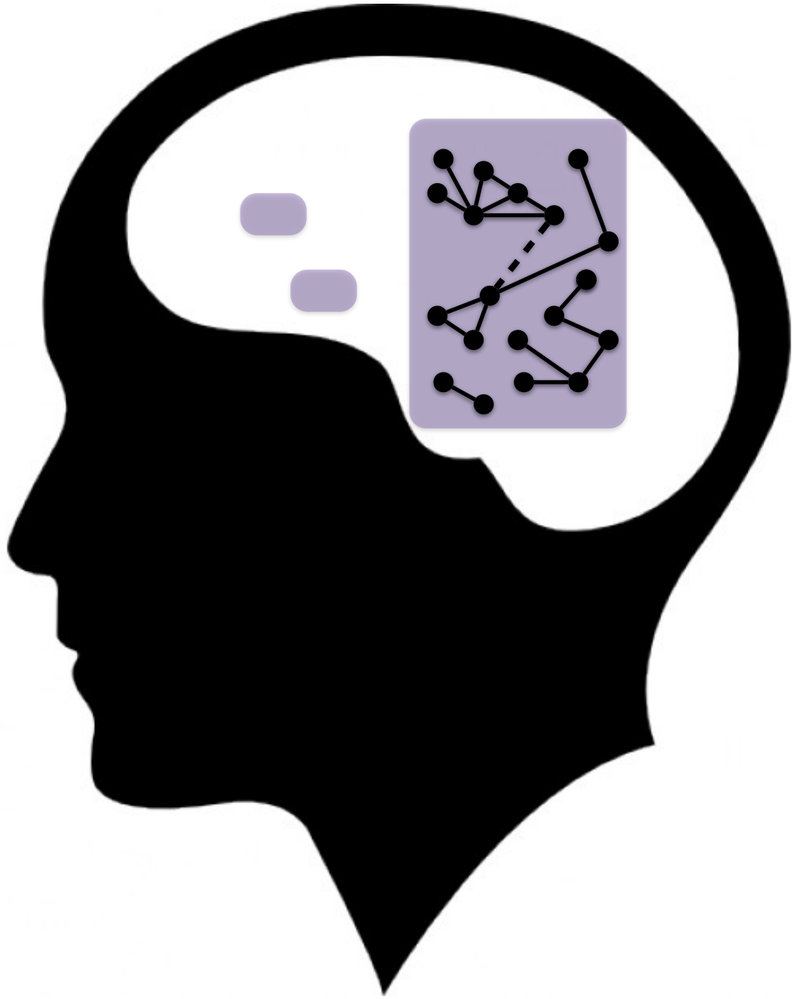
# Cognitive Load Theory



Goal-free effect

Modality effect

# Cognitive Load Theory



- Goal-free effect
- Modality effect
- Worked example effect
- Variability effect
- Redundancy effect
- Expertise reversal effect

# Worked example effect

# Worked example effect

**Step 1: Identify the shapes**

There are two right triangles with sides that are 90 ft and the red line as hypotenuse.

**Step 2: Recall the formula**

Pythagorean theorem:

$a^2 + b^2 = c^2$

**Step 3: Substitute known values**

$90^2 + 90^2 = c^2$

**Step 4: Solve for c**

$8100 + 8100 = c^2$

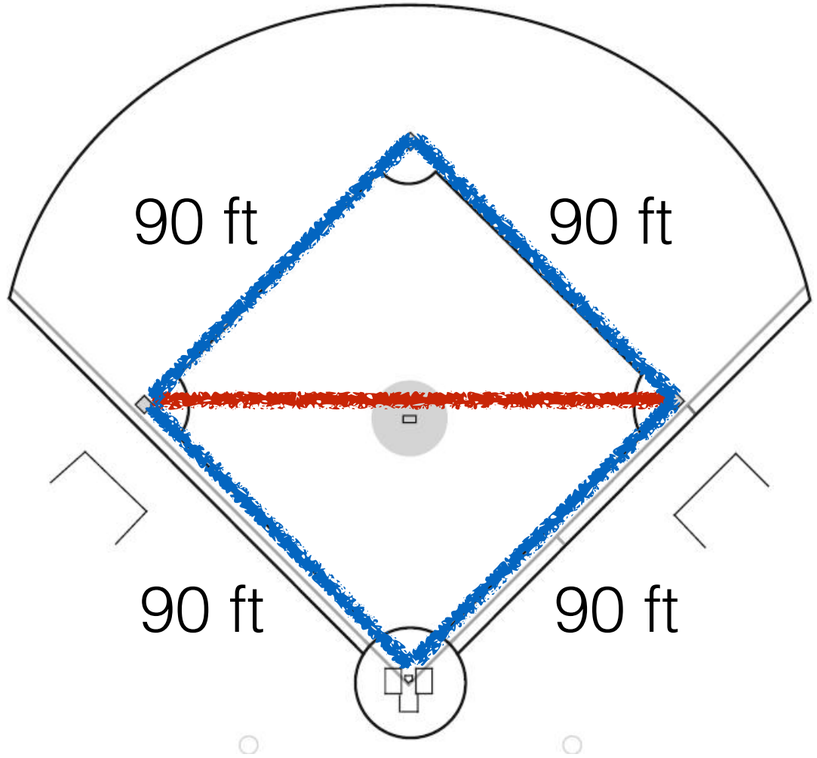
$16{,}200 = c^2$

$\text{sqrt}(16{,}200) = \text{sqrt}(c^2)$

$90\ \text{sqrt}(2) = c$

**Step 5: Make a selection**

Since $1 < \text{sqrt}(2) < 2$, $90 < c < 180$, so the correct answer is (2) between 90 and 180 ft.

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1. It is less than 90 ft.
2. It is between 90 and 120 ft.
3. It is greater than 120 ft.

# Variability effect

**Calculate distance between (1,1) and (4,5)**

**Step 1: Identify the facts**

Distance is the length of a hypotenuse, for a triangle with sides as the change in x and the change in y.

**Step 2: Recall the formula**

Pythagorean theorem:

$a^2 + b^2 = c^2$

**Step 3: Substitute known values**

$(4-1)^2 + (5-1)^2 = c^2$

**Step 4: Solve for c**

$3^2 + 4^2 = c^2$

$9 + 16 = c^2$

$25 = c^2$

$5 = c$

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**Low variability:**

Find distance between (2,3) and (8,11).

# Variability effect

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**Low variability:**

Find distance between (2,3) and (8,11).

**Medium variability:**

Find distance between (2,1) and (x,13).

# Variability effect

## Calculate distance between (1,1) and (4,5)

**Step 1: Identify the facts**

Distance is the length of a hypotenuse, for a triangle with sides as the change in x and the change in y.

**Step 2: Recall the formula**

Pythagorean theorem:

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$3^2 + 4^2 = c^2$

$9 + 16 = c^2$

$25 = c^2$

$5 = c$

**Low variability:**

Find distance between (2,3) and (8,11).

**Medium variability:**

Find distance between (2,1) and (x,13).

**High variability:**

Find (x,y) that has distance of 5 from (3,4).

# Redundancy effect

The redundancy effect occurs when information is presented in a way that includes redundant material. One example of this is to present the same idea using both visual and executive modalities, such as reading from a PowerPoint slide that has a lot of text on it. The text itself is processed initially as visual imagery, then as auditory as we "read aloud" to ourselves internally. This induces extraneous cognitive load as our minds have to cross-reference the three forms to make sure they are the same. The effect is made worse when the instructor's voice is also reading the words. Those words must also be cross-checked for accuracy. In the end, the information is lost before it can be transferred to LTM.

# Notice anything?

# Redundancy effect

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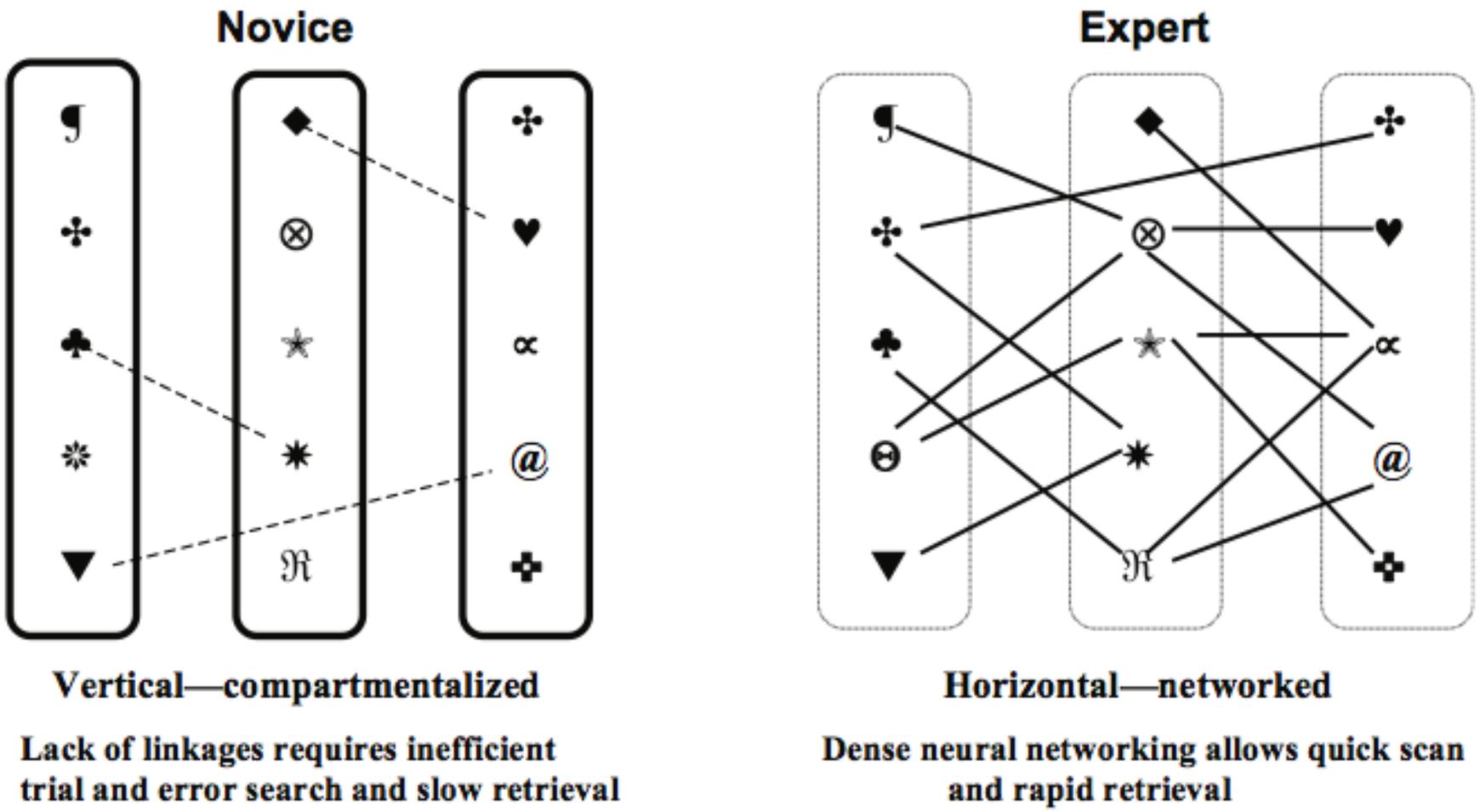
Don't abandon UDL

# Expertise reversal effect



GOOD

R

I

S

E

# GOOD

**R**etrieval practice

**I**

**S**

**E**

# GOOD

**R**etrieval practice

**I**nterleaving

**S**

**E**

# GOOD

**R**etrieval practice

**I**nterleaving

**S**pacing

**E**

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**R**etrieval practice

**I**nterleaving

**S**pacing

**E**laboration

# GOOD

**R**etrieval practice

**I**nterleaving

**S**pacing

**E**laboration

Deliberative effort
Pre-learning
Growth mindset
Metacognition

| GOOD | BAD |
| --- | --- |
| **R**etrieval practice | **P** |
| **I**nterleaving | **R** |
| **S**pacing | **I** |
| **E**laboration | **Ma** |
| | **L** |

Deliberative effort
Pre-learning
Growth mindset
Metacognition

| GOOD | BAD |
| --- | --- |
| **R**etrieval practice | **P**assive observation |
| **I**nterleaving | **R** |
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| **E**laboration | **Ma** |
| | **L** |

Deliberative effort
Pre-learning
Growth mindset
Metacognition

## GOOD

**R**etrieval practice

**I**nterleaving

**S**pacing

**E**laboration

Deliberative effort
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## BAD

**P**assive observation

**R**ereading texts

**I**

**Ma**

**L**

## GOOD

**R**etrieval practice

**I**nterleaving

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**E**laboration

Deliberative effort
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## BAD

**P**assive observation

**R**ereading texts

**I**ntuitive judgments

**Ma**

**L**

## GOOD

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## BAD

**P**assive observation

**R**ereading texts

**I**ntuitive judgments

**Ma**ssed practice

**L**earning styles

# Assessment jigsaw

When is it good to use?

What is the effort and impact?

How does it RISE?

# Recommended reading