When is Too Much Not Enough?

Using Cognitive Theories of Learning to Shape Instructional Choices

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What is “learning?”

Einstellung

	A	B	C	Target
Sample	29	3		20

127-21-3-3

163-14-25-25

43-18-10-10

42-9-6-6

59-20-4-4

49-23-3-3

39-15-3-3

48-18-4-4

36-14-8-8

J.D. Bransford *et al.*, *How People Learn: Brain, Mind, Experience, and School.* National Academy Press. 2000.
https://www.nap.edu/catalog/9853/how-people-learn-brain-mind-experience-and-school-expanded-edition

Einstellung

	A	B	C	Target
Critical 1	23	49	3	20
Critical 2	15	39	3	18
Critical 3	18	48	4	22
Critical 4	14	36	8	6

Einstellung Solution:
49 - 23 - 3 - 3 = 20

Direct Solution:
23 - 3 = 20

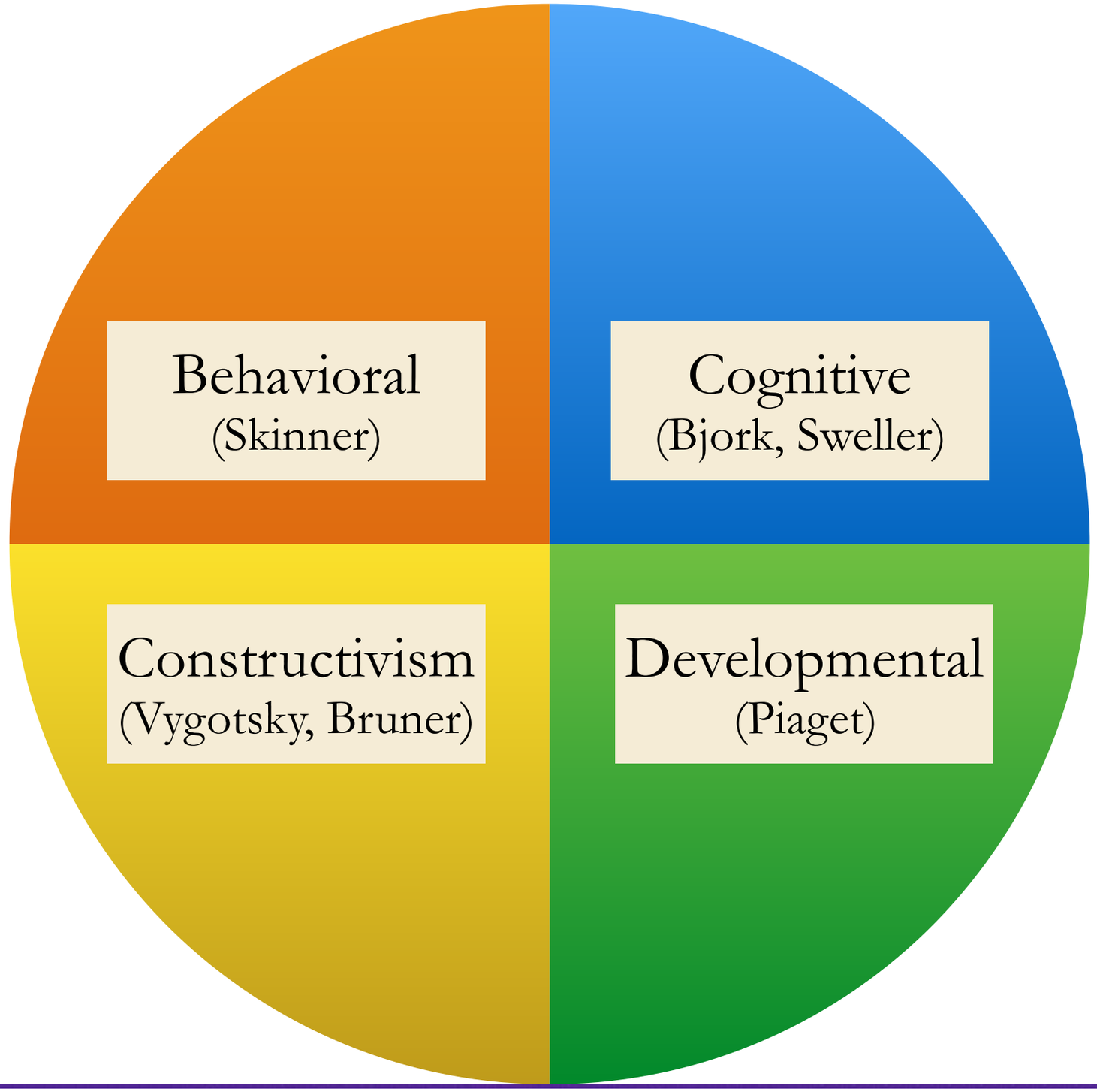
J.D. Bransford *et al.*, *How People Learn: Brain, Mind, Experience, and School.* National Academy Press. 2000.
https://www.nap.edu/catalog/9853/how-people-learn-brain-mind-experience-and-school-expanded-edition

Einstellung

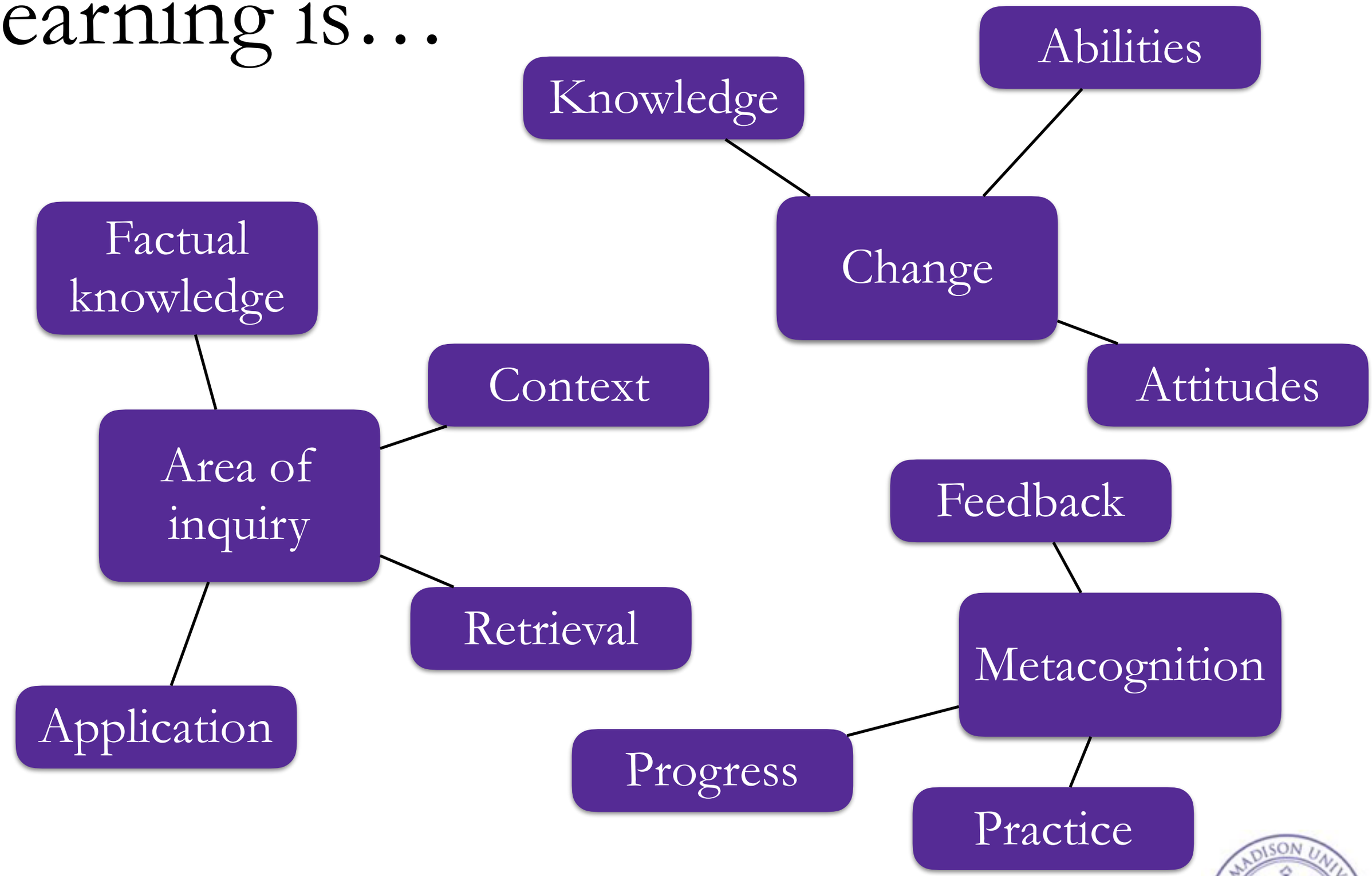
	Einstellung (percent)	Direct (percent)	No solution (percent)

J.D. Bransford *et al.*, *How People Learn: Brain, Mind, Experience, and School*. National Academy Press. 2000. https://www.nap.edu/catalog/9853/how-people-learn-brain-mind-experience-and-school-expanded-edition

Branches of Educational Psychology



Learning is…


Knowledge
Abilities
Change
Attitudes
Factual knowledge
Context
Area of inquiry
Retrieval
Application
Feedback
Metacognition
Progress
Practice

Learning is…misunderstood

<u>Common myths about learning:</u>

M. Pasupathi, *How We Learn*. The Great Courses. Chantilly, VA, USA: The Teaching Company, 2012.
P. Brown, H. Roediger, and M. McDaniel, *Make It Stick : The Science of Successful Learning*. Cambridge, MA, USA: Harvard University Press, 2014.

In-class Physics Demos

The evidence supporting active learning suggests that passive engagement with information can contribute to reinforcing misconceptions. One study examined how effective in-class physics demonstrations were in helping to understand concepts. All students began with a reading assignment. Some students then took part in an in-class demonstration; the control group did not observe or take part in a demonstration. The students completed a short test to conclude the experiment. Which group did the **worst** on the post-test, missing the most points?

In-class Physics Demos

Which group did the **worst** on the post-test, missing the most points?

(A) Students who did not observe a demo (control group)
(B) Students who only observed the demo
(C) Students who predicted the outcome before it occurred by writing down a guess
(D) Students who discussed the outcome with peers after observing wh

mode	correct	incorrect
no demo	30%	70%
observe	18%	82%
predict	29%	71%
discuss	30%	70%

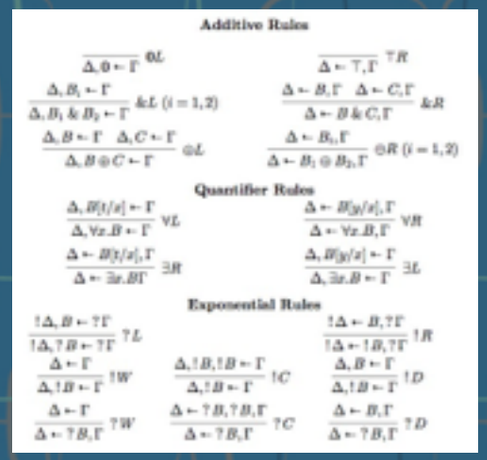
E. Mazur, Keynote address at ICER 2011.
https://computinged.wordpress.com/2011/08/17/eric-mazurs-keynote-at-icer-2011-observing-demos-hurts-learning-and-confusion-is-a-sign-of-understanding/

Knowledge and human cognitive architecture

Types of Knowledge

Biologically Primary

Biologically Secondary



Additive Rules

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

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

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

Quantifier Rules

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

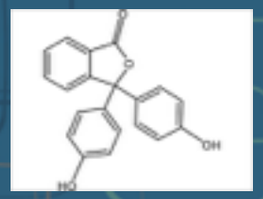
$$\frac{\Delta \vdash B[t/x], \Gamma}{\Delta \vdash \exists x.B\Gamma}\ \exists R \qquad \frac{\Delta, B[y/x] \vdash \Gamma}{\Delta, \exists x.B \vdash \Gamma}\ \exists L$$

Exponential Rules

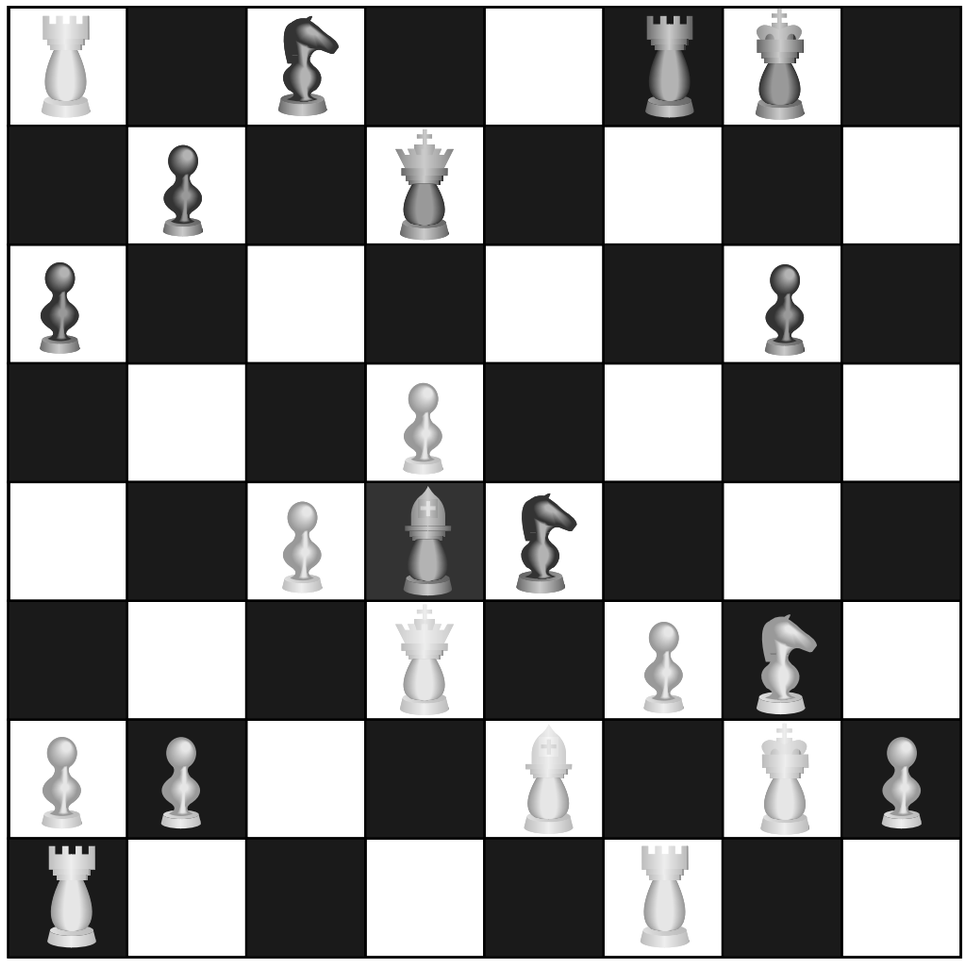
$$\frac{!\Delta, B \vdash ?\Gamma}{!\Delta, ?B \vdash ?\Gamma}\ ?L \qquad \frac{!\Delta \vdash B, ?\Gamma}{!\Delta \vdash !B, ?\Gamma}\ !R$$

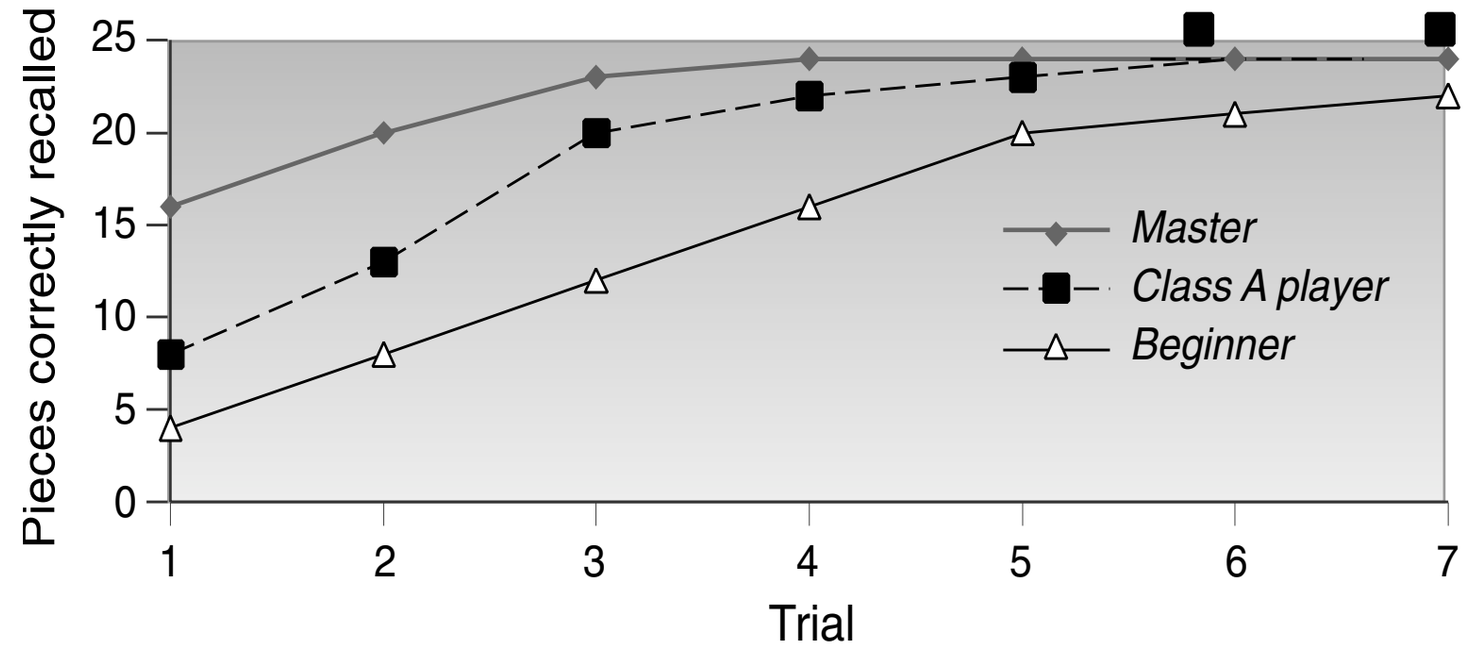
$$\frac{\Delta \vdash \Gamma}{\Delta, !B \vdash \Gamma}\ !W \qquad \frac{\Delta, !B, !B \vdash \Gamma}{\Delta, !B \vdash \Gamma}\ !C \qquad \frac{\Delta, B \vdash \Gamma}{\Delta, !B \vdash \Gamma}\ !D$$

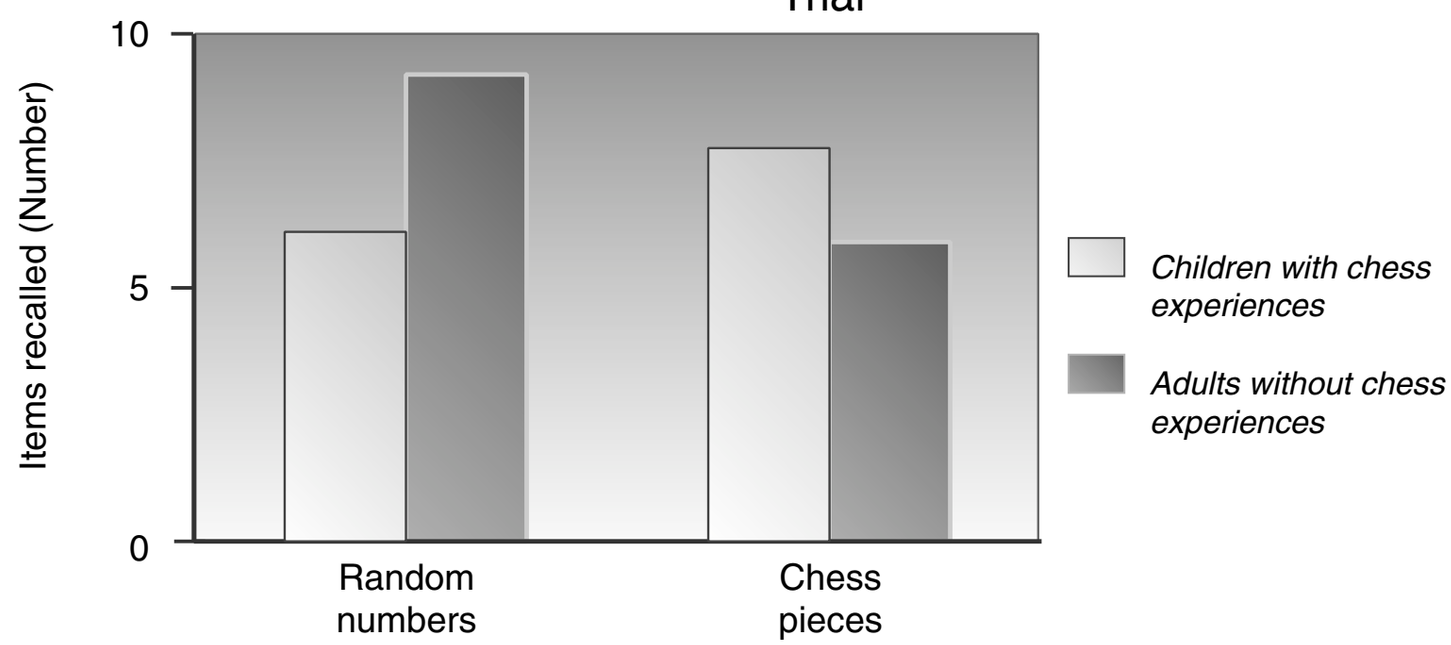
$$\frac{\Delta \vdash \Gamma}{\Delta \vdash ?B, \Gamma}\ ?W \qquad \frac{\Delta \vdash ?B, ?B, \Gamma}{\Delta \vdash ?B, \Gamma}\ ?C \qquad \frac{\Delta \vdash B, \Gamma}{\Delta \vdash ?B, \Gamma}\ ?D$$



Retrieval Fluency







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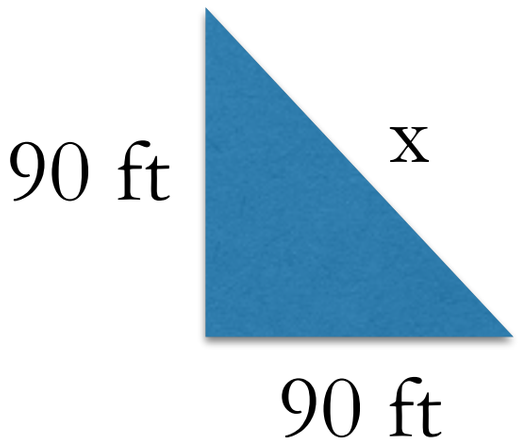
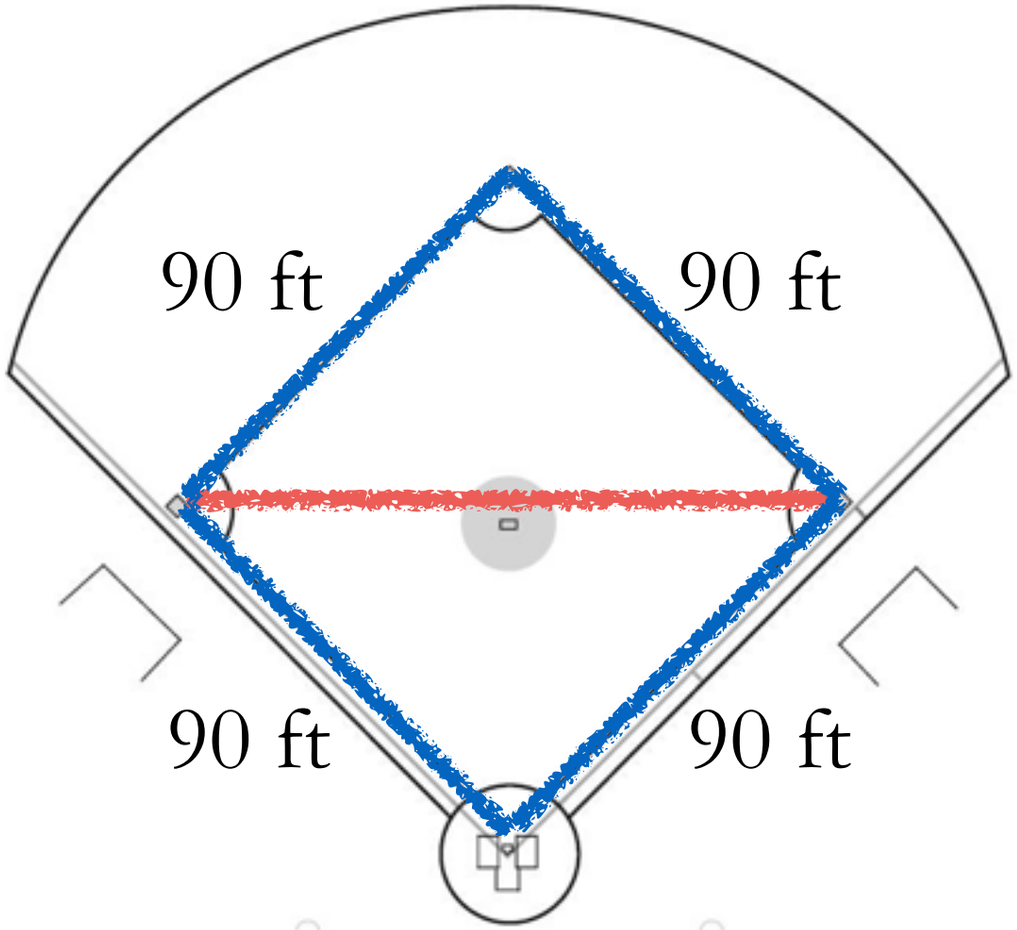
Far transfer





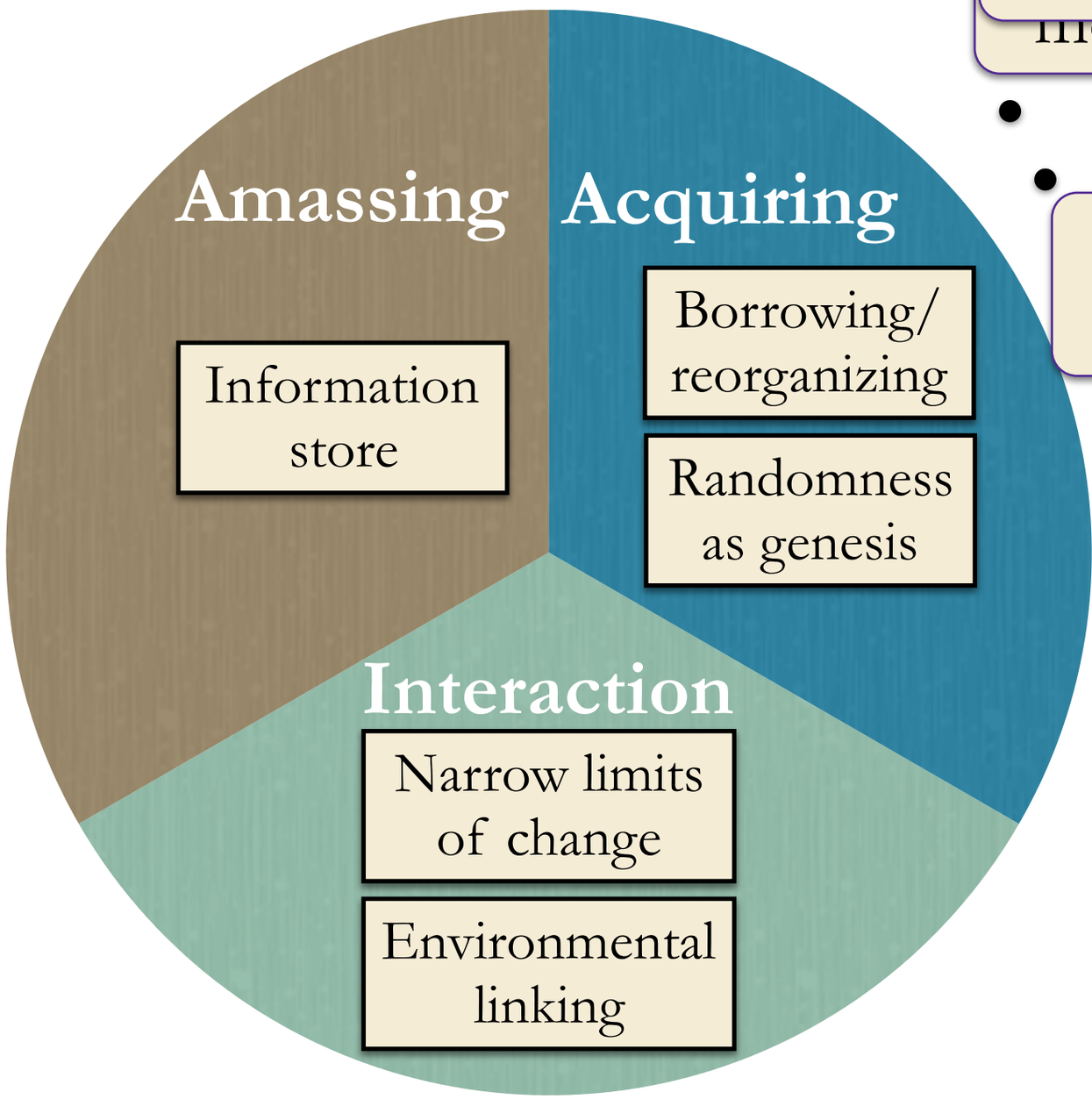
Apply the Pythagorean theorem to the above triangle to find the value of x.

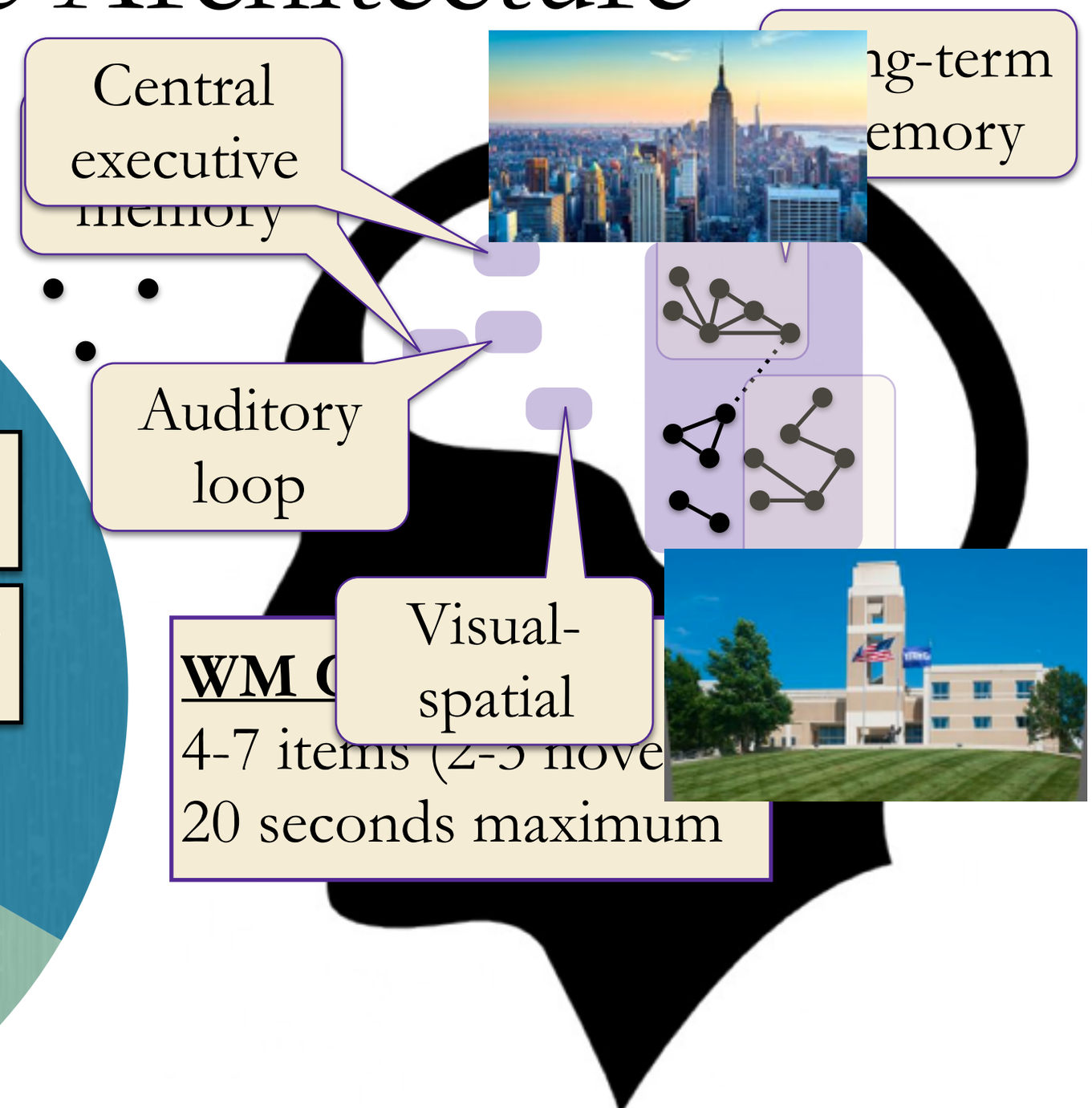
In a baseball diamond, the distance between each base is 90 ft. Which of the following is true about the shortest distance between 1st and 3rd bases (the red line shown above)?

1. It is less than 90 ft.
2. It is between 90 and 180 ft.
3. It is greater than 180 ft.

Memory Architecture

Human Cognitive Architecture





Key findings

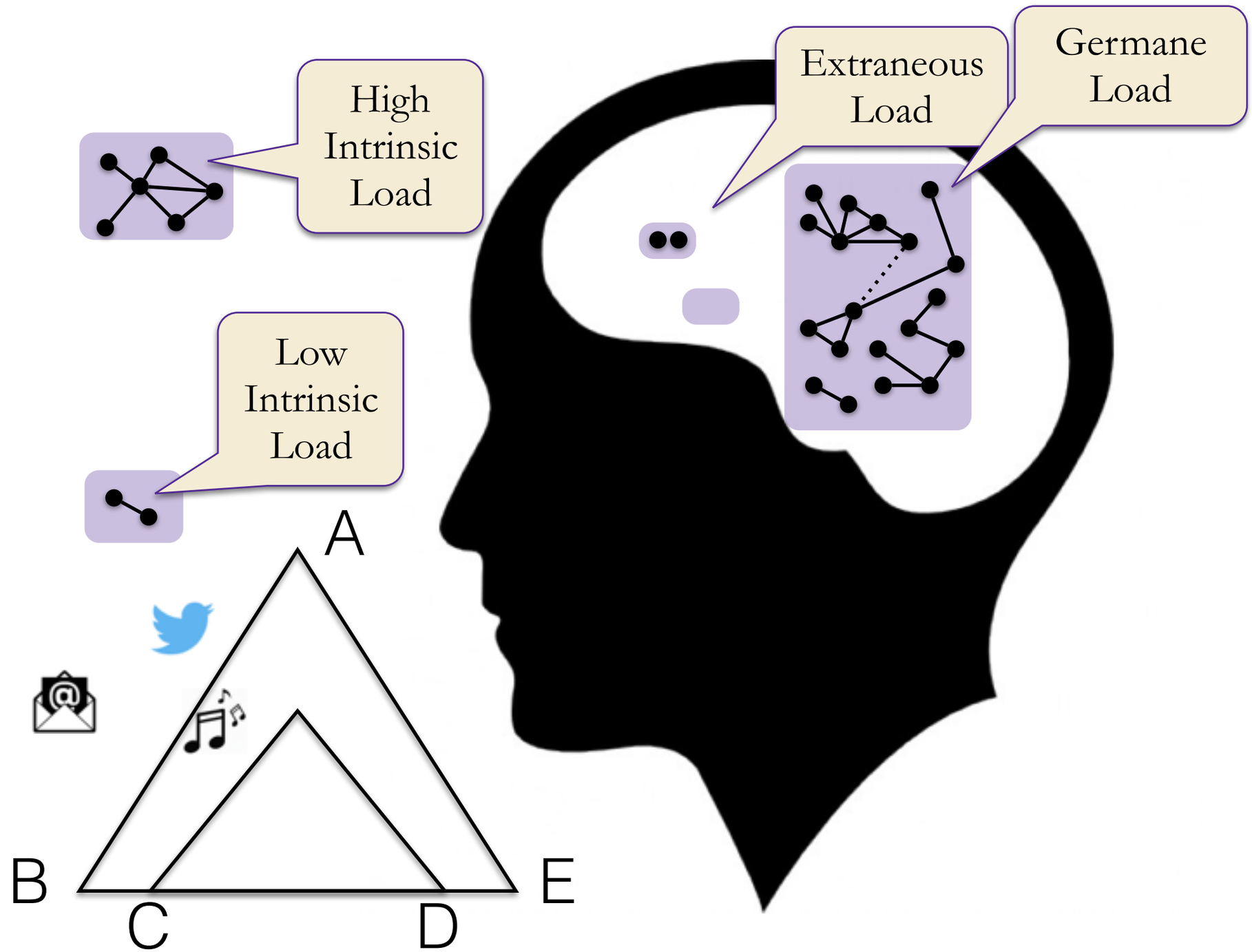
What works:

What doesn't:

P. Brown, H. Roediger, and M. McDaniel, *Make It Stick : The Science of Successful Learning*. Cambridge, MA, USA: Harvard University Press, 2014.

Cognitive load theory and its effects

Cognitive Load Theory



- Goal-free effect
- Modality effect
- Worked example effect
- Imagination effect
- Variability effect
- Transient info effect
- Redundancy effect

Worked example

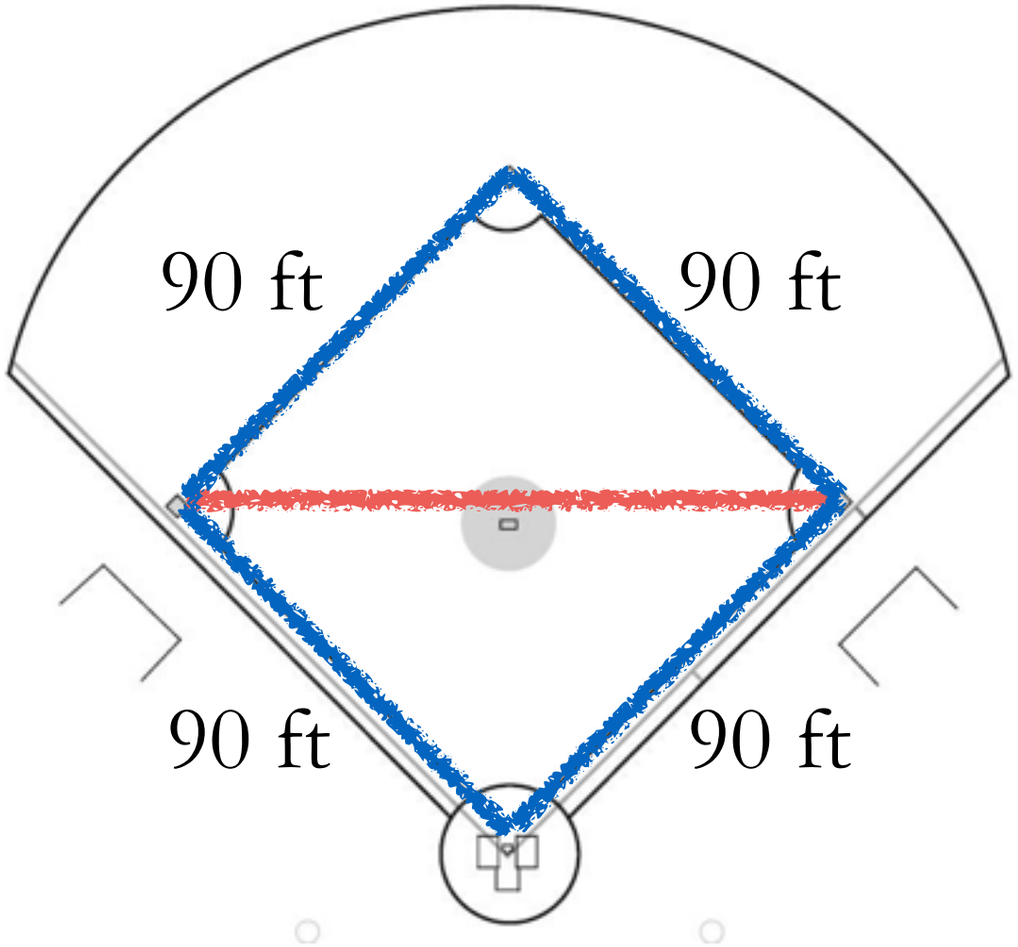
Step 1: Identify the shapes
There are two right triangles with sides that are 90 ft and the red line as hypotenuse.

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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3. It is greater than 180 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
$3^2 + 4^2 = c^2$
$9 + 16 = c^2$
$25 = c^2$
$5 = c$

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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Applications of effects

Testing effect	Goal-free effect	Worked example effect	Imagination effect
Modality effect	Variability effect	Redundancy effect	Transient info effect

Expertise reversal and guidance fading effects

Questions?