

# *Transformative Games* *LEARNING BY DESIGN*

## **The Neurophysiology of Learning and Memory**

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# Argument

To understand how games work, they must be studied independently of other disciplines.

We must then develop operational definitions that map to other disciplines, particularly the Learning Sciences.

If we do not align GBL with the Learning Sciences, GBL will be a short-lived endeavor.

1. Each game is an experiment.
2. Our experiments need to be grounded in theory.
3. Falsifiable experiments need to be conducted to refine theory.
4. Design-based experiments need to be conducted to see if experiments generalize to classrooms.

# Rebuttal

"FASCIST! REDUCTIONIST!  
ART ESCAPES ALL DEFINITION!"



# Counter Rebuttal

It's already happened. Game designers and developers have a language to describe their craft, and they develop new operational definitions as needed.

Someone just needs to take care of the mapping.



# Counter-Counter Rebuttal

A CREATIVE ACT IS  
ONLY CREATIVE  
ONCE!

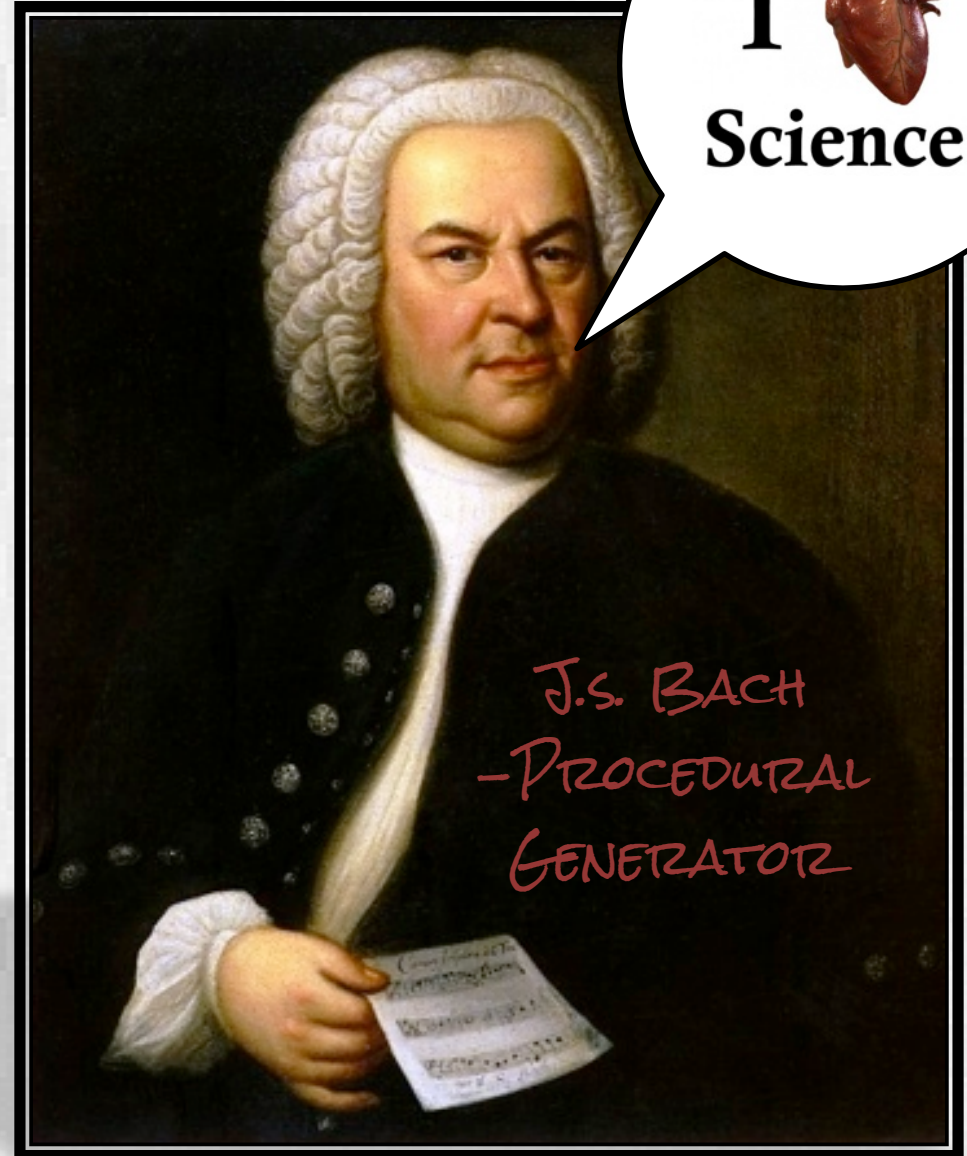
PREVIOUS SUCCESS  
CAN'T PREDICT  
FUTURE OUTCOMES!

# Not necessarily...

Creativity is a process that results in content.

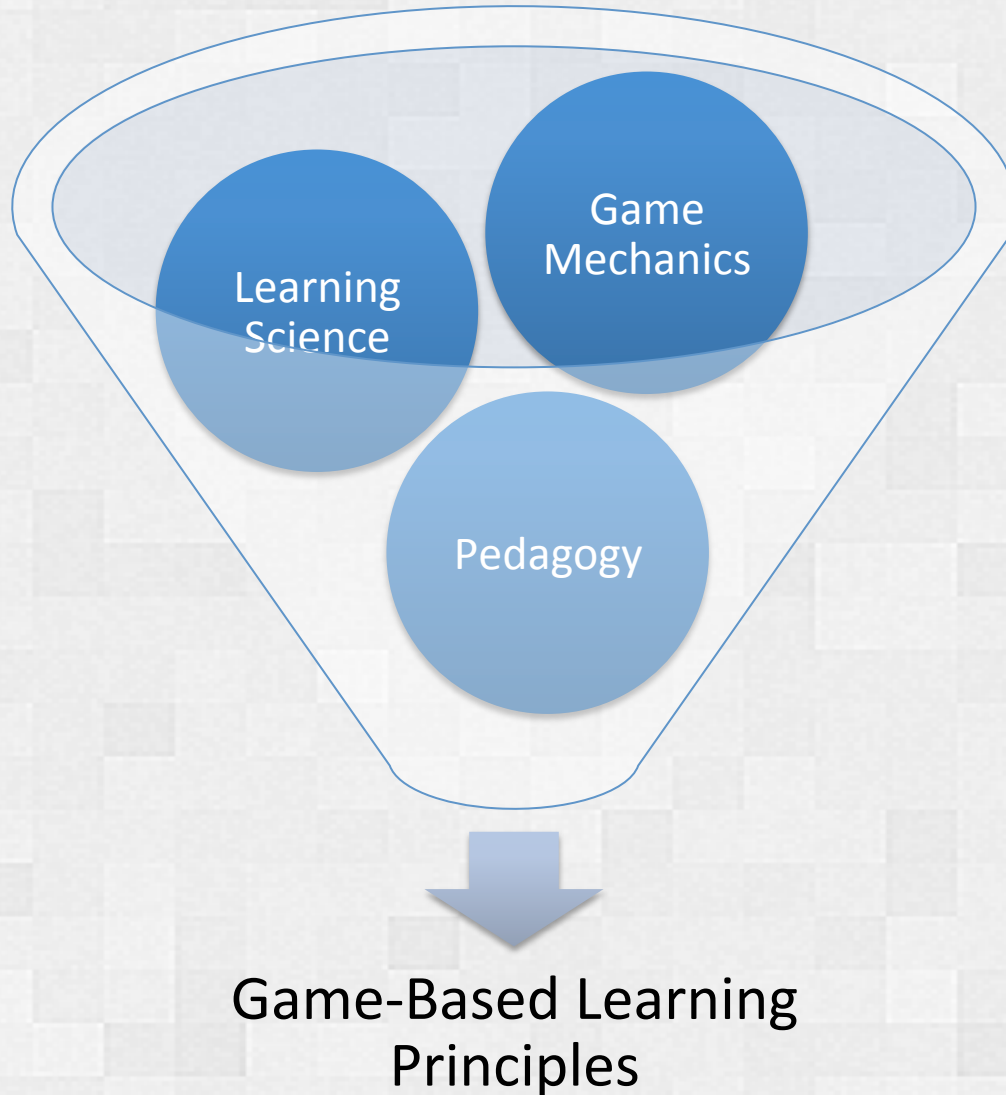
Content may only be considered original once.

However, the process can be repeated *ad infinitum*.





# Let's mix it up



# **Game-Based Learning**

Principles and Practices

Version 1.0

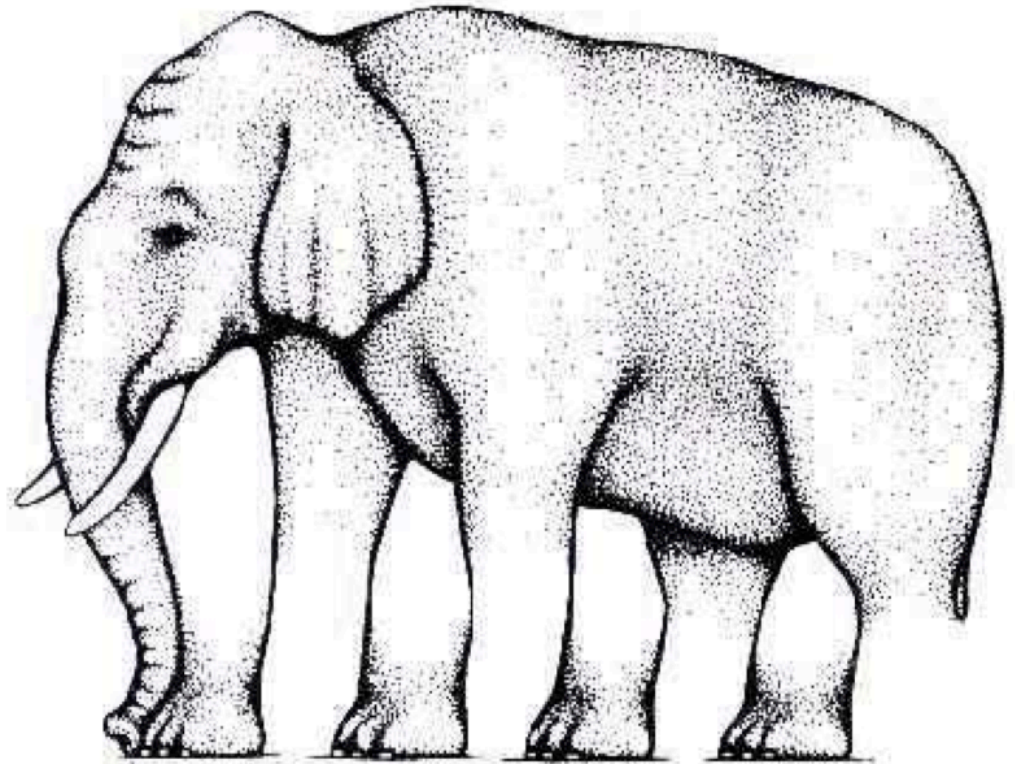
# GBL Principle 1

Learning is ultimately a physiological process. Read as much as you can about perception, attention, learning, memory, reasoning, and motivation.

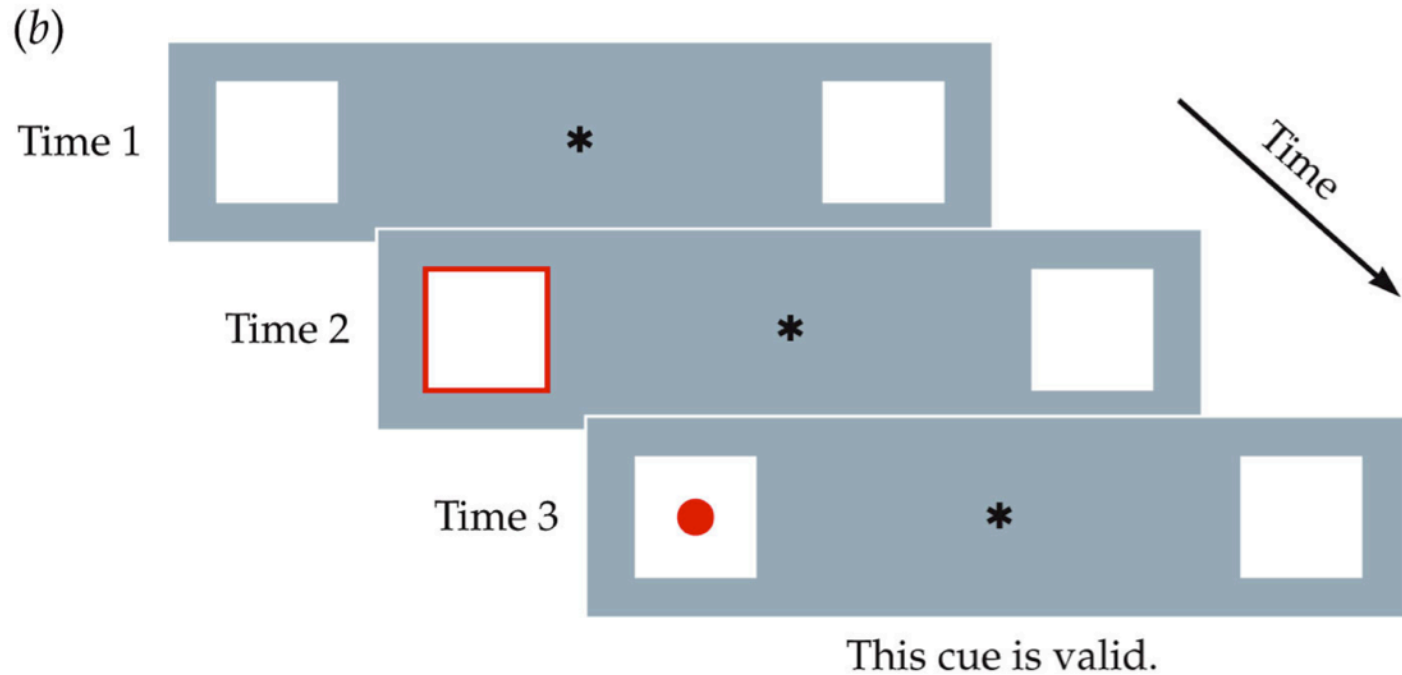


# Perception

- Our senses are bombarded with data
- Attention is used to gate information processing
- To process the visual array with equal resolution would require enormous heads (and birth canals)



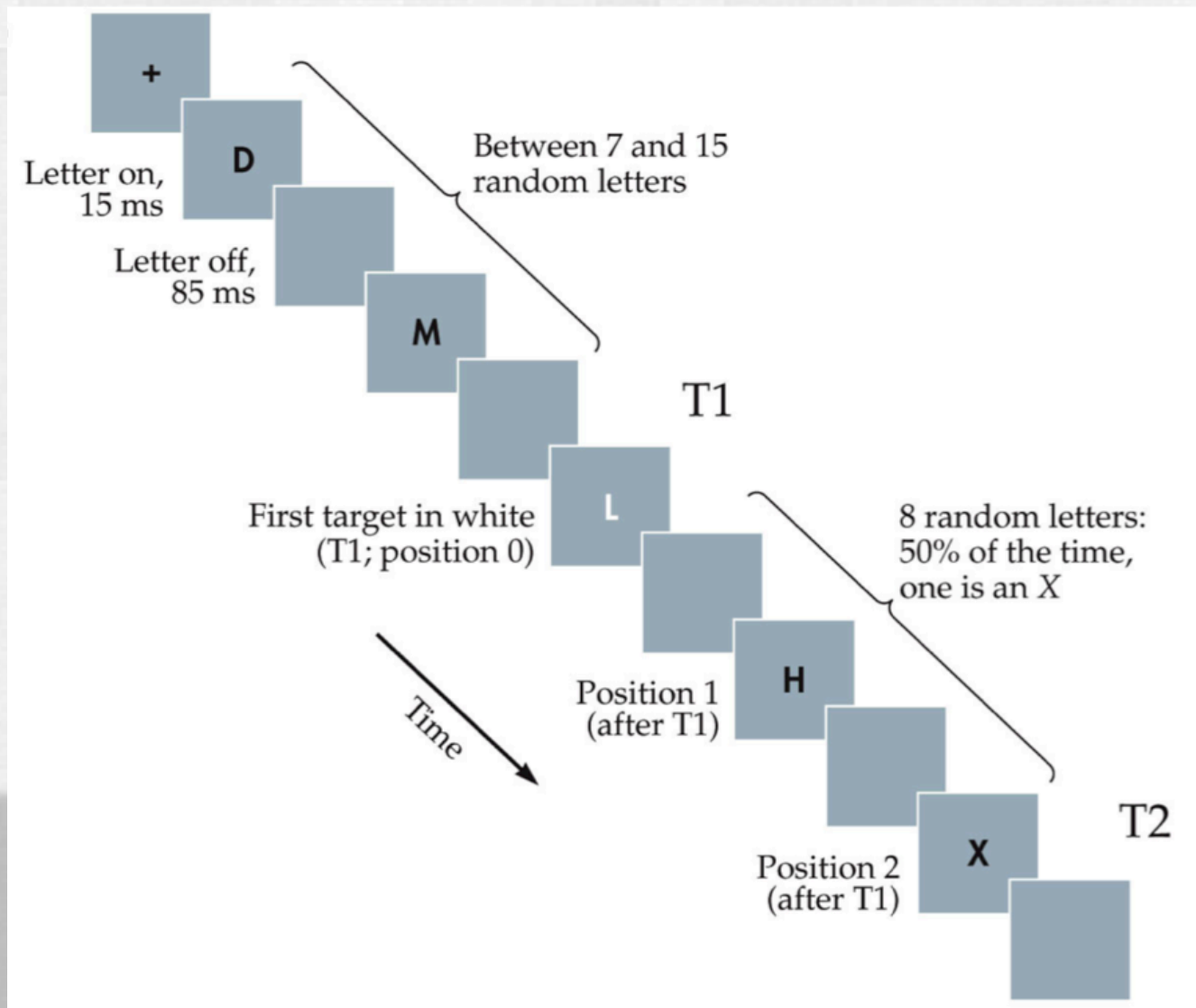
# Selective Attention



Endogenous cue - comes from within

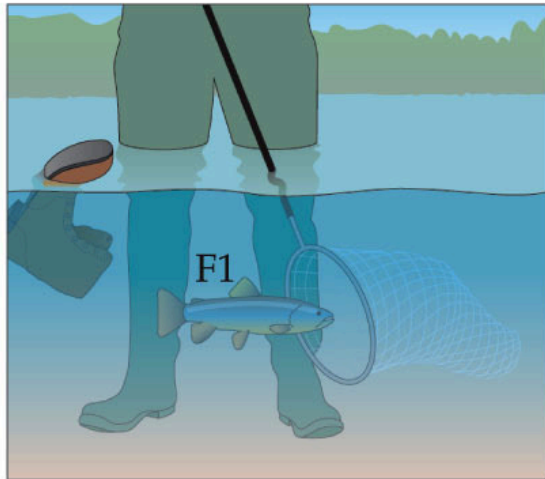
Exogenous cue - comes from the environment  
(e.g., ambulance siren)

# Attentional Blink



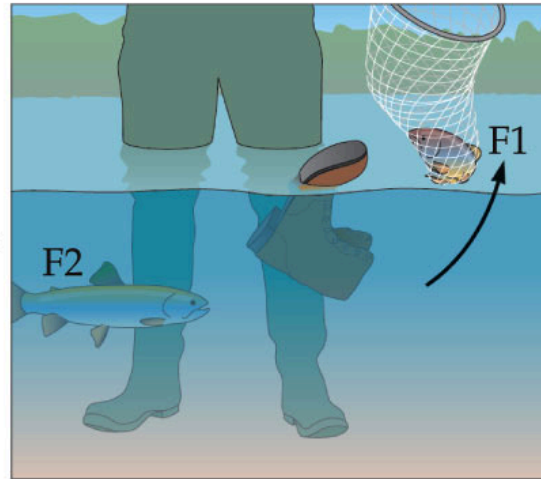
# Attentional Blink

(a)



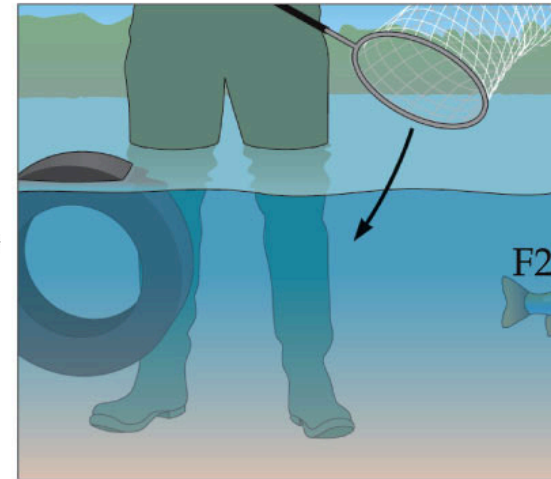
Time →

(b)



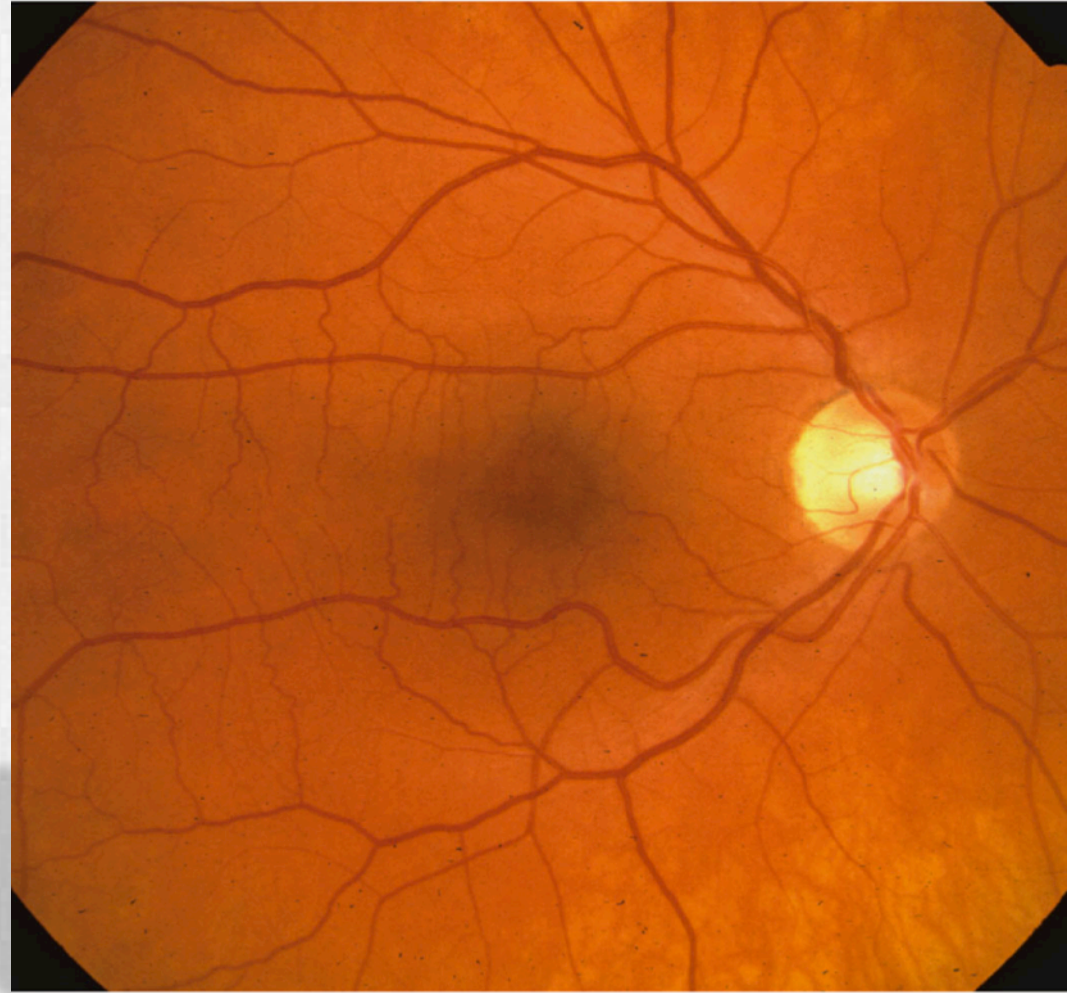
Time →

(c)



# Perceptual “Filling In”

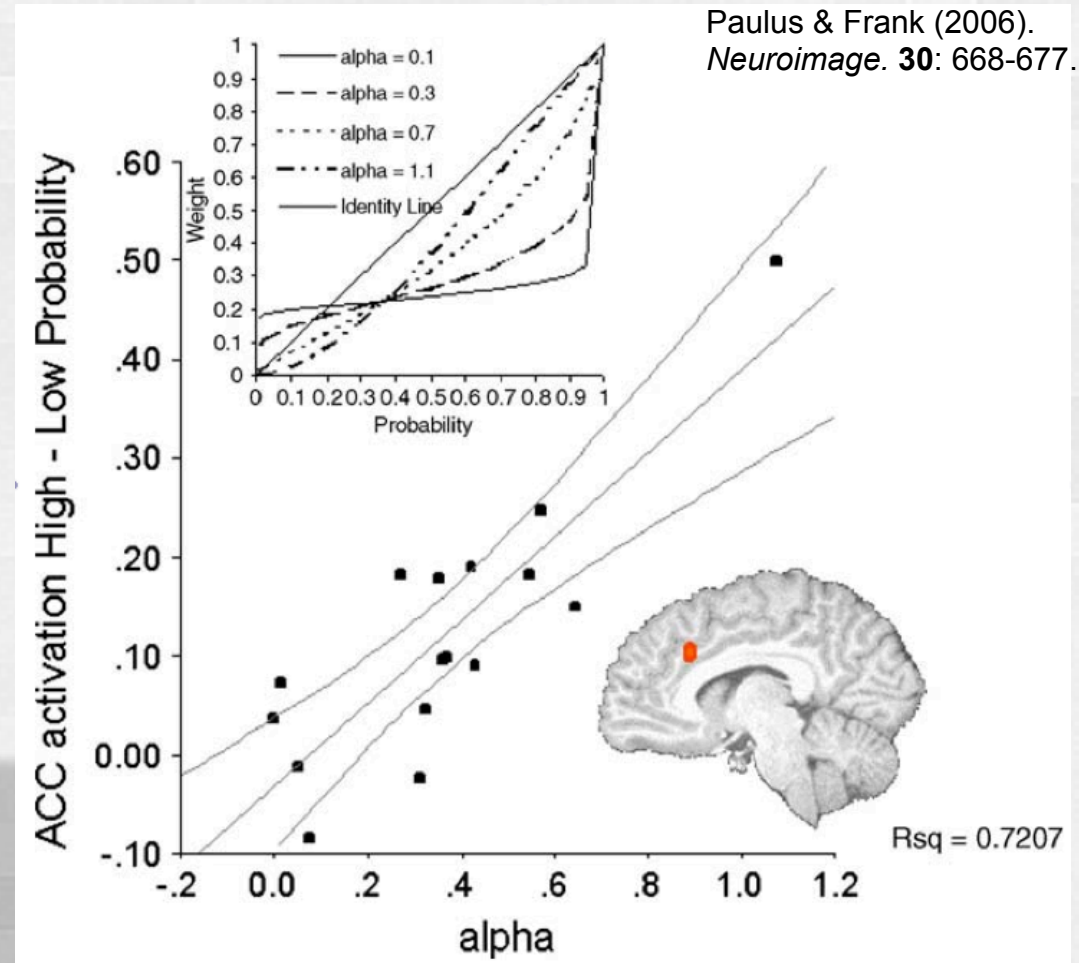
- There is a blind spot in the visual field corresponding to the optic disk
- The brain uses available evidence to “fill in” for missing input





# Decision Making

- Prospect Theory (Tversky & Kahneman, 1979)
- $Utility = probab \times value$
- We make errors when dealing with rare outcomes
- Activity in anterior cingulate cortex correlates with perceived utility



# **GBL Principle 2**

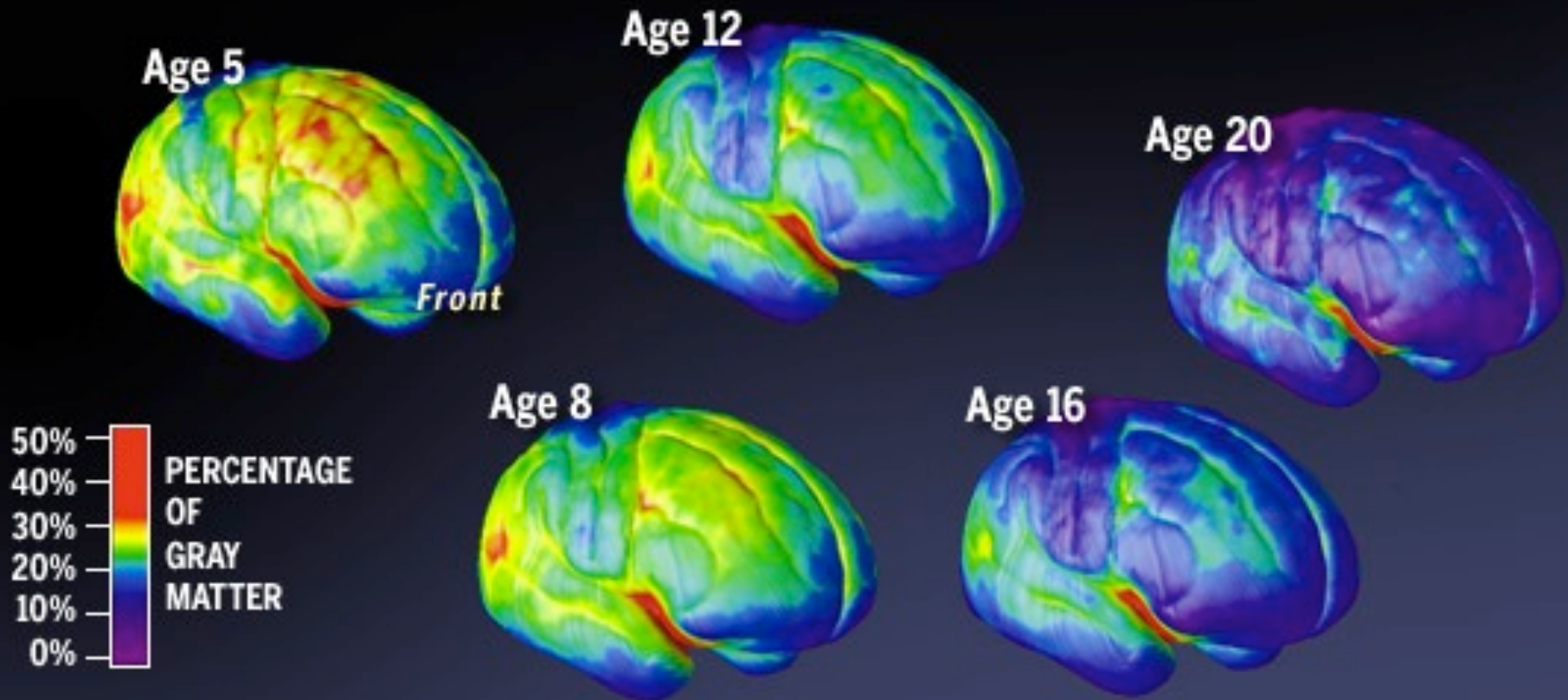
Recognize key differences in cognition between age groups and other populations.

# Know your audience

- Individual differences are critical
- One size does not fit all
- Understand unique needs of your learners
- Games provide opportunities for individualized learning



# Development of Executive Function



Source: Paul Thompson, UCLA

# GBL Principle 3a

Identify the desired learning outcomes. Reconcile these outcomes with standard pedagogy and accepted methods of assessment.



# Operational Definitions

**Learning and memory are theoretical concepts that cannot be directly measured.**



## Independent Variables

- Operational definitions informed by learning outcomes

## Black Box

## Dependent Variables

- Learning outcomes
- Derived from accepted methods and/or standard assessments

# **GBL Principle 3b**

Distinguish processes (e.g., critical thinking) from content (e.g., the historic journey of Lewis and Clark).

# Multiple Memory Systems

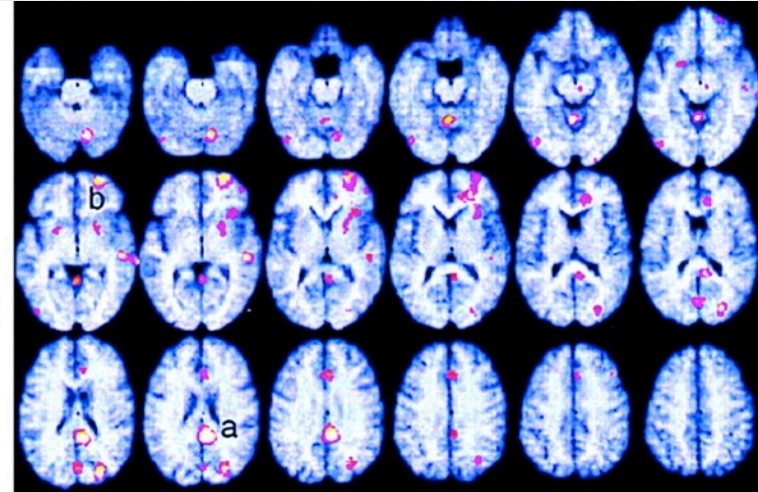
## Episodic Memory

- Largely for events
- Supported by hippocampus, subiculum, entorhinal cortex, perirhinal cortex & parahippocampus cortex

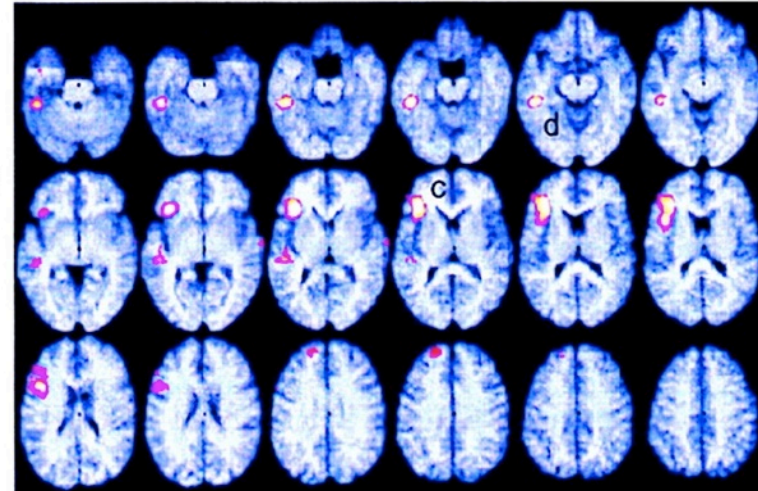
## Semantic Memory

- Largely for facts
- Supported by entorhinal cortex, perirhinal cortex & parahippocampus cortex

Episodic  
minus  
Semantic  
retrieval



Semantic  
minus  
Episodic  
retrieval

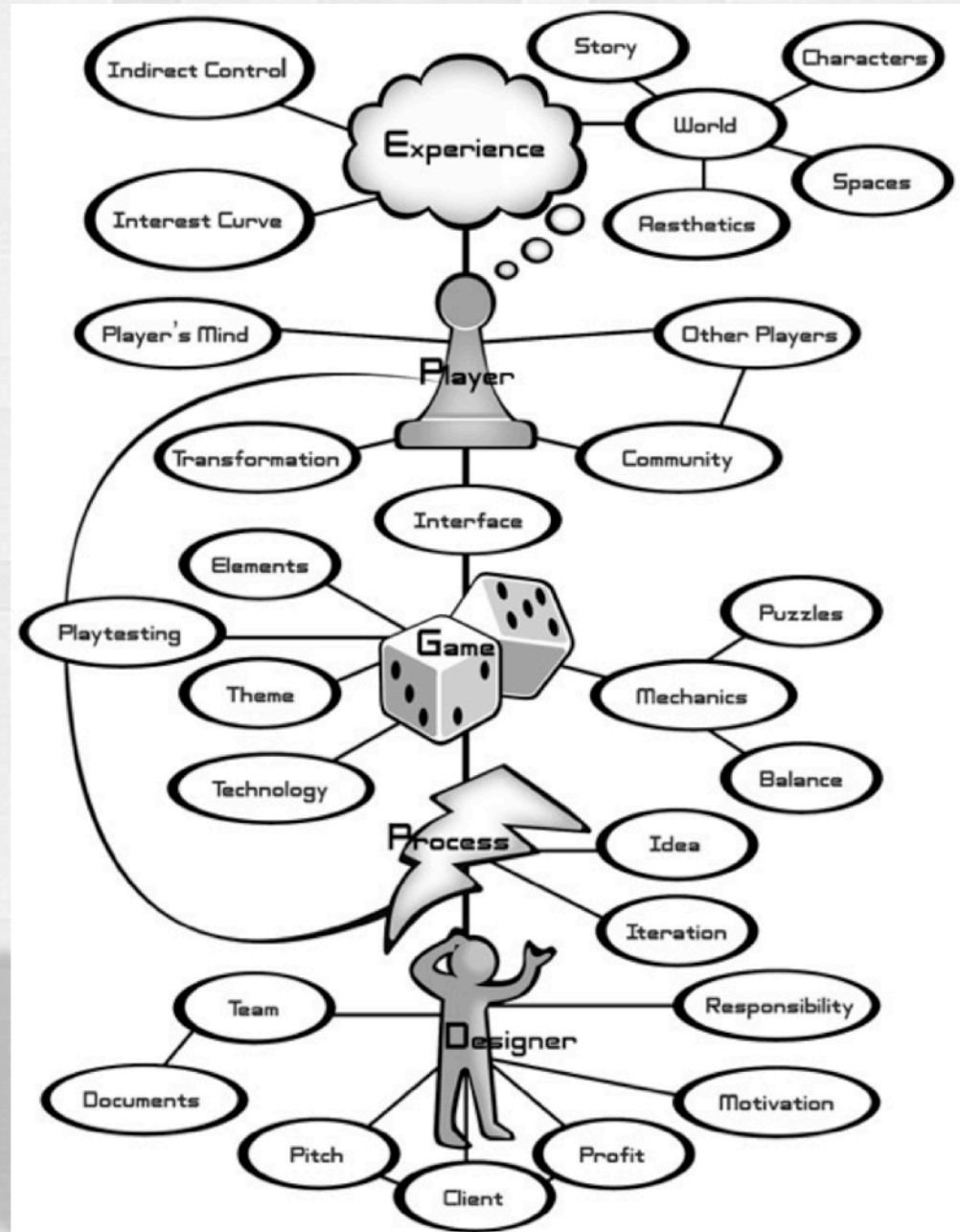


# GBL Principle 4

Become an advocate for the player.  
The game is a vehicle to create an  
experience in the player's mind. You  
are the architect of that experience.

# Influencing Mental Models

- The retina and brain process an unfathomable amount of data to create a 3-D representation of the world from the 2-D retinal image
- Games create opportunities for the player to “fill in.”
- Players fill in for missing/impoverished data.
- Unsolved problems are presented to players.
- Solutions to problems update the mental model.





# GBL Principle 5

Develop a core game mechanic that directly supports learning outcomes. Ideally, the core mechanic and the in-game pedagogy are identical.

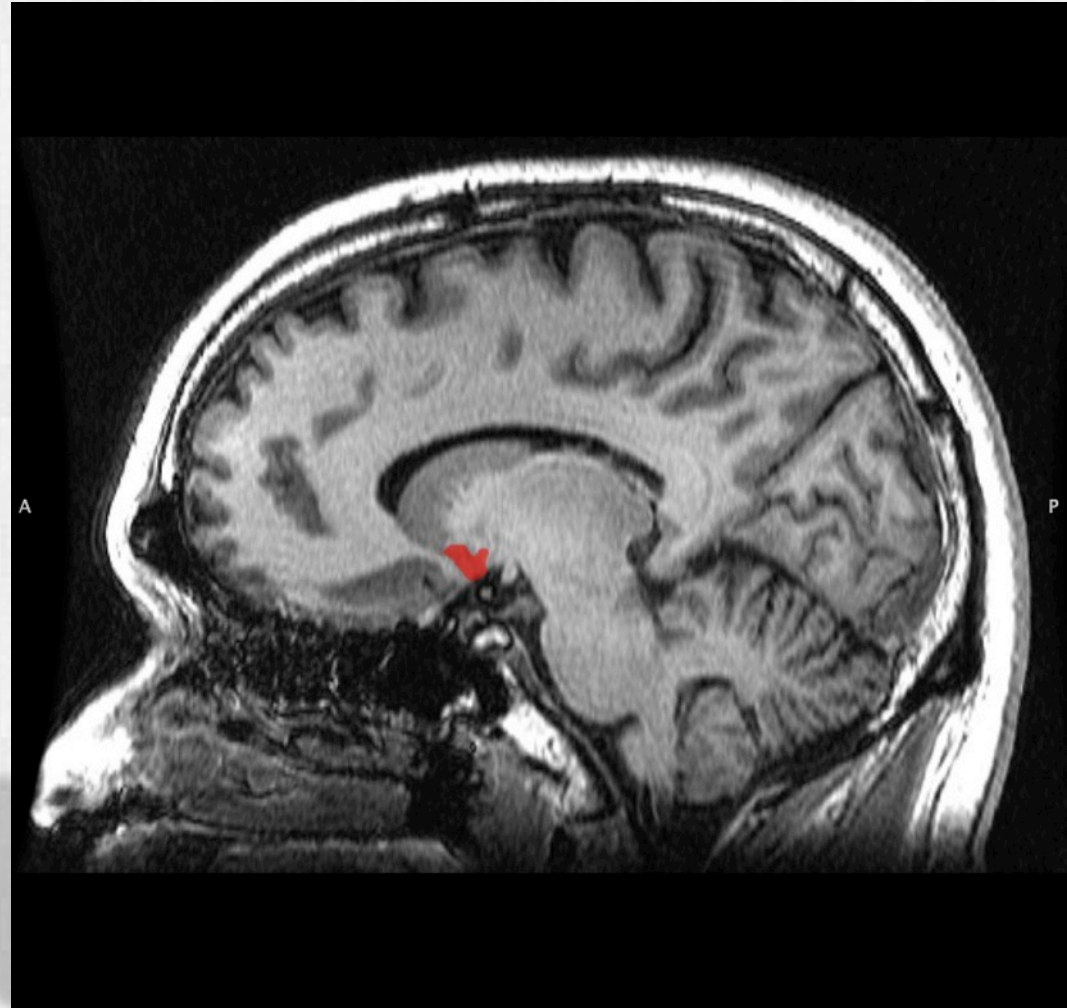
# Avoid “Chocolate Covered Broccoli”

- Core game mechanic is the most prevalent or most important behavior in the game
- The core mechanic must be wedded to the behaviors you are trying to shape with your pedagogy
- Otherwise, the game mechanic might overshadow the pedagogy



# Intrinsic vs. Extrinsic Rewards

- Reward is signaled in the brain by the delivery of dopamine to the nucleus accumbens, which strengthens neural connections between stimuli and responses
- Extrinsic rewards like money can devalue intrinsic rewards
- Secondary reinforcers take on the value of primary reinforcers
- How do you get a musician to complain? Get her a gig.



# **GBL Principle 6**

Create game objectives that  
coincide with the learning outcomes



# Successive Approximations

- You can have several learning objectives
- These may occur in stages
- By *scaffolding* the stages of learning, you might achieve your final learning outcome
- We learn more when we can attach new knowledge to existing schemas
- Spaced learning or distributed learning maximizes retention

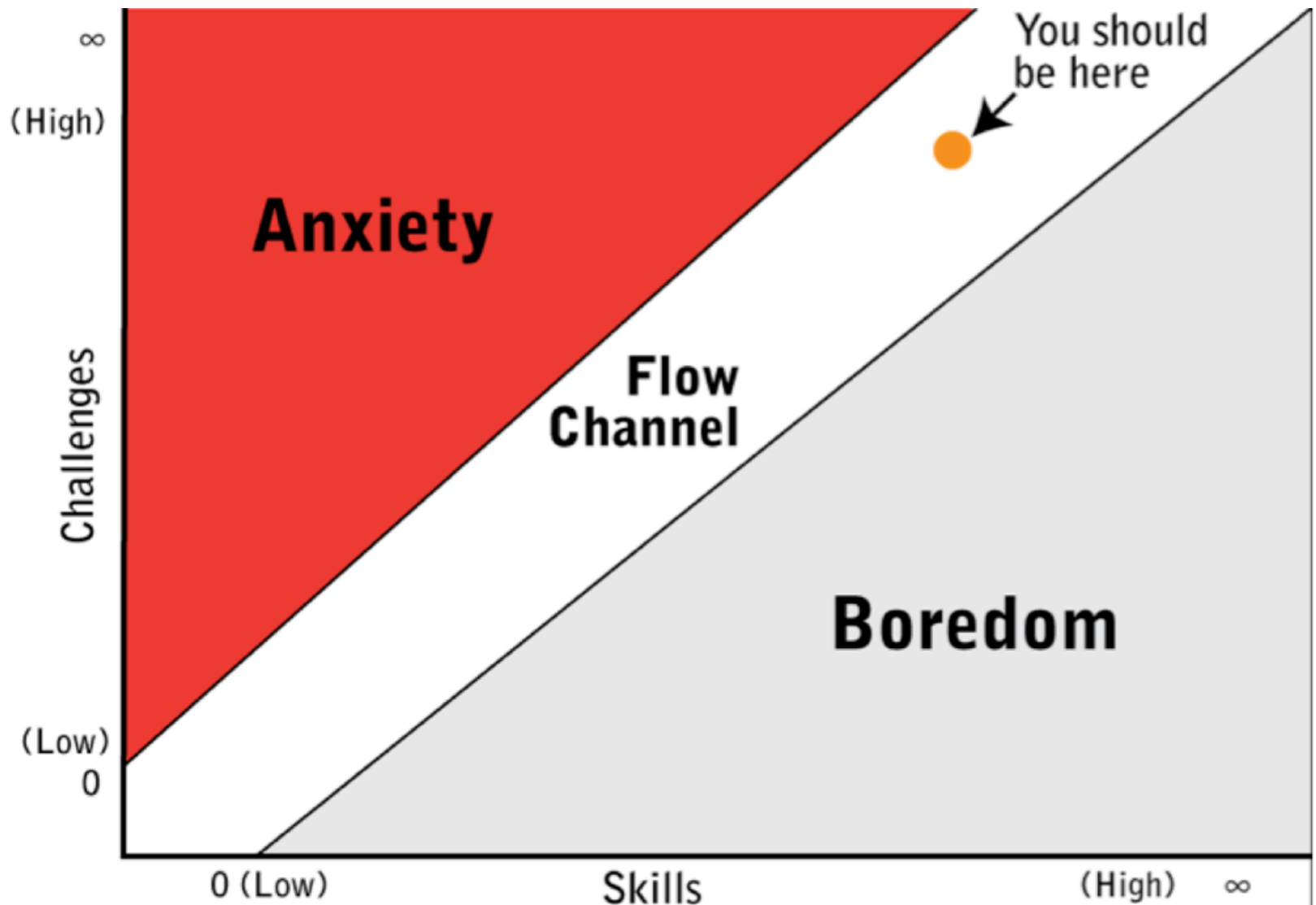




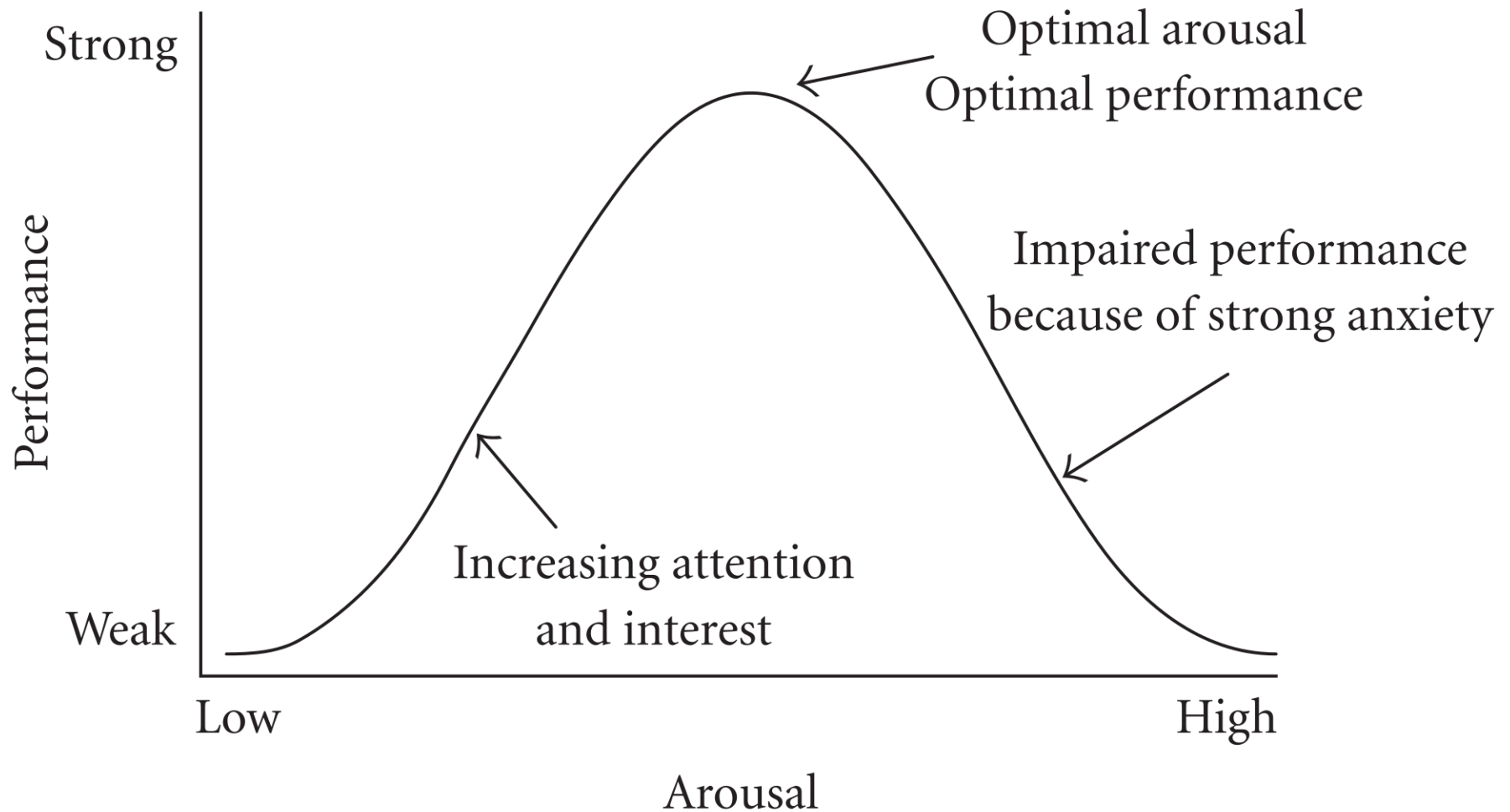
# GBL Principle 7

Use *flow* to sustain engagement  
until players achieve the learning  
outcomes

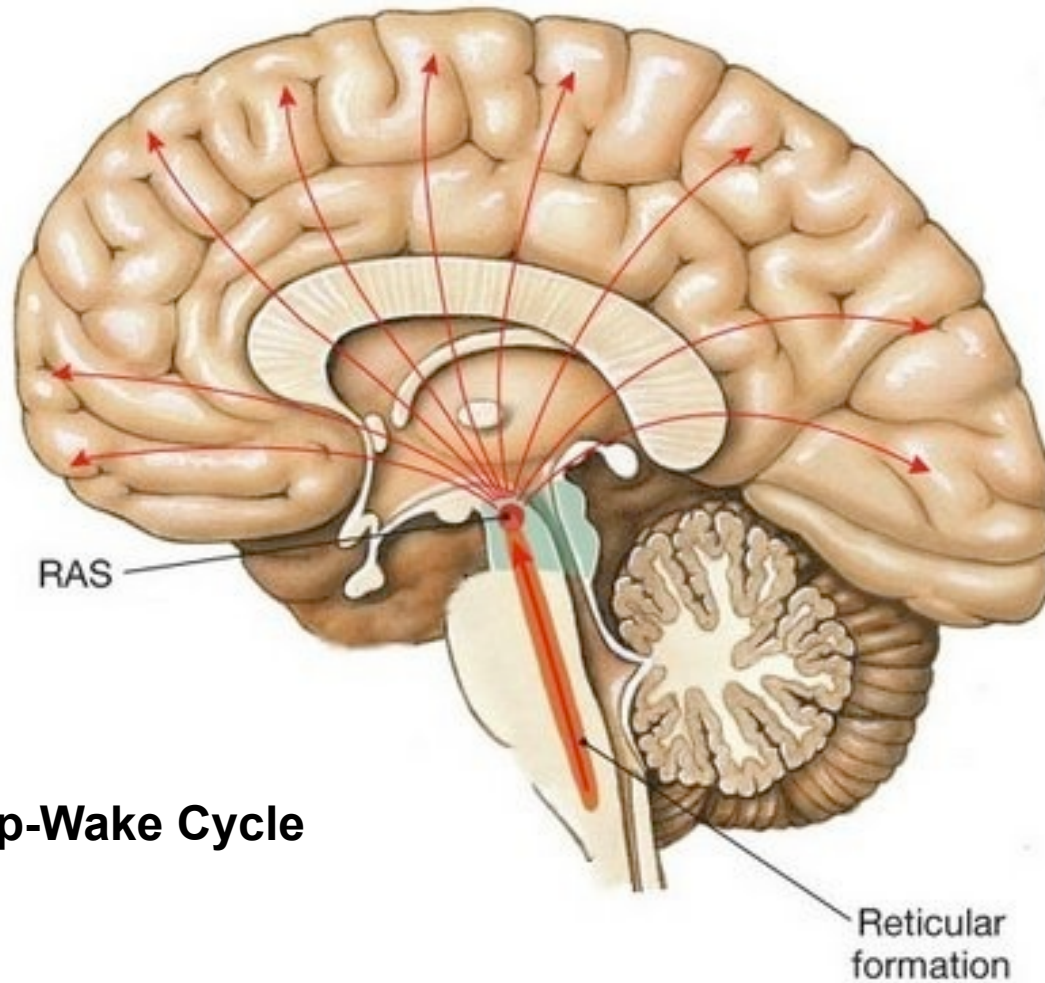
# Flow



# Yerkes-Dodson Law

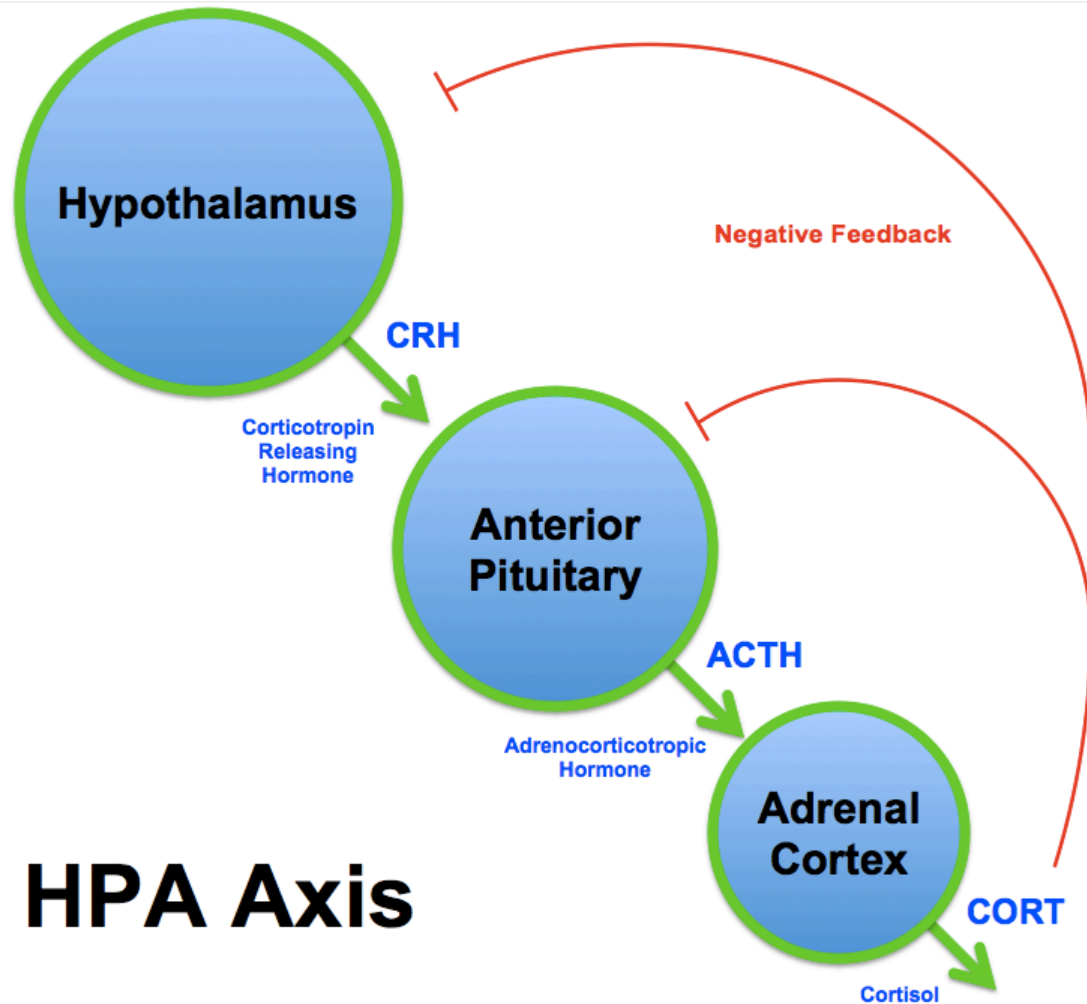


# Reticular Activating System



**Mediates Sleep-Wake Cycle**

# HPA-Axis Supports Stress



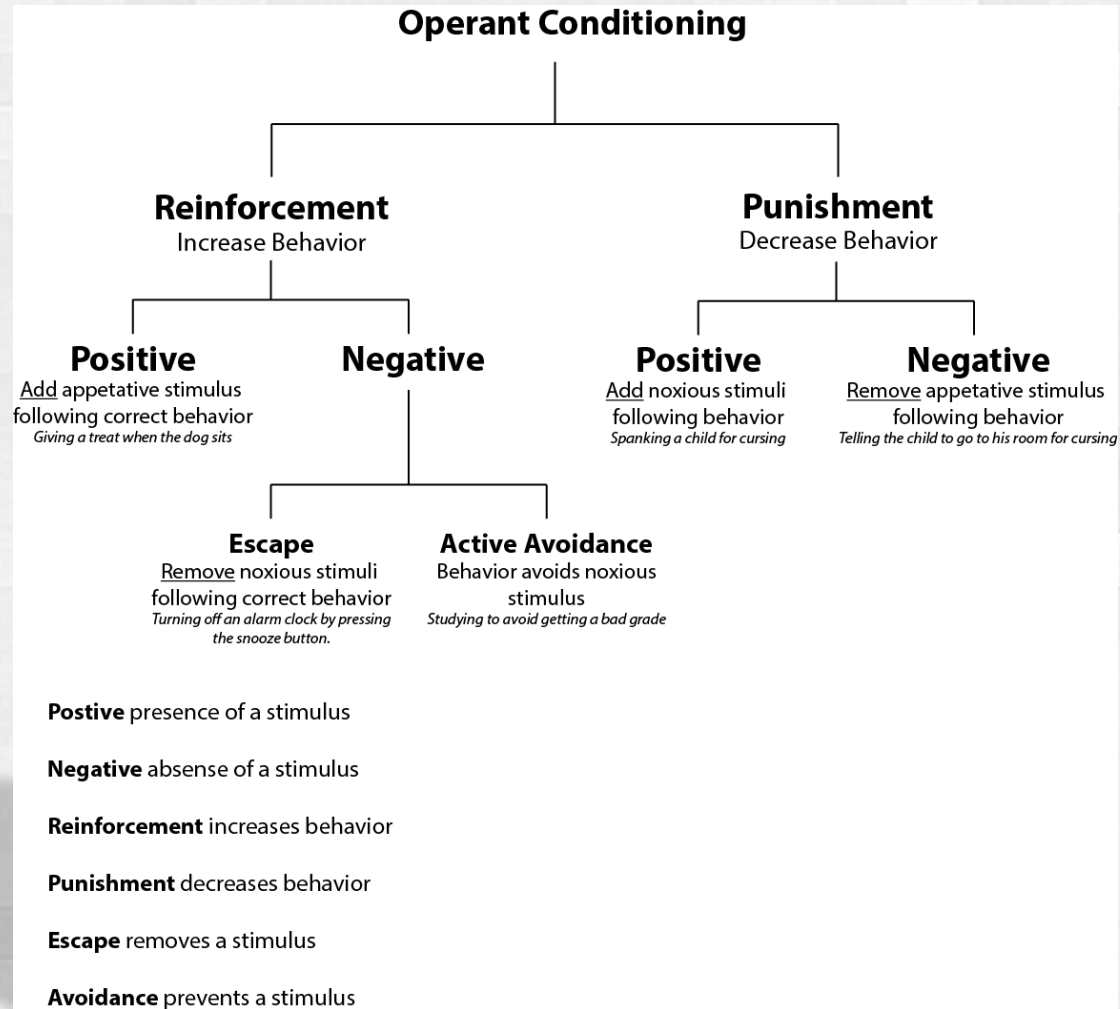


# **GBL Principle 8**

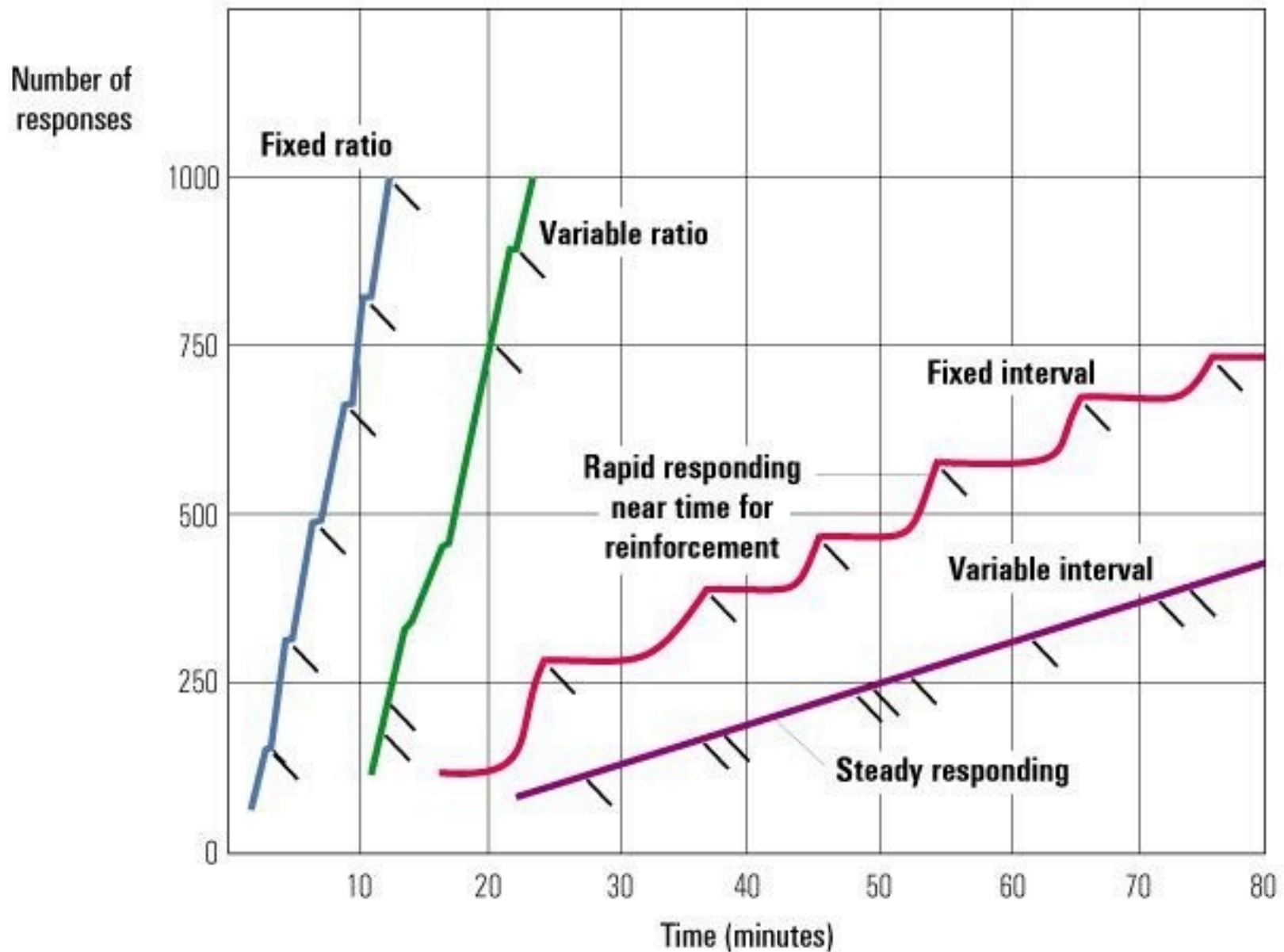
Use Applied Behavior Analysis  
(ABA) to shape desirable behaviors

# Operant Conditioning

- Reward – supported by the nucleus accumbens
- Punishment – supported in part by neural circuits for stress
- Timing between stimulus, response, and reward also mediated by the interpositus nucleus of the cerebellum



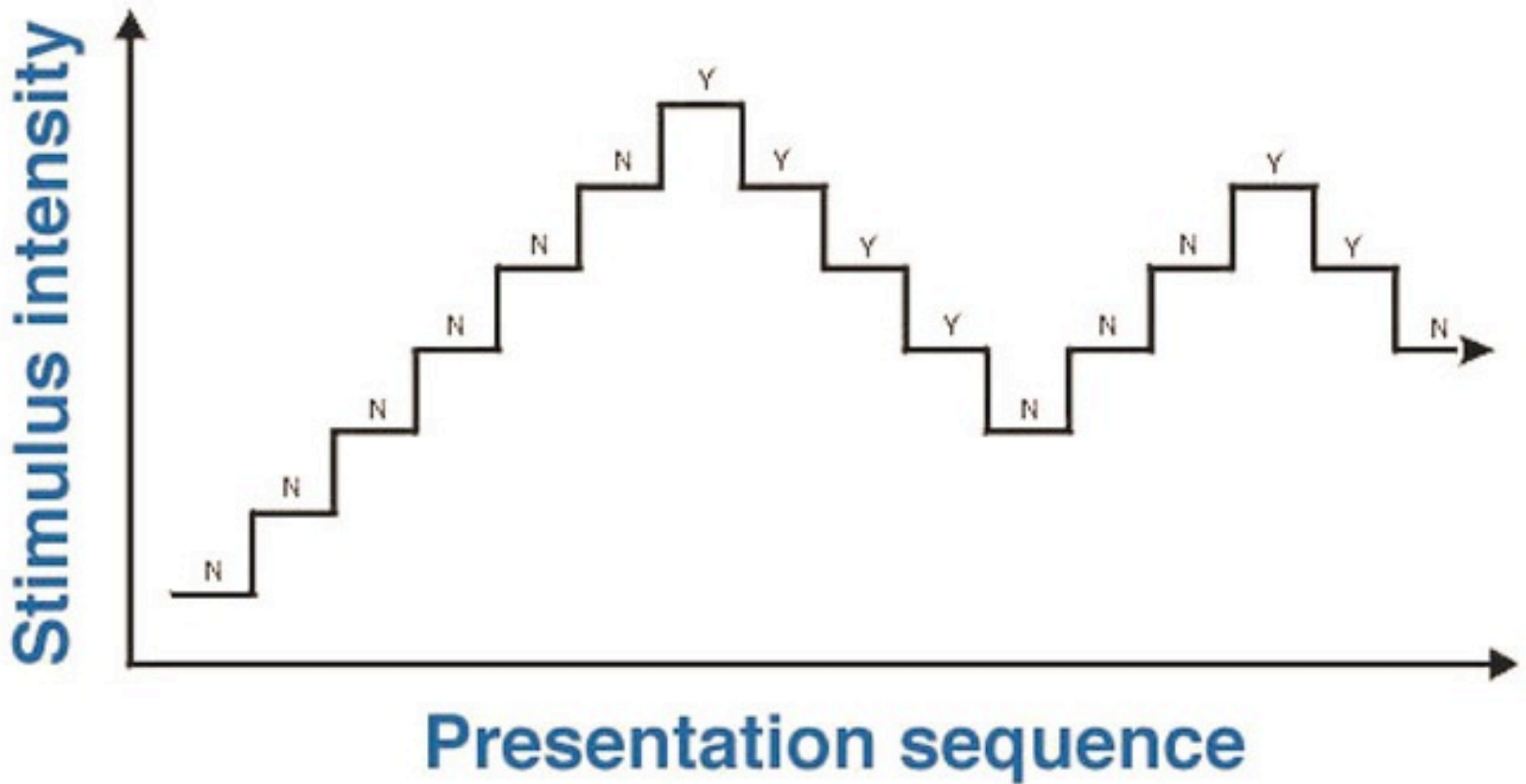
# Reward Schedules



# GBL Principle 9

Adjust task difficulty according to performance using classic psychophysical staircase procedures

# 1-up/1-down Staircase Method





# GBL Principle 10

Embed your method of assessment  
into the game

# In-Game Assessment

1. Saves time
2. Can be used to adjust difficulty to each individual's need
3. Can be compared to post-game assessments
  - a. Determine reliability
  - b. Determine generalizability of learning

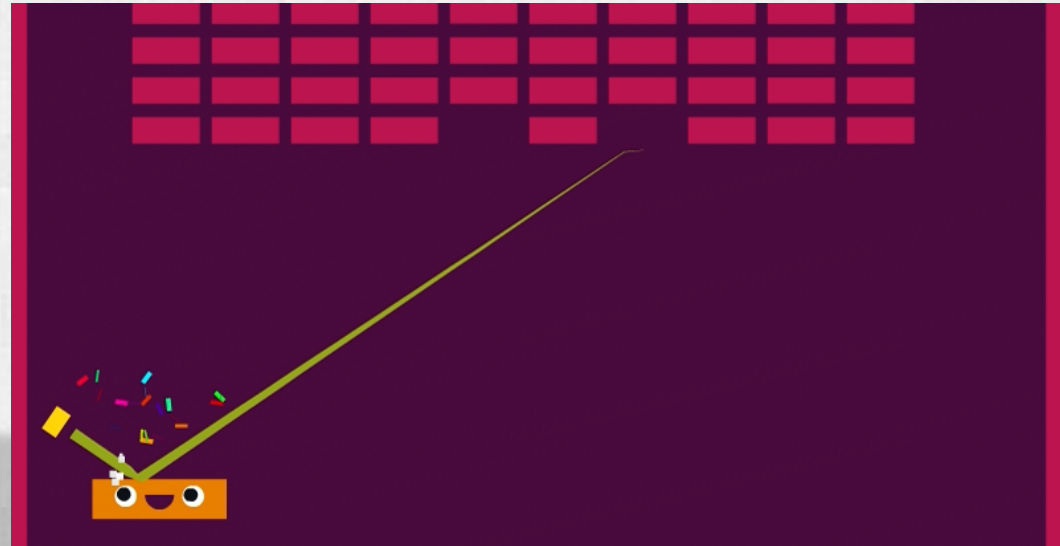


# **GBL Principle 11**

Provide short- and long-term  
feedback regarding performance

# “Juice it or loose it”

1. Short-term feedback lets the user know how to behave
2. Keeps users in a state of flow and sustains engagement
3. Immediate reinforcement stimulates neural circuits for motivation
4. Simulation enhances vigilance



Jonasson & Purho (2013) *Juice it or loose it*. <http://www.GDCVault.com>



# Long-term Feedback

1. Serves the learning outcomes
2. Serves the game objective(s)
3. Sustains motivation
4. Inventories spare working memory. The player can focus on the main task.
5. Compound schedules can use ST and LT feedback to support complicated behaviors





# GBL Principle 12

Identify and repurpose established game mechanics, resources, and vocabulary whenever possible.

Learning is easiest when we introduce subtle changes to existing schemas.

# Attach New Learning to Old Schemas

## P.T.S.D.

Disabling anxiety, nightmares, or flashbacks after a traumatic event.

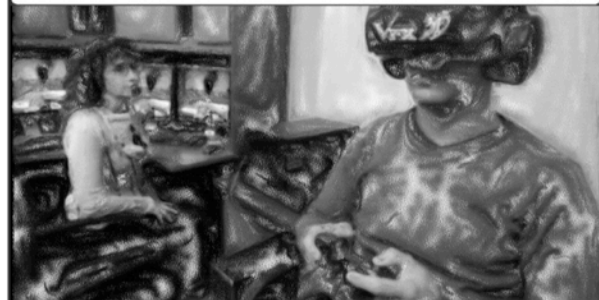


+1 Card  
+2 Actions

\$2

## Exposure

Facing your phobia by desensitizing yourself to the situation.



+2 Copper +1 Buy  
Helps Specific Phobia, Social Anxiety, Agoraphobia, and Panic Attacks

\$1

# GBL Principle 13

Identify the formal elements of your genre, including the number of players, objectives, procedures, rules, resources, conflict, boundaries and outcomes.

# Boundaries



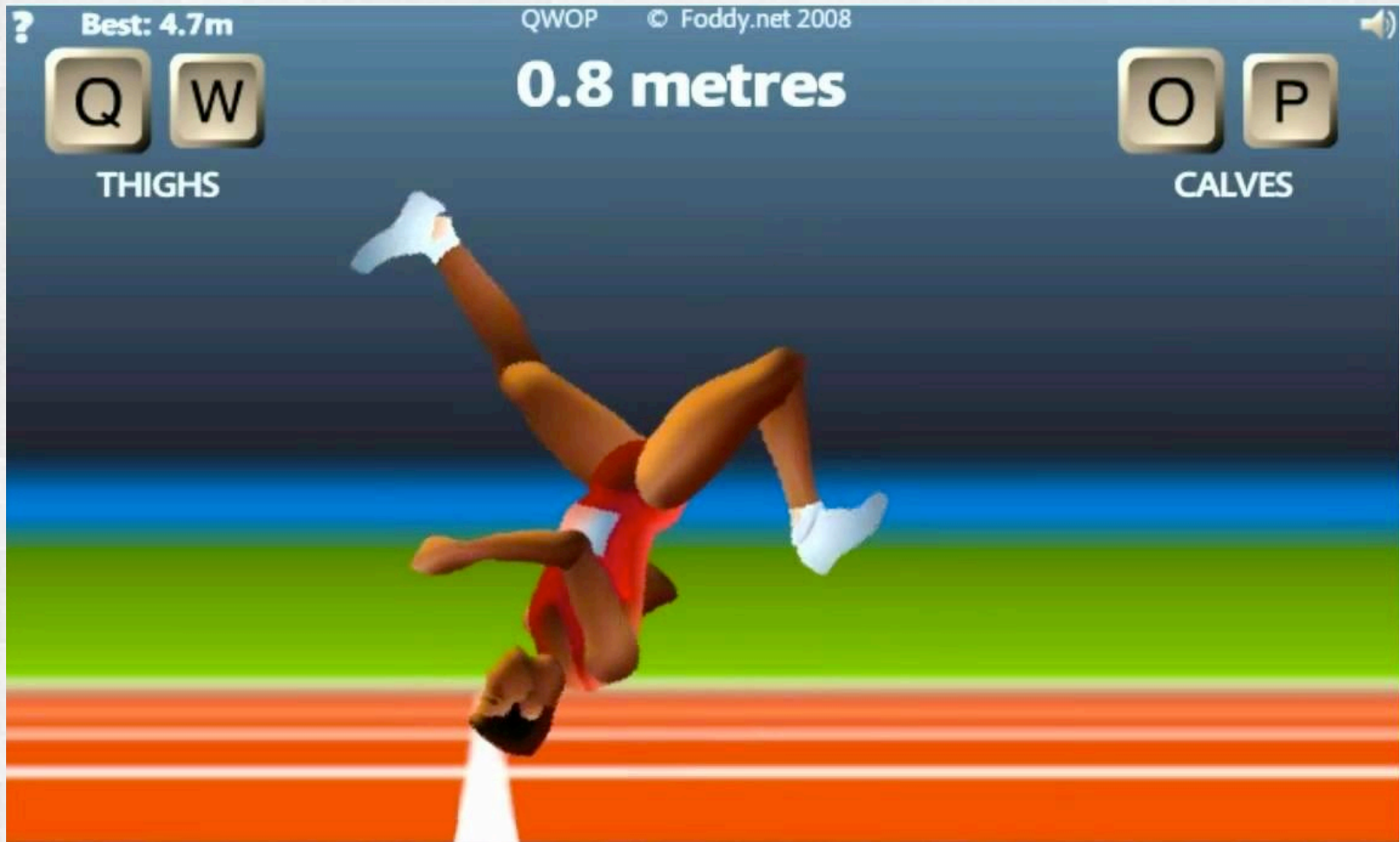


# Boundaries



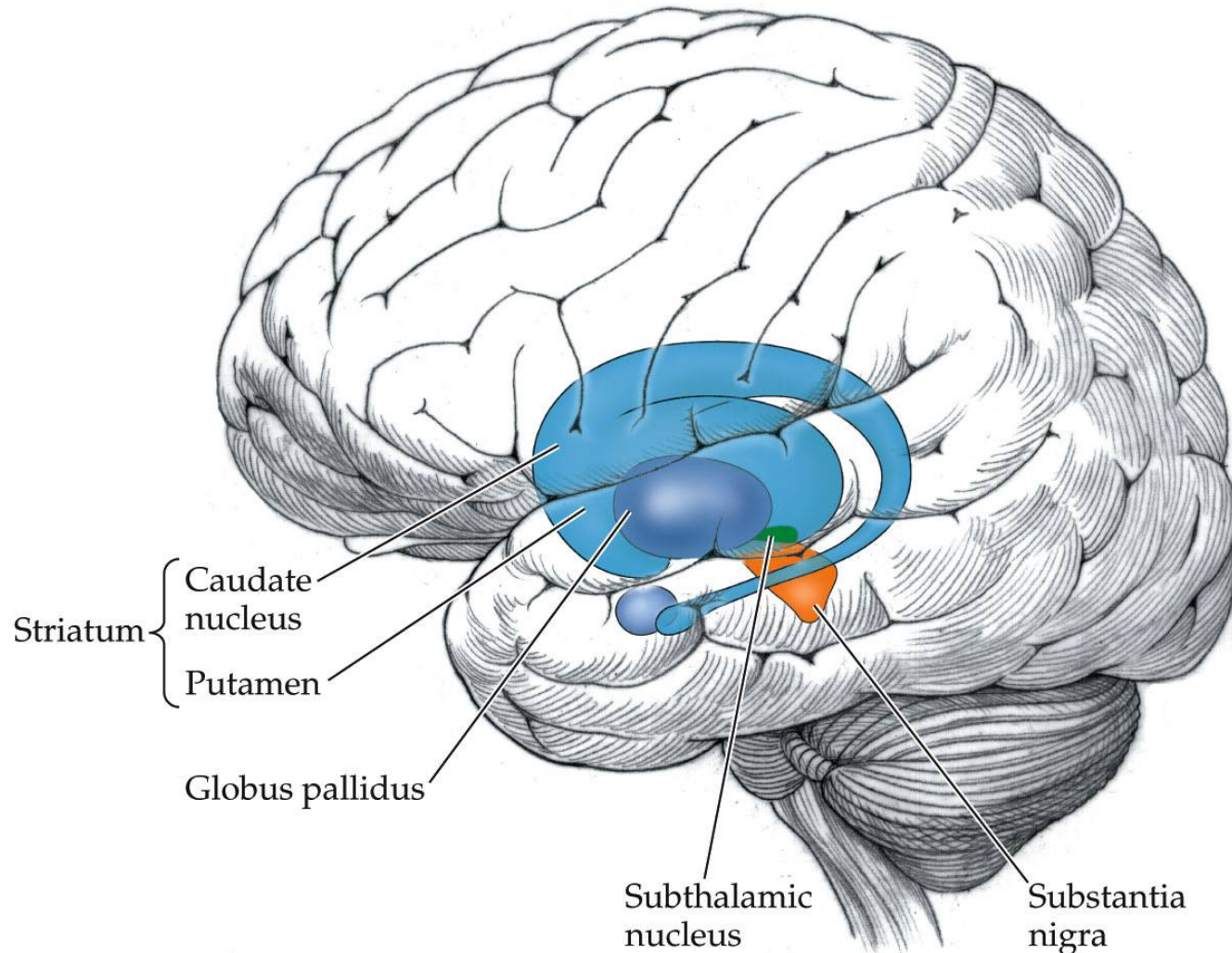


# Boundaries



QWOP is only fun because it messes with automatic processes in the Basal Ganglia

# Basal Ganglia



# GBL Principle 14

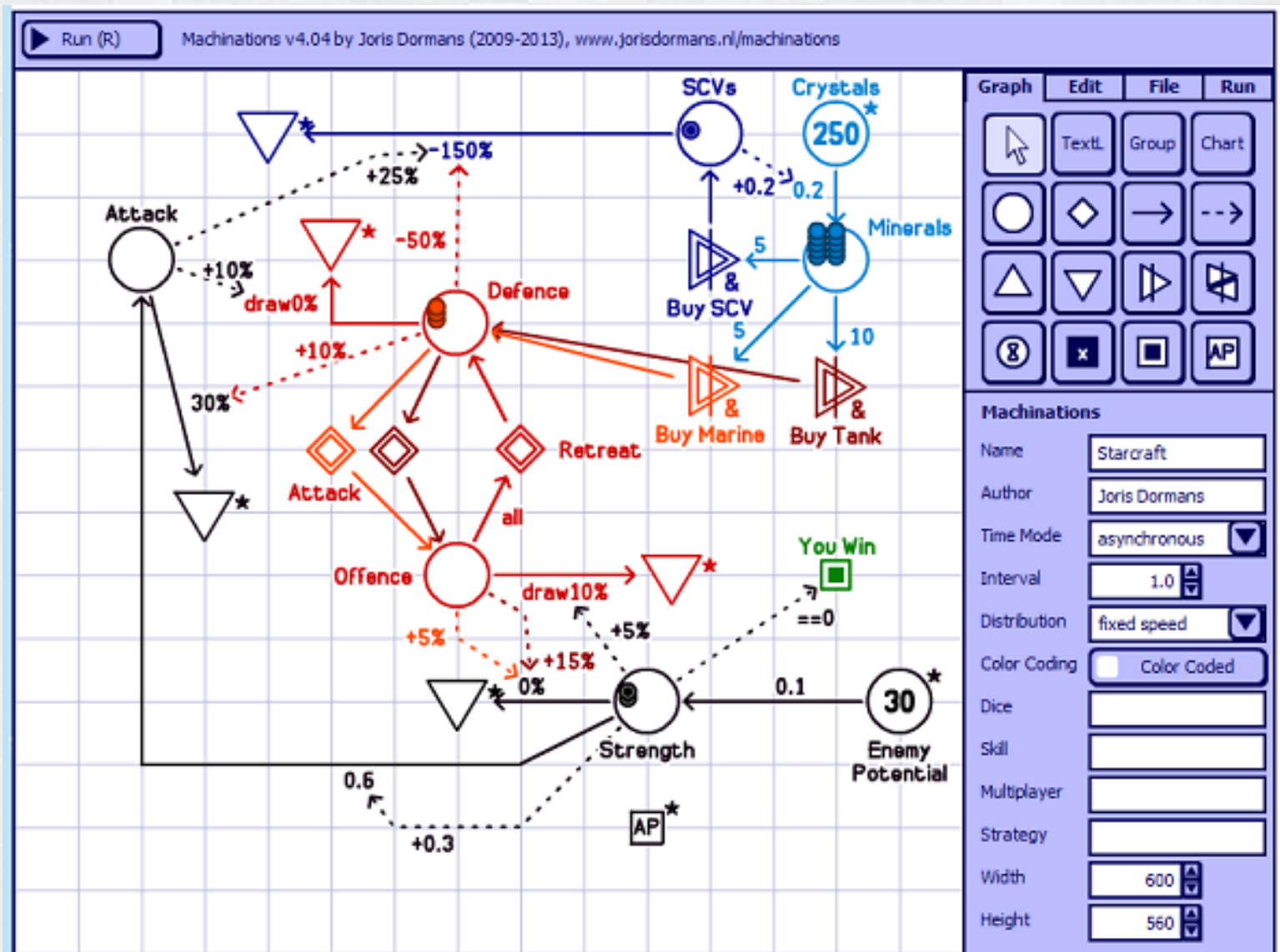
Create system dynamics and game economies that appropriately support the learning outcomes



# Resource Management in SimCityEdu



# Machination is a Computer Model





# GBL Principle 15

Develop dramatic elements that sustain engagement without contradicting or obfuscating the learning outcomes.

Identify the game genre, narrative style, voice (i.e., first person, second person, 3<sup>rd</sup> person omniscient), metaphors, characters, story, aesthetics, and dramatic story arc.

# Chess



# No wait... Chess





**Oh yeah... Chess**

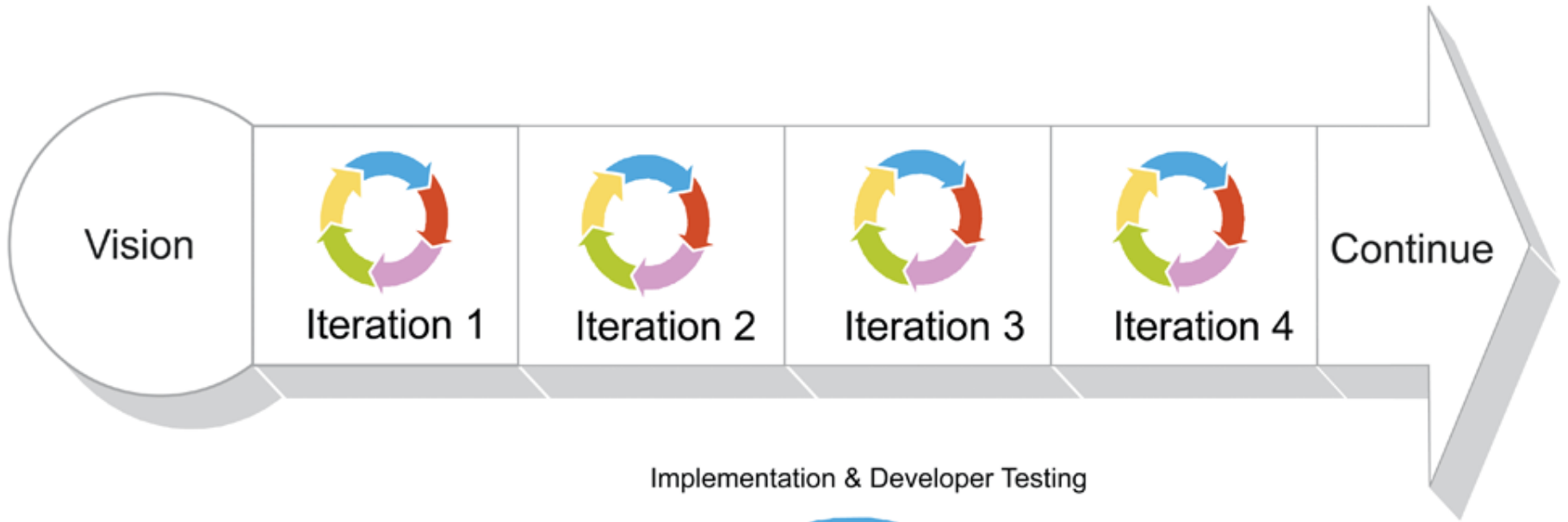


# GBL Principle 16

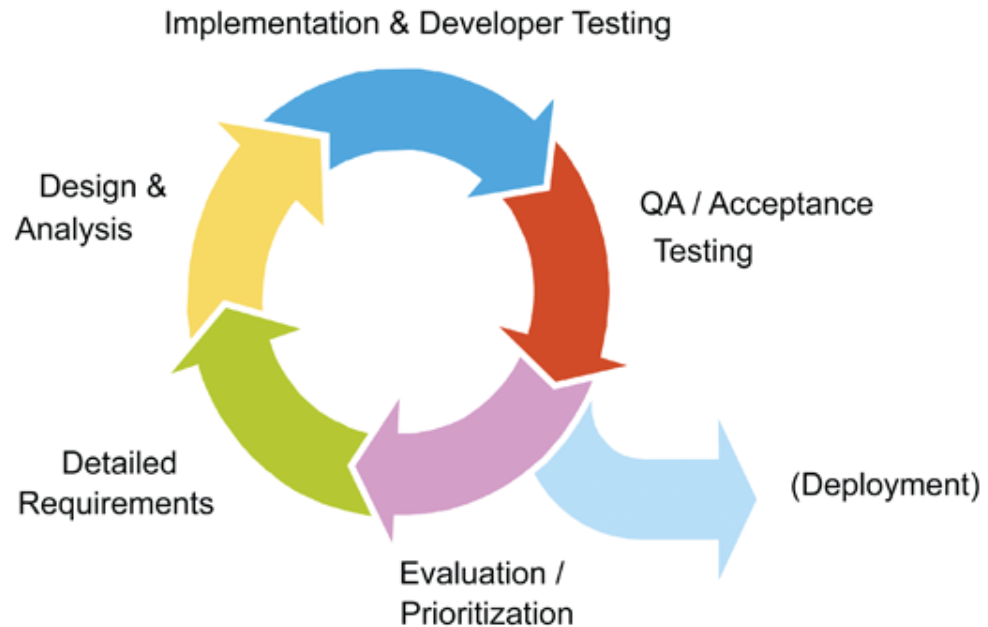
Use an iterative approach to game development (e.g., brain storming, refinement, paper prototyping, digital prototyping, Q & A, and play-testing).



# SCRUM



## Iteration Detail



# GBL Principle 17

Be weary of *fun killers* including trivial challenges, insurmountable challenges, lack of novelty, and arbitrary consequences for actions.



# Resources

- Fullerton, T. (2008). *Game design workshop: a playcentric approach to creating innovative games*. Morgan Kaufmann: Burlington, MA.
- Gee, J. P. (2007). *What video games have to teach us about learning and literacy*. Palgrave Macmillan: Hampshire, England.
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- Koster, R. (2013). *A theory of fun for game design (2<sup>nd</sup> ed.)*. O'Reilly Media Inc., Sebastopol, CA.
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- Shaffer, D. W. (2006). *How computer games help children learn*. Palgrave Macmillan: Hampshire, England.
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