The Neuroscience of Learning

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Key Information

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Course Outline

Week One: How We Learn
- Topic 1. Repetition and Hebbian Learning
- Topic 2. Feedback and Types of Learning

Week Two; How We Learn
- Topic 1. Long Term Potentiation and Synaptic Plasticity
- Topic 2. Dopamine and the Basal Ganglia

Week Three: What We Learn
- Topic 1. Explicit Memory
- Topic 2. Implicit Memory

Week Four: What We Learn
- Topic 1. Neural Basis of Memory
- Topic 2. Internal Models

Week Five: How We Can Improve Learning
- Topic 1. Distributed Practice, Random Practice, Variable Practice
- Topic 2. Specificity of Practice, Part-Whole Practice, Mental Imagery

Week Six: How We Can Improve Learning
- Topic 1. Sleep, Diet, and Exercise
- Topic 2. Age, Learning Disorders

How do we learn?

REPETITION

Definition: Learning

Changes in internal processes that are reflected by relatively stable changes in performance.

Performance vs. Learning

Performance	Learning
What you do at a given point in time	Relatively enduring change in the capacity to perform

Performance vs Learning

Performance = What You See

Learning = Internal Changes

Learning may be inferred from Performance

BUT

Performance may not be an indicator of Learning

Explicit vs Implicit Learning

Explicit

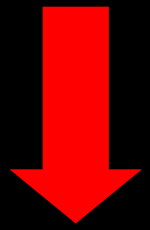
Improvement with awareness

Implicit

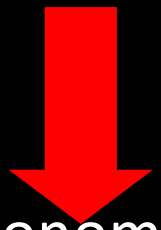
Improvements without awareness

Fitt's and Posner's Model (1967)

Cognitive



Associative



Autonomous

Stage I : Cognitive

Slow

Stiff

Inefficient

Ineffective

Many Errors

Stage II : Associative

Increasing coordination

Increasing speed

Increasing accuracy

Decreasing cognition (movement)

Increasing cognition (context)

Consistent error detection

Some error correction

Stage III : Autonomous

Consistent

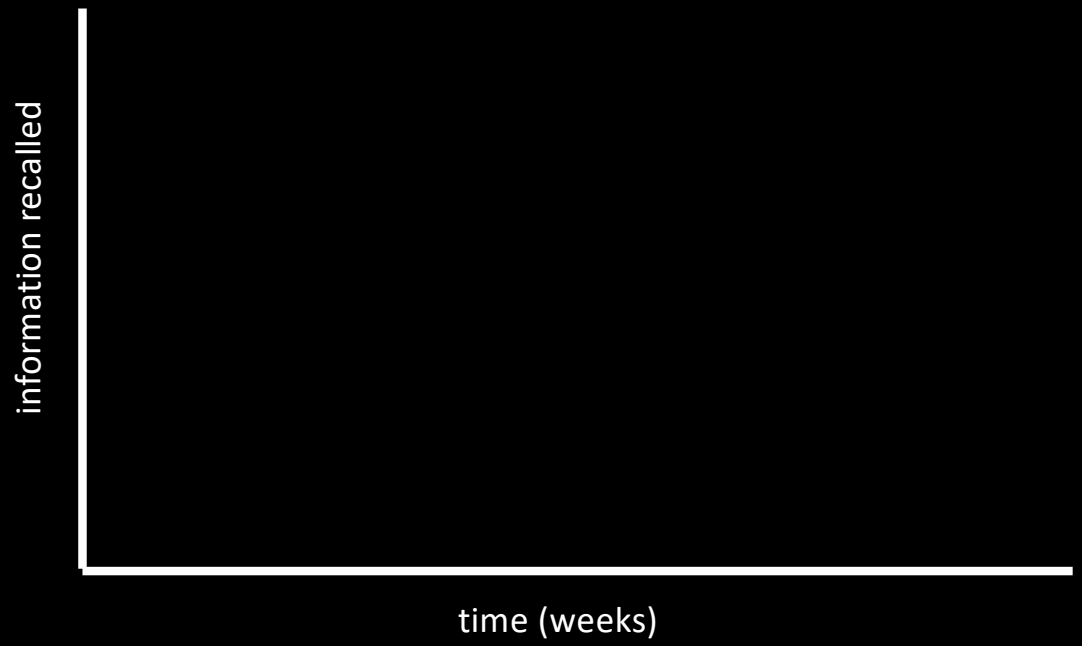
Highly effective and efficient

Rapid error detection and correction

No conscious control of movements

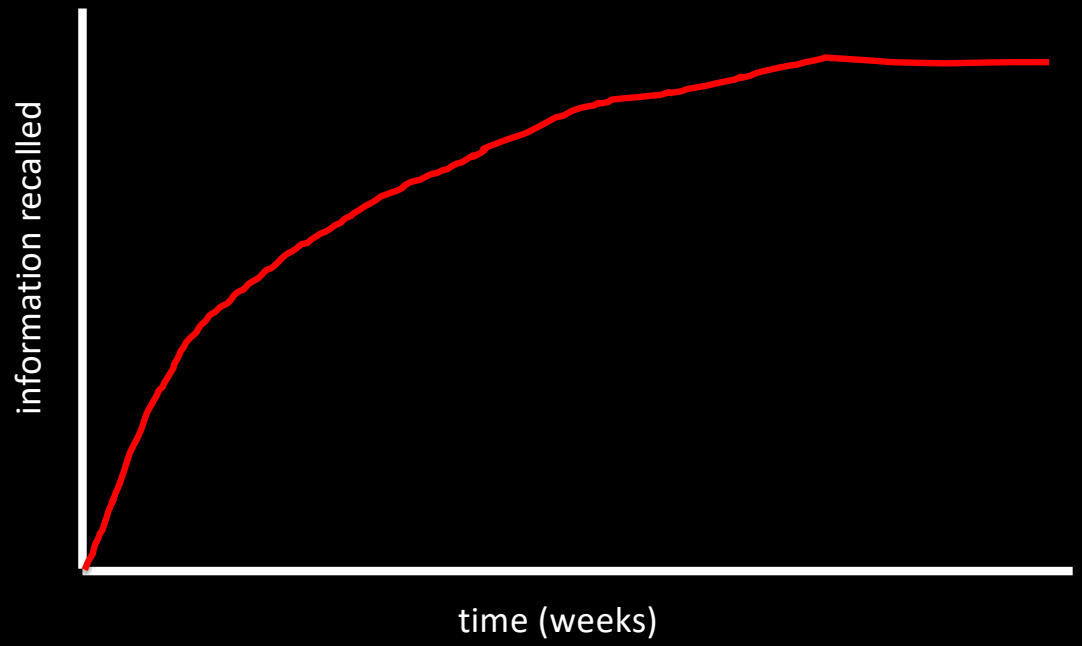
Highly adaptable

Question?



Imagine you study for a course. Using the plot outline above, sketch a graph of how how much you would learn as a function of time (in weeks).

Question?

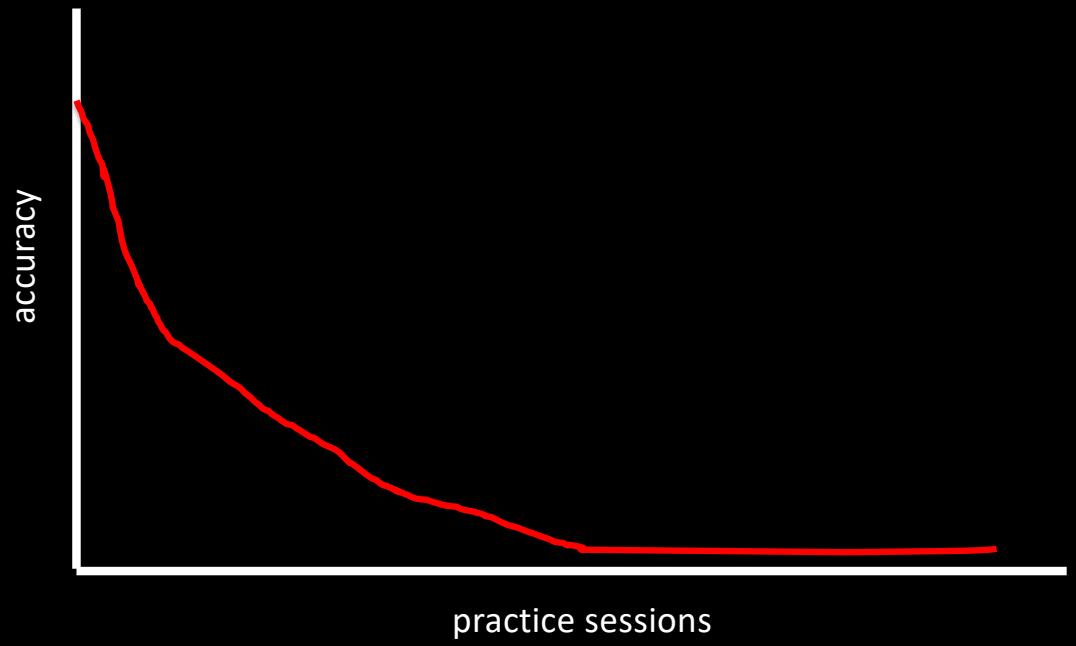


Imagine you study for a course. Using the plot outline above, sketch a graph of how how much you would learn as a function of time (in weeks).

Question?

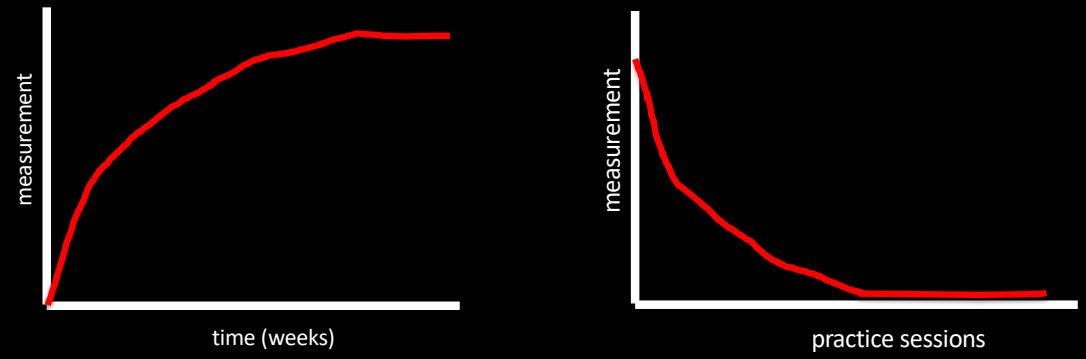
Imagine a course instructor cruelly made you practice golf putting for a semester. Sketch a plot of how the distance of the end of the putt from the hole would change as a function of practice.

Question?



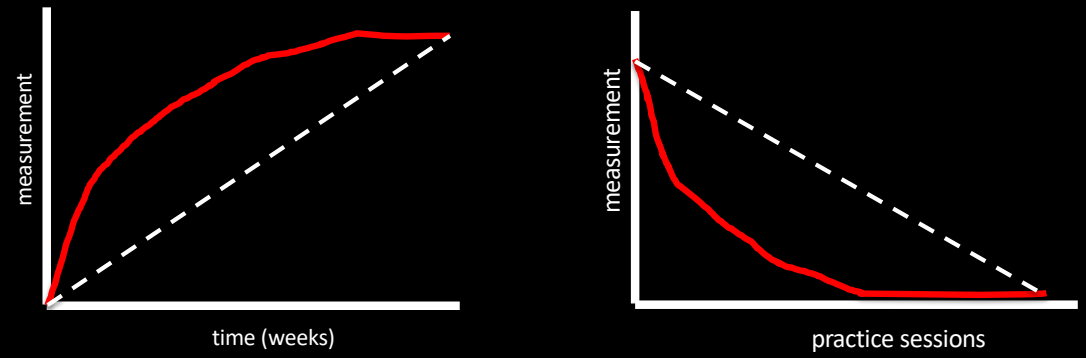
Imagine a course instructor cruelly made you practice golf putting for a semester. Sketch a plot of how the distance of the end of the putt from the hole would change as a function of practice.

The Power Law of Practice



So why the POWER Law of Practice?

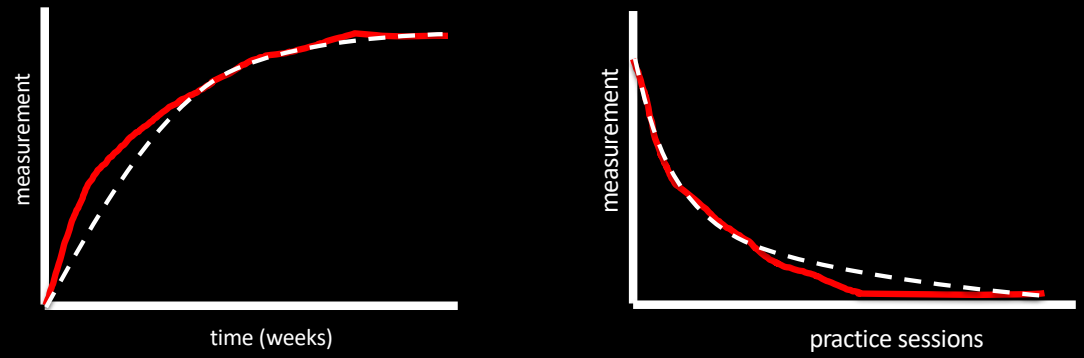
The Power Law of Practice



Its not a linear function:

$y = mx + b$

The Power Law of Practice

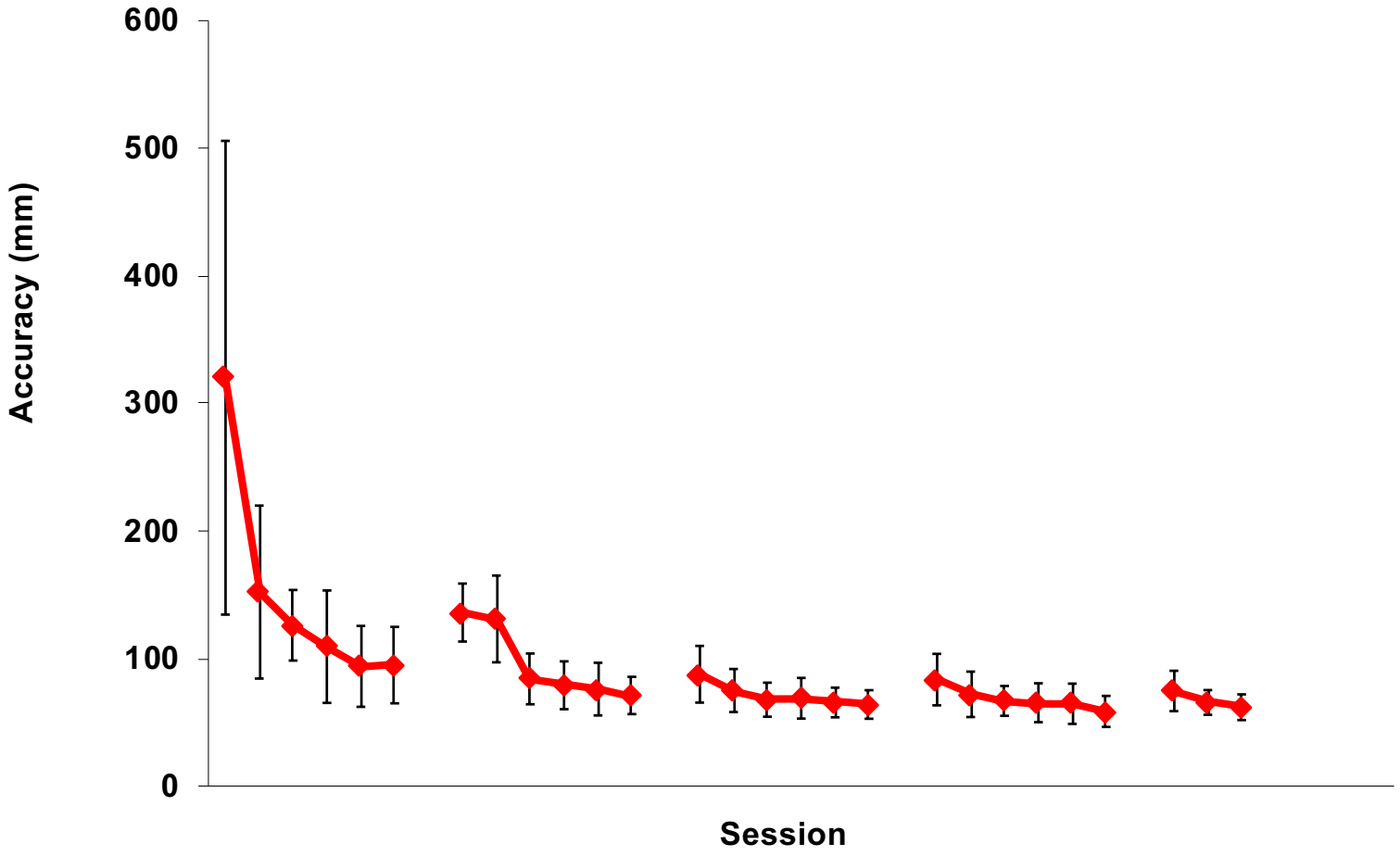


The shape of the learning curve is best described as a “non-linear” function

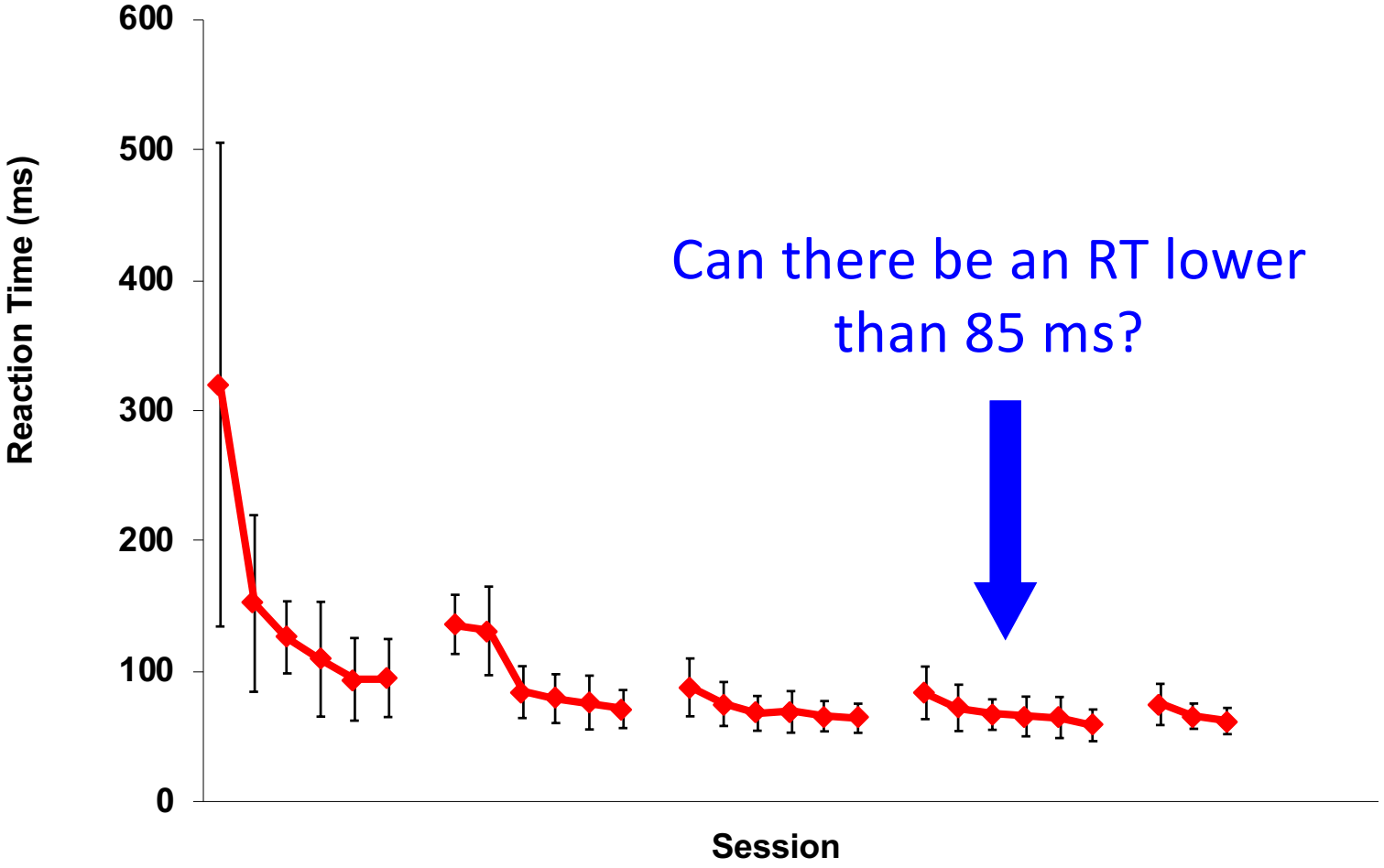
$y = mx^n + b$

Think back to high-school – this is a power term and if its value is not “1” then this is a non-linear function (quadratic, cubic, etc)

Restart Cost



Floor Effect



Repetition and Expertise

Expert Ability is Domain / Task Specific

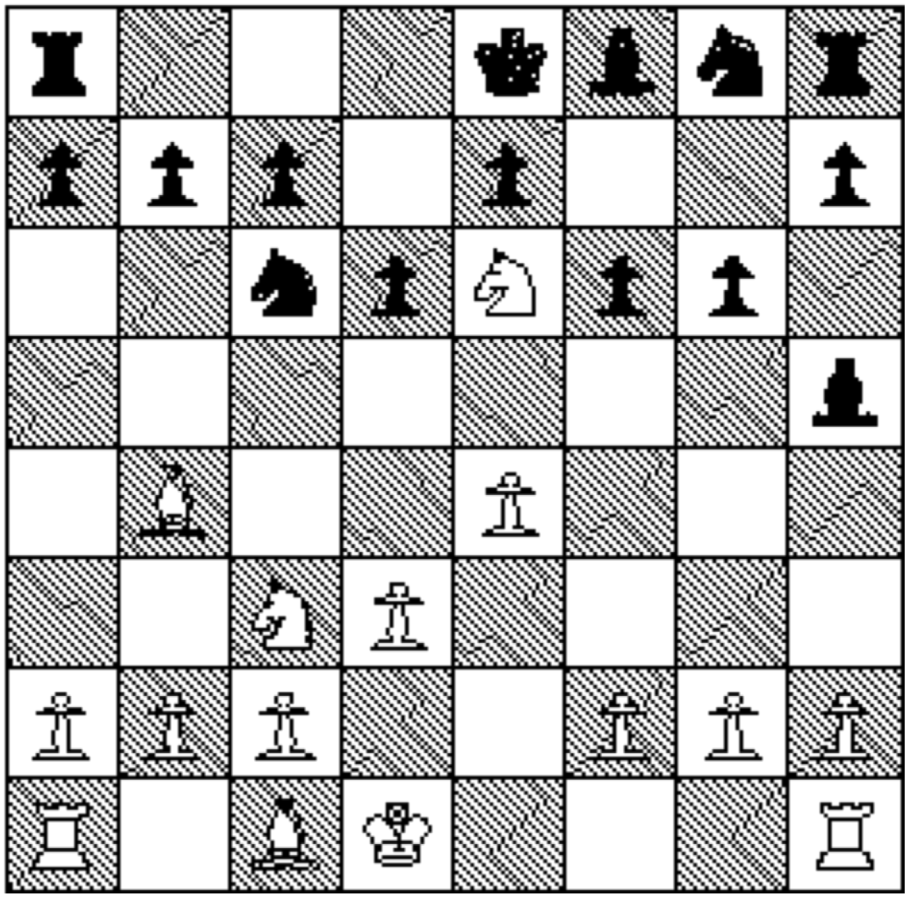
i.e. Enhanced Speed ≠ Enhanced RT

i.e. General vs Specific Perception

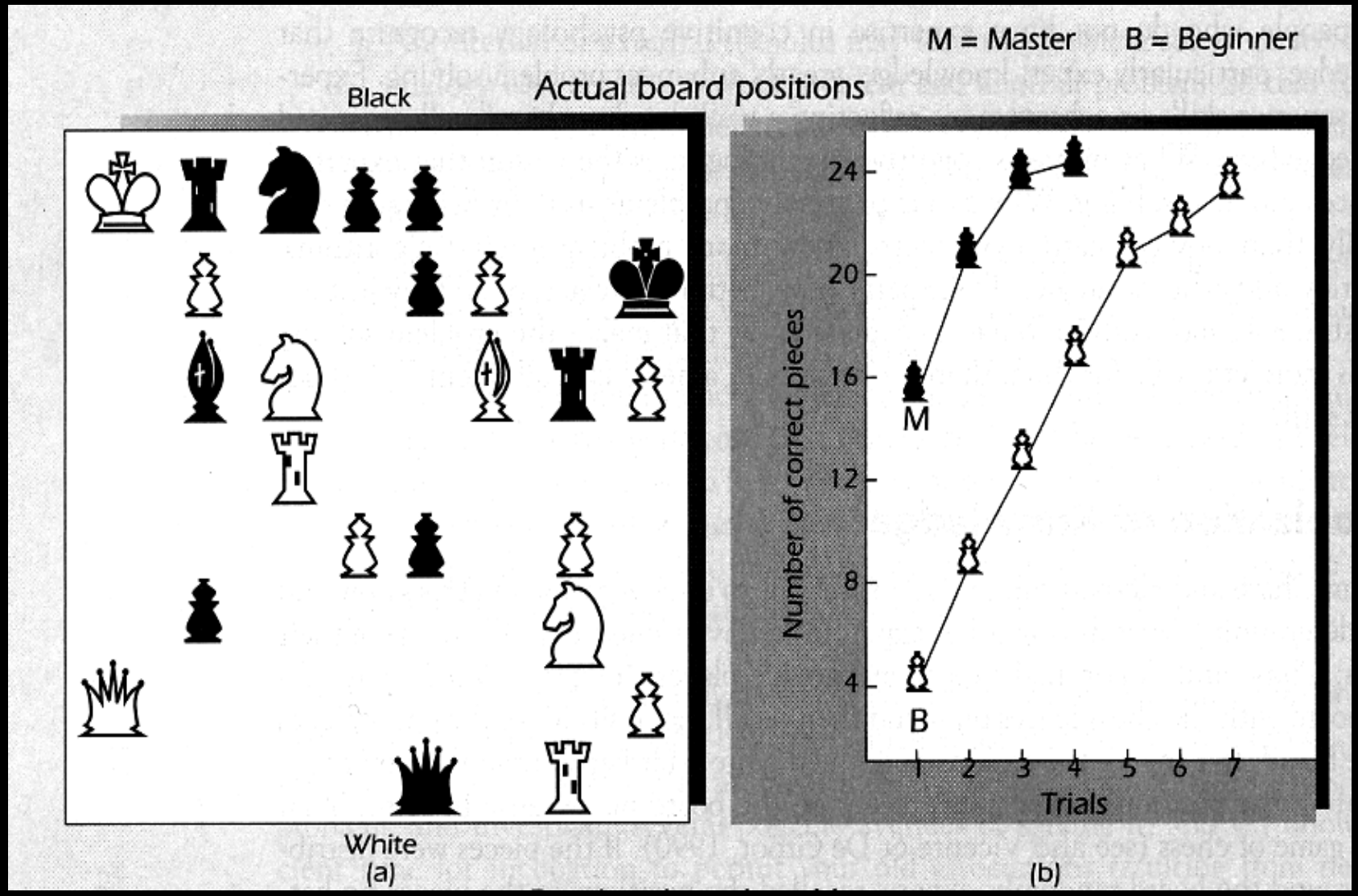
Starkes, 1987

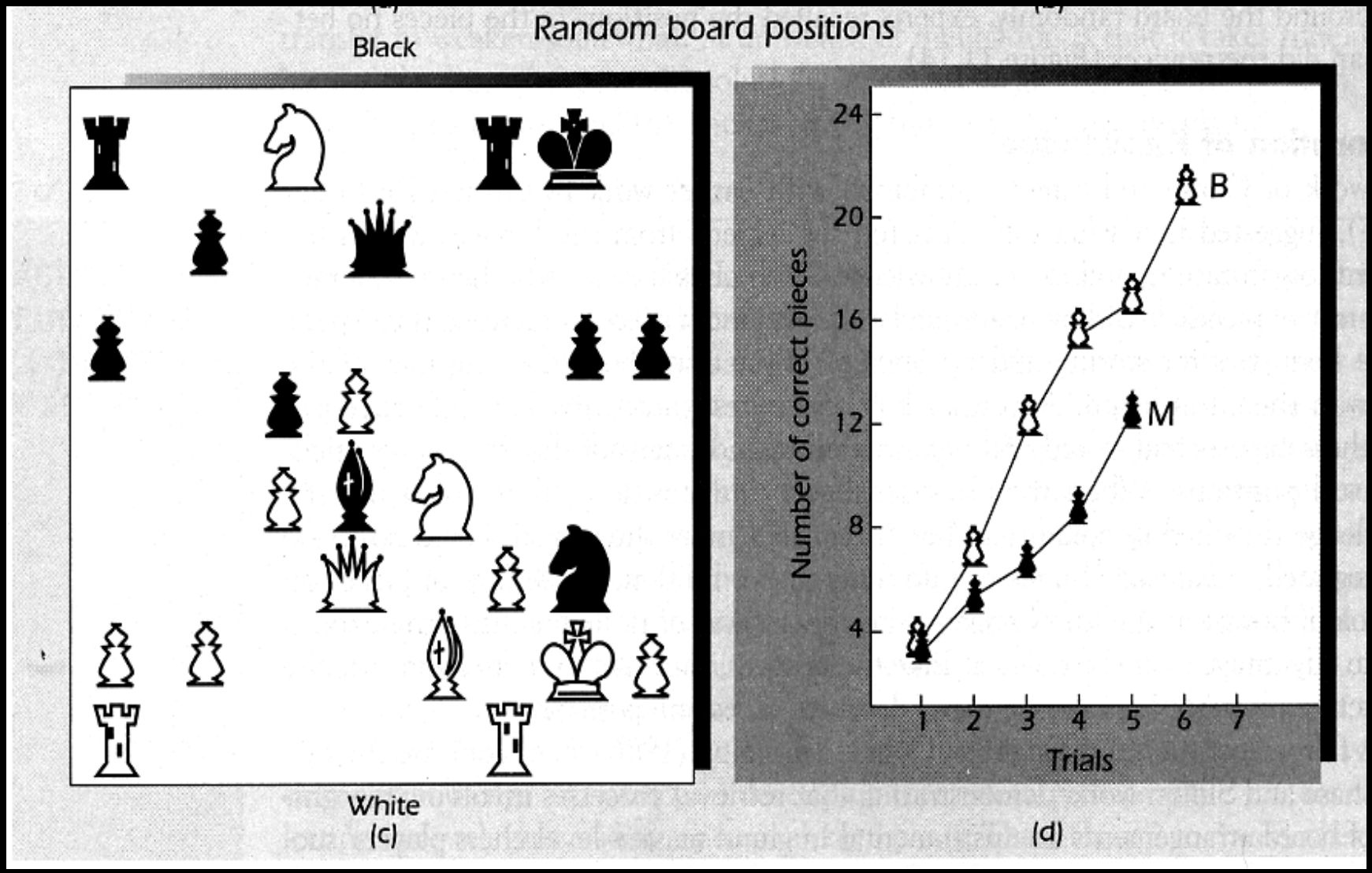
i.e. Cognitive Recall Ability

Chase & Simon, 1973, Expert Chess Players

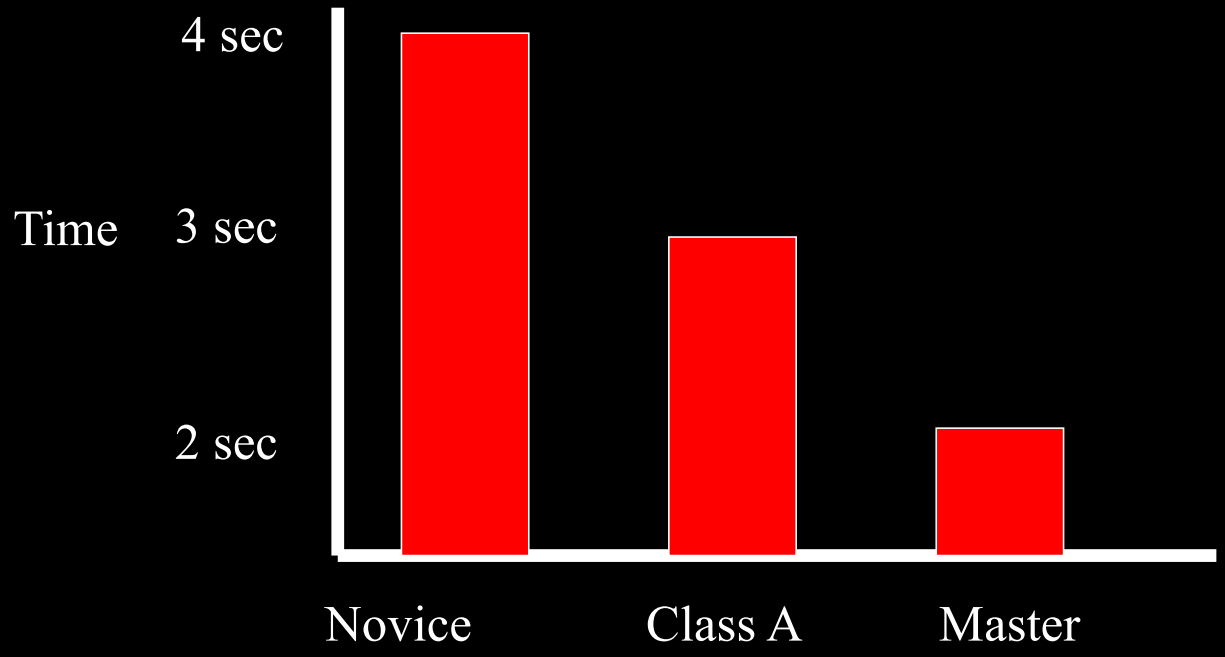



8
7
6
5
4
3
2
1
a b c d e f g h


M = Master
B = Beginner
Actual board positions
Black
White
(a)
Number of correct pieces
24
20
16
12
8
4
M
B
1
2
3
4
5
6
7
Trials
(b)


Random board positions
Black
White
(c)
Number of correct pieces
24
20
16
12
8
4
B
M
1
2
3
4
5
6
7
Trials
(d)

Look-back Time

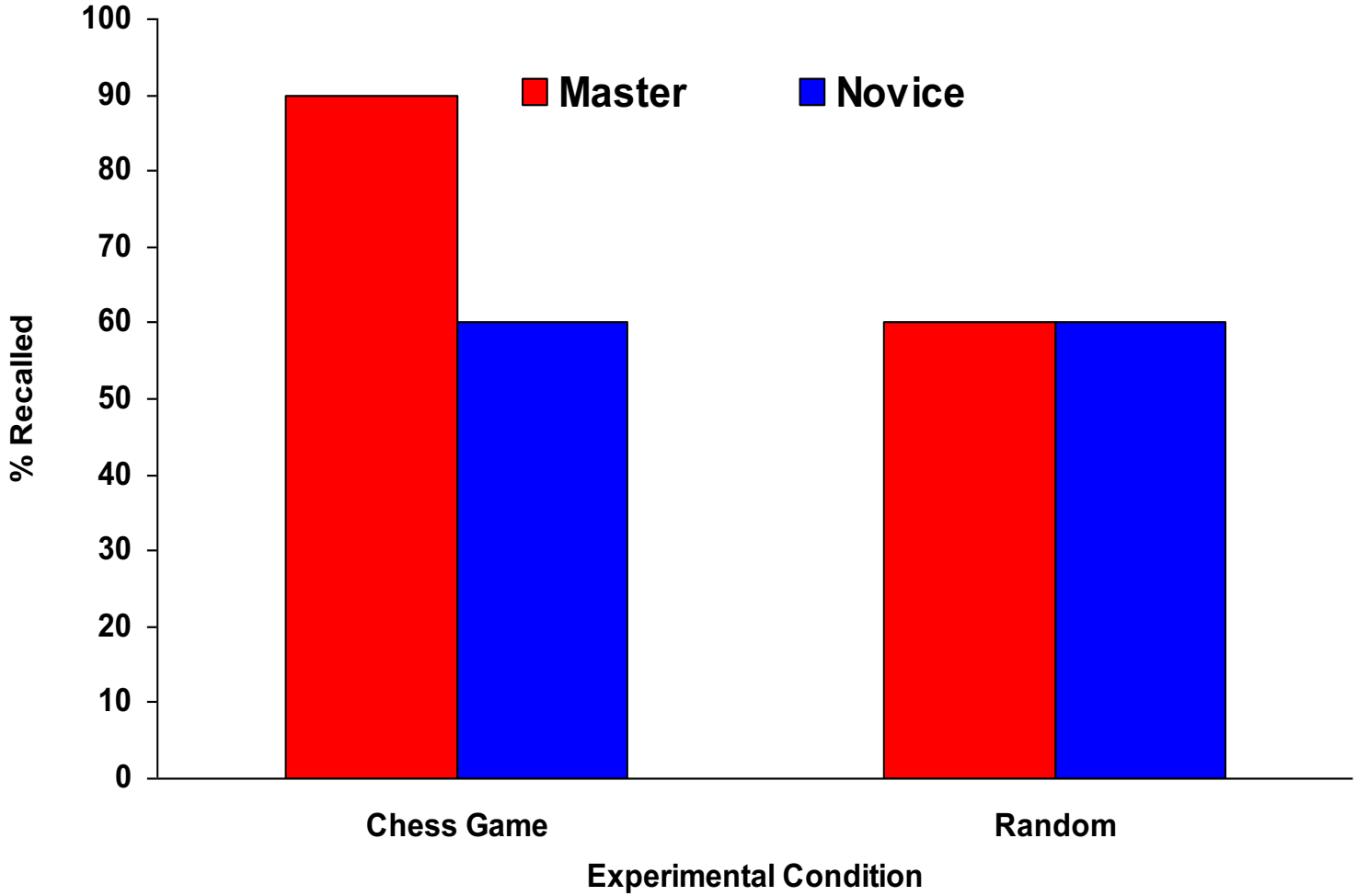


Time spent studying board decreased with increasing expertise

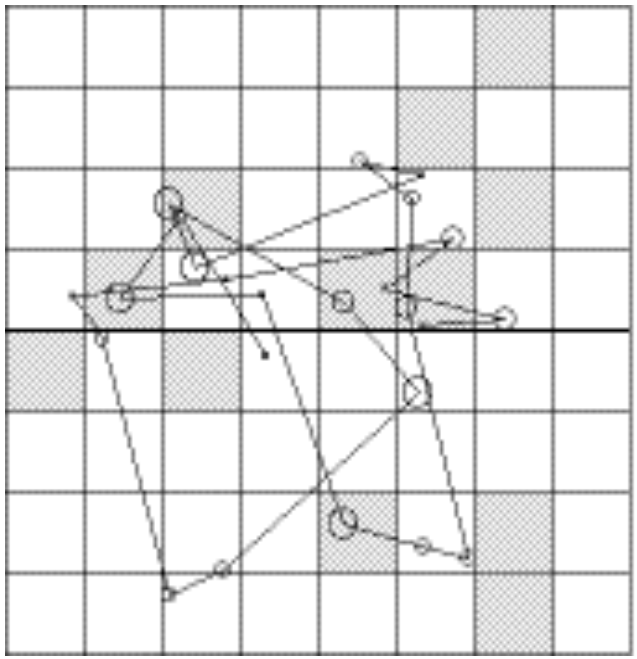
Long-term recall for games

Player	% Correct	Pieces/chunk	Chunks/Position
Master	99	4.0	7.7
Class A	95	2.5	10.5
Beginner	90	1.2	22.8

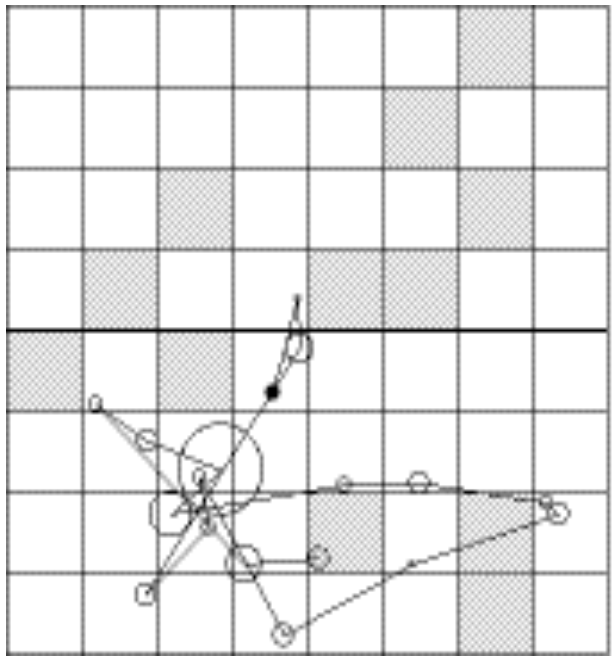
Simon & Chase


100
90
80
70
60
50
40
30
20
10
0
% Recalled
Master
Novice
Chess Game
Random
Experimental Condition

Expert Eye Scan



Novice Eye Scan



Deliberate Practice

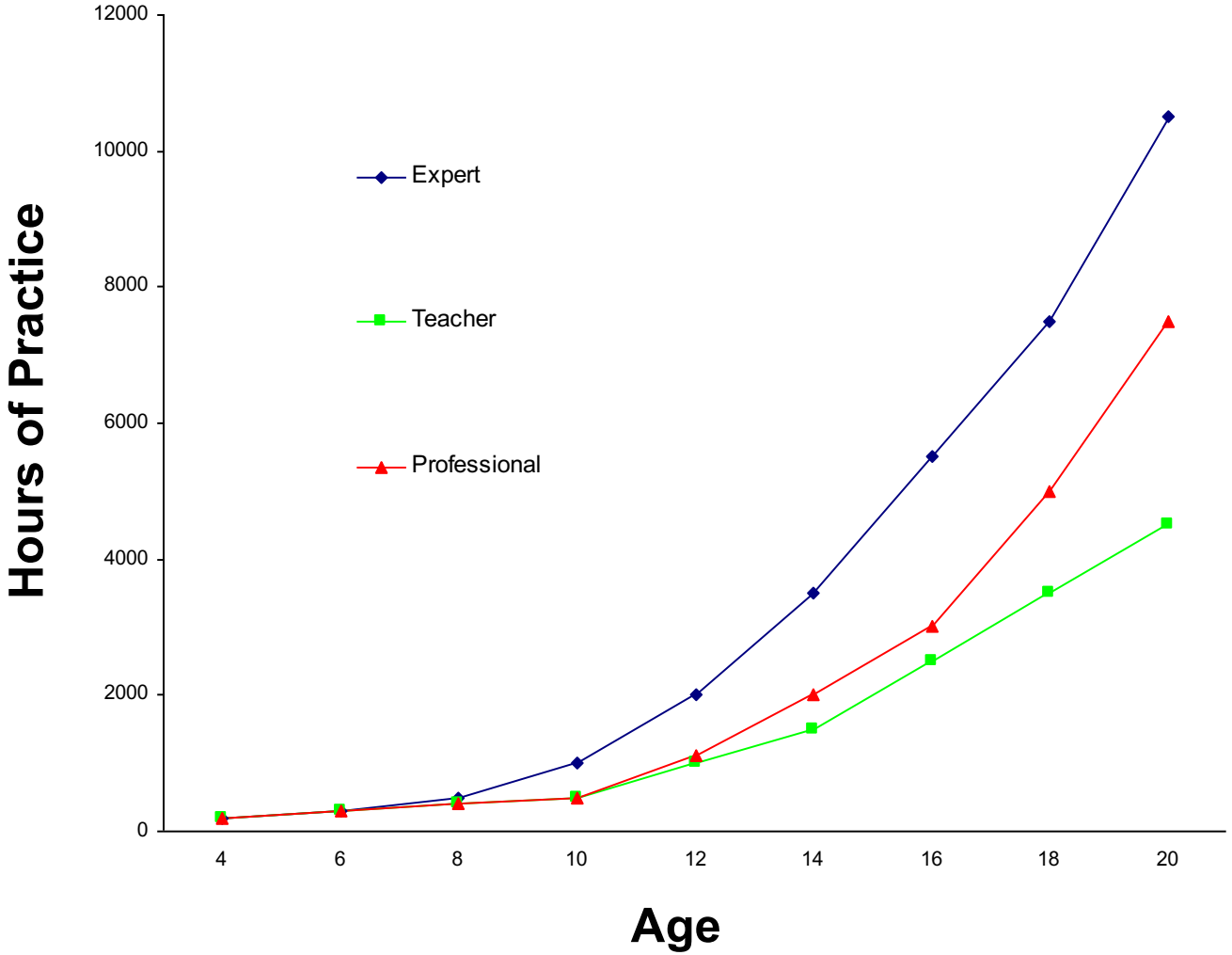
Ericsson, Krampe, & Tesch-Romer (1993)
Expertise in Music: Violin and Piano

Examined Experts, Professionals, Teachers

Played Violin or Piano

No differences in:
Complex Movement Coordination
Timing Tasks

Ericsson, Krampe, & Tesch-Romer (1993)



What accounts for the differences?

Time spent engaged in
DELIBERATE PRACTICE

Characteristics of Deliberate Practice

Highly Structured Activity

Specific / Relevant

Weaknesses Targeted / Performance Monitored

Effortful

Unenjoyable

No Reward

Deliberate Practice

10 years or 10,000 hours to become an expert

This number is lower in sport (5000 – 10000+)

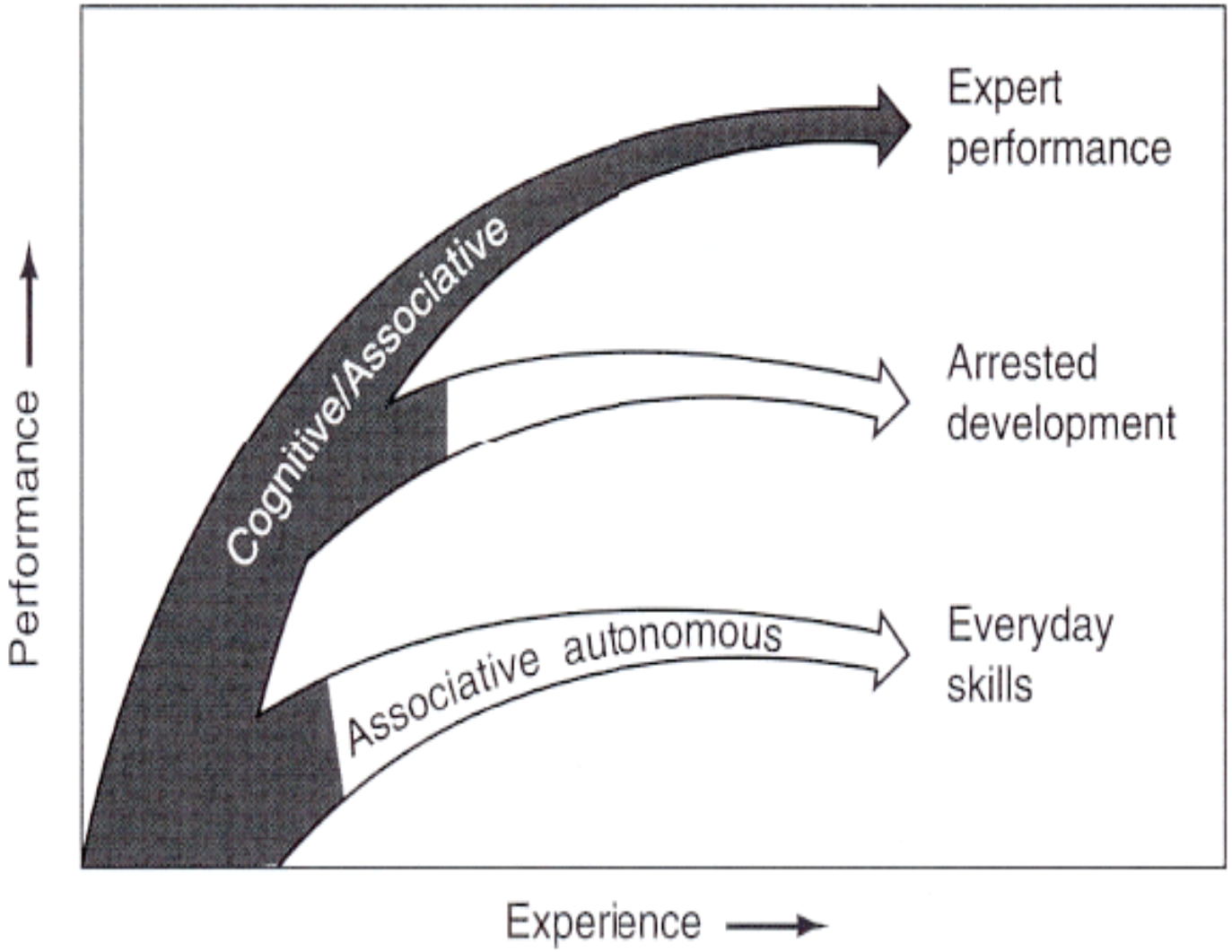
Resisting Automaticity

Cognitive/Associative phase

- Experts fight off automaticity through increasingly complex representations

Automaticity Phase

- Novices reach “arrested development”

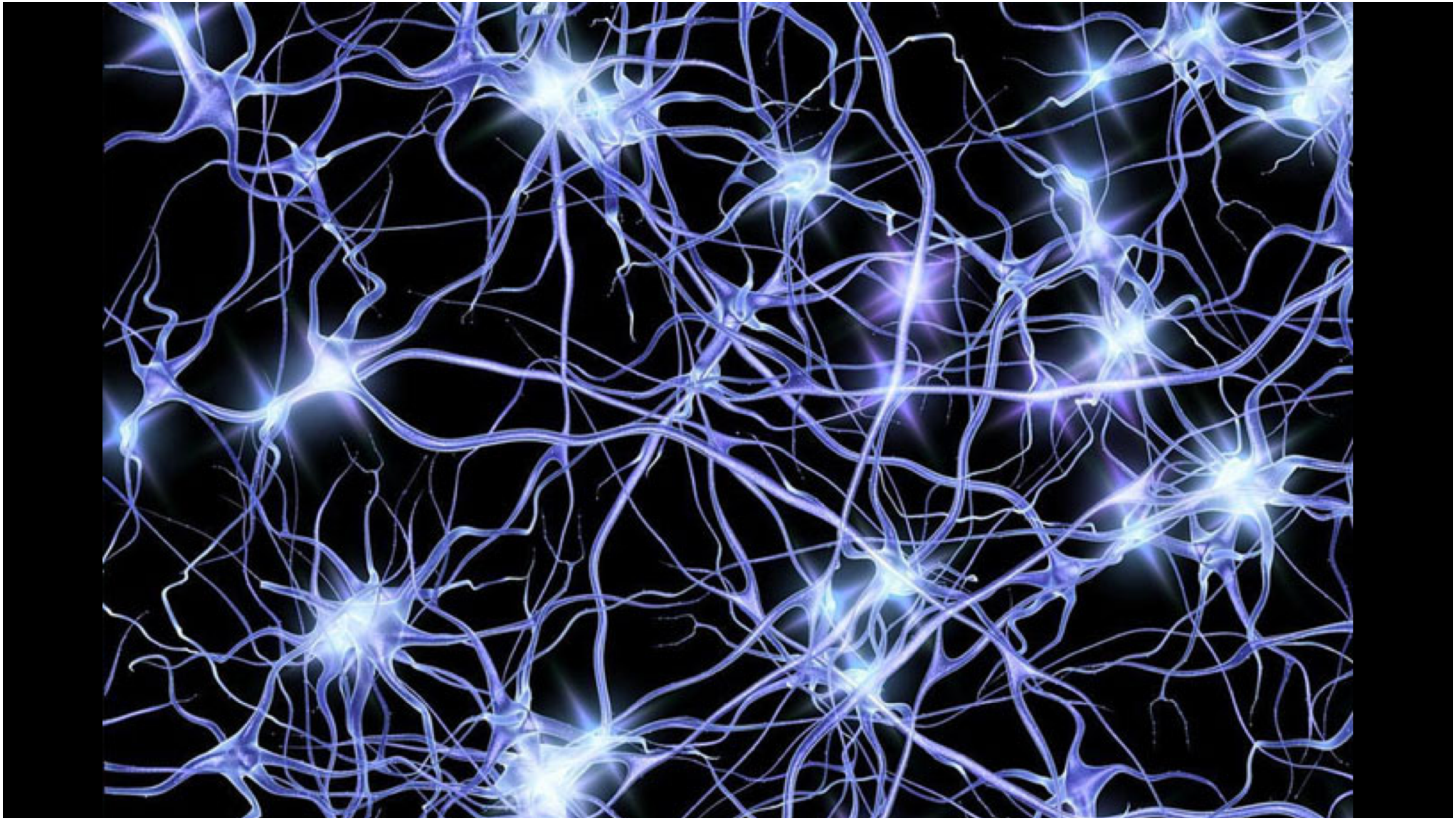

Expert
performance
Arrested
development
Everyday
skills
Cognitive/Associative
Associative autonomous
Performance
Experience

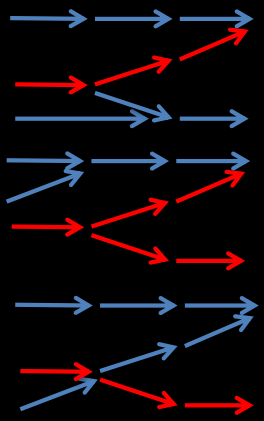
How we learn?

1. Repetition

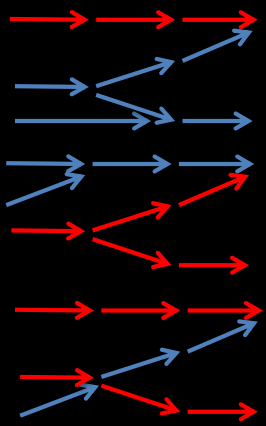
But why?

What is learned?

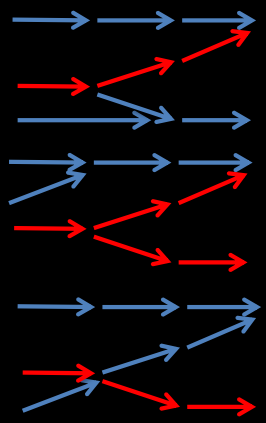


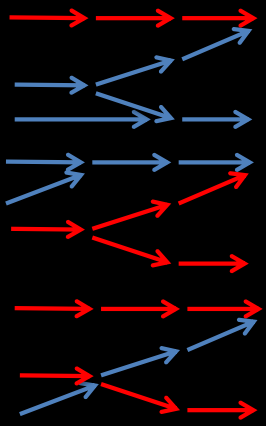


= DOG



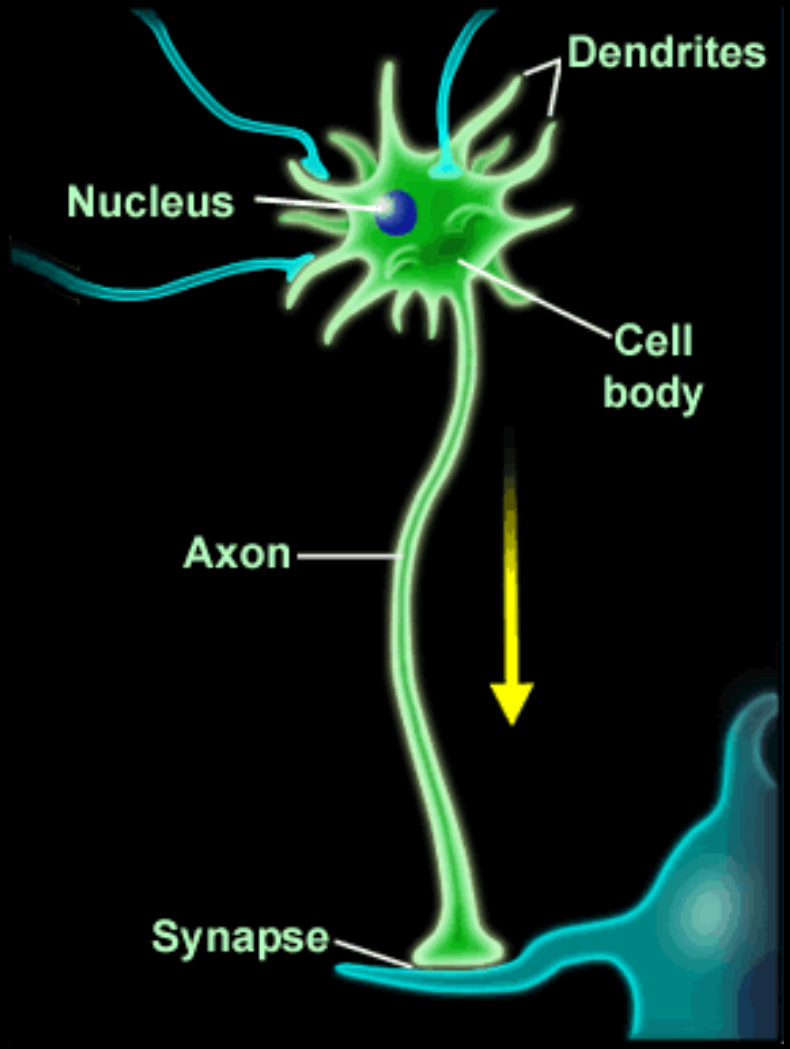
= CAT

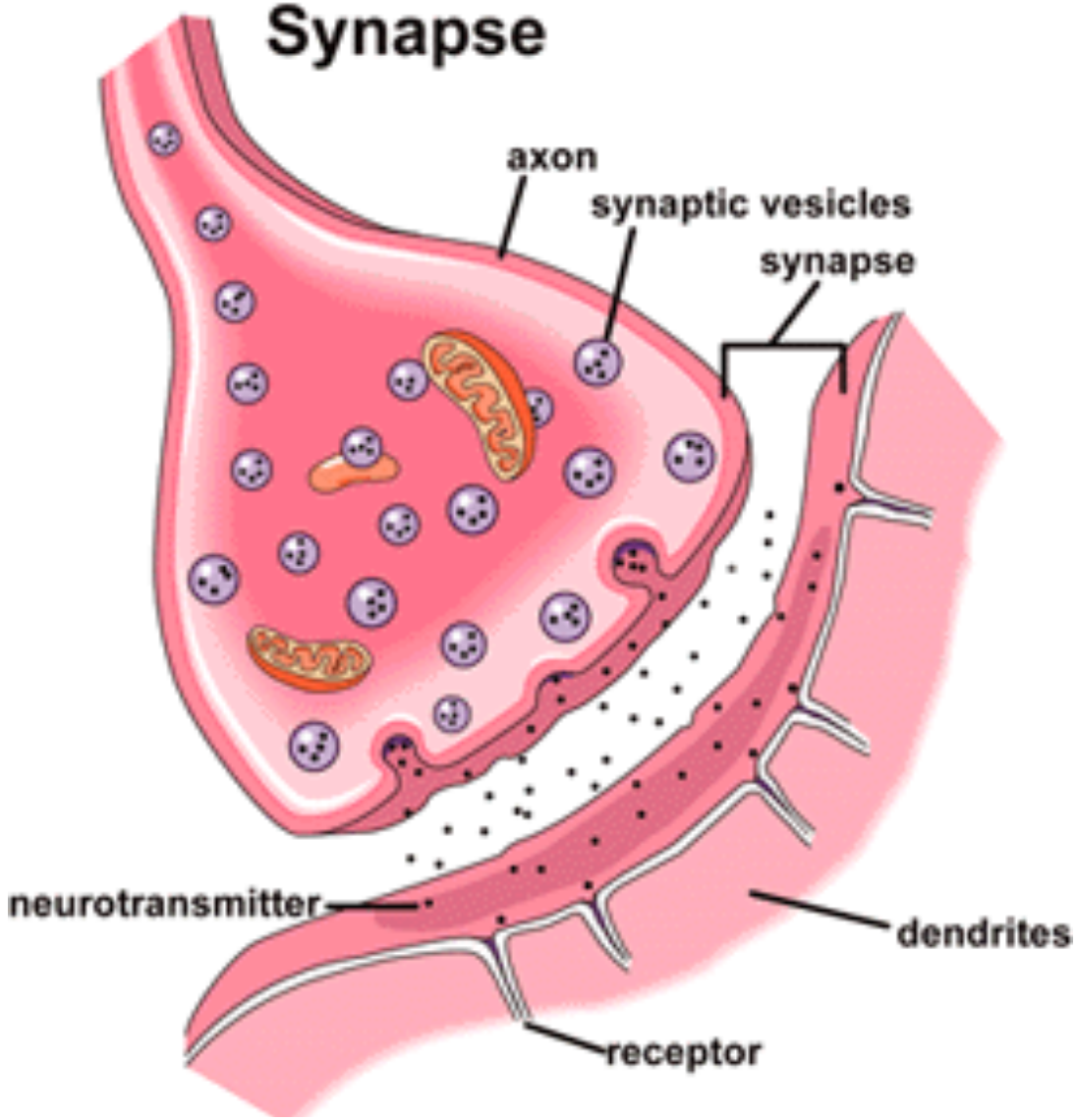





CLANK
4
22
TBJ

A bit about neurons…


Dendrites
Nucleus
Cell body
Axon
Synapse


Synapse
axon
synaptic vesicles
synapse
neurotransmitter
dendrites
receptor

Hebbian Learning

Hebb (1949)

"When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased"

"The organization of behavior"

Hebb's Rule

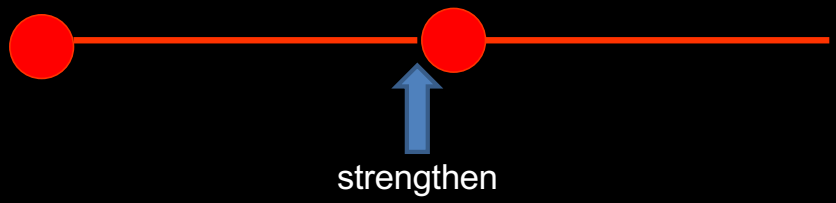
From a learning perspective, the goal of the system is to increase the strength of the neural connections that are effective.

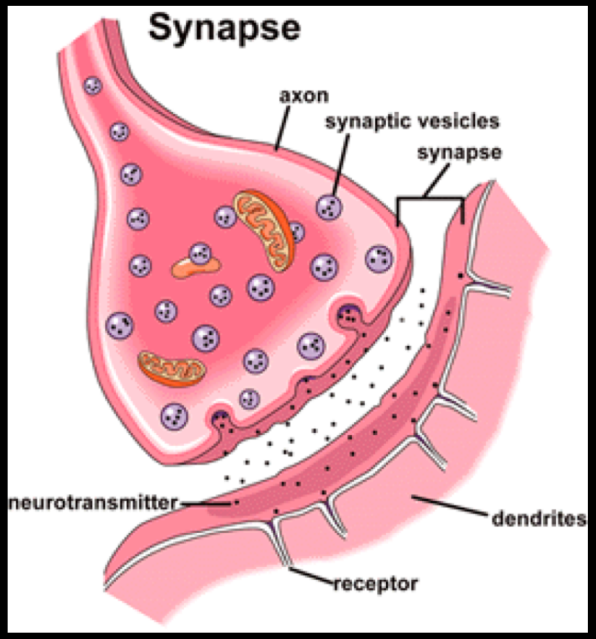
Hebb's Rule:

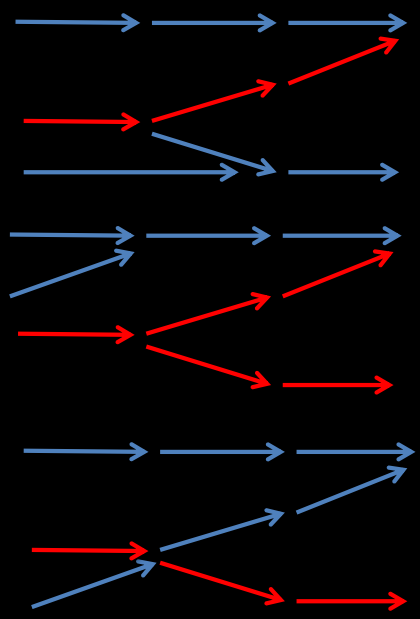
"neurons that fire together wire together"

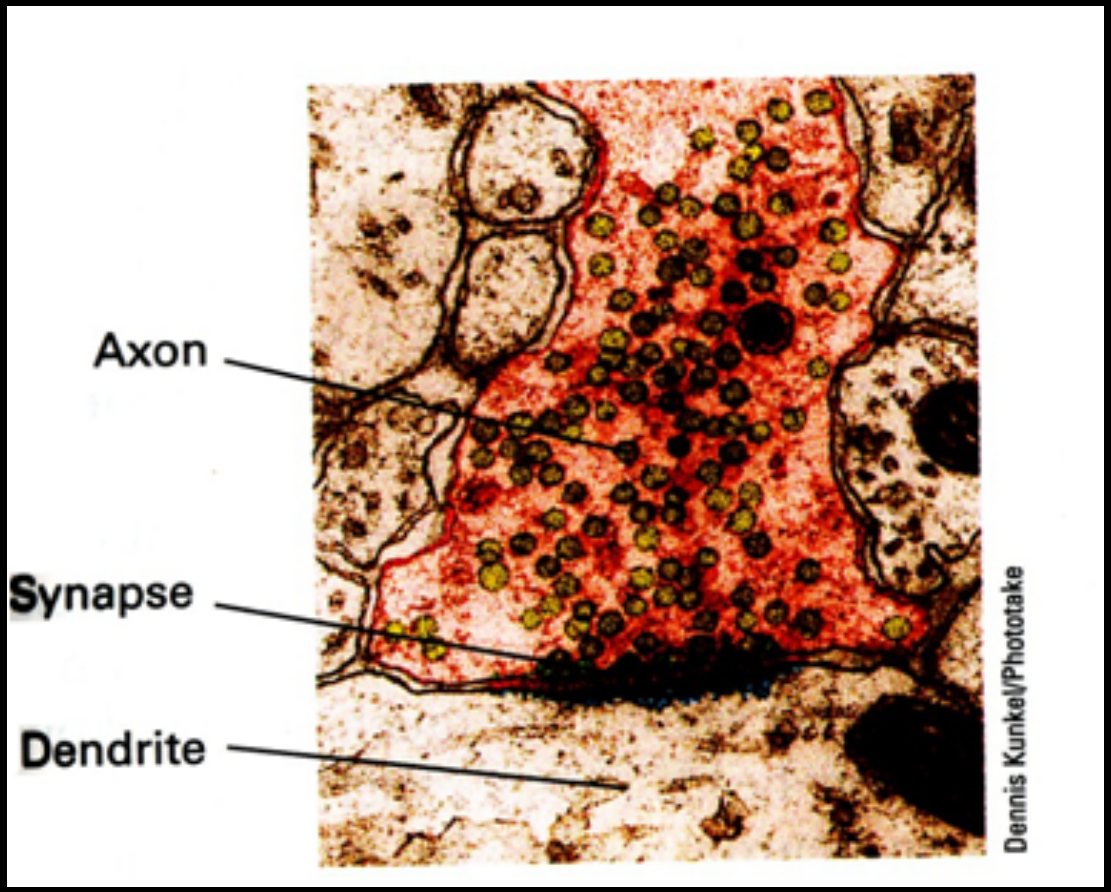
“Cat”

“Dog”

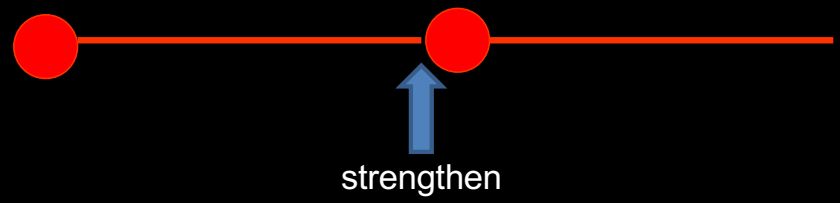

strengthen

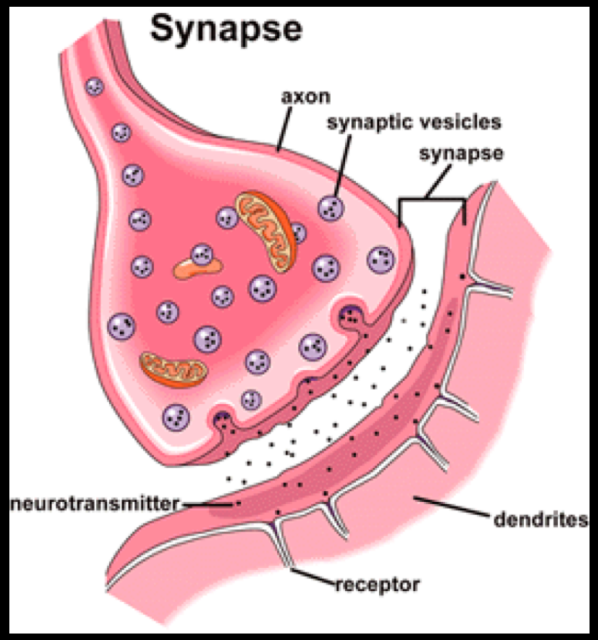

Synapse
axon
synaptic vesicles
synapse
neurotransmitter
dendrites
receptor





How does this change?





HOW?

“Synaptic Plasticity”

Definition: Learning

Changes in internal processes (neural connections are strengthened) that are reflected by relatively stable changes in performance (because these changes are relatively permanent).