# 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

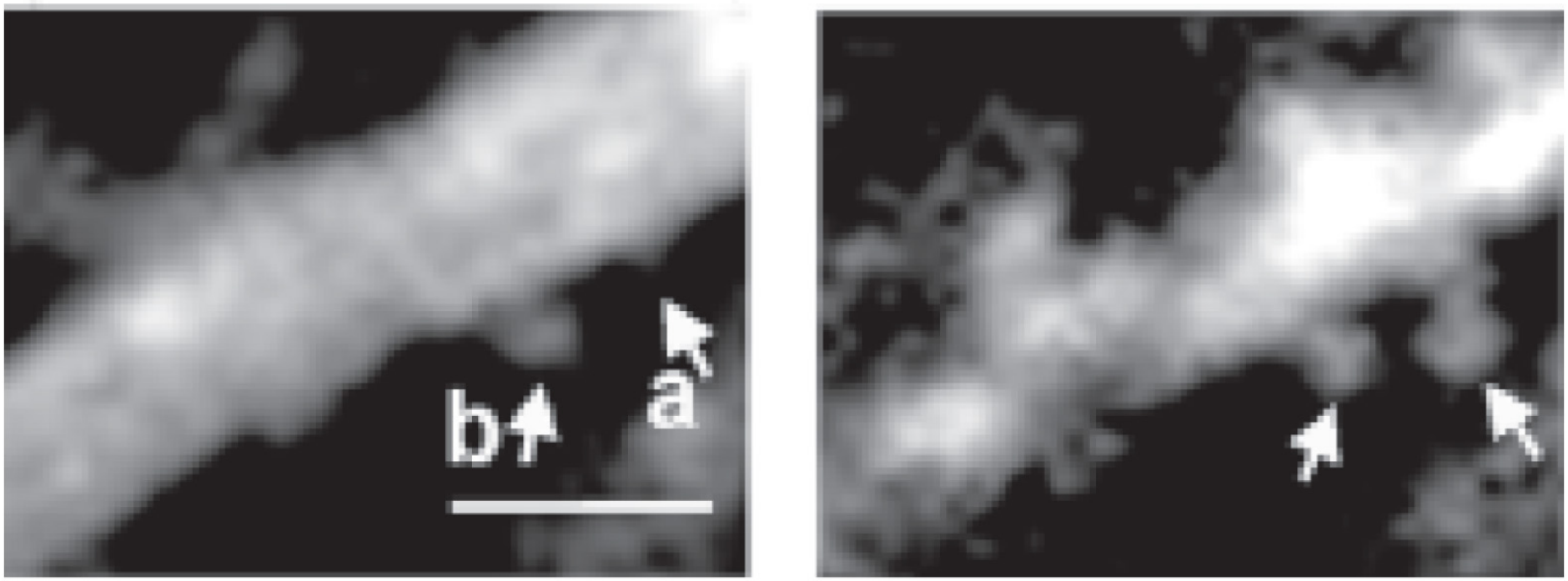
**Week Five: How We Can Improve Learning**
- **Topic 1. Distributed Practice, Random Practice, Variable Practice**
- **Topic 2. Specificity of Practice, Part-Whole Practice, Mental Imagery**

**Week Six: How We Can Improve Learning: March 13th**
- **Topic 1. Sleep, Diet, and Exercise**
- **Topic 2. Age, Learning Disorders**

How do we learn?

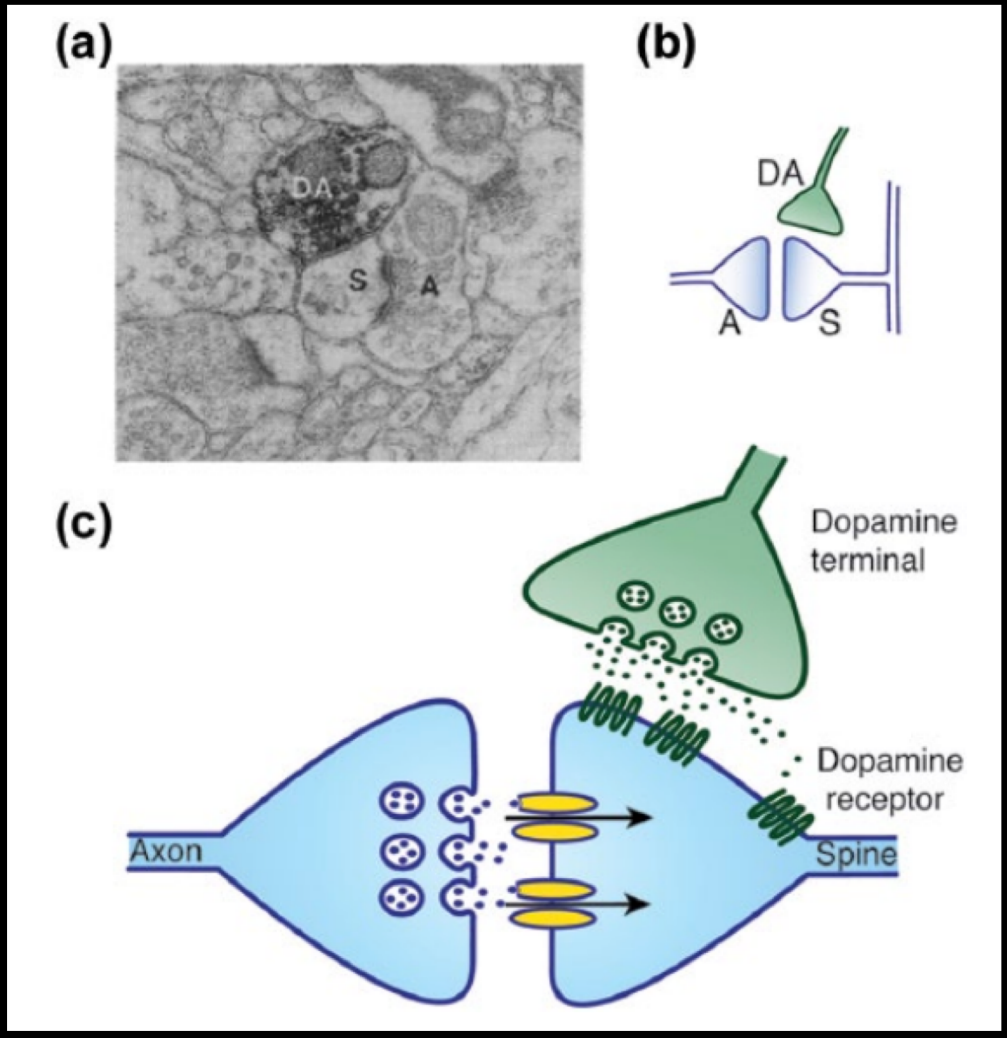
# REPETITION and FEEDBACK

# C7B12F10.eps



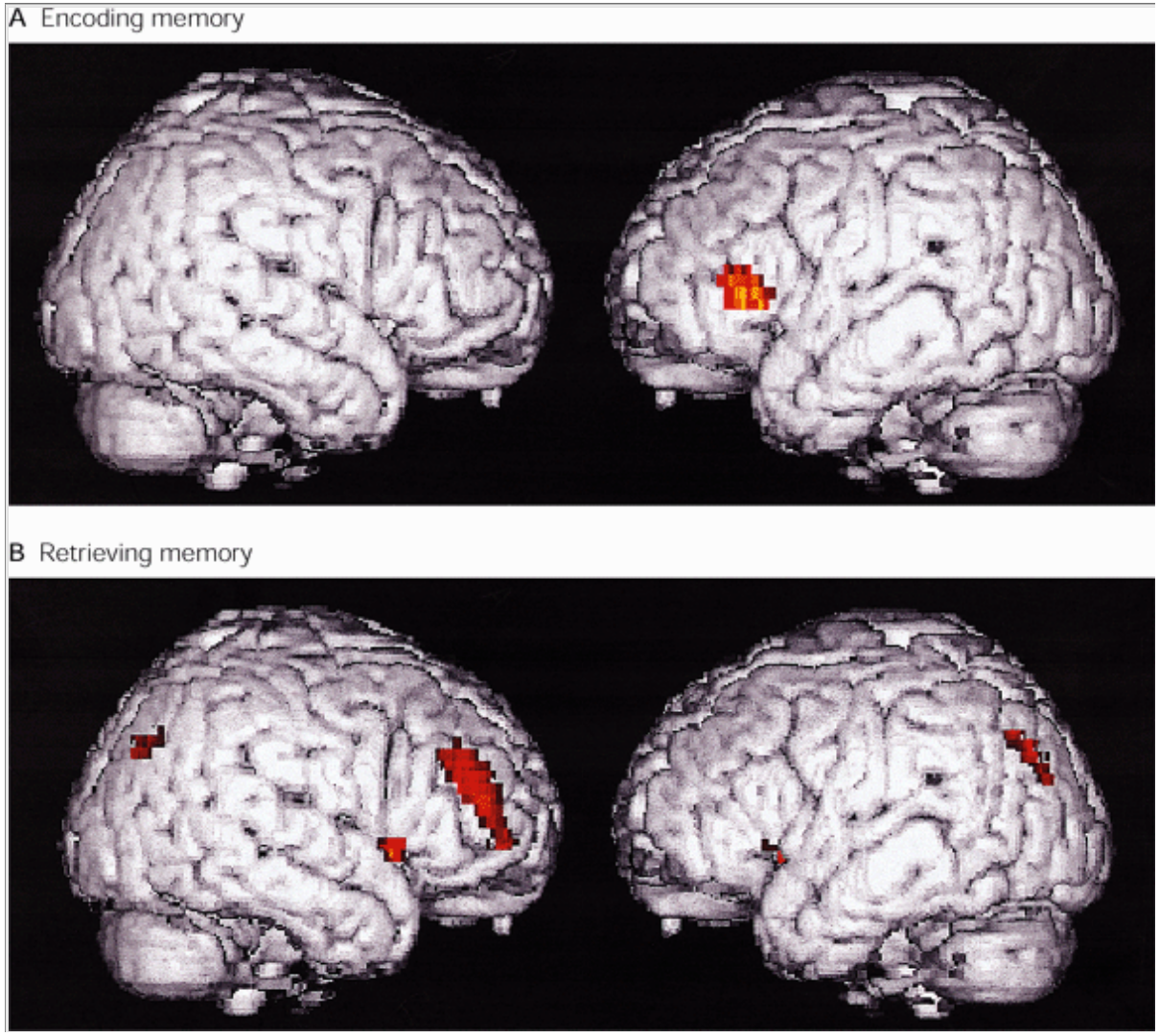

Before LTP

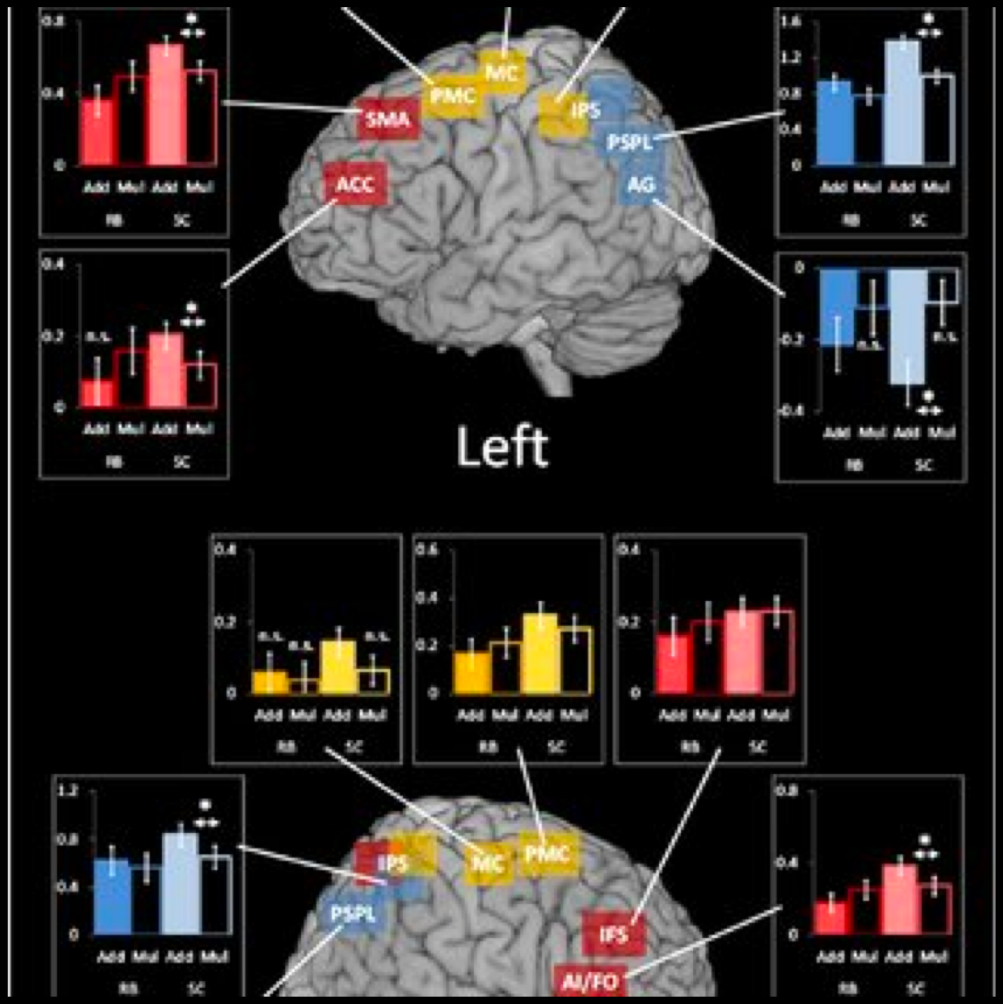
After LTP


(a)
DA
S
A
(b)
DA
A
S
(c)
Dopamine terminal
Dopamine receptor
Axon
Spine

What do we learn?

# EXPLICIT and IMPLICIT MEMORIES

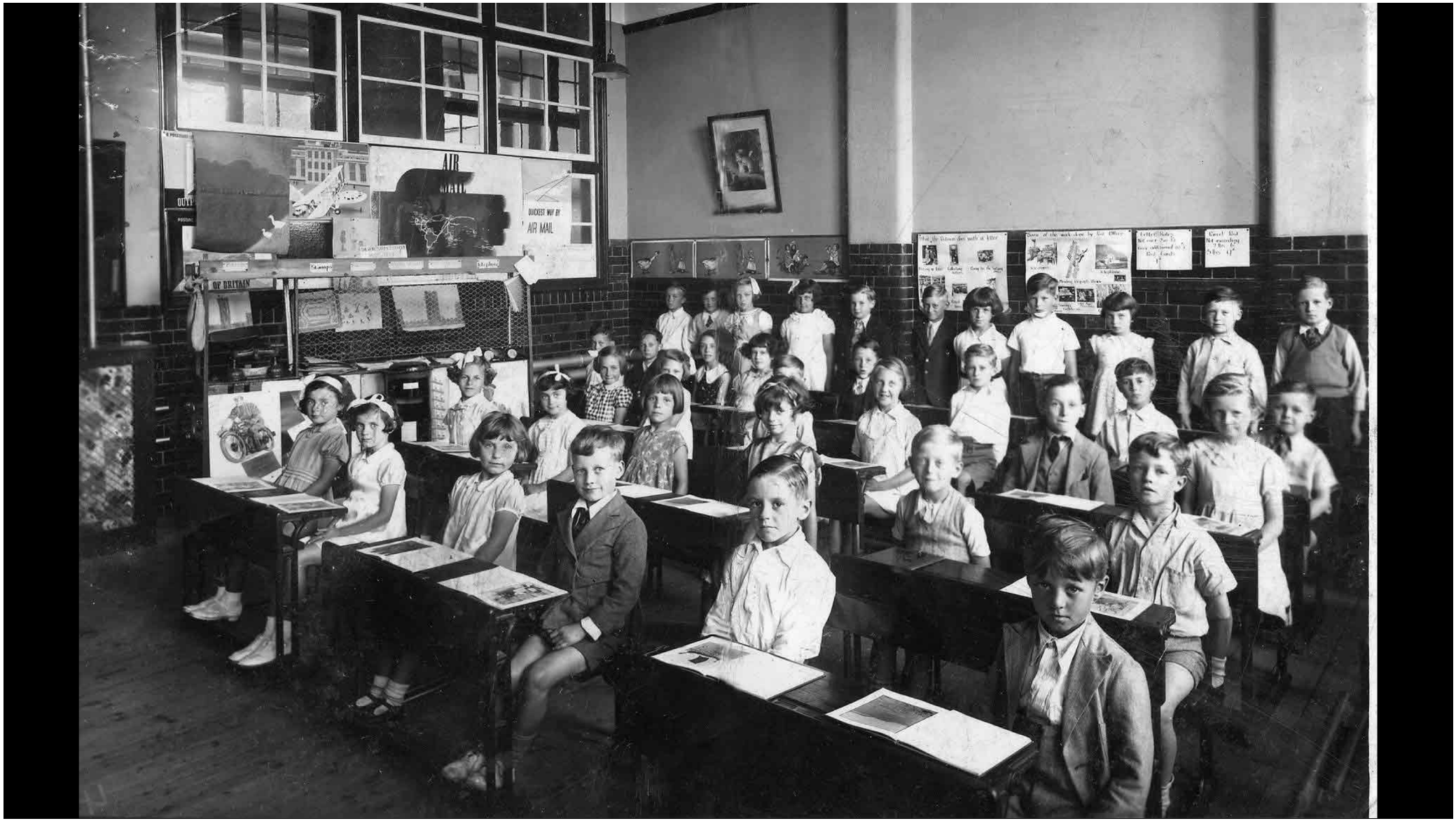

A Encoding memory
B Retrieving memory




# Procedural Memory

# How Can We Improve Learning?

## The Design of Learning Environments


AIR
QUICKEST WAY BY
AIR MAIL
OF BRITAIN

Science AAAS





**Blah?** Traditional lecture classes have higher undergraduate failure rates than those using active learning techniques, new research finds.

Wikimedia

# Lectures aren't just boring, they're Ineffective, too, study finds

By Aleszu Bajak | May. 12, 2014 , 3:00 PM

# Massed versus Distributed Practice

# Practice Scheduling

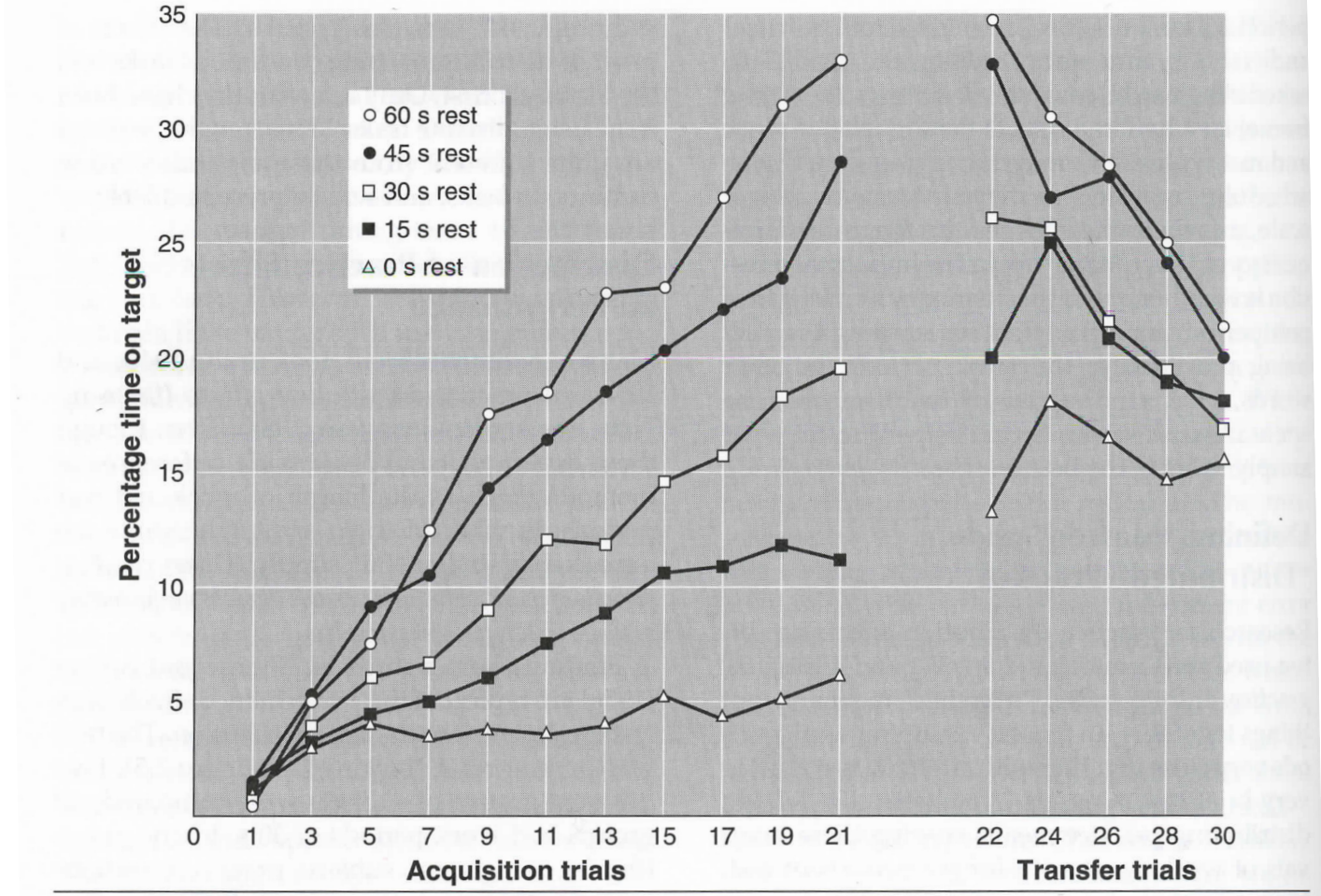
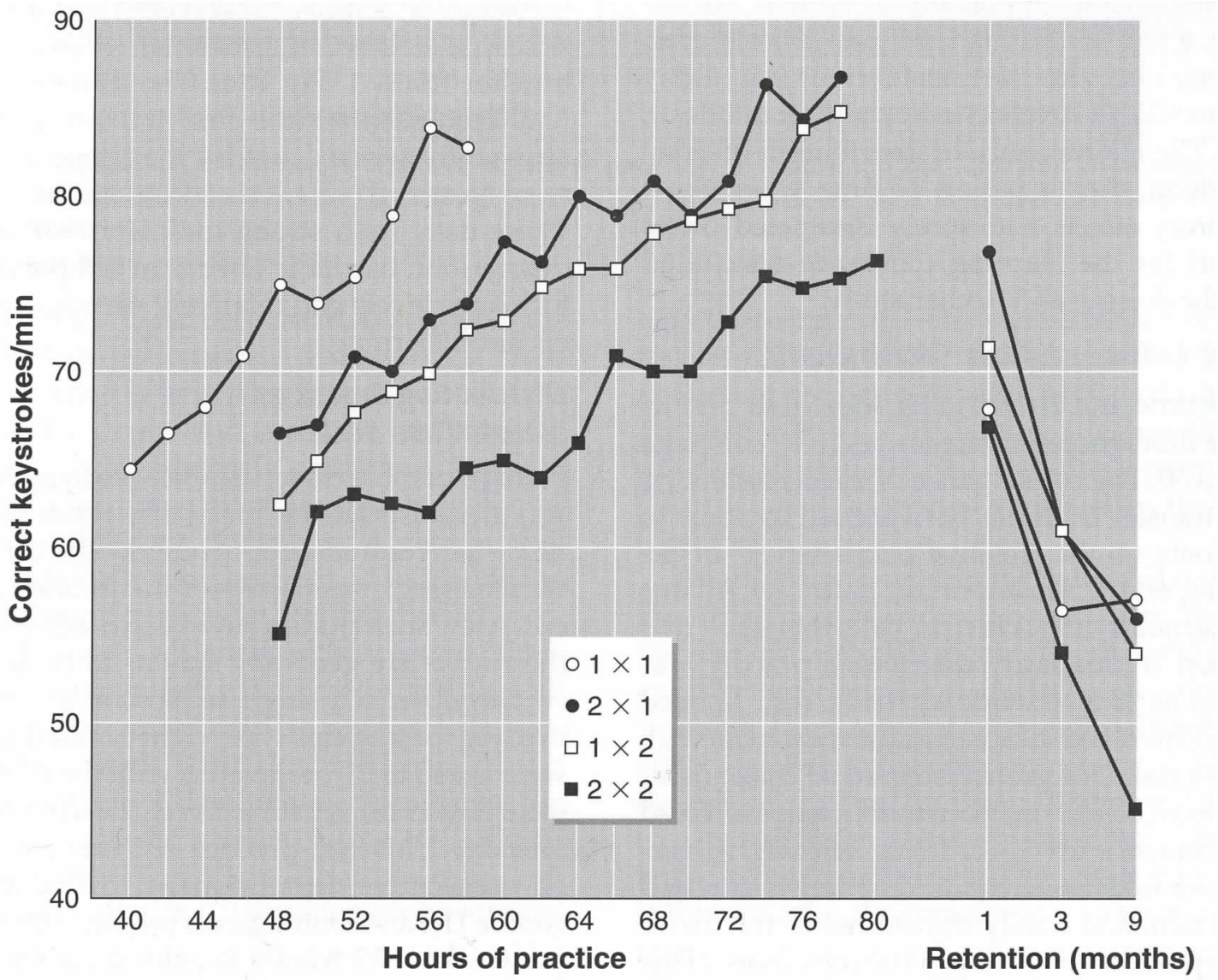
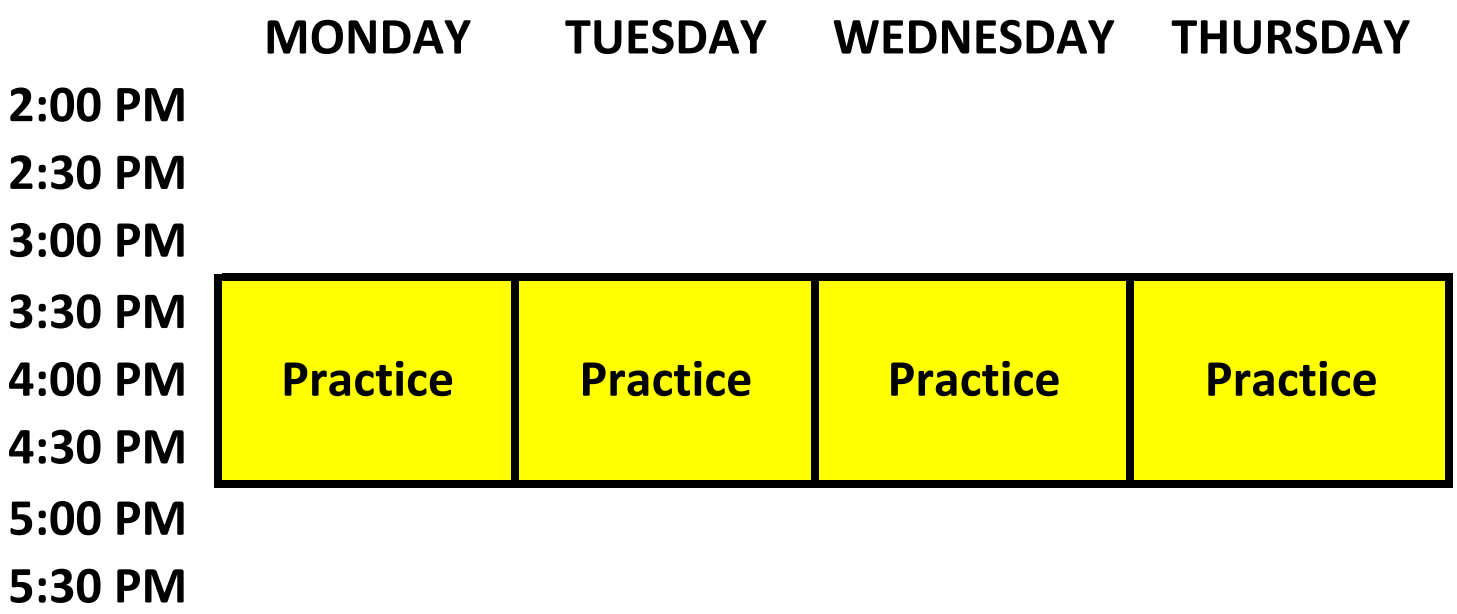
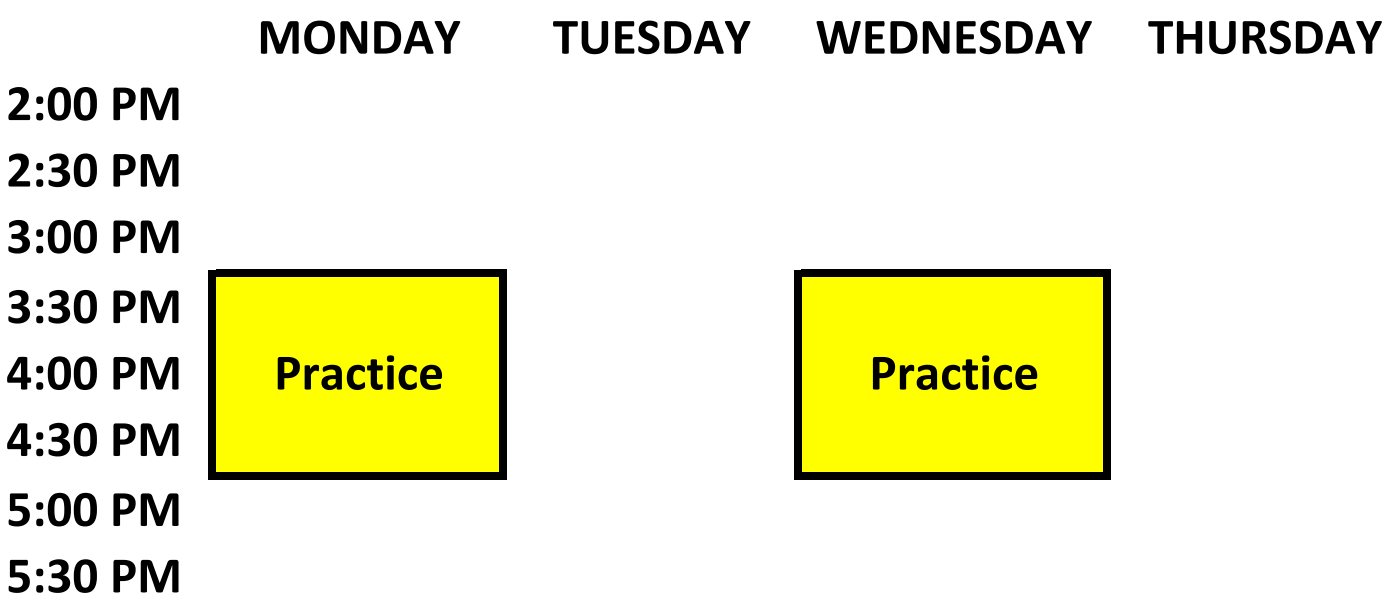



**Figure 11.3.** Distribution-of-practice effects on a pursuit rotor task in acquisition and retention. Trials were 30 s in duration, and separate groups received either 0, 15, 30, 45, or 60 s between practice trials. Retention trials were done with 0 s rest between trials.

Reprinted from Bourne and Archer, 1956.

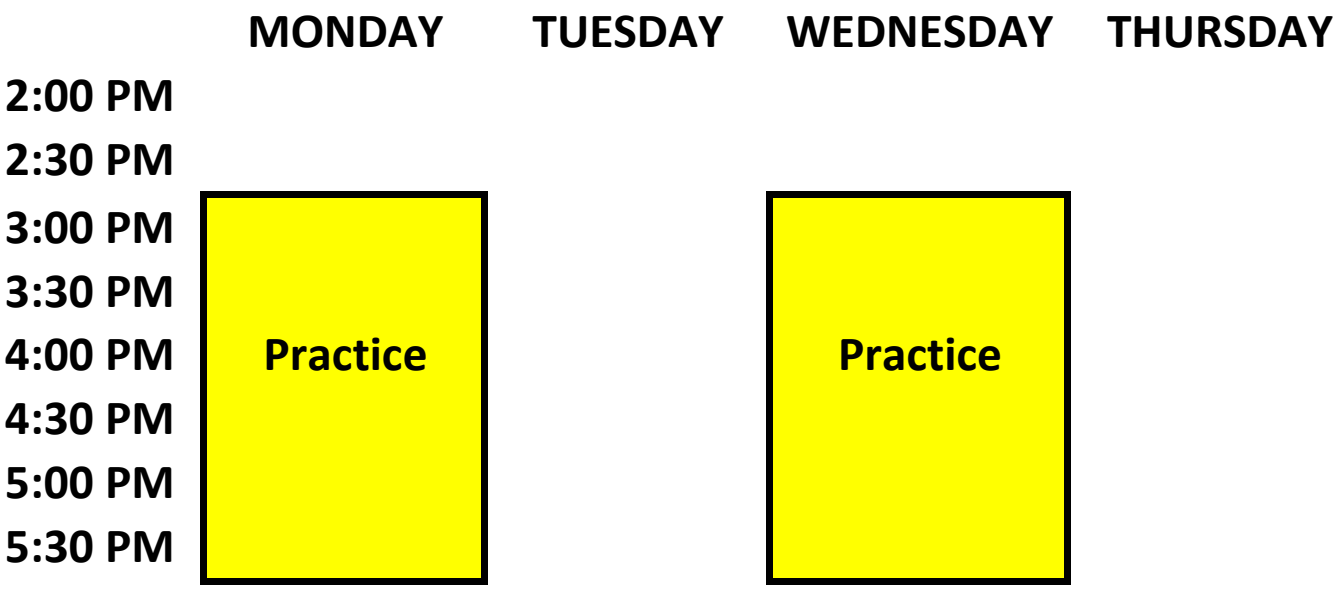

90
80
70
60
50
40
Correct keystrokes/min
40
44
48
52
56
60
64
68
72
76
80
1
3
9
Hours of practice
Retention (months)
1 × 1
2 × 1
1 × 2
2 × 2


MONDAY
TUESDAY
WEDNESDAY
THURSDAY
2:00 PM
2:30 PM
3:00 PM
3:30 PM
4:00 PM
4:30 PM
5:00 PM
5:30 PM
Practice
Practice
Practice
Practice


MONDAY
TUESDAY
WEDNESDAY
THURSDAY
2:00 PM
2:30 PM
3:00 PM
3:30 PM
4:00 PM
4:30 PM
5:00 PM
5:30 PM
Practice
Practice

# Tenet One

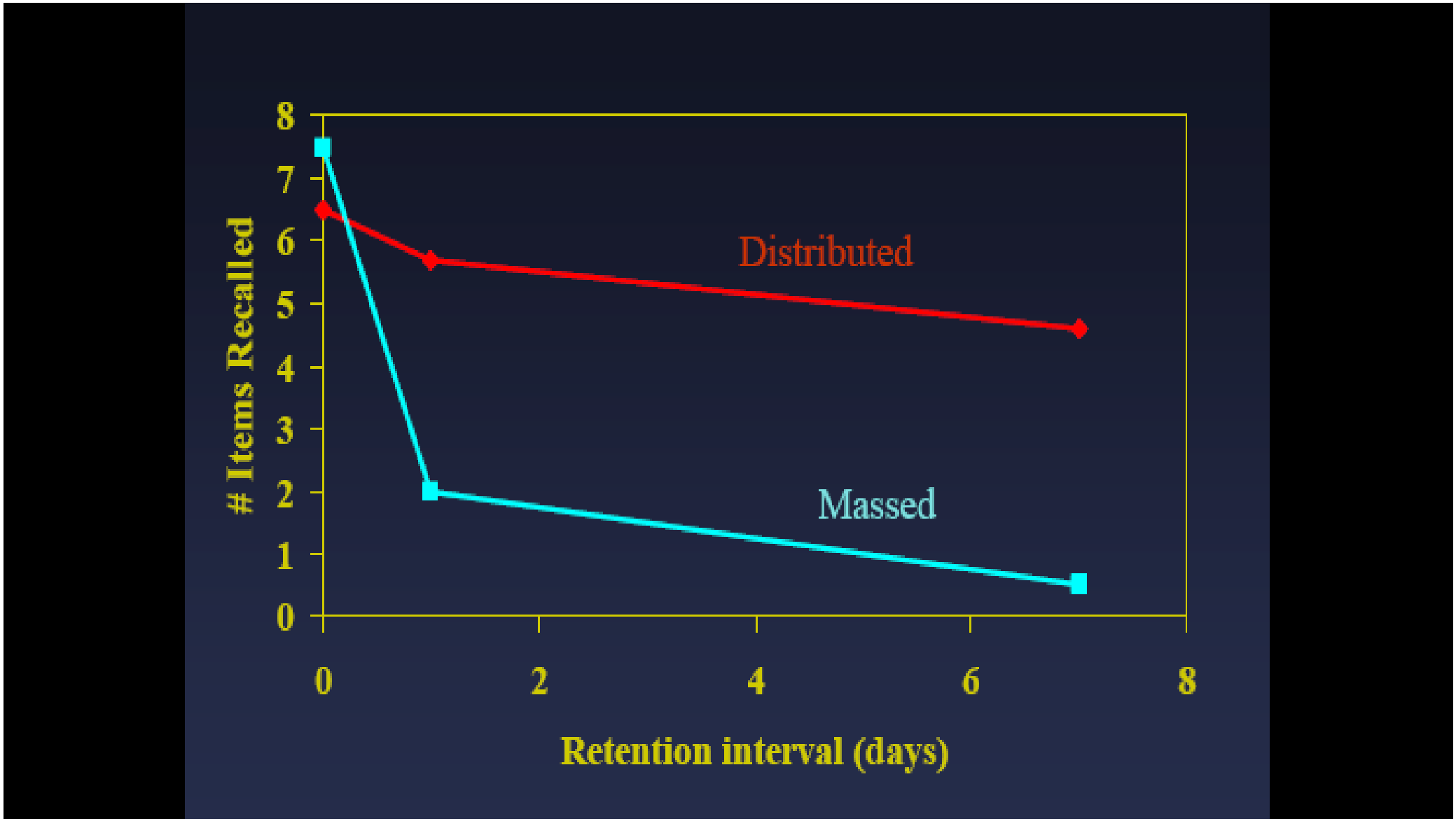
A *distributed* practice schedule does not mean less overall time. The total amount of practice time should be the same as with a *massed* schedule.


MONDAY
TUESDAY
WEDNESDAY
THURSDAY
2:00 PM
2:30 PM
3:00 PM
3:30 PM
4:00 PM
4:30 PM
5:00 PM
5:30 PM
Practice
Practice

| | MONDAY | TUESDAY | WEDNESDAY | THURSDAY |
|---|---|---|---|---|
| 2:00 PM | | | | |
| 2:30 PM | | | | |
| 3:00 PM | | | | |
| 3:30 PM | **Practice** (Offense) | **Practice** (Defense) | **Practice** (Offense) | **Practice** (Defense) |
| 4:00 PM | | | | |
| 4:30 PM | | | | |
| 5:00 PM | | | | |
| 5:30 PM | | | | |

# Tenet Two

Distributed practice benefits are not physiological – the learner simply needs time away from the practice of a given skill for consolidation to occur. Think of it as "neural rest".

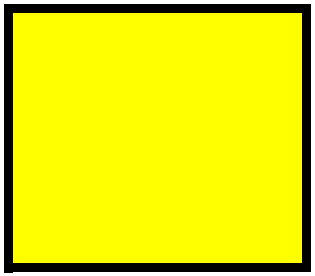

# Items Recalled
8
7
6
5
4
3
2
1
0
0
2
4
6
8
Retention interval (days)
Distributed
Massed

# Drill Scheduling

10 mins

10 mins

10 mins



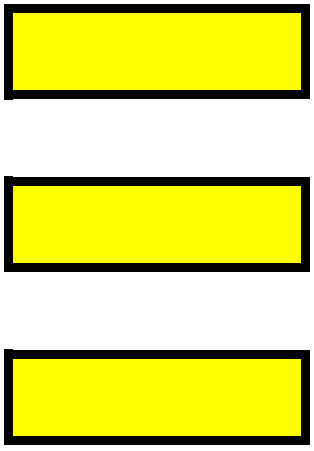
10 mins

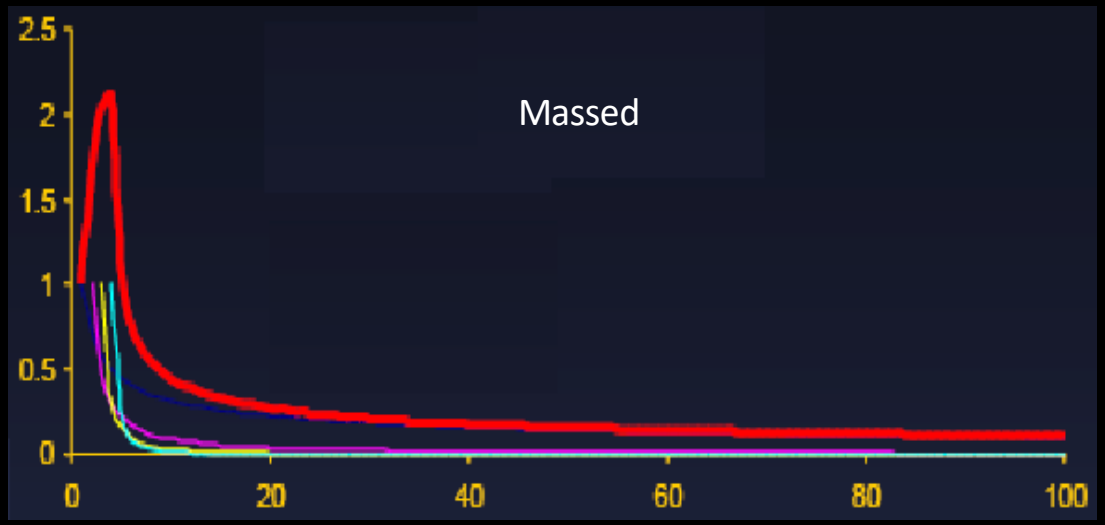
10 mins

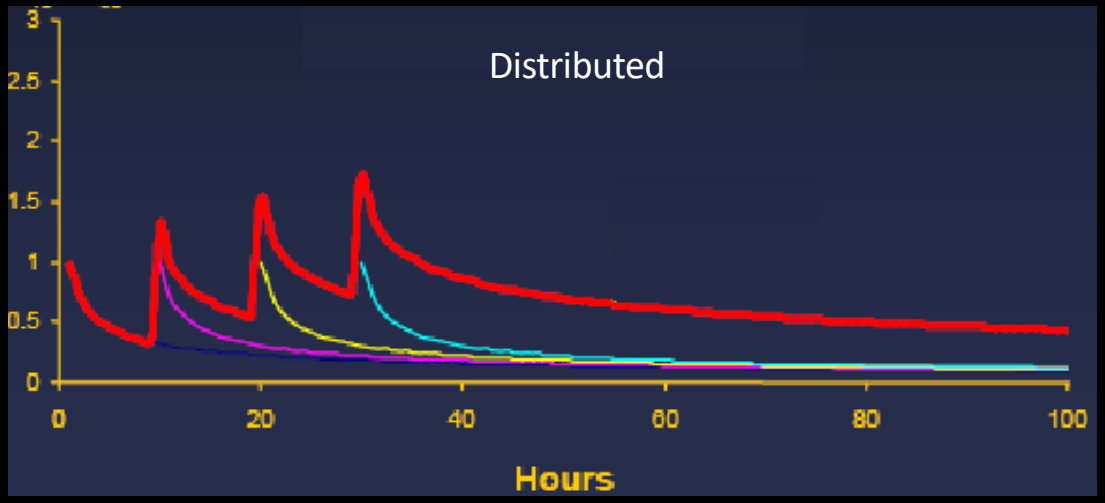
10 mins

10 mins

10 mins




Massed
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100


Distributed
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
Hours

# Tenet Three

The length of distributed practice is a continuum. One 30 minute drill could be spilt in 3 x 10 minutes, 6 x 5 minutes, or even 15 x 2 minutes.

# Tenet Four

The rest period for distributed practice can contain practice of another skill, but only if the content of the two skills do not overlap.

# Evidence for Massed vs Distributed Practice Effects

Balance Tasks

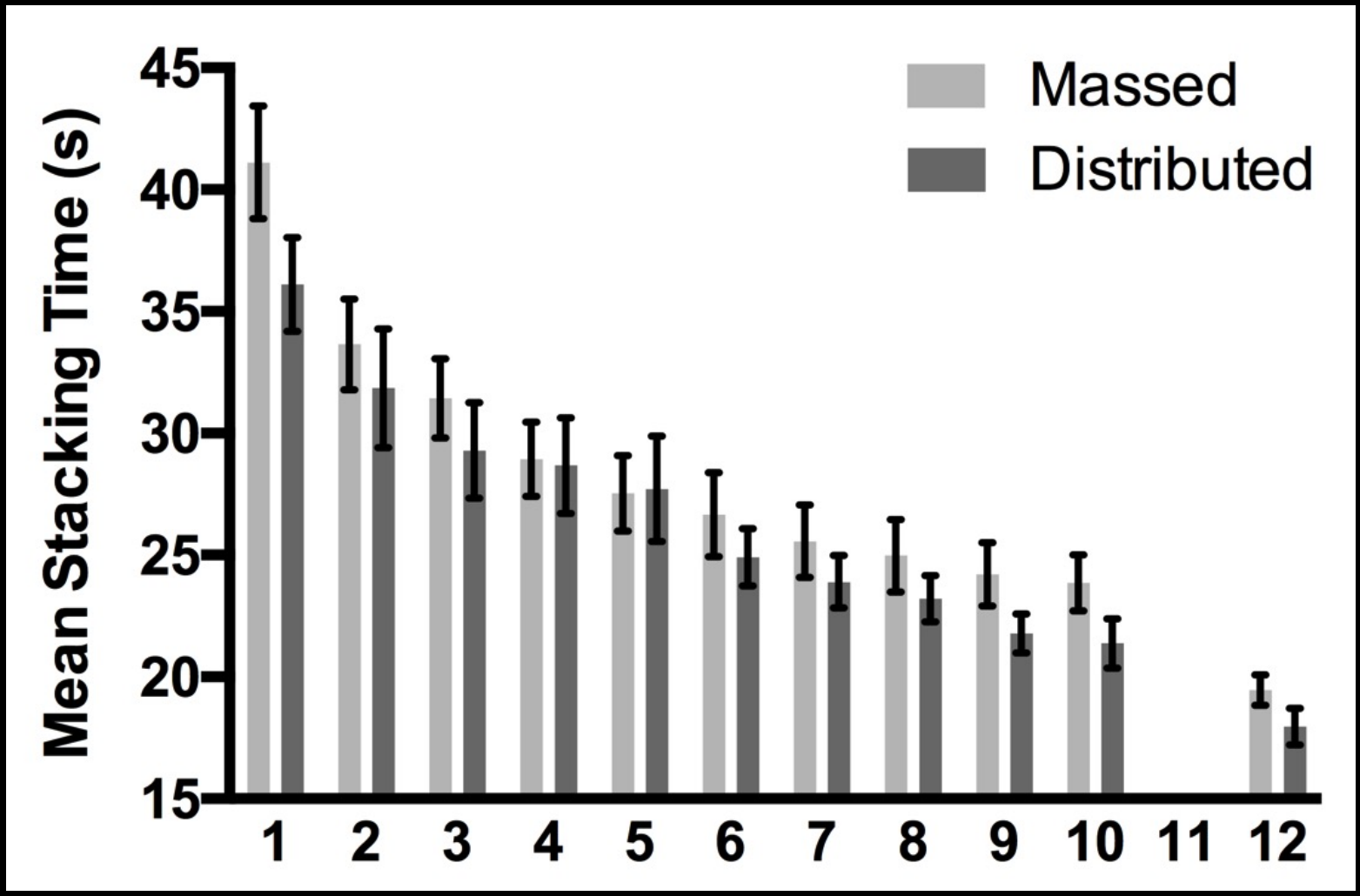
Best performance on a Balance Board for Group that Practiced 57 % of 30 minute block (vs 20, 30, 40, 57, 77 %)

*Graw (1968)*

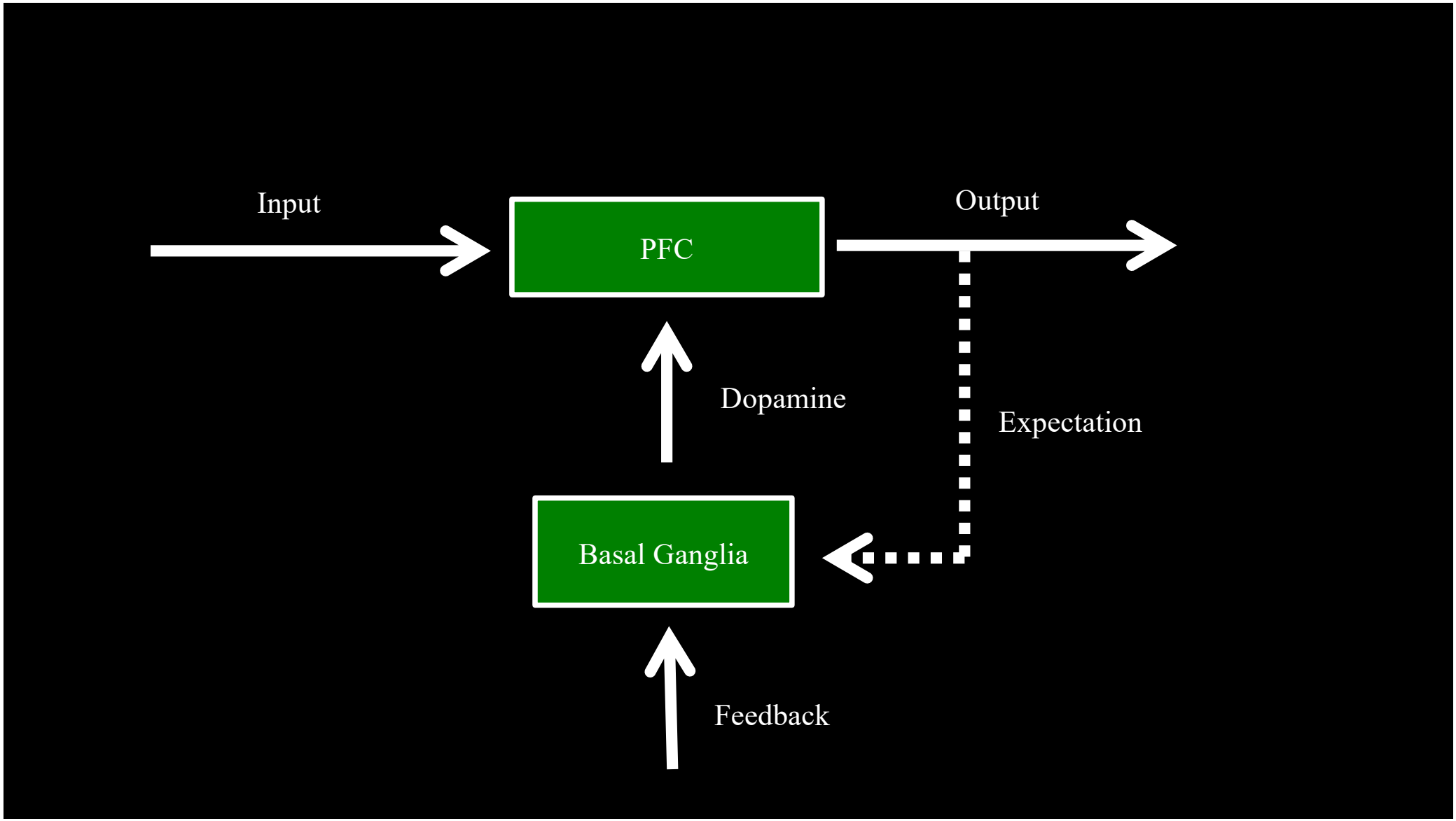
Postal Workers

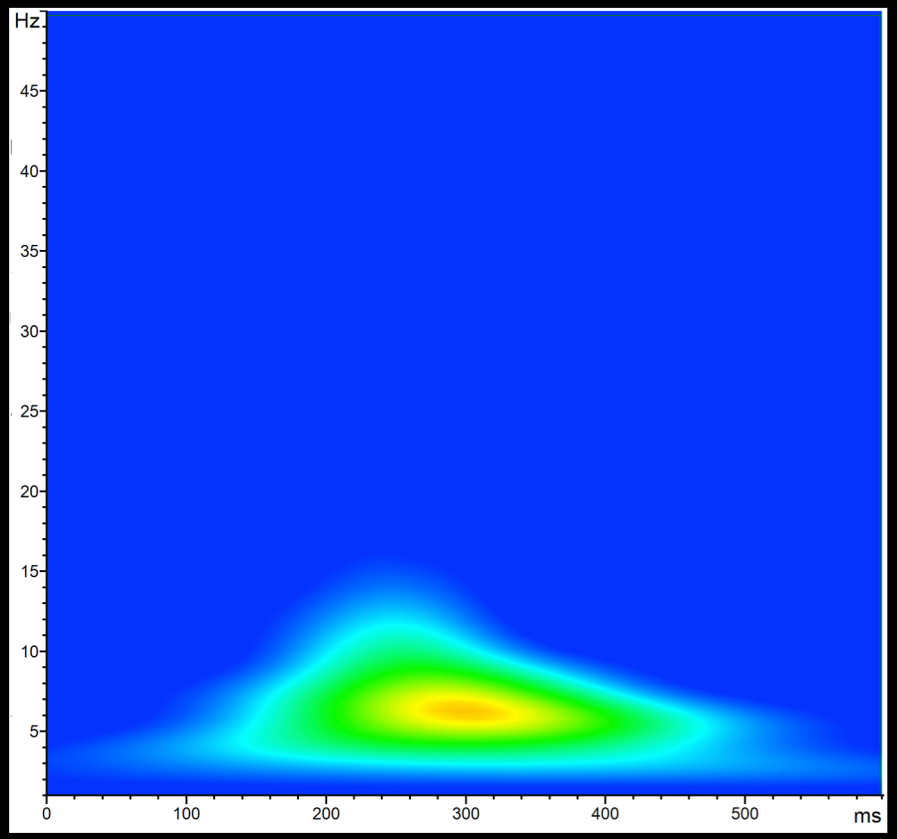
12 weeks x 1 hour more effective than 3 weeks x 2 per day x 2 hour practice

*Baddeley and Longman (1978)*

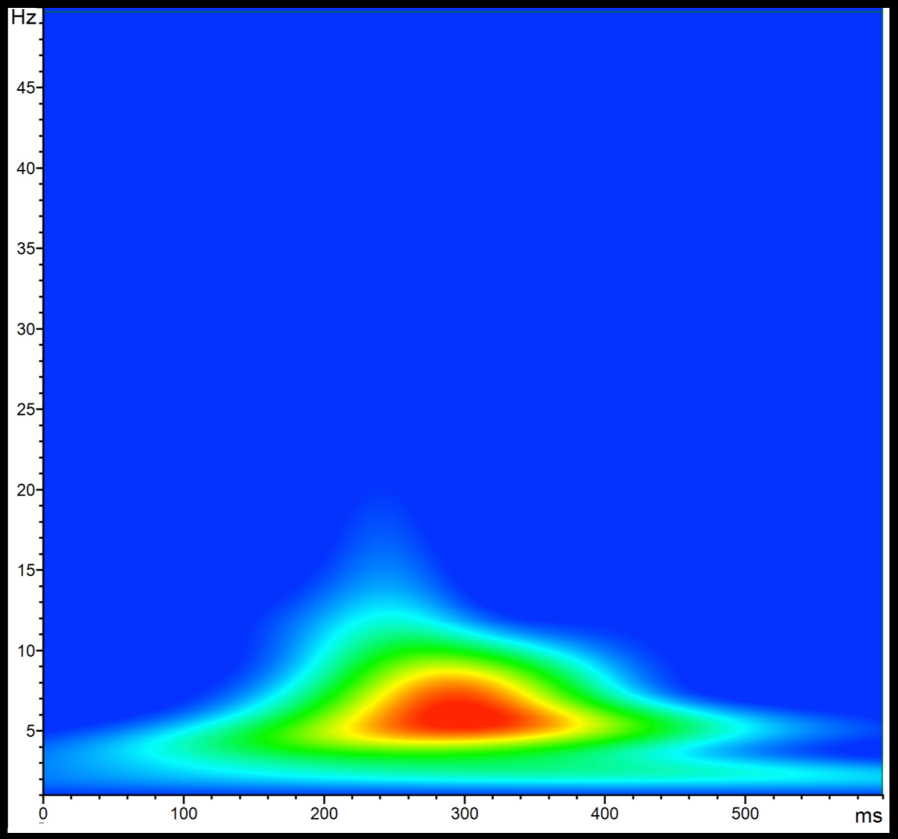

Mean Stacking Time (s)
45
40
35
30
25
20
15
1
2
3
4
5
6
7
8
9
10
11
12
Massed
Distributed

What is the optimal number of practices per week and optimal practice length?


Input
PFC
Output
Dopamine
Expectation
Basal Ganglia
Feedback



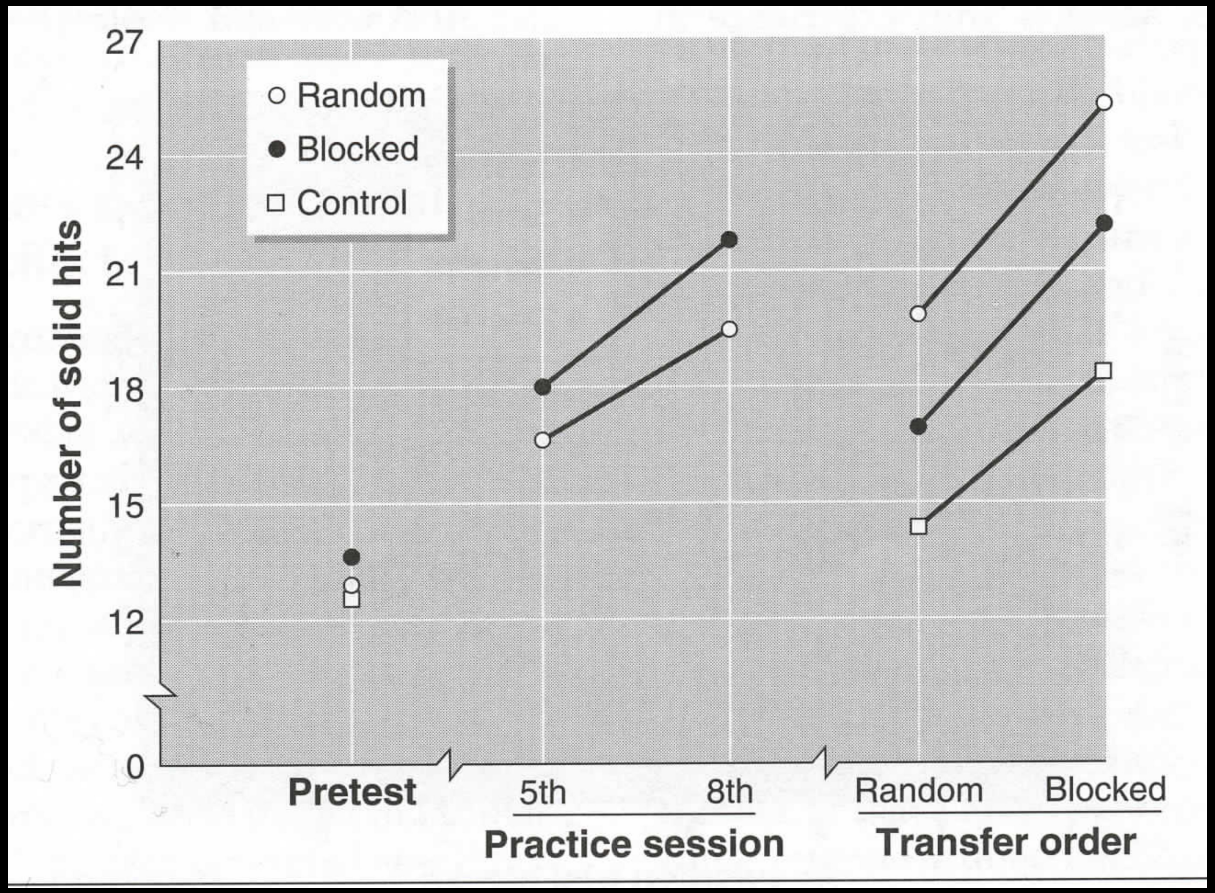

Massed



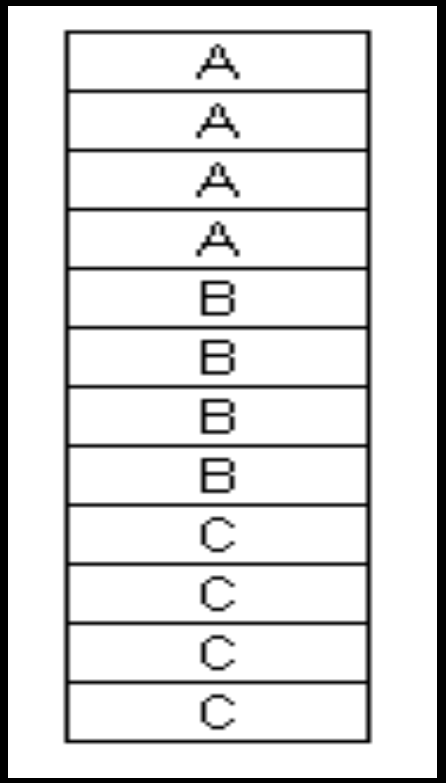

Distributed

In Class Activity:
Apply the principles of Distributed Practice to this Class

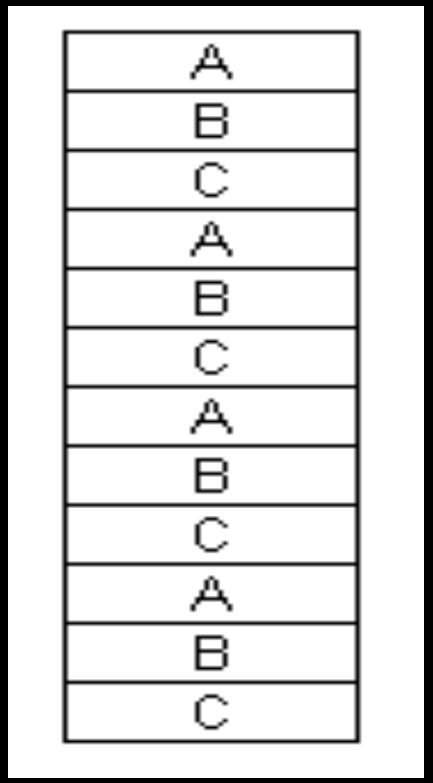
# Blocked and Random Practice


Number of solid hits
27
24
21
18
15
12
0
Random
Blocked
Control
Pretest
5th
8th
Practice session
Random
Blocked
Transfer order

# Random vs Blocked Practice




**Blocked**




**Random**

# Tenet One

The total number of repetitions of a skill within a practice session must remain the same – random practice simply manipulates the order of the skills within a drill.

# Tenet Two

Random practice is a continuum – in a ideal random practice situation a skill is never practiced more than once in a row.

# Random Practice

Generally poorer performance during acquisition

BUT

Greater RETENTION in TRANSFER

i.e. LEARNING

Shea & Morgan (1979)

Task: Arm Movement Pattern

Blocked : task A then task B then task C

Random : random schedule involving A, B, and C

# Contextual Interference
# (Shea and Morgan, 1979)

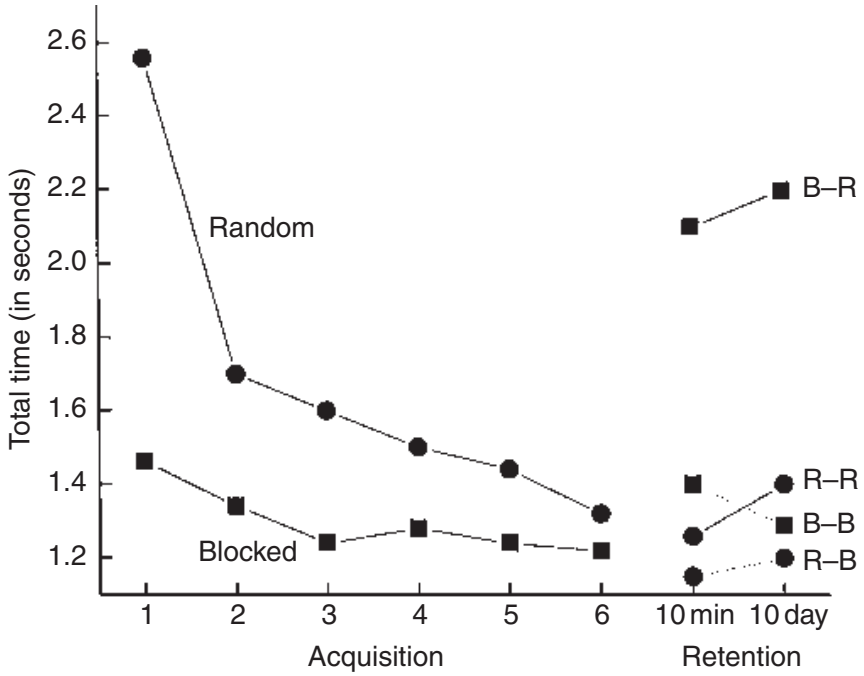
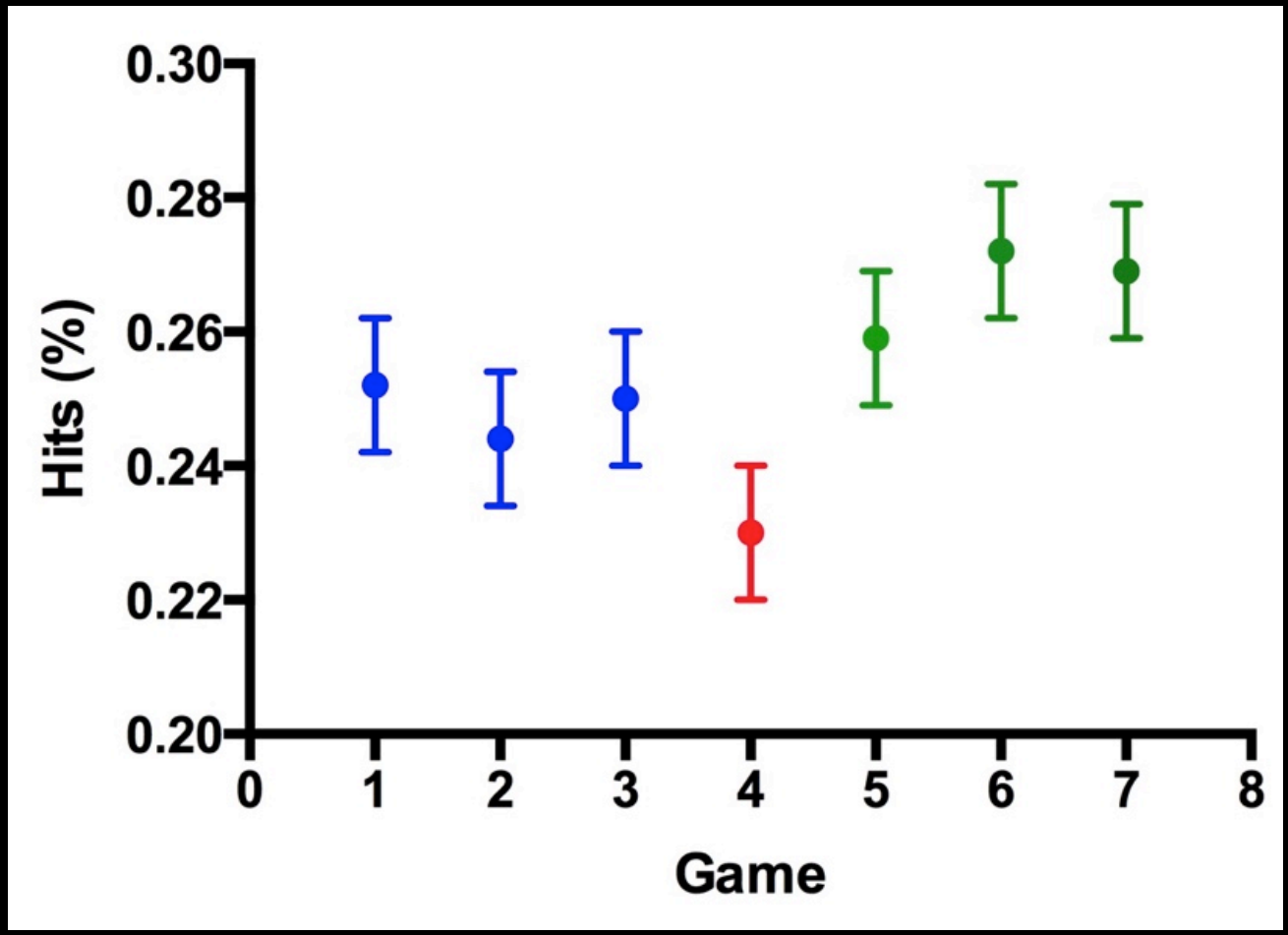



*Figure 2.2* Results of the Shea and Morgan (1979) experiment.

Why does random practice work?




Pluta & Krigolson (In Prep)

Is random practice always better?

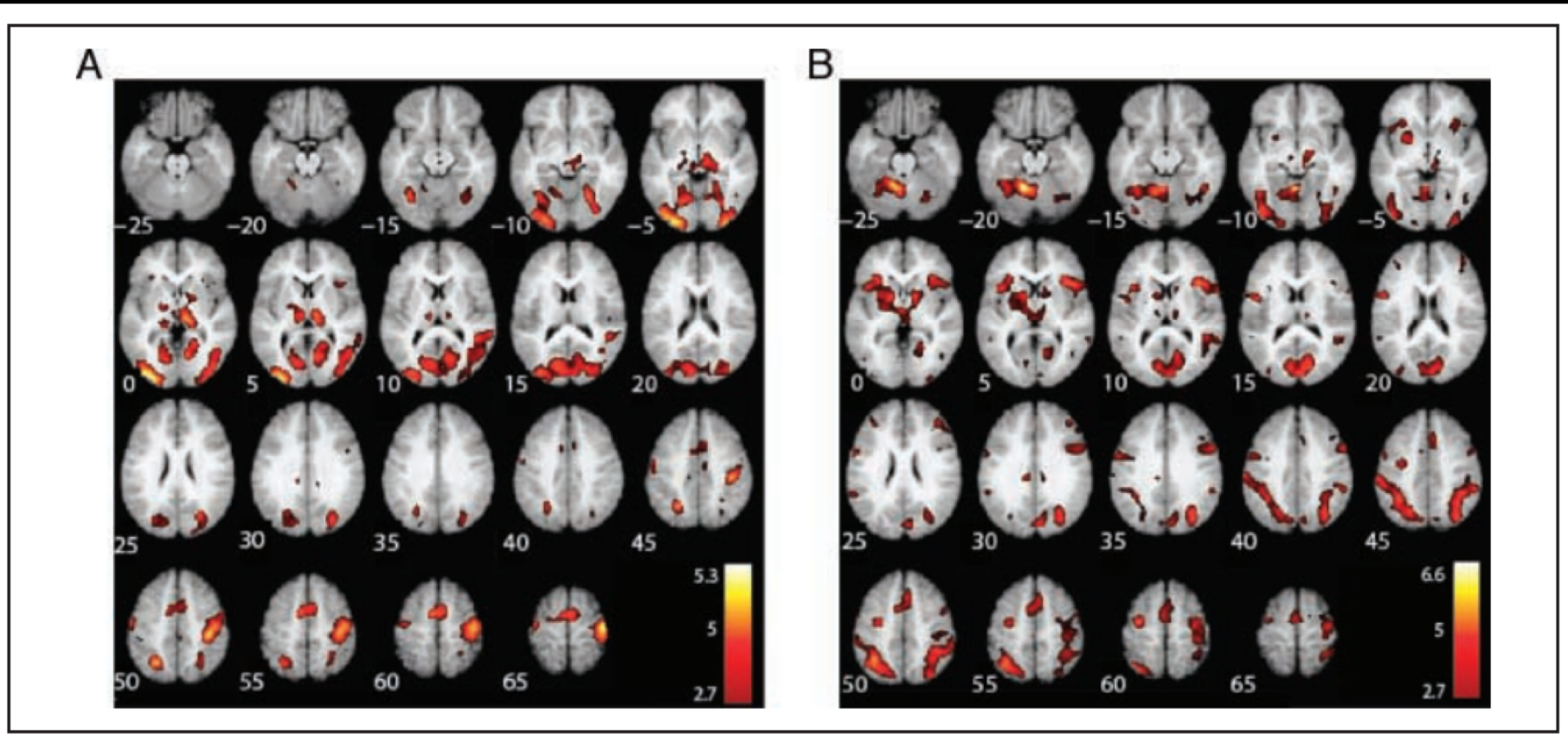
# Tenet Three

There is evidence to suggest that early in learning is it better to use a BLOCKED practice schedule.

# Neural Substrates of Contextual Interference during Motor Learning Support a Model of Active Preparation

**Article** *in* Journal of Cognitive Neuroscience · December 2007

DOI: 10.1162/jocn.2007.19.11.1854 · Source: PubMed

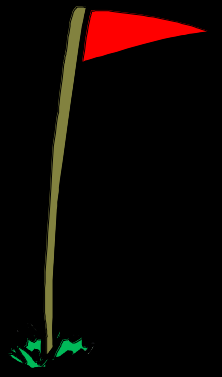

A
−25
−20
−15
−10
−5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
5.3
5
2.7
B
−25
−20
−15
−10
−5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
6.6
5
2.7

In Class Activity:
Apply the principles of Random Practice to something you have learned

# Constant vs Variable Practice

10 trials

1 trial



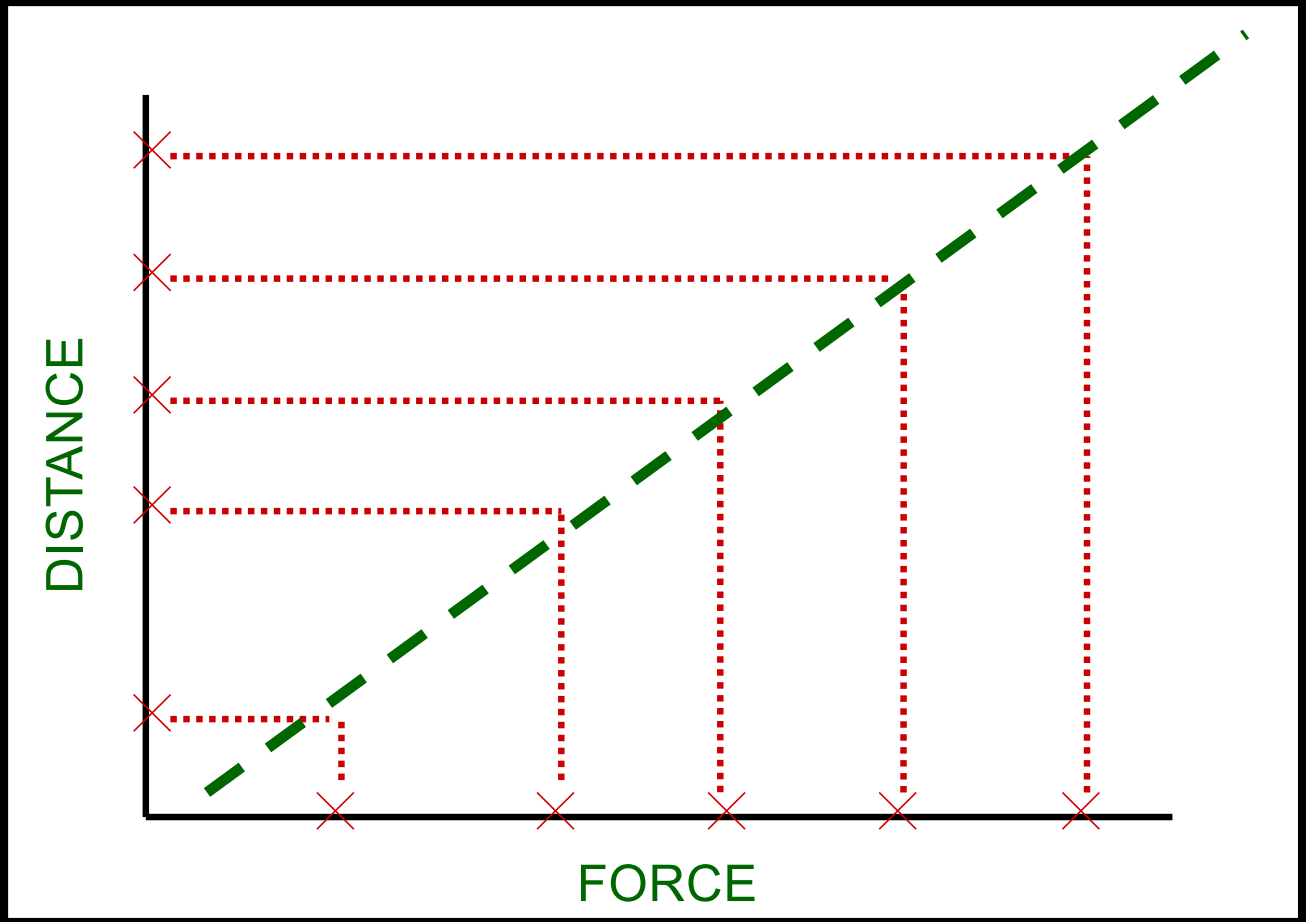
Constant Practice

parameters do not change from trial to trial

Variable Practice

parameters change from trial to trial

# Schema Theory



# KEY POINT

Variable practice only works if the parameters of the motor program are not exceeded

# Constant Practice Early, Variable Practice Later...

Practice Design: (Lai Qin, 1999)

Constant 1st Half → Relative Timing
Variable 2nd Half → Parameter Learning

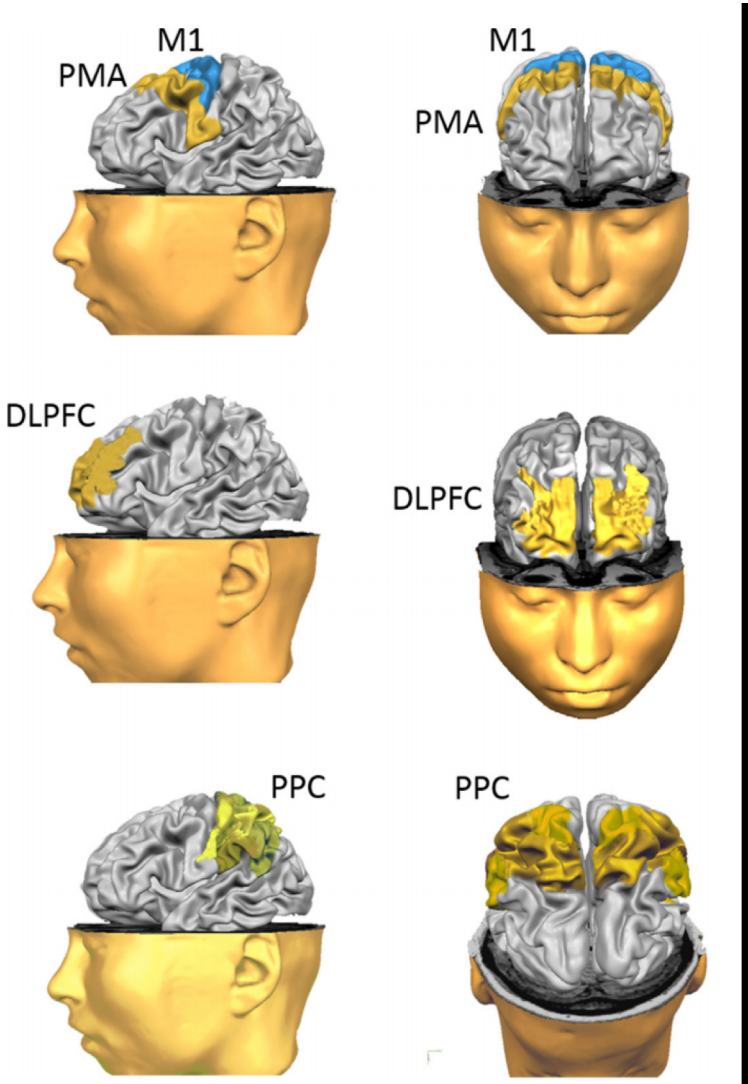



**Fig. 4.** (A) M1 and PMA (PMC and SMA) localization; (B) DLPFC; (C) PPC. (Image adapted from BrainVoyager Brain Tutor software).

In Class Activity:
Apply the principles of Variable Practice to something you have learned