

Some examples

Q550: Models in Cognitive Science



Steps of Cognitive Modeling:

- 1) Conceptual theory → formal description
- 2) Ad hoc **assumptions** to complete formal description
- 3) Parameter estimation
- 4) Compare predictions to empirical data
- 5) Iterate to constrain

Steps of Cognitive Modeling:

- 1) Conceptual theory → formal description
- 2) Ad hoc **assumptions** to complete formal description
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- 4) Compare predictions to empirical data
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 - We have to make simplifying assumptions to formalize
 - These can be wrong, they can be attacked, and they involve intuition (which we hate)
 - Try to minimize assumptions, but they are unavoidable
 - We also can't model all processes, so we may ignore input representations (leave random), or represent a process with a descriptive function

Our Approaches:

- ***Existence Proof:*** Within this system, there exists a set of parameters that will explain the phenomenon
- ***Model Comparison:*** Formalize conceptual theories and compare their performance on a task designed to constrain between them (nested vs. non-nested)
- ***Create a new model:*** For your phenomenon, no process model exists. So you created a new one, and should be able to generalize to novel tasks. This often requires *post hoc* model design

Example 1: An Existence Proof

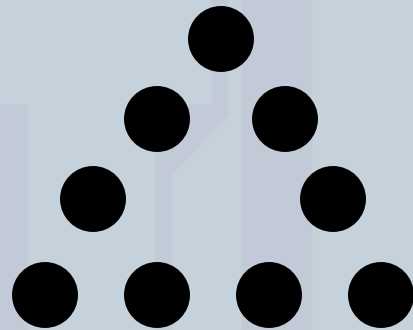
- Given a phenomenon, there exists a set of parameters in Model X that will produce the phenomenon
- Usually used w/ Occam's razor to show that a simpler system is sufficient without the need to propose additional assumptions.
- Weak, b/c there may be many sets of parameters that do not account for the phenomenon
- With existence proof, you rarely make a priori predictions; the data are well known

Example: Original Hintzman paper: don't need to propose separate memory system for instances and abstraction

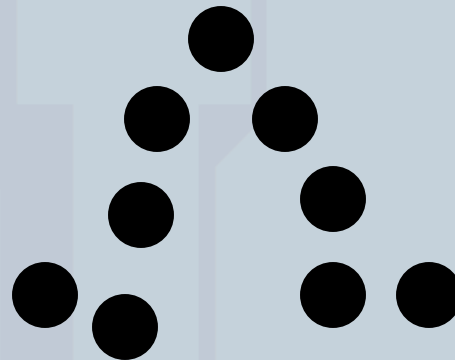
Now: Use same model to account for process dissociation between categorization and recognition of same stimuli

- Process dissociation: When trained on category exemplars, we can test with recognition or classification of old exemplars
- These two processes do not behave the same across time...recognition degrades much faster than classification
- This has lead researchers to suggest that we form an abstraction of the category stored *separately* from memory of the instances
- Can we simulate the process dissociation over time without needing two memory stores?
- Also, the only parameter that will change is time
- We'll just expand on Minerva

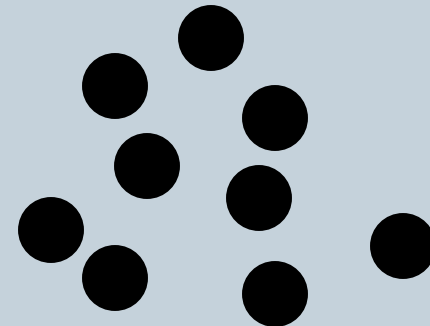
Posner & Keele (1968)



Prototype



Low-level
Distortion



High-level
Distortion

Exemplars are all distortions of their category prototype

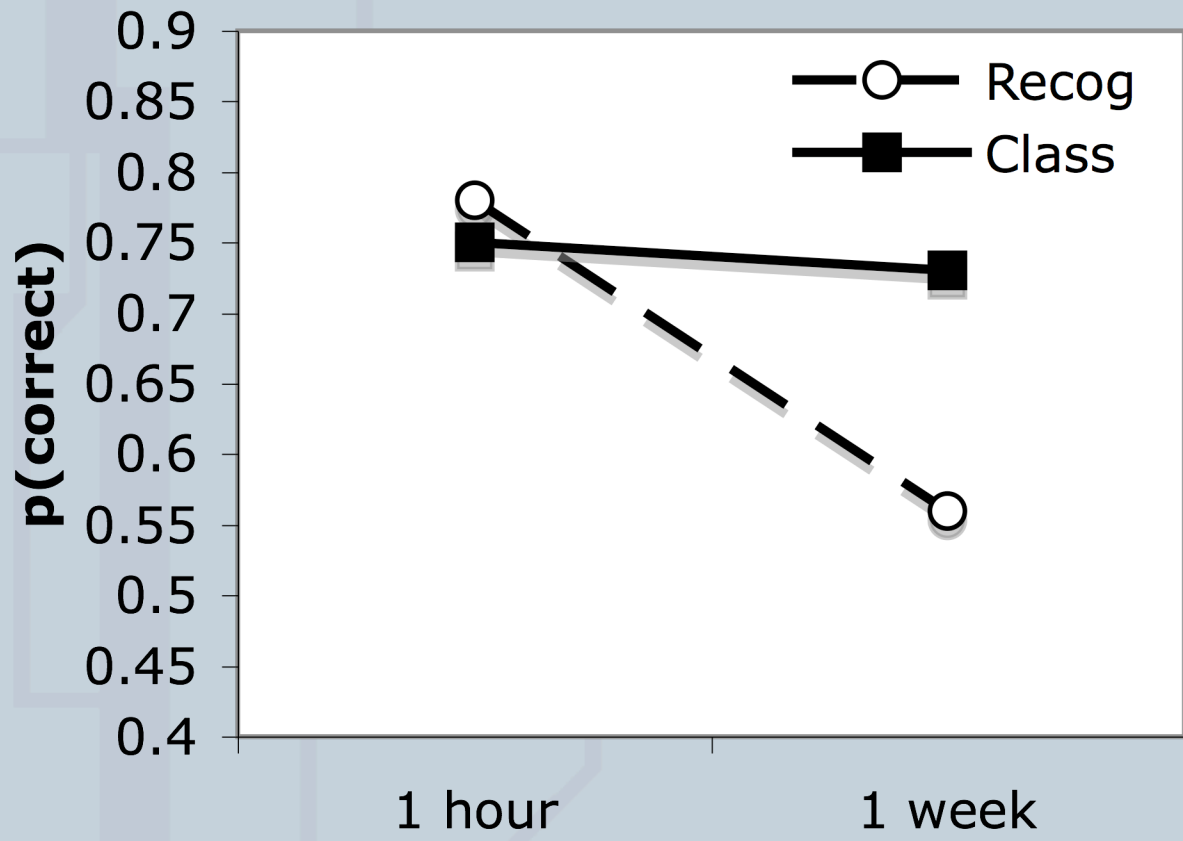
Subjects learn to classify exemplars into A, B, C categories, but never see the prototype

After learning, subjects classify or make old/new judgments on the exemplars they learned

- You are trained on patterns, then see them again and recognize/classify --> we will vary delay between training and test to increase forgetting. This will all be between Ss to avoid testing artifacts
- Simply record $p(\text{correct})$ (classify/recognize)

Retention Interval

		1 hour	1 week
Task	Recog	n = 10	n = 10
	Class	n = 10	n = 10



Before I try to model anything: Is this impression reliable?

1 Hour

Recog

0.75

0.82

0.69

0.73

0.78

0.89

0.68

0.81

0.78

0.79

0.78

Class

0.69

0.74

0.76

0.78

0.72

0.69

0.7

0.78

0.79

0.77

0.75

1 Week

Recog

0.52

0.58

0.63

0.62

0.59

0.58

0.55

0.51

0.49

0.51

0.56

Class

0.78

0.74

0.77

0.7

0.72

0.65

0.67

0.72

0.75

0.72

0.73

MEAN:

0.7727273

0.7427273

0.5581818

0.7227273

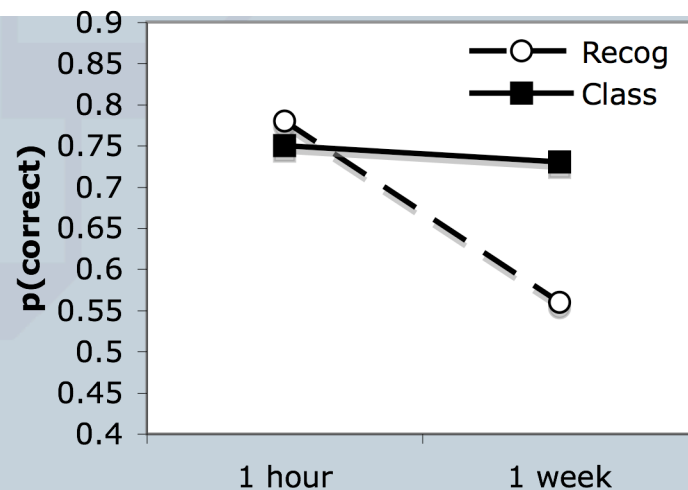
Tests of Between-Subjects Effects

Dependent Variable: VAR00002

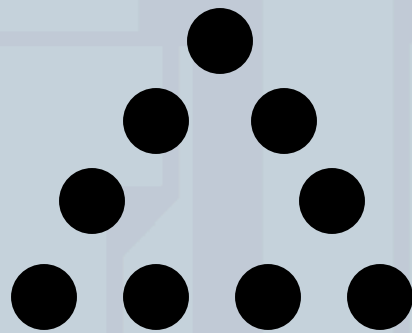
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power ^a
Corrected Model	.276 ^b	3	9.196E-02	38.298	.000	114.893	1.000
Intercept	19.516	1	19.516	8127.941	.000	8127.941	1.000
TASK	4.489E-02	1	4.489E-02	18.696	.000	18.696	.988
DELAY	.137	1	.137	57.011	.000	57.011	1.000
TASK * DELAY	9.409E-02	1	9.409E-02	39.186	.000	39.186	1.000
Error	8.644E-02	36	2.401E-03				
Total	19.878	40					
Corrected Total	.362	39					

a. Computed using alpha = .05

b. R Squared = .761 (Adjusted R Squared = .742)



Minerva: Conceptual Framework



Prototype

+ - - + - + + - + ...



Label
"Category A"

+ + - + - - - + + - + - ..





Pattern

Label

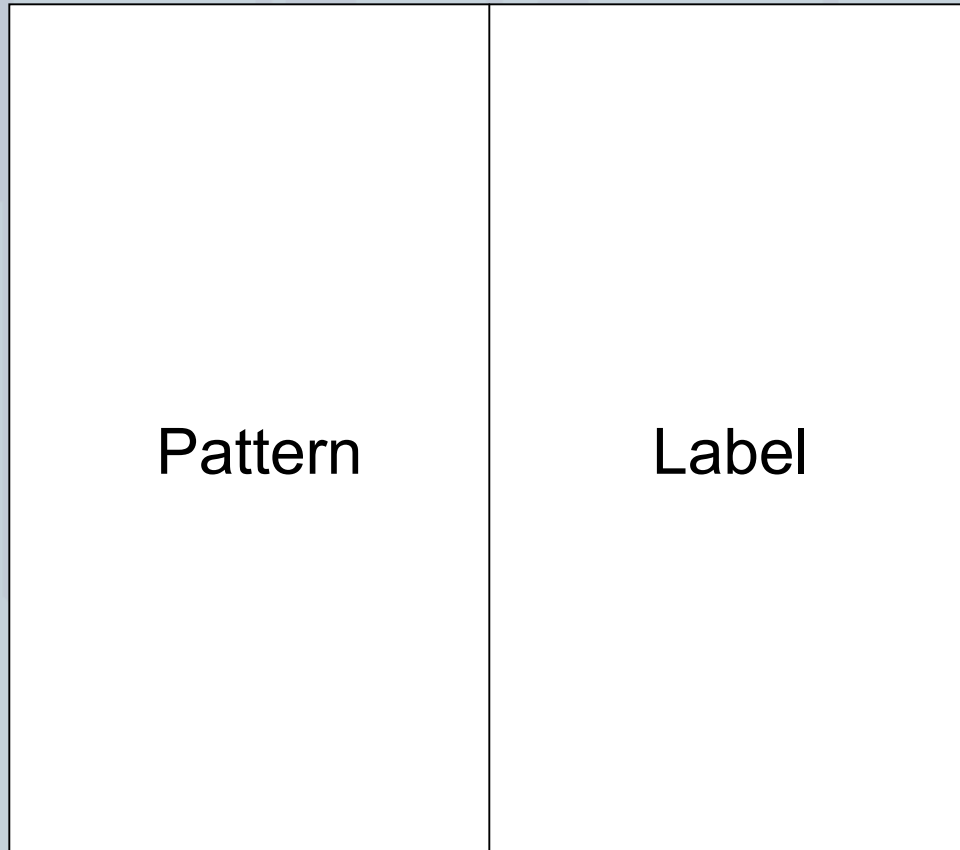
Memory

$$A_i = \left(\sum_{j=1}^N P_j M_{i,j} \frac{1}{N_R} \right)^3$$

Probe

| | |
|-----------------|---------------------|
| - + + - + - ... | 0 0 0 0 0 0 (Cat ?) |
|-----------------|---------------------|

A



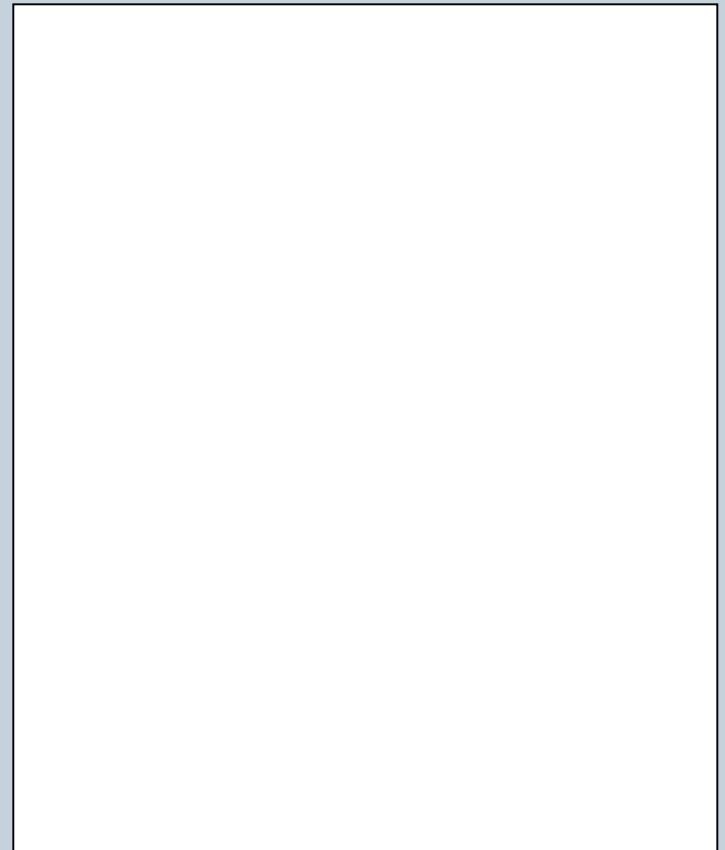
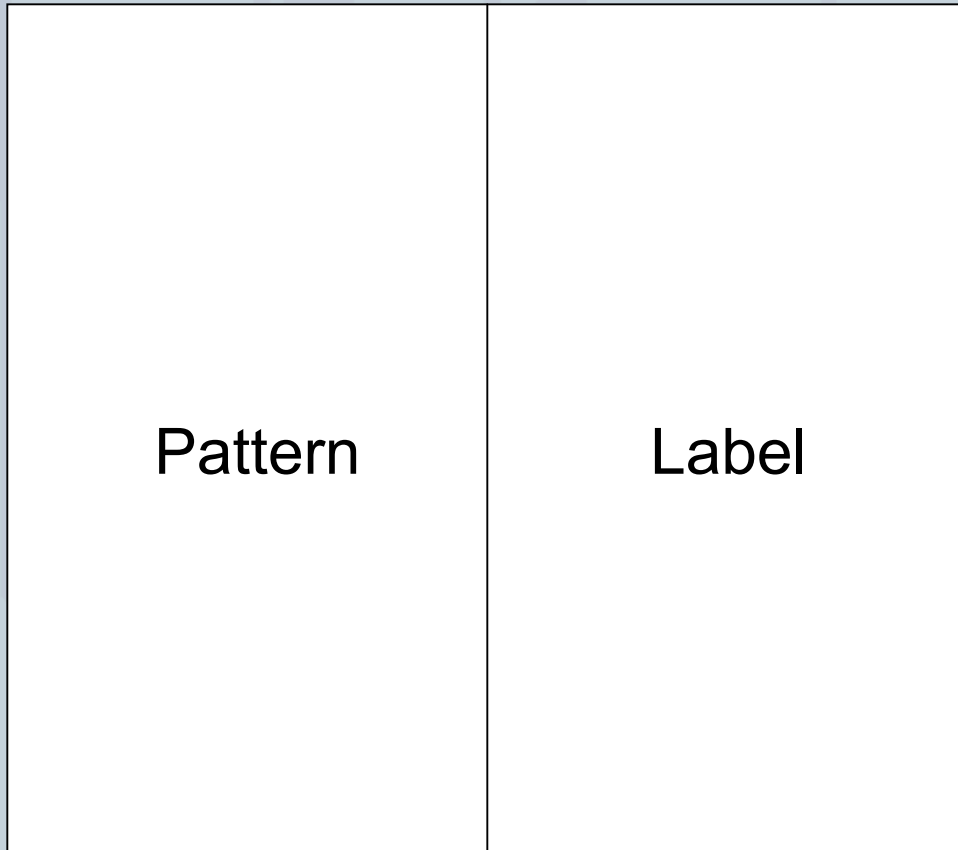
Memory

$$A_i = \left(\sum_{j=1}^N P_j M_{i,j} \frac{1}{N_R} \right)^3$$

Probe

| | |
|-----------------|---------------------|
| - + + - + - ... | 0 0 0 0 0 0 (Cat ?) |
|-----------------|---------------------|

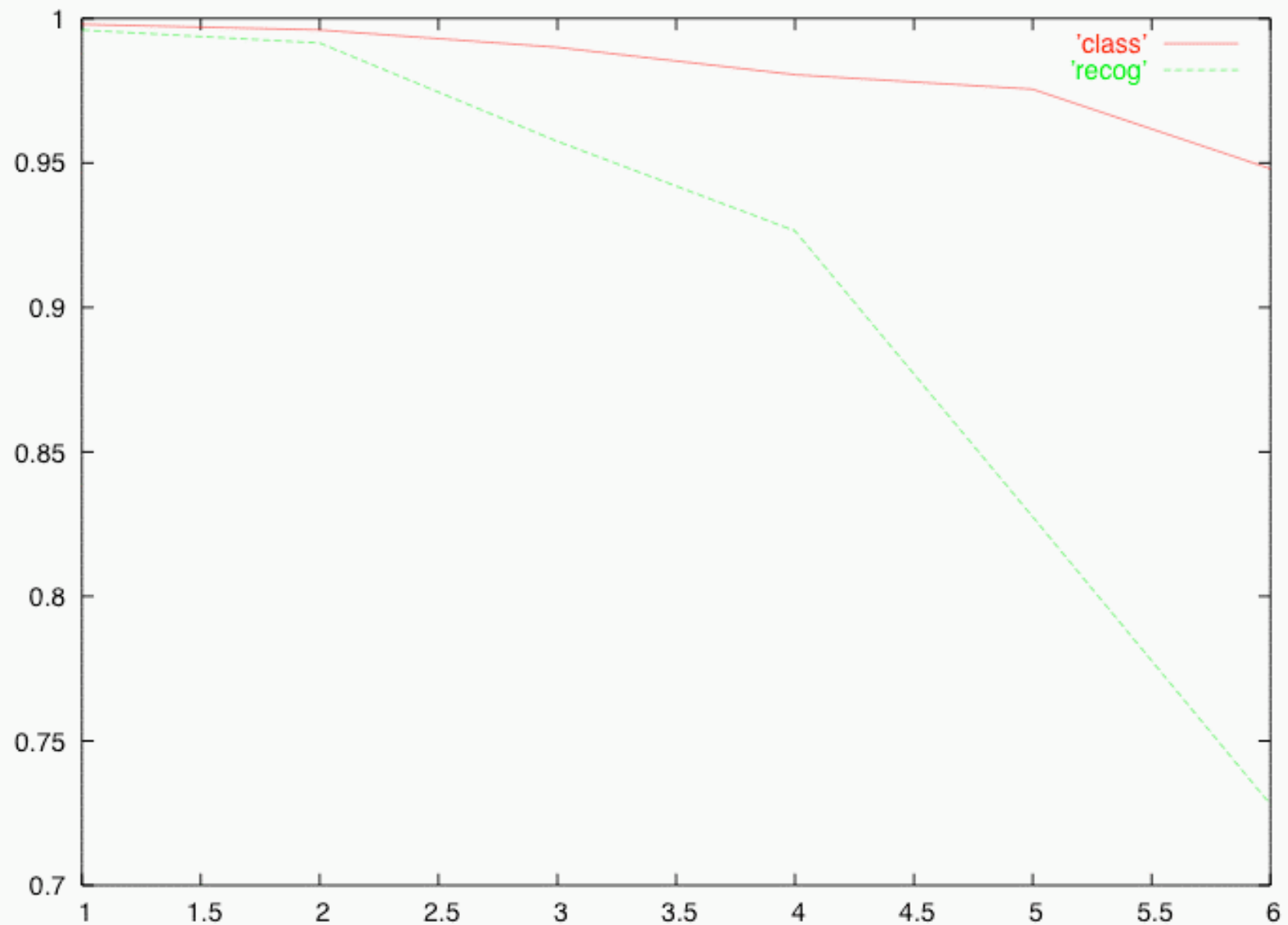
A



Memory

Echo

From Tulving.f95:



Example 2: Theories of Forgetting

Forgetting: inability to retrieve information from memory

Complicated by three processes:

ENCODING -- STORAGE -- RETRIEVAL

Any of these could be responsible for failure to get something out of memory (or a combination)

Likely Truth: different types of info are lost by different sources

$$M_t = M_{t-1} + \sum_{i=1}^t I_i$$

$$M_t = \alpha M_{t-1} + I_i$$

Decay Theory: The strength of a memory trace decays over time as iron rusts with time (McGeoch, 1932)

- Power law: Strength of trace decays as a power function of the retention interval (both at the neural and behavioral levels)
- Thorndike's Law of Disuse

Old Decay: $M_t = \alpha M_{t-1} + I_i$

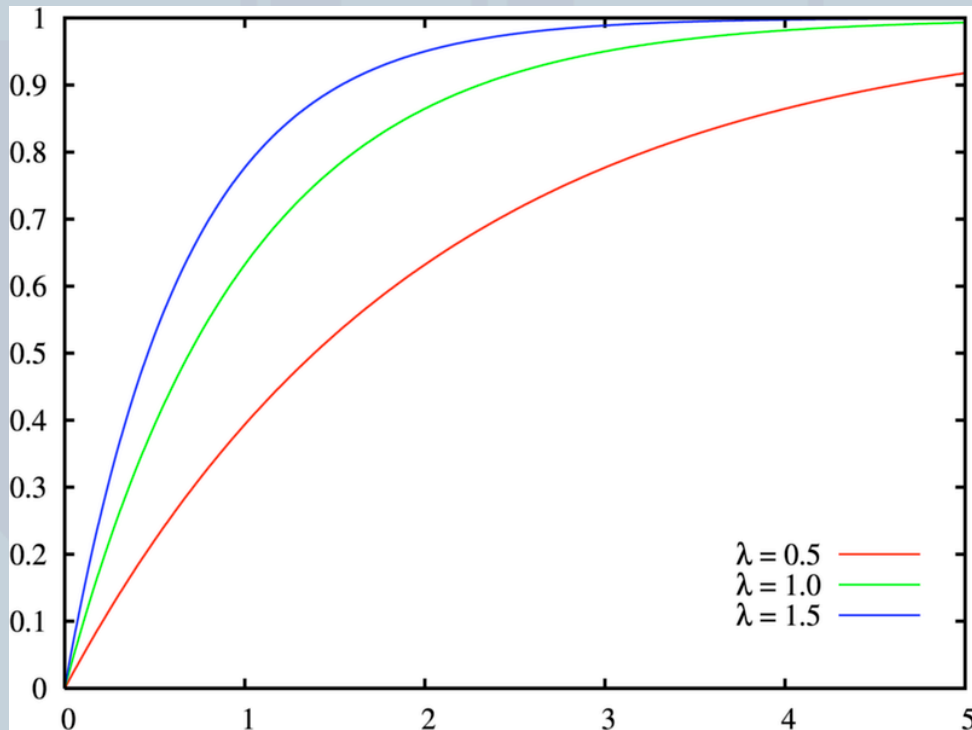
But, decay should be dependent on time

New Decay:

At time t ; for $i = 1$ to N : $M_i = e^{-\lambda t_\Delta} M_i$

Where $t_\Delta = t - t_{encode}$

Exponential CDF: $f(x) = 1 - e^{-\lambda x}$



$x \geq 0$

$\lambda > 0$

- Rust and memory decay: time is not the causal agent for either
- Forgetting may be a power function of time, but decay is confounded with interference: As time goes on, more things are stored, increasing the probability of retrieval failure

Interference Theory: Forgetting is a result of retrieval failure

- Jenkins & Dollenbach (1924): After identical time delays, Ss who slept after learning recalled more than those who remained awake (fewer intervening activities = less interference)
- PI: prior learning interferes with recall of newer information
- RI: new learning interferes with recall of prior information

This is difficult to put in an equation, but we can still formalize it

Consolidation Theory: Information is not forgotten, but may not be encoded if it is not consolidated. After presentation, a period of inactivity is required (*perseveration*). The longer this period, the more likely the trace will be consolidated. If a trace is consolidated, it does not decay, and retrieval is perfect

- Ebbinghaus, retrograde amnesia, ECS, sleep

Predictions:

- 1) A period of inactivity is more conducive to consolidation than activity
- 2) If perseveration is interrupted, the trace cannot be consolidated and will not be stored
- 3) If consolidation is prevented, the item should not be retrieved b/c storage was not completed

$$M_i = M_{i-1} + I_i$$

$$M_i = M_{i-1} + (1 - e^{-\lambda t})I_i$$

$$M_i = M_{i-1} + \text{bin}(\text{uniform}, 1 - e^{-\lambda t})I_i$$

Where bin returns 1 if uniform $< 1 - e^{-\lambda t}$
0 if uniform $\geq 1 - e^{-\lambda t}$

If (persev) then: $M_i = M_{i-1} + \text{bin}(\text{uniform}, 1 - e^{-\lambda t})I_i$

Else: $M_i = M_{i-1} + \text{bin}(\text{uniform}, e^{-\lambda t})I_i$

Forgetting may be due to:

Encoding failure (Consolidation)

Storage failure (Decay)

Retrieval failure (Interference)

If we look at only STM, both consolidation and decay predict rapid decay with time if S is cannot rehearse or consolodate

Decay is linked to time, not necessarily number of items

Interference doesn't care about time, just number of items

Waugh-Norman paradigm:

- Present digits/words; S learns successive associations. At end of list, S is given an item that was in the list and recalls the item that followed it.
- We'll vary presentation speed 1 item/sec vs. 4 items/sec
- Assume items have *some* perceptual similarity (XGH, KCF)
- Assume perfect association: memory is a matrix where each vector is S//R
- Vector elements are binary
- Selection rule is the same for both, only memory changes

$$p(R | S) = \frac{\sum_{i=1}^D |M_i|}{D}$$

Decay:

At item i , for $j = 1$ to i : $M_j = e^{-\lambda t_\Delta} M_j$

Where: $t_\Delta = t_i - t_{encode}$

Interference: A new item can overwrite any shared features with an existing item with a random probability

| t | Item presented | Memory |
|---|-----------------|---|
| 1 | + - + + - - + - | + - + + - - + - |
| 2 | - - + - - - - - | + 0 + + 0 - + -
- - + - - - - - |
| 3 | + - - - + + - + | 0 0 + + 0 - + -
- 0 + - - - 0 -
+ - - - + + - + |

1 item/second

#####

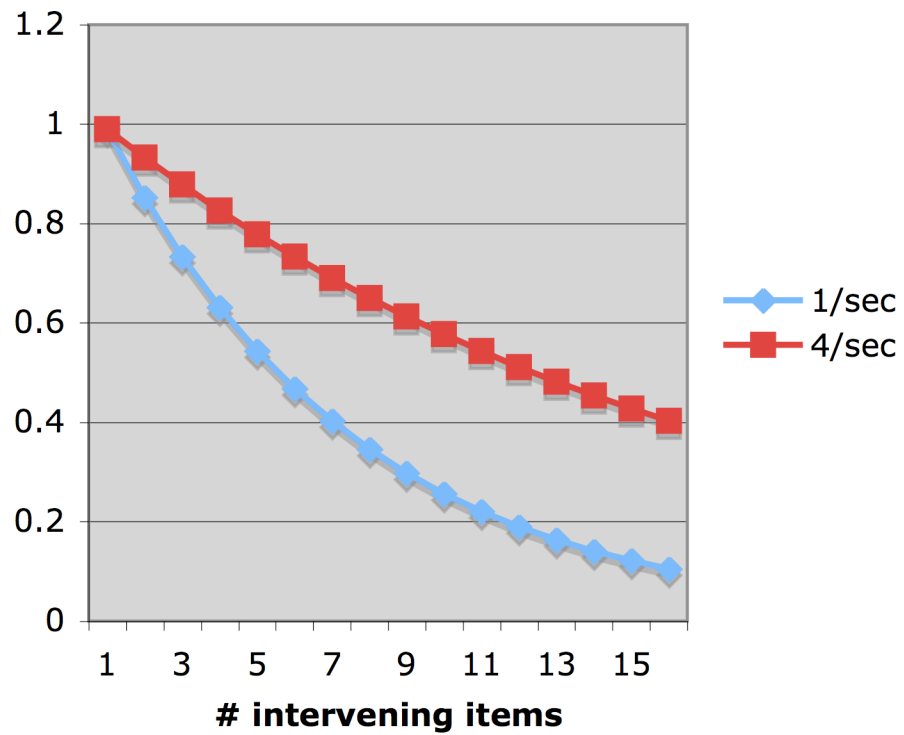
SHIP

4 items/second

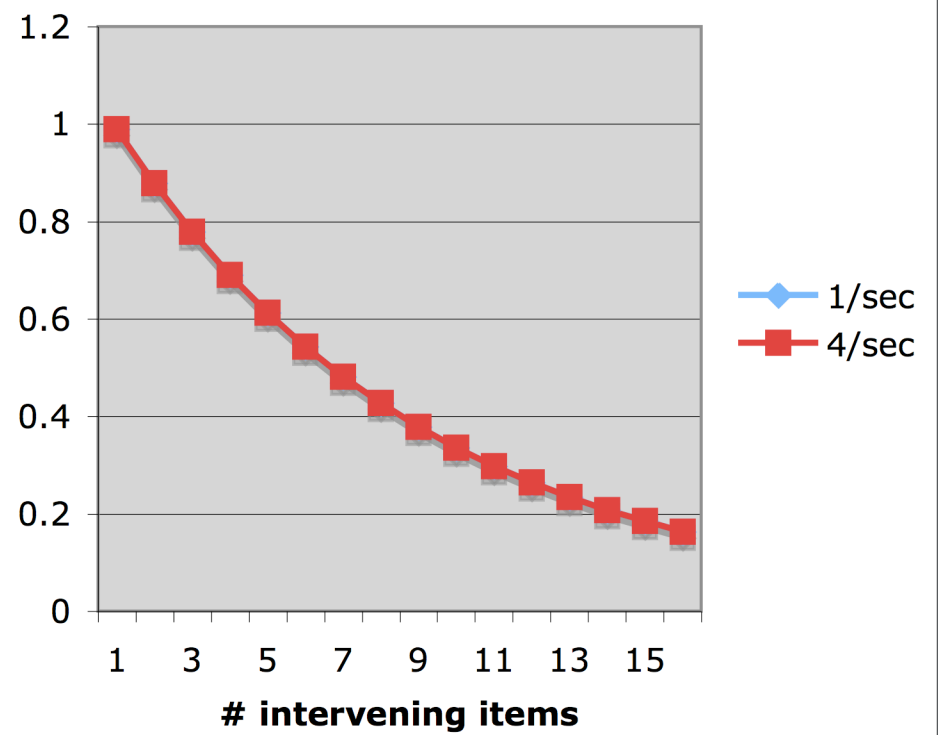
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TABLE

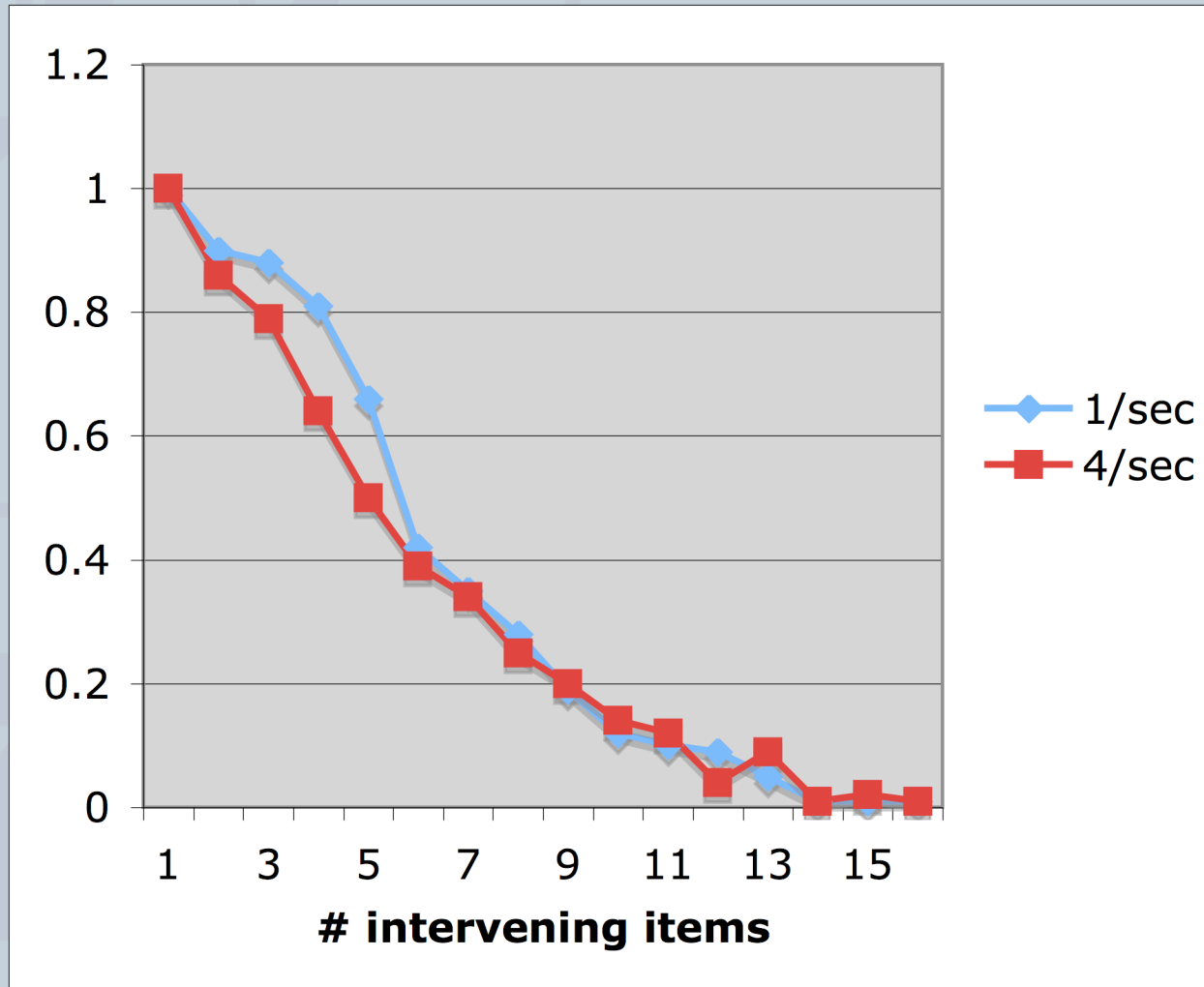
Decay



Interference



Humans



From Forget.f95:

