Course Syllabus

tinyurl.com/IssuesMethods

Optimizing Student Learning Using Cognitive Models

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University of Colorado

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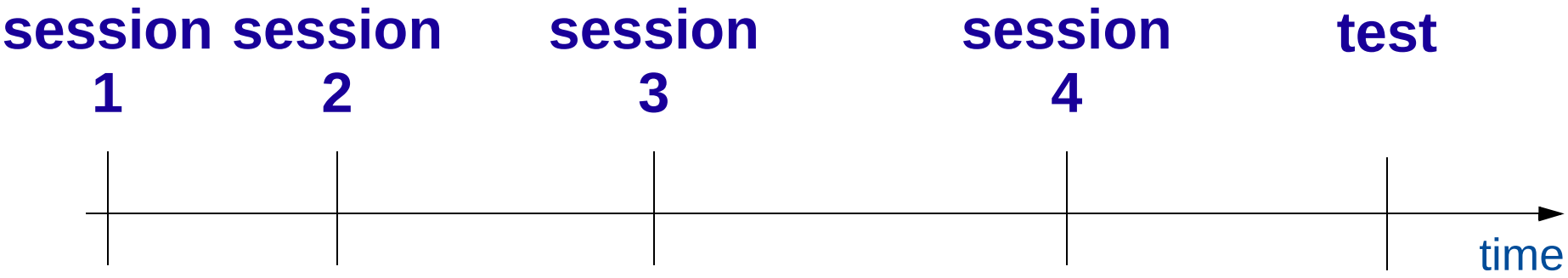
Study Schedule

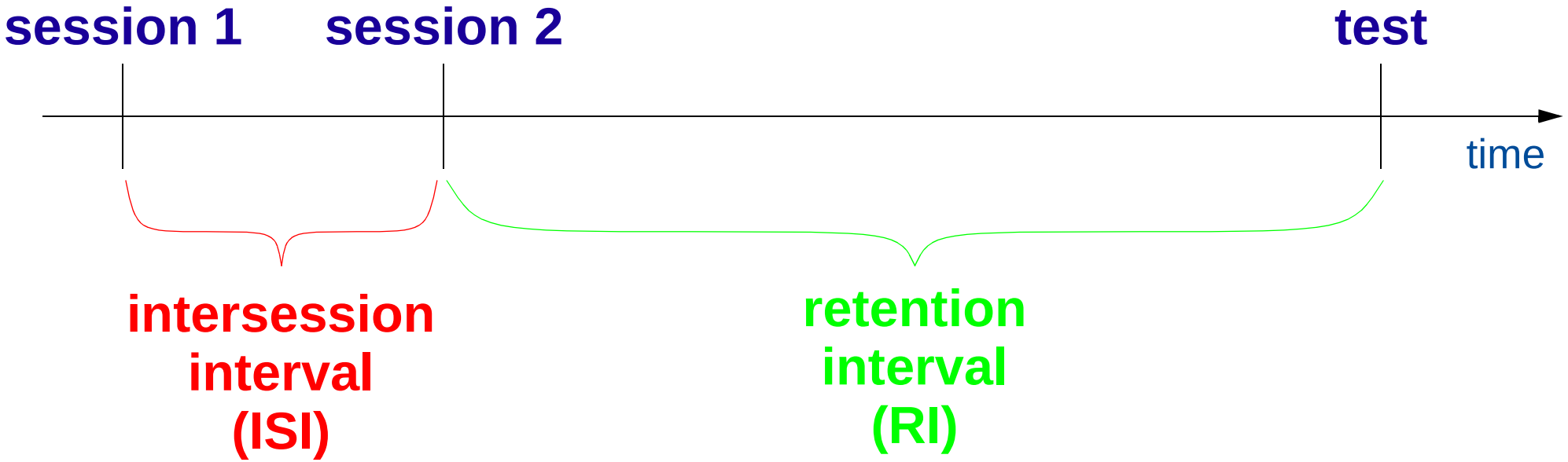


Spacing Effect

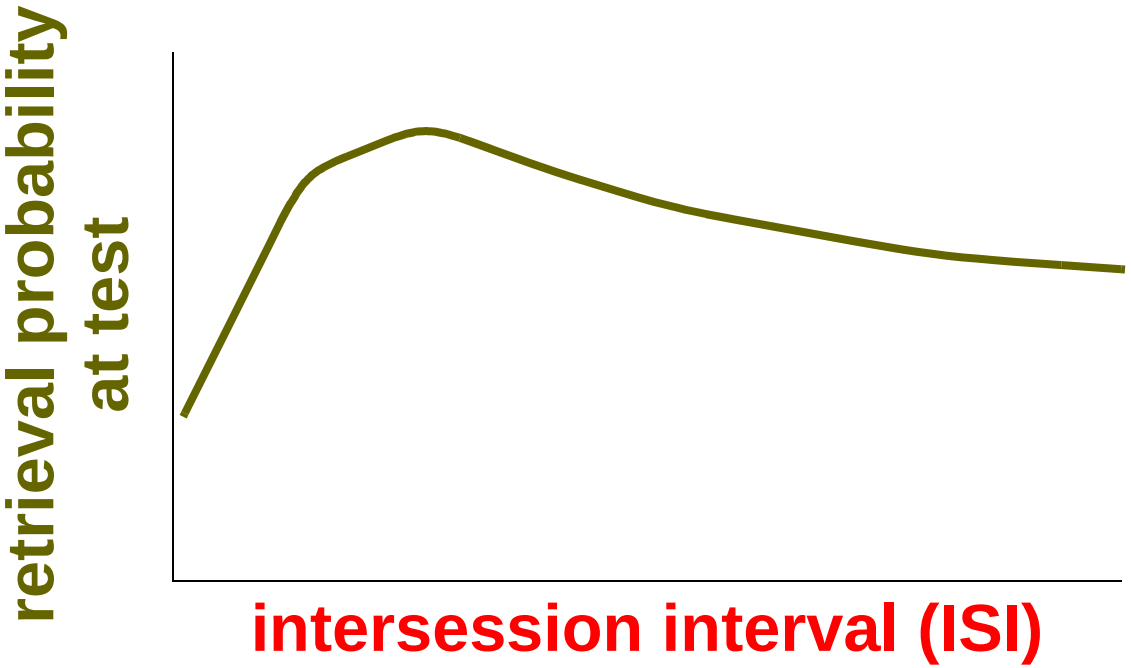
"Spaced study leads to better memory than massed study."

"Don't cram before an exam."

Experimental Paradigm



Spacing Function



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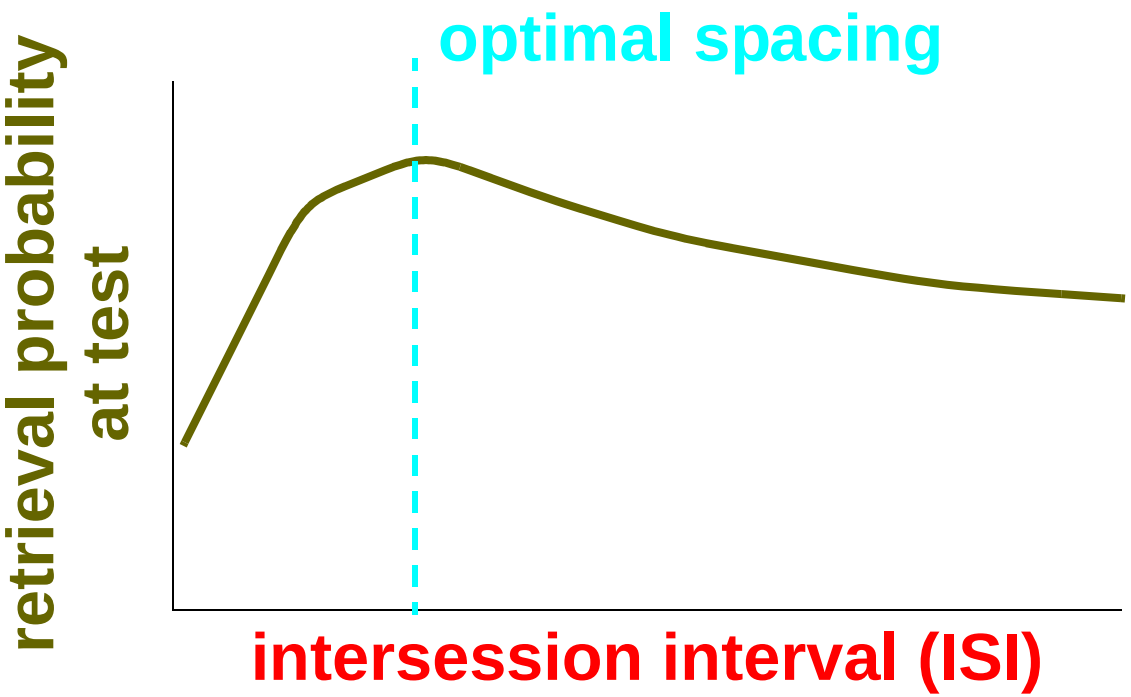

Predictive Utility Theories of Spacing Effects

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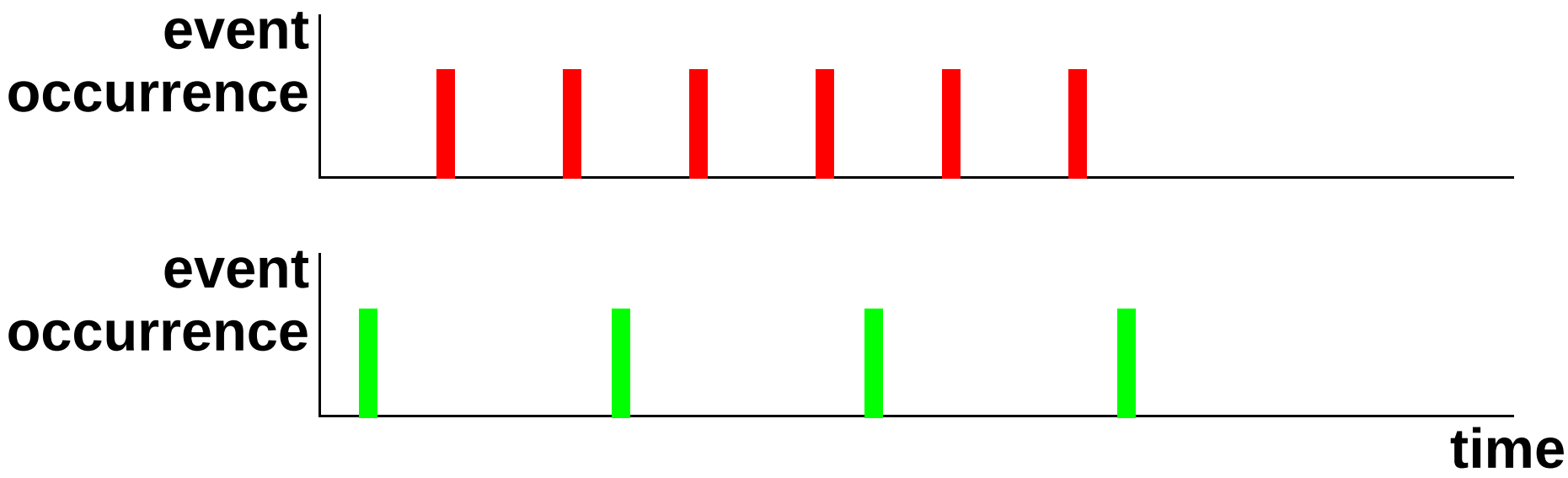
Suppose that memory
- **is limited in capacity, and/or**
- **is imperfect and allows intrusions.**

To achieve optimal performance, memories should be erased if they are not likely to be needed in the future.



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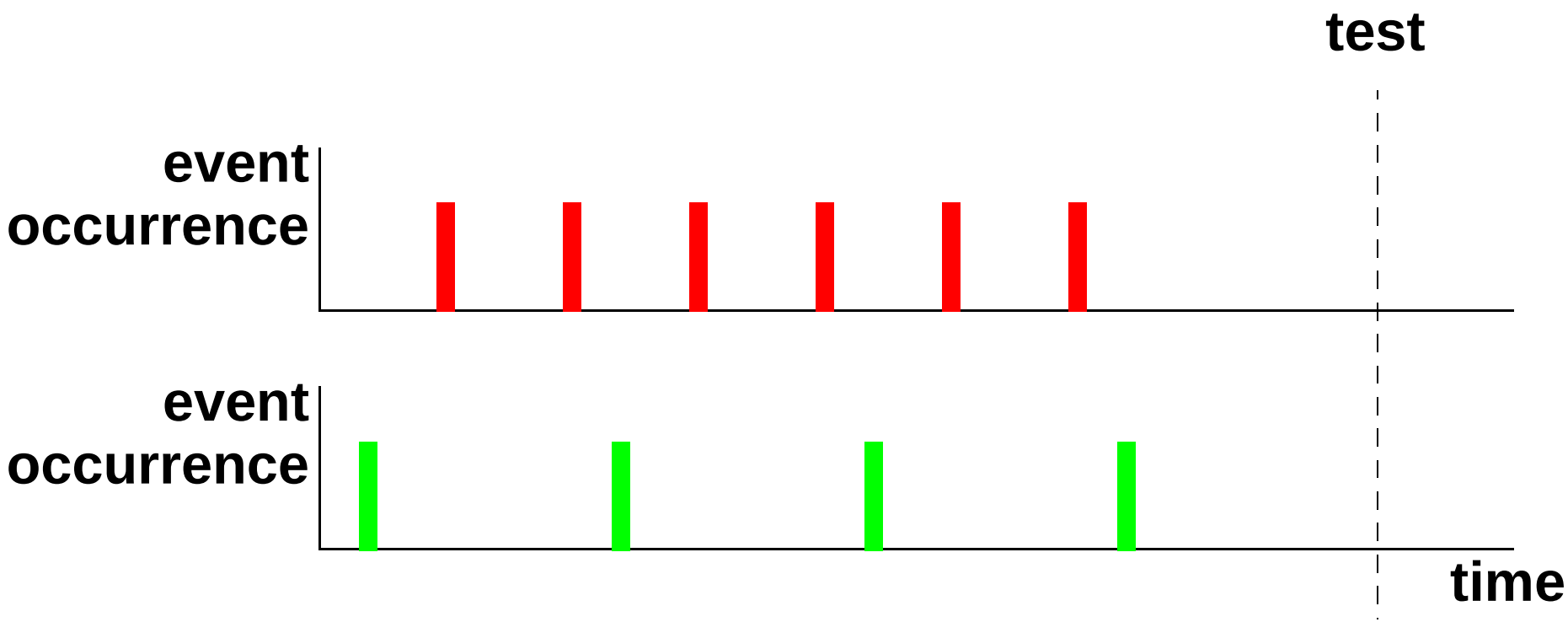
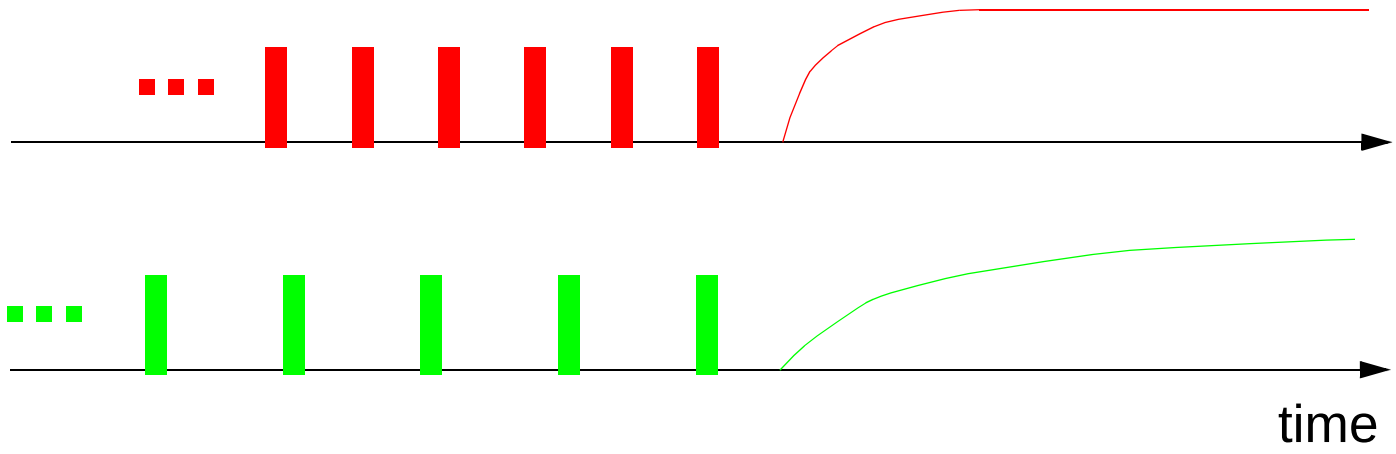


Staddon, Chelaru, & Higa (2002)

Rats habituate to a repeated stream of stimuli.

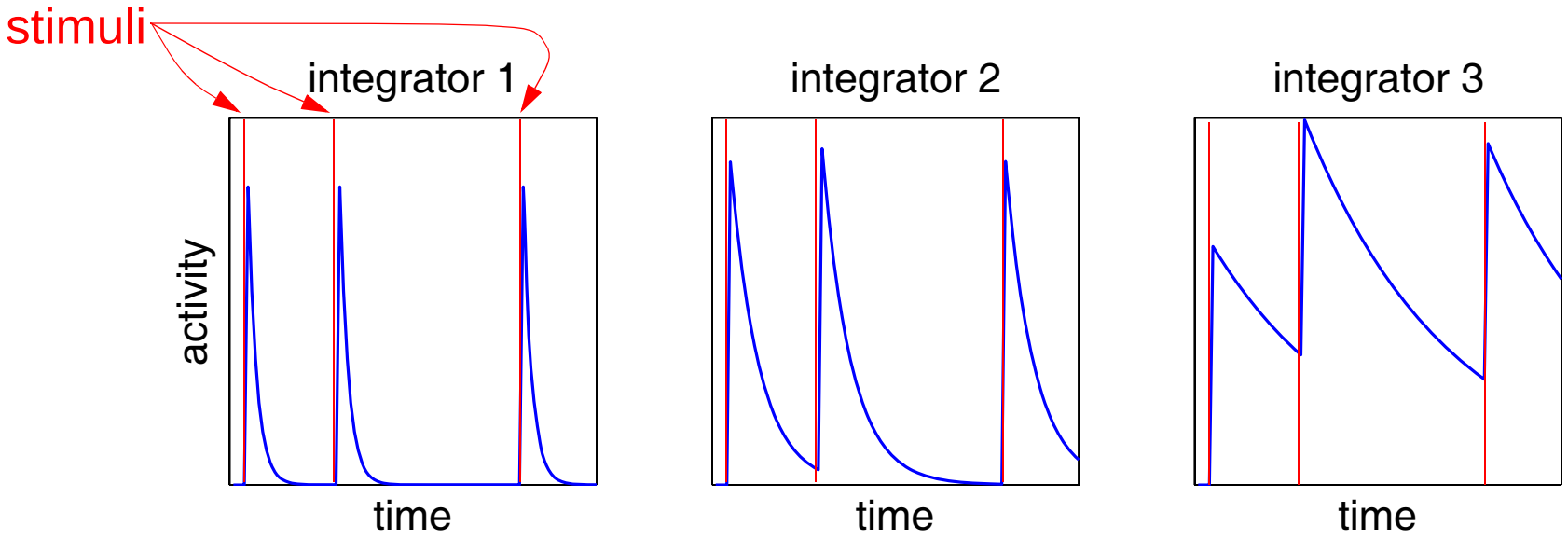
Time for recovery from habituation ~ rate of stimuli

Longer-lasting memory for stimuli delivered at slower rate



Staddon, Chelaru, & Higa (2002)

Each item to be learned represented by memory consisting of *leaky integrators* at multiple time scales.



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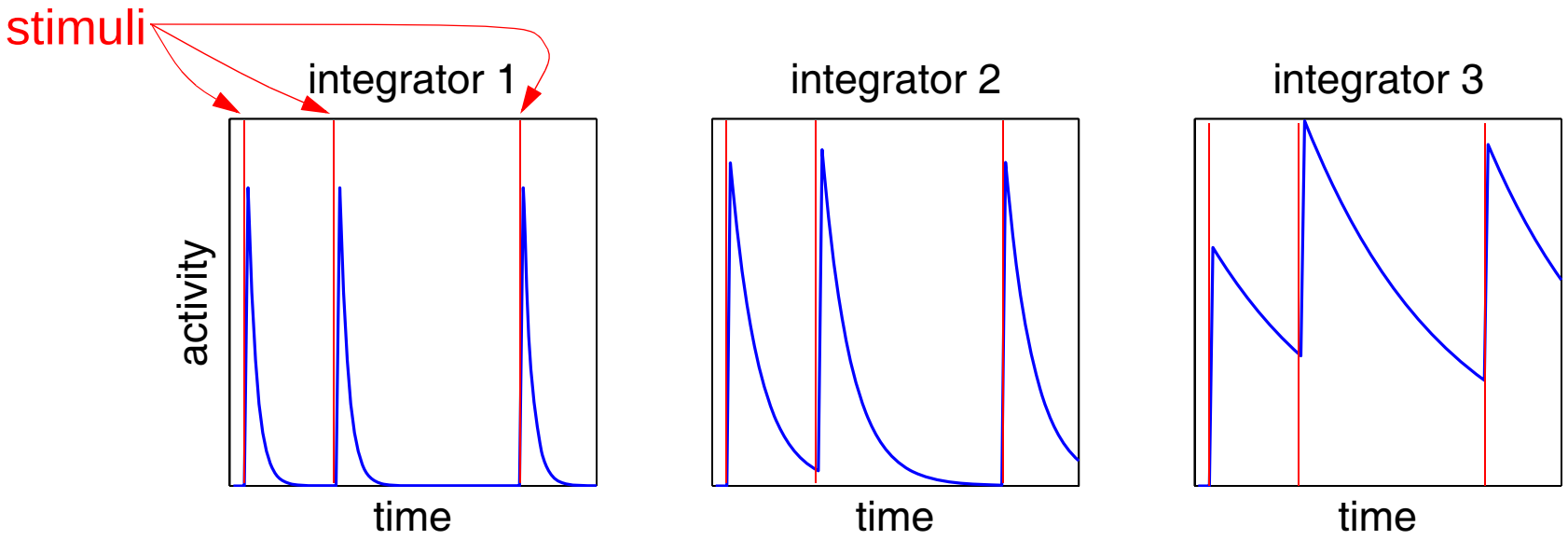

Memory trace is the sum of the integrator activities.

Staddon, Chelaru, & Higa (2002)

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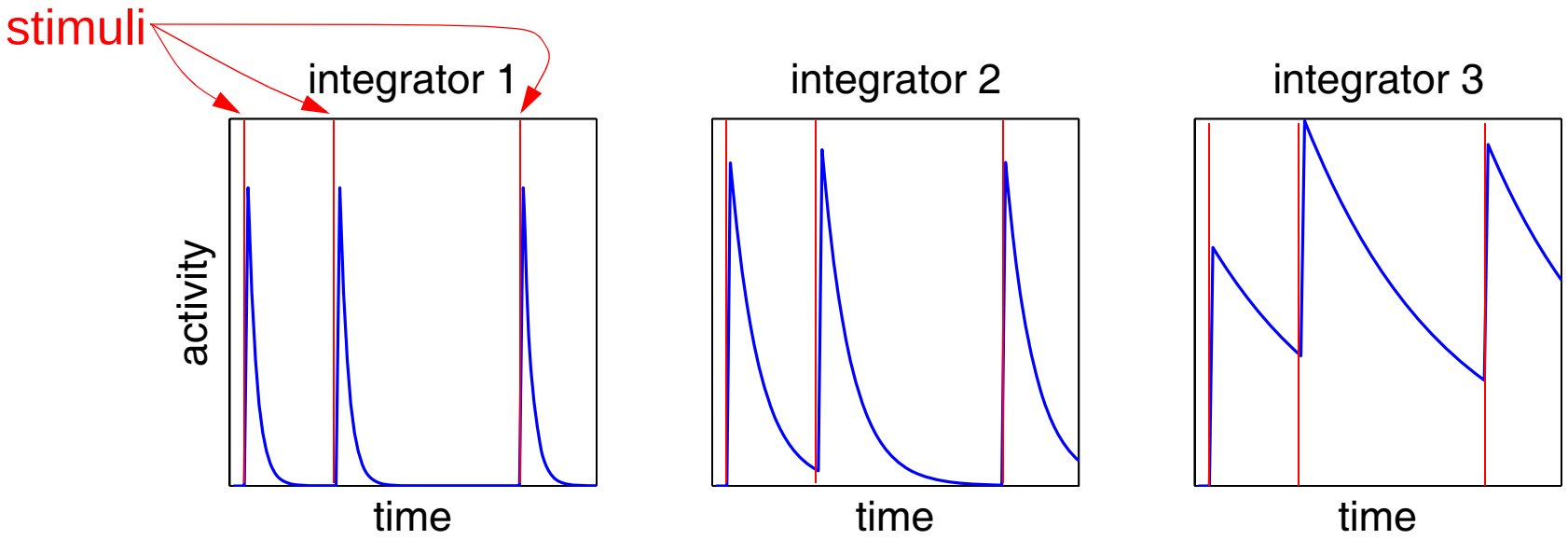


Memory trace is the sum of the integrator activities.

Memory storage rule

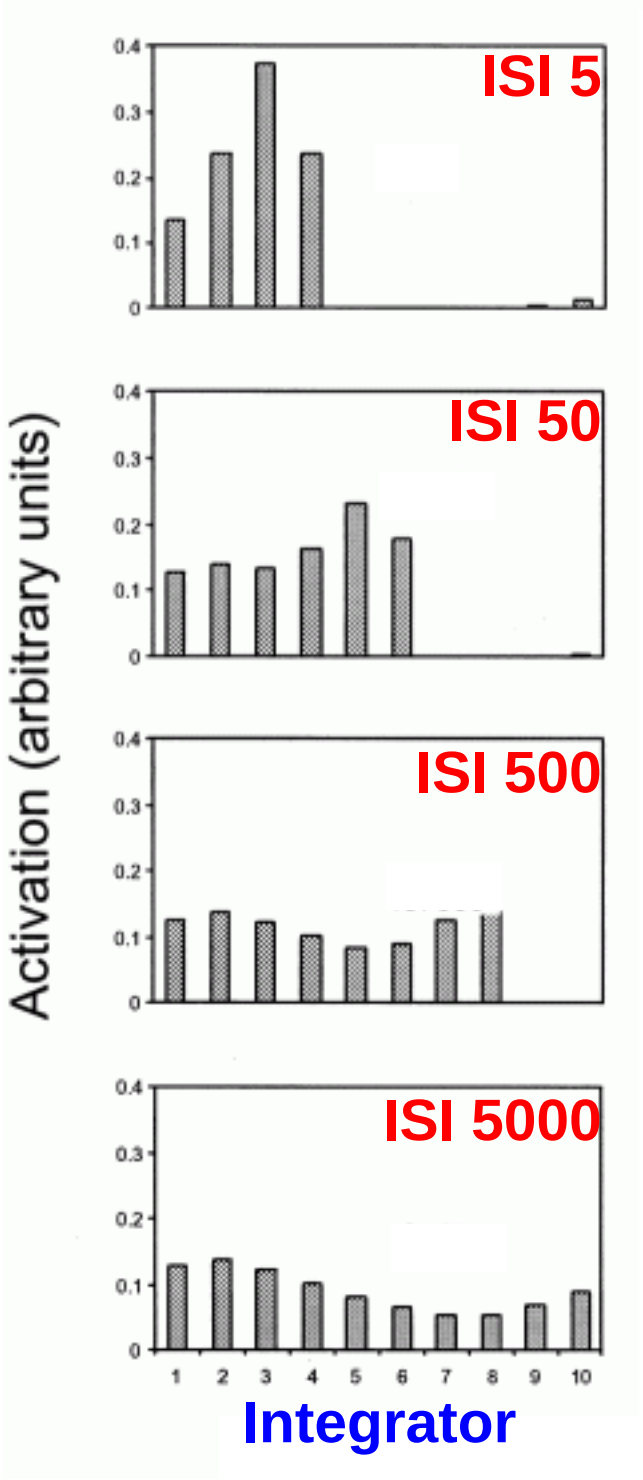
Integrators with long time constants get activated only when integrators with short time constants have decayed.

Example

10 integrators

Stimulus repeatedly presented at various ISIs

Greater spacing ⇒ memory shifts to longer time-scale integrators ⇒ more durable memory



Example

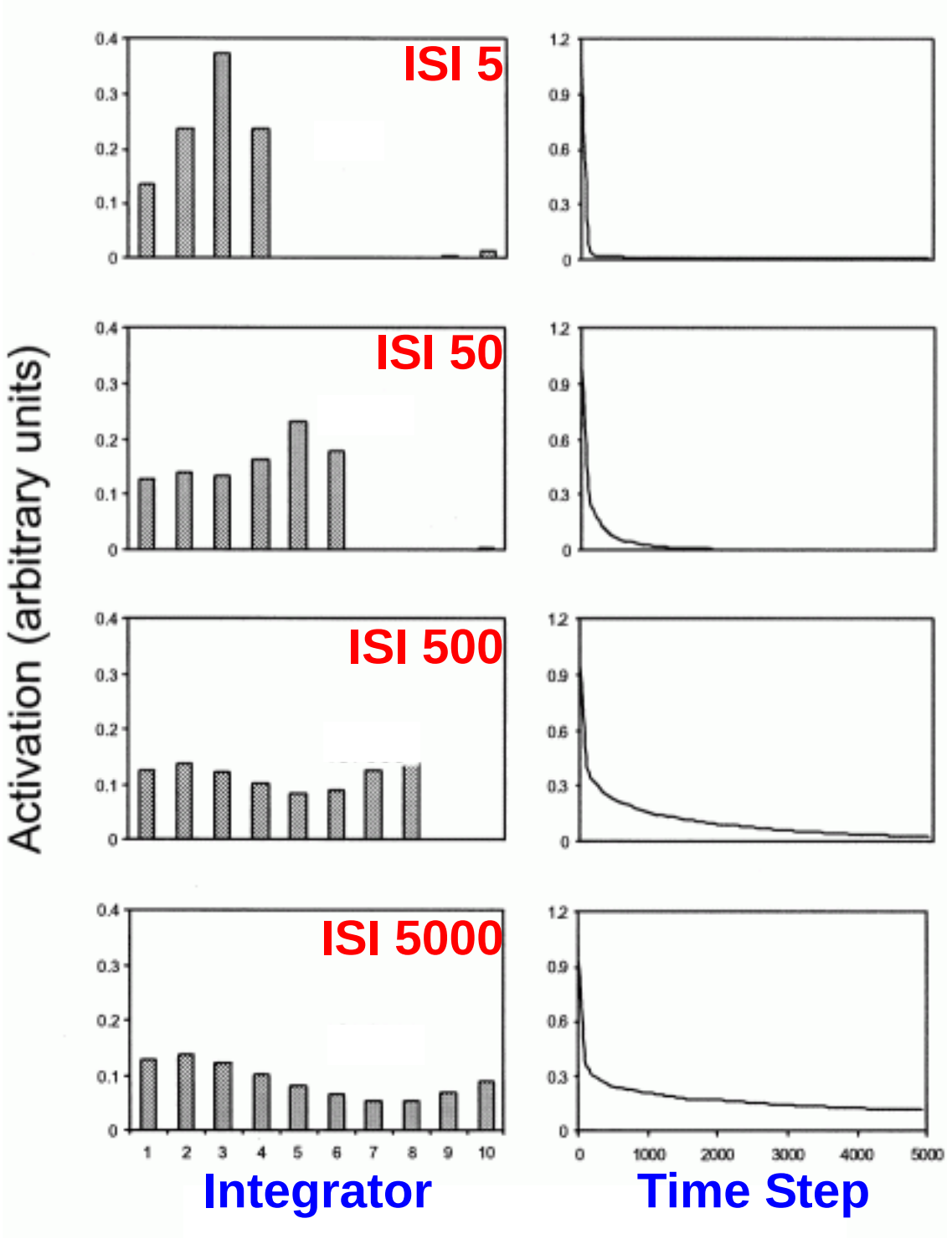
10 integrators

Stimulus repeatedly presented at various **ISIs**

Greater spacing ⇒ memory shifts to longer time-scale integrators ⇒ more durable memory

Model is sensitive to predictive utility

Slower forgetting following longer ISI stimulus sequences.



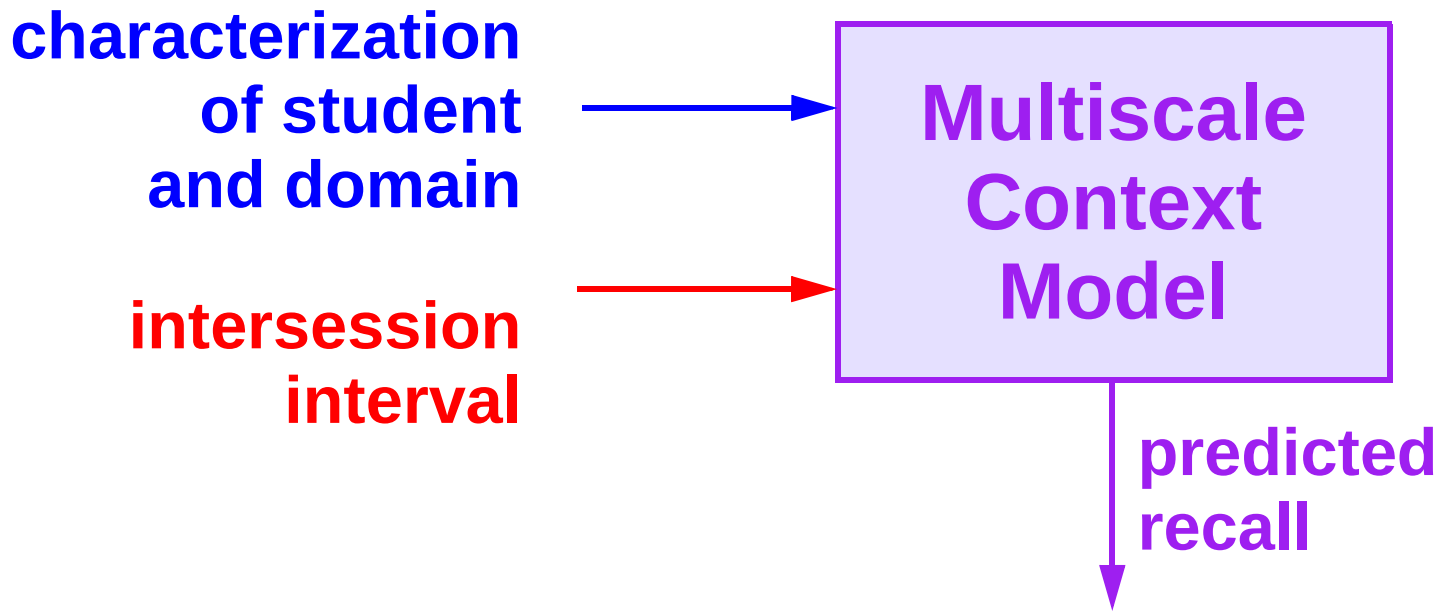
Limitation of Staddon et al. Model

Model was evaluated only on rat habituation studies, which have *many* stimulus presentations.

Parameters not sufficiently well specified to model human spacing studies.

----> Multiscale Context Model (MCM)

Predicting Spacing Curve



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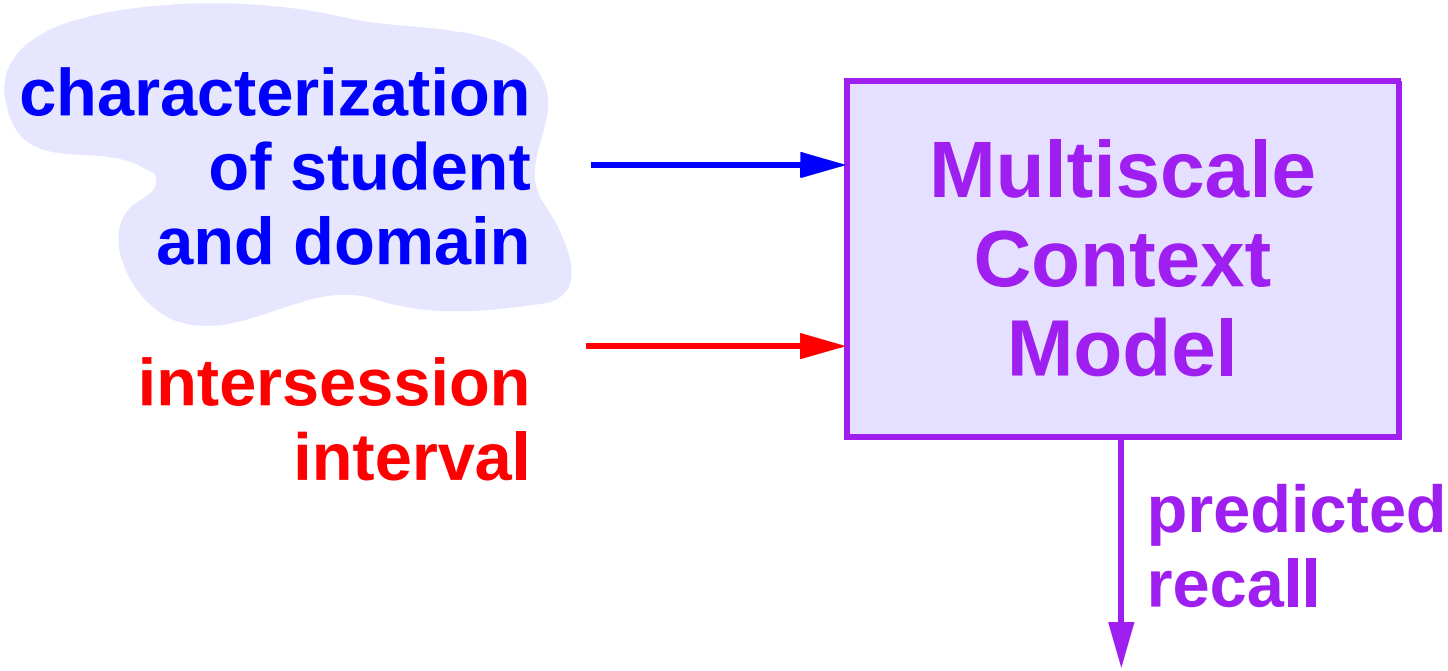

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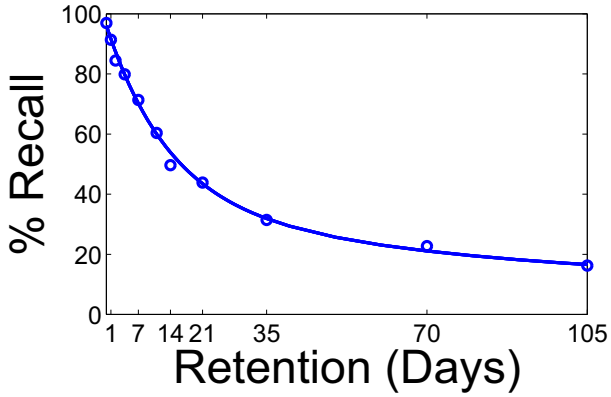


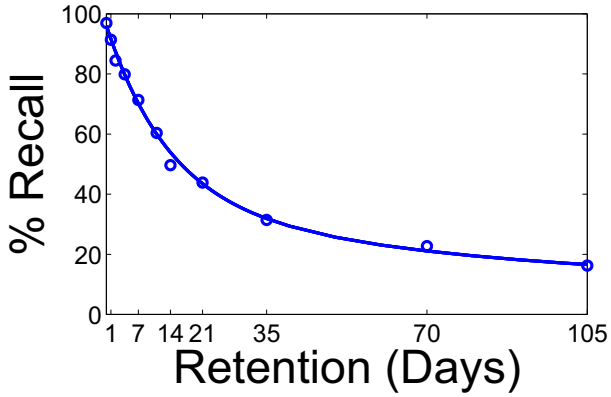
forgetting after one study session

intersession interval

Multiscale Context Model

predicted recall

Predicting Spacing Curve



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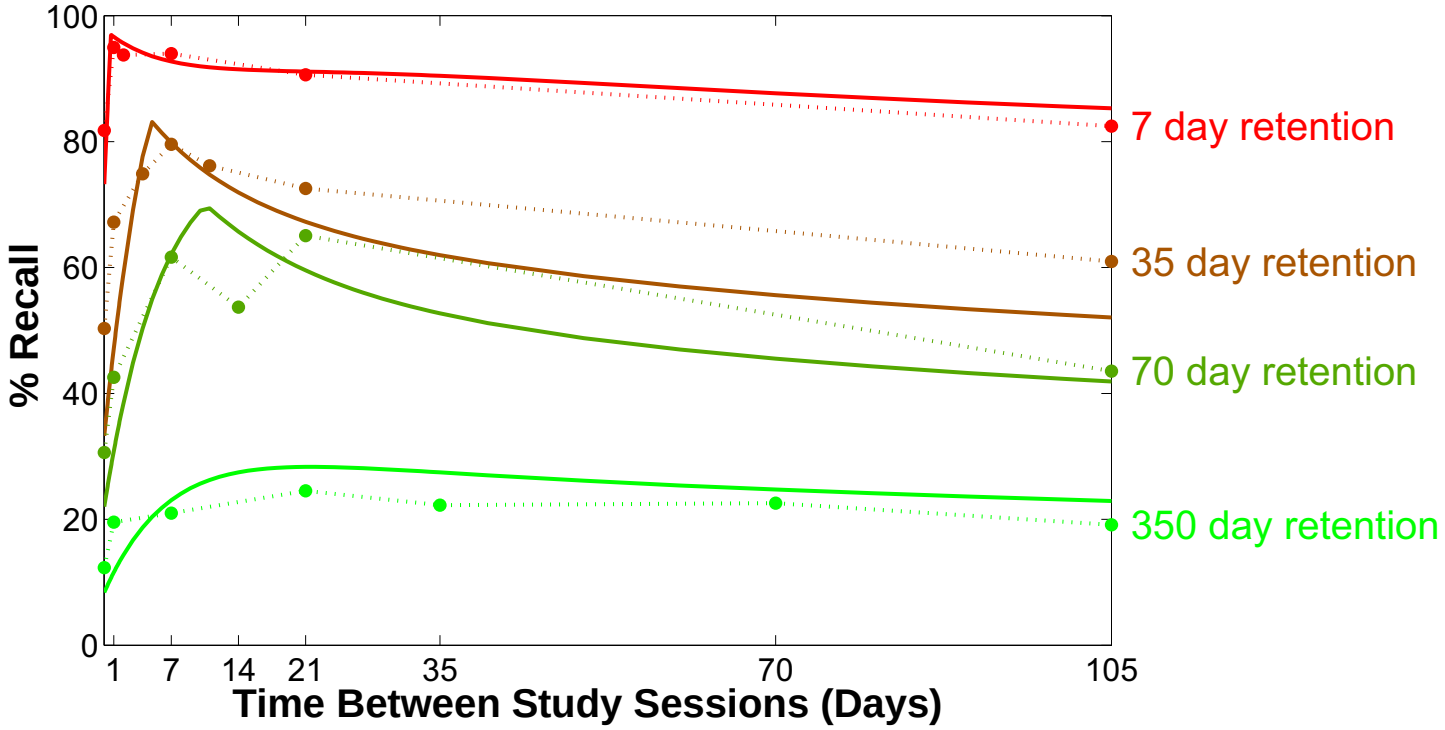
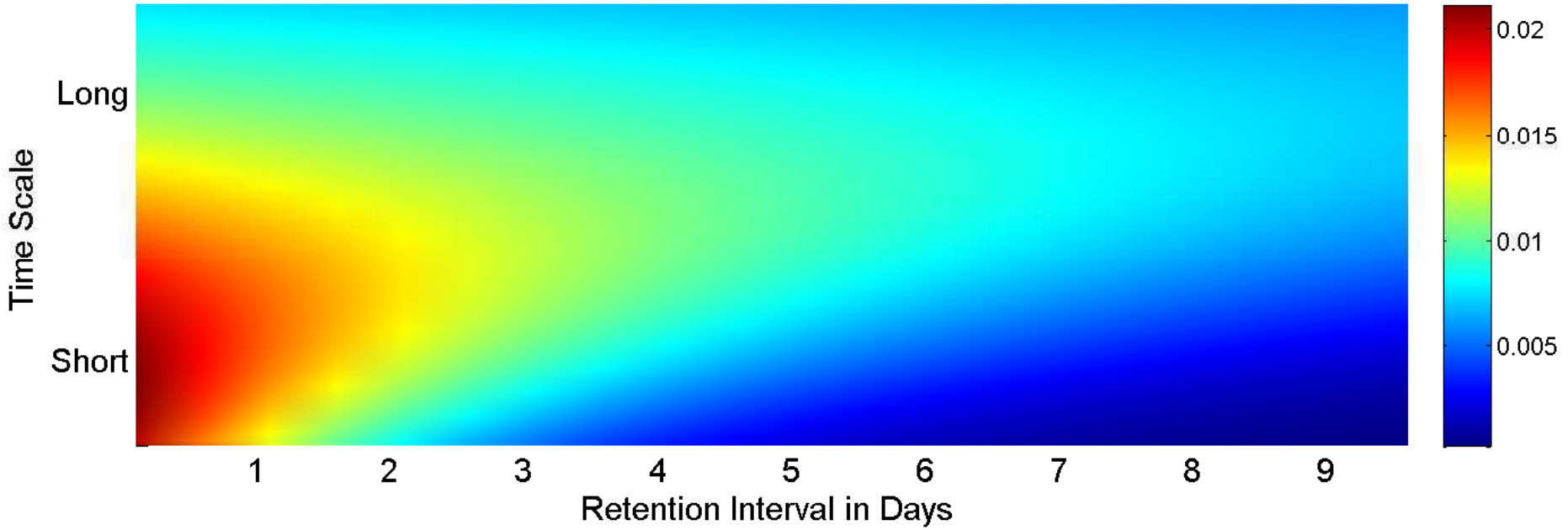
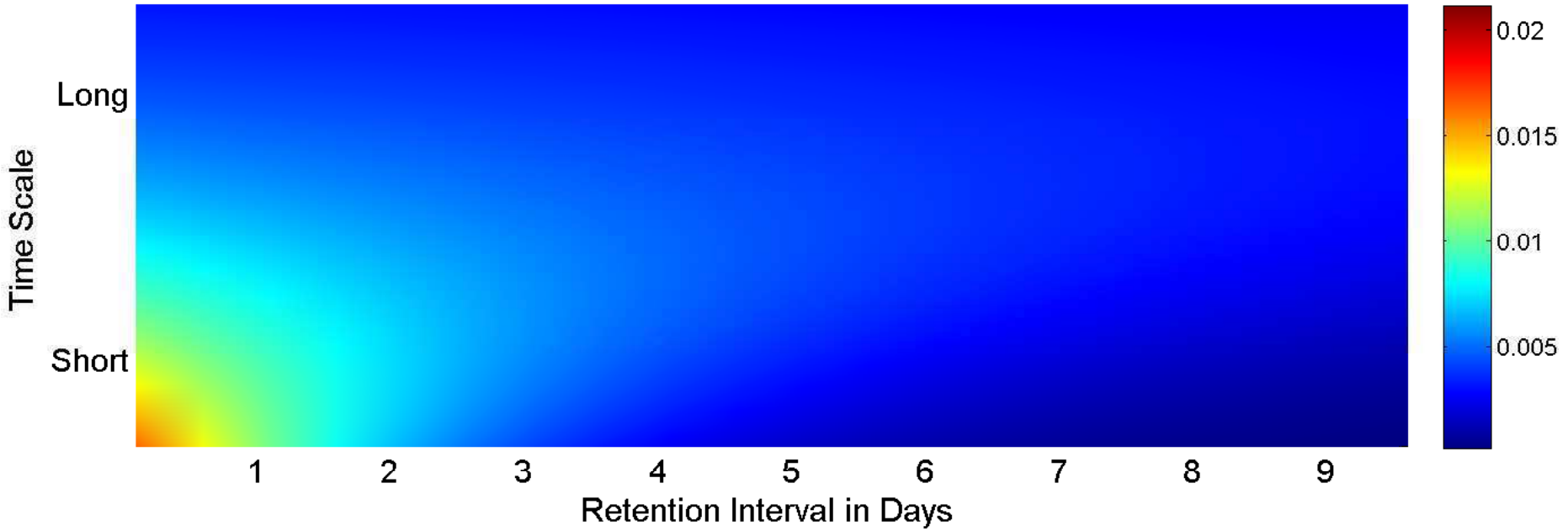


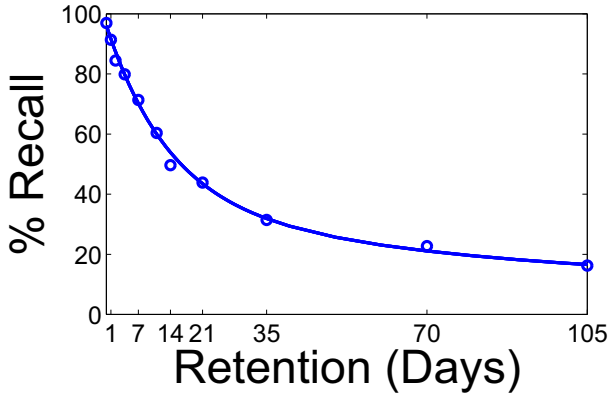
MCM Activations Across Time Scales



study sessions spaced 15 minutes apart



Beyond The Spacing Curve



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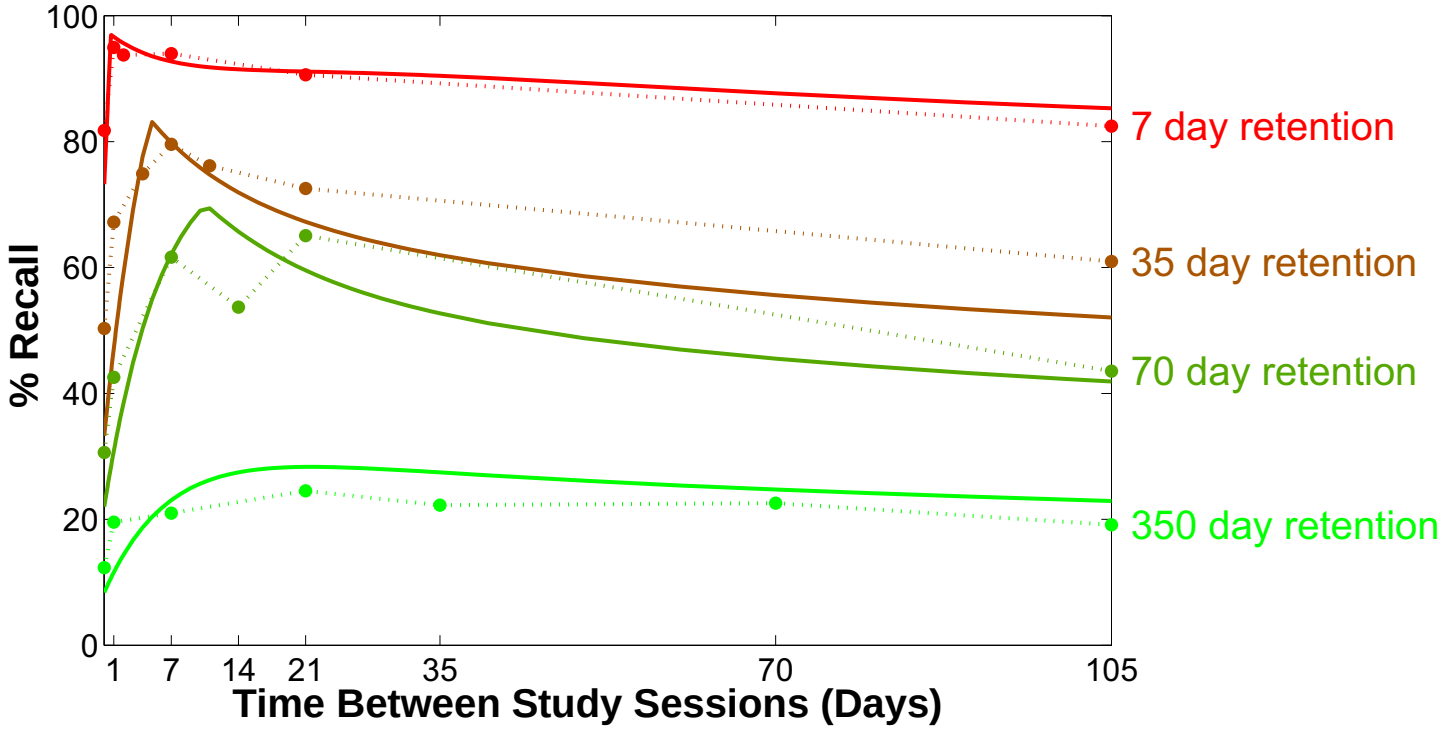

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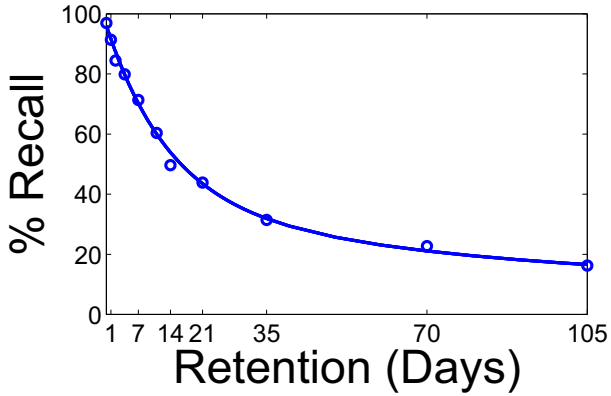


forgetting after one study session

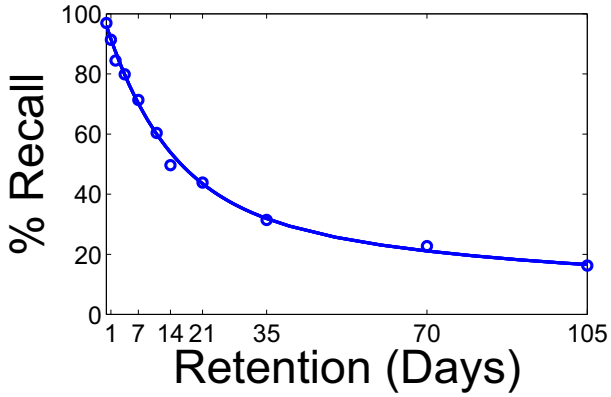
study schedule

lag between session 1 and 2 = 10 days
lag between session 2 and 3 = 20 days
lag between session 3 and test = 50 days

Multiscale Context Model

predicted recall

Beyond The Spacing Curve



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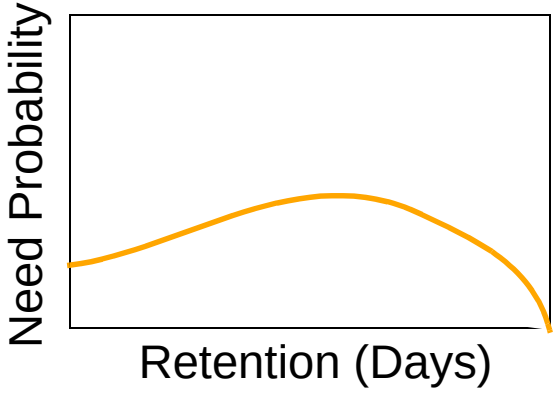

need distribution

Numerical Optimization Routine

optimal study schedule

Software Tools to Enhance Human Learning

Software Tools to Enhance Human Learning

Domain: fact learning

- foreign languages
- medicine
- survival skills

Software Tools to Enhance Human Learning

Domain: fact learning

Manipulation: study schedule

- lag between sessions
- number and duration of sessions (even controlling for total time)
- prioritization of items

Software Tools to Enhance Human Learning

Domain: fact learning

Manipulation: study schedule

Evaluation: measure of retention

accuracy at some future time (e.g., GRE exam date)

expected accuracy over some future window of time (e.g., trip to Germany)

Existing Flashcard Software

Many web sites, iPhone apps, etc.

- studyblue.com
- chinglish-online.com
- spaced-ed.com
- smart.fm
- totalrecalllearning.com
- flashcardexchange.com
- supermemo.org
- mnemosyne-proj.org
- anki

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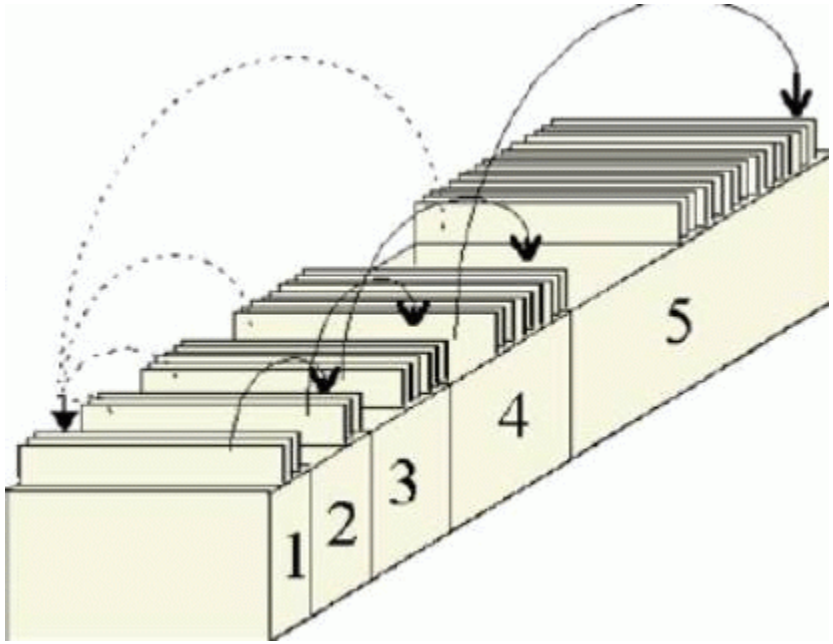
anki

All incorporate spacing based on some variant of heuristic system developed by Leitner (1972)

- New flashcards start in bin 1
- Cards tested correctly promoted to next bin.
- Higher bins: longer lag before next review
- Cards tested incorrectly demoted.



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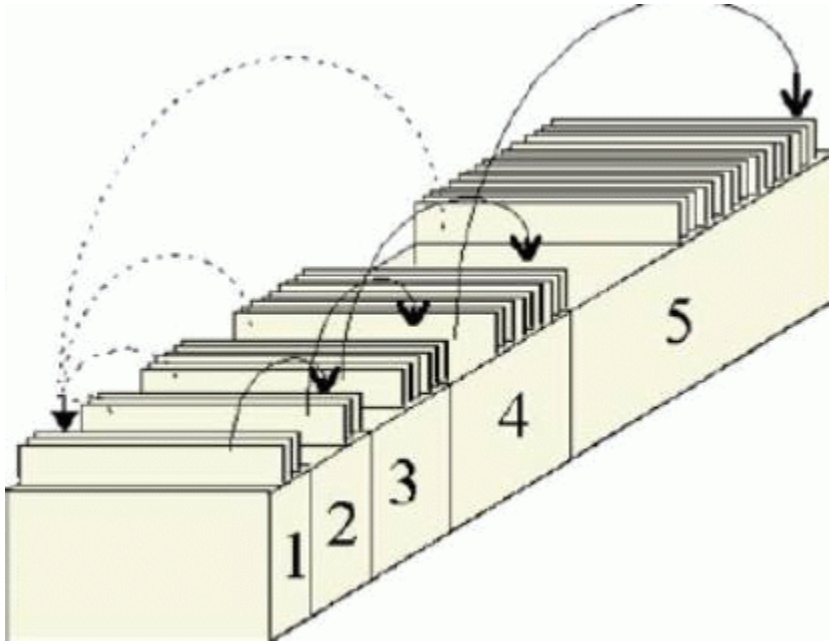


Goal: study card at the point of *desireable difficulty* (Bjork, 1994), i.e., when the individual is on the verge of forgetting.

Problems With Current Tools

- **Optimal spacing depends on window of time over which material needs to be accessible.**

  Therefore, can’t prescribe a study schedule without specifying the window.

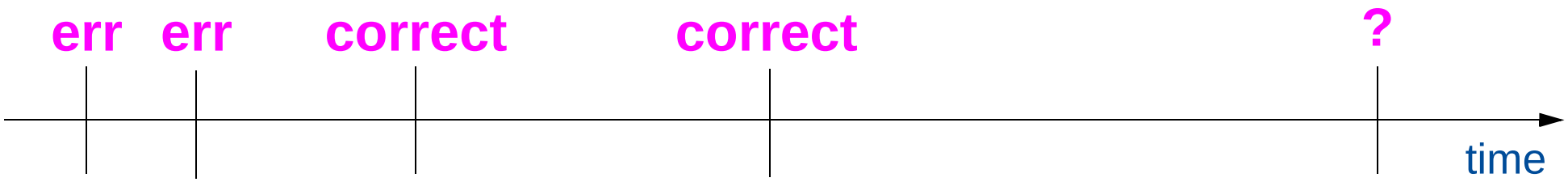
- **Forgetting depends on specific individual, item, and study history.**

  Leitner box is ‘one size fits all’.

Improving Predictions Using A Cognitive Model

We can use MCM to predict how strong a given item is in memory for a given student based on that item's study history.

E.g., student 12's study history for dog-hund



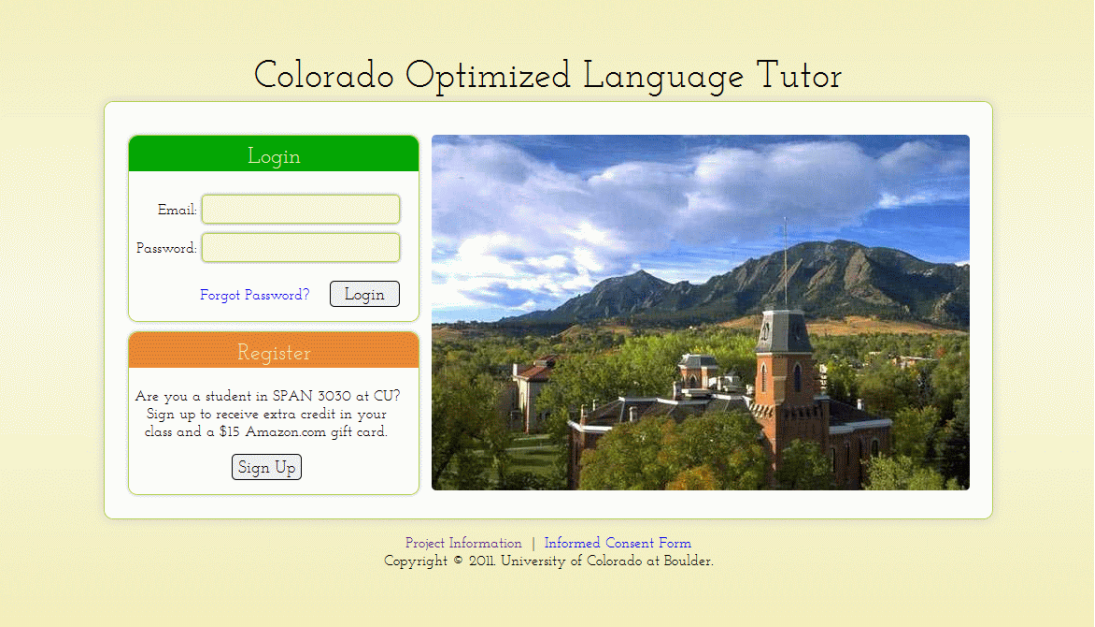
Collaborative filtering approach

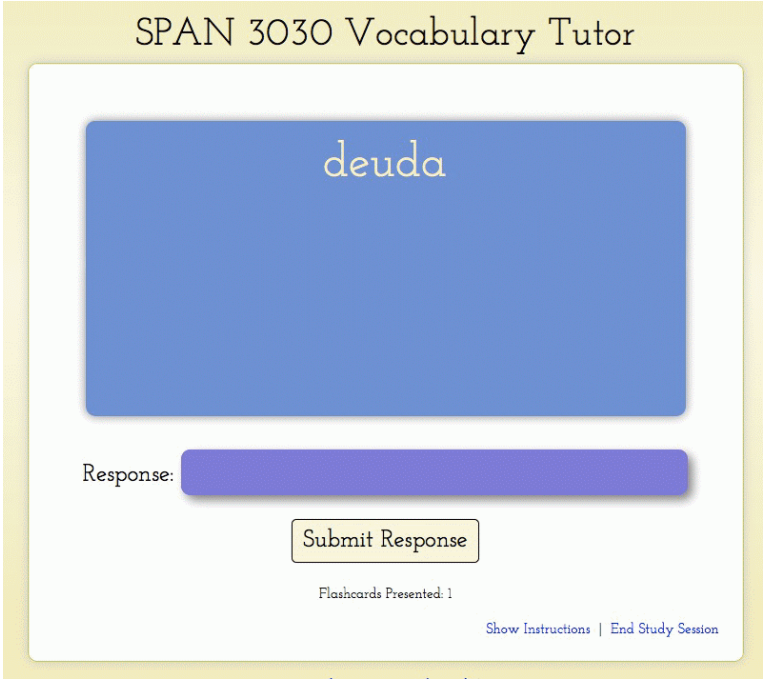
Use data from a population of students to strengthen predictions about individual students.

Use data from a population of items to strengthen predictions about individual items.

-> Fancier version of MCM that can predict individual differences in student ability and item difficulty

Colorado Optimized Language Tutor (COLT)





Debugged in 2010-2011

Advanced business Spanish course at CU Boulder

Fall 2012

Experiment In Denver area middle school

Spanish II (grade 8)

~ 180 students in 6 class periods

new vocabulary introduced each week for 10 weeks

quiz at the end of each week

Integrating COLT into curriculum

replaced previously used flashcard software (conjuguemos.com)

class restructured to have 3 30-minute COLT sessions per week

Focus On Regular Review

Conjuguemos.com does not encourage review

students choose which week's material to study

COLT incorporates review into study

Friday: practice new vocabulary to criterion; any additional time spent on review

Tuesday: practice new vocabulary to criterion; any additional time spent on review

Thursday: quiz on new vocabulary; any additional time spent on review

~ 25 min / week of the 90 min / week spent on review

Within-Student Comparison Of Three Review Schedulers

- **Massed**

  Continue studying the current week's material during the review time.

  Like cramming for the exam

- **Generic spaced**

  Study material from the previous week

  (For a population of students studying foreign language vocabulary in an experimental setting, 1 week was optimal for retention intervals of around 1-2 months)

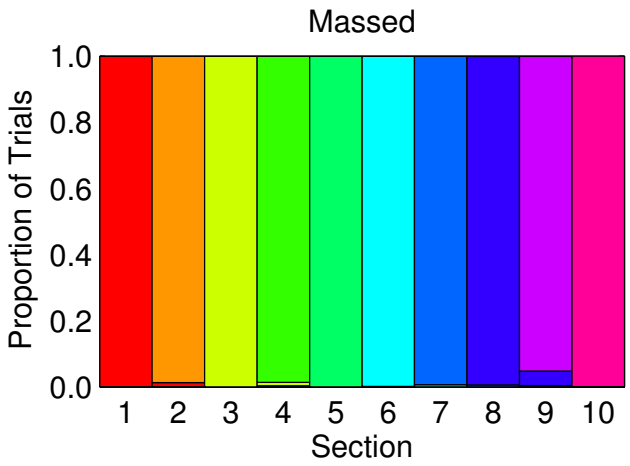
- **Personalized spaced**

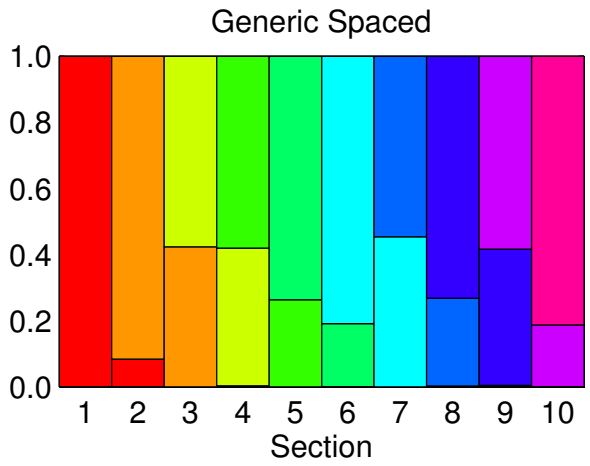
  Select material for review for a particular student based on that student's study history and performance

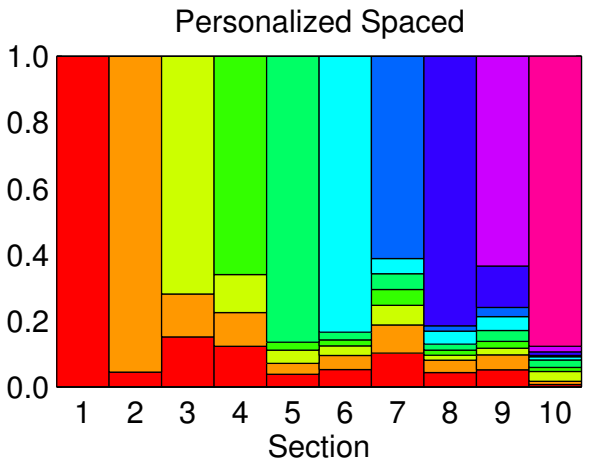
  Use MCM to predict memory strength of each item for each student

  Scheduler selects the material that is on the verge of being forgotten according to MCM.

Scheduler Behavior







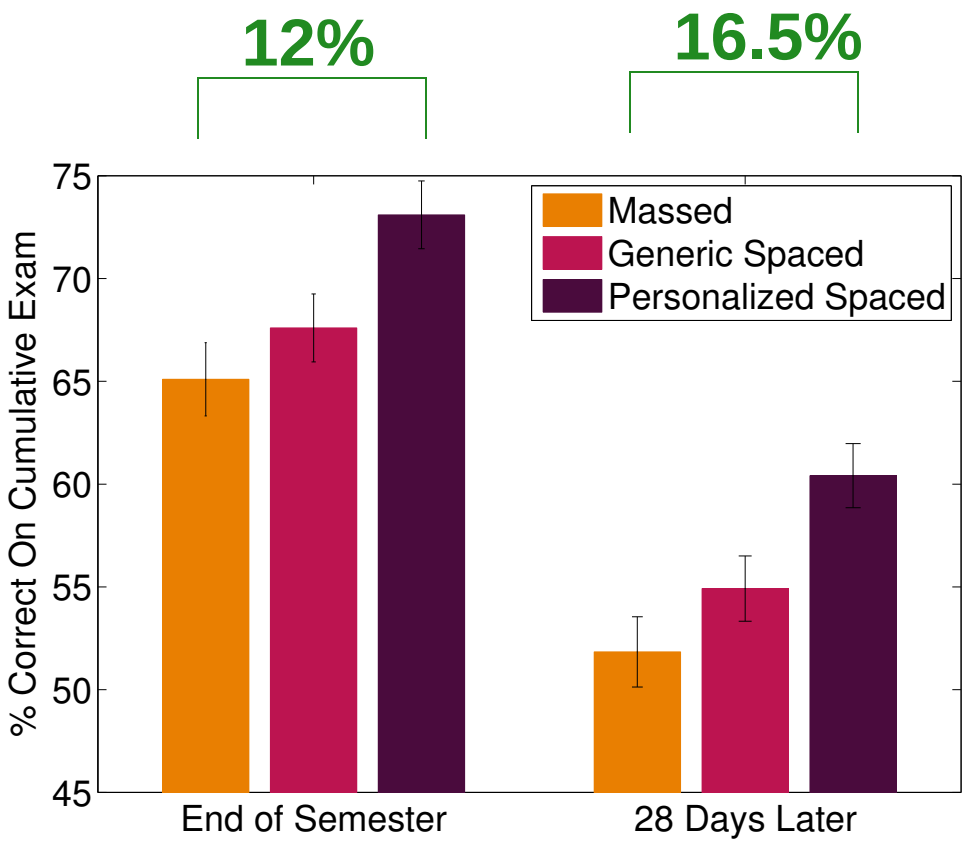
Evaluating COLT

Cumulative final administered at end of semester

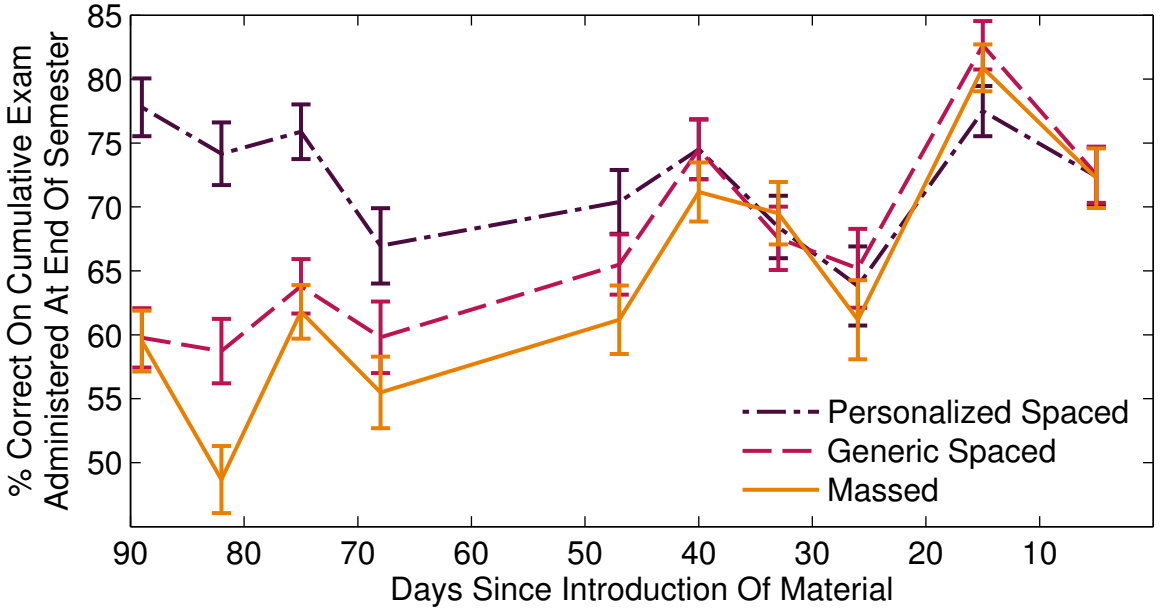
Half of the items tested before holiday break (mid December)

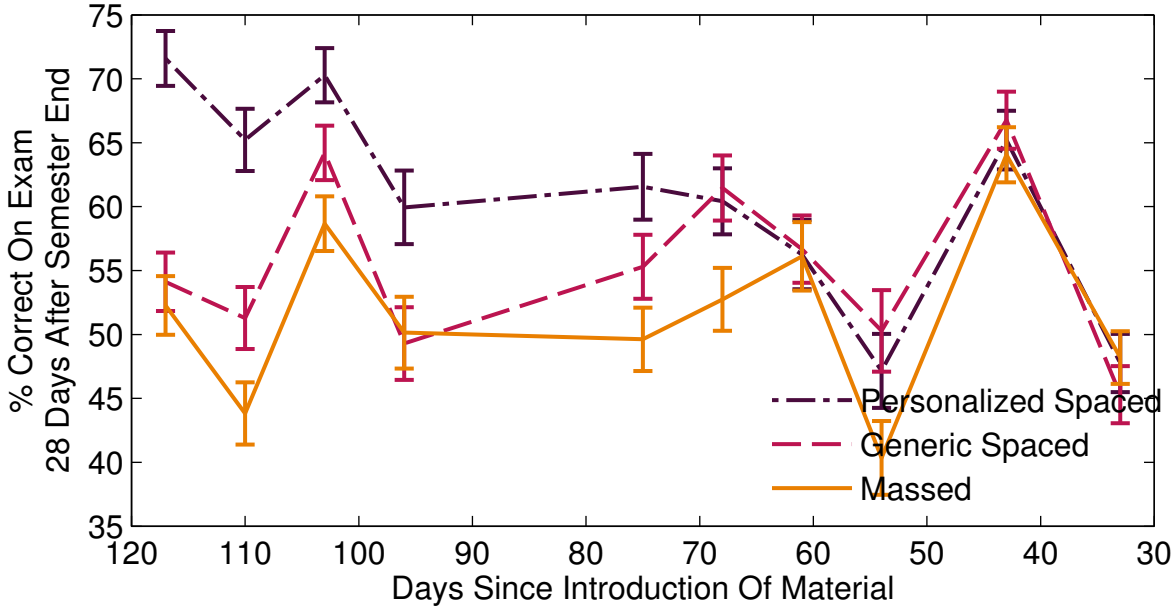
Half of the items tested after holiday break (mid January)

Performance by review condition



Evaluating COLT: Breakdown By Section





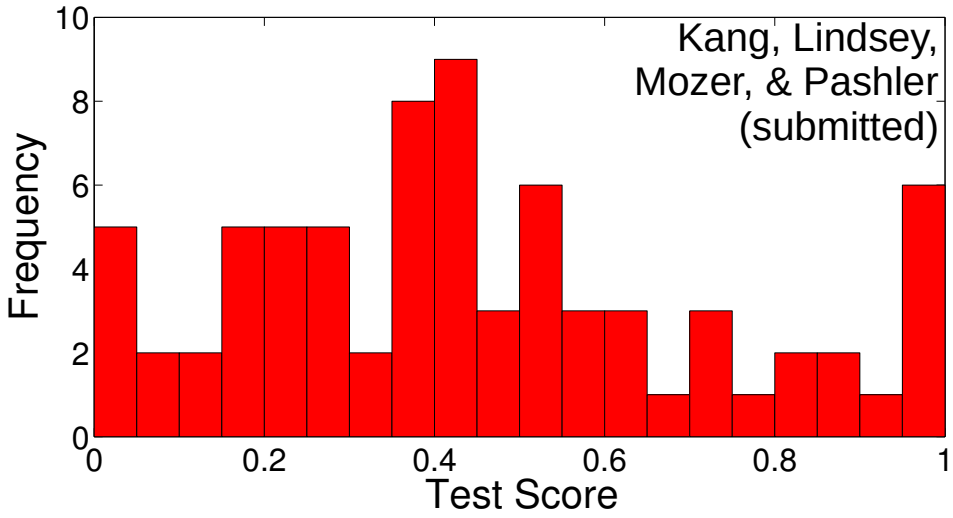
To Be Continued...

Individual Differences

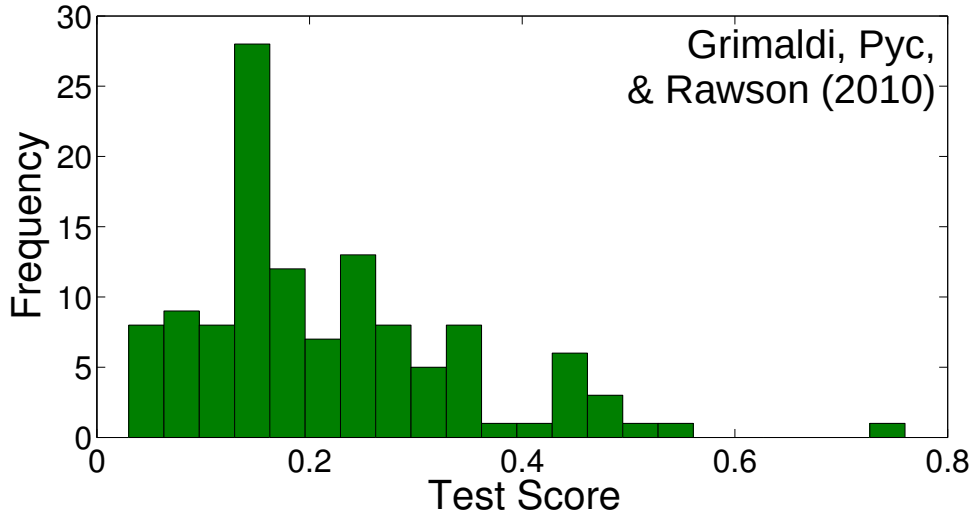
Learning and retention is typically studied using populations of students and items.

But individual differences exist and are important.

Distribution of *student* scores
(Japanese-English vocabulary)



Distribution of *item* scores
(Lithuanian-English vocabulary)



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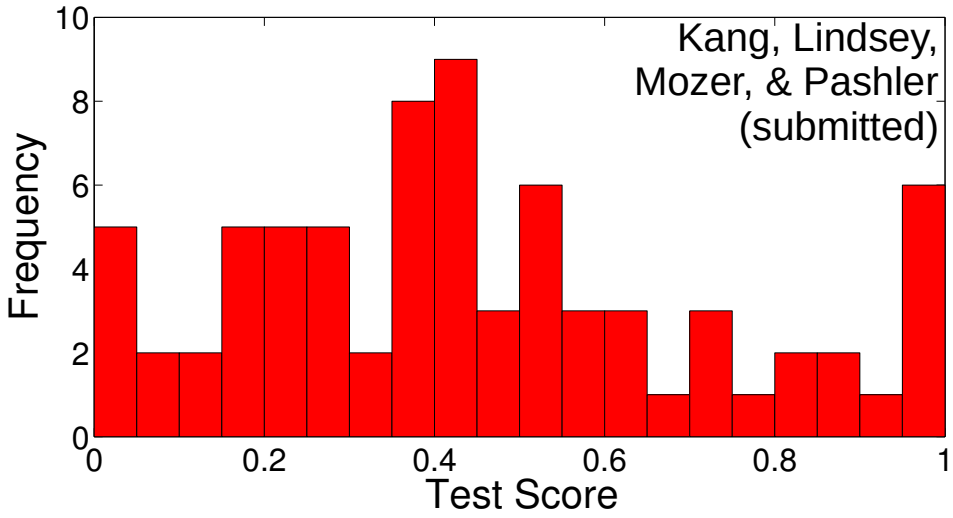

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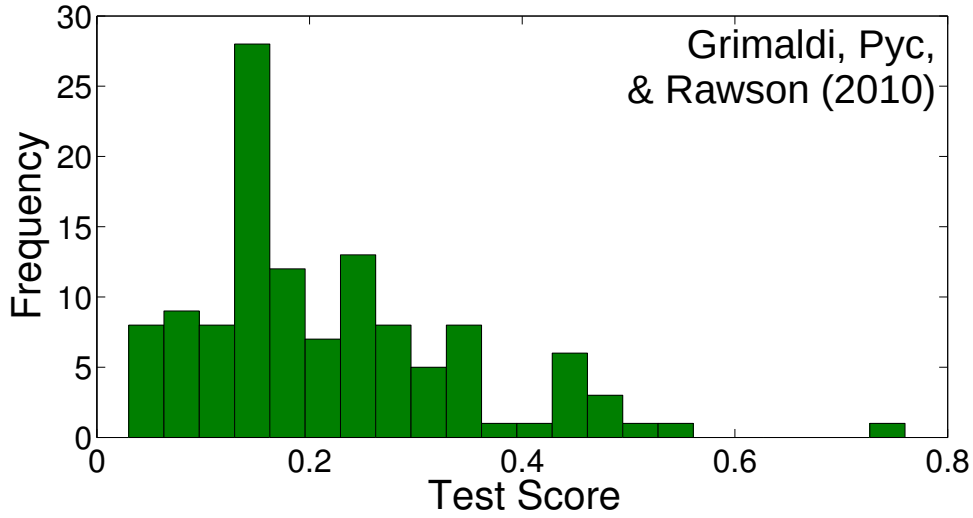


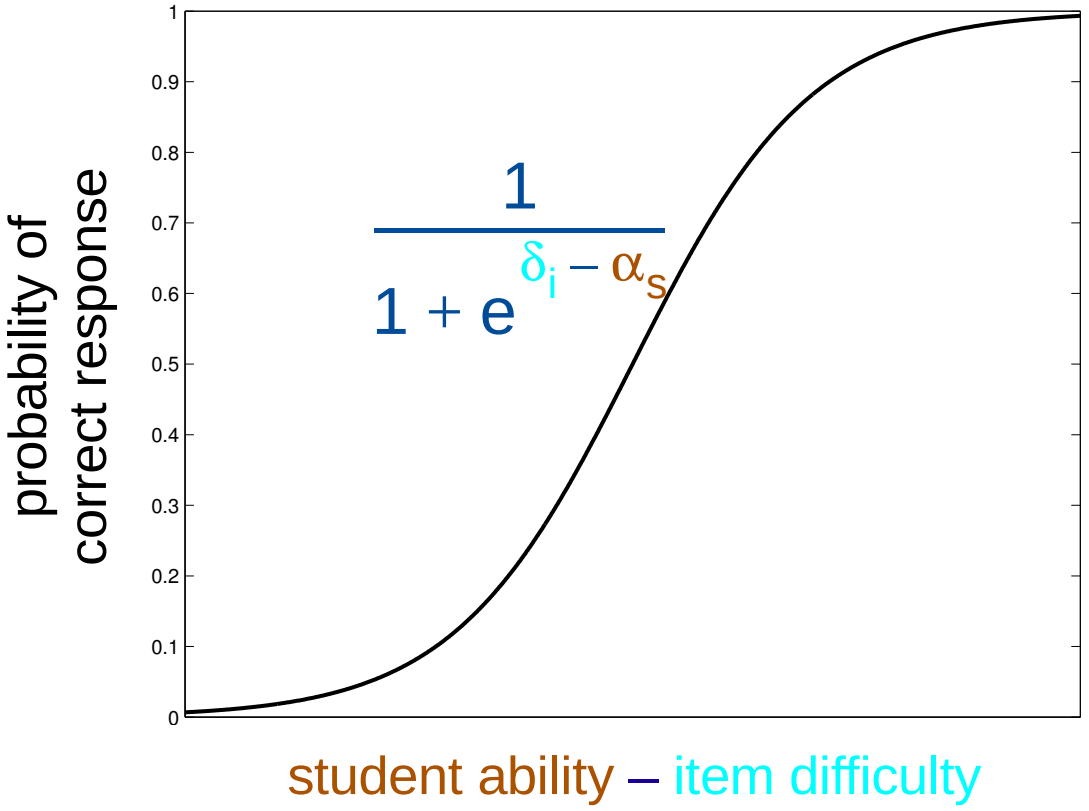
Challenge: infer a particular student's state of knowledge for a particular item from very weak feedback.

Item Response Theory

Traditional approach to modeling student and item effects in test taking (e.g., SATs)

δ_i latent difficulty of item i

α_s latent ability of student s



Time invariant theory

Extending Item-Response Theory To Consider Time

- time to test
- number of study sessions
- spacing of sessions

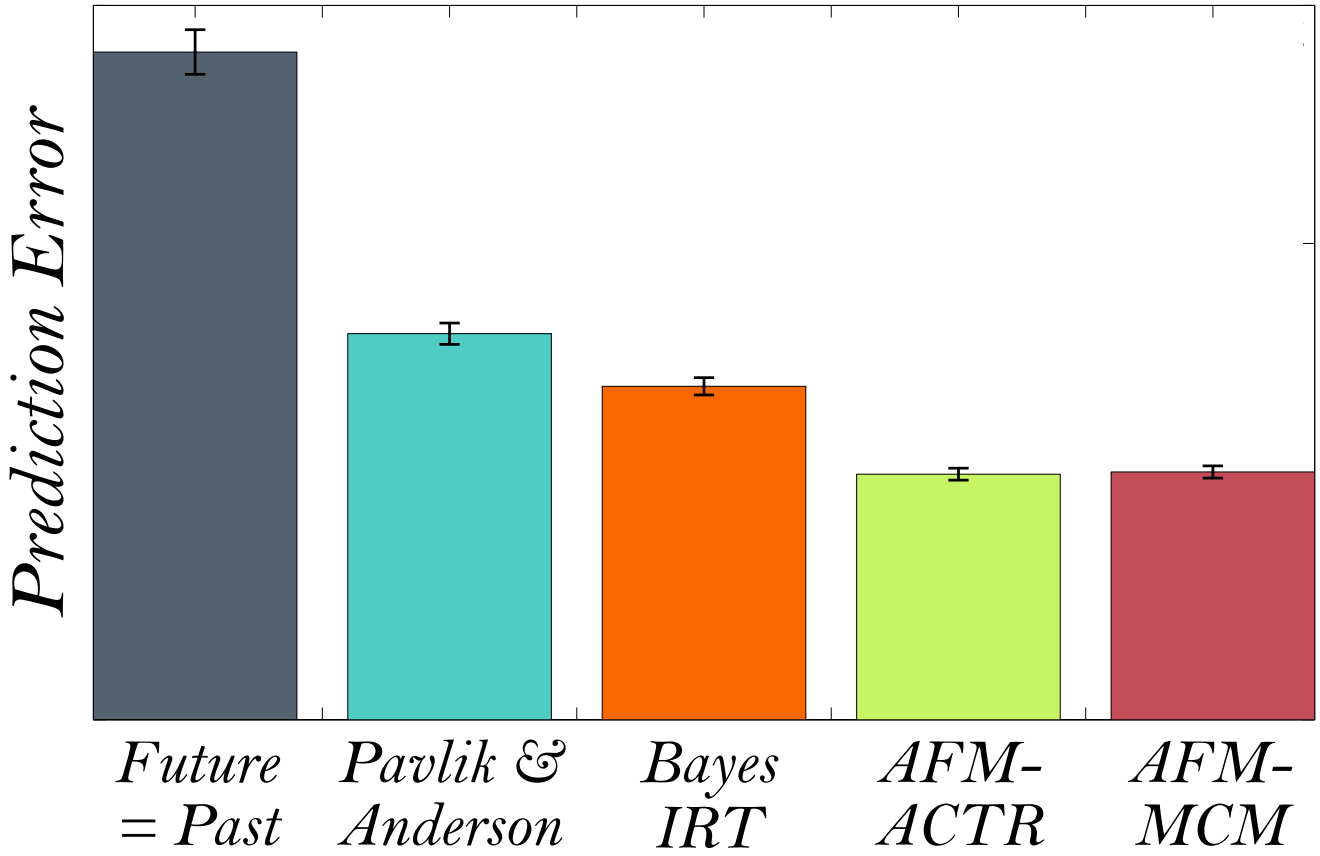
Extending Item-Response Theory To Consider Time

- time to test
- number of study sessions
- spacing of sessions

incorporate model of memory and forgetting

Predictions Of Alternative Memory Models

Use all data from days 1-*n* to predict student recall on day *n+1*



Why Hasn’t Cognitive Science Had A Greater Impact on Education?

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Most guidance is *qualitative*

- “Space your study”
- “The harder you work to learn, the better you’ll retain”
- “Relate new material to be learned to learner’s existing knowledge”

Why Hasn’t Cognitive Science Had A Greater Impact on Education?

Most guidance is *qualitative*

“Space your study”

“The harder you work to learn, the better you’ll retain”

“Relate new material to be learned to learner’s existing knowledge”

Quantitative **modeling and prediction can provide specific, customized, detailed guidance.**

- particularly useful if there’s significant variability across individuals and materials