

CSCI 1377

Tools for Thought

Mnemonics II

Spaced Repetition Systems

“I alone have more memories than all mankind since the world began.”

— Jorge Luis Borges, *Funes the Memorious* (1962)

**Engaged retrieval over time
strengthens memory**

Testing effect: tests improve recall over studying

Materials: TOEFL exam passage

“Sea otters are a small mammal that lives in the waters along North America's west coast from California to Alaska. A few years ago some of the sea otter populations off of the Alaskan coast started to decline rapidly [...]”

Procedure:

Phase 1

7 min study

→ 7 min restudy

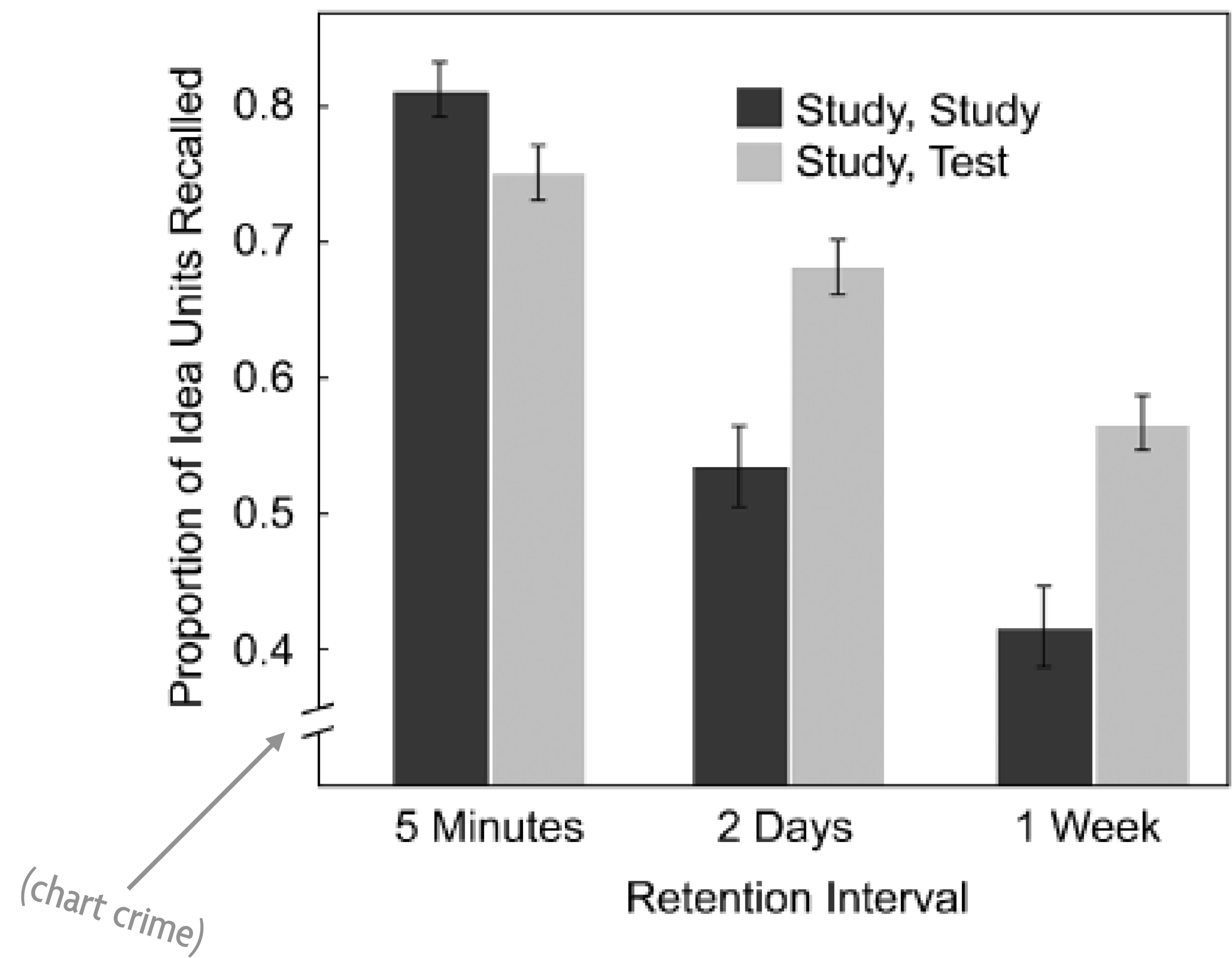
OR

→ 7 min recall test

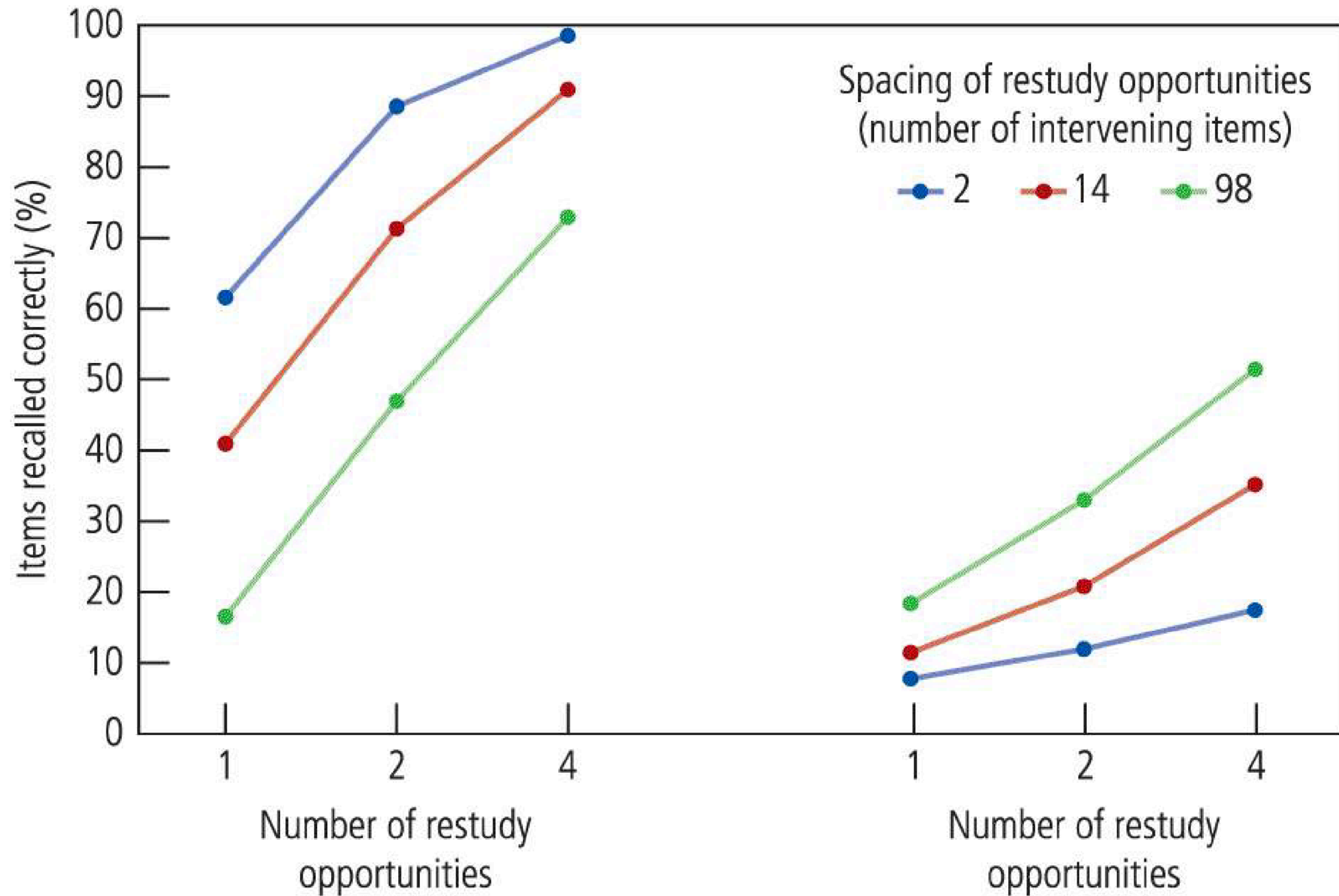
Phase 2

Recall test after
5 min, 2 days, 1 week

Testing effect: tests improve recall over studying



Spacing effect: spacing improves retention



(a) Results of last test on first day

(b) Results of first test on next day

Anderson. *Cognitive Psychology*. 2020

Pavlik and Anderson. "Practice and forgetting effects on vocabulary memory: An activation-based model of the spacing effect" 2005

Spaced repetition systems

**operationalize the
testing & spacing effects**

Primitives of an SRS: cards and decks

Card is a question + answer, deck is a collection of cards

说

请你再说一遍。

说

shuō

speak

verb

请你再说一遍。

Qǐng nǐ zài shuō yī biàn.

Sandhi: Qíng nǐ zài shuō yí biàn.

Can you please say it again.



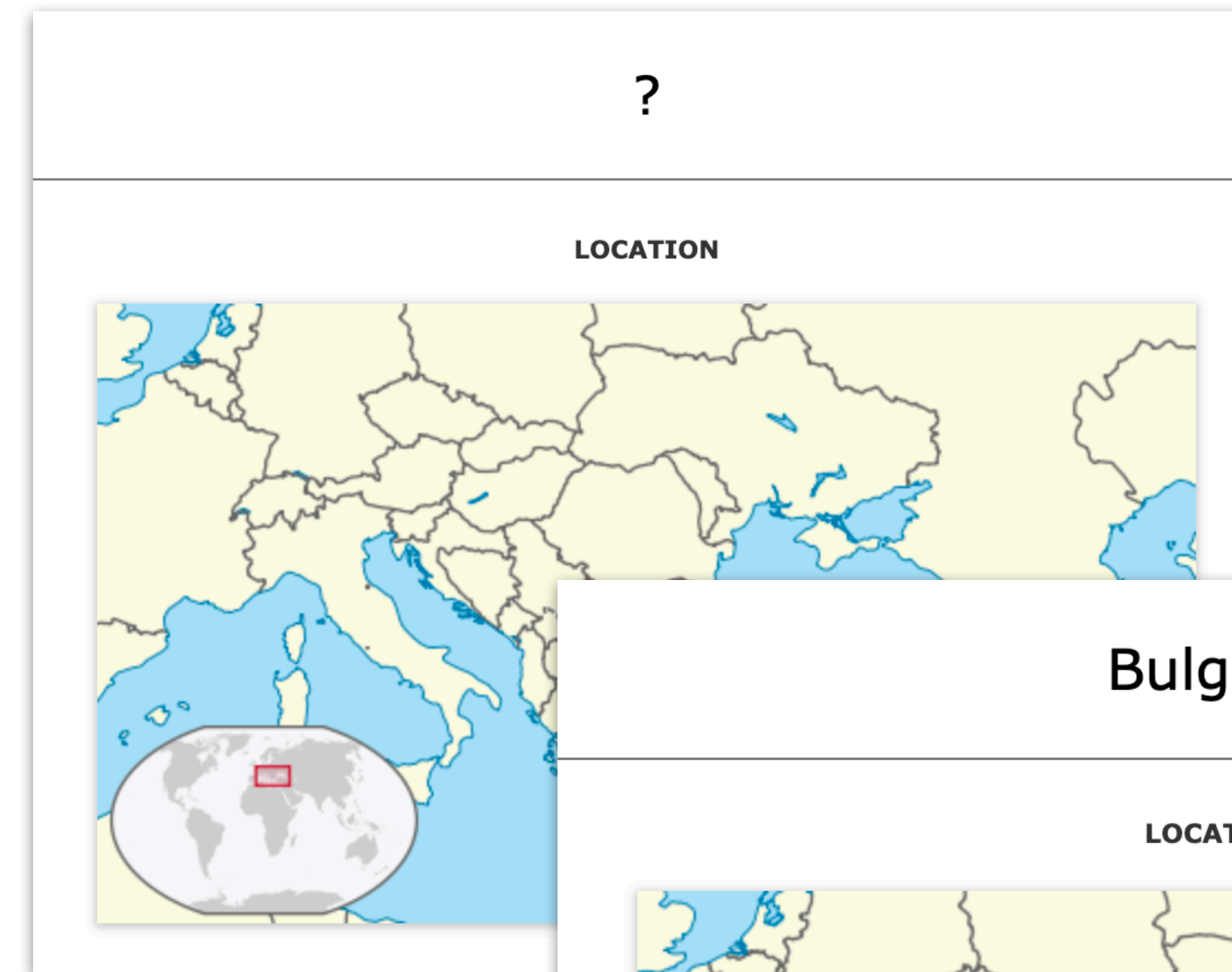
Primitives of an SRS: cards and decks

Card is a question + answer, deck is a collection of cards

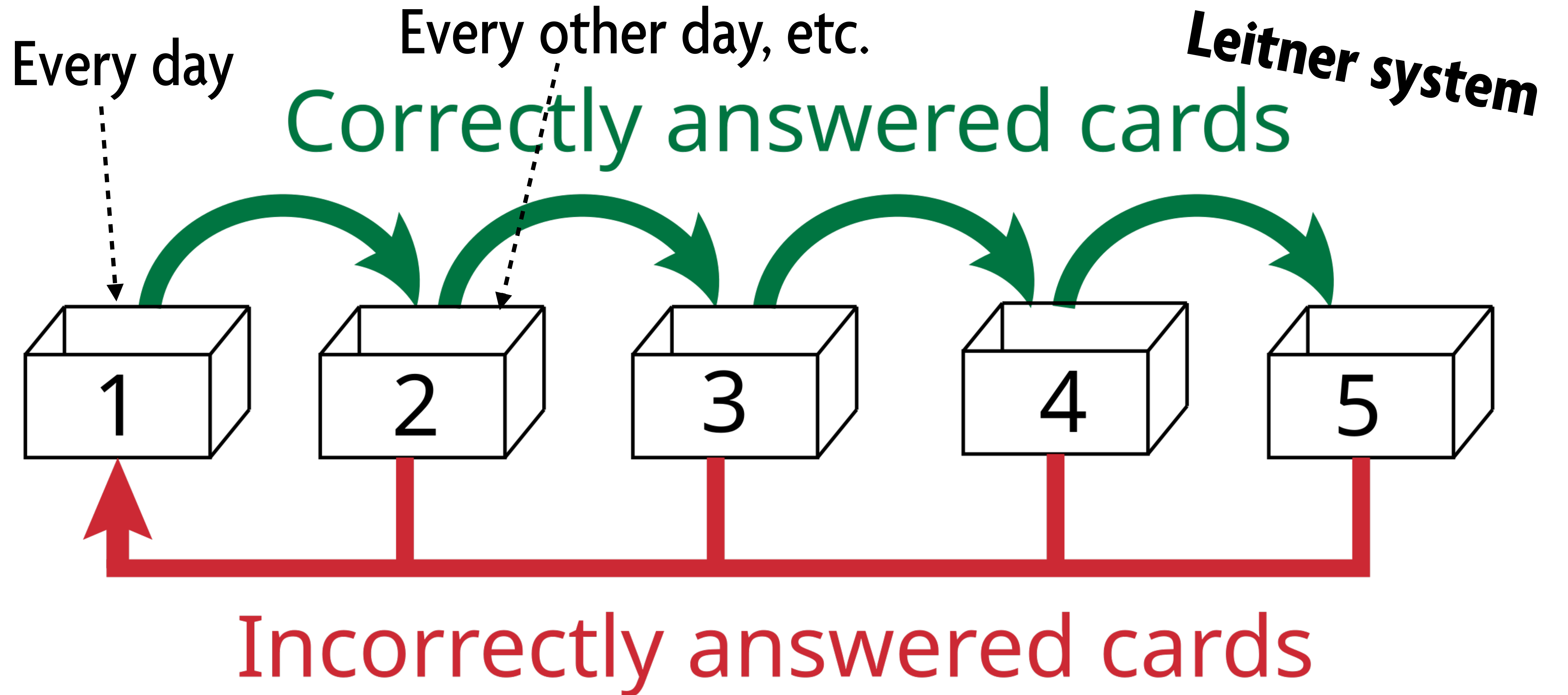
The Intrinsic apoptosis pathway ends with the activation of **[this caspase]**, the extrinsic pathway ends with the activation of **[this caspase]**, both initiator caspases converge into the common pathway by activating **[these two caspsases]**

The Intrinsic apoptosis pathway ends with the activation of **caspase-9**, the extrinsic pathway ends with the activation of **caspase-8**, both initiator caspases converge into the common pathway by activating **caspase 3 and 6 (executioner caspases)**

Big Robbins Page 56



Primitives of an SRS: spacing algorithms



Anki is the canonical modern SRS



Used by 86% of med students

+1 letter grade on med exams

Used by Jeopardy champions
Roger Craig and Arthur Chu

Standard use of SRS

- Find a deck
 - Shared decks on the internet, e.g., ankiweb.net/shared/decks
 - Create on your own deck manually or programmatically (AI...?)
- Review the SRS app every day
 - Configure # new cards per day based on time availability
- Repeat until memorious!

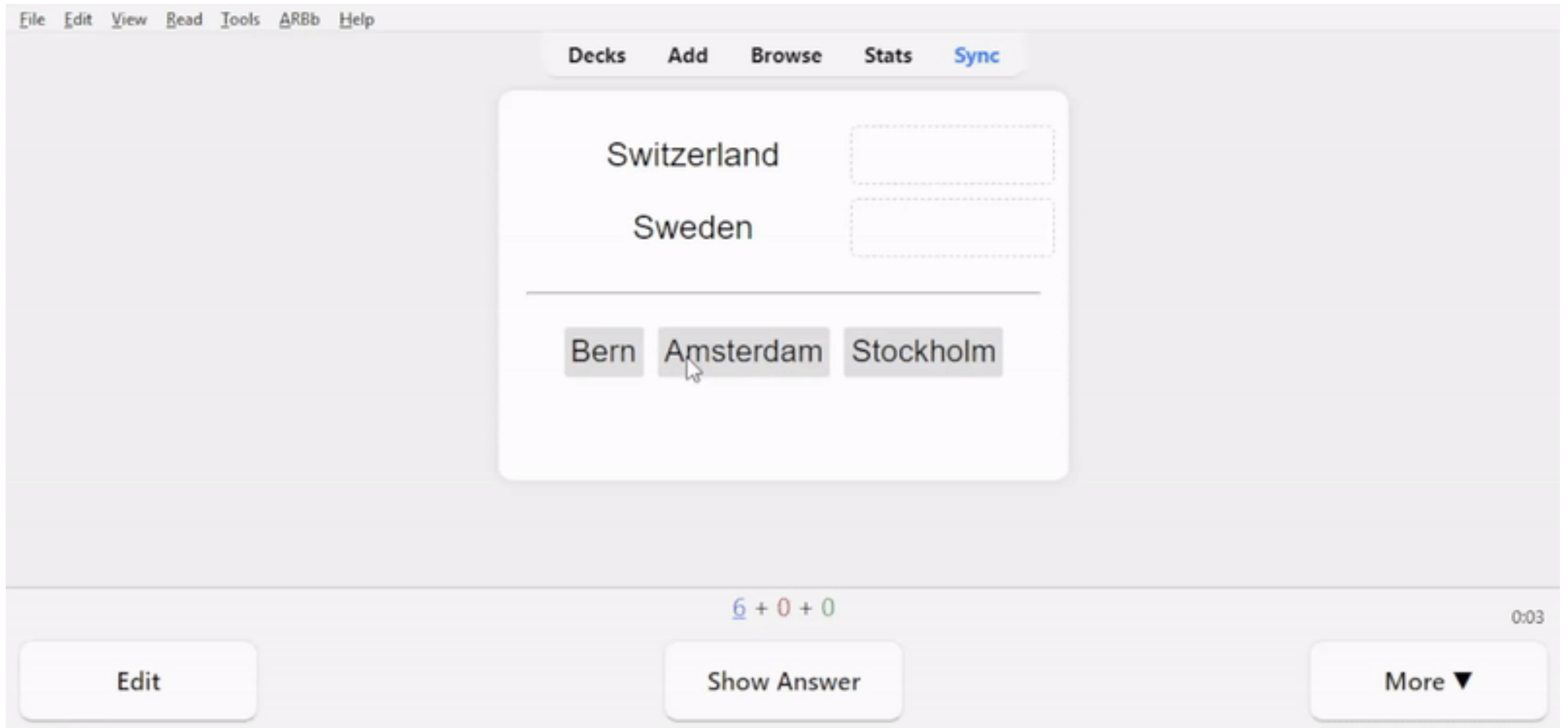
When to use SRS?

- Gwern Branwen: “On average, when I’m studying a new topic, I’ll add 3–20 questions a day.”
 - “I find one of the best uses for [SRS] is, [...] to add in words from A Word a Day and Wiktionary, memorable quotes I see, personal information such as birthdays (or license plates, a problem for me before), and so on.”
- Michael Nielsen: “I find Anki a great help when reading research papers”
 - “What's the size of a Go board?”; “How many human game positions did AlphaGo learn from?”; “Where did AlphaGo get its training data?”
 - “I continued to add questions as I wrote my article, ending up adding several hundred questions in total”
 - “Part of developing Anki as a virtuoso skill is cultivating the ability to use it for types of understanding beyond basic facts.”

Question formats can limit contrived memorization

Sweden - [capital] Switzerland - [capital]	Sweden - <u>Stockholm</u> Switzerland - <u>Bern</u>
Sweden - [capital] Switzerland - [capital]	Sweden - <u>Stockholm</u> Switzerland - <u>Bern</u>
Switzerland - [capital] Sweden - [capital]	Switzerland - <u>Bern</u> Sweden - <u>Stockholm</u>

Question formats can limit contrived memorization



1. Integrating SRS into new contexts

Integrating SRS into an online textbook

In a manner, quantum computing is a bit different from classical computing. A qubit has two possible states, which is a two-dimensional state space. Here's a picture of a qubit's state space.

How many dimensions does the state space of a qubit have?

Click anywhere to reveal

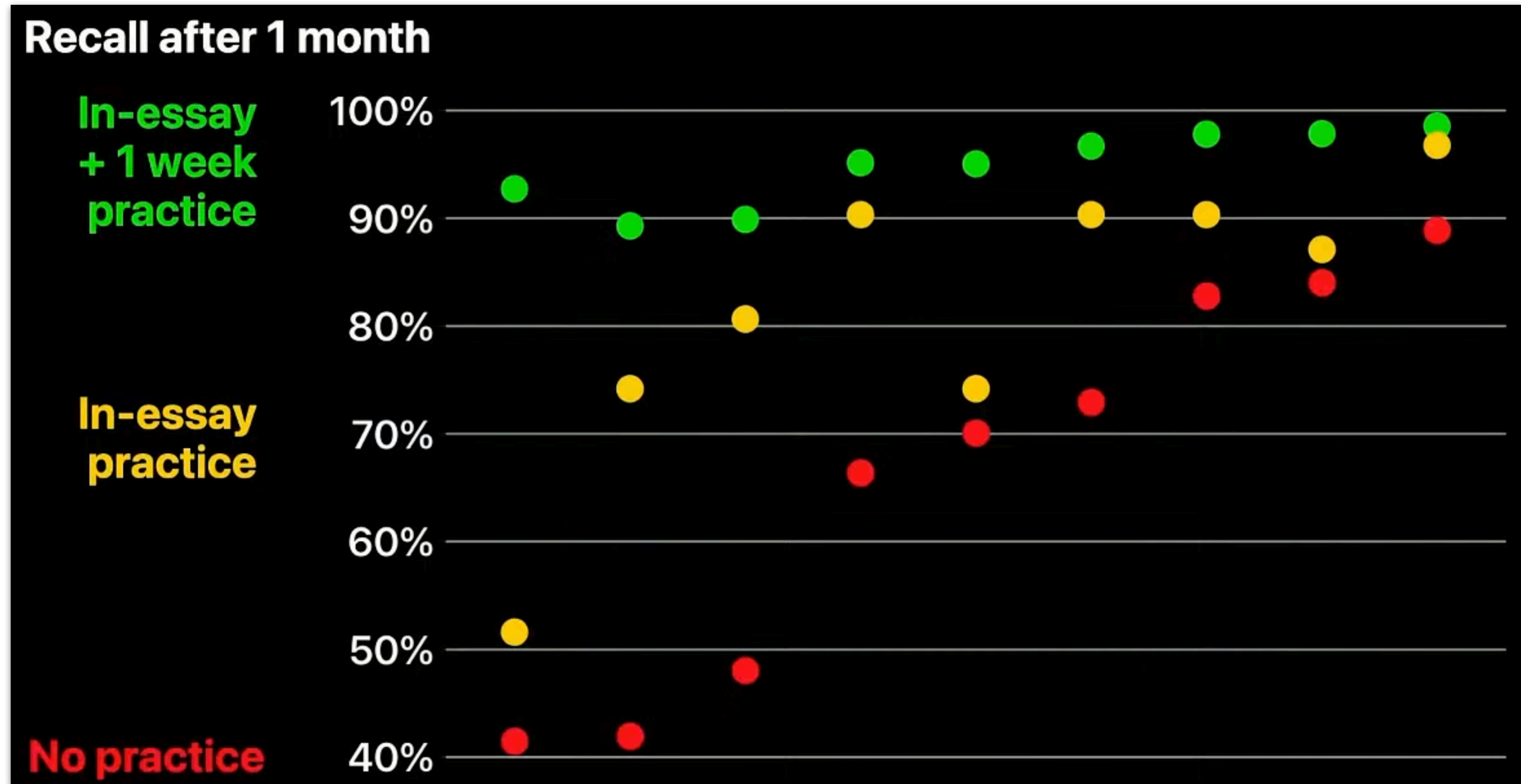
2

in-text 1 week 3 weeks 3 months long-term

Didn't remember Remembered

Didn't remember Remembered

Preliminary results show significant improvements



Question ID, sorted by difficulty

Orbit: a platform for integrated SRS

```
<orbit-reviewarea color="lime">  
  <orbit-prompt  
    question="What's the working name for Andy's  
              experimental mnemonic medium platform?"  
    answer="Orbit"  
  ></orbit-prompt>  
</orbit-reviewarea>
```

Quickly review what you just read.

ORBIT



5d

2wk

1mo

2mo

4mo

1yr

What's the working name for
Andy's experimental mnemonic
medium platform?

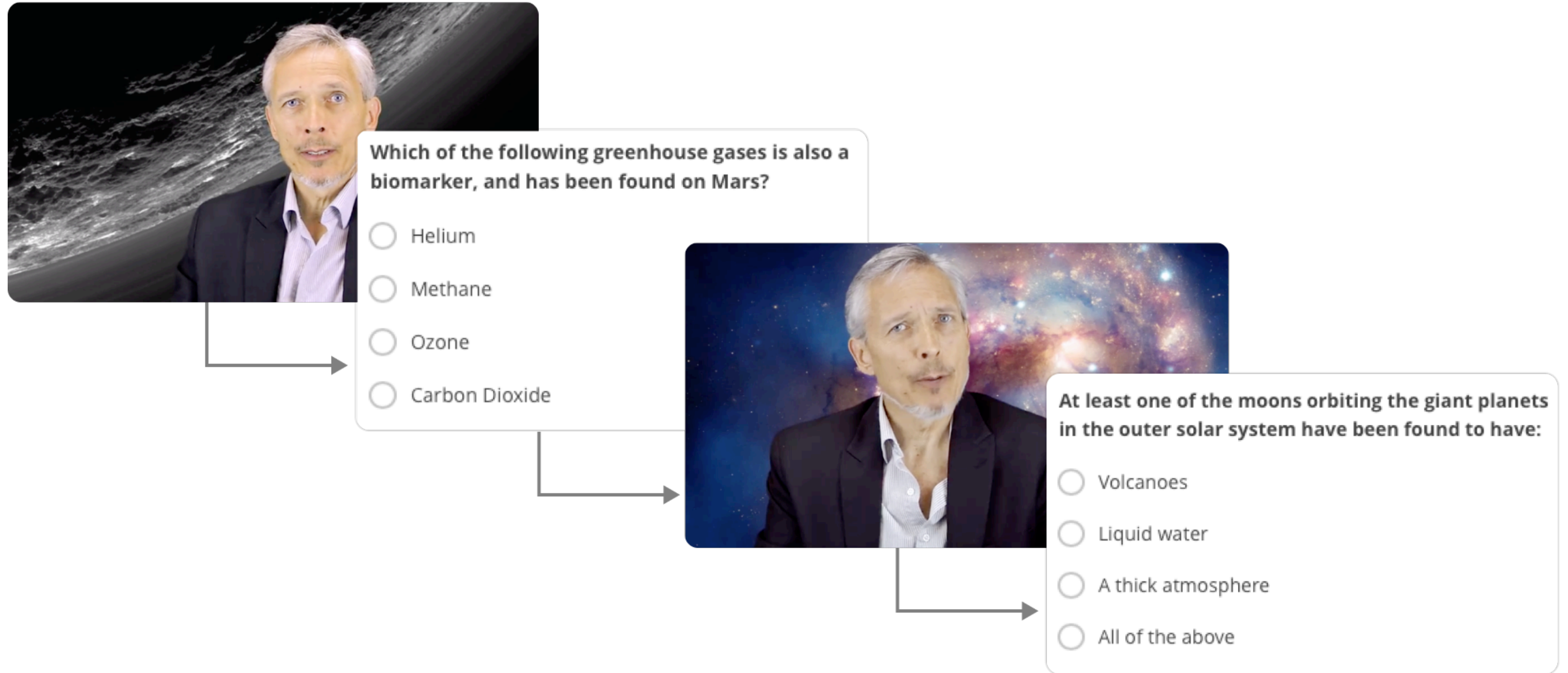
TEST MODE: Actions will not be saved.



Show Answer

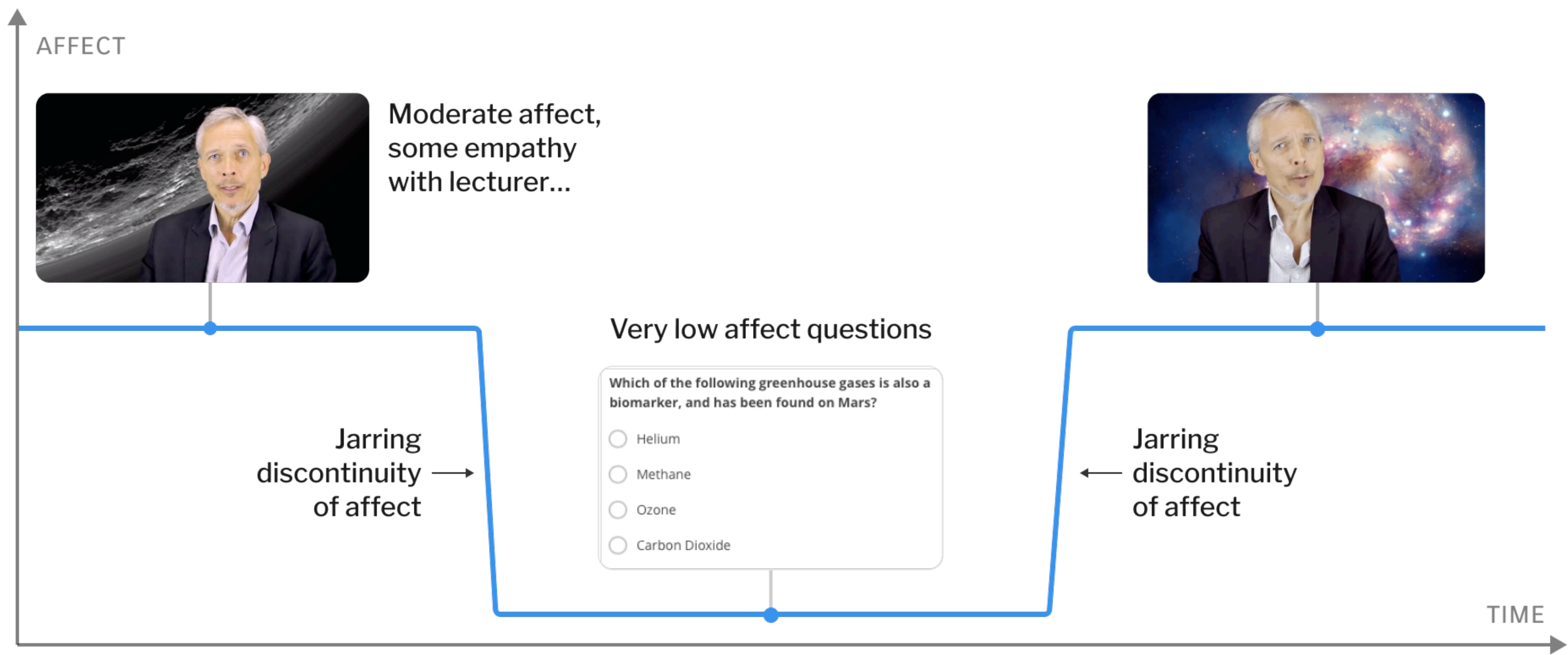
Skip >>

What would a mnemonic medium for video look like?



From Coursera, “Astronomy: Exploring Time and Space.”

What would a mnemonic medium for video look like?

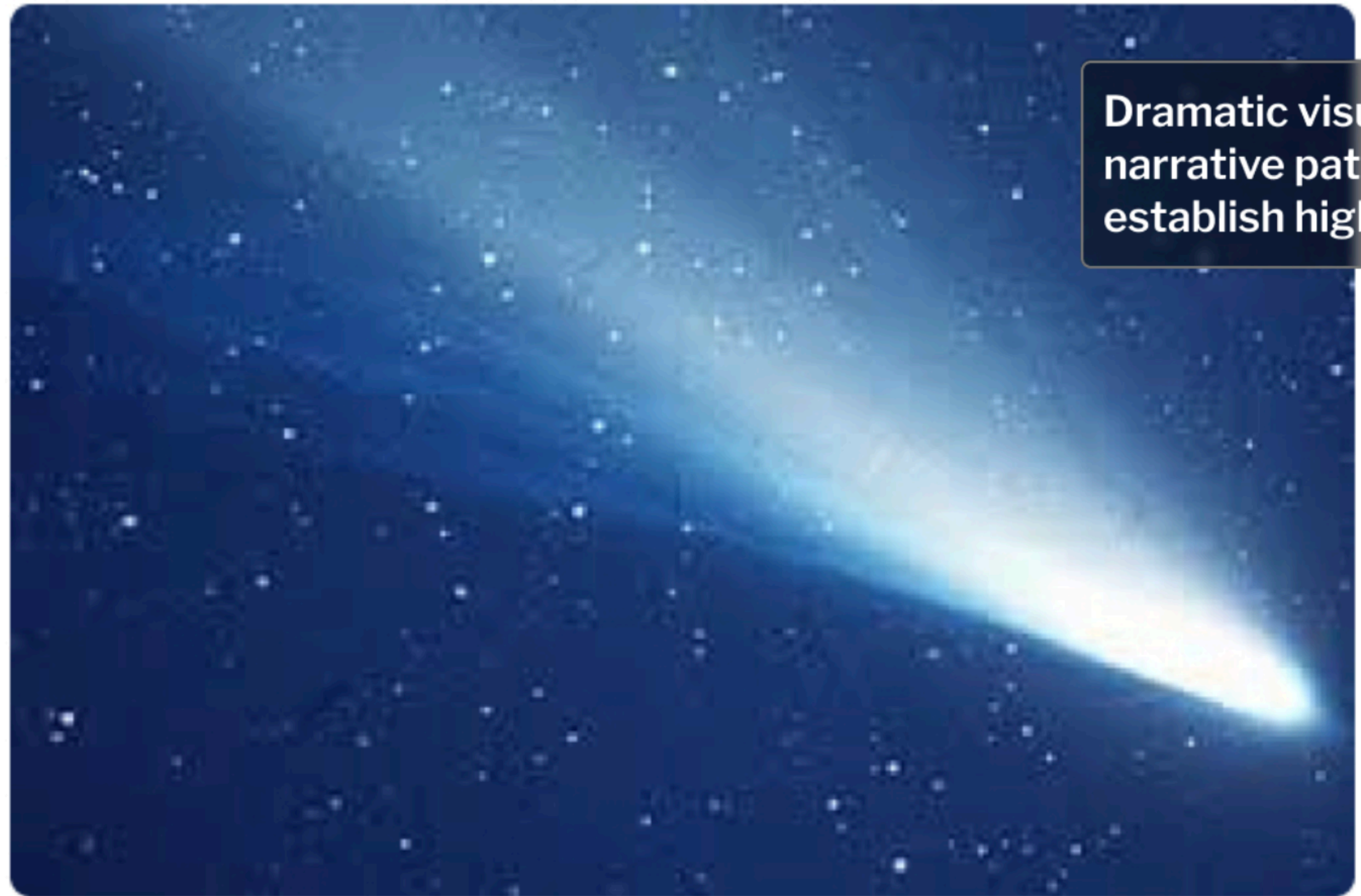


What would a mnemonic medium for video look like?

NARRATOR:

“In 1908, a piece of a comet hit the Earth. Hurtling at more than 100,000 km/h, it was a mountain of ice the size of a football field and weighing almost a million tons.

If such an explosion happened today, it might be thought, in the panic of the moment, to be produced by a nuclear weapon.



Dramatic visuals and narrative pathos establish high affect

What would a mnemonic medium for video look like?

“A cometary fragment will produce a great radiant fireball and a mighty blast wave. It’ll burn trees and level forests. Yet despite all that destruction, can you see why comets usually leave no crater in the ground?”



The narrator smoothly pivots to a question for the viewer, right in the middle of the video.

What would a mnemonic medium for video look like?

(no narration)

The crater flyover and music continue while the viewer thinks...

We keep friction low to maintain immersion: the input is “tap anywhere.”

The question interface shares the screen with the video

Tap to hear the answer

What would a mnemonic medium for video look like?

“We humans like to think of the heavens as stable, serene, unchanging. But comets suddenly appear and hang ominously in the sky, night after night, for weeks.”

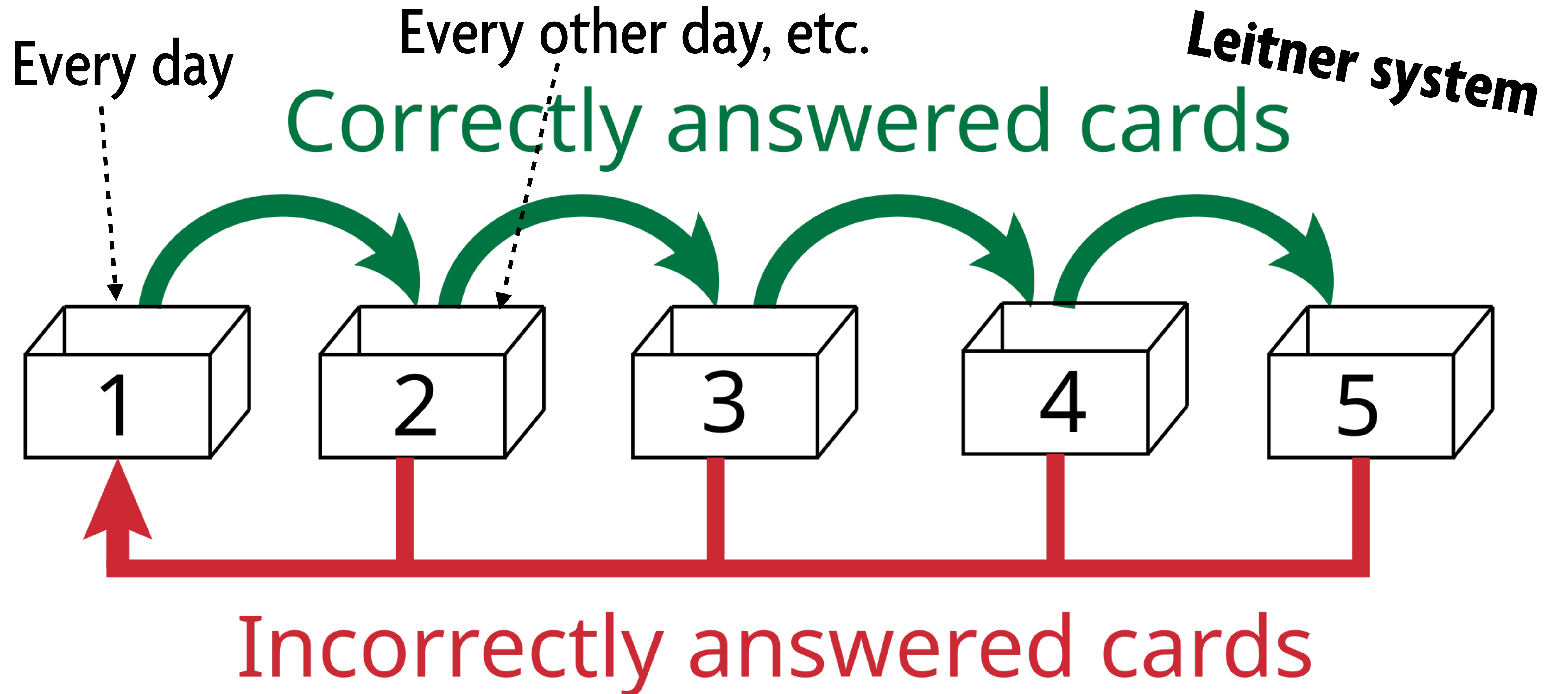
The narrator continues onto other topics while the viewer marks whether they knew the answer

Did you get that answer?



2. Designing new spacing algorithms

Primitives of an SRS: spacing algorithms



Leitner spacing algorithm, roughly

input: user grade q ,
interval I

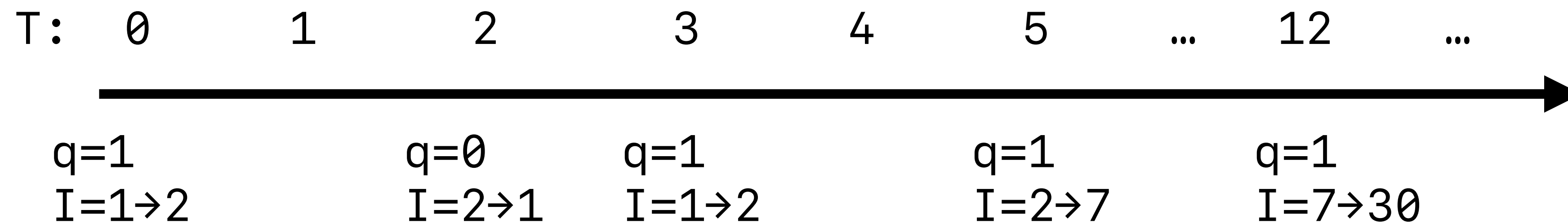
output: updated interval I

```
if  $q = 1$  (correct)
then
```

```
   $I \leftarrow$  case  $I$ 
    | 1  $\rightarrow$  2
    | 2  $\rightarrow$  7
    | 7  $\rightarrow$  30
    | 30  $\rightarrow$  365
```

```
else (incorrect)
   $I \leftarrow \emptyset$ 
```

```
end
```



Expanding spacing improved short-term recall over uniform or contracting spacing

Materials:

12 names of fictitious people

Decks: 1 study card w/ 3 recall practice cards for each name

Spacing:

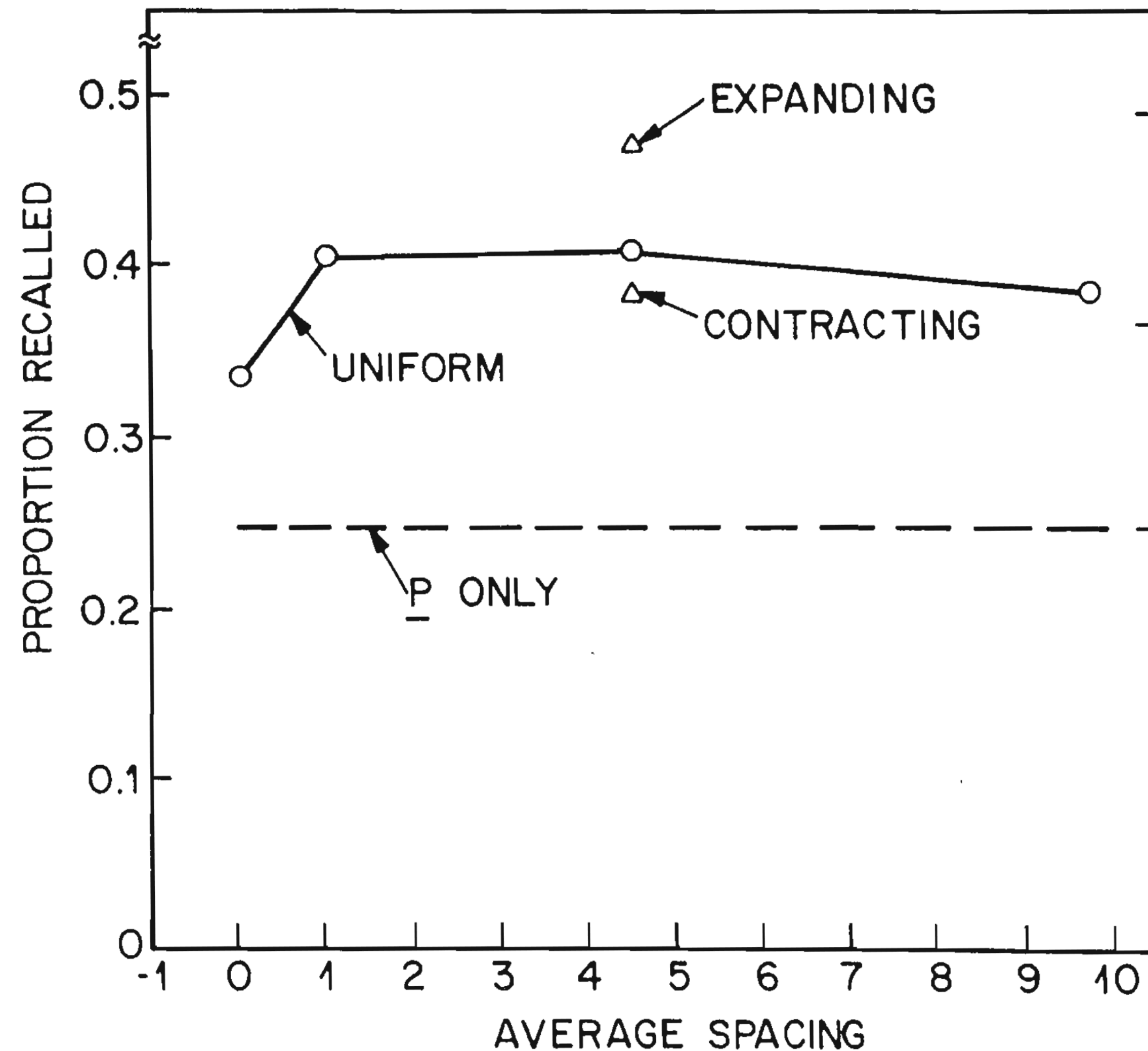
- Uniform: 0,0,0 + 4,4,4 + 10,10,10
- Expanding: 0,3,10
- Contracting: 10,3,0

Procedure: practice desk → 30min distraction → recall test

Example 0,3,10 deck

0 (*Study:* Will Crichton
Recall: Will _____
Study: Zheyuan Wu
Recall: Zheyuan _____
Study: Nico DiLullo
Recall: Will _____
Recall: Nico _____) 3

Expanding spacing improved short-term recall over



SuperMemo-2 (SM-2) algorithm

input: user grade q ,
repetition number n
easiness factor EF ,
interval I

output: updated values of
 n , EF , and I

$q = 0$ complete blackout
1 incorrect, but hazy
2 incorrect, but close
3 correct with difficulty
4 correct with hesitation
5 perfect response

if $q \geq 3$ (correct response)
then

$I \leftarrow$ **case** n

| 0 $\Rightarrow$ 1

| 1 $\Rightarrow$ 6

| _ $\Rightarrow$ **round**($I \times EF$)

$n \leftarrow n + 1$

else (incorrect response)

$I \leftarrow 1$

$n \leftarrow 0$

end if

$EF \leftarrow$ **adjust-easiness**(EF , q)

adjust-easiness(EF , q):

$d \leftarrow 5 - q$

return **max**(

$EF + 0.1 - 0.08d - 0.02d^2$,
1.3)

Example SM-2 trace for one card

T		$\emptyset$	1	...	7	...	22
q grade		3	5		4		1
n successes	$\emptyset$	1	2		3		$\emptyset$
I interval	1	1	6		15		1
EF easiness	2.50	2.36	2.46		2.46		1.92