Testing Computer-Aided Mnemonics and Feedback for Fast Memorization of High-Value Secrets


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Summary

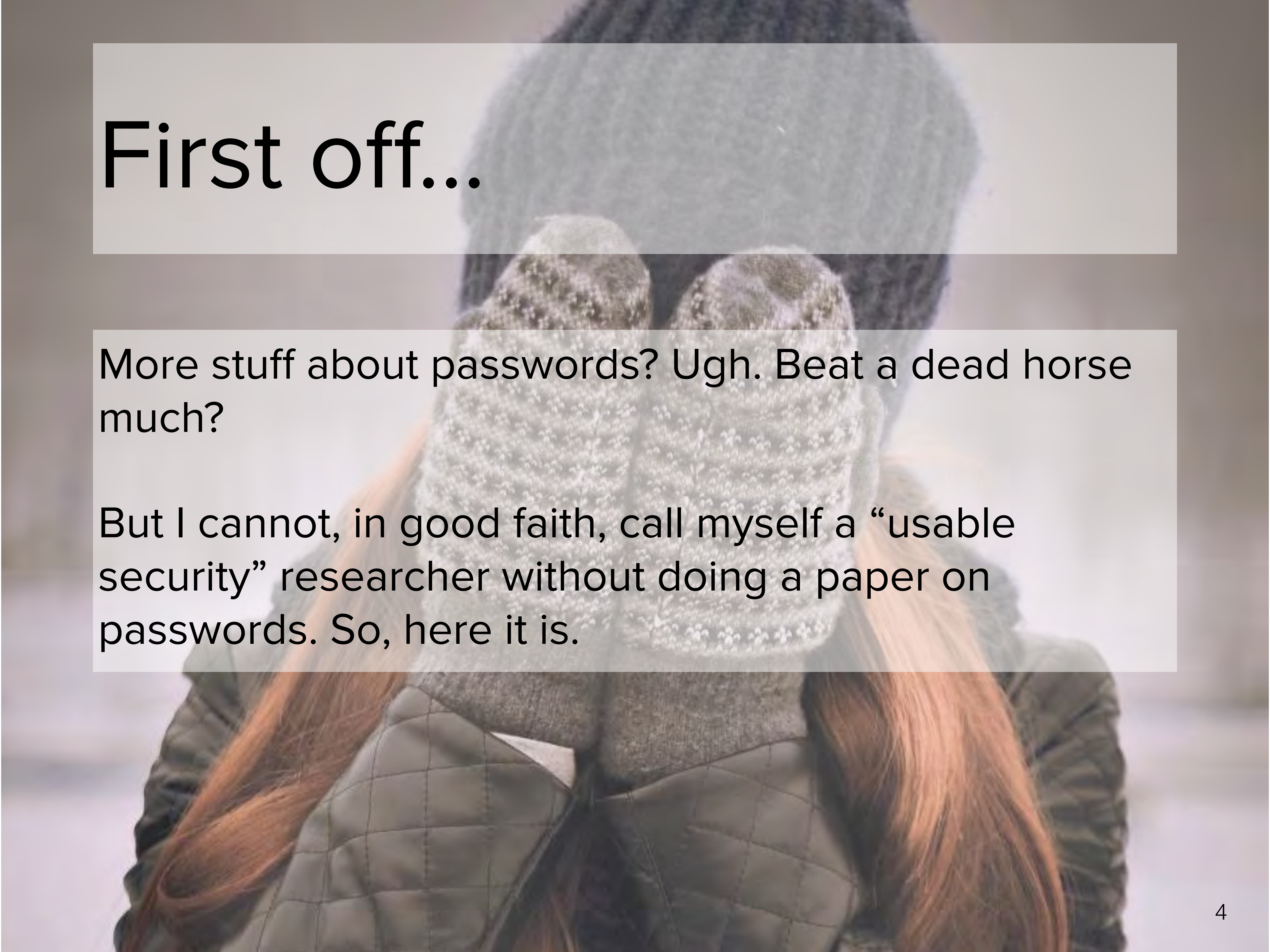
Question: Can computer-assisted mnemonics help people learn strong, randomly assigned passwords quickly and with high long-term recall?

Method: Design and implementation of two computer-assisted mnemonic training regimens and an experimental evaluation of their effectiveness.

Summary

Outcome: Our **story** mnemonic, in which users weave chunks of their random secret into sentences, works really well (7.5 learning sessions, 84% two-week recall)

cat leaf wind
A pink cat _ _ is chasing a giant _ _ _ _ blowing in the _ _ _ _.

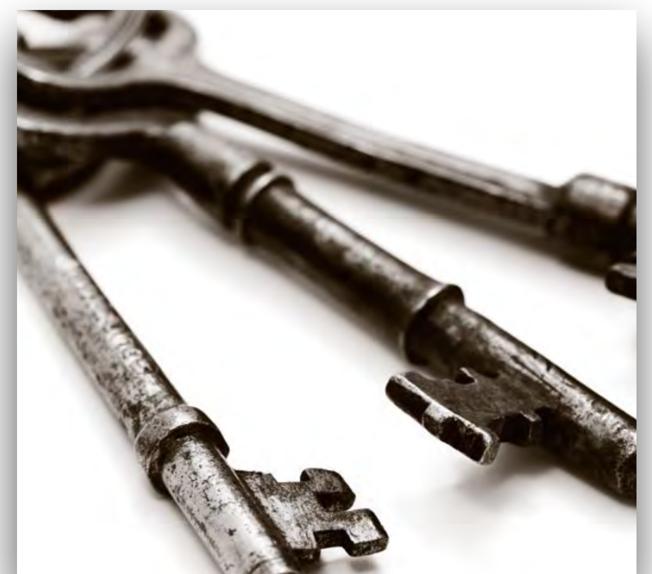


First off…

More stuff about passwords? Ugh. Beat a dead horse much?

But I cannot, in good faith, call myself a “usable security” researcher without doing a paper on passwords. So, here it is.

Sometimes, we need strong secrets



Password managers

Encrypted drives

Journalists / whistle blowers

Strong passwords

If we still need strong passwords, we should make strong passwords easy to use.

Typical approach: **Teach** people strong password generation strategies. But people aren’t random enough.

Out-of-vogue approach: Give people randomly assigned strong passwords. But, people can’t remember anything…right?

Actually, it works...

Bonneau & Schechter (2014) conditioned lay people to learn strong assigned secrets (56.4 bits) incrementally.

On login, had people enter assigned secret (which is shown after a delay that gradually increases).

People could avoid delay if they enter the assigned secret from memory.

Example: apple beetle crane dog ear flame

User ID:

hotshot@handsome.cc

Password:

apple beet

User ID:

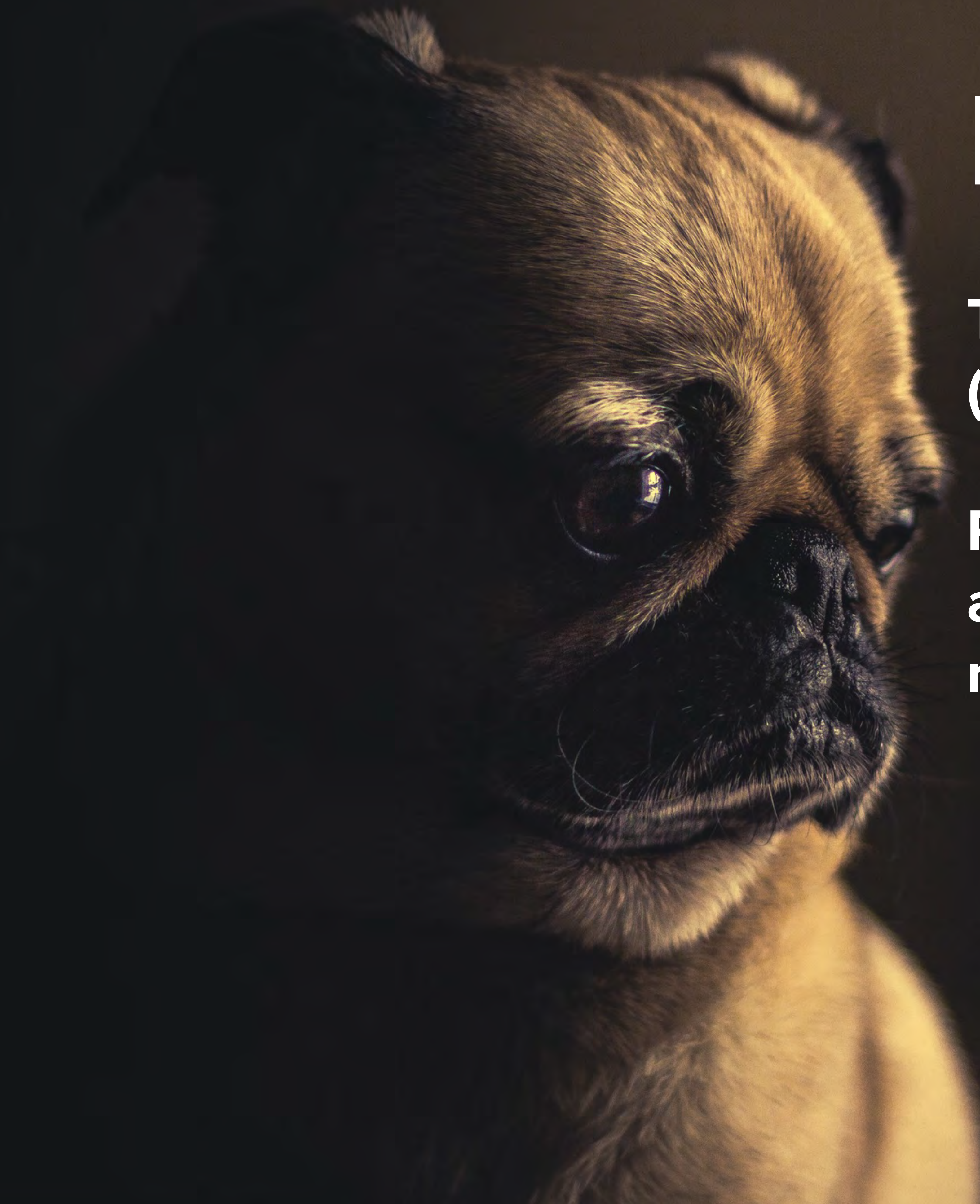
hotshot@handsome.cc

Password:

apple beetle crane dog ear flame

apple beet|


94% of participants memorized all of their secret words.



But...

The process was long (required 36 sessions)

Recall fell sharply after 2 weeks (62% remembered)

Can we do better?

Ideally, the process should:

- Require fewer training sessions

- Retained for longer

Mnemonics?!

“Strategies to enhance the learning and recall of information”

Most useful when memorizing lists.

Basic idea: Transform abstract, difficult to visualize concepts into tangible, easy to visualize concepts.

Memorize: apple, beetle, crane

Chain-type

Weave list items into narrative chain.

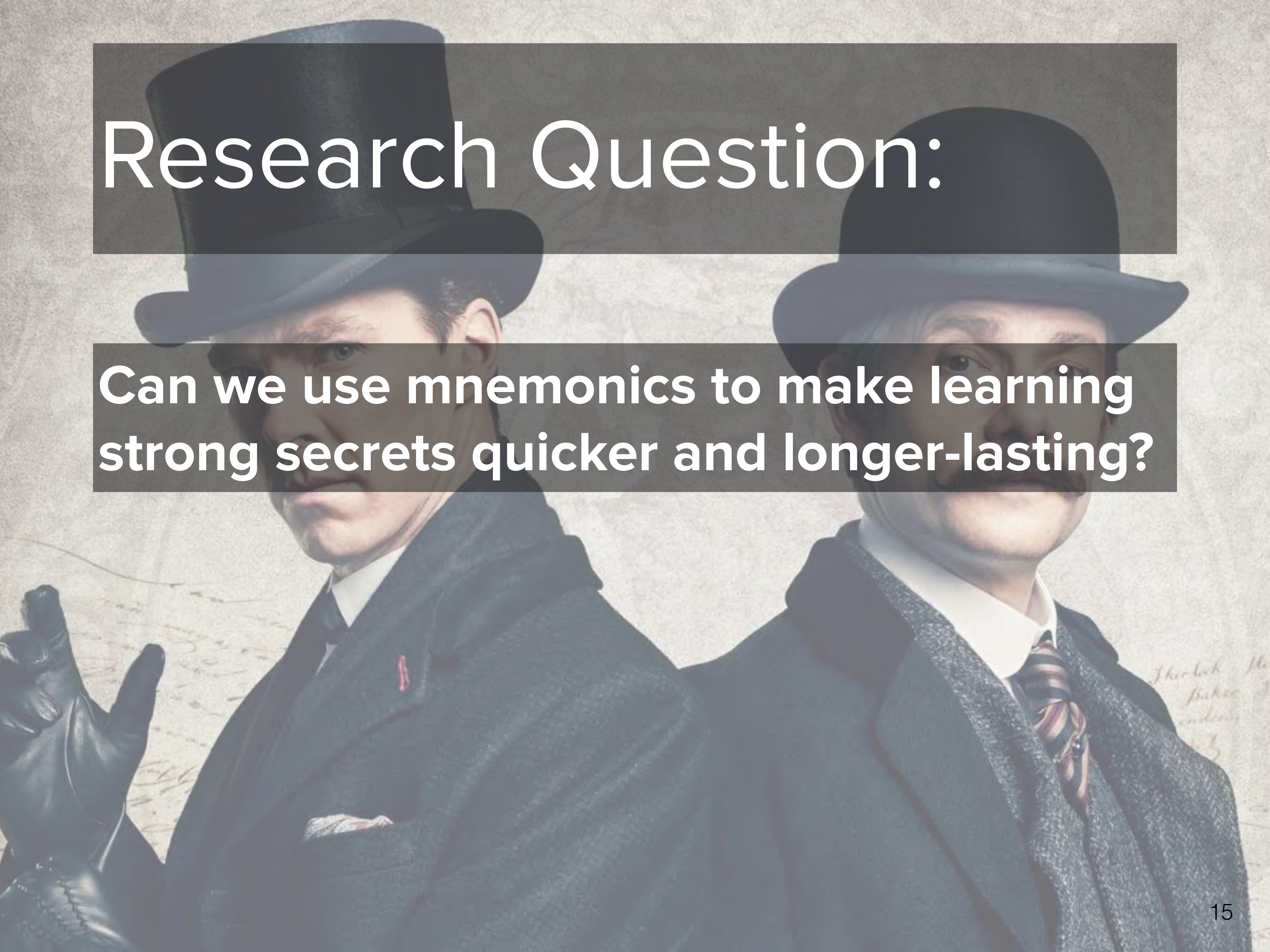
an **apple** being eaten by a **beetle** while being lifted up by a **crane.**

Peg-type

Peg list items onto cueing structure.

one is *nun*	a *nun* throwing an **apple**
two is *shoe*	a *shoe* squashing a **beetle**
three is *tree*	a *tree* being lifted by a **crane**

Research Question:



Can we use mnemonics to make learning strong secrets quicker and longer-lasting?

Our contribution

1. Two computer-assisted mnemonic training schemes designed to incrementally teach people strong secrets.

2. Experimental evaluation of these training schemes relative to the rote baseline akin to prior work.

Method

Method Overview

Recruit participants, via MTurk, for a recurring “attention” test over 10 days.

Assign participants, randomly, to a treatment or control group.

Teach participants a randomly selected strong secret with an assigned training regimen.

Compare, across training regimens, *how fast participants learn their secrets* and *how well they remember their secret words 2-weeks after* the fact.

Recruitment

Participants solicited via MTurk to take “attention test”.

“Attention test” cover story used to distract participants from focusing on learning their secret words.

Participants had to return to do 45 attention tests over maximum of 10 days with at least 1 hour between each.

Assignment

Participants were randomly assigned to one of five experimental groups:

Story: Mnemonic treatment.

Peg-Word: Mnemonic treatment.

Feedback: Active learning treatment.

Rote: Control. Baseline from prior work.

Dropout: Control. No secret words.

Assignment

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Feedback: Active learning treatment.

Dropout: Control. No secret words.

Teach secret

Secret Encoding: 6 nouns randomly selected out of a broader set of 676 options (56.4 bits).

Assigned in two, 3-word chunks.

Presented one chunk at a time — only shown second chunk after "learning first" (entering 3x consecutively from memory)

Teach secret

apple beetle crane

apple	beetle	cra

On each login, participants had to enter their secret words.

If they couldn't remember, they would eventually be shown their words to copy.

Comparison

Primarily interested in two comparisons of mnemonic vs rote baseline:

- **Number of learning sessions required**: Lower is better (previous study rote method: median of 36)

- **2-week recall rate**: Higher is better (previous study rote method: 62%)

Experimental Groups

3 Groups

Story Mnemonic: Users wrote two sentences, each containing three of their secret words, in order.

Peg-Word Mnemonic: Users were given public “peg” words and created sentences linking each peg to a secret.

Rote Baseline: No special training. Users just had to manually enter words to the best of their memory.

Dimensions of Variance: mnemonic creation, chunk rehearsal, and hint progression.

Rote Baseline

Mnemonic Creation: none

Chunk Rehearsal: Text-boxes with hints ultimately rendered on top for copying.

Hint Progression: Started at 0 seconds, progresses up to a maximum of 10 seconds with a 0.5 second increase every subsequent attempt.

apple	beetle	crane
apple	beetle	cra

Story Mnemonic

Mnemonic Creation: Asked participants to write a *visual, memorable* sentence stringing together all three words.

Example: cat, leaf, wind => A pink *cat* is chasing a giant *leaf* blowing in the *wind*.

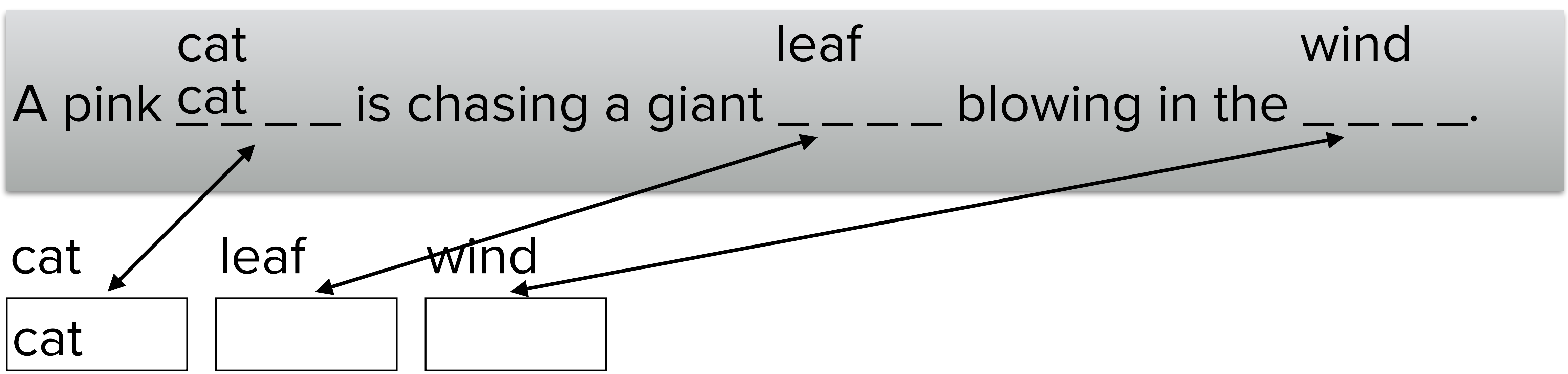
Participants had to comply to proceed — our app checked whether the story sentence was valid.

Story Mnemonic

Chunk Rehearsal: Three-phases of chunk rehearsal to gradually wean participants off mnemonic assistance.

Introduced the *hint well* to facilitate this gradual transition. The hint well allowed participants to enter their secret words *inline*.

Phase 1: Full assistance



Story Mnemonic

Phase 2: Reduced assistance

[redacted] cat _ _ [redacted] _ _ _ _ [redacted] _ _ _ _.

cat		

Phase 3: No assistance

cat		

Story Mnemonic

Phase Transition: Start in full-assistance, then reduced-assistance, then no-assistance. Transition after first entering from memory in previous phase.

Hint Progression: Start at 1 second, max of 10 seconds. Increment by 0.5 seconds on each attempt.

Peg-Word Mnemonic

Mnemonic Creation: First, asked participants to select rhyme-based peg words. Then, asked participants to write three visual, memorable sentences stringing together public peg words with secret words.

Example: cat, leaf, wind

1 is {**nun**, bun, gun, sun}

2 is {**shoe**, shrew, zoo, screw}

3 is {**tree**, bee, key, sea}

Peg-Word Mnemonic

Public peg word	Secret word	Mnemonic hint sentence
nun	cat	The nun pulls the screeching cat off of her head.
leaf	shoe	The leaf lands gracefully in the worn old shoe.
wind	tree	The wind has no effect on the steadfast tree.

Participants had to comply to proceed — our app checked whether the peg sentences were valid.

Peg-Word Mnemonic

Chunk Rehearsal: Same three-phases of chunk rehearsal to gradually wean participants off mnemonic assistance. *Difference*: hint sentences were shown per word instead of per chunk.

cat

One is nun. The nun pulls the screeching _ _ _ _ off of her head.

cat leaf wind

But hints still operated per-chunk, not per-word.

Peg-Word Mnemonic

Phase Transition: Same as story.

Hint Progression: Same as story.

Results

Learning Speed & Memorability

Some Descriptive Stats

351 participants signed up.

242 participants finished.

31 years old on average (sd 10).

52 percent female.

	Rote	Story	Peg
Assigned	71	81	75
Completed	51	57	48
2-week return	42	48	43

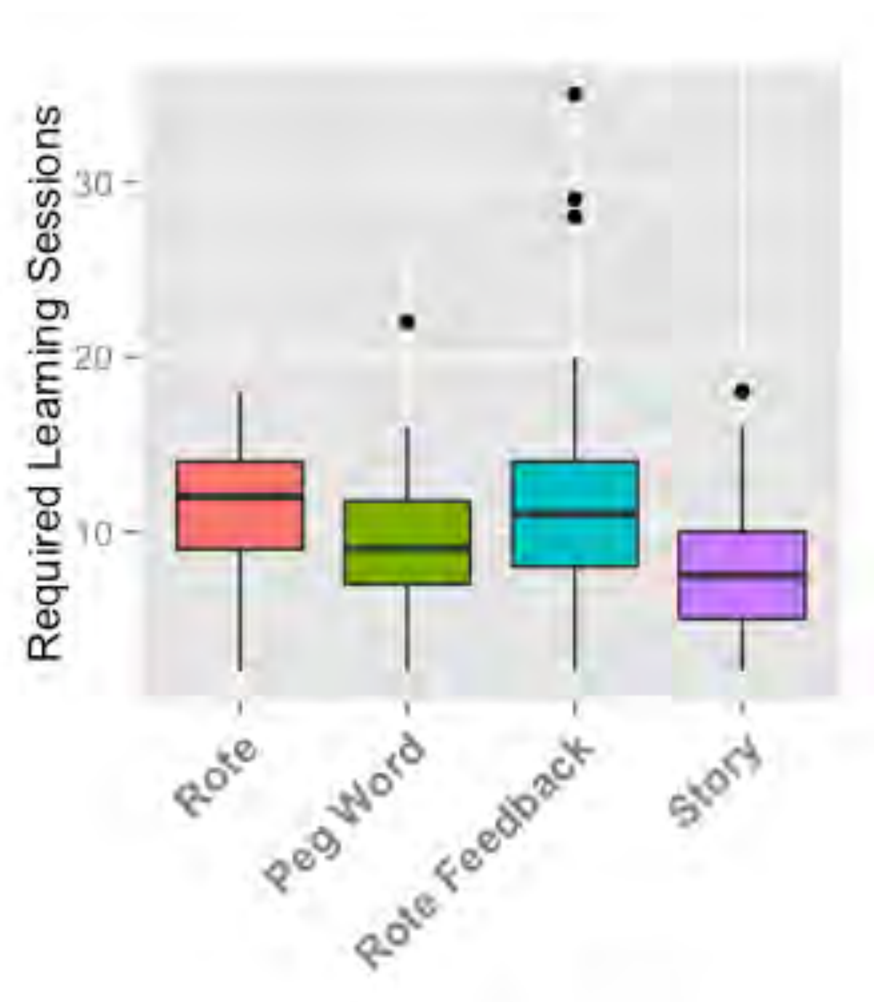
Learning sessions

Participants who entered their secret words, from memory, three consecutive times had *learned* their secret words.

The number of sessions *prior* to that 3-chain were "learning sessions".

Q1: How did the number of learning sessions differ between those in our mnemonic treatments versus those in the rote baseline?

Learning Sessions



Both story (7.5) and peg-word (9) participants required significantly fewer learning sessions than rote (12).

2-Week Recall Rate

Q2: How did the 2-week recall rate vary between participants in the mnemonic treatments versus the rote baseline?

2-Week Recall Rate

Name	Entropy	Example
Perfect	56.4	apple beetle crane dog ear flame
Single Swap	53.8	apple crane beetle dog ear flame
Forgot One	49.6	apple ? crane dog ear flame
Relaxed Order	46.9	ear apple dog beetle flame crane

2-Week Recall Rate

	Story	Peg-Word	Rote
Perfect	*75%*	42%	60%
Single Swap	**84%**	47%	65%
Forgot One	*84%*	67%	74%
Relaxed Order	**86%**	47%	65%

p<0.05
p<0.10

Takeaways

Story did significantly better than Rote.

Peg-Word, surprisingly, did worse (but non-significant).

Results Summary

Mnemonics require fewer learning sessions and can provide recall benefits, but only if not too complicated.

Story mnemonic did best, providing significant improvements over rote on both reducing required learning sessions and 2-week recall.

We can perhaps improve retention further if we also facilitate remembering the mnemonics themselves.

Conclusion

Some use-cases warrant the use of provably strong secrets.

Bonneau and Schechter (2014): Lay people can reliably learn such secrets through conditioning, but it takes a while and recall falls sharply after extended disuse.

We designed and implemented two computer-assisted mnemonic training regimens to speed-up learning and increase recall rates after extended disuse.

Our **story** mnemonic did both of those things, but our **peg-word** mnemonic was surprisingly ineffective.

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Key-takeaway:
Our computer-assisted story mnemonic decreased the required number of sessions required to learn and increased the two-week recall rates of strong, randomly assigned secrets.

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