Towards Implicit Visual Memory-Based Authentication

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Types of Authentication

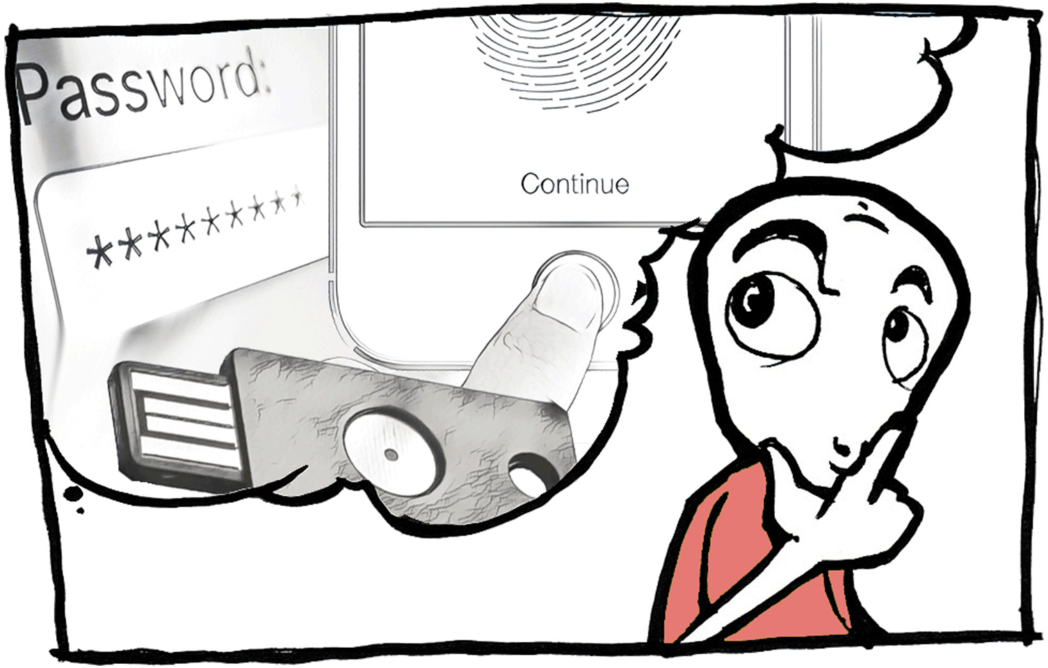
Competing requirements of **security** and **usability.** [1]

Common Factors:

1) **Knowledge (Password, PIN)**
2) Biometrics (Fingerprint, Face)
3) Possession (Token)

Reinforced by:

- 2-Factor Authentication
- Risk-based Authentication
- Continuous Authentication



[Ref. 1] Joseph Bonneau et al.: The Quest to Replace Passwords: A Framework for Comparative Evaluation of Web Authentication Schemes. (SP '12)

Knowledge-based Authentication

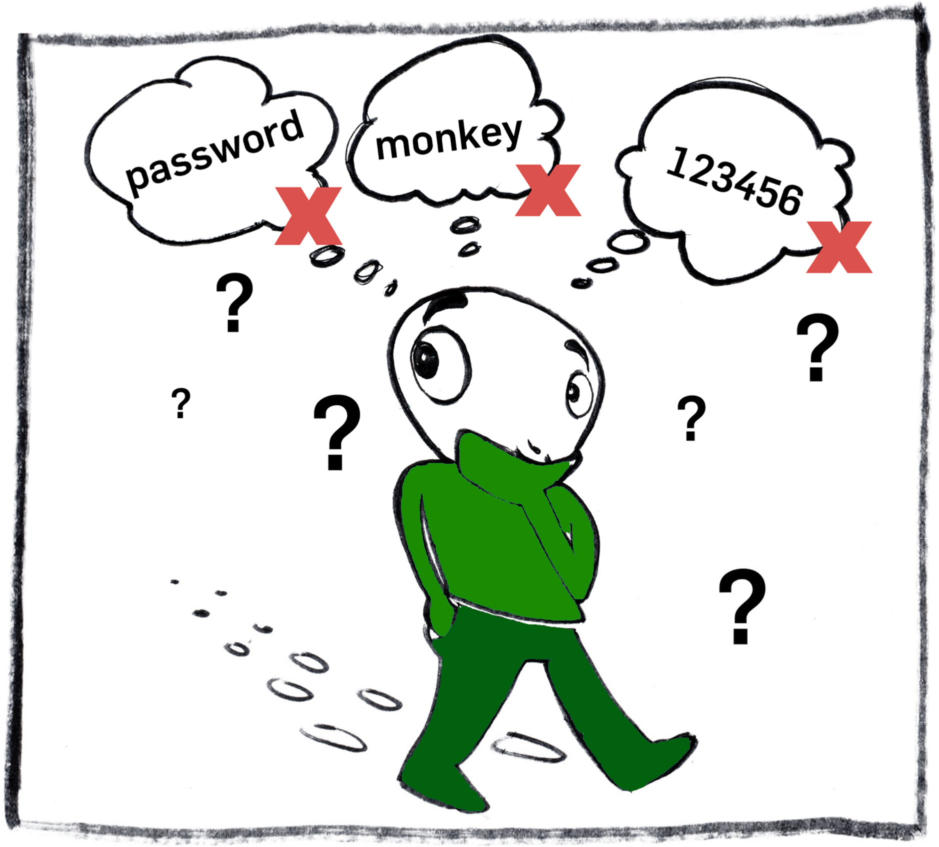
Example: Passwords

1) Create a secure password
2) Remember the password
3) Provide at time of authentication

All steps involved are hard for users.

→ High cognitive burden

→ Password reuse
→ Password resets



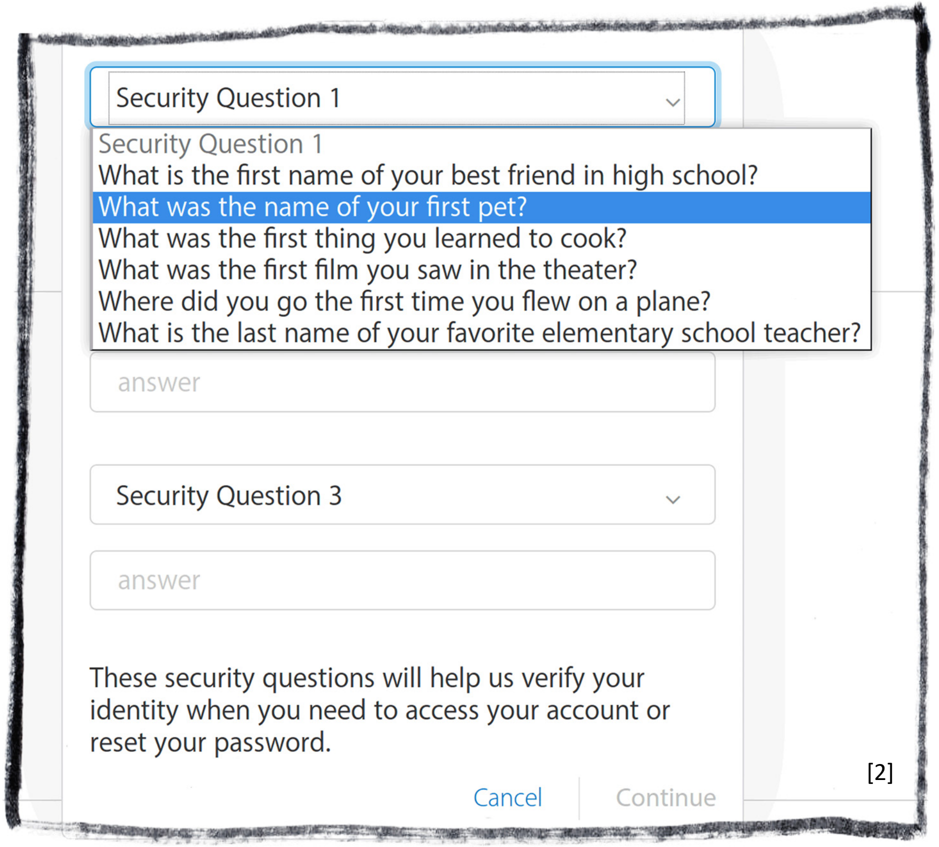
Fallback Authentication

Used to regain access if the primary means of authentication is lost!

Different:
- Memorability
- Rate limiting
- Time required to authenticate

→ Often the weakest link in the chain (Sarah Palin, Mat Honan, …)

→ We need to design better systems!



Security Question 1

Security Question 1
What is the first name of your best friend in high school?
What was the name of your first pet?
What was the first thing you learned to cook?
What was the first film you saw in the theater?
Where did you go the first time you flew on a plane?
What is the last name of your favorite elementary school teacher?

These security questions will help us verify your identity when you need to access your account or reset your password.

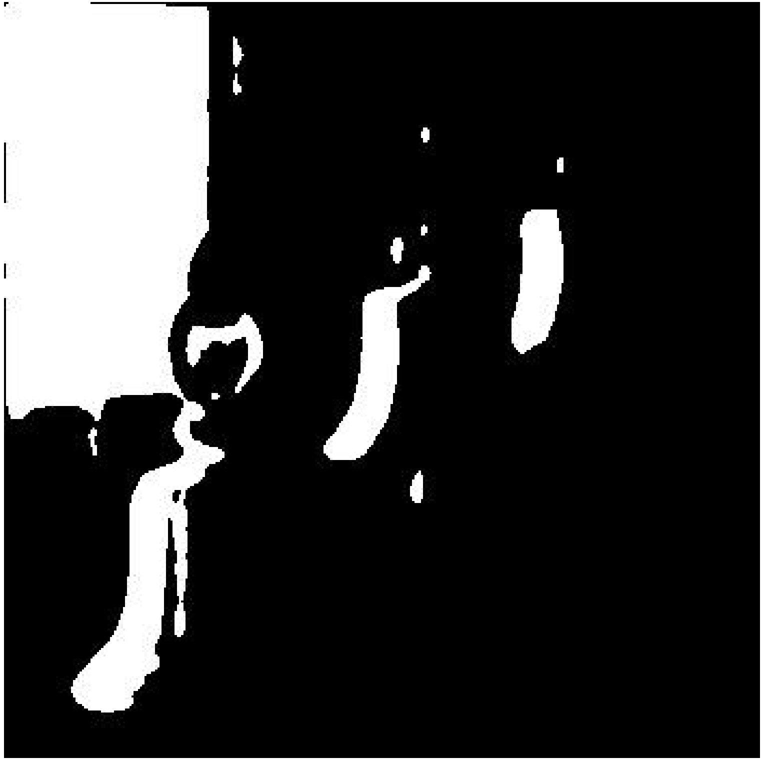
[2]

[Ref. 2] Joseph Bonneau et al.: Secrets, Lies, and Account Recovery: Lessons from the Use of Personal Knowledge Questions at Google. (WWW '15)

Let’s Play

Before we start, a short game.

Priming



Priming

Priming

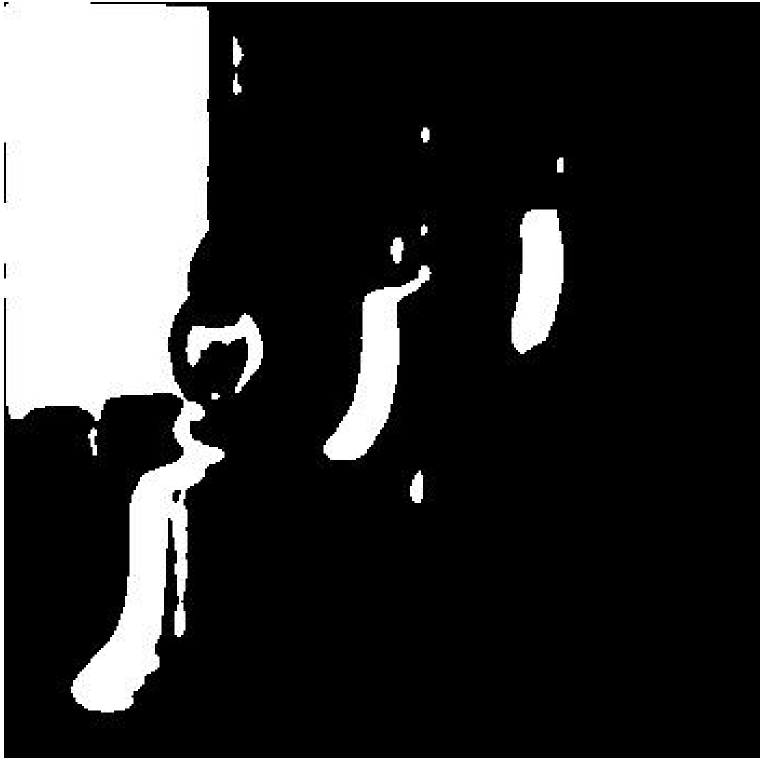
Bells

Priming

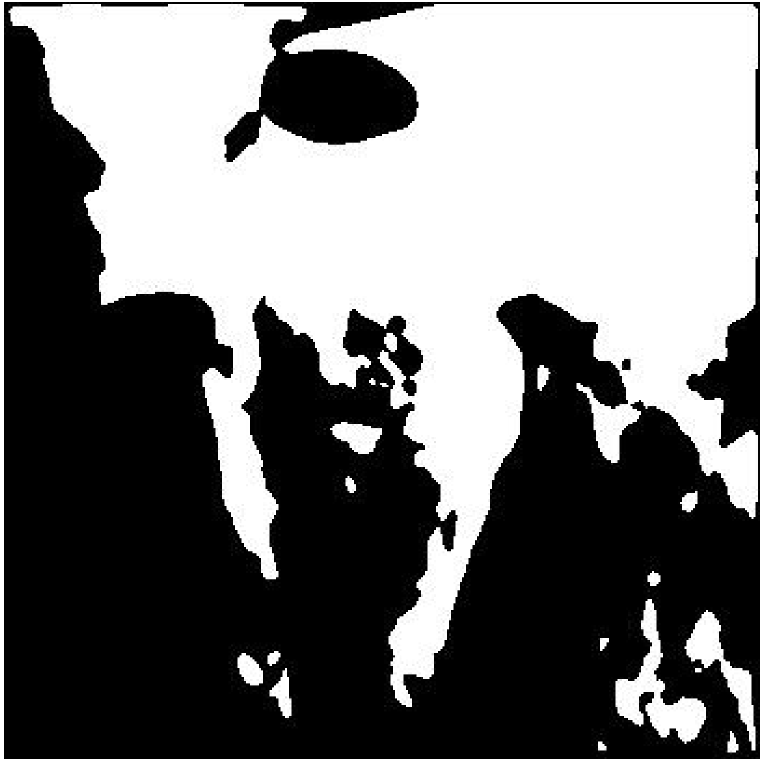
Bells

Priming

Bells



Priming



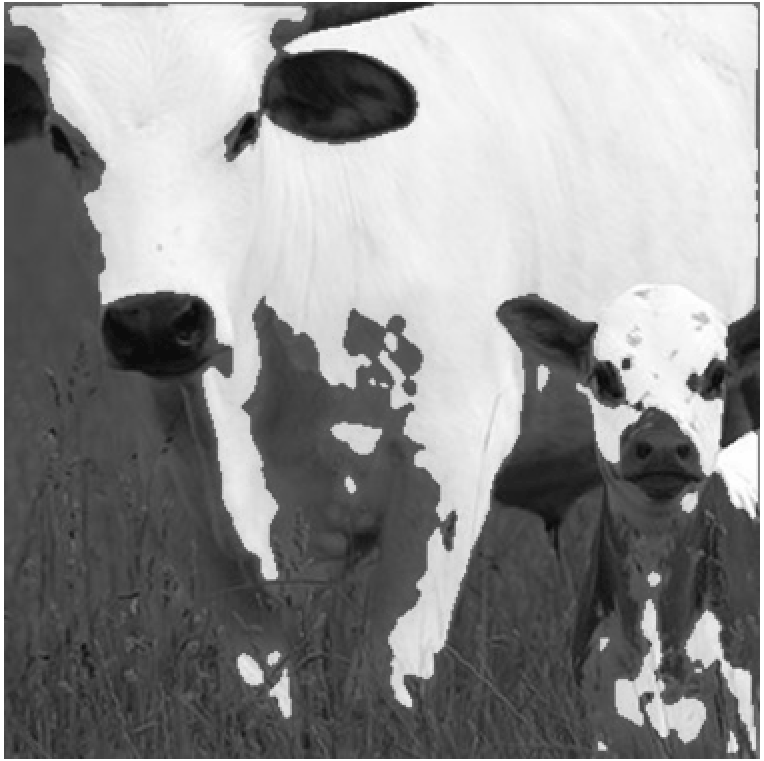
Priming

Priming

Cows

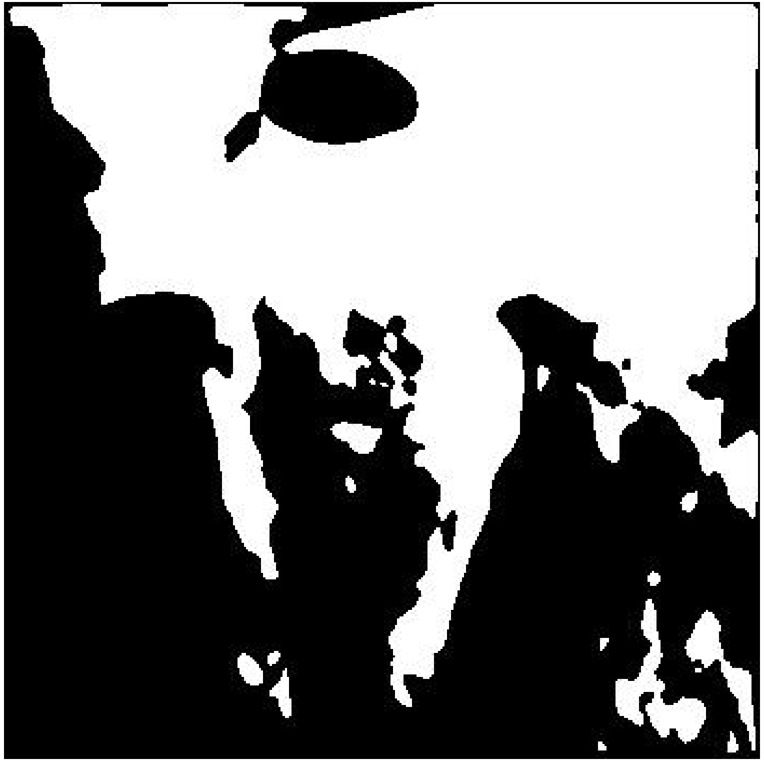
Priming

Cows

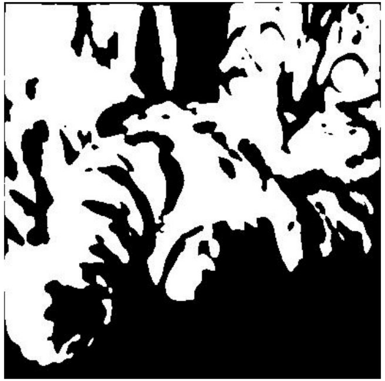


Priming

Cows



Mooney Images



Thresholded two-tone images showing a single object.

Recognition:

- Hard to recognize at first sight
- Sudden recognition (aha! / Eureka-effect)
- Intrinsically / By marking the contour of object / Showing the original image

Value for Authentication?

- Trigger brain processes involved in **implicit memory**.

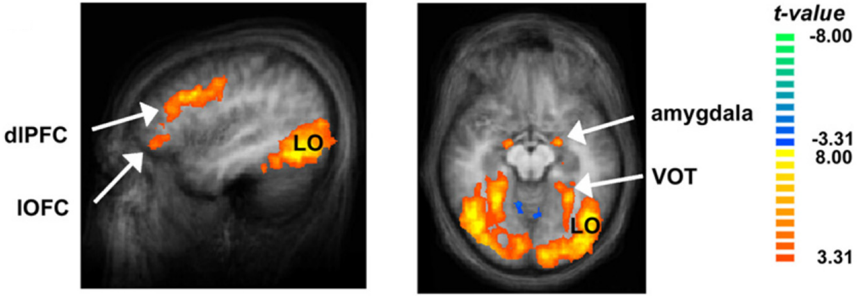
Implicit Memory

Unintentional recollection of information.

Can be observed in *habitual* behavior, i.e., riding a bike, playing an instrument.

We are not aware of the information stored in our memory.

We can trigger the implicit memory by a process called *priming*.



Ludmer et al. Neuron 2011 [3]

[Img. 1] Twitter Emoji ("Twemoji"), CC-BY 4.0 https://creativecommons.org/licenses/by/4.0/

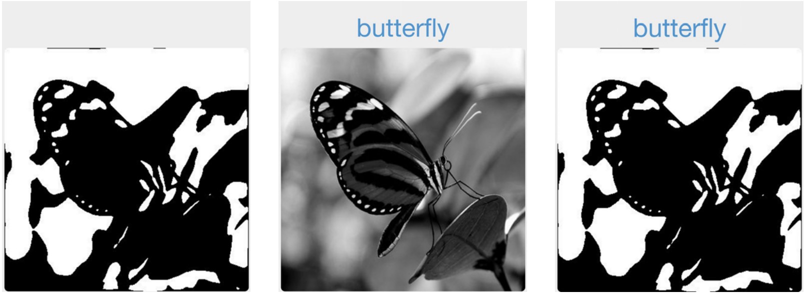
[Ref. 3] Rachel Ludmer et al.: Uncovering Camouflage: Amygdala Activation Predicts Long-Term Memory of Induced Perceptual Insight. (Neuron '11)

MooneyAuth

Relieves users of the cognitive burden of remembering an explicit password.

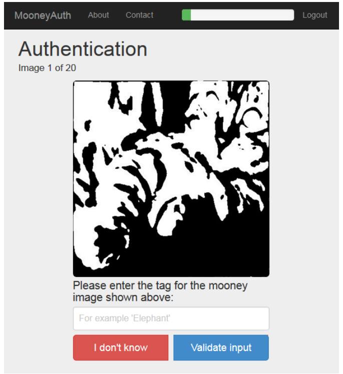
1) Enrollment / Priming:

- Prime on set of random Mooney images.
- We show every image twice.



2) Authentication:

- Primed + non-primed Mooney images are presented to the user.
- User is requested to label the images.
- Scoring algorithm based on surprisal of observed events.
- User authenticated: score > threshold.



Authentication

Image 1 of 20

Please enter the tag for the mooney image shown above:

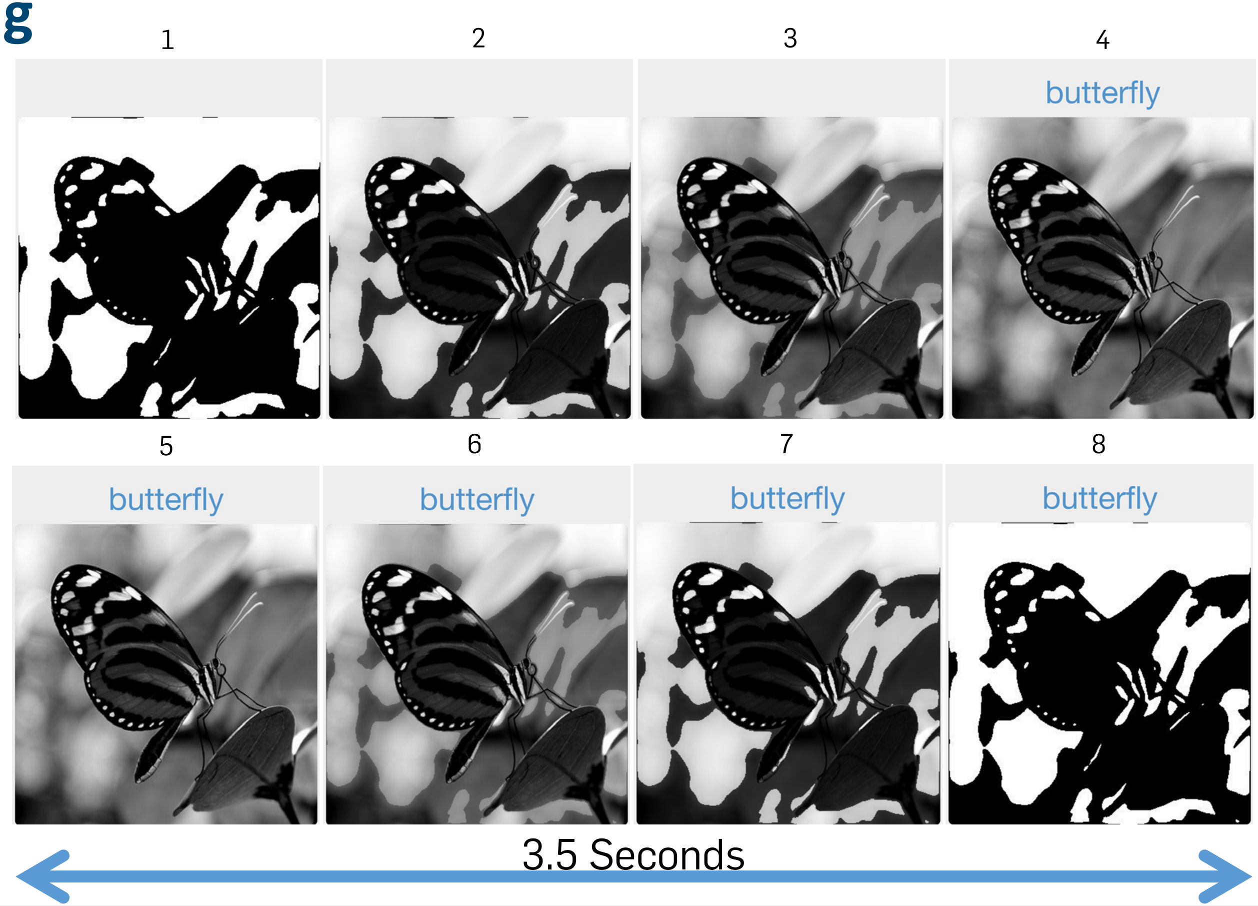
For example 'Elephant'

Enrollment / Priming

- Smooth transition

- Takes 3.5 seconds per image.

- In a user study we primed 10 images



Authentication

Primed + non-primed images are presented.

Task:

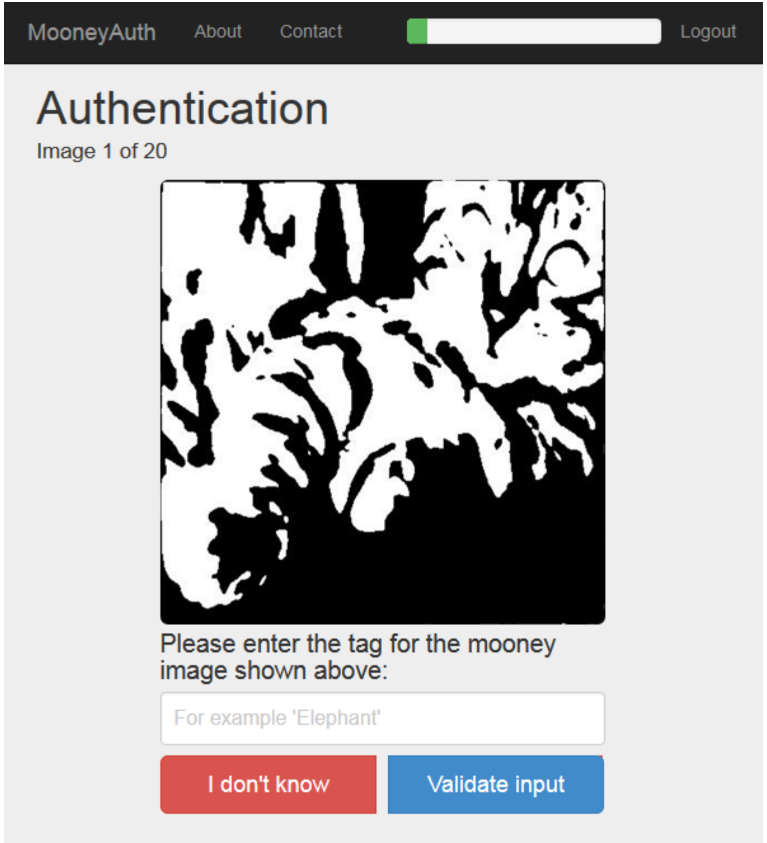
User has to **label** the image

or

skip by pressing the I don't know button.

Assumption:

User labels primed images more often correctly (and faster).



Authentication

Image 1 of 20

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Scoring

- Score derived from the self-information (surprisal) of the observed events.

- There are four events that can occur:

	Correct Label	Incorrect Label
Primed	p_i	$1\text{-}p_i$
Non-Primed	n_i	$1\text{-}n_i$

$$I(E_{primed,correct}) = -\log_2 P(correct \mid primed)$$

→ A “good” Mooney image has a high p_i, but low n_i value.

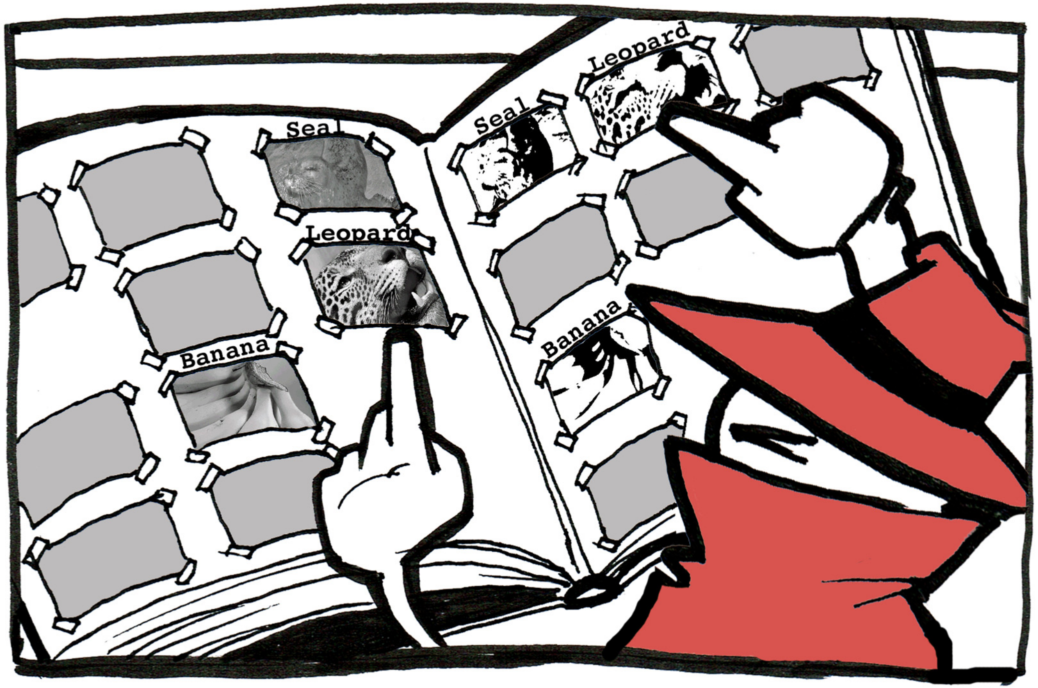
Attacker Model

The security does not rely on secrecy of the hidden object.

We provide the attacker with the solution for every Mooney image:

- Mooney image
- Original grayscale image
- Correct label

The scheme can not be broken by computer vision algorithms!

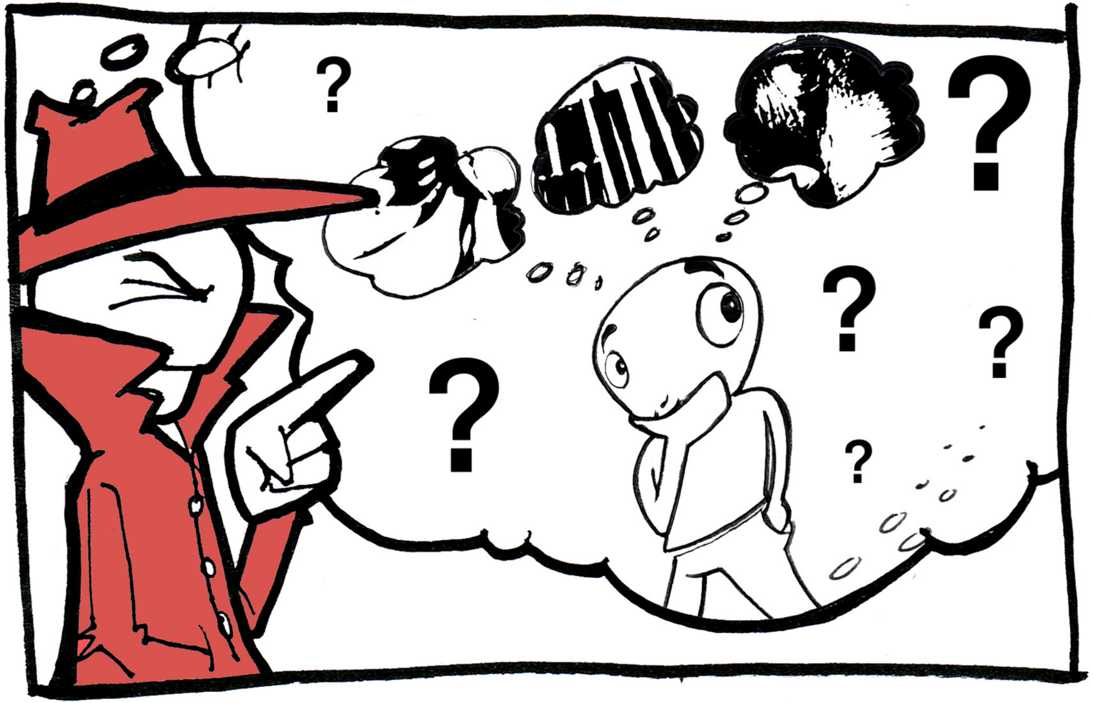


Attacker Model

Secret: Knowing which images the user was primed on.

During enrollment images are selected by the server:

- No user selection bias
- Random guessing
- Rate limit guessing attempts



Main Results

Does implicit memory-based authentication work?

User Studies

Pre Study

230 participants
20 days

Goals:
- Get p_i, n_i for Scoring
- Test Label Matching

Long-Term Study

~130 participants
8.5 months

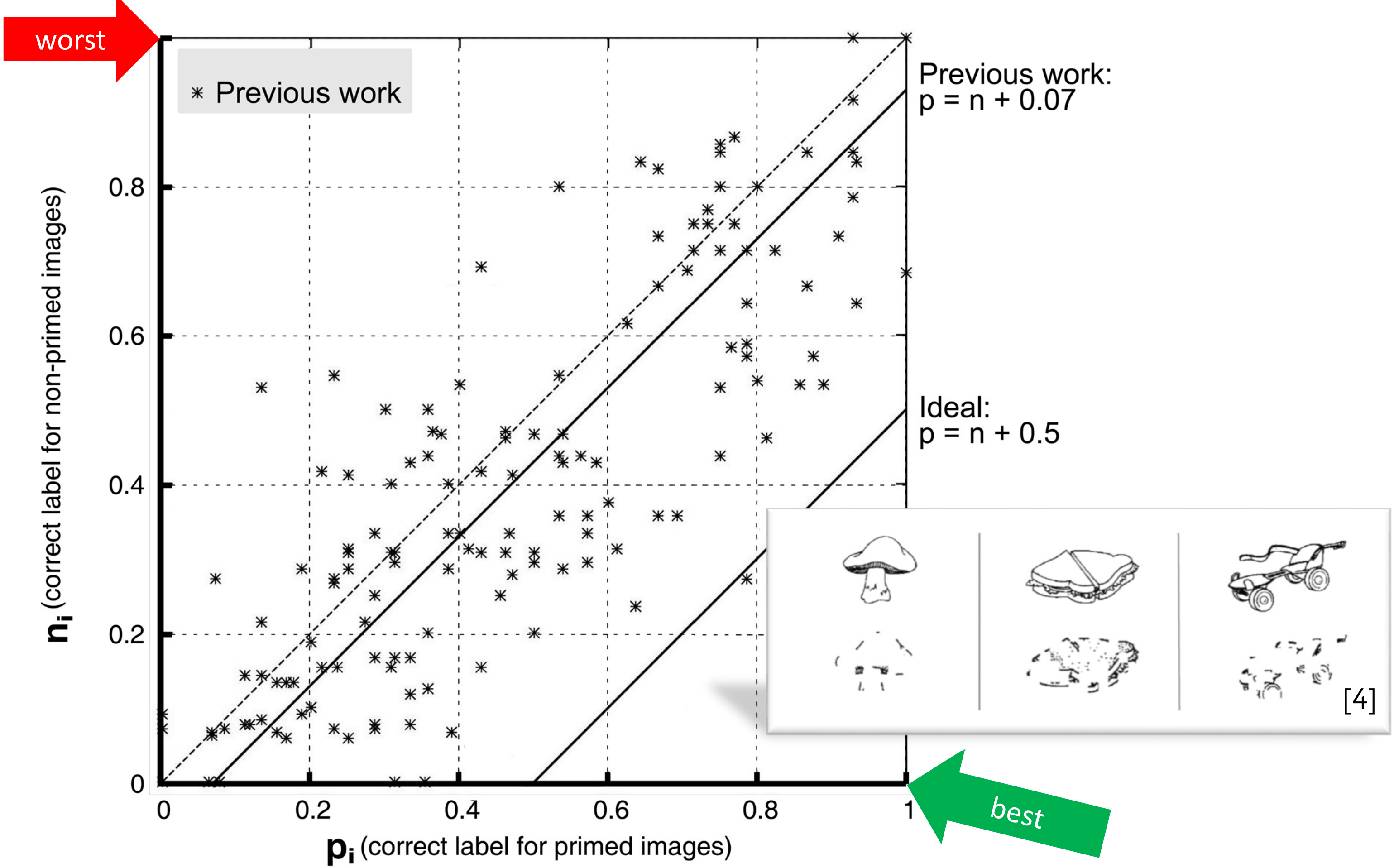
Goals:
- Long-Term Effects

Main Study

70 participants
21 days

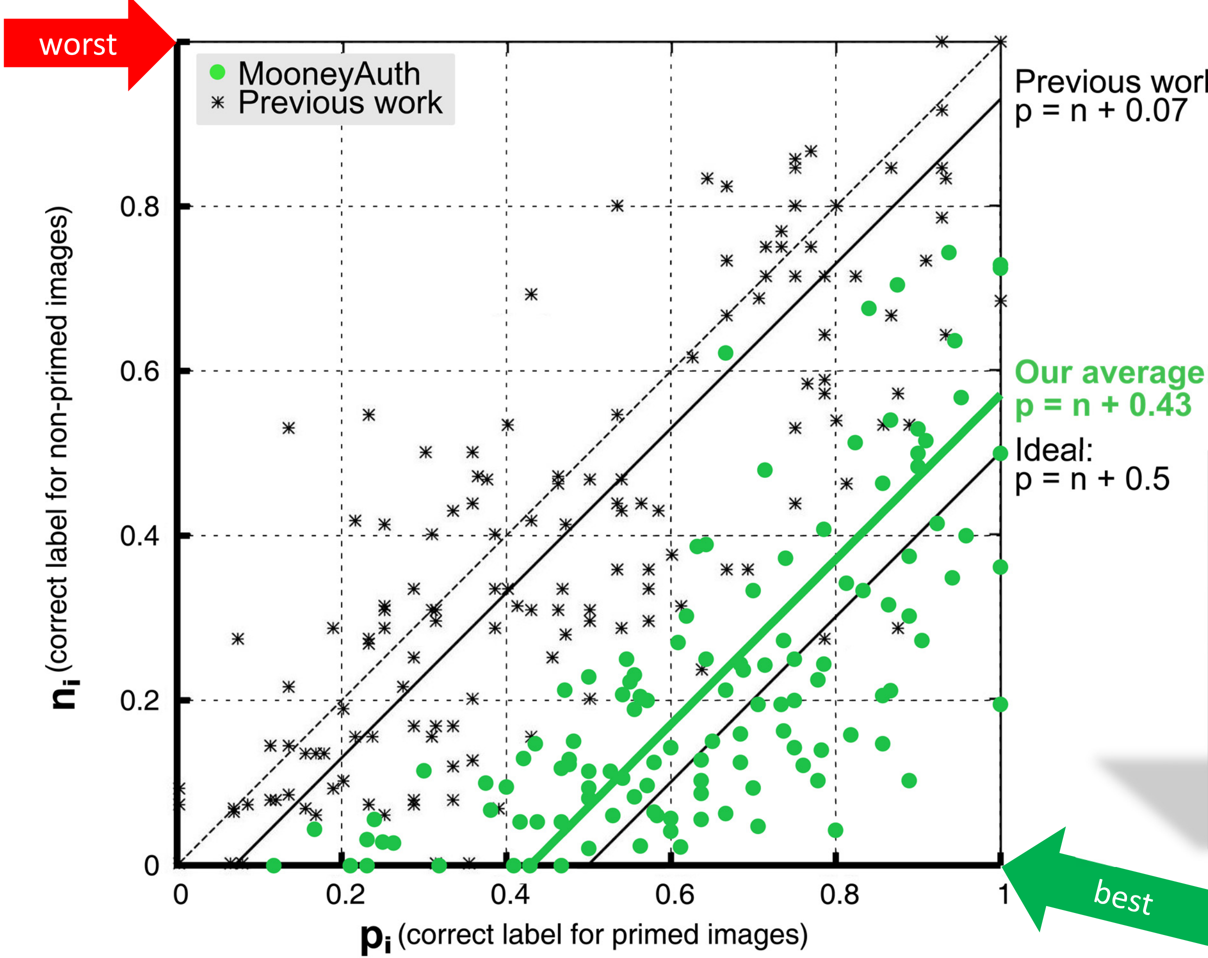
Goals:
- Performance Measure

Previous Work



[Ref. 4] Tamara Denning, Kevin D. Bowers, Marten van Dijk, and Ari Juels: Exploring Implicit Memory for Painless Password Recovery. (CHI '11)

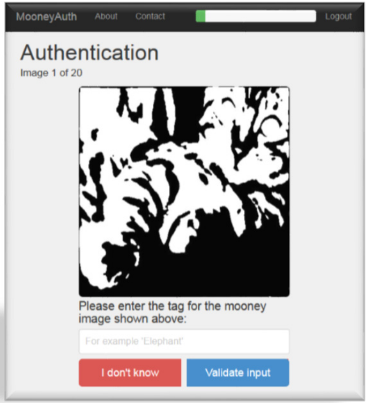
Our Result



Previous work: $p = n + 0.07$

Our average: $p = n + 0.43$

Ideal: $p = n + 0.5$



Authentication

Image 1 of 20

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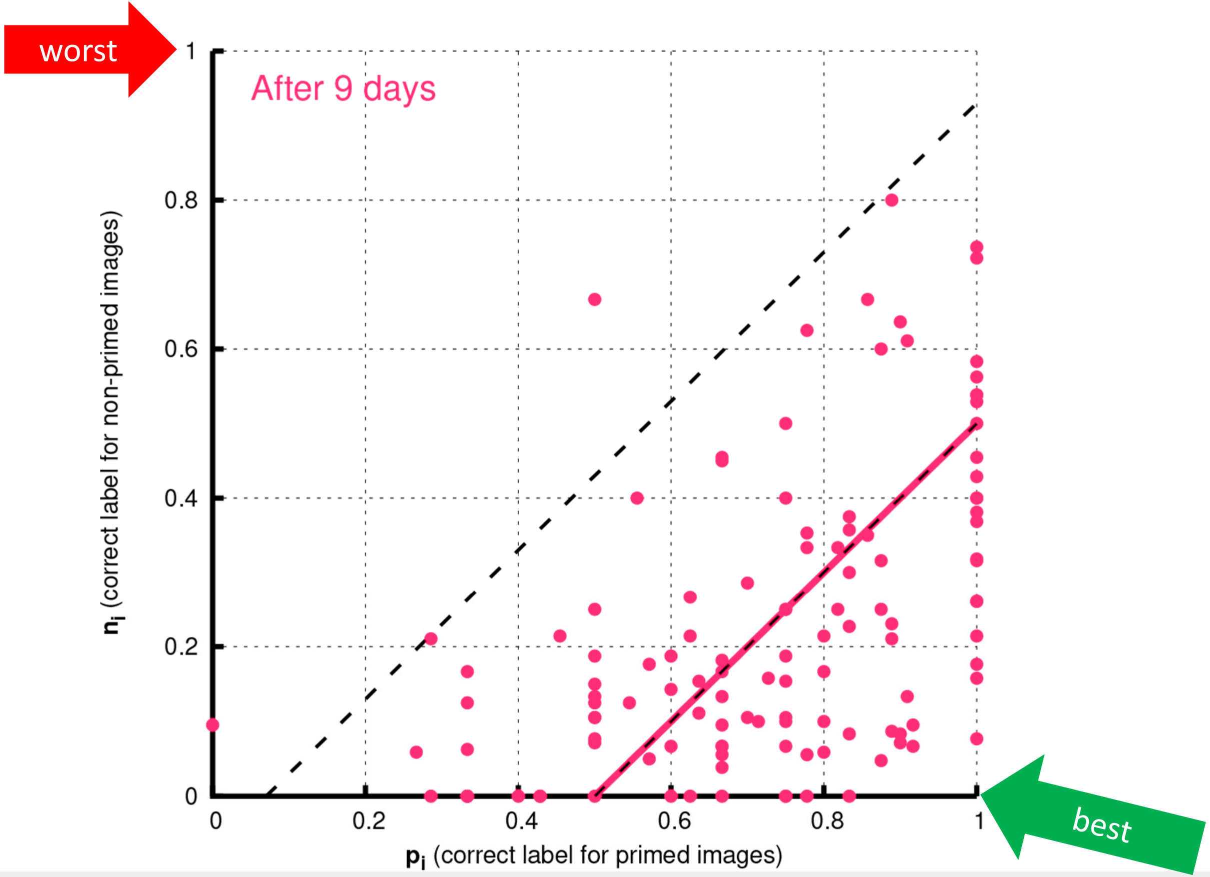
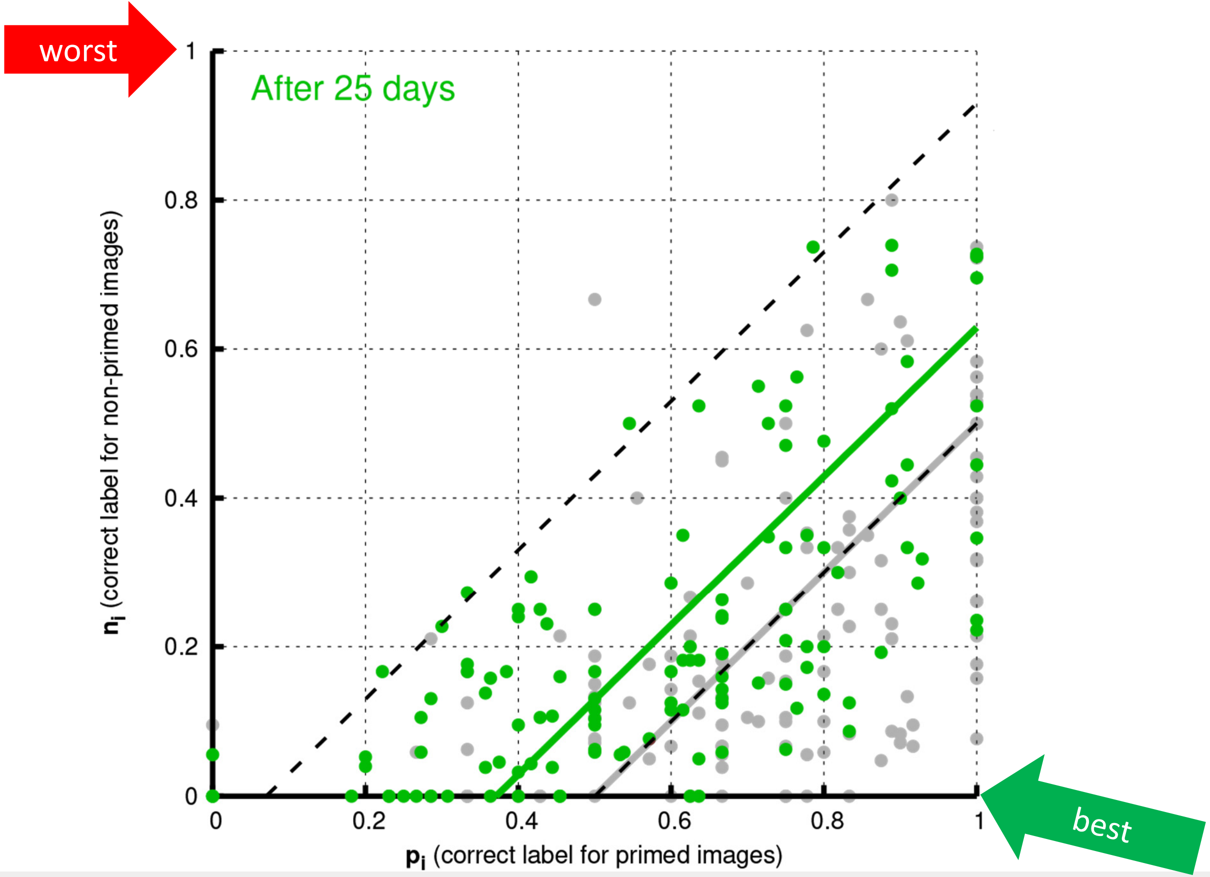
Long-Term Results

How long does the priming last?

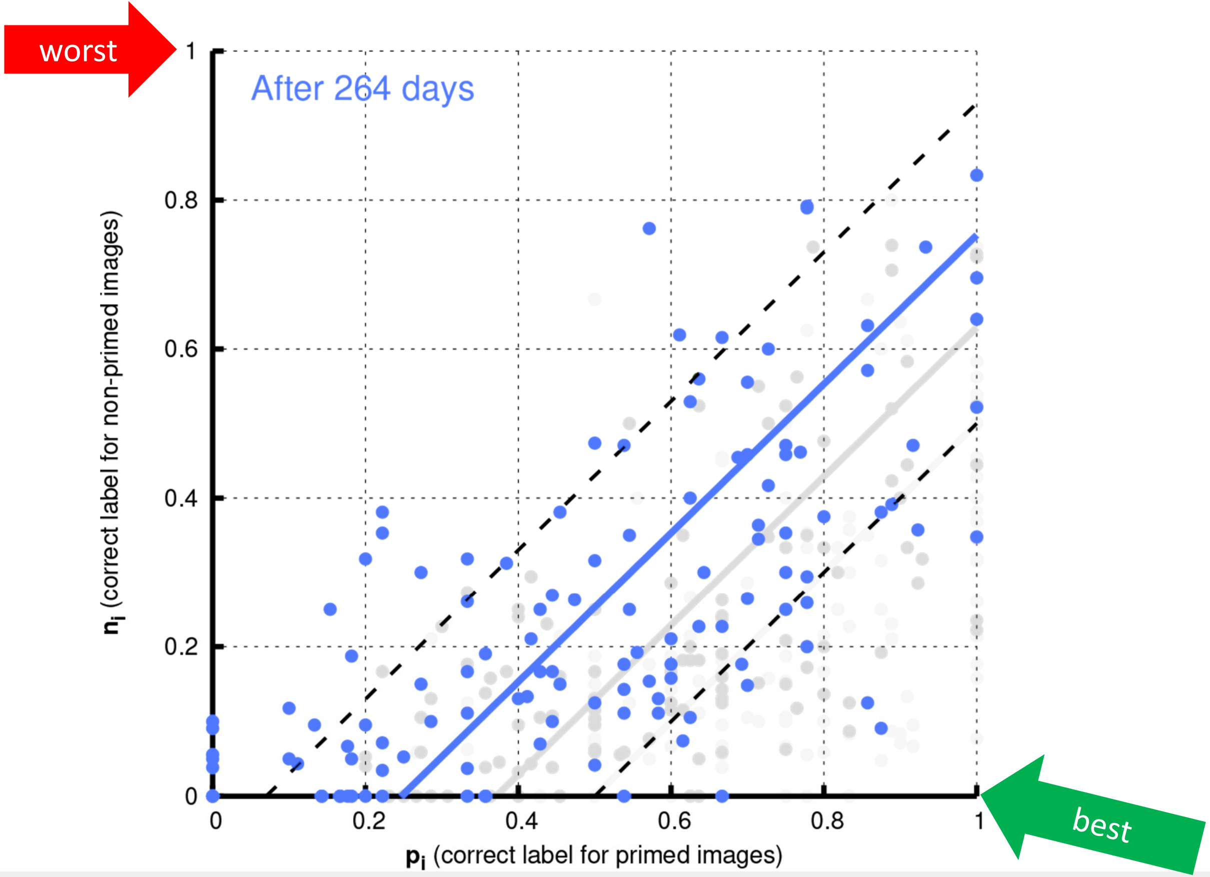
Priming Effect Decline Over Time:



Priming Effect Decline Over Time:



Priming Effect Decline Over Time:



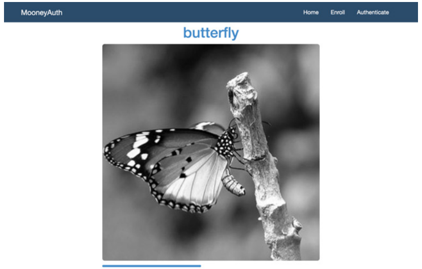
Benefits and Limitations

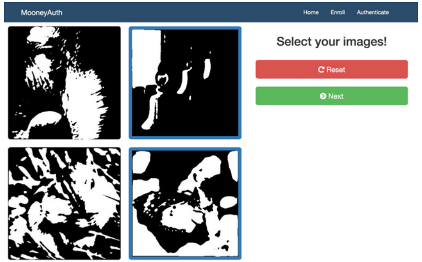
Benefits:

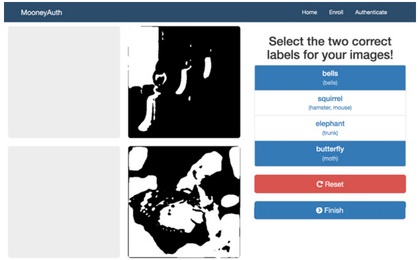
- High memorability
- Server selected secret (no user bias)

Limitations:

- Cumbersome to label (software keyboard, time required)
- Unexplored: Interference effects (use for multiple services)
- Phishing
- Shoulder surfing
- Secure storage of secret







Let’s Play Again!

Back to the game.

Authentication

?

Authentication

Authentication

Cows

Authentication

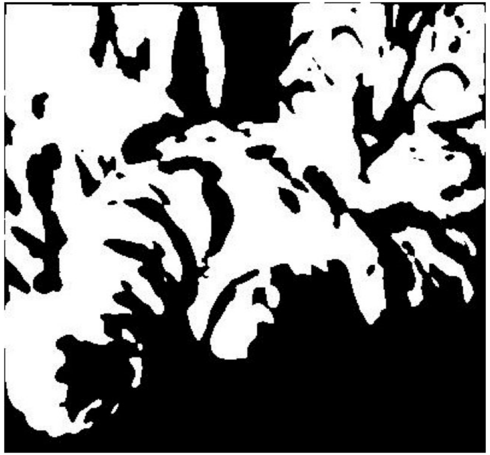
?

Authentication

Authentication

Elephant

Takeaway



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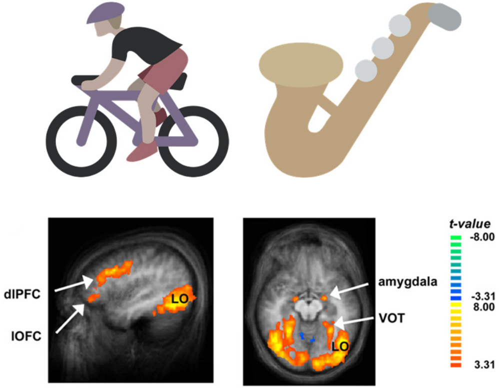
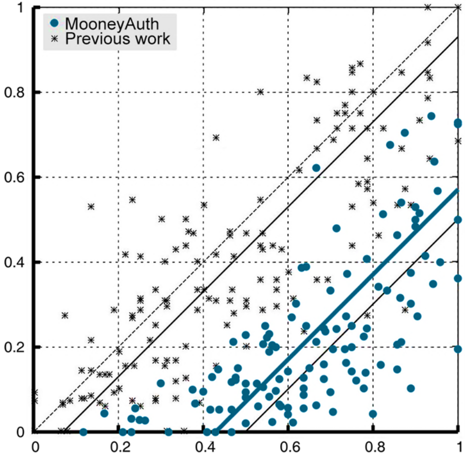


Implicit Memory



Implicit Memory-Based Authentication

Demo? mooneyauth.org

Mooney Image Generation

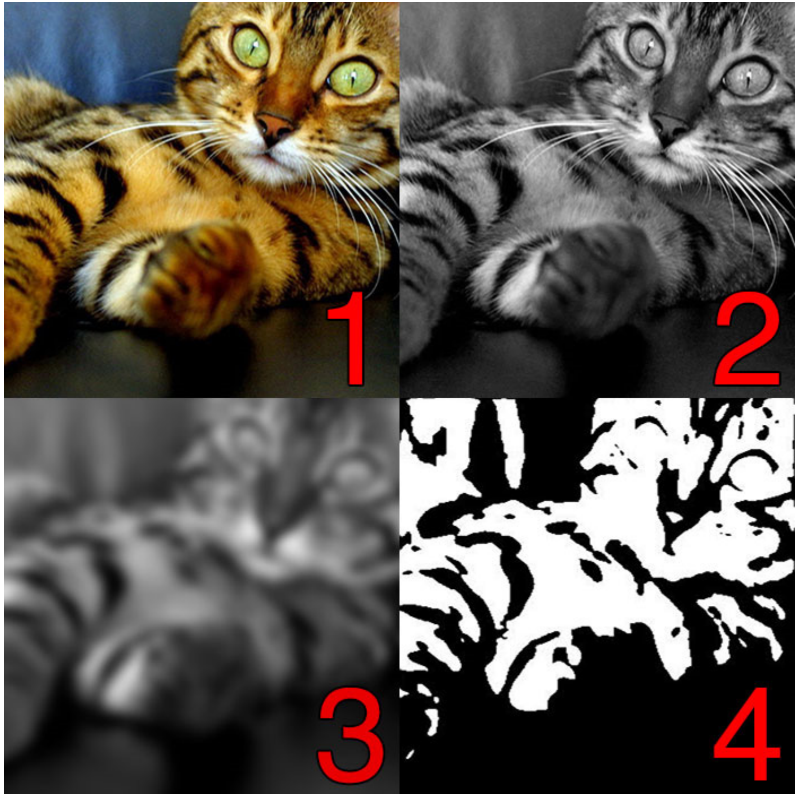
1) Image search with nouns from “MRC Psycholinguistic Database”.

1) Convert images to gray-scale.

2) Smoothing via Gaussian filter.

3) Apply Otsu’s histogram based thresholding algorithm.

4) Filter for mean recognition rate of 5 sec. and longer. [5]



[Ref. 5] Fatma Imamoglu et al.: Changes in Functional Connectivity Support Conscious Object Recognition. (NeuroImage ‘12)