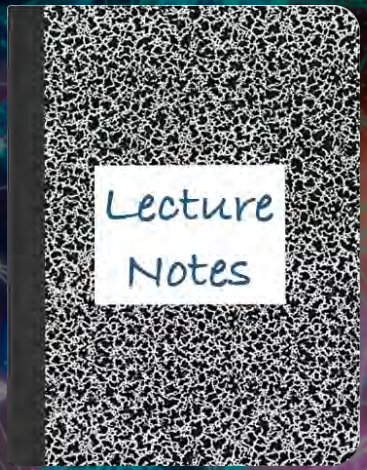
CS 419: Computer Security

Week 15: CAPTCHA



Paul Krzyzanowski

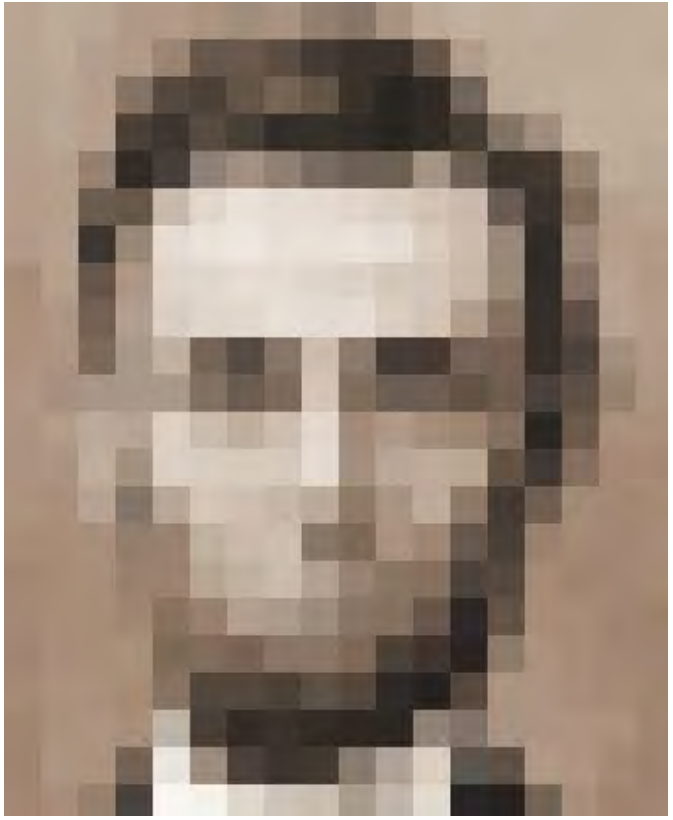
CAPTCHA: Detecting Humans

Gestalt Psychology (1922-1923)

- **Max Wertheimer, Wolfgang Köler, Kurt Koffka**
- **Laws of organization**
  - Proximity
    - We tend to group things together that are close together in space
  - Similarity
    - We tend to group things together that are similar
  - Good Continuation
    - We tend to perceive things in good form
  - Closure
    - We tend to make our experience as complete as possible
  - Figure and Ground
    - We tend to organize our perceptions by distinguishing between a figure and a background

Source: http://www.webrenovators.com/psych/GestaltPsychology.htm

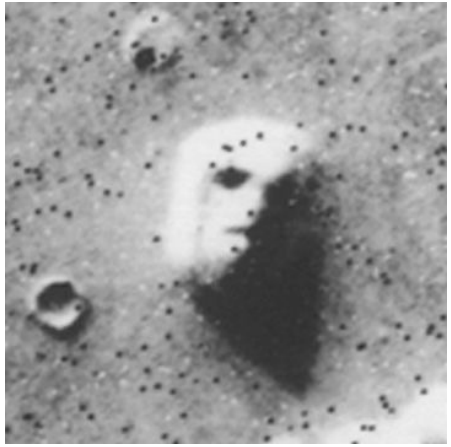
Gestalt Psychology



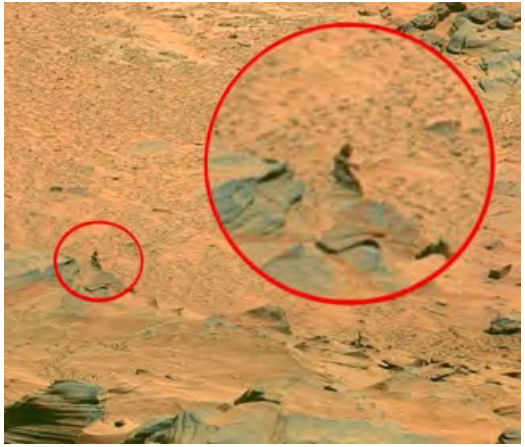
18 x 22 pixels

Objects on Mars?

Elvis

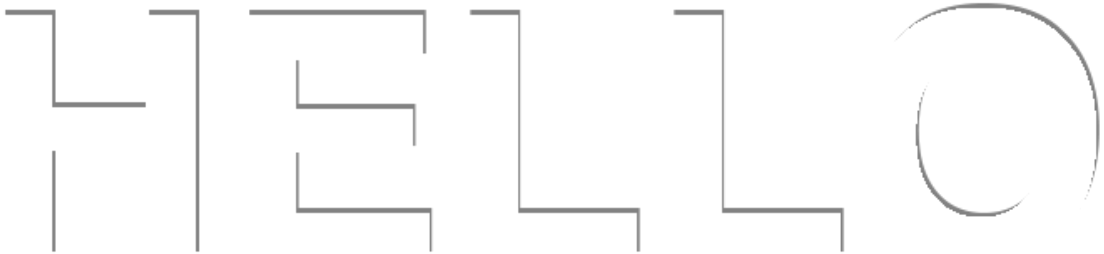


Face

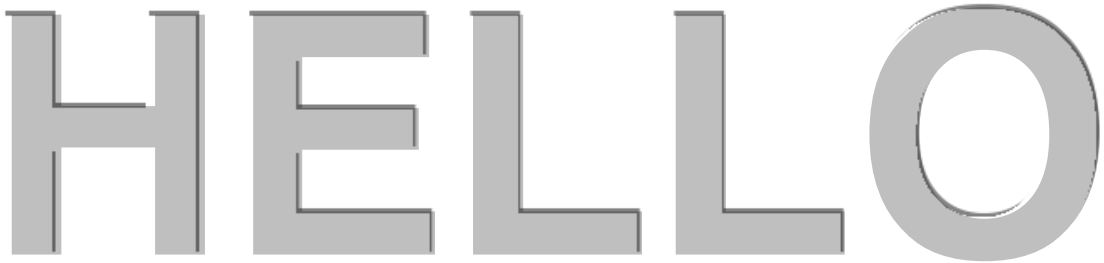


Female statue

Gestalt Psychology: text continuity



Gestalt Psychology



Authenticating humanness

Battle the Bots

- Create a test that is easy for humans but extremely difficult for computers

CAPTCHA: Completely Automated Public Turing test to tell Computers and Humans Apart

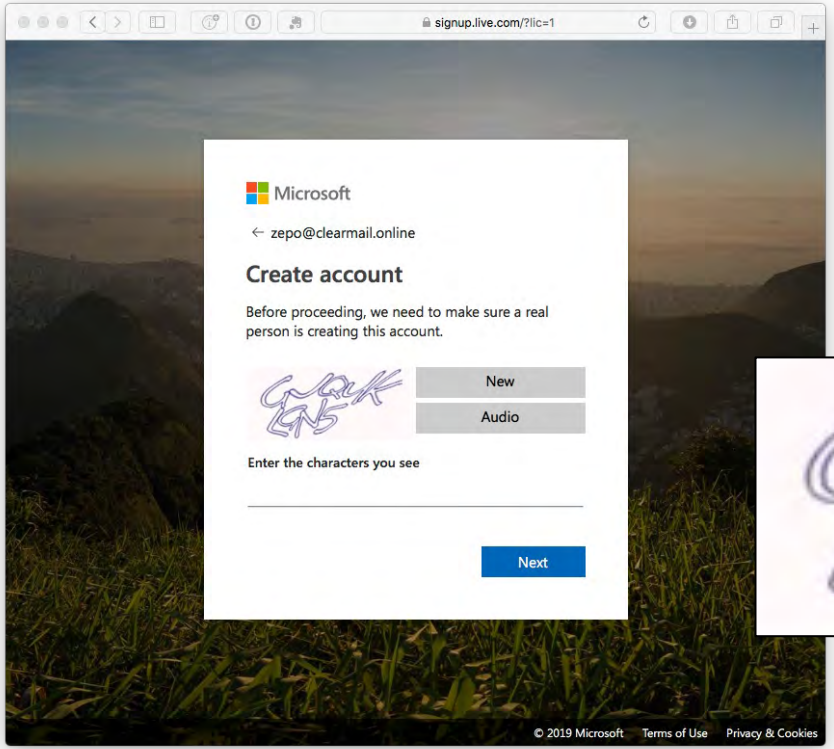
- Image Degradation
  - Exploit our limits in OCR technology
  - Leverages human Gestalt psychology: reconstruction

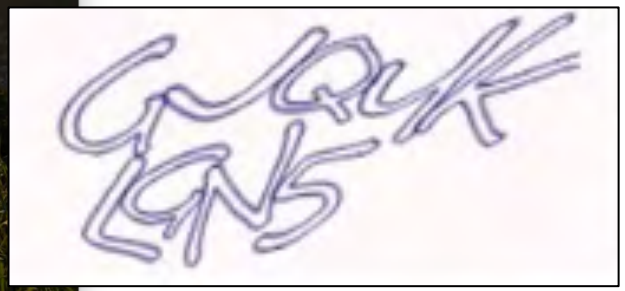
Origins

- 1997: AltaVista – prevent bots from registering URLs with the search engine
- 2000: Yahoo! and Manuel Blum & team at CMU
  - EZ-Gimpy: one of 850 words
- Henry Baird @ CMU & Monica Chew at UCB
  - BaffleText: generates a few words + random non-English words

CAPTCHA Example (2019)

Microsoft

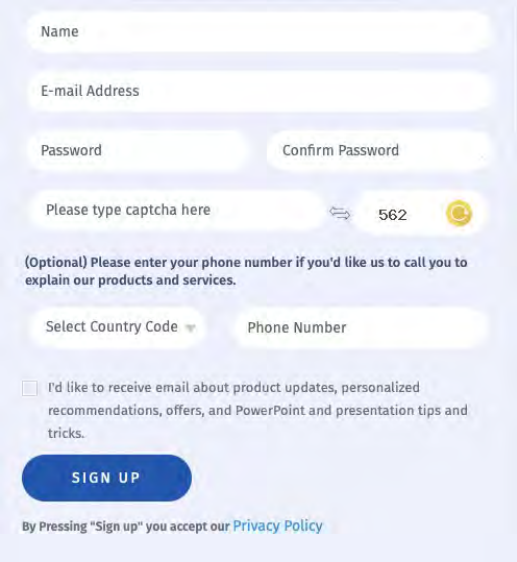


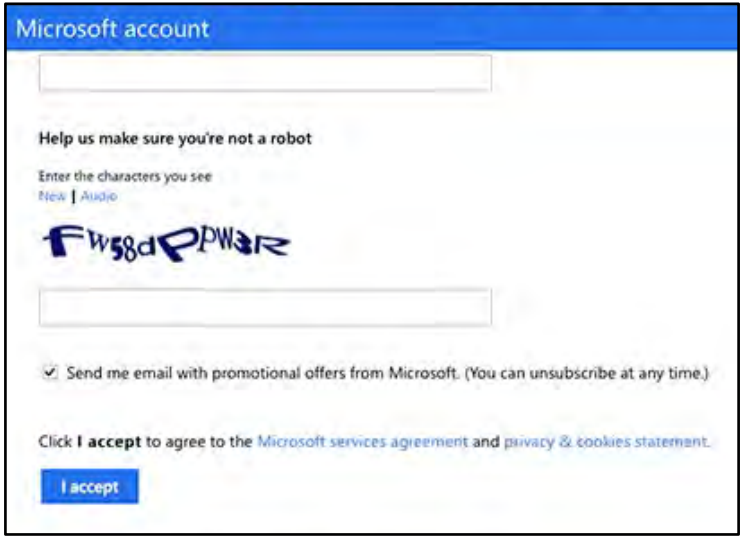


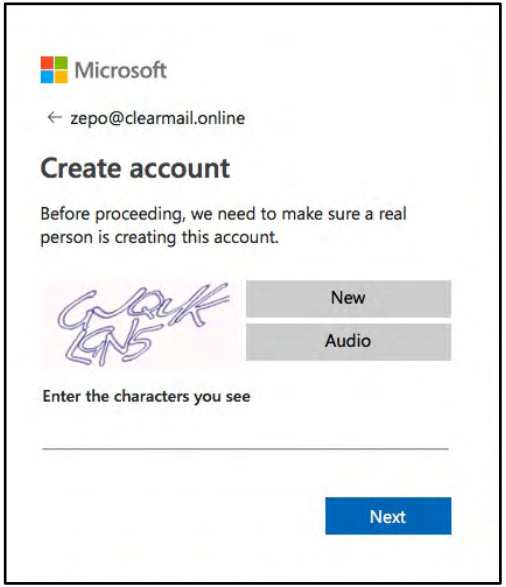
See captchas.net

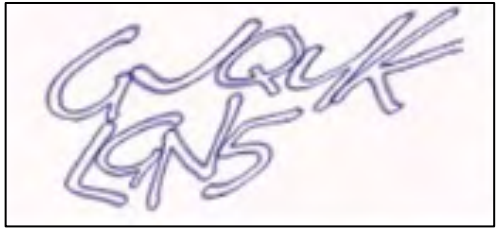
They had to get more difficult

Advances in character recognition led to automated solving









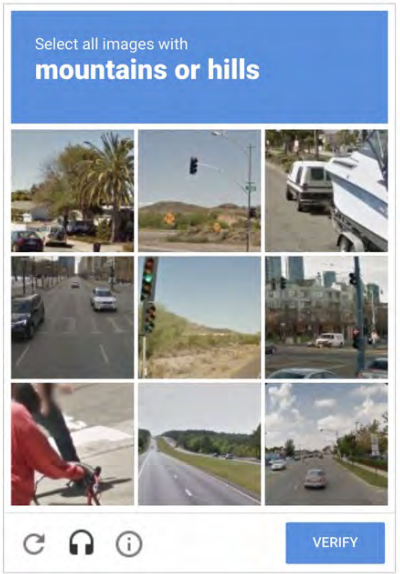
Problems

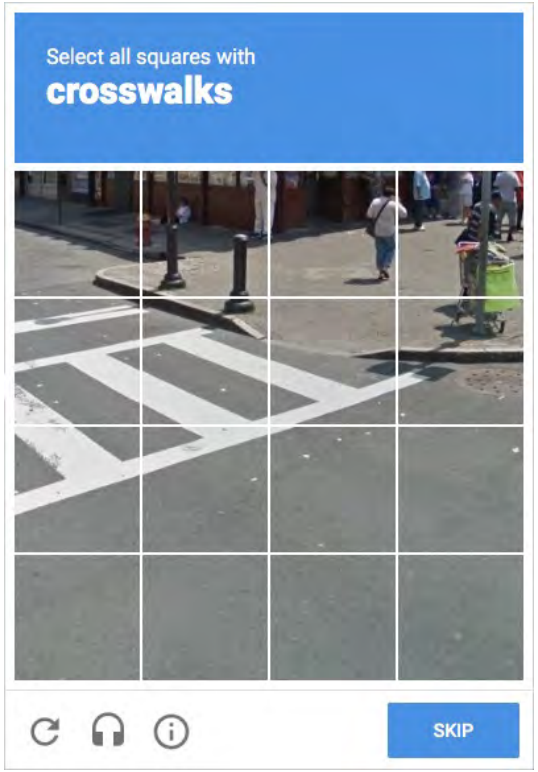
- **Accessibility**
  - Visual impairment → audio CAPTCHAs
  - Deaf-blind users are left out
  - Typing text was more tedious on mobile devices

- **Frustration**
  - OCR & computer vision has improved a lot!
  - Challenges that are difficult for computers may be difficult for humans
- **Attacks**
  - Man in the middle attacks
    - Use human labor – CAPTCHA farms
  - Automated CAPTCHA solvers
    - Initially, educated guesses over a small vocabulary

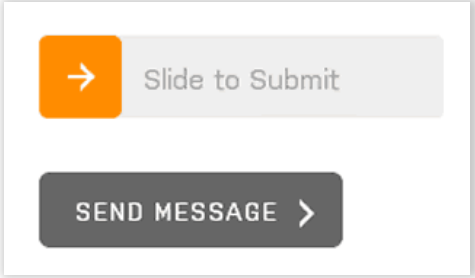
Alternate approaches

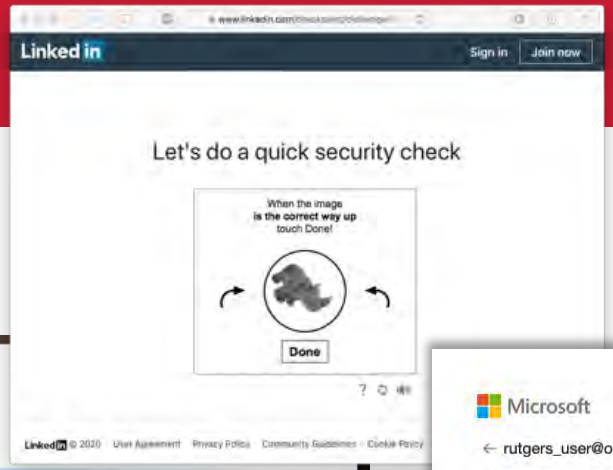
- **Puzzles, scene recognition**

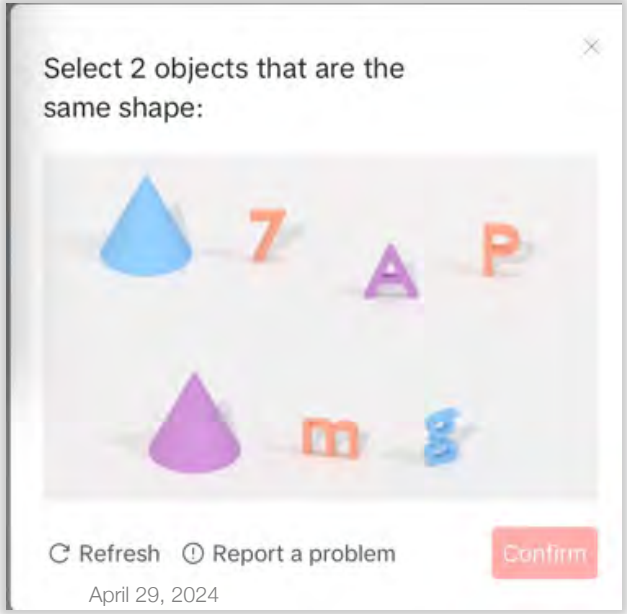


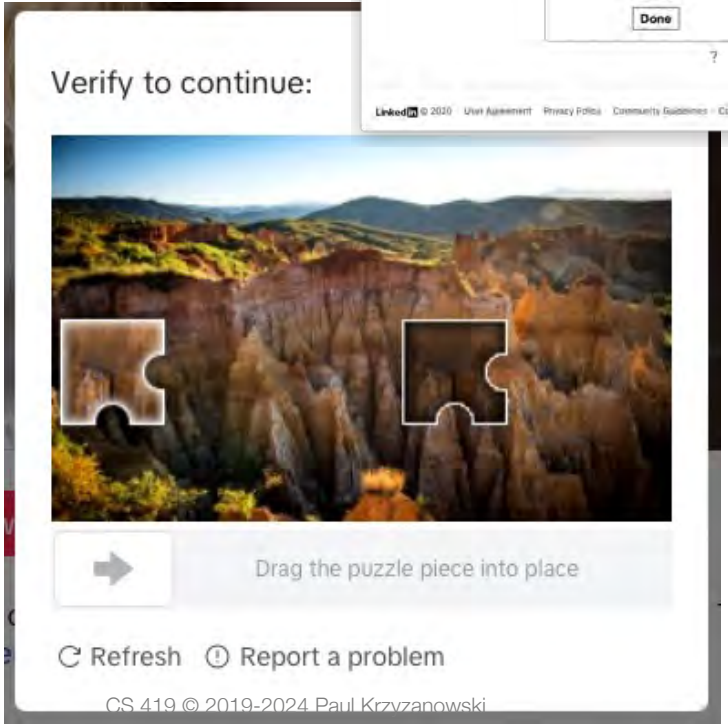


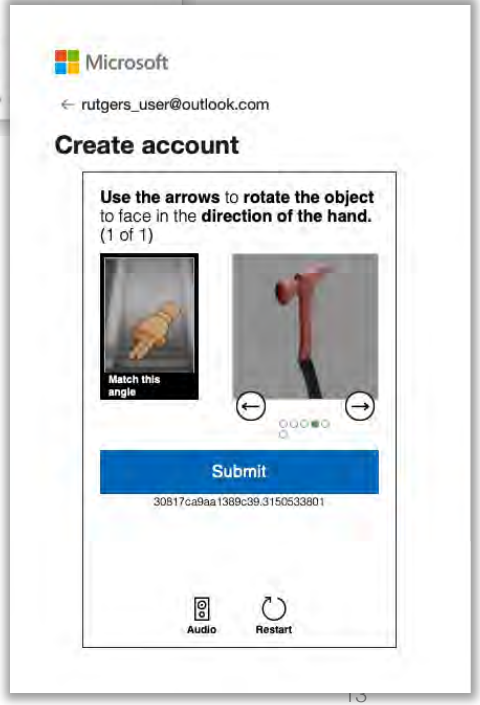
Alternate Approaches







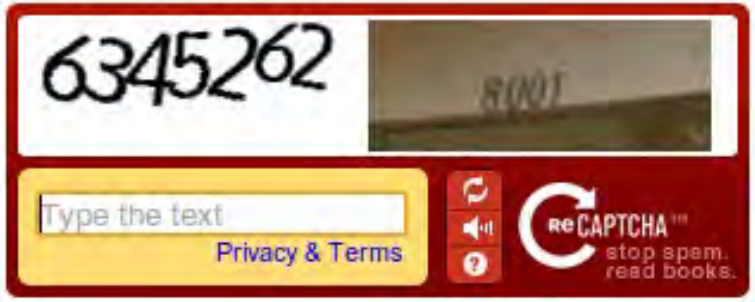




reCAPTCHA

Ask users to translate images of real words & numbers from archival texts

– Human labor fixed up the archives of the New York Times



Two sections

(1) known text

(2) image text

– Assume that if you get one right then you get the next one correct
  • Try it again on a few other people to ensure identical answers before marking it correct

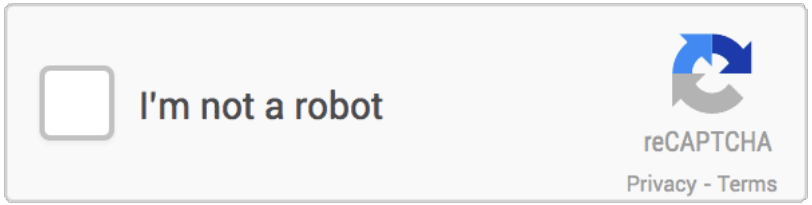
Google bought reCAPTCHA 2009

– Used free human labor to improve transcription of old books & street data

By 2014:
Google found that AI could crack CAPTCHA & reCAPTCHA images with 99.8% accuracy

NoCAPTCHA reCAPTCHA

Just ask users if they are a robot

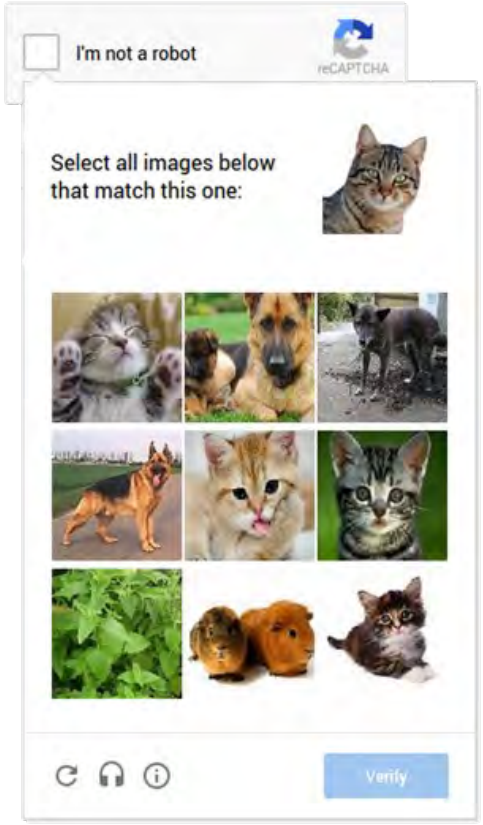


- **Reputation management**
  - "Advanced Risk Analysis backend"
  - Check IP addresses of known bots
  - Check Google cookies from your browser
  - Considers user's engagement with the CAPTCHA: before, during, and after
    - Mouse movements & acceleration, precise location of clicks
- **Latest version: invisible reCAPTCHA**
  - Don't even present a checkbox

NoCAPTCHA fallback

If risk analysis fails,

- Present a CAPTCHA
- For mobile users, present an image identification or labeling problem



Other approaches: Text/email verification

- **Text/email verification**
  - Ask users for a phone # or email address
  - Similar to two-factor authentication but we're not authenticating the user
  - Service sends a message containing a verification code
    - Still susceptible to spamming & automation
    - Makes the process more cumbersome
    - Requires users to disclose some information

- **Measure form completion times**
  - Users take longer than bots to fill out and submit forms
  - Measure completion times
    - Bots can program delays if they realize this is being done

The End