Web Security

Week 10 - Authentication

Old Dominion University
Department of Computer Science
CS 495/595 Spring 2022
Michael L. Nelson <mln@cs.odu.edu>

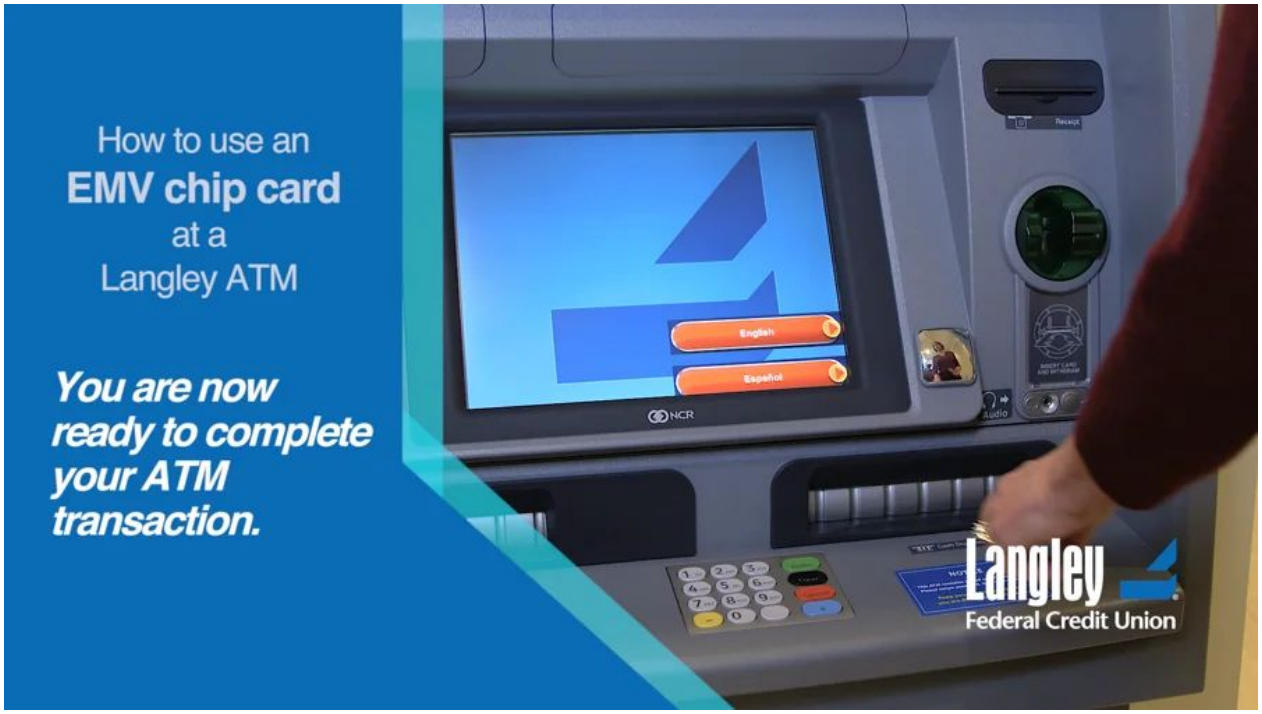
2022-03-28

How can we build systems which are secure even when the attacker has the user's password?

What is authentication?

- Idea: Verify the user is who they say they are
- Authentication systems classically use three factors:
  - Something you know (e.g., a password)
  - Something you have (e.g., a phone, badge, or cryptographic key)
  - Something you are (e.g., a fingerprint or other biometric data)
- The more factors used, the more sure we are that the user is who they say they are

ATMs = two factor authentication



1. what you have (card)
2. what you know (PIN)

Authentication vs. Authorization

- Authentication: Verify the user is who they say they are
  - Login form
  - Ambient authority (e.g., HTTP cookies)
  - HTTP authentication
- Authorization: Decide if a user has permission to access a resource
  - Access control lists (ACLs)
  - Capability URLs
    - https://www.w3.org/TR/capability-urls/

NIST Special Publication 800-63, Revision 3

Digital Identity Guidelines

Authentication establishes confidence that the claimant has possession of an authenticator(s) bound to the credential, and in some cases in the attribute values of the subscriber (e.g., if the subscriber is a U.S. citizen, is a student at a particular university, or is assigned a particular number or code by an agency or organization). Authentication does not determine the claimant's authorizations or access privileges; this is a separate decision, and is out of these guidelines' scope. RPs can use a subscriber's authenticated identity and attributes with other factors to make authorization decisions. Nothing in this document suite precludes RPs from requesting additional information from a subscriber that has successfully authenticated.

https://pages.nist.gov/800-63-3/sp800-63-3.html

Good practices that are not always followed

- Usernames should be stored case insensitively
  - nelson is the same user as Nelson
  - @WebSciDL is the same as @webscidl
- Usernames should be unique
  - Two users should not share the same username

Users choose weak passwords

Top 25 most common passwords by year according to SplashData

Rank	2011[4]	2012[5]	2013[6]	2014[7]	2015[8]	2016[3]	2017[9]	2018[10]
1	password	password	123456	123456	123456	123456	123456	123456
2	123456	123456	password	password	password	password	password	password
3	12345678	12345678	12345678	12345	12345678	12345	12345678	123456789
4	qwerty	abc123	qwerty	12345678	qwerty	12345678	qwerty	12345678
5	abc123	qwerty	abc123	qwerty	12345	football	12345	12345

https://www.sentinelone.com/blog/7-signs-weak-password/

Designing password requirements

- Left on their own, users will choose weak passwords
- Solution: Let's enforce password requirements
  - What should the requirements be?

Payment Card Industry Data Security Standard (PCI DSS)

PASSWORD BEST PRACTICES

To minimize the risk of being breached, businesses should change vendor default passwords to strong ones, and never share them – each employee should have its own login ID and password.

Change your passwords regularly

Treat your passwords like a toothbrush. Don't let anyone else use them and get new ones every three months.

Don't share passwords

Insist on each employee having its own login ID and password – never share!

Make passwords hard to guess

The most common passwords are "password", "password1" and "123456." Hackers try easily-guessed passwords because they're used by half of all people. A strong password has seven or more characters and a combination of upper and lower case letters, numbers, and symbols (like !@#$&*). A phrase that incorporates numbers and symbols can also be a strong password – the key is picking a phrase with specific meaning to you so it's easy to remember, like a favorite hobby, for example (like ILove2Fish4Trout!).

https://blog.pcisecuritystandards.org/infographic-strong-passwords

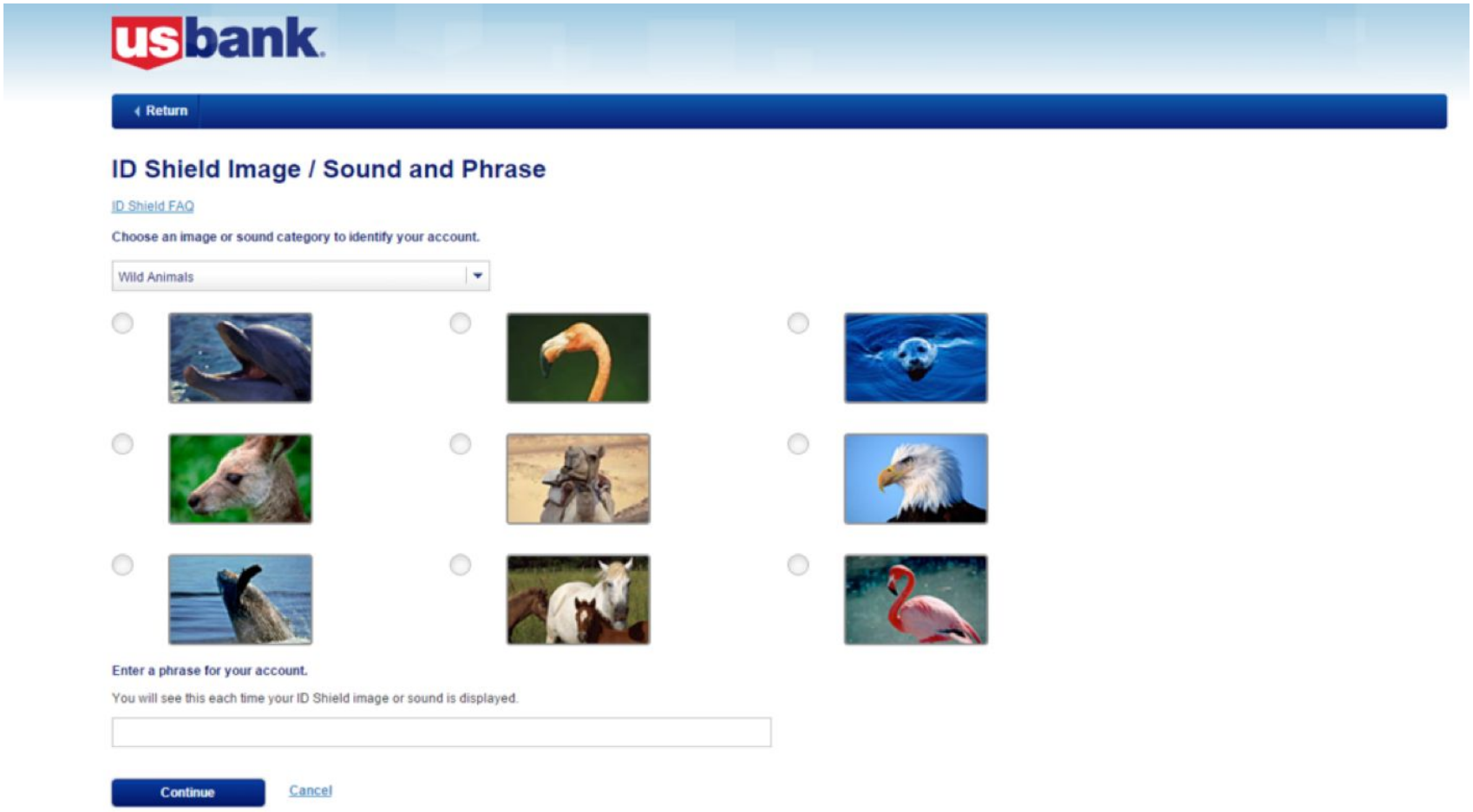
Password requirement best practices (outdated)

- Ensure passwords are "complex", i.e. composed of numeric, alphabetic (uppercase and lowercase) characters in addition to special symbols and similar characters
- Force users to change passwords regularly
- Require new passwords not previously used by the user
- Example of a good password: `P@ssw0rd1`

Terrible password requirement practices

- Maximum length of 8-10 characters
- Minimum password age policy (to prevent password requirement dodging)
- Disable copy-and-paste
- Password hints which lack sufficient entropy
- Show an on-screen keyboard and make user click to enter password

Bank login "security images"



Studying the Effectiveness of Security Images in Internet Banking

Joel Lee
Carnegie Mellon University
Pittsburgh, PA
jlee@cmu.edu

Lujo Bauer
Carnegie Mellon University
Pittsburgh, PA
lbauer@cmu.edu

***Abstract*—Security images are often used as part of the login process on internet banking websites, under the theory that they can help foil phishing attacks. Previous studies, however, have yielded inconsistent results about users' ability to notice that a security image is missing and their willingness to log in even when the expected security image is absent. This paper describes an online study of 482 users that attempts to clarify to what extent users notice and react to the absence of security images. We also study the contribution of various factors to the effectiveness of security images, including variations in appearance and interactivity requirements, as well as different levels of user motivation. The majority of our participants (73%) entered their password when we removed the security image and caption. We found that features that make images more noticeable do not necessarily make them more effective at preventing phishing attacks, though some appearance characteristics succeed at discouraging users from logging in when the image is absent. Interestingly, we find that habituation, the level of financial compensation, and the degree of security priming, at least as explored in our study, do not influence the effectiveness of security images.**

I. Introduction

Many of the major Internet banking websites display a security image and caption each time a user logs into the account as a security measure [1]. When a user first registers for an account, she is prompted to pick a security image from a list of security images as well as to create a caption to

phishing site, users' ability to notice that an expected image is missing and then refuse to log in is not well understood.

Previous studies of the effectiveness of security images have reached divergent conclusions: in one, 92% of participants proceeded to log into their bank account even when

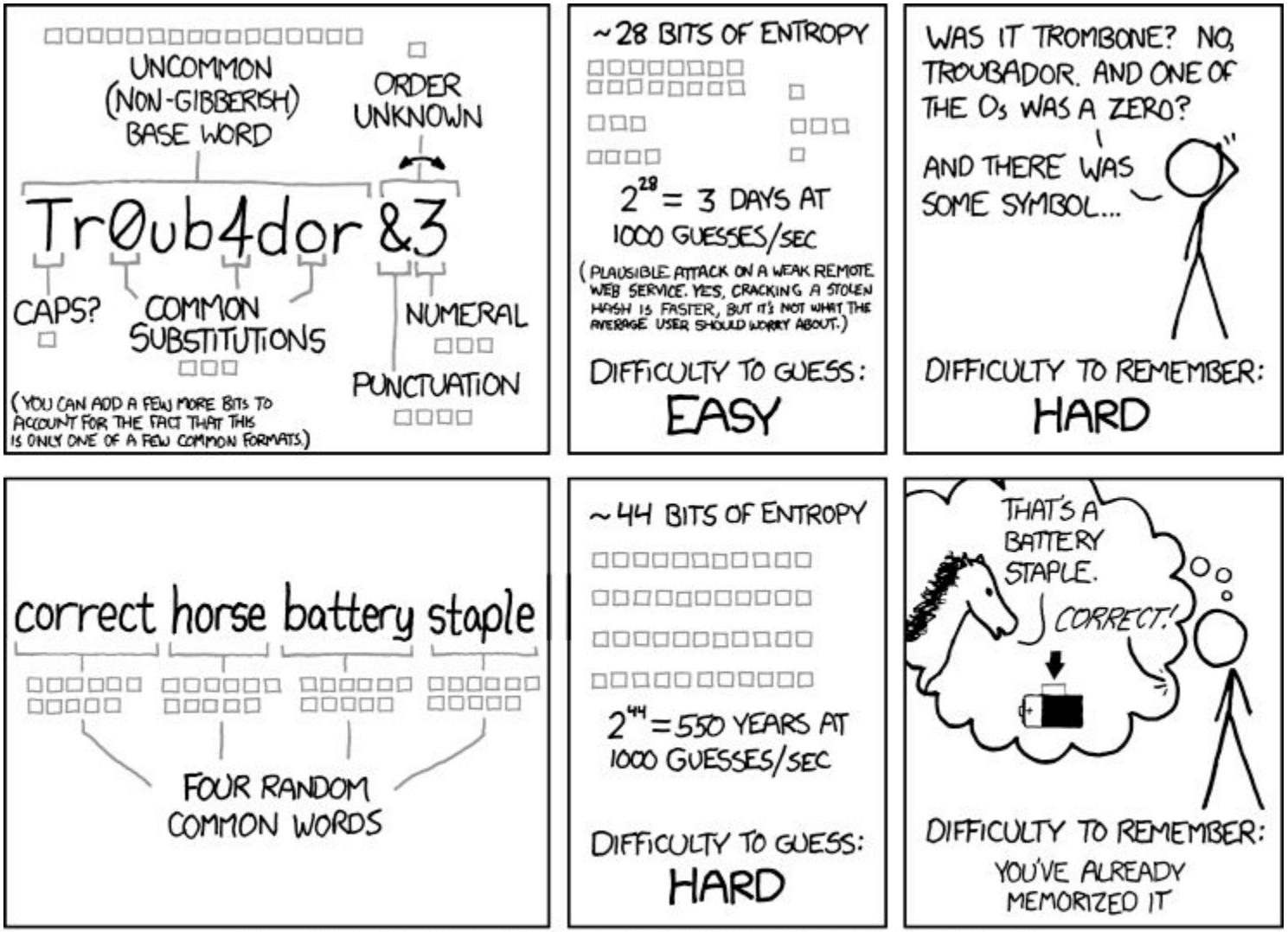
react to the absence of security images, and the factors that influence the effectiveness of security images. We study 482 participants in an online setting, as they interact with a simulated banking web site over a period of several days. Our simulated banking web site closely mimics a real banking web site, and over the course of the study participants are required to log in to the site two times for one condition and five times for all other conditions. We assign each participant to one of 12 conditions, which vary in the visual characteristics of the image, in the amount of interaction required to log in and the

The majority of our participants (73%) entered their password when we removed the security image and caption. We found that features that make images more noticeable do not necessarily make them more effective at preventing phishing attacks, though some appearance characteristics succeed at discouraging users from logging in when the image is absent.

http://users.ece.cmu.edu/~lbauer/papers/2014/w2sp2014-securityimages.pdf

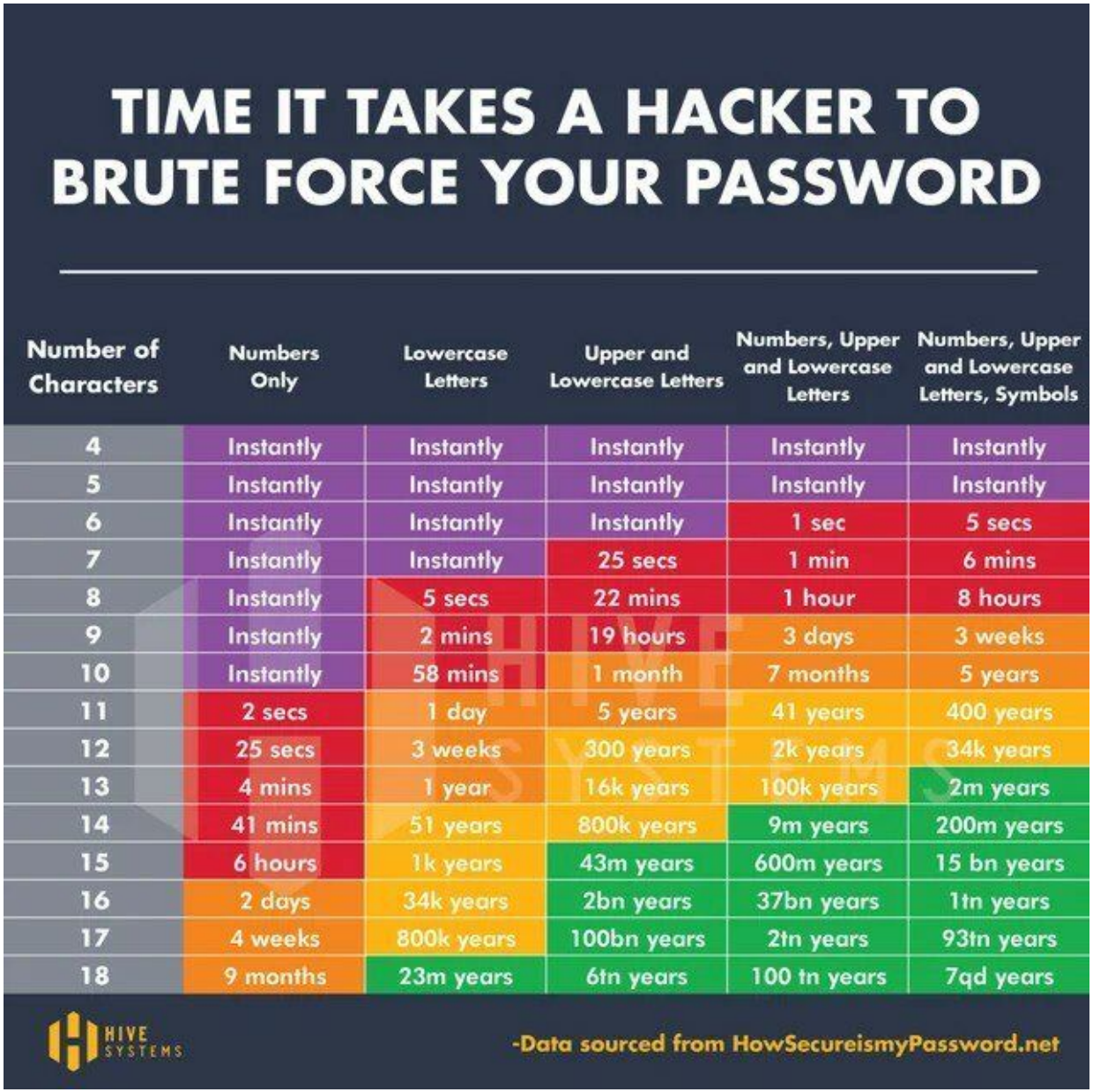
What we've learned about password requirements

- Complex isn't necessarily strong
  - Numeric, alphabetic, special symbols doesn't lead to stronger passwords
  - "Choosing multiple words from a suitably large dictionary of words may result in stronger passwords even if all of the words appear in dictionaries, are spelled with lowercase letters, and no punctuation is used"
  - Instead, check passwords against known leaked breach data
- Changing passwords regularly leads to weak passwords
- Length is the most important factor
  - old guidance about "short but complex" is invalidated by the current feasibility of building fast, brute force cracking systems



THROUGH 20 YEARS OF EFFORT, WE'VE SUCCESSFULLY TRAINED EVERYONE TO USE PASSWORDS THAT ARE HARD FOR HUMANS TO REMEMBER, BUT EASY FOR COMPUTERS TO GUESS.

https://xkcd.com/936/



TIME IT TAKES A HACKER TO BRUTE FORCE YOUR PASSWORD

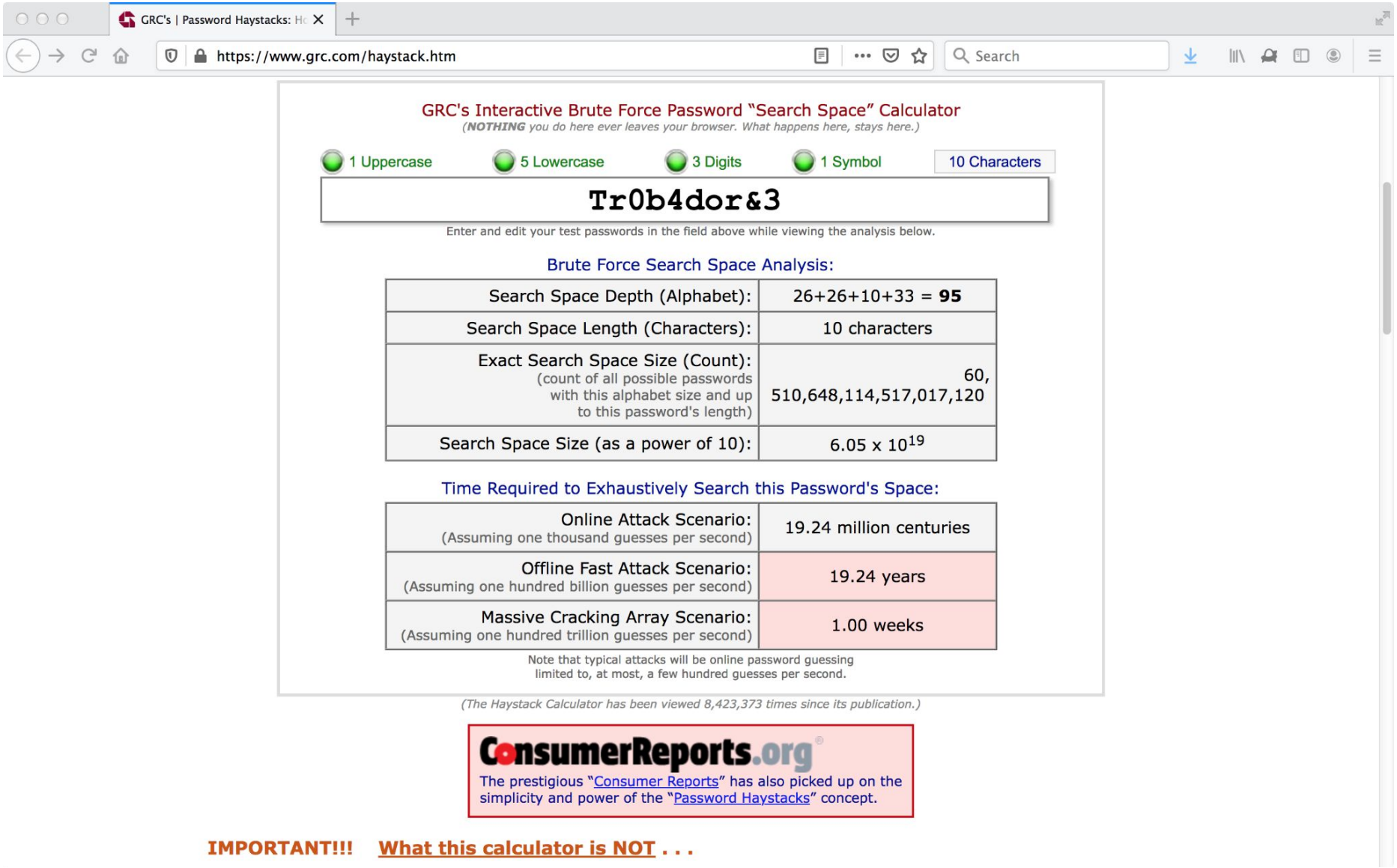
Number of Characters	Numbers Only	Lowercase Letters	Upper and Lowercase Letters	Numbers, Upper and Lowercase Letters	Numbers, Upper and Lowercase Letters, Symbols
4	Instantly	Instantly	Instantly	Instantly	Instantly
5	Instantly	Instantly	Instantly	Instantly	Instantly
6	Instantly	Instantly	Instantly	1 sec	5 secs
7	Instantly	Instantly	25 secs	1 min	6 mins
8	Instantly	5 secs	22 mins	1 hour	8 hours
9	Instantly	2 mins	19 hours	3 days	3 weeks
10	Instantly	58 mins	1 month	7 months	5 years
11	2 secs	1 day	5 years	41 years	400 years
12	25 secs	3 weeks	300 years	2k years	34k years
13	4 mins	1 year	16k years	100k years	2m years
14	41 mins	51 years	800k years	9m years	200m years
15	6 hours	1k years	43m years	600m years	15 bn years
16	2 days	34k years	2bn years	37bn years	1tn years
17	4 weeks	800k years	100bn years	2tn years	93tn years
18	9 months	23m years	6tn years	100 tn years	7qd years

HIVE SYSTEMS

-Data sourced from HowSecureismyPassword.net

https://community.spiceworks.com/topic/2286767-the-time-it-takes-to-crack-a-password-visualized

https://www.grc.com/haystack.htm



https://www.grc.com/haystack.htm

Password requirement best practices (updated)

- Minimum password length should be at least 8 characters
- Maximum password length should be at least 64 characters
  - Do not allow unlimited length, to prevent long password denial-of-service
  - Common gotcha: bcrypt has a max length of 72 ASCII characters
- Check passwords against known breach data
- Rate-limit authentication attempts
- Encourage/require use of a second factor

Good practices that are not always followed

- Do not silently truncate long passwords
- Do not restrict characters
  - Unicode and whitespace characters should be allowed
- Do not include passwords in plaintext log files
- Obvious: Use TLS for all traffic

TECH FACEBOOK CYBERSECURITY

Facebook stored hundreds of millions of passwords in plain text

60

By Jacob Kastrenakes | @jake_k | Mar 21, 2019, 12:03pm EDT

SHARE

https://www.theverge.com/2019/3/21/18275837/facebook-plain-text-password-storage-hundreds-millions-users

NIST Special Publication 800-63, Revision 3

Digital Identity Guidelines

Further, whereas systems choose keys at random, users attempting to choose memorable passwords will often select from a very small subset of the possible passwords of a given length, and many will choose very similar values. As such, whereas cryptographic keys are typically long enough to make network-based guessing attacks untenable, user-chosen passwords may be vulnerable, especially if no defenses are in place.

https://pages.nist.gov/800-63-3/sp800-63-3.html

Network-based guessing attacks

- Three primary types of attack
  - Brute force: Testing multiple passwords from dictionary or other source against a single account
  - Credential stuffing: Testing username/password pairs obtained from the breach of another site
  - Password spraying: Testing a single weak password against a large number of different accounts

Network-based guessing defenses

- Limit the rate at which an attacker can make authentication attempts, or delay incorrect attempts
- Keep track of IP addresses and limit the number of unsuccessful attempts
- Temporarily ban the user after too many unsuccessful attempts

CAPTCHA

- "Completely Automated Public Turing test to tell Computers and Humans Apart"
  - https://en.wikipedia.org/wiki/CAPTCHA
- Reverse Turing test

Recognizing Objects in Adversarial Clutter: Breaking a Visual CAPTCHA

Greg Mori
Computer Science Division
University of California, Berkeley
Berkeley, CA 94720
mori@cs.berkeley.edu

Jitendra Malik
Computer Science Division
University of California, Berkeley
Berkeley, CA 94720
malik@cs.berkeley.edu

Abstract

In this paper we explore object recognition in clutter. We test our object recognition techniques on Gimpy and EZ-Gimpy, examples of visual CAPTCHAs. A CAPTCHA ("Completely Automated Public Turing test to Tell Computers and Humans Apart") is a program that can generate and grade tests that most humans can pass, yet current computer programs can't pass. EZ-Gimpy (see Fig. 1, 5), currently used by Yahoo, and Gimpy (Fig. 2,9) are CAPTCHAs based on word recognition in the presence of clutter. These CAPTCHAs provide excellent test sets since the clutter they contain is adversarial; it is designed to confuse computer programs. We have developed efficient methods based on shape context matching that can identify the word in an EZ-Gimpy image with a success rate of 92%, and the requisite 3 words in a Gimpy image 33% of the time. The problem of identifying words in such severe clutter provides valuable insight into the more general problem of object recognition in scenes. The methods that we present are instances of a framework designed to tackle this general problem.

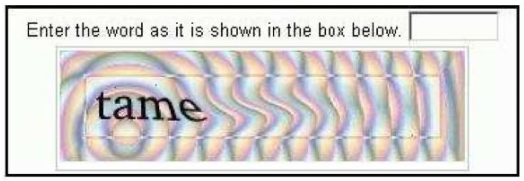


Figure 1: An EZ-Gimpy CAPTCHA in use at Yahoo

Figure 2: A Gimpy CAPTCHA. The task is to list 3 different words from the image.

2. Current computer programs can't pass

CAPTCHA stands for "Completely Automated Public Turing test to Tell Computers and Humans Apart".

The concept behind such a program arose from real world problems faced by internet companies such as Yahoo and AltaVista. Yahoo offers free email accounts. The intended users are humans, but Yahoo discovered that various web pornography companies and others were using "bots" to sign up for thousands of email accounts every minute from which they could send out junk mail. The solution was to require that a user solve a CAPTCHA test before they receive an account. The program picks a word from a dictionary, and produces a distorted and noisy image of the word (see Fig. 1). The user is presented the image and is asked to type in the word that appears in the image. Given the type of deformations used, most humans succeed at this test, while

https://www2.cs.sfu.ca/~mori/research/papers/mori_cvpr03.pdf

Problems with CAPTCHAs

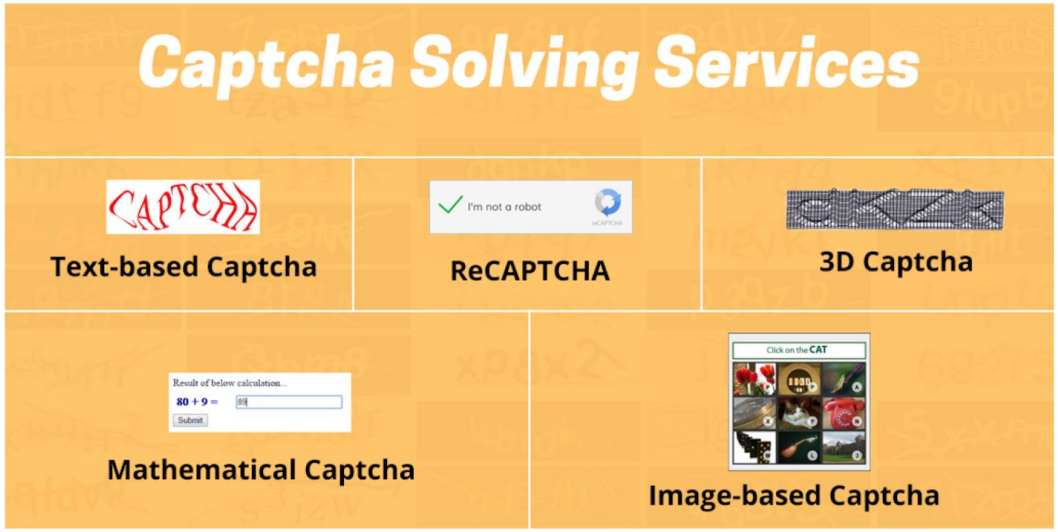
- It takes the average person approximately 10 seconds to solve a typical CAPTCHA
- Difficult for users with visual impairment to use
  - Security of the CAPTCHA is only as strong as the weakest form of CAPTCHA offered
- Attackers can proxy CAPTCHA requests to another user in real-time
- Dark market services offer cheap CAPTCHA solving services powered by humans

prowebscraper.com/blog/top-10-captcha-solving-services-compared/

ProWebScraper

HOME FEATURES SOLUTION PRICING API CONTACT US SCRAPE 100 PAGES FOR FREE

Top 10 Captcha Solving Services Compared



It's a familiar story and it usually goes like this:

Sam needs to get a lot of form filling dor Screenshot ly...It could be for various purposes- SEO link

SEARCH

Search...

Go

Need Help in Web Scraping?

We'll help you find the right Web Scraping Solution.

Contact Us

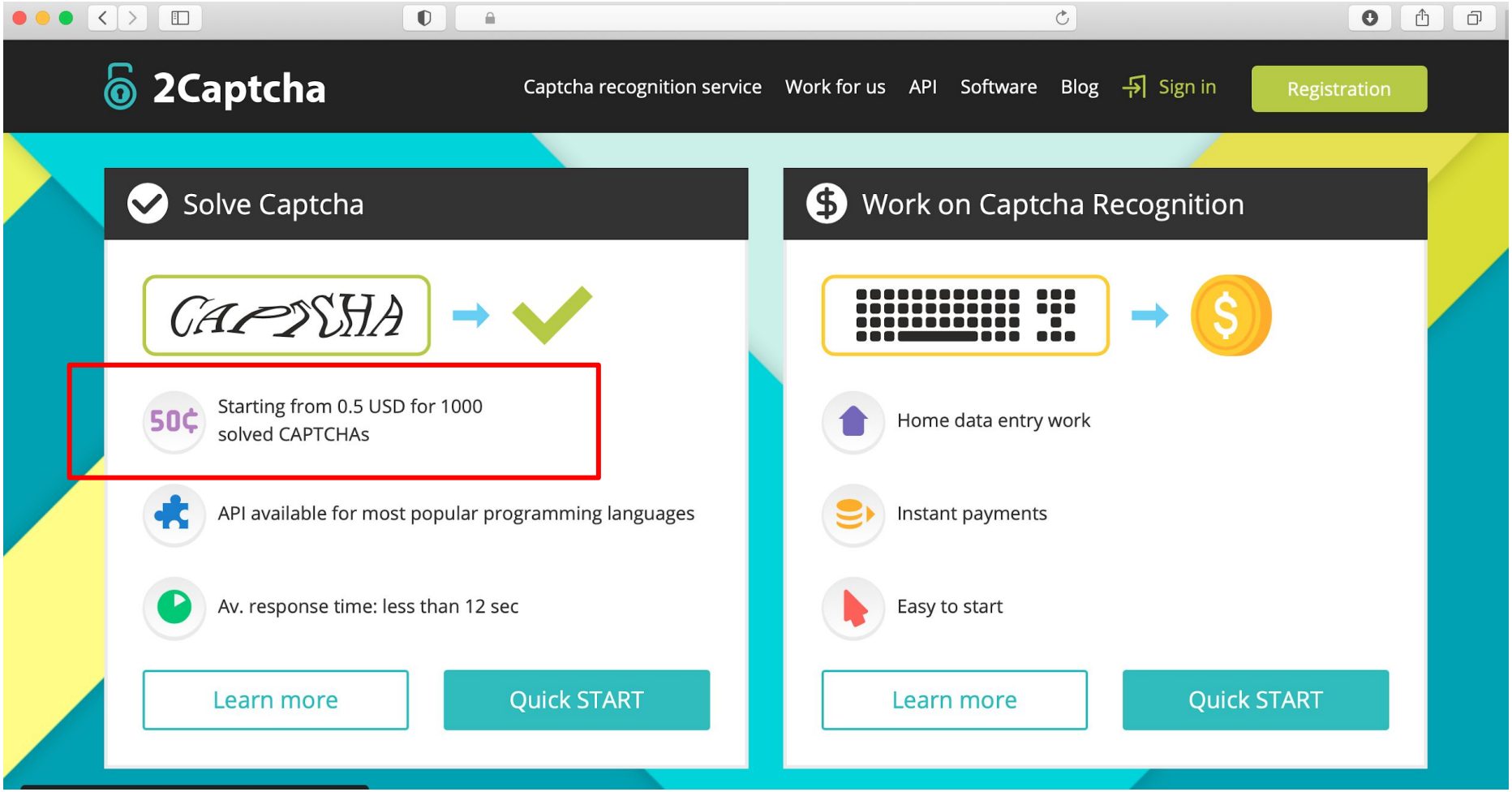
RECENT POSTS

Top 10 Price Scraping Tools Compared [2021]

January 19, 2021

Privacy - Terms

https://prowebscraper.com/blog/top-10-captcha-solving-services-compared/



https://2captcha.com/

The End is Nigh: Generic Solving of Text-based CAPTCHAs

Elie Bursztein
Google
elieb@google.com

Jonathan Aigrain
Stanford University
jonathan.aigrain@gmail.com

Angelika Moscicki
Google
moscicki@google.com

John C. Mitchell
Stanford University
jcm@cs.stanford.edu

Abstract

Over the last decade, it has become well-established that a captcha's ability to withstand automated solving lies in the difficulty of segmenting the image into individual characters. The standard approach to solving captchas automatically has been a sequential process wherein a segmentation algorithm splits the image into segments that contain individual characters, followed by a character recognition step that uses machine learning. While this approach has been effective against particular captcha schemes, its generality is limited by the segmentation step, which is hand-crafted to defeat the distortion at hand. No general algorithm is known for the character collapsing anti-segmentation technique used by most prominent real world captcha schemes.

This paper introduces a novel approach to solving captchas in a single step that uses machine learning to attack the segmentation and the recognition problems simultaneously. Performing both operations jointly allows our algorithm to exploit information and context that is not available when they are done sequentially. At the same time, it removes the need for any hand-crafted component, making our approach generalize to new captcha schemes where the previous approach can not. We were able to solve all the real world captcha schemes we evaluated accurately enough to consider the scheme insecure in practice, including Yahoo (5.33%) and ReCaptcha (33.34%), without any adjustments to the algorithm or its parameters. Our success against the Baidu (38.68%) and CNN (51.09%) schemes that use occluding lines as well as character collapsing leads us to believe that our approach is able to defeat occluding lines in an equally general manner. The effectiveness and universality of our results

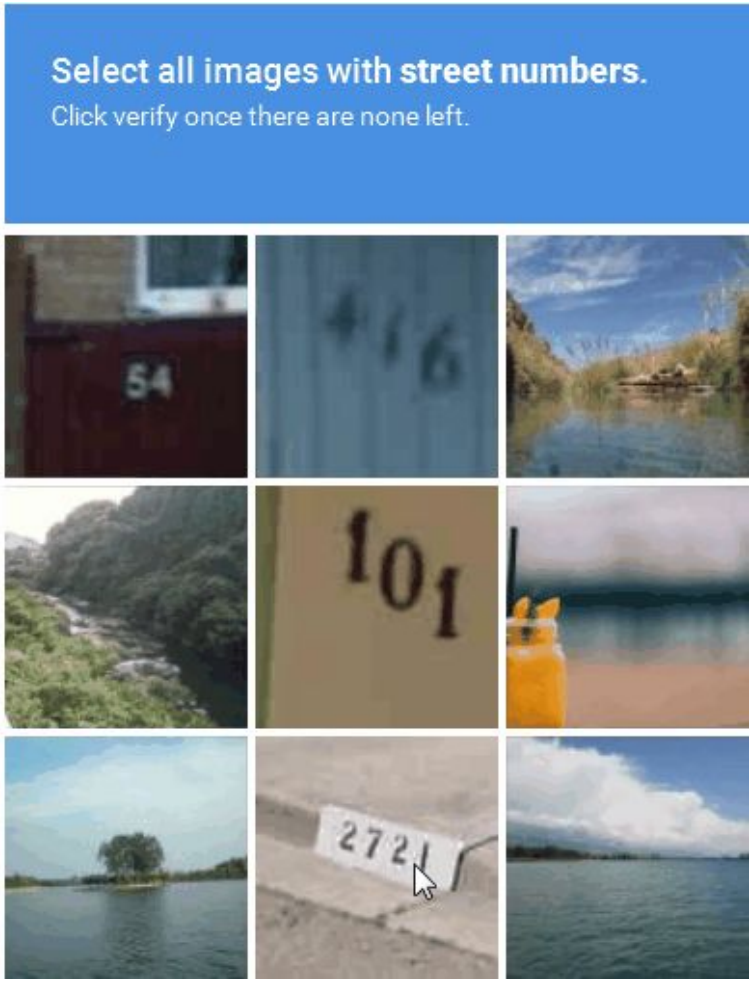
1 Introduction

Many websites use CAPTCHAs [39], or *Completely Automated Public Turing tests to tell Computers and Humans Apart,* to block automated interaction with their sites. For example, GMail uses captchas [1] to block access by automated spammers, eBay uses captchas to improve its marketplace by blocking bots from flooding the site with scams, and Facebook uses captchas to limit creation of fraudulent profiles used to spam honest users or cheat at games. The most widely used captcha schemes use combinations of distorted characters and obfuscation techniques that humans can recognize but that may be difficult for automated scripts. Captchas are sometimes called *reverse Turing tests*, because they are intended to allow a computer to determine whether a remote client is human or machine.

Due to the proficiency of machine learning algorithms at recognizing single letters, it has become well-established that a captcha's ability to withstand automated solving lies in the difficulty of segmenting the image into individual characters [12, 10]. The standard approach to solving captchas automatically has been a sequential process wherein a segmentation algorithm splits the image into segments that contain individual characters, followed by a character recognition step that uses machine learning [13]. This is known as the *segment then recognize* approach. While this approach has been effective against particular captcha schemes [15, 4], its generality is limited by the segmentation step, which is hand-crafted to defeat the distortion at hand. No general algorithm is known for the character collapsing anti-segmentation technique used by most prominent real world captcha schemes. This technique is called *negative*

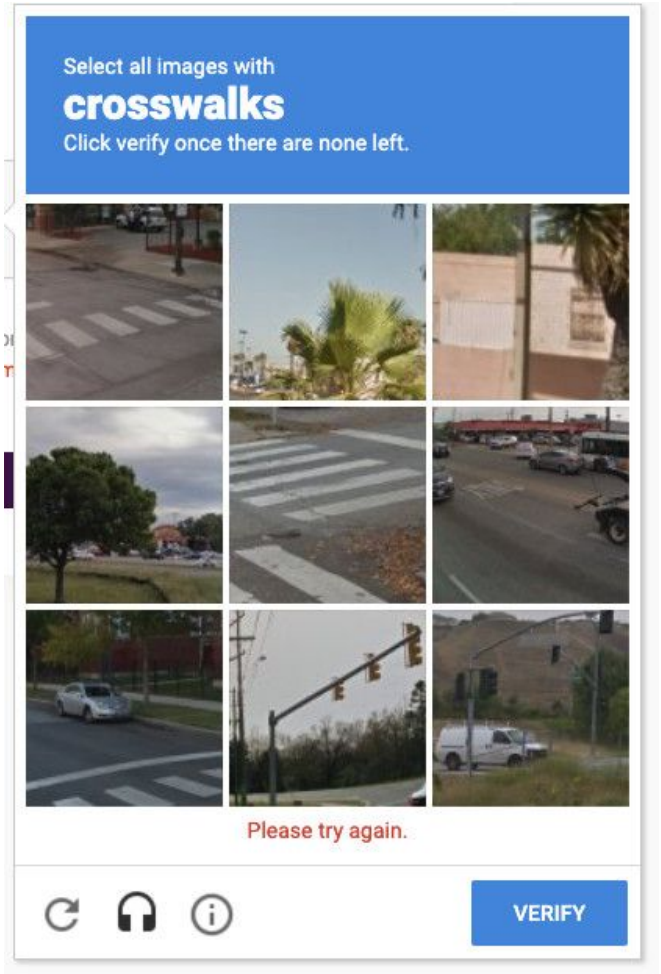
https://www.usenix.org/conference/woot14/workshop-program/presentation/bursztein

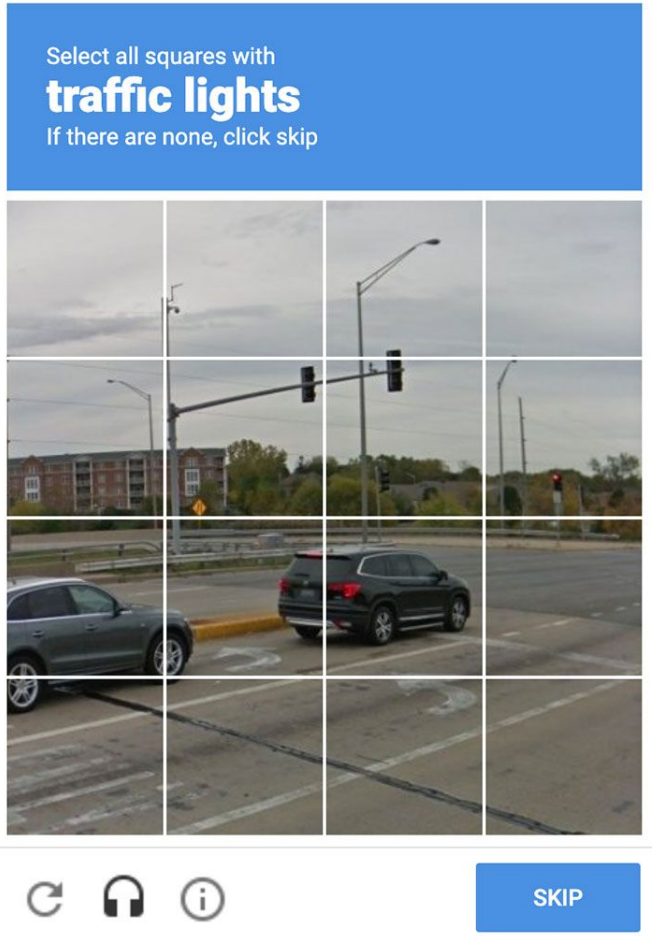
Security isn't the only goal of CAPTCHAs



https://medium.com/a-dose-of-curiosity/how-does-the-i-am-not-a-robot-checkbox-work-c24d426a82a1

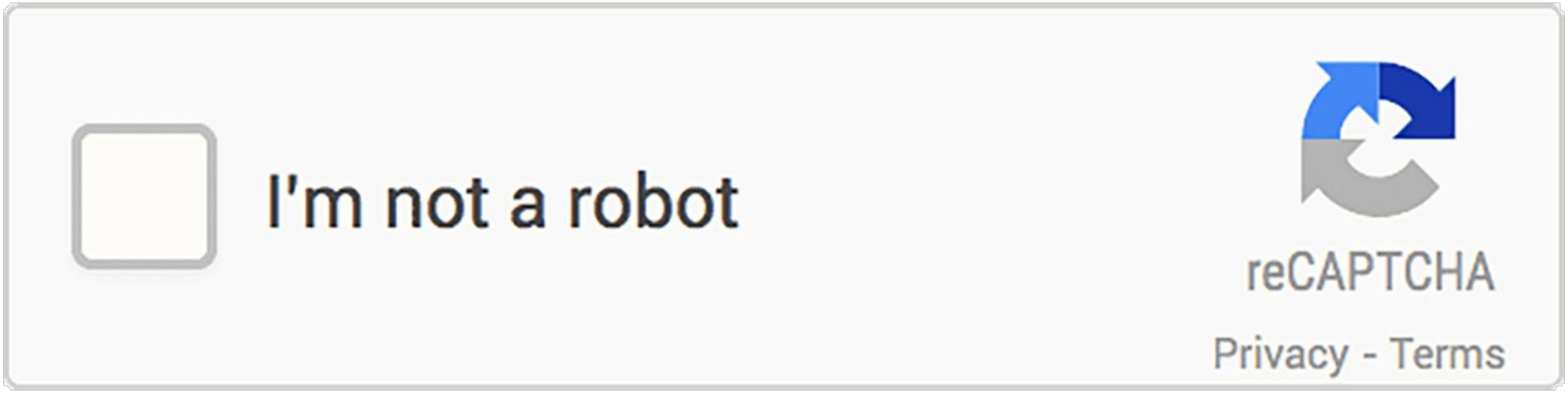
You are training the machine





https://www.vox.com/22436832/captchas-getting-harder-ai-artificial-intelligence

https://altitudemarketing.com/blog/captcha-explained/

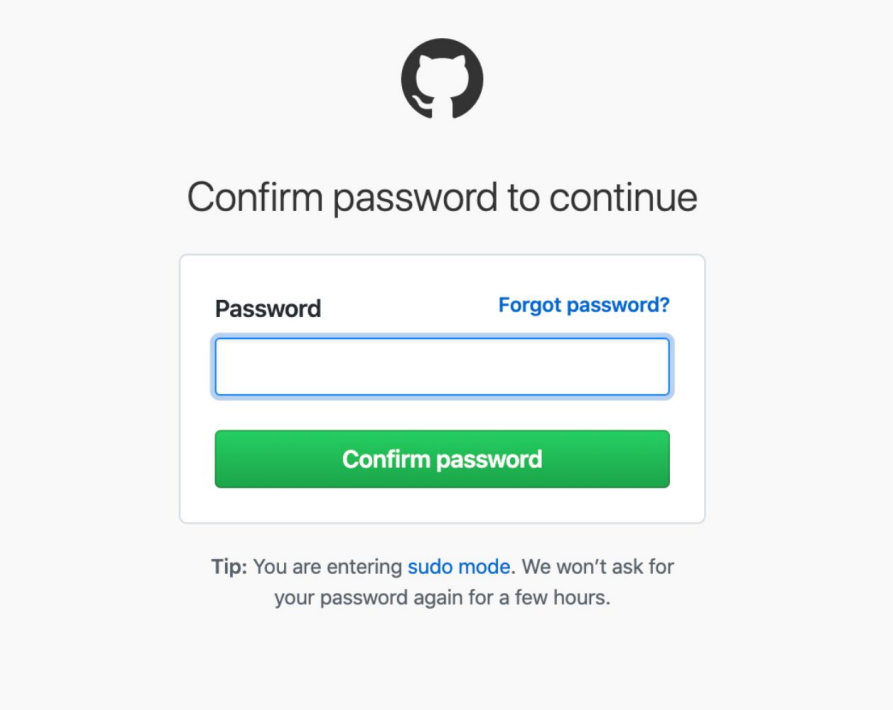


https://en.wikipedia.org/wiki/ReCAPTCHA

https://medium.com/a-dose-of-curiosity/how-does-the-i-am-not-a-robot-checkbox-work-c24d426a82a1

Reauthenticate for sensitive features

- Defense-in-depth against XSS, CSRF, session hijacking, physical access
- Before: change password, change email, add new shipping address



Response discrepancy information exposure

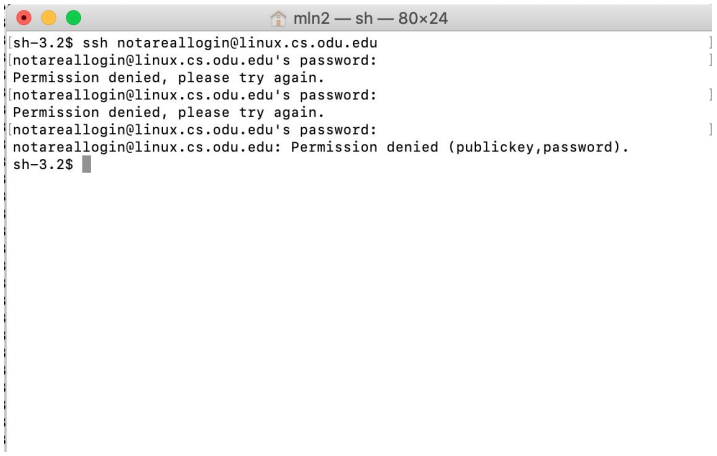
- **Information exposure**: Information is leaked to an attacker that should not be leaked
- **Response discrepancy**: "The software provides different responses to incoming requests in a way that allows an actor to determine system state information that is outside of that actor's control sphere."

Response discrepancy: error messages

- Respond with a generic error message regardless of whether:
  - The username or password was incorrect
  - The account does not exist
  - The account is locked or disabled
- Don't forget password reset and account creation!

Response discrepancy: Login

- Incorrect response examples:
  - "Login for User foo: invalid password"
  - "Login failed, invalid user ID"
  - "Login failed; account disabled"
  - "Login failed; this user is not active"
- Correct response example:
  - "Login failed; Invalid user ID or password"



Response discrepancy: Password recovery

- Incorrect response examples:
  - "We just sent you a password-reset link"
  - "This email address doesn't exist in our database"
- Correct response example:
  - "If that email address is in our database, we will send you an email to reset your password"

Response discrepancy: Account creation

- Incorrect response examples:
  - "This user ID is already in use"
  - "Welcome! You have signed up successfully"
- Correct response example:
  - "A link to activate your account has been emailed to <input email address>"

Response discrepancy: HTTP status codes

- Any difference will leak info to the attacker, even HTTP status codes
- Incorrect response examples:
  - *Sometimes* HTTP 200: "Login failed; Invalid user ID or password"
  - *Sometimes* HTTP 403: "Login failed; Invalid user ID or password"
- Correct response example:
  - Always HTTP 403: "Login failed; Invalid user ID or password"

Response discrepancy: Timing

Bad:

```
const userExists = await lookupUserExists(username)
if (userExists) {
  const passwordHash = hash(password)
  const isValid = await lookupCredentials(username, passwordHash)
  if (!isValid) {
    throw Error('Invalid username or password')
  }
} else {
  throw Error('Invalid username or password')
}
```

Response discrepancy: Timing

Good:

```
const passwordHash = hash(password)
const isValid = await lookupCredentials(username, passwordHash)
if (!isValid) {
  throw Error('Invalid username or password')
}
```

- Beware of using early returns in authentication code
- The code above is *slower but consistent*

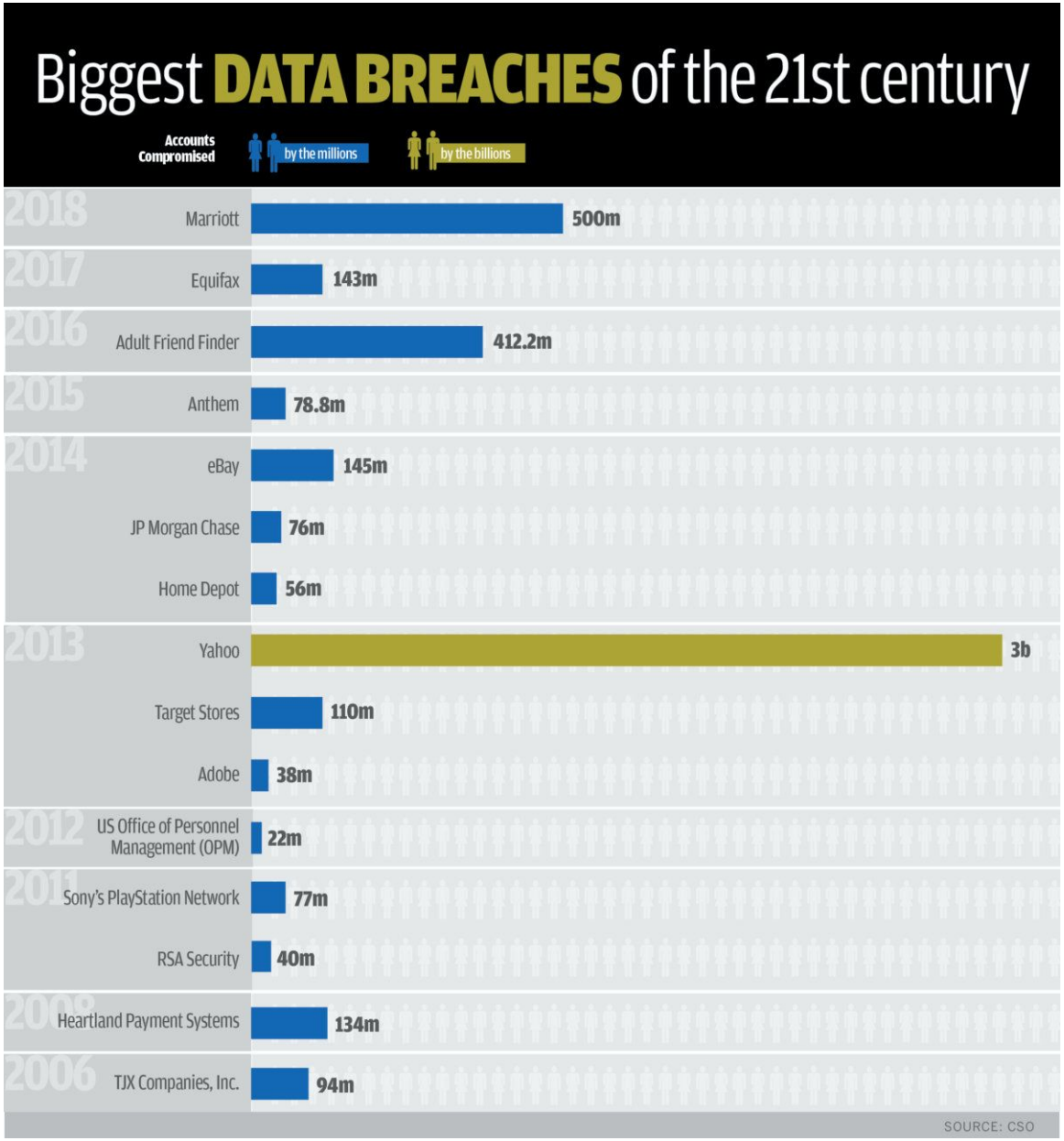
Response discrepancy: Mitigation tradeoffs

- Mitigations make user experience worse
  - Generic error messages are less useful to the user
  - Can frustrate legitimate users
- Rate-limiting authentication attempts will prevent user enumeration at scale, while allowing friendly error messages to remain

Data breaches

2020 was record breaking for record compromises

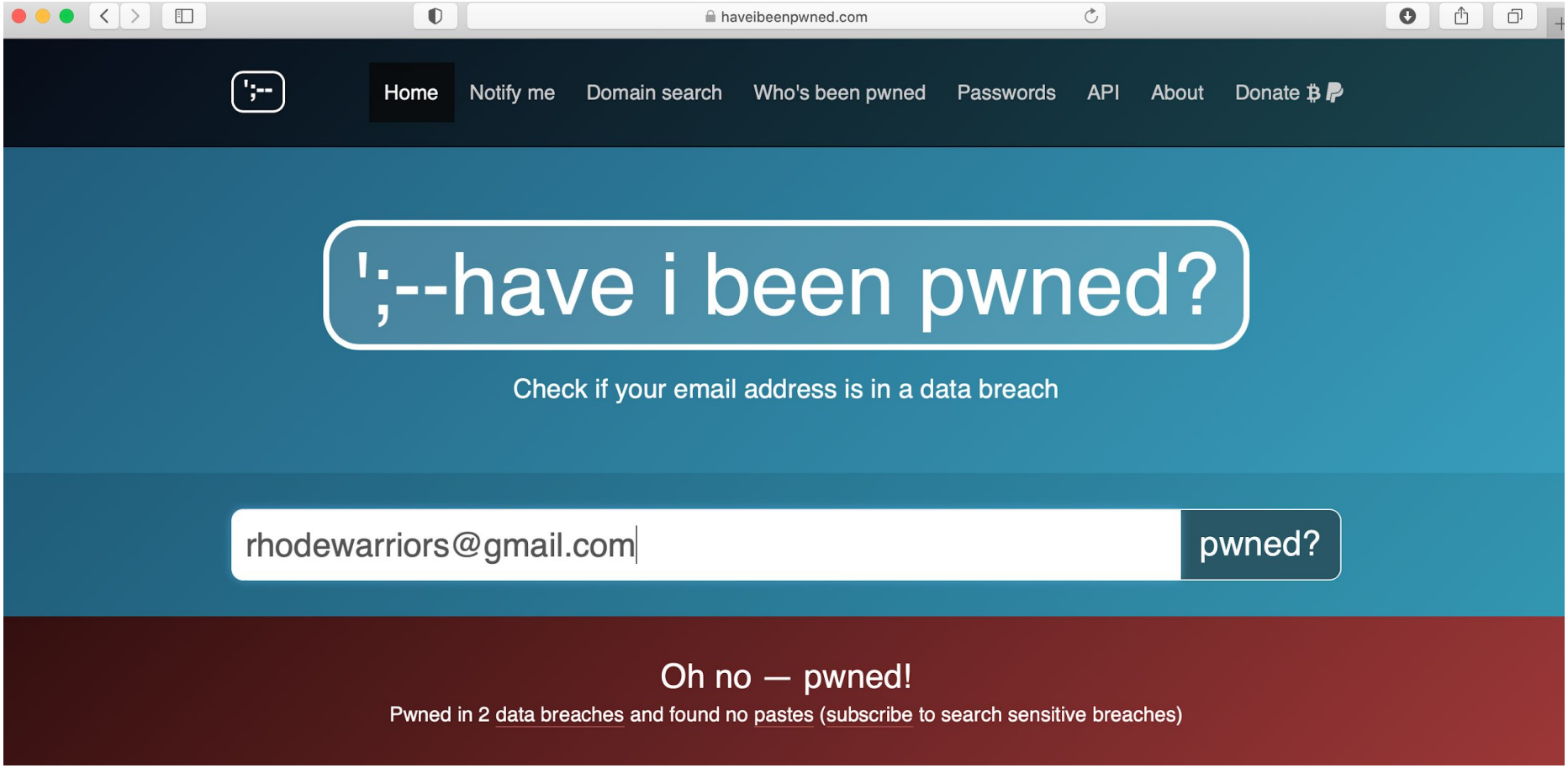
https://venturebeat.com/2021/03/29/canalys-more-data-breaches-in-2020-than-previous-15-years-despite-10-growth-in-cybersecurity-spending/



https://laptrinhx.com/the-18-biggest-data-breaches-of-the-21st-century-2296465893/

Were you in a breach?

- The answer is almost certainly "Yes"
- HaveIBeenPwned.com service
  - Check for your email in breaches
  - Check for your password in breaches
  - Websites or password managers can check passwords against the list



https://haveibeenpwned.com

How are passwords stored?

- **Important**: Never, ever, ever store passwords in plaintext
- In a data breach, the attacker will learn all users' passwords and be able to attack their accounts on other sites, assuming the user has re-used their password across sites (very likely)

http://twitterleakeddatabase.blogspot.com/2018/10/twitter-leaked-database-32-million.html

Never store passwords like this!

```
alice:password
bob:hunter2
charlie:correcthorsebatterystaple
david:hunter2
```

Never store plaintext passwords

- Important: Hash the plaintext password, then store the hash in the database
- Cryptographic hash function: Algorithm that maps data of arbitrary size (the "message") to a bit string of a fixed size (the "hash value")
  - One-way function: infeasible to invert
  - Deterministic: same message always results in the same hash value
  - ~~Quick to compute: we often call hash functions thousands of times~~
  - No collisions: infeasible to find different messages with same hash value
  - Avalanche effect: small change to message changes hash value extensively

Example: Hashing passwords

```
const crypto = require('crypto')
const sha256 = s => crypto.createHash('sha256').update(s).digest('hex')

const user = await createUser(username, sha256(password))

// later...

const isValid = sha256(otherPassword) === passwordHash
```

User table (hashed)

```
alice:XohImNooBHFR0OVvjcYpJ3NgPQ1qq73WKhHvch0VQtg=
bob:9S+9MrKzuG/4jvbEkGKChfSCrxXdyylUH5S89Saj9sc=
charlie:0mk89QsPD4FIJQv8IcHnoSe6qjOzKvcNuTevydeUxWA=
david:9S+9MrKzuG/4jvbEkGKChfSCrxXdyylUH5S89Saj9sc=
```

Problems with just hashing

- Users who have identical passwords are easy to spot
- Pre-computed lookup attacks are easy
  - SHA256 is quite fast to compute
  - Rainbow tables are easy to generate
- Rainbow table: a precomputed table for reversing cryptographic hash functions

Password salts

- Goal:
  - Prevent two users who use identical passwords from being revealed
  - Add entropy to weak passwords to make pre-computed lookup attacks intractable
- Solution: A salt is fixed-length cryptographically-strong random value
  - No need to keep the salt secret; can be stored alongside the password (salt is usually 16, 32, or 64 bytes)
  - Concatenate the salt and the password before hashing it

Example: Hashing and salting passwords

```
const crypto = require('crypto')
const sha256 = s => crypto.createHash('sha256').update(s).digest('base64')

const salt = crypto.randomBytes(16).toString('base64')
const passwordHash = sha256(salt + password)
const user = await createUser(username, salt, passwordHash)

// later...

const otherPasswordHash = sha256(salt + otherPassword)
const isValid = otherPasswordHash === passwordHash
```

User table (hashed and salted)

```
username:salt:password

alice:ciMTj87Q5Ti/PDfSUM4jcAT6cFJWVwJFjEbMc2sqAn0=:AQAi
FDIbEUk5Wdoe6tTL+bnCBOIsectOW2SfftG0je8=
bob:NB9zdy/OIVnGHkPK7fK01saCcIpXrWV5rdtW8i5k/XY=:uxIXXv
frQ8/gTwrbTtgnsqsZCAw/y24O8nU3qlho5GE=
charlie:hetbWcTifseB9K3IQQPr6c/eMJyj3kVTqq/l+FqYf78=:Fy
kuFcJV0AjBLyxMuQWrvuSTjRXyXStitVteWUJmPlM=
david:IZu5hPamBS/QY4ILZzTcyVY8TK17Dt9hmXW7bC4XbCc=:ydVe
+vA56bKbA0oXzRfYtkABUXaxgkF4ngB0xNJRvA4=
```

Just use `bcrypt`

- Password hashing function designed by Niels Provos and David Mazières
  - https://www.npmjs.com/package/bcrypt
  - https://en.wikipedia.org/wiki/Bcrypt
- Expensive key setup algorithm
  - You don't want speed in a password hash function
- Automatically handles all password salting complexity and includes it in the hash output

Example: Just use `bcrypt`

```
const bcrypt = require('bcrypt')
const HASH_ROUNDS = 10

const passwordHash = bcrypt.hashSync(password, HASH_ROUNDS)
const user = await createUser(username, passwordHash)

// later...

const isValid = bcrypt.compareSync(otherPassword, passwordHash)
```

`bcrypt` hash string

Description [edit]

A bcrypt hash string is of the form:

```
$2b$[cost]$[22 character salt][31 character hash]
```

For example:

```
$2a$10$N9qo8uLOickgx2ZMRZoMyeIjZAgcfl7p92ldGxad68LJZdL17lhWy
\__/\/ \____________________/\_____________________________/
 Alg Cost      Salt                        Hash
```

Where:

- `$2a$` : The hash algorithm identifier (bcrypt)
- `10` : Cost factor (2^{10} ==> 1,024 rounds)
- `N9qo8uLOickgx2ZMRZoMye` : 16-byte (128-bit) salt, base64-encoded to 22 characters
- `IjZAgcfl7p92ldGxad68LJZdL17lhWy` : 24-byte (192-bit) hash, base64-encoded to 31 characters

https://en.wikipedia.org/wiki/Bcrypt

User table (bcrypt)

```
alice:$2b$10$aQNe4MK0HDhrkus8GZGQL.Nj11nsx12VTMTDBkykiL
/jRbb.fJuGC

bob:$2b$10$TSbaMNCCq6.xNkDVszwwhO9Fpb.eeW6aUSIFzGkPoQrs
5RahskOUO

charlie:$2b$10$.5KcQQNEfnkPBYxeiqS2ZeePXLT5J30HG7zngfes
yGuc0js37X41e

david:$2b$10$l8n7ZLsq13ygE0m3cQ8oEuBjPnGcGBUA4zvJhnsKgy
DEZdEd2EFXa
```

How attackers use a breach database

- Machine capable of cracking 100B+ passwords per second against SHA256 can be built for $20,000 (as of July 2019)
- Try every password which has been disclosed in a breach (>500M passwords). Think of this as “every password anyone has ever thought of, ever.” Statistically, this will break >70% of user passwords
- The complete list just takes 5ms to try, so an attacker can run the complete list against 200 accounts every second
- Build a list of popular phrases, song lyrics, news headlines to pick up another 5-7% of user passwords

https://techcommunity.microsoft.com/t5/azure-active-directory-identity/your-pa-word-doesn-t-matter/ba-p/731984

Multi-factor authentication

- Microsoft: "Based on our studies, your account is more than 99.9% less likely to be compromised if you use MFA"
- Common additional factors:
  - Something you have (e.g., a phone, badge, or cryptographic key)
  - Something you are (e.g., a fingerprint or other biometric data)

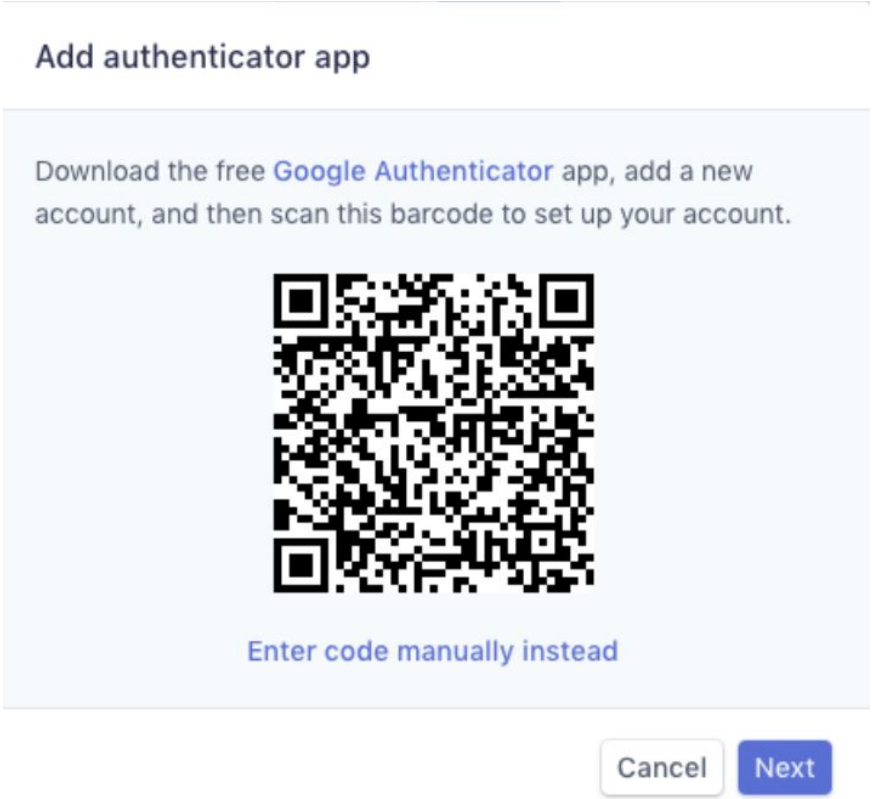
Multi-factor authentication

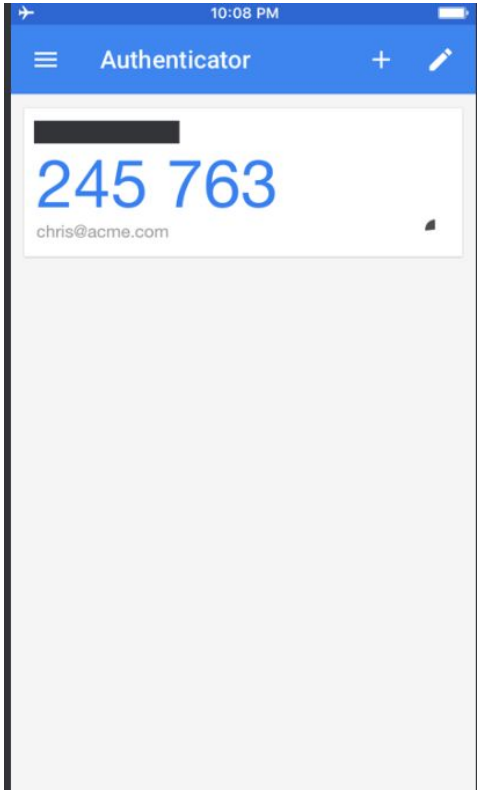
- Choosing a strong password **can** prevent these attacks:
  - Password spray: Guessing, hammering, low-and-slow
  - Brute force: Database extraction, cracking
- Choosing a strong password **cannot** prevent these attacks:
  - Credential stuffing: Breach replay, list cleaning
  - Phishing: Man-in-the-middle, credential interception
  - Keystroke logging: Malware, sniffing
  - Local discovery: Dumpster diving, physical recon, network scanning
  - Extortion: Blackmail, insider threat

Selectively requiring MFA

- To preserve user experience, consider only requiring MFA for:
  - A new browser/device or IP address
  - An unusual country or location
  - An IP address that appears on known blocklists
  - An IP address that has tried to login to multiple accounts
  - A login attempt that appears to be scripted rather than manual

Time-based One-Time Passwords (TOTP)





Time-based One-Time Passwords (TOTP)

1. Server creates a secret key for specific user
2. Server shares secret key with the user's phone app
3. Phone app initializes a counter
4. Phone app generates a one time password using secret key and counter
5. Phone app changes the counter after a certain interval and regenerates the one time password

Time-based One-Time Passwords (TOTP)

Server generates unique secret key for user:

```
const secretKey = crypto.randomBytes(160)

await addSecretKeyForUser(username, secretKey)

// Now give secret key to user via QR code...
```

Time-based One-Time Passwords (TOTP)

Generate the current one-time password:

```
const counter = Date.now() / (30 * 1000)
const hmacHash = crypto.createHmac('sha1', secretKey).update(counter).digest()

const offset = hmacHash[19] & 0xf
const truncatedHash = (hmacHash[offset++] & 0x7f) << 24 |
  (hmacHash[offset++] & 0xff) << 16 |
  (hmacHash[offset++] & 0xff) << 8 |
  (hmacHash[offset++] & 0xff)

const finalOTP = truncatedHash % (10 ^ 6)
```

Final thoughts

- Always hash and salt your passwords
- "Just use bcrypt"
- Consider how to protect users even when attackers know their password