Prioritizing Security Practices via Large-Scale Measurement of User Behavior

Ariana Mirian
April 21, 2023

UCSDCSE
Computer Science and Engineering

The Internet is not a safe place

Security technologies have made the Internet safer

Many attacks exploit the human in the loop

Many attacks exploit the human in the loop

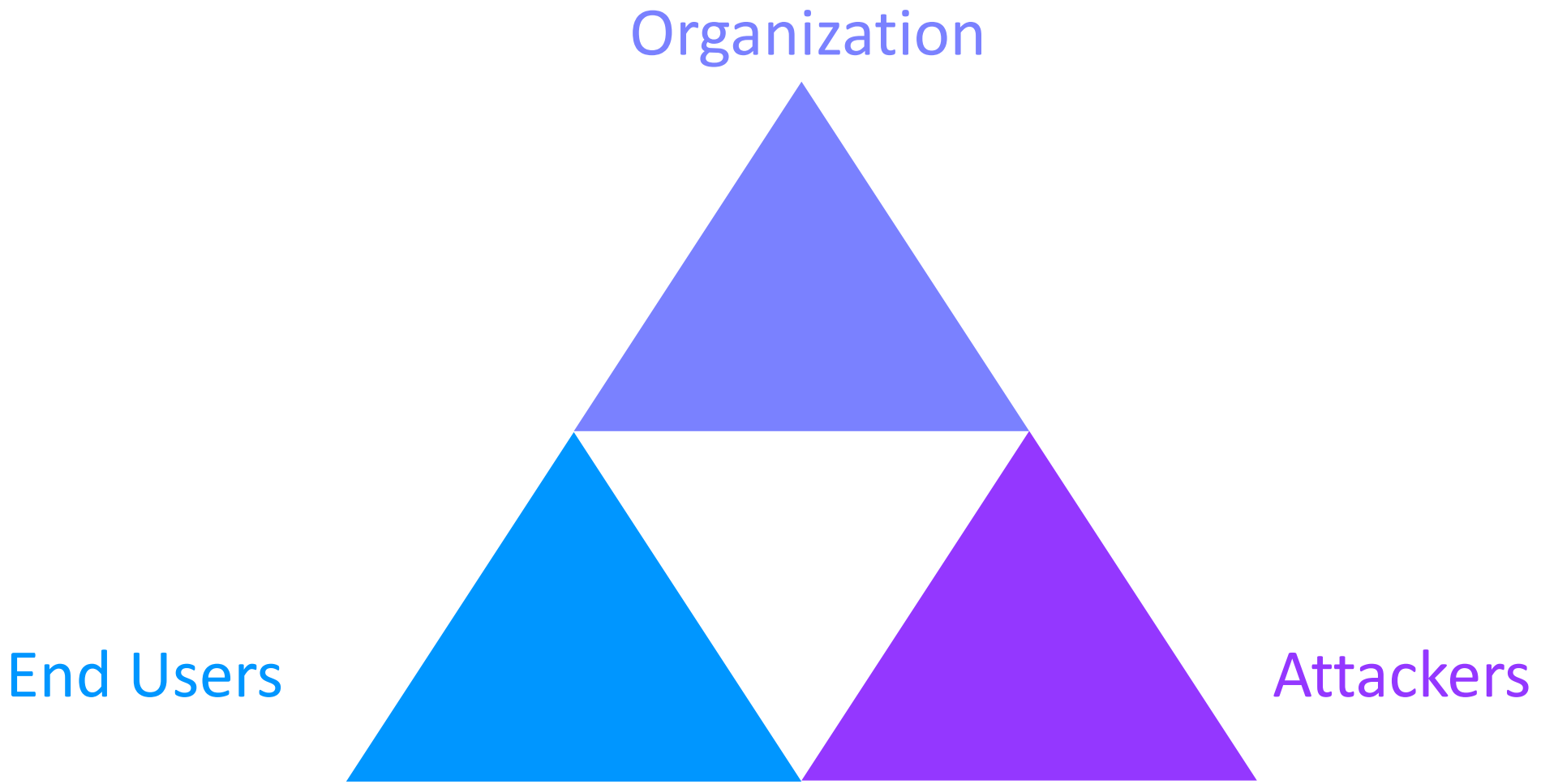
Verizon Data Breach report indicates that 82% of attacks involved “The Human Element”

Technology isn’t the end answer – we need to account for the human in the loop as well

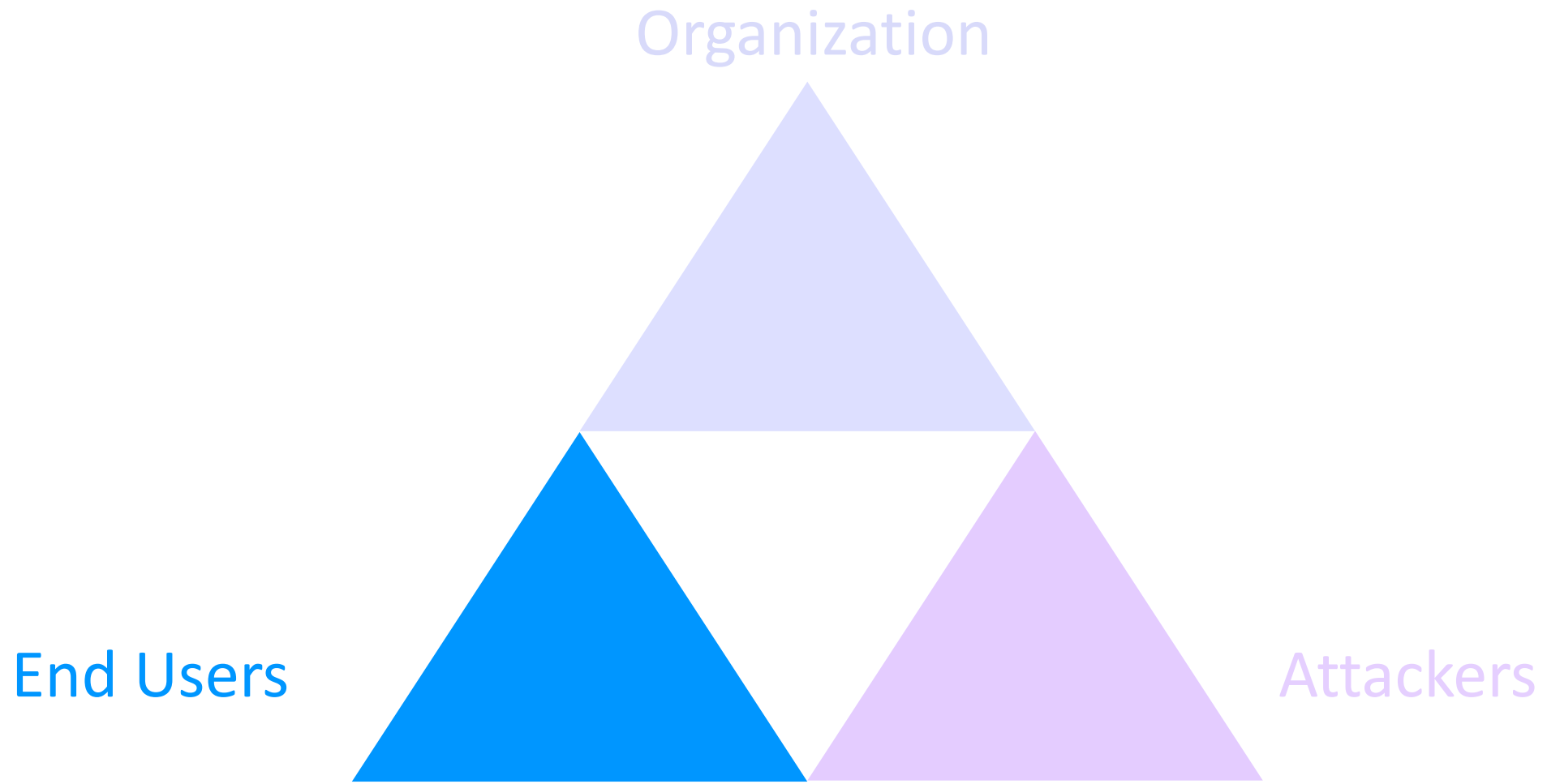
Users also have limited time and energy

Understanding user behaviors via large-scale empirical measurement can help us better prioritize security processes

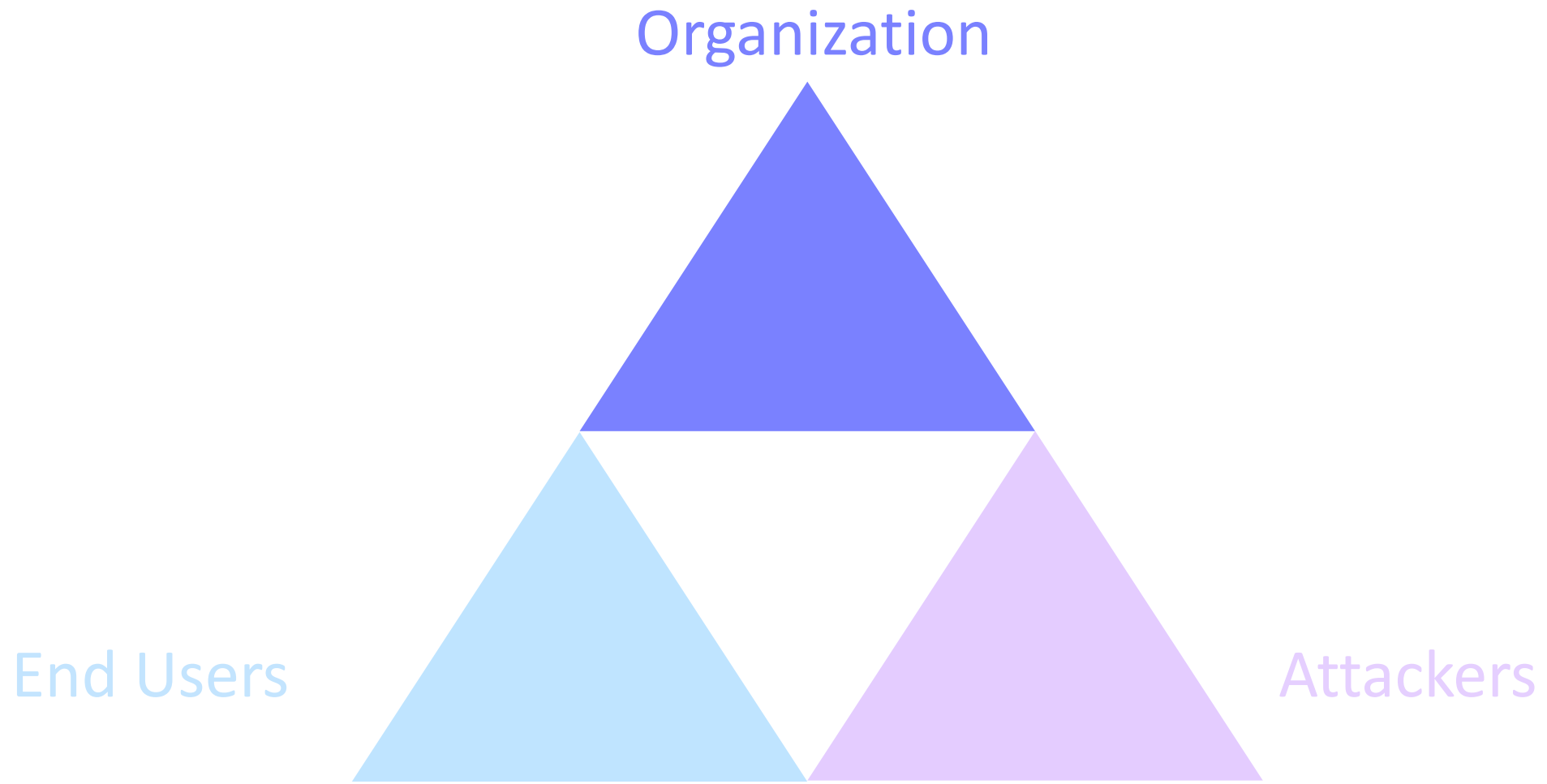
Understanding user behaviors to better prioritize security processes



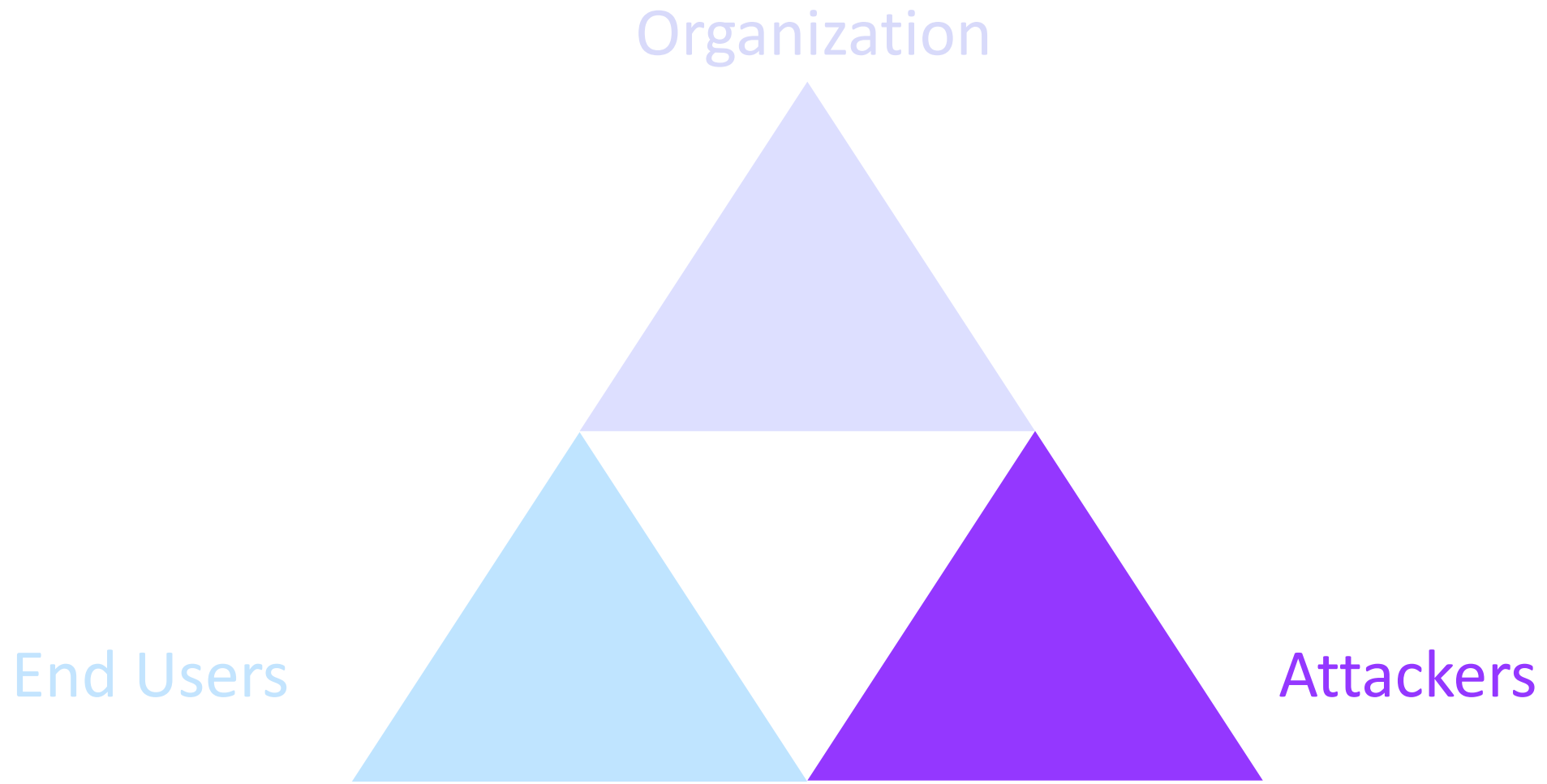
Understanding user behaviors to better prioritize security processes



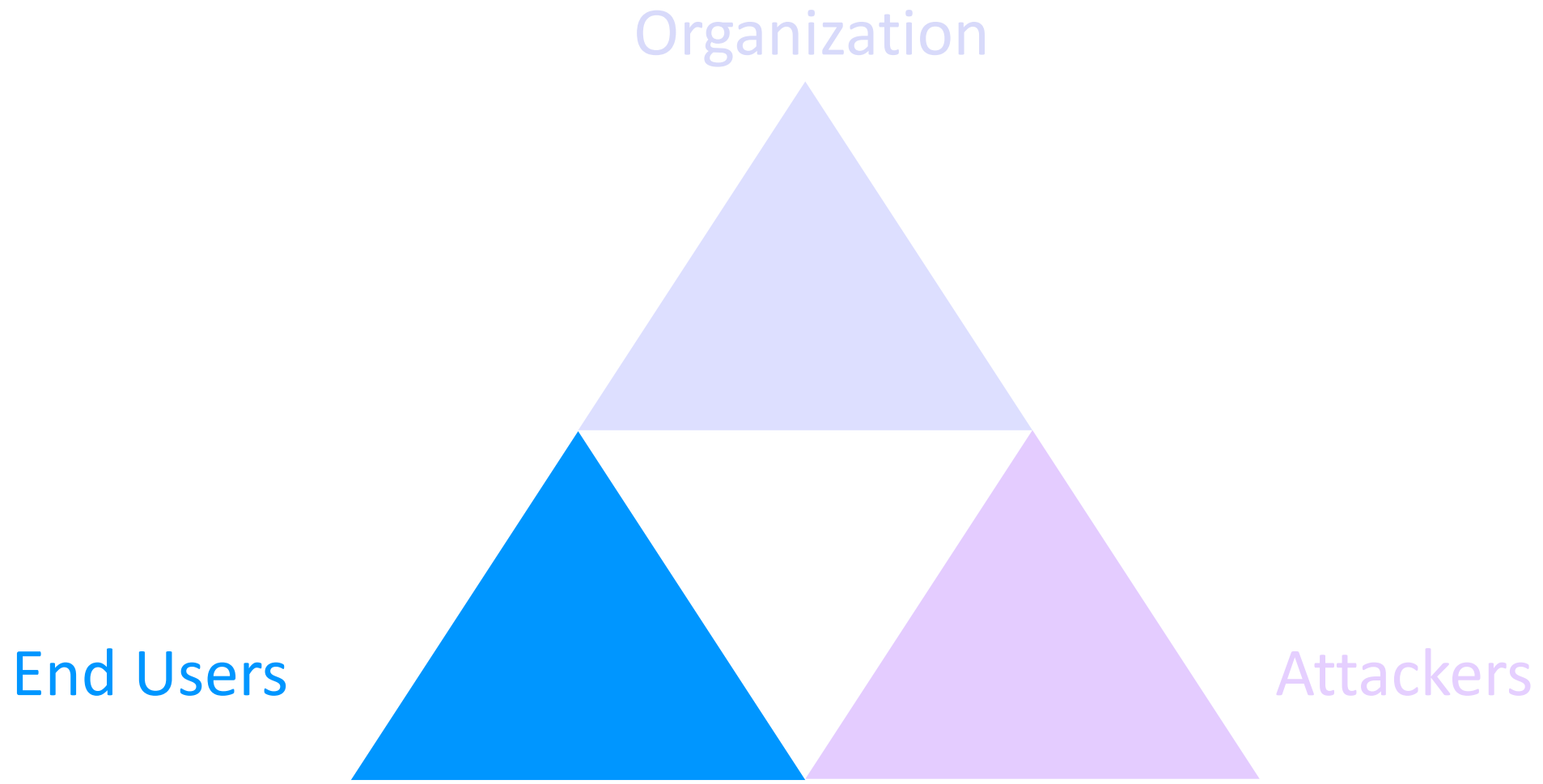
Understanding user behaviors to better prioritize security processes



Understanding user behaviors to better prioritize security processes

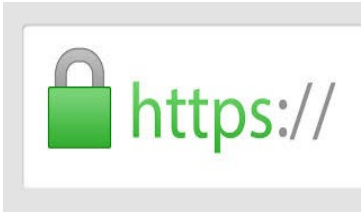


Understanding user behaviors to better prioritize security processes

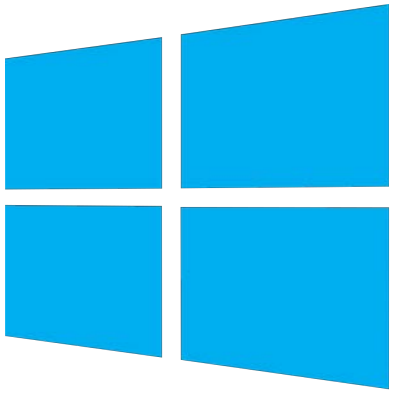


Security “Best” Practices

Antivirus



Use HTTPS



Use Mainstream OS

Quickly Update

Avoid Risky Sites

Security “Best” Practices

Antivi

d

r

“...no one can hack my mind”: Comparing Expert and Non-Expert Security Practices

Iulia Ion
Google
iuliaion@google.com

Rob Reeder
Google
rreeder@google.com

Sunny Consolvo
Google
sconsolvo@google.com

ABSTRACT

The state of advice given to people today on how to stay safe online has plenty of room for improvement. Too many things are asked of them, which may be unrealistic, time consuming, or not really worth the effort. To improve the security advice, our community must find out what practices people use and what recommenda-

carefully considering the most worth-while advice to recommend is imperative. Even if users accept some responsibility for protecting their data [23, 43] and want to put in some effort [41], we should be thoughtful about what we ask them to do [20] and only offer advice that is effective and realistic to be followed.

Existing literature on giving good advice suggests that for recip-ients to follow it, the advice should be (a) useful, comprehensible

Quickly Update

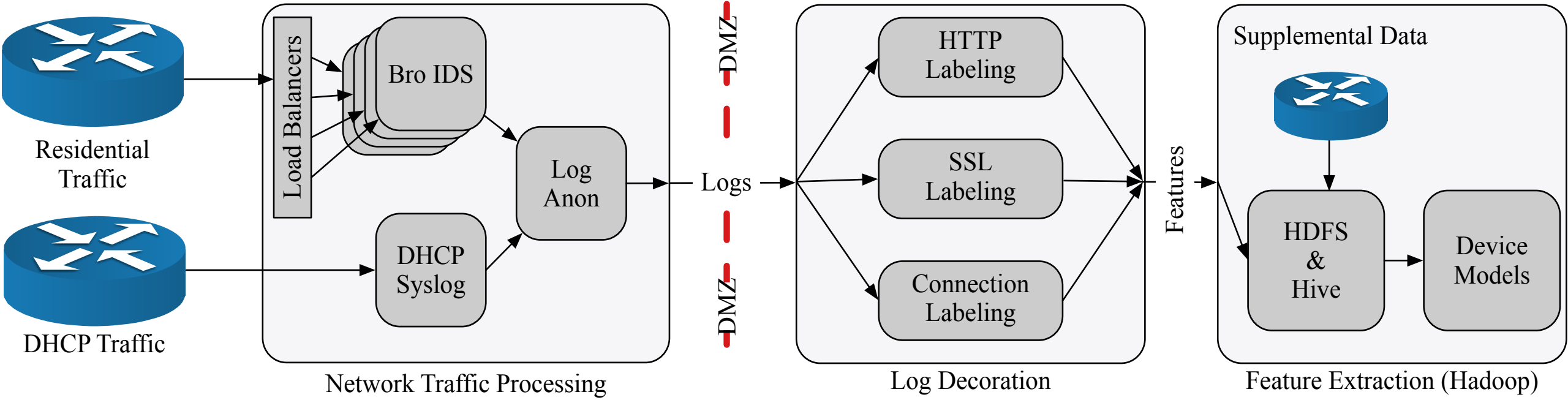
Avoid Risky Sites

How effective are best practices at mitigating compromise?

Anonymized Network Traffic

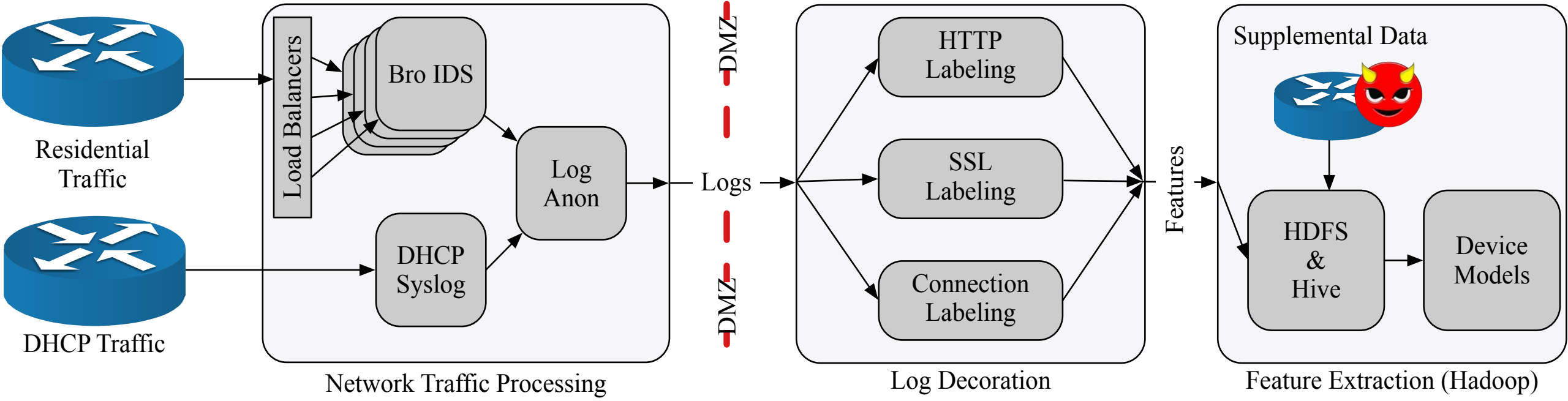
Anonymized Network Traffic

Ground Truth
about device compromise



Full Traffic Flows from Residential Network

Anonymized and annotated with additional metadata



Full Traffic Flows from Residential Network

Anonymized and annotated with additional metadata

Labeled with ground truth data on compromise

Full Dataset

6 months of data: 15,291 desktop/laptops, 682 (4.5%) compromised

Security Practices	Applications	Network Usage	Type of Device
Antivirus	Browser Updates	Time online	Desktop/ Laptop
Mainstream OS	Peer-To-Peer	TLD usage	Mobile
OS Updates	Flash	Traffic profile	IoT

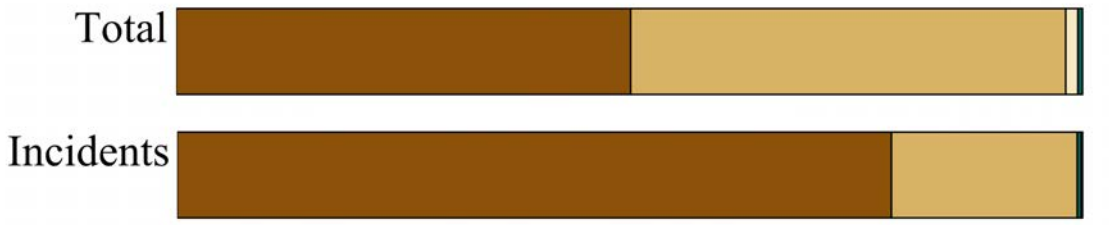
Full Dataset

6 months of data: 15,291 desktop/laptops, 682 (4.5%) compromised

Security Practices	Applications	Network Usage	Type of Device
Antivirus	Browser Updates	Time online	Desktop/ Laptop
Mainstream OS	Peer-To-Peer	TLD usage	Mobile
OS Updates	Flash	Traffic profile	IoT

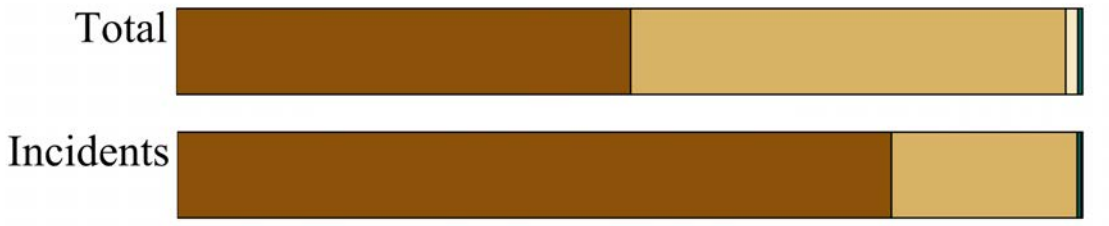
Best Practice: Use a Mainstream OS

Best Practice: Use a Mainstream OS



Operating System	*Incidents*	*Total Devices*
Windows	538 (7.0%)	7,668
Mac OS	140 (1.9%)	7,339
ChromeOS	1 (0.5%)	205
Linux Variant	3 (3.8%)	79

Best Practice: Use a Mainstream OS

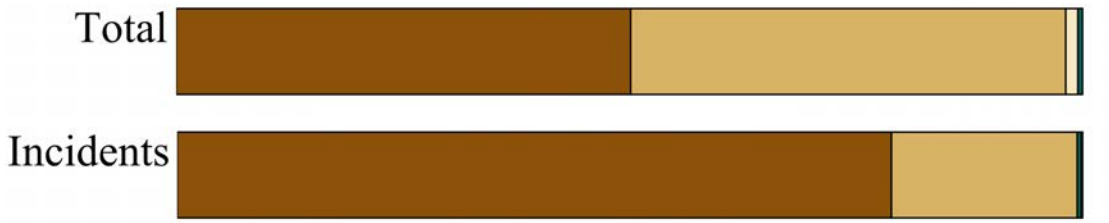


Operating System	*Incidents*	*Total Devices*
Windows	538 (7.0%)	7,668
Mac OS	140 (1.9%)	7,339
ChromeOS	1 (0.5%)	205
Linux Variant	3 (3.8%)	79

Baseline compromise: 4.5%

Windows 3.8x incident rate vs. Mac

Best Practice: Use a Mainstream OS



Operating System	*Incidents*	*Total Devices*
Windows	538 (7.0%)	7,668
Mac OS	140 (1.9%)	7,339
ChromeOS	1 (0.5%)	205
Linux Variant	3 (3.8%)	79

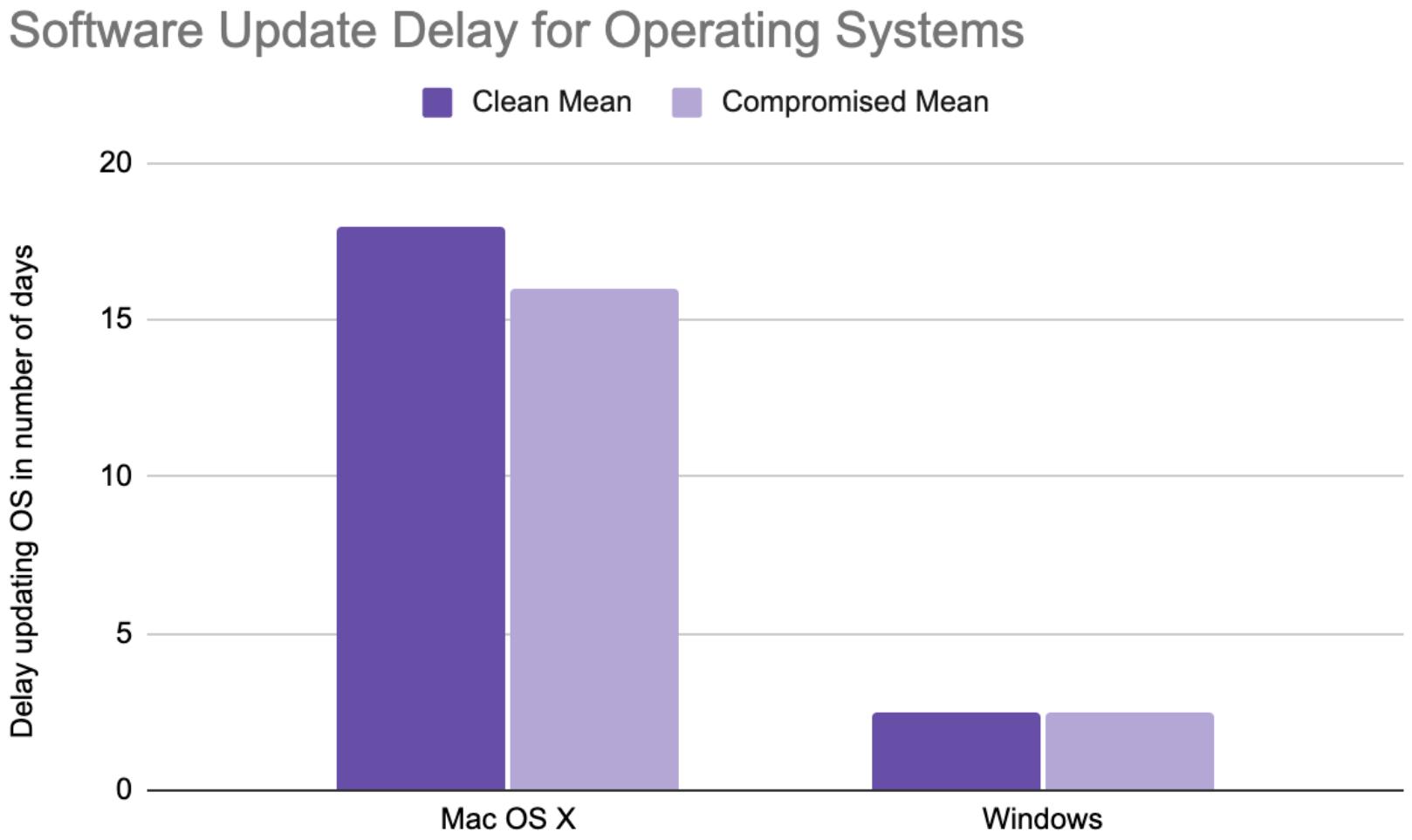
Baseline compromise: 4.5%

Windows 3.8x incident rate vs. Mac

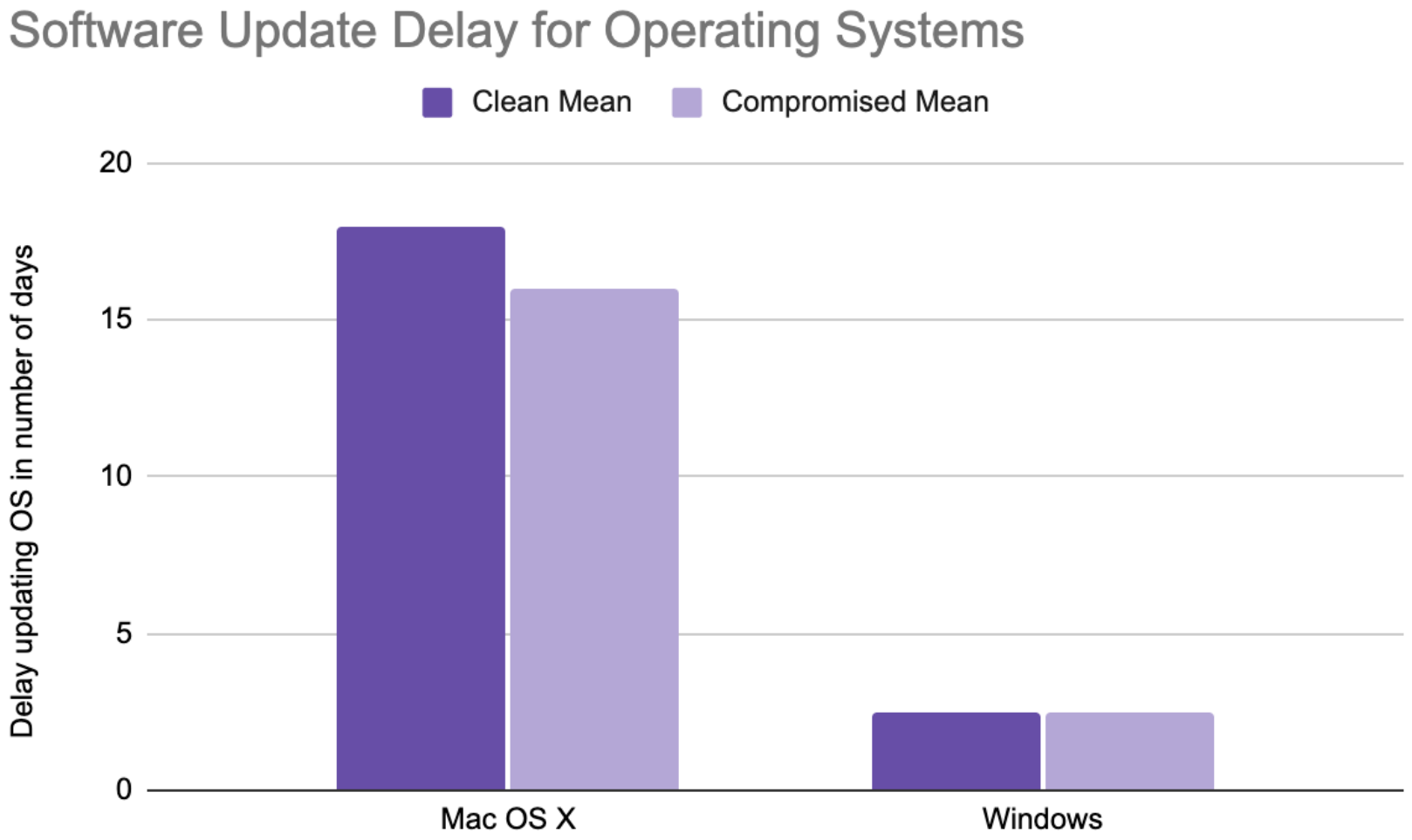
Having a mainstream OS may make a user more susceptible to compromise because that's what attackers are targeting

Best Practice: Update Operating System

Best Practice: Update Operating System

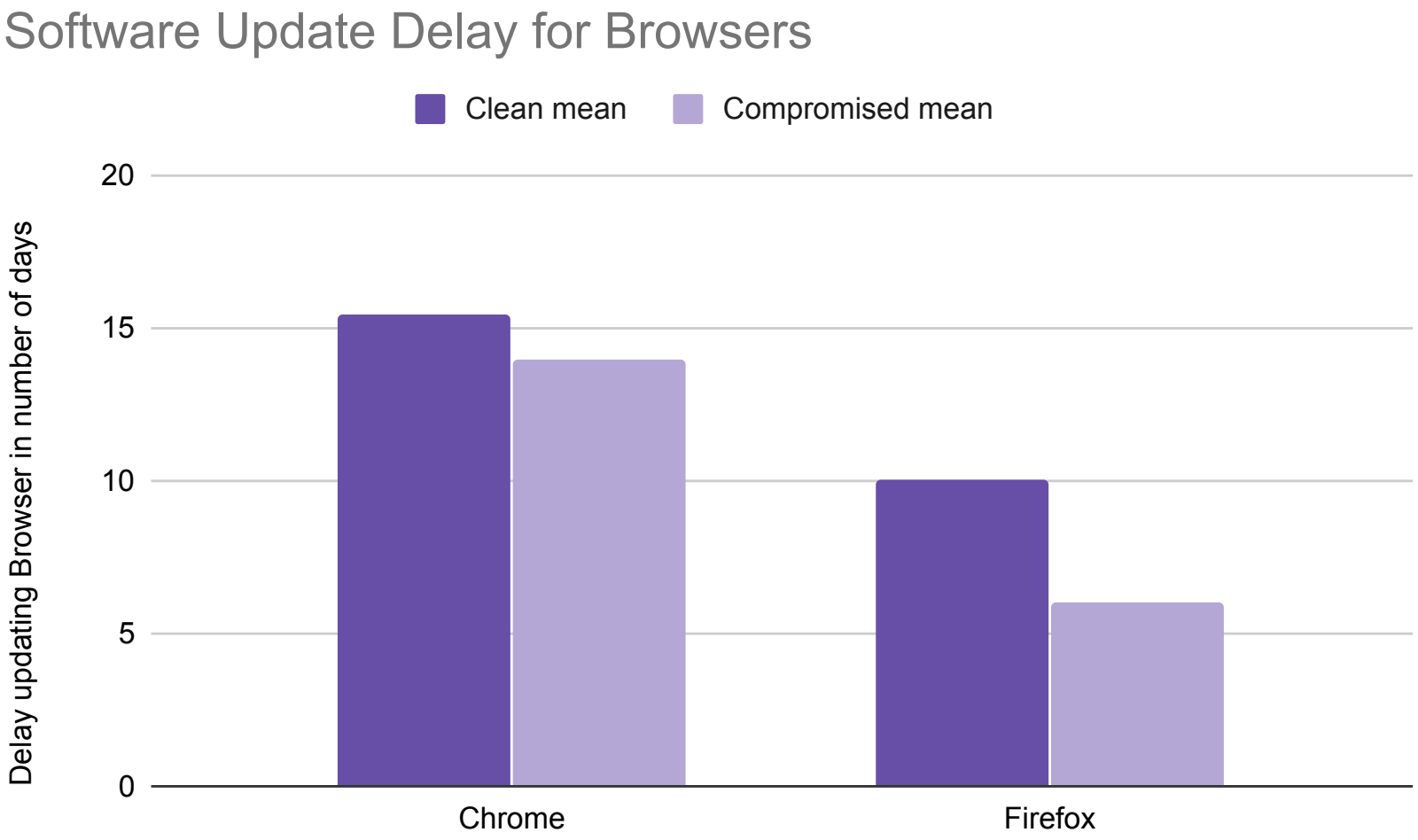


Best Practice: Update Operating System

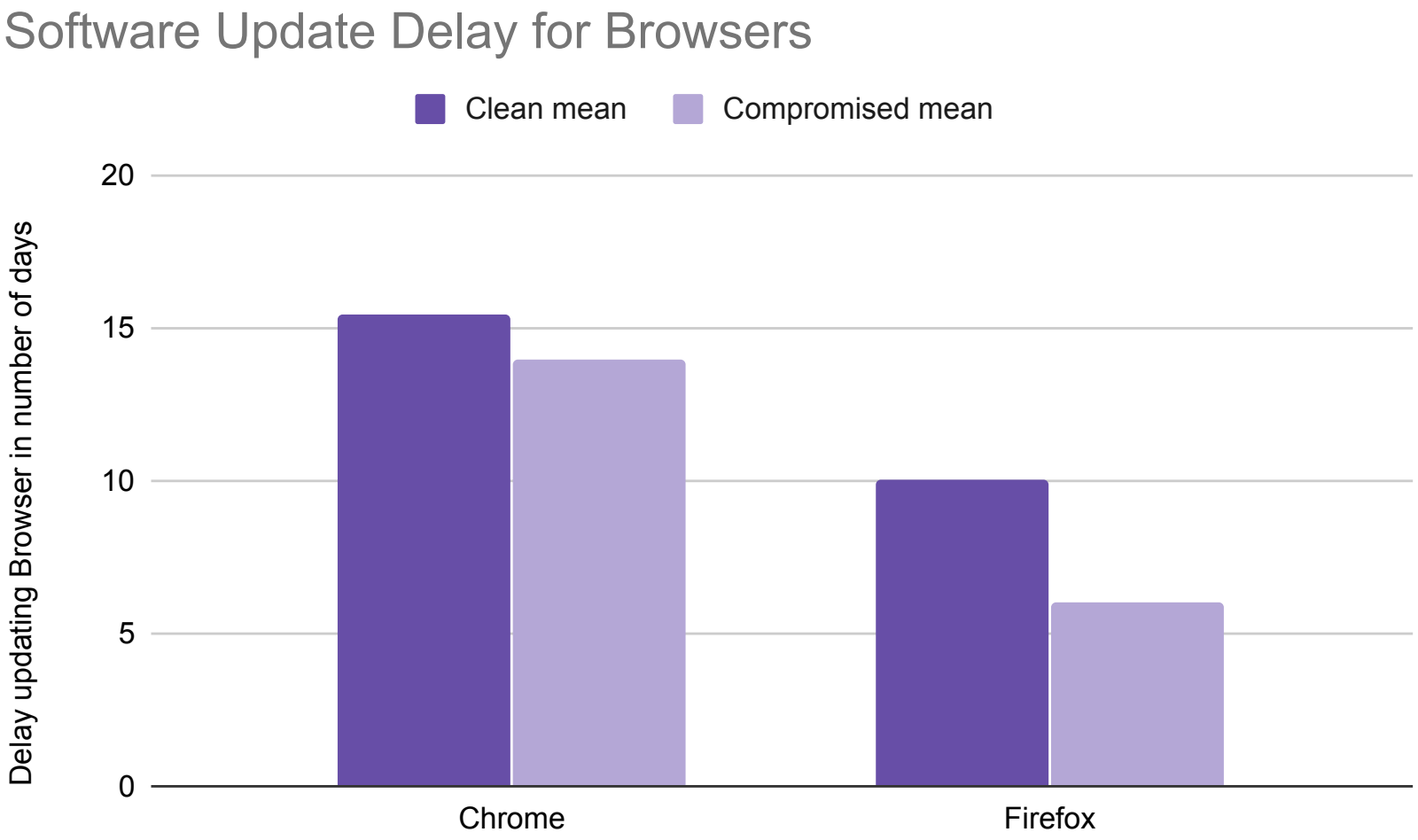


No strong difference in update rate

Best Practice: Update Browsers



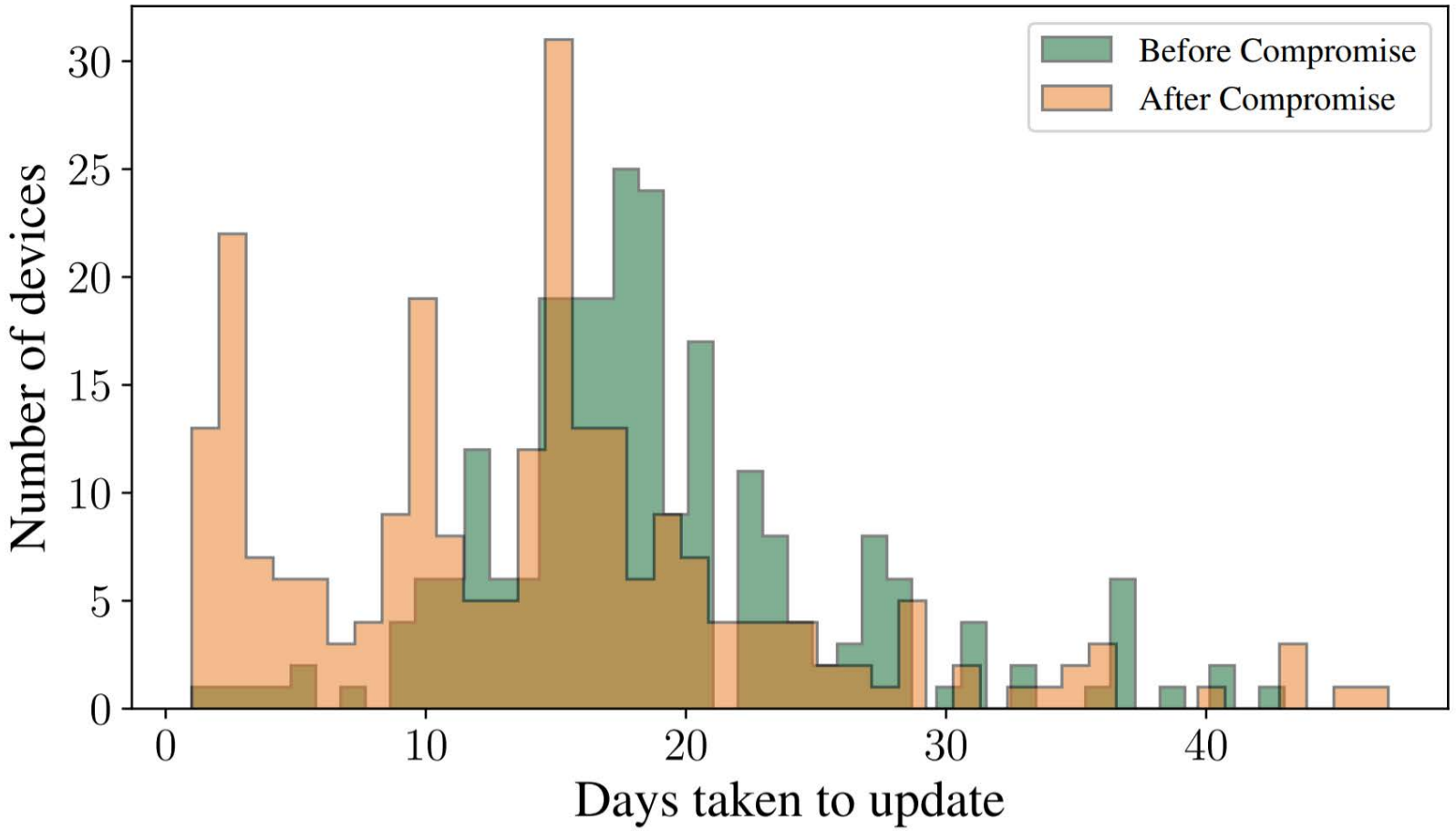
Best Practice: Update Browsers



Clean devices update slower than their compromised counterparts; statistically significant

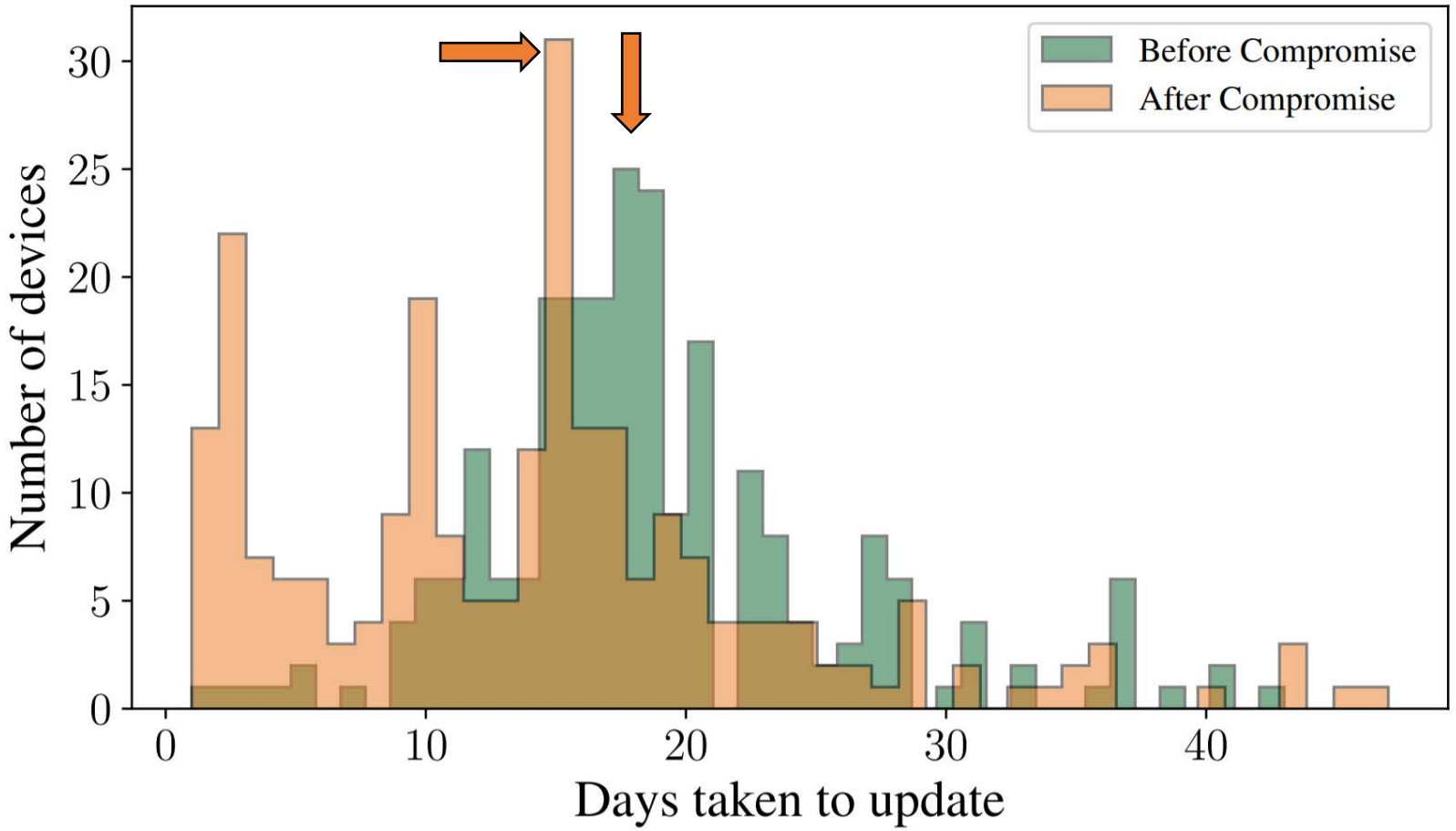
Best Practice: Update Browsers

Chrome Updates: Compromised Devices



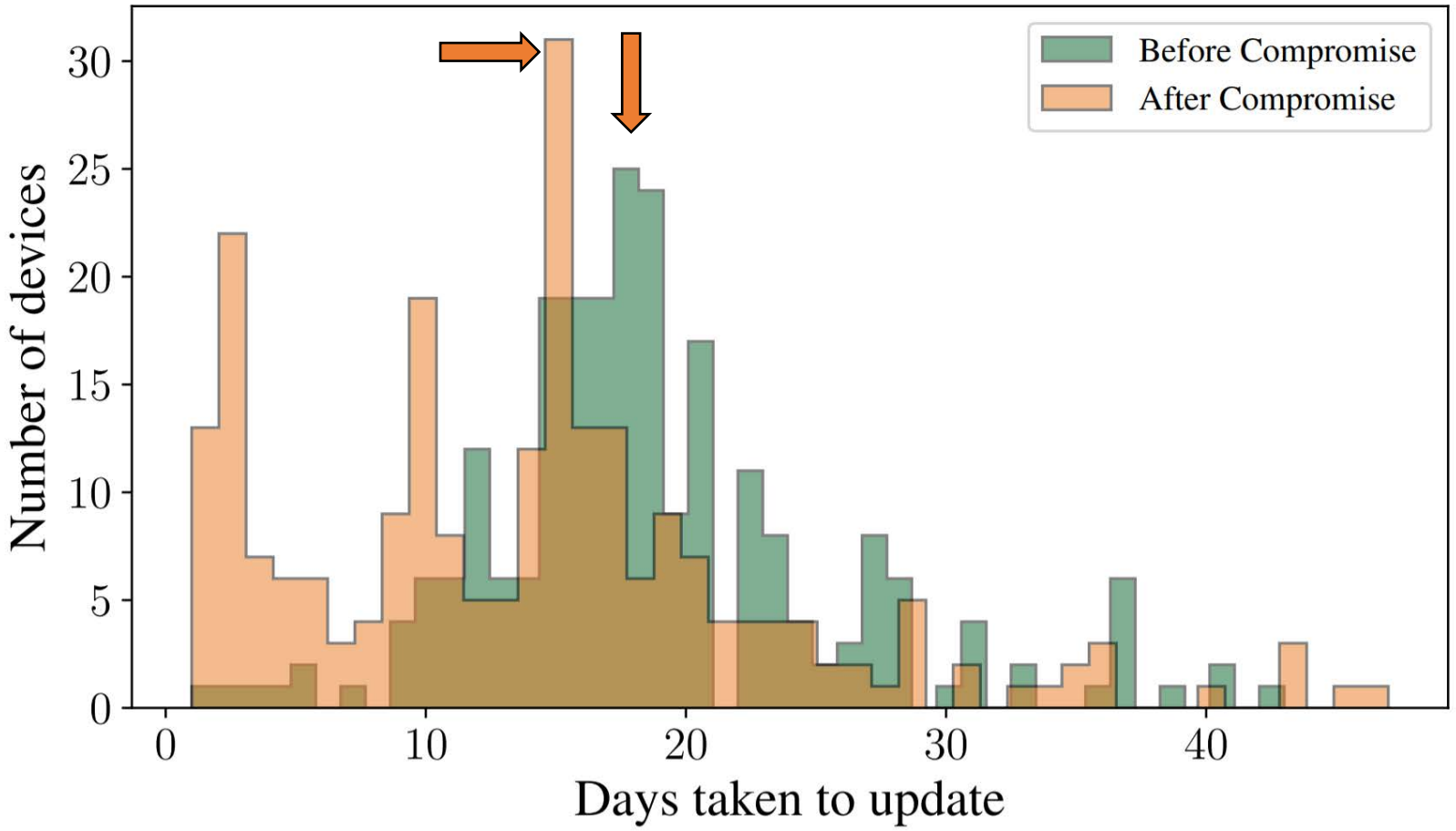
Best Practice: Update Browsers

Chrome Updates: Compromised Devices



Best Practice: Update Browsers

Chrome Updates: Compromised Devices



Compromised devices update faster after compromise

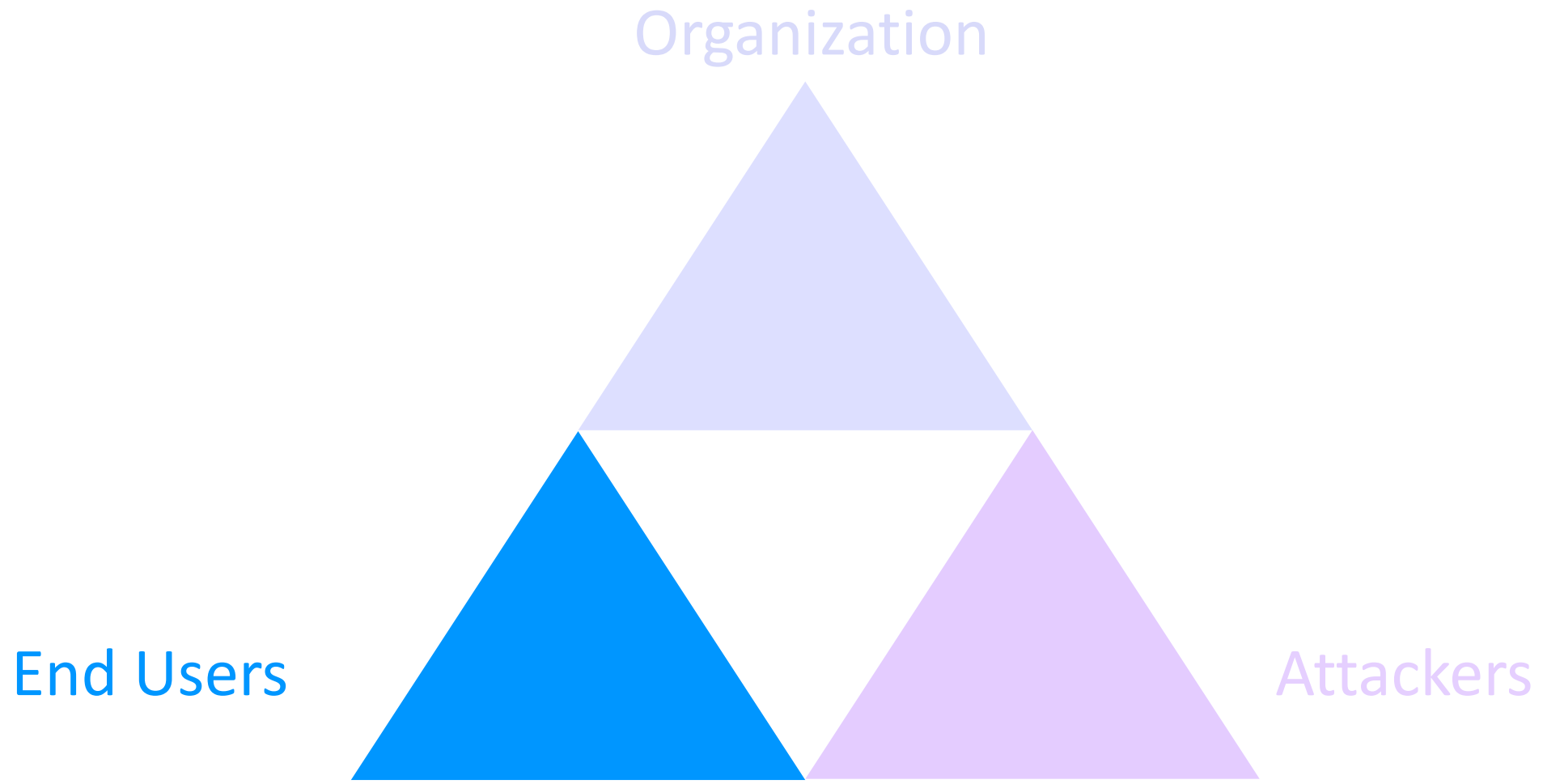
End User Behavior and Relation to Outcome

Examined best practices like using a mainstream OS and updating software

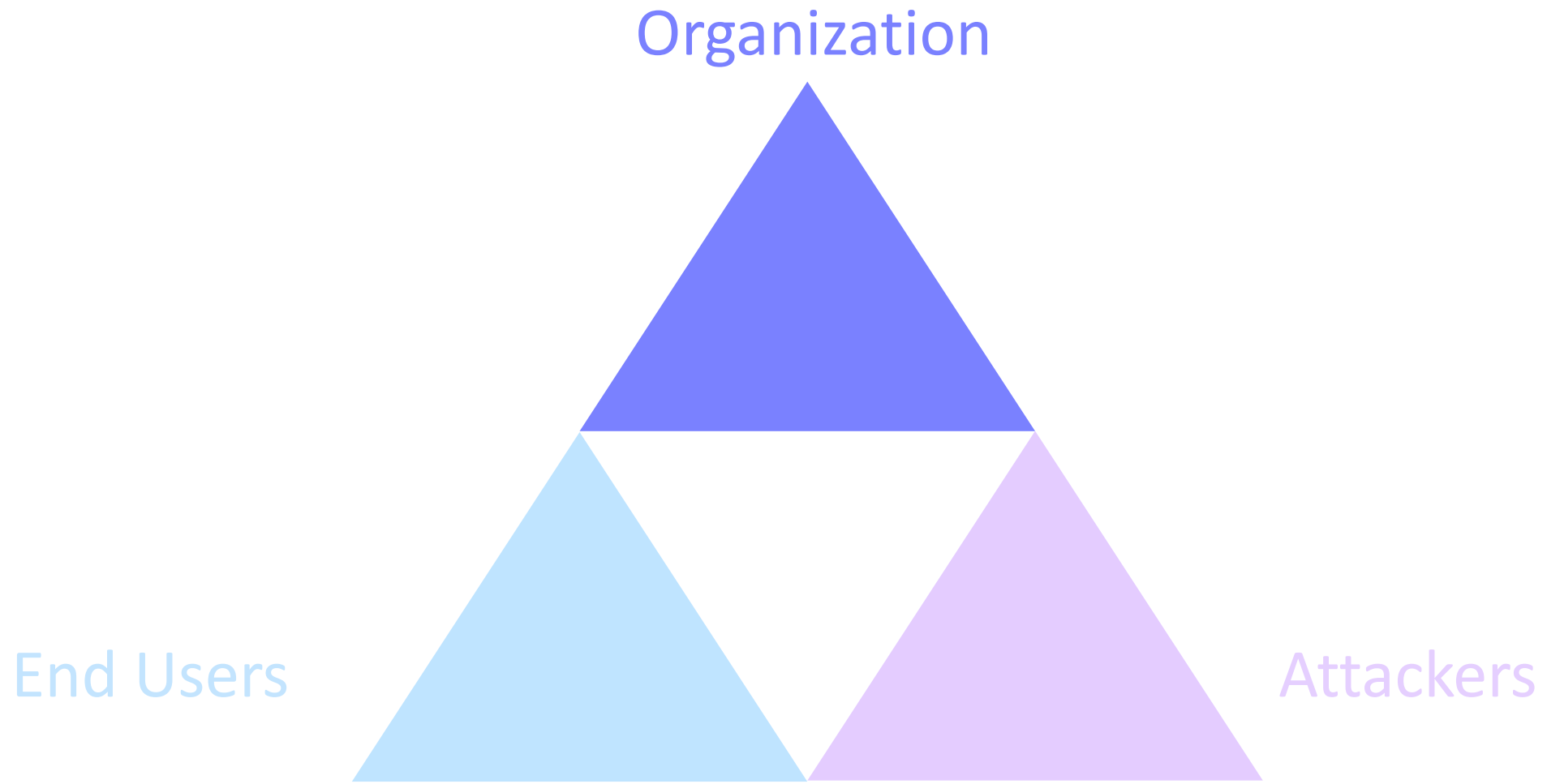
Found little empirical basis for best practices

Best practices can help, but we should prioritize behaviors that matter

Understanding user behaviors to better prioritize security processes



Understanding user behaviors to better prioritize security processes



Organizations sometimes change security policies

Organizations sometimes change security policies

Adoption of 2FA

Migration to new service

Changing passwords

Organizations sometimes change security policies

Adoption of 2FA

Migration to new service

Changing passwords

What communication mechanisms are most effective at prompting user change?

Password Update Data

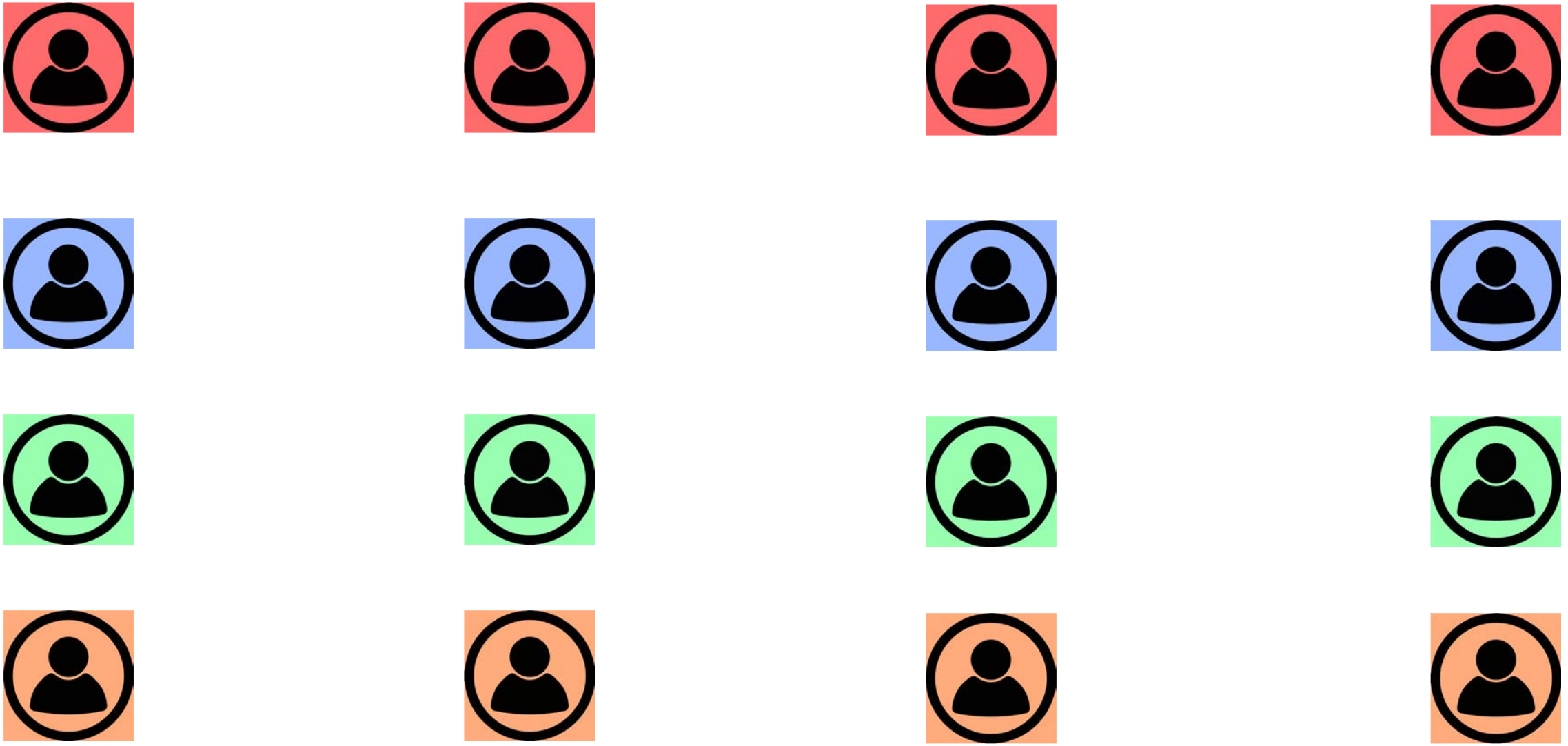
Possible because of collaboration with ITS Security team

Logs of password updates, employee metadata, scrambled accounts

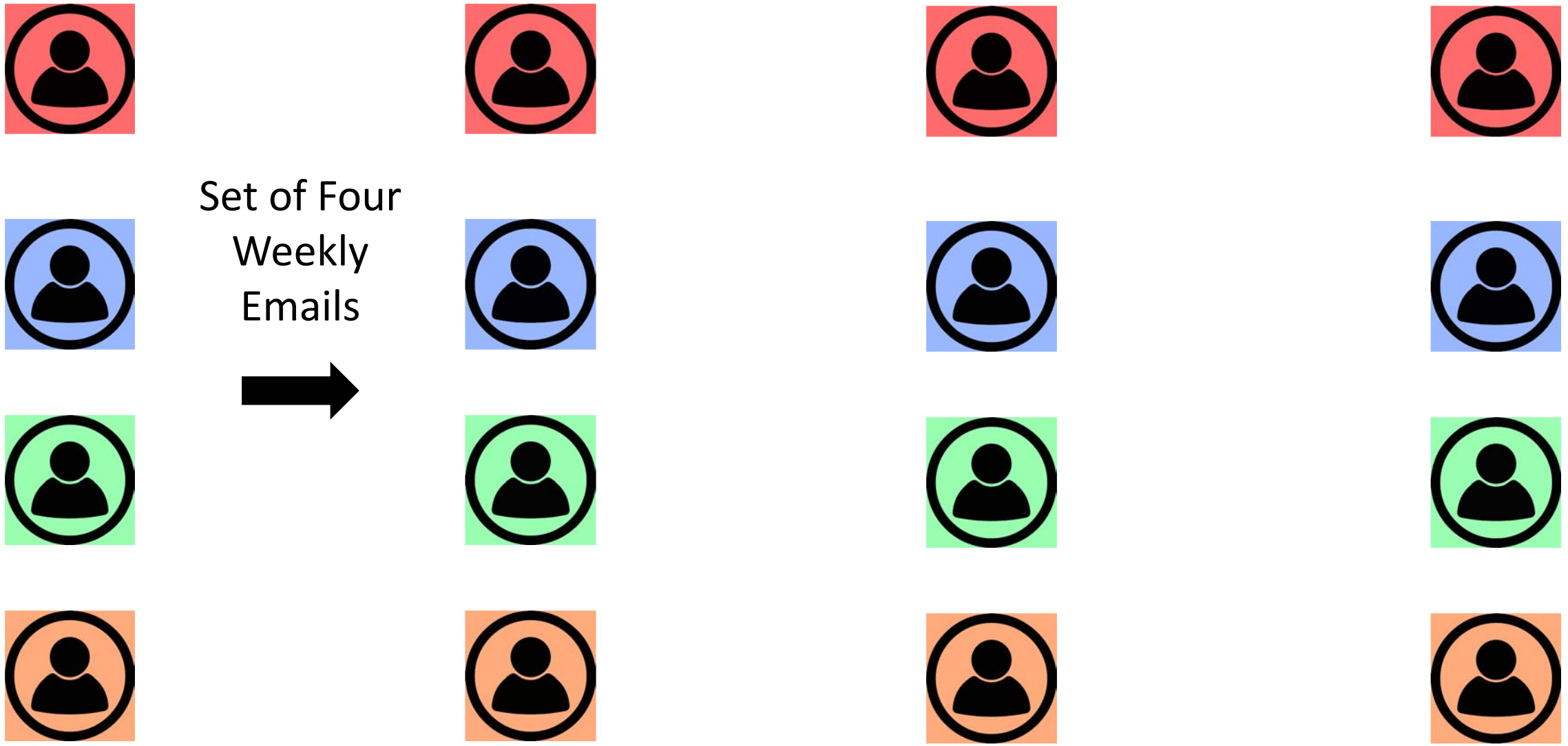
Communication messages and when they were sent

10K Employees

10K Employees



10K Employees



As part of our continuing effort to protect the UC San Diego community's data and systems, we are undergoing a campuswide password change action. Ensuring your passwords are strong is critical to protecting both your personal data and campus resources.

In addition to enhanced password security features, the minimum number of characters required for an AD password has been increased from 7 to 12 or more characters.

To meet the new minimum 12-character requirement, the UC San Diego Office of Information Assurance has begun requiring that all AD account holders make a one-time change of AD passwords after August 3, 2021.

How Do I Change My AD Password?

Successfully changing your AD password depends on the devices you are using and your location. Visit How to Change Your AD Password for more information and steps to reset devices and workstations.

Do I Have to Change My AD Password?

Yes, you are required to change your AD password, even if your current password is 12 or more characters in length.

Note that this change does not affect Business Systems SSO accounts.

When Do I Change My AD Password?

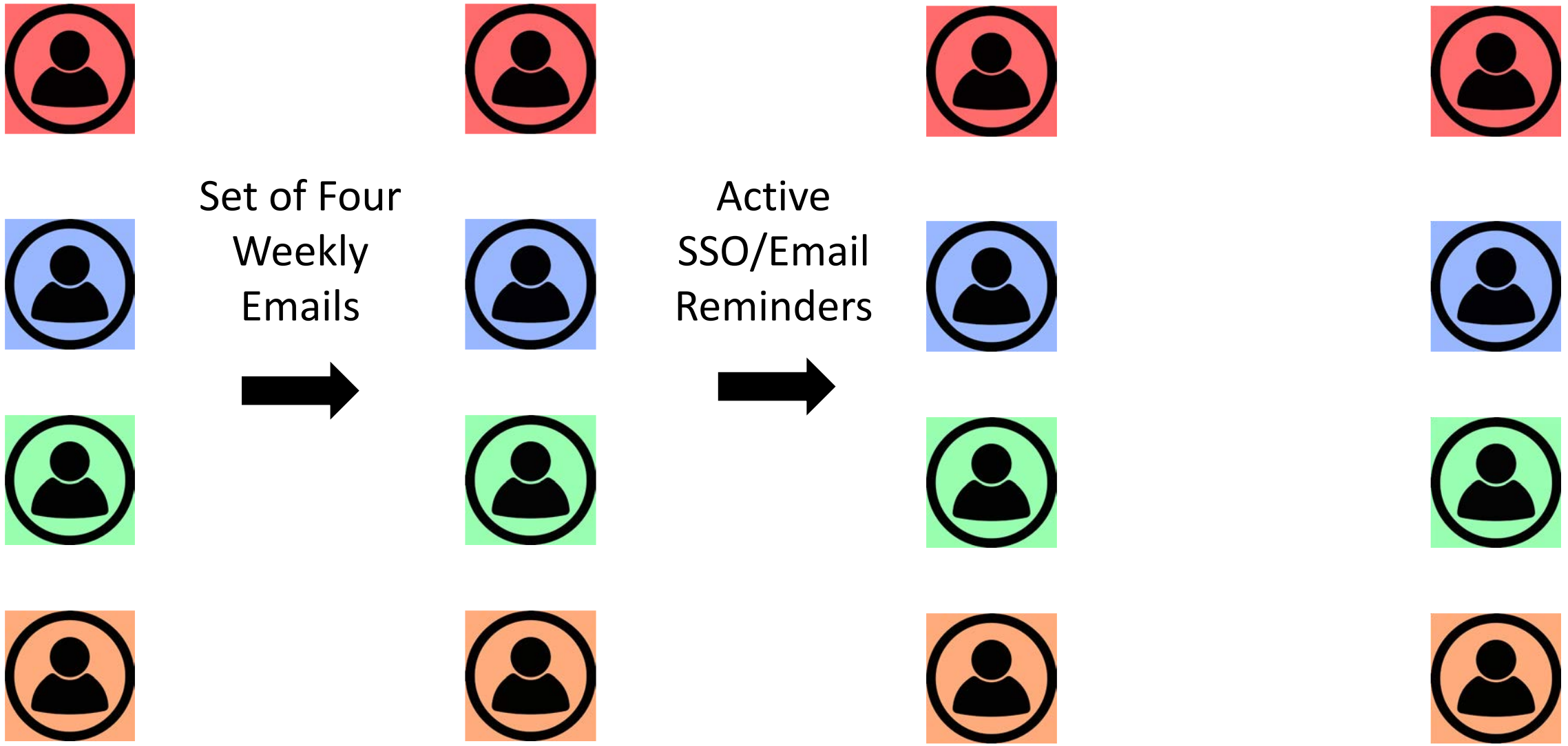
Campus academics, staff and affiliates whose **last names begin with H through N** are required to change AD passwords **any time between September 1 and September 22.**

All campus academic, staff, affiliate, Health Sciences and UC San Diego Health AD account holders have been split into groups, each group assigned dates for password changes. See the list of all groups and their assigned change dates.

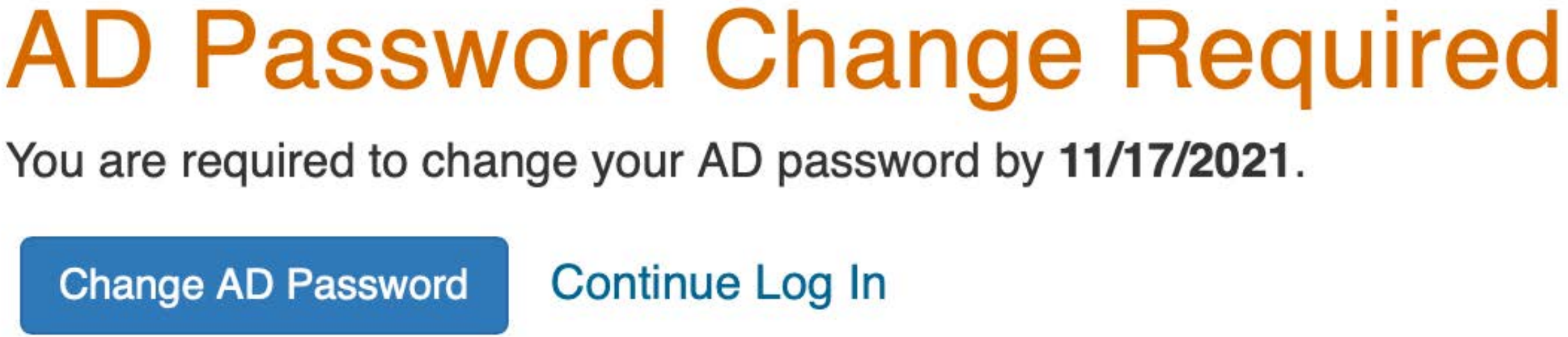
The LastPass Password Management Tool

Improve password security for all of your university accounts with the UC San Diego tested and approved LastPass password management software. Visit LastPass.ucsd.edu to learn more and register.

10K Employees



SINGLE SIGN-ON (V3.3)



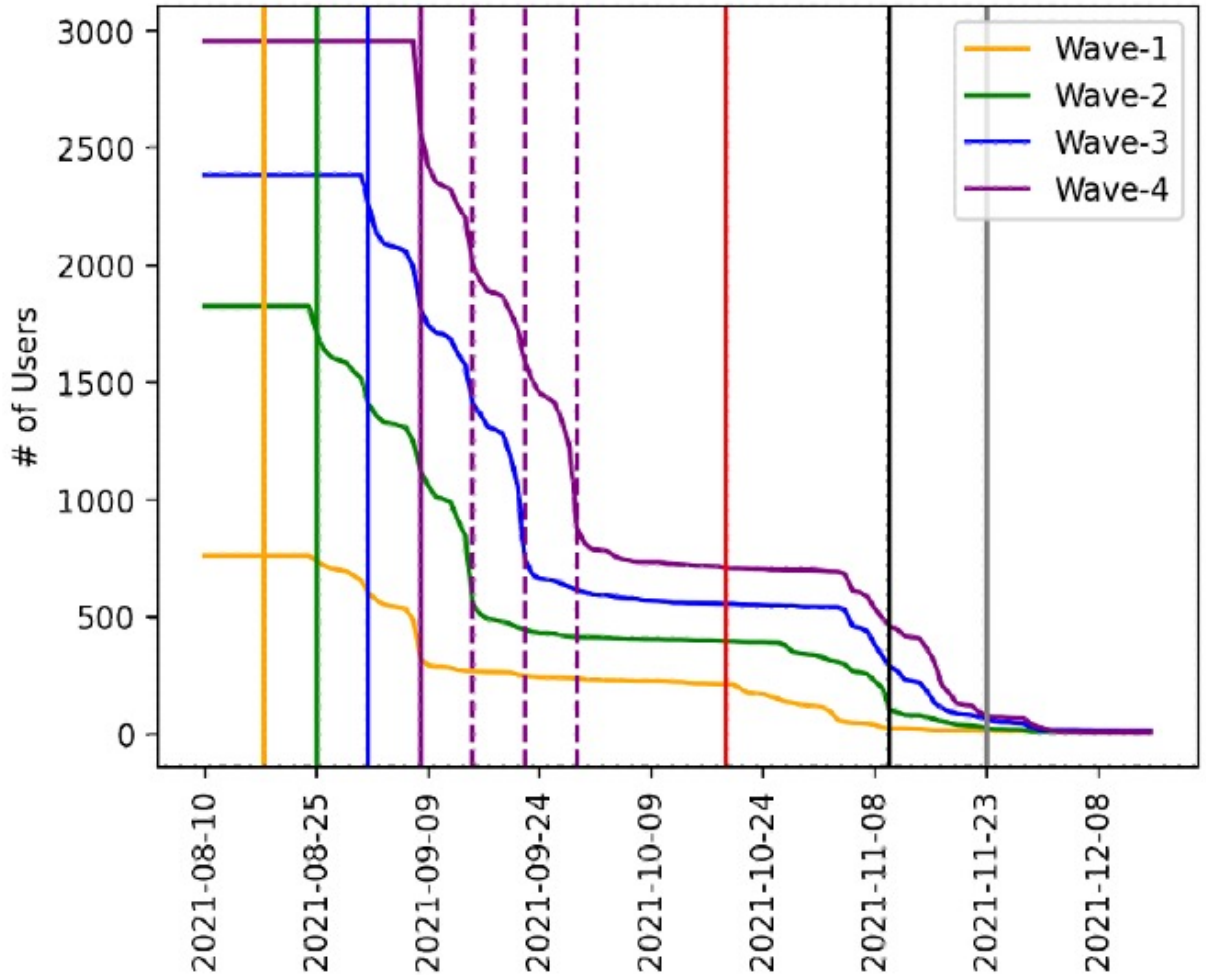
10K Employees

Proportion of Change Modalities

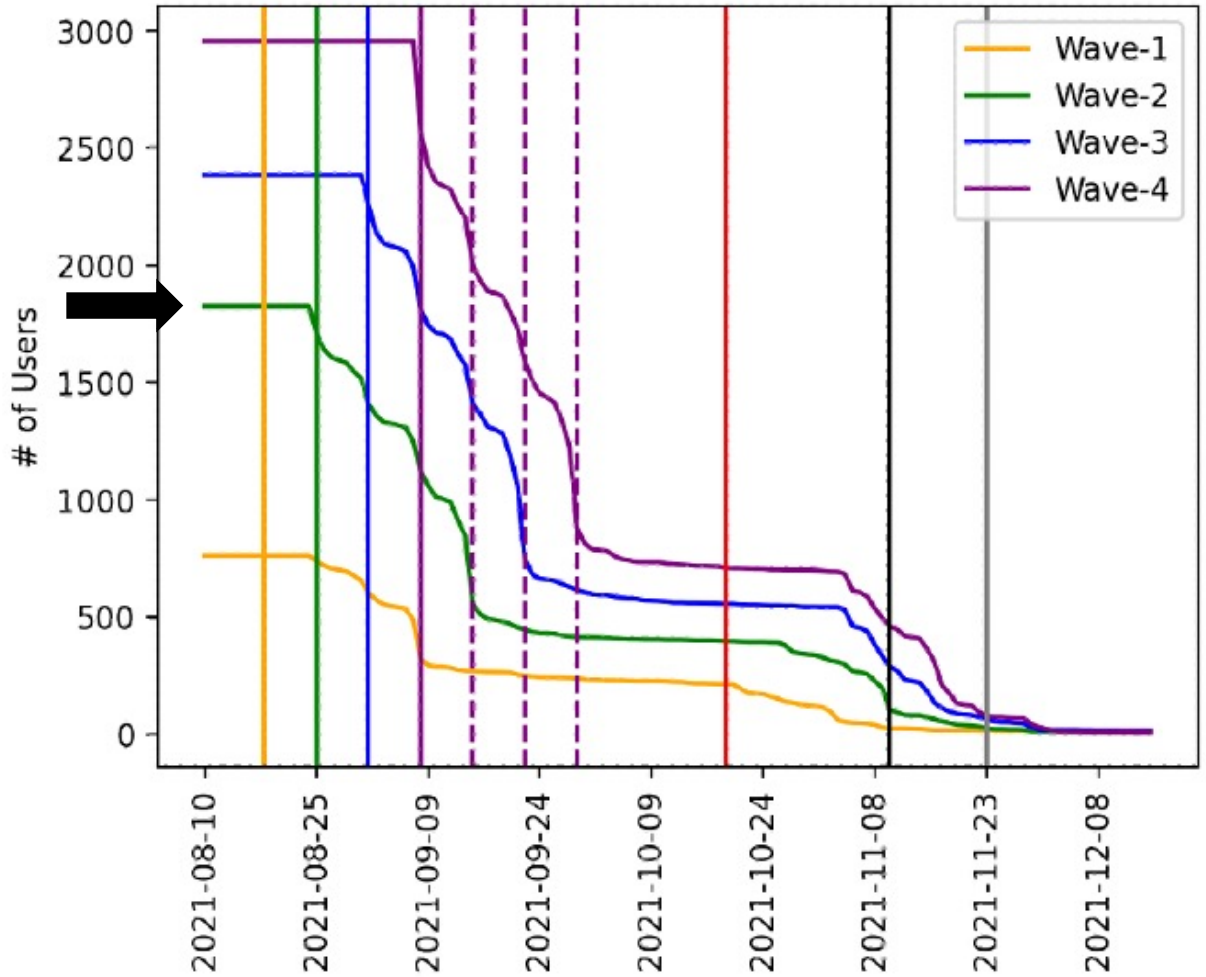
81.3% are single change users

12.2% are multiple change users

5.42% are scrambled users

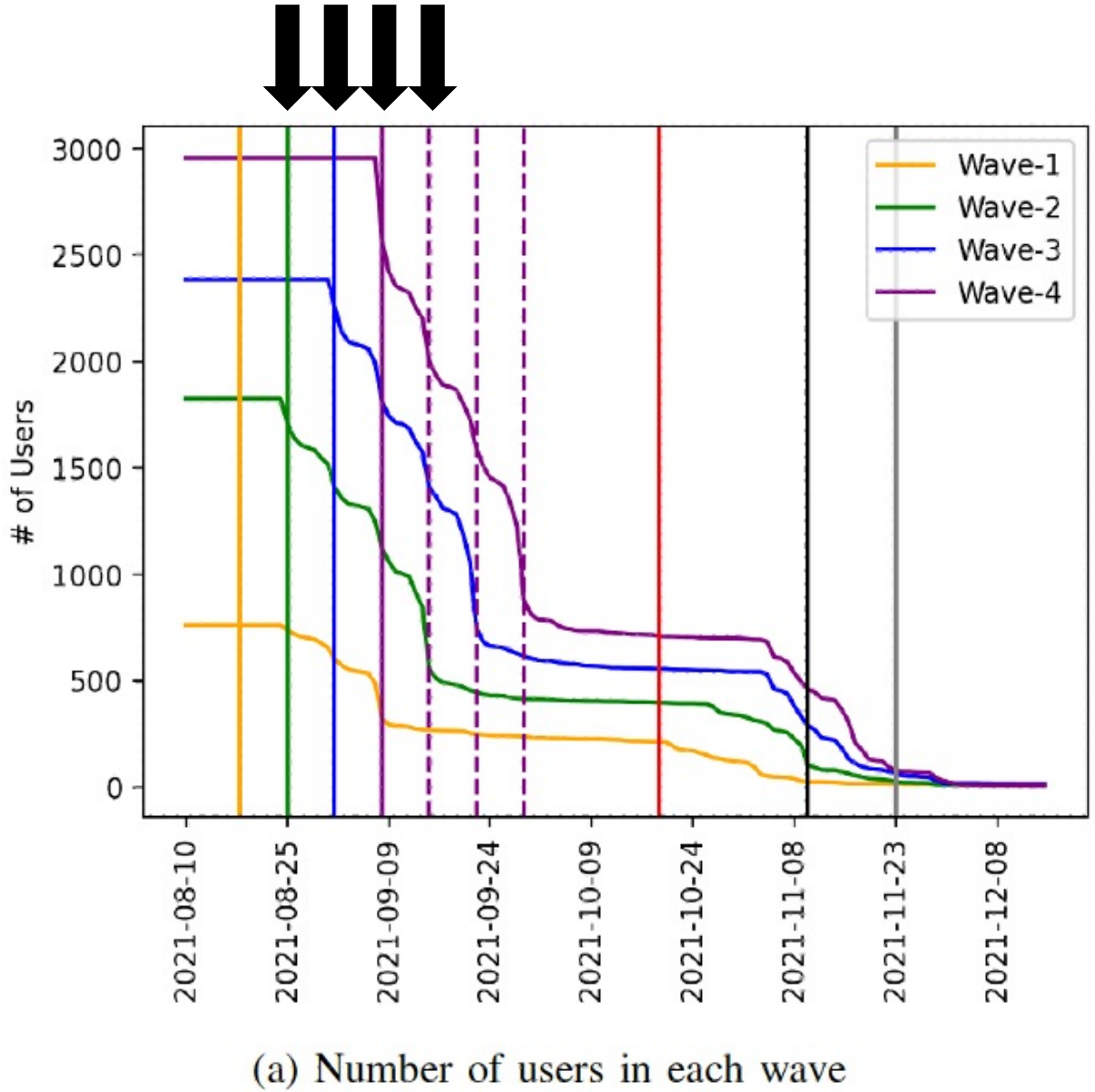


(a) Number of users in each wave



(a) Number of users in each wave

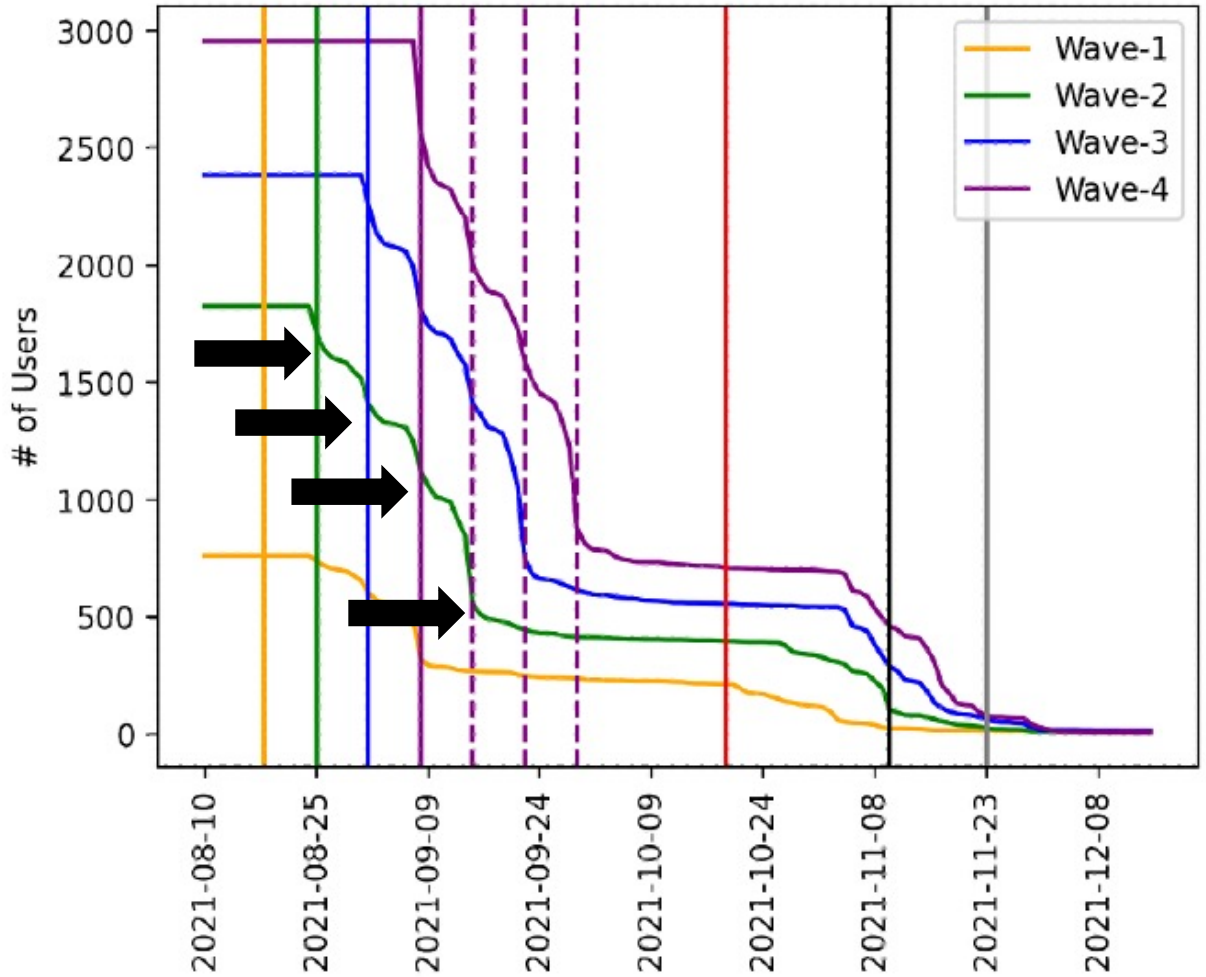
Each color represents a wave and the number of users who have not changed their password



(a) Number of users in each wave

Each color represents a wave and the number of users who have not changed their password

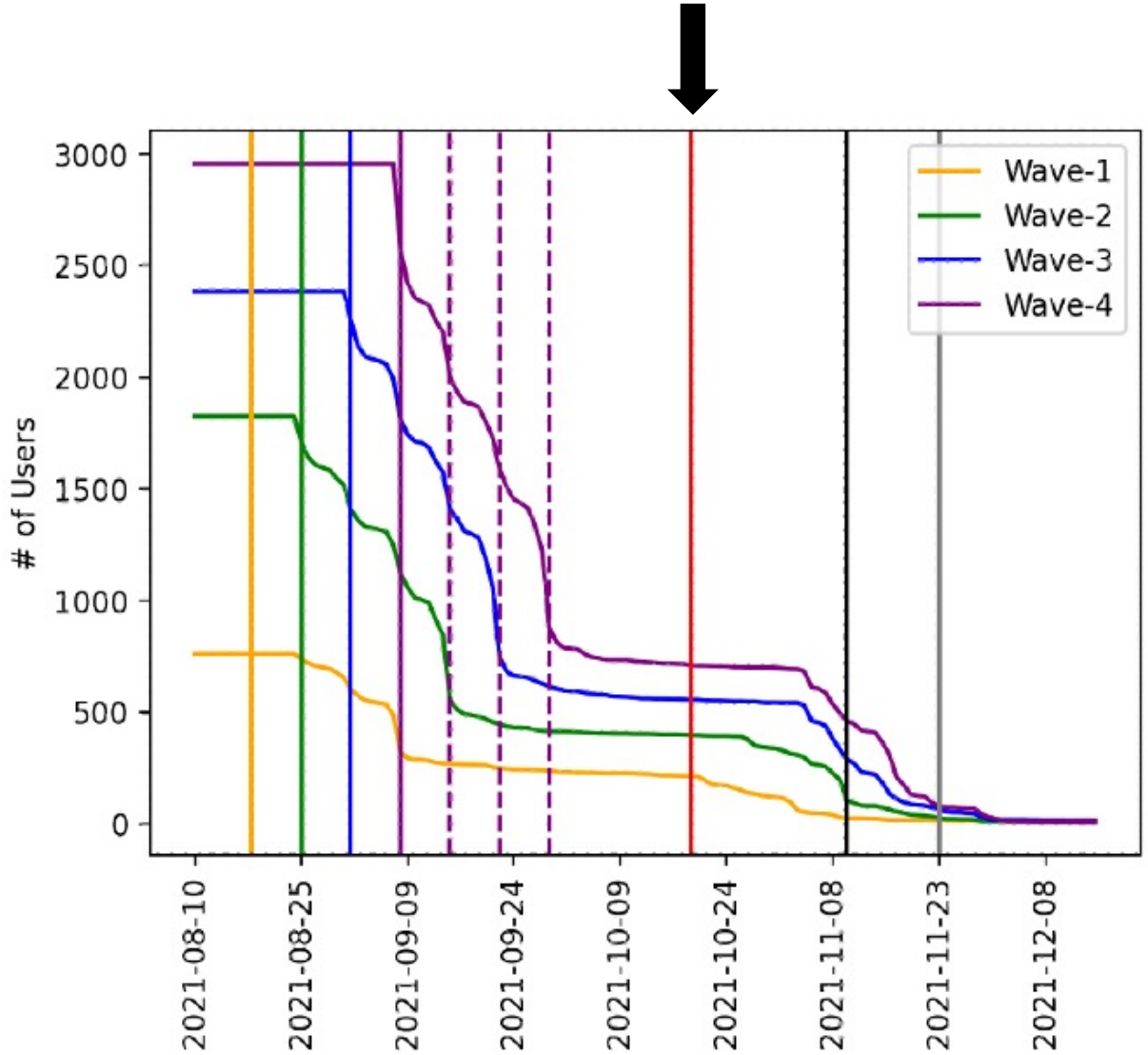
Solid vertical lines matching color of waves represent initial email communication



(a) Number of users in each wave

Each color represents a wave and the number of users who have not changed their password

Solid vertical lines matching color of waves represent initial email communication

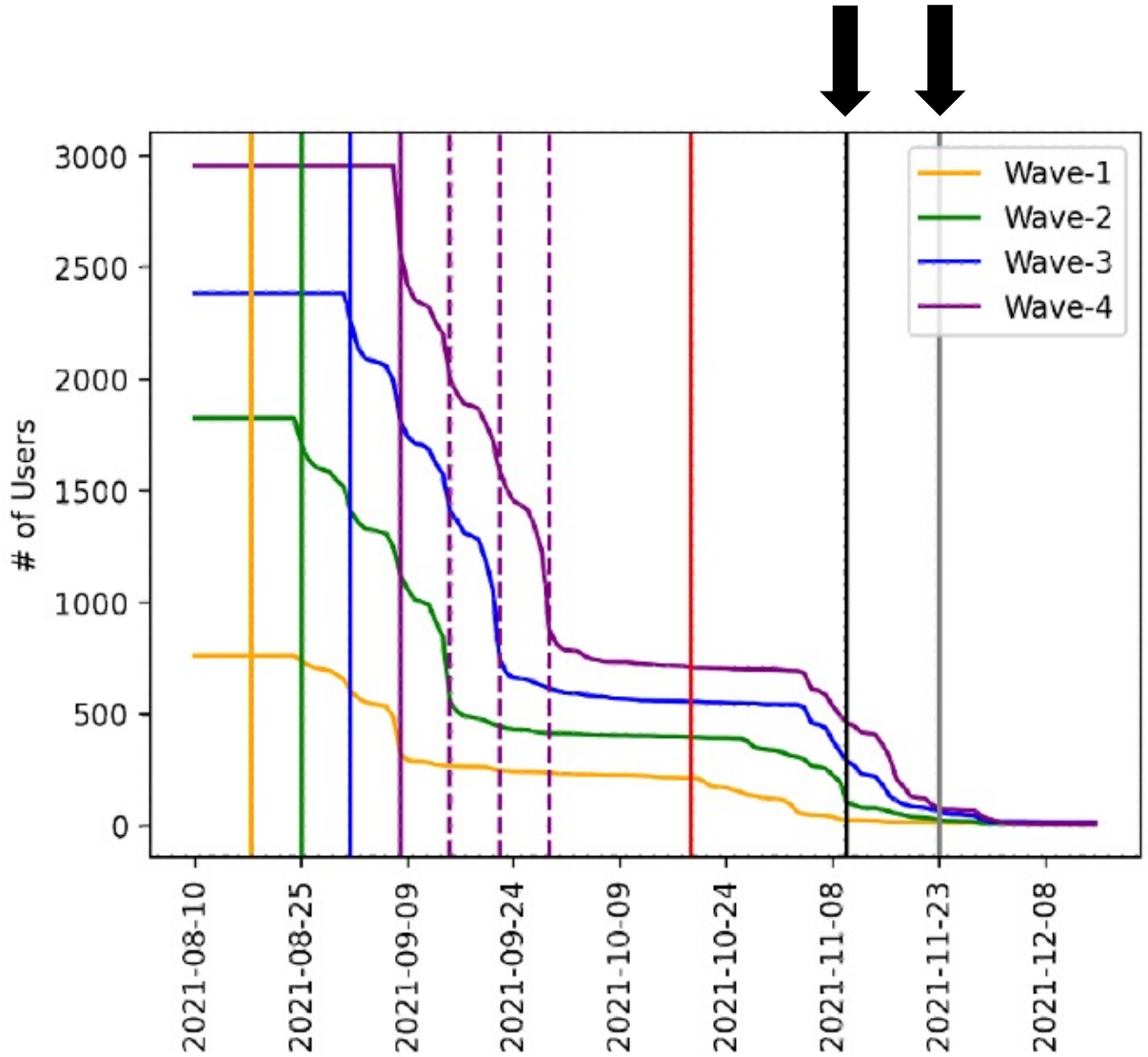


(a) Number of users in each wave

Each color represents a wave and the number of users who have not changed their password

Solid vertical lines matching color of waves represent initial email communication

Solid vertical red line represents the start of the SSO Active Directory intercept



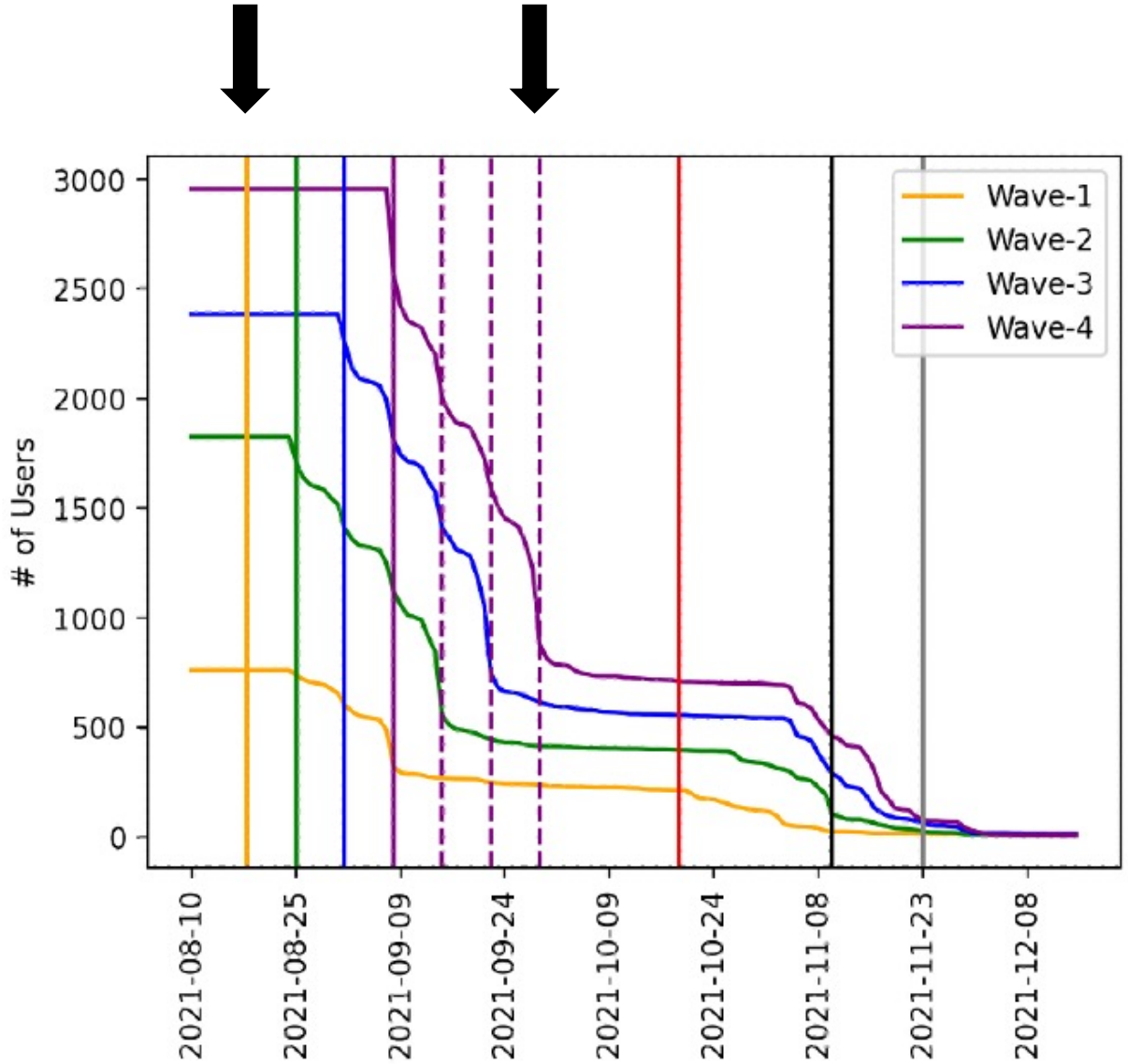
(a) Number of users in each wave

Each color represents a wave and the number of users who have not changed their password

Solid vertical lines matching color of waves represent initial email communication

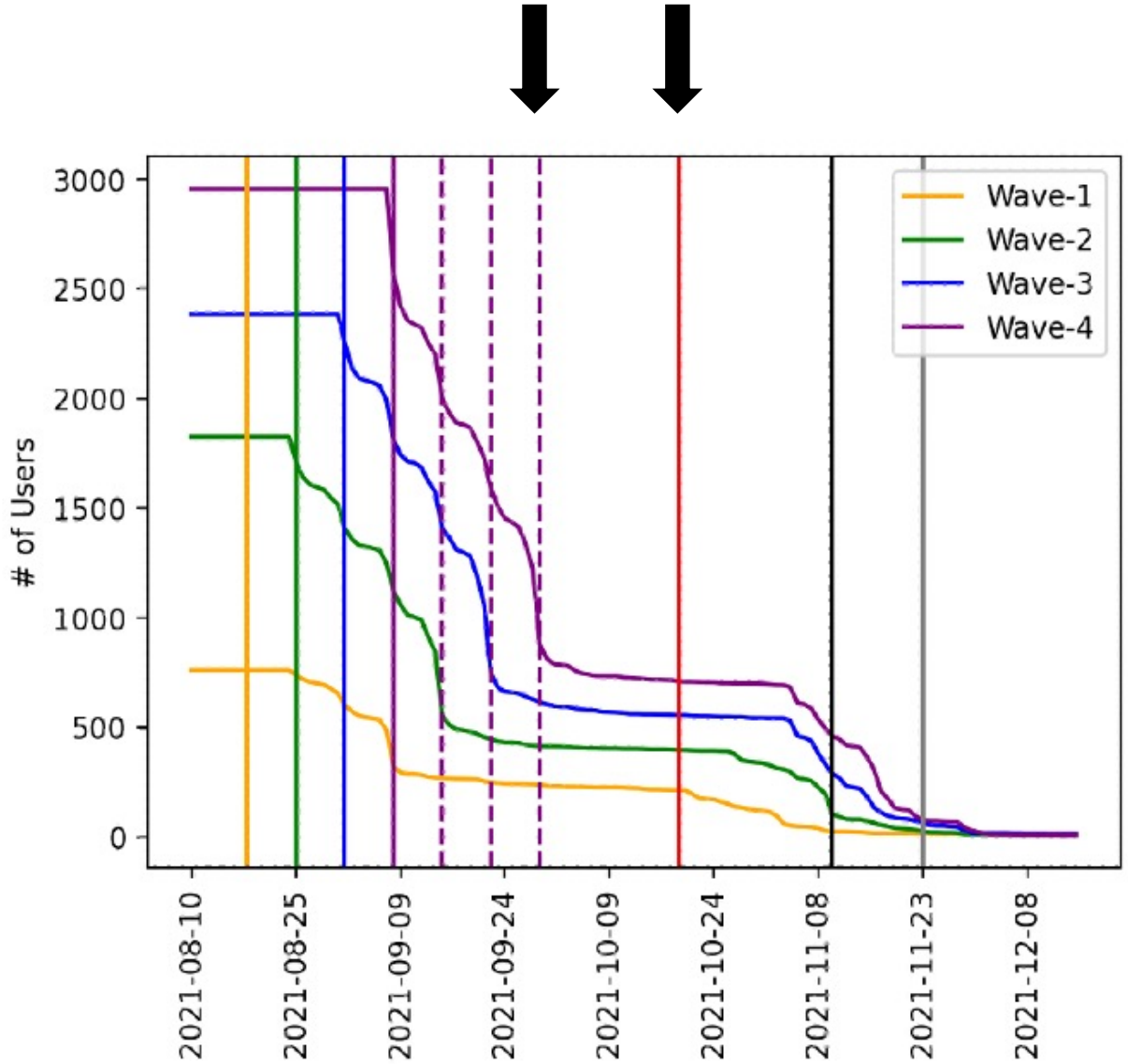
Solid vertical red line represents the start of the SSO Active Directory intercept

Solid black/grey lines represent the start of final email communications (SSO intercept active)



(a) Number of users in each wave

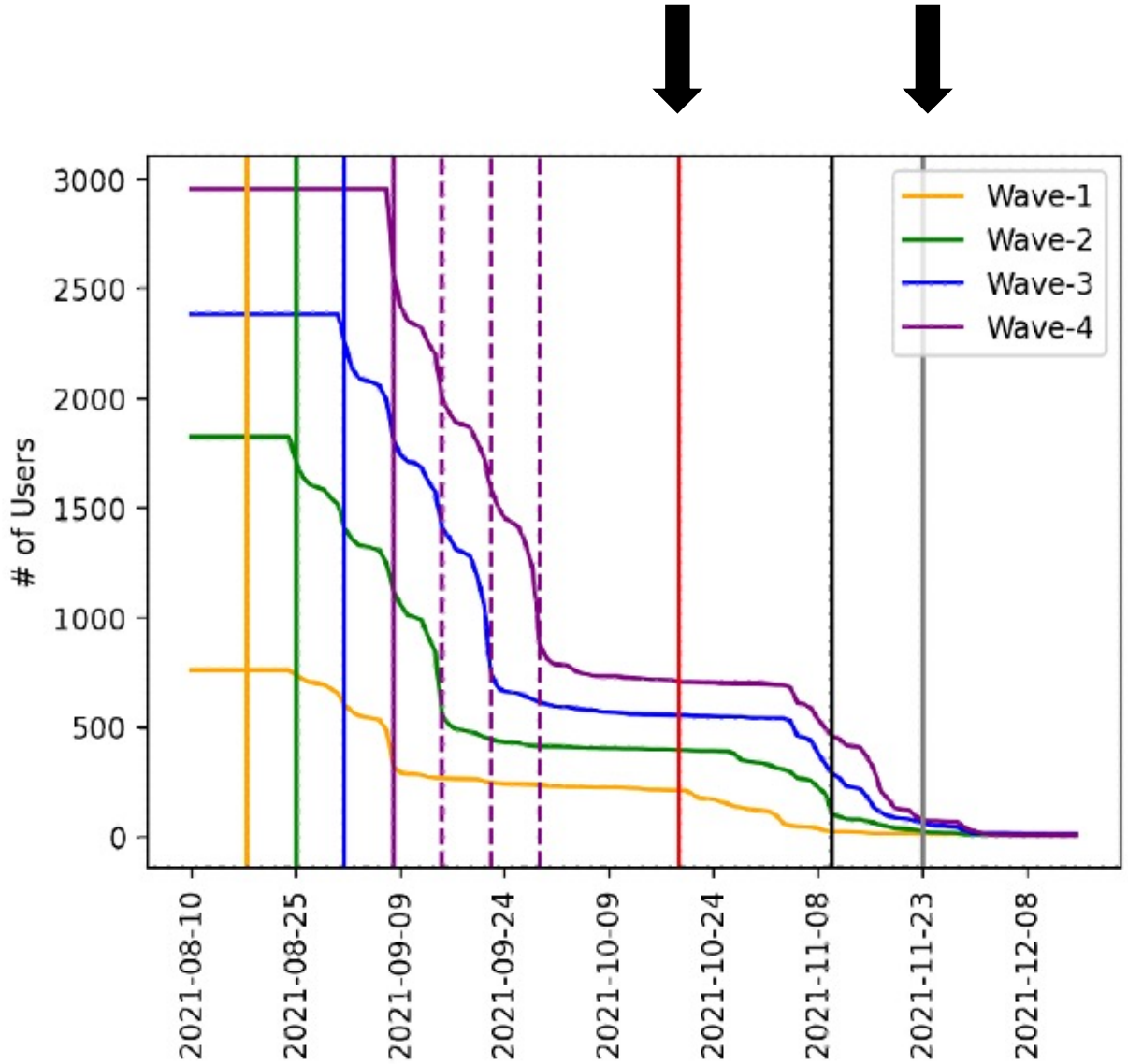
Period during initial email waves is categorized as “responsive period”



(a) Number of users in each wave

Period during initial email waves is categorized as “responsive period”

Period in between communications is categorized as “idle” period

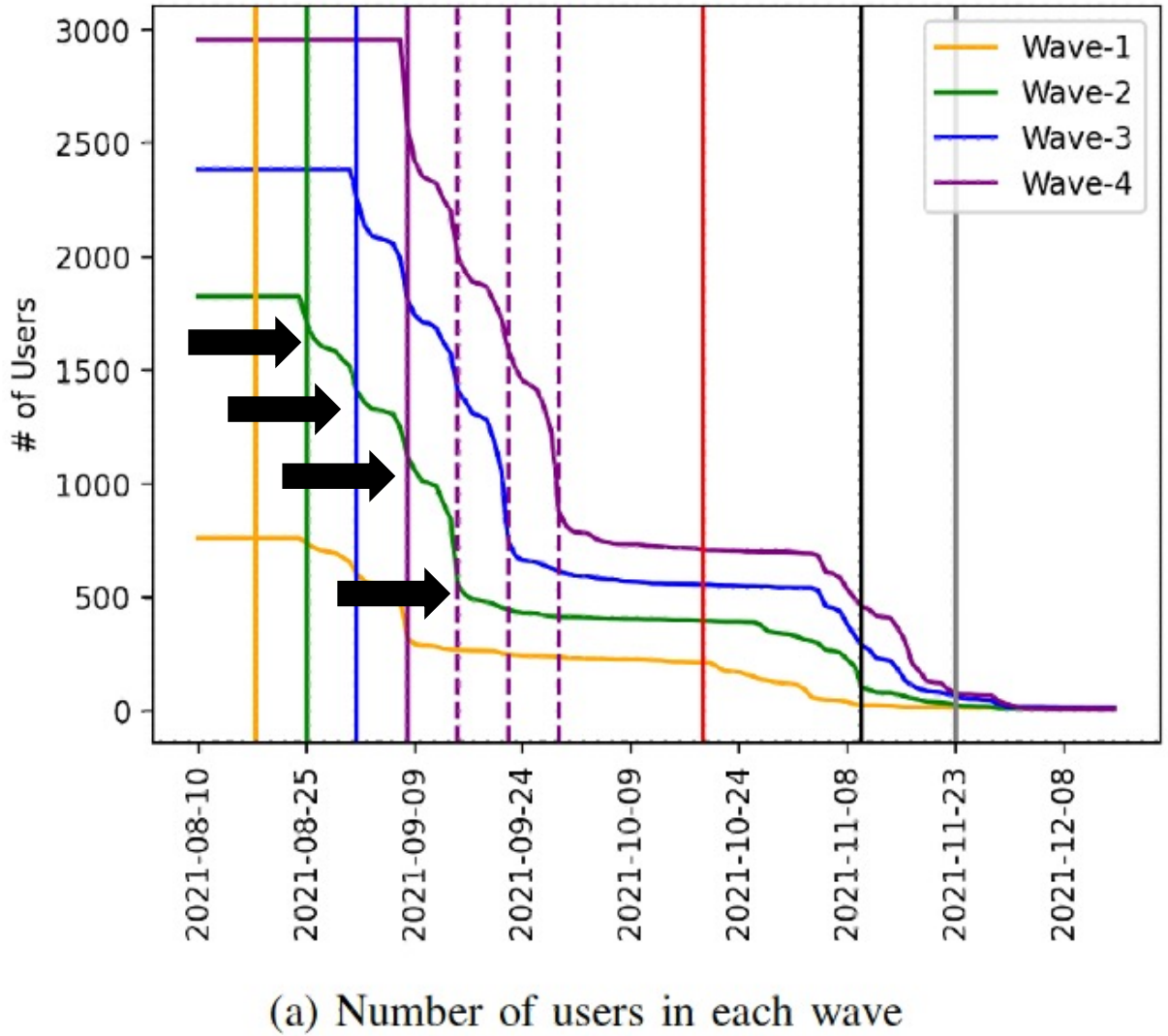


(a) Number of users in each wave

Period during initial email waves is categorized as “responsive period”

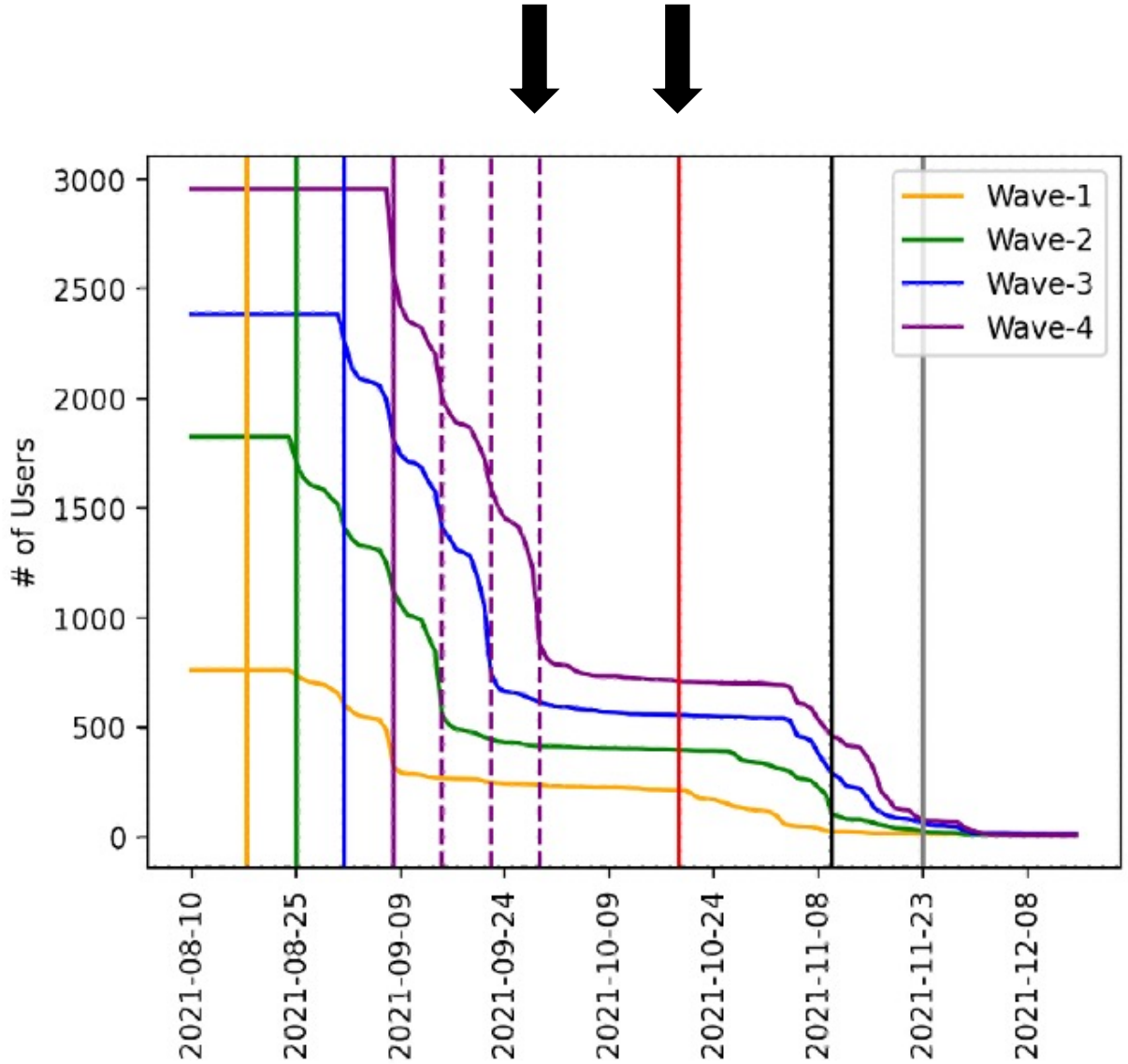
Period in between communications is categorized as “idle” period

Period during SSO intercept/final email communications is the “interventional” period



(a) Number of users in each wave

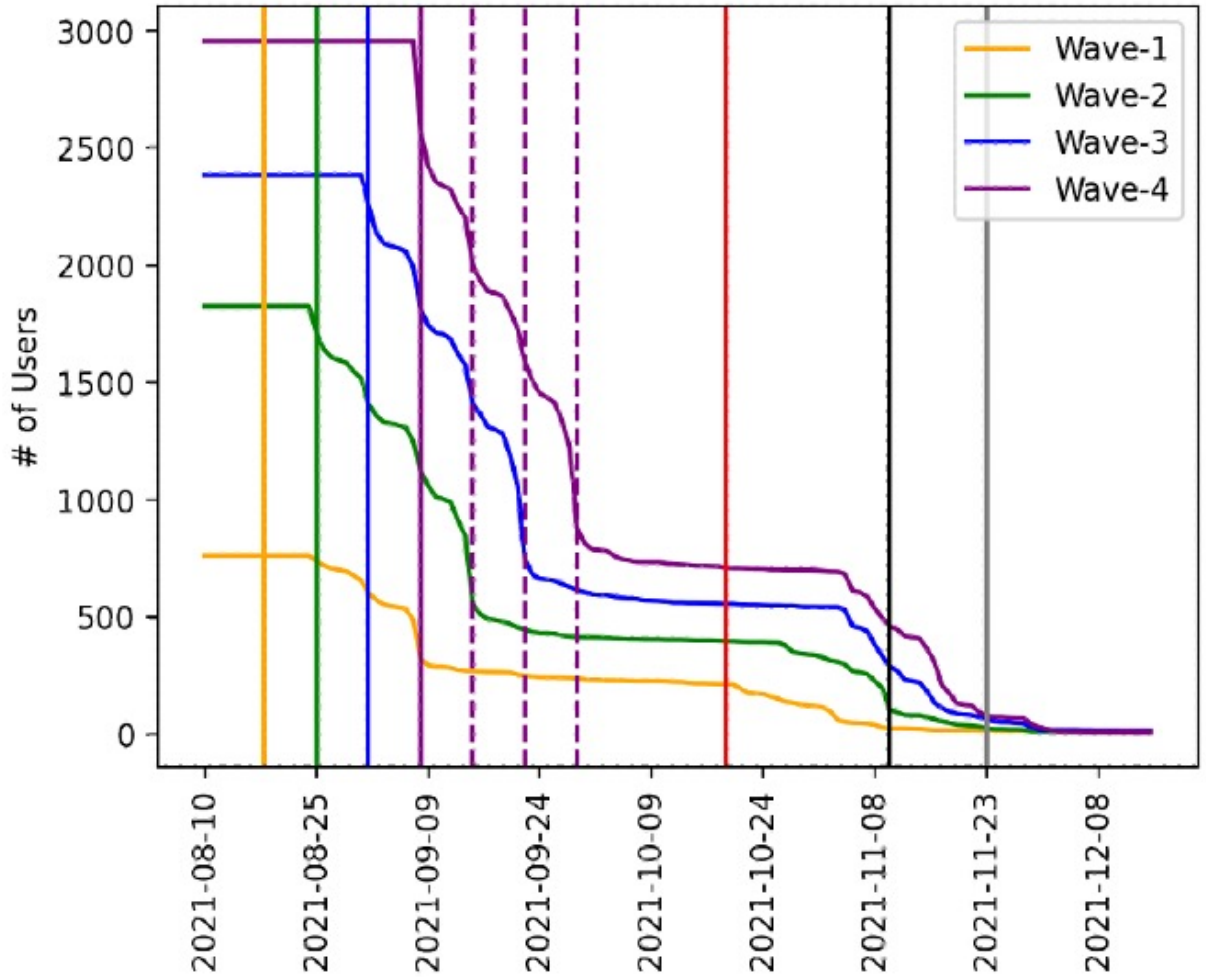
Repetitive emails are useful but have potential diminishing effectiveness



(a) Number of users in each wave

Repetitive emails are useful but have potential diminishing effectiveness

“Idle” period produces little change in users



(a) Number of users in each wave

Repetitive emails are useful but have potential diminishing effectiveness

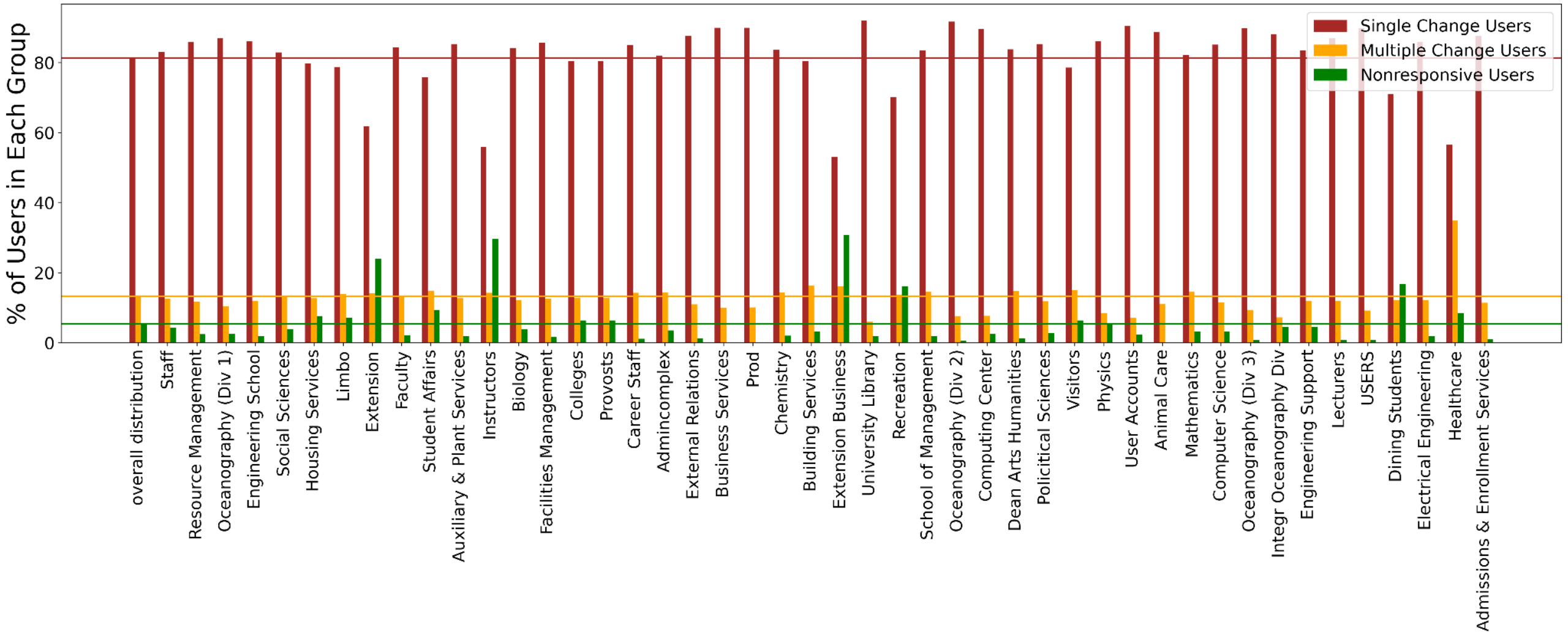
“Idle” period produces little change in user

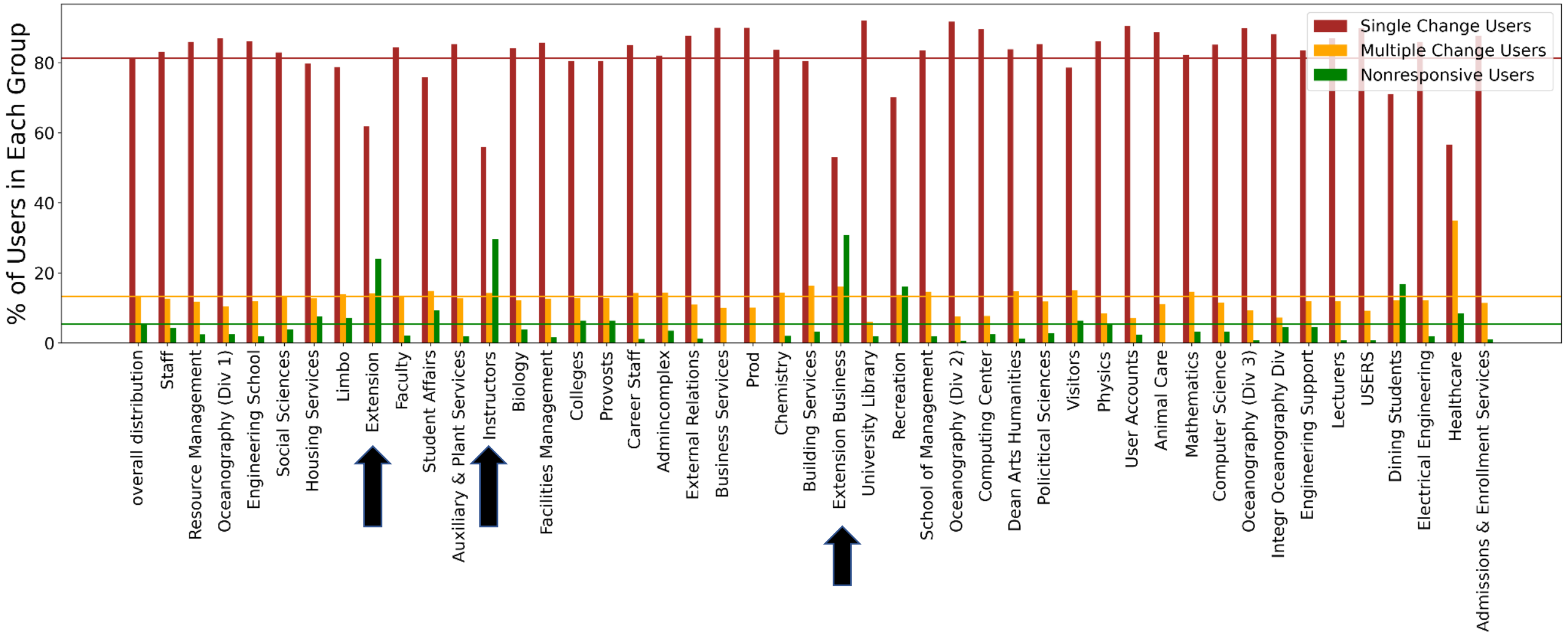
SSO is most effective communication with ~80% user change rate in isolated period

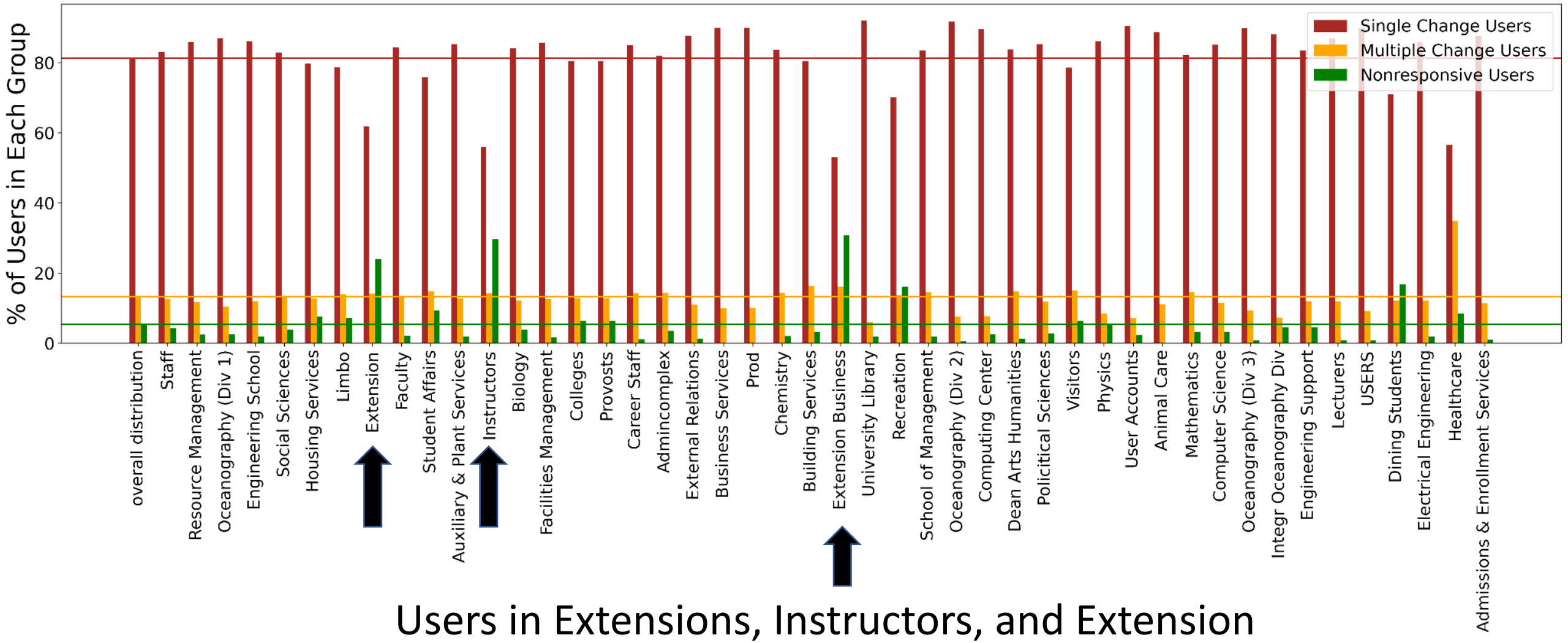
Why do users lag in their update behavior?

Examine a user’s organizational unit and relate it to their change status

Organizational unit is a proxy for someone’s department on campus


% of Users in Each Group
0
20
40
60
80
Single Change Users
Multiple Change Users
Nonresponsive Users
overall distribution
Staff
Resource Management
Oceanography (Div 1)
Engineering School
Social Sciences
Housing Services
Limbo
Extension
Faculty
Student Affairs
Auxiliary & Plant Services
Instructors
Biology
Facilities Management
Colleges
Provosts
Career Staff
Admincomplex
External Relations
Business Services
Prod
Chemistry
Building Services
Extension Business
University Library
Recreation
School of Management
Oceanography (Div 2)
Computing Center
Dean Arts Humanities
Policitical Sciences
Visitors
Physics
User Accounts
Animal Care
Mathematics
Computer Science
Oceanography (Div 3)
Integr Oceanography Div
Engineering Support
Lecturers
USERS
Dining Students
Electrical Engineering
Healthcare
Admissions & Enrollment Services


% of Users in Each Group
0
20
40
60
80
Single Change Users
Multiple Change Users
Nonresponsive Users
overall distribution
Staff
Resource Management
Oceanography (Div 1)
Engineering School
Social Sciences
Housing Services
Limbo
Extension
Faculty
Student Affairs
Auxiliary & Plant Services
Instructors
Biology
Facilities Management
Colleges
Provosts
Career Staff
Admincomplex
External Relations
Business Services
Prod
Chemistry
Building Services
Extension Business
University Library
Recreation
School of Management
Oceanography (Div 2)
Computing Center
Dean Arts Humanities
Policitical Sciences
Visitors
Physics
User Accounts
Animal Care
Mathematics
Computer Science
Oceanography (Div 3)
Integr Oceanography Div
Engineering Support
Lecturers
USERS
Dining Students
Electrical Engineering
Healthcare
Admissions & Enrollment Services



Users in Extensions, Instructors, and Extension Business are significantly overrepresented in the non-responsive user population

Why do users lag in their update behavior?

Repeated same analysis for single change users

Examined relation between organizational unit and when user changed

Why do users lag in their update behavior?

Repeated same analysis for single change users

Examined relation between organizational unit and when user changed

Building services, Recreation, and Dining services are over-represented in the intervention period

Users in peripheral organizations take more time to respond

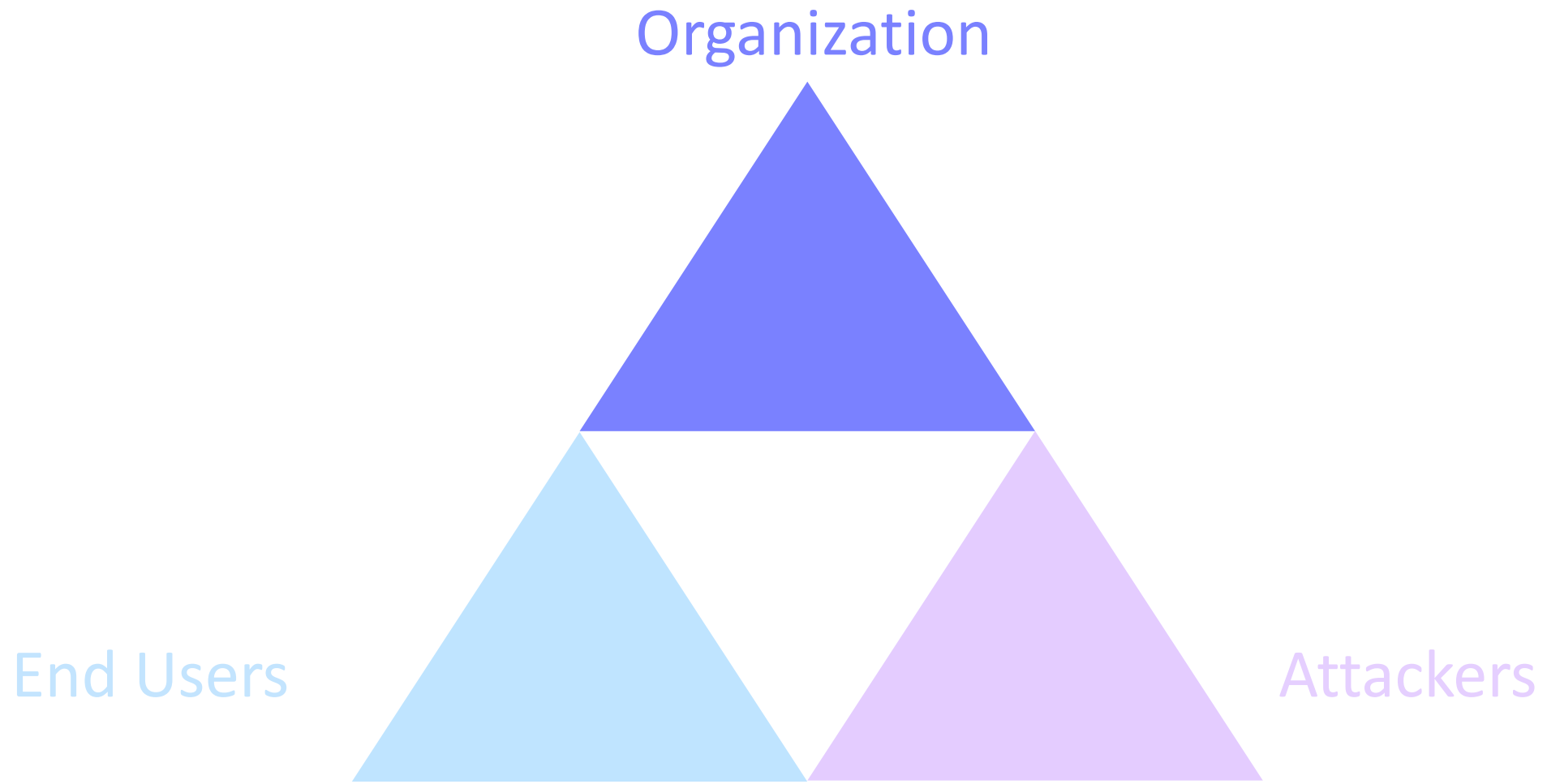
Organizational Effective Communication

SSO is the most effective communication mechanism, email still useful

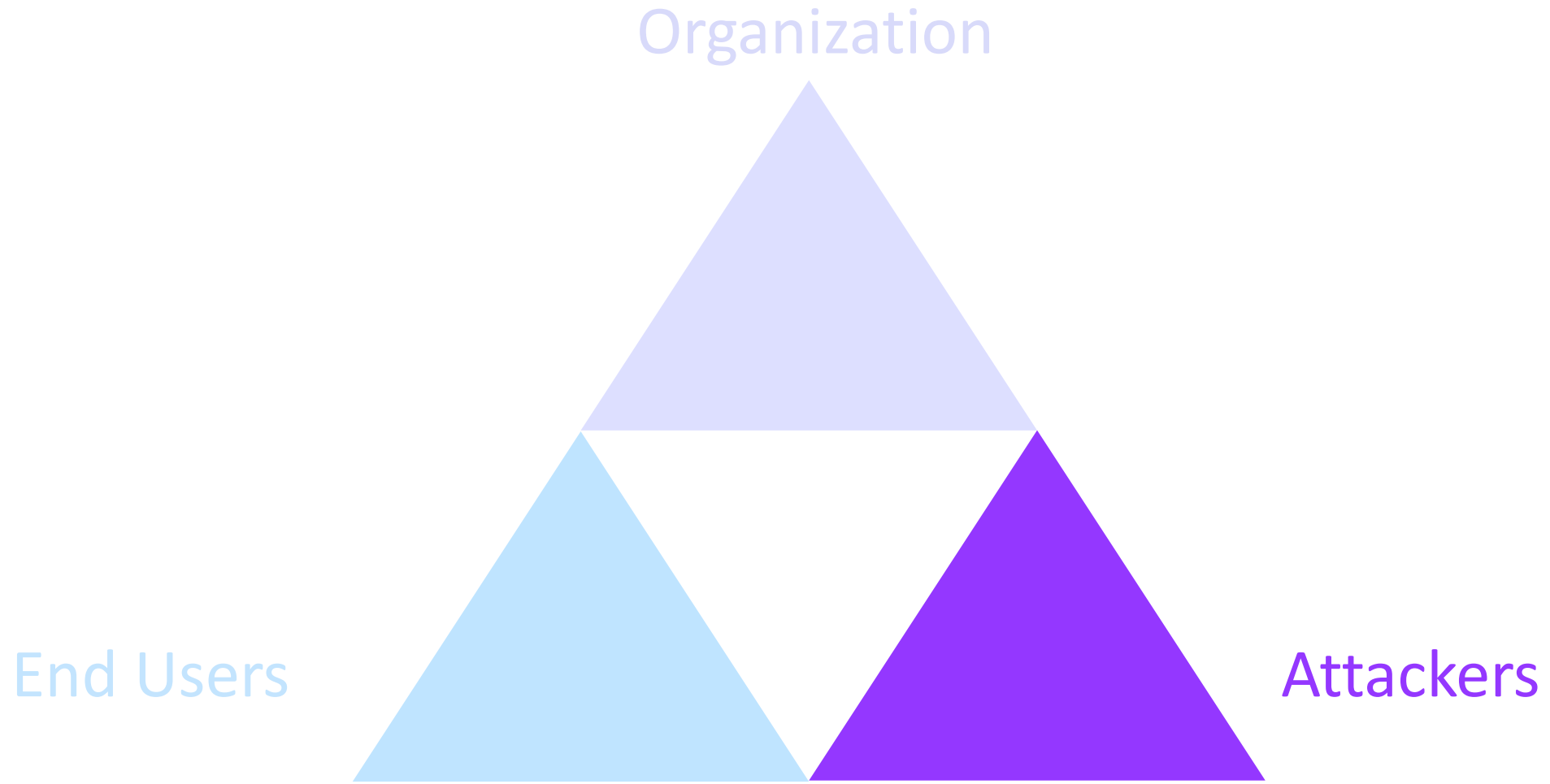
Peripheral users might not use same communication mechanisms as other units on campus, and thus lag in their update behavior

Lessons can and have been used for future policy changes

Understanding user behaviors to better prioritize security processes



Understanding user behaviors to better prioritize security processes



Email accounts are rich in information…

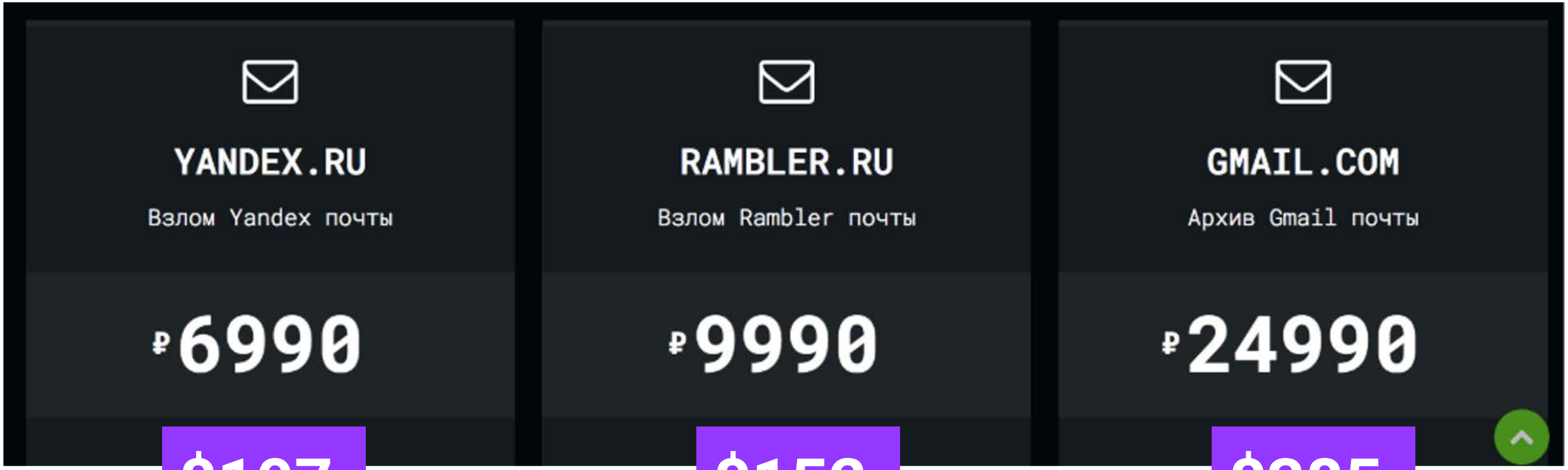
Defenses have made large scale attacks difficult

What are your hopes and dreams?

Targeted attacks remain an issue

Targeted attacks remain an issue

Underground markets provide hack services for hire



$107

$152

$385

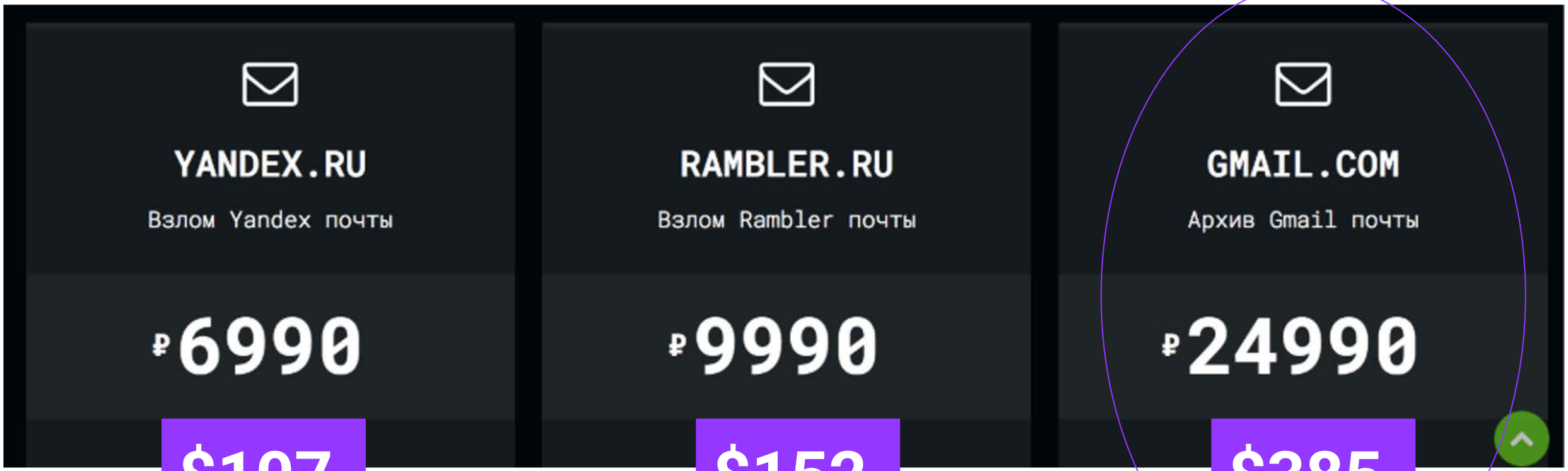
“Hack for hire” market not yet examined

How large is the market?

How sophisticated are the methods of attack?

How widely used are these services?

Focus on Gmail, but results can be generalized

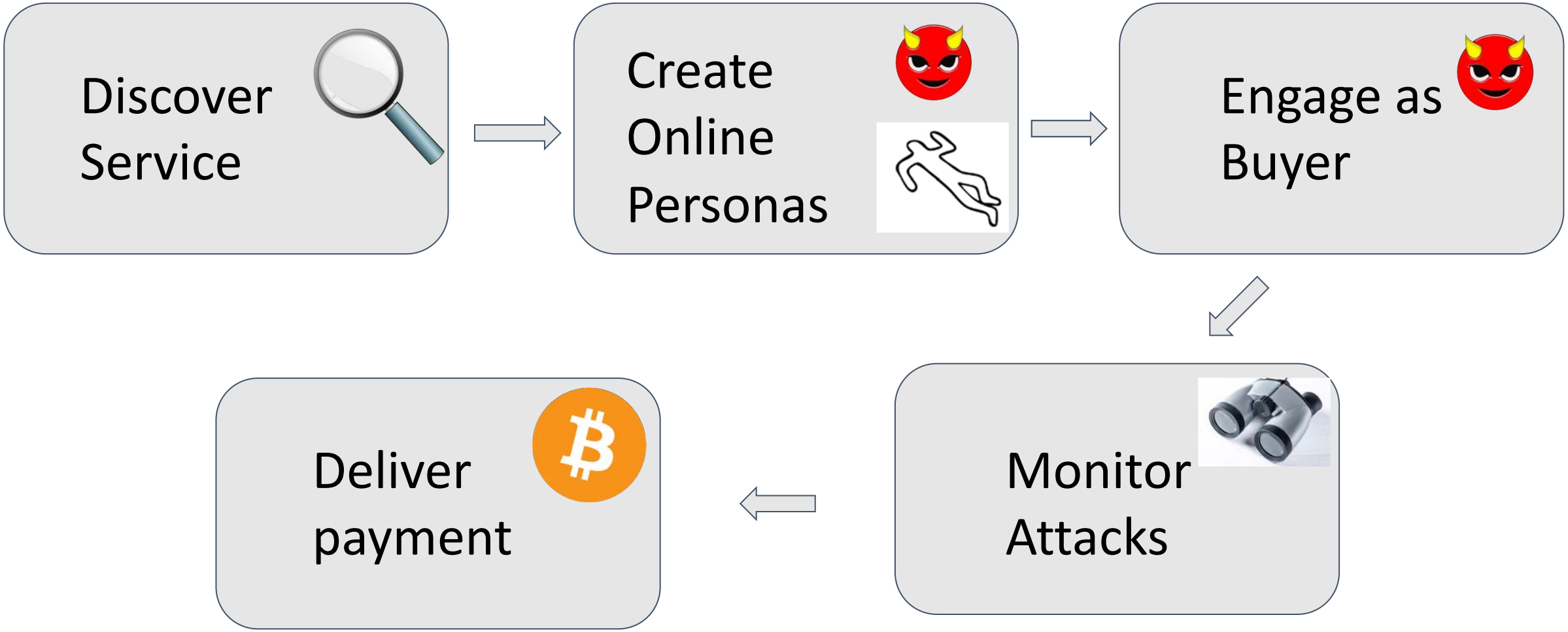


$107

$152

$385

Overview of process

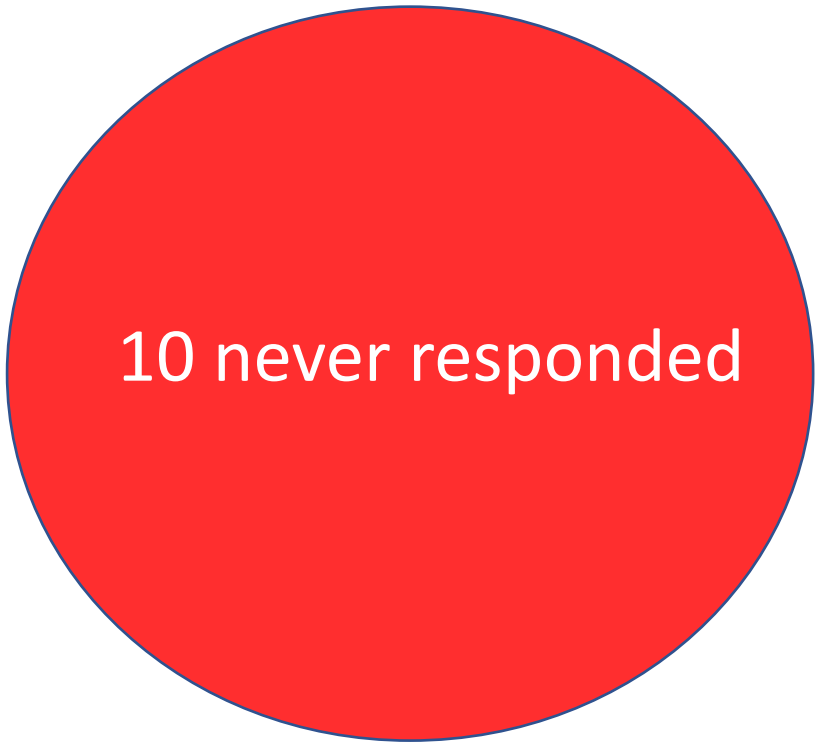


How large is the market?

How sophisticated are the methods of attack?

How widely used are these services?

Breakdown of 27 services



How large is the market?

How sophisticated are the methods of attack?

How widely used are these services?

How sophisticated are the methods of attack?

We never observed: brute force logins, communication outside of email

How sophisticated are the methods of attack?

We never observed: brute force logins, communication outside of email

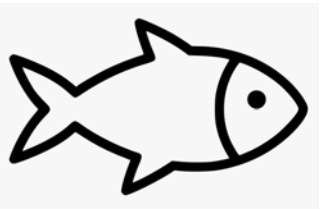
One service sent malware executable that wouldn’t run

How sophisticated are the methods of attack?

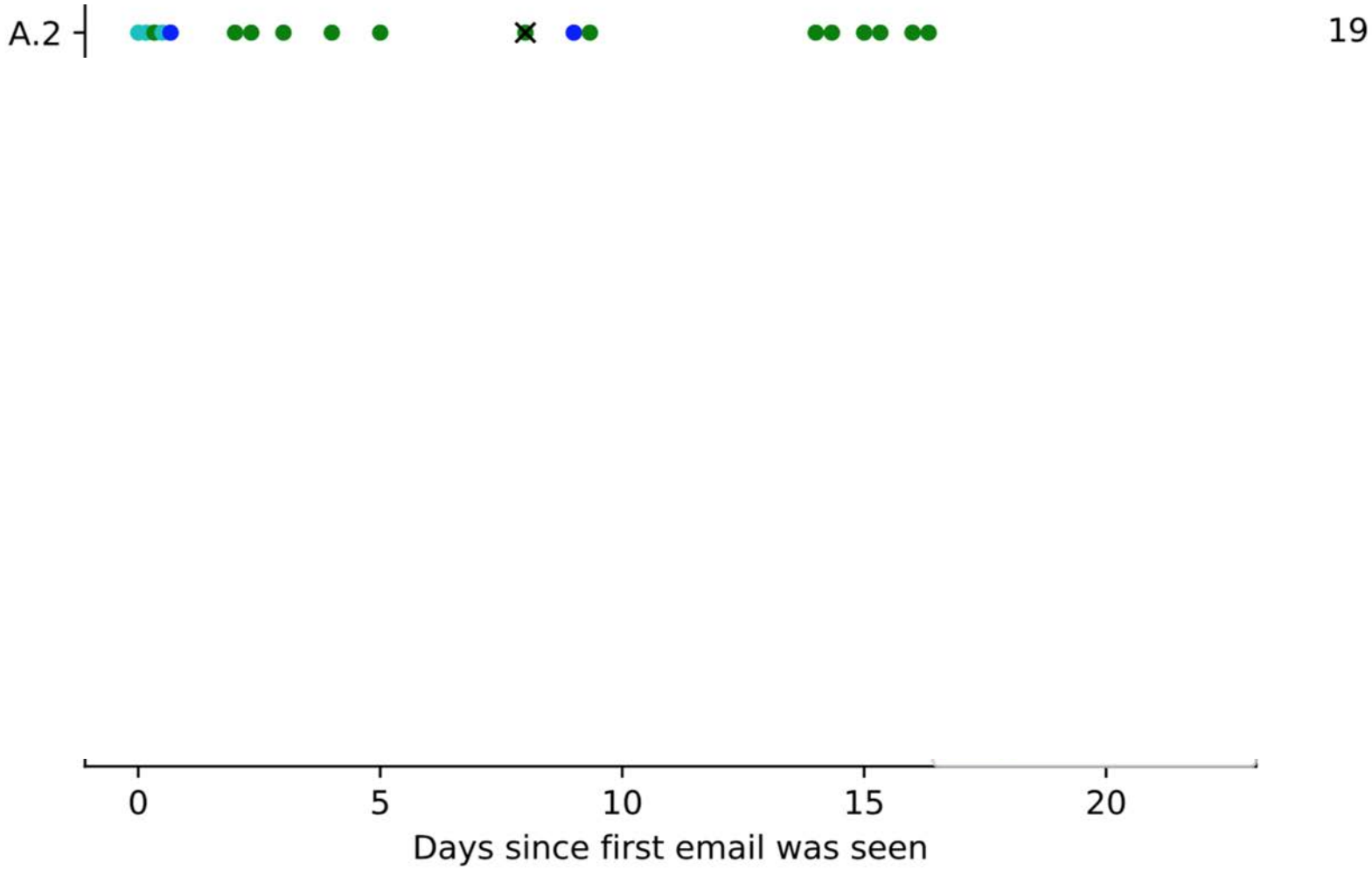
We never observed: brute force logins, communication outside of email

One service sent malware executable that wouldn't run

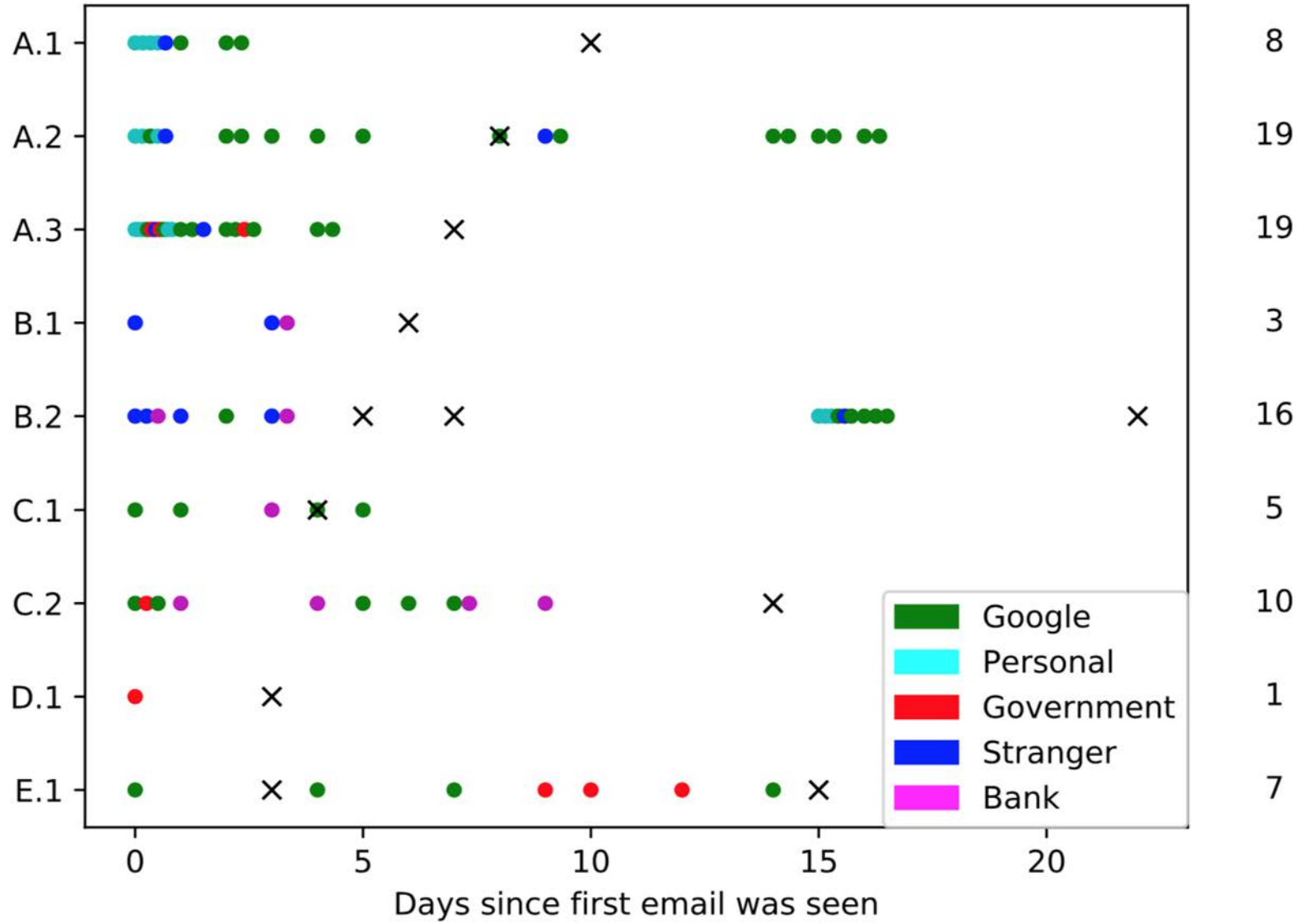
Four of the five services used phishing in their attacks



Phishing attacks were persistent and personalized

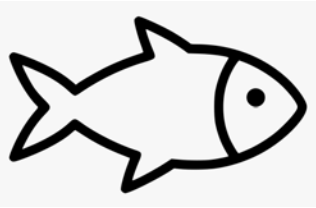


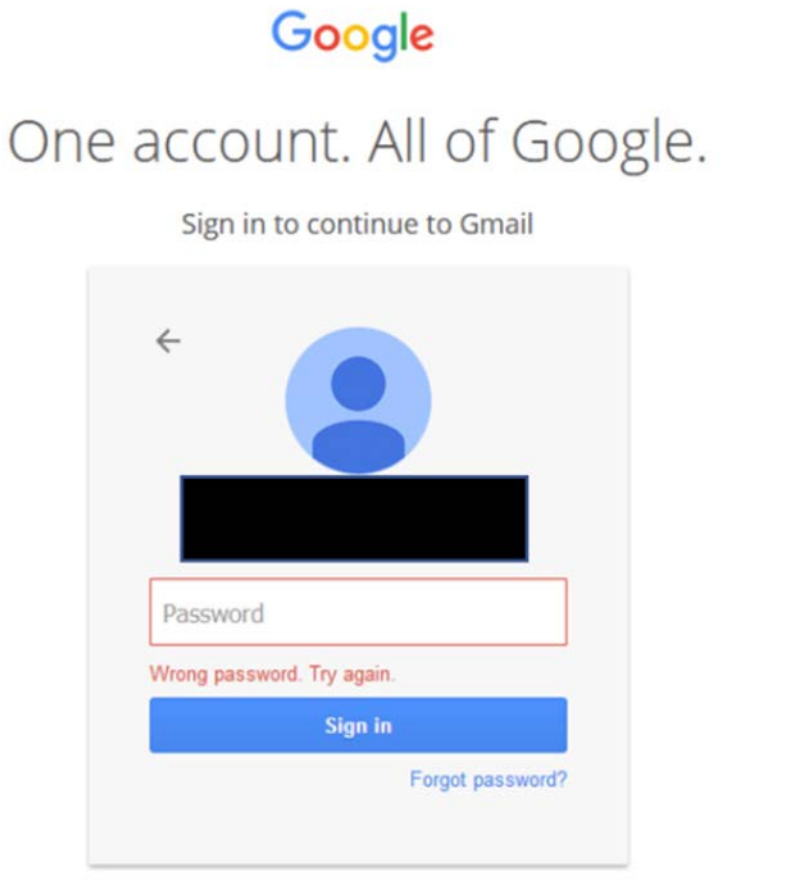
Phishing attacks were persistent and personalized

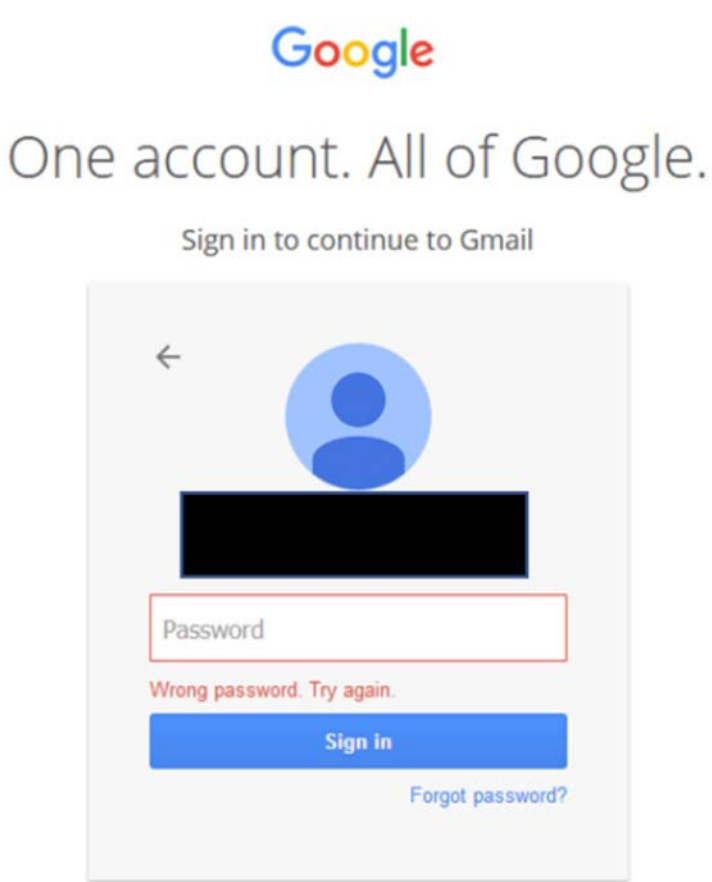


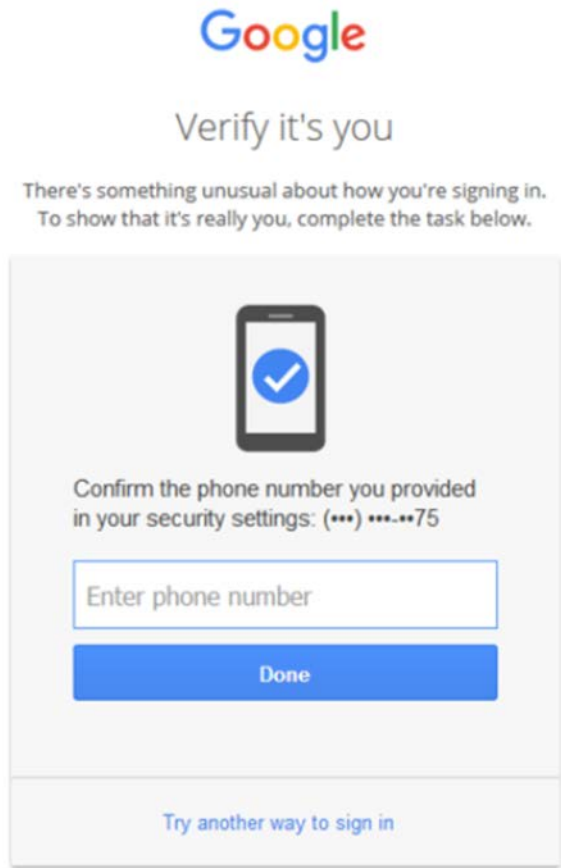
Targeted attacks were able to bypass 2FA

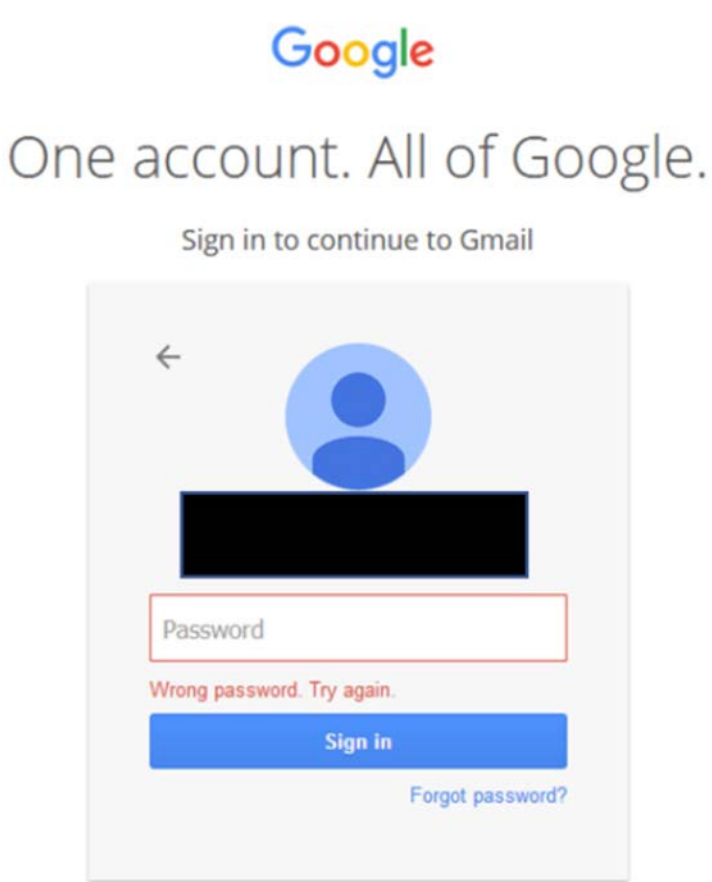
Most phishing attacks accounted for 2FA in their phishing flow

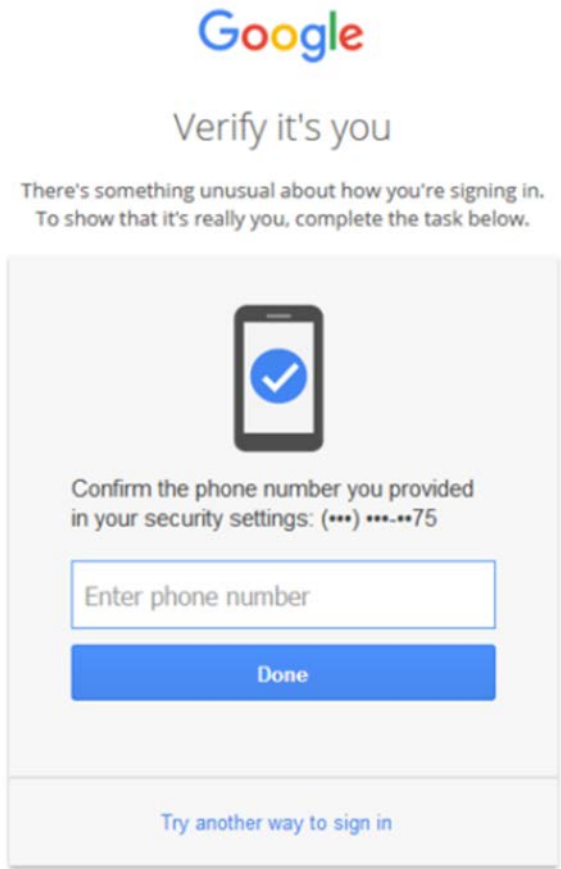


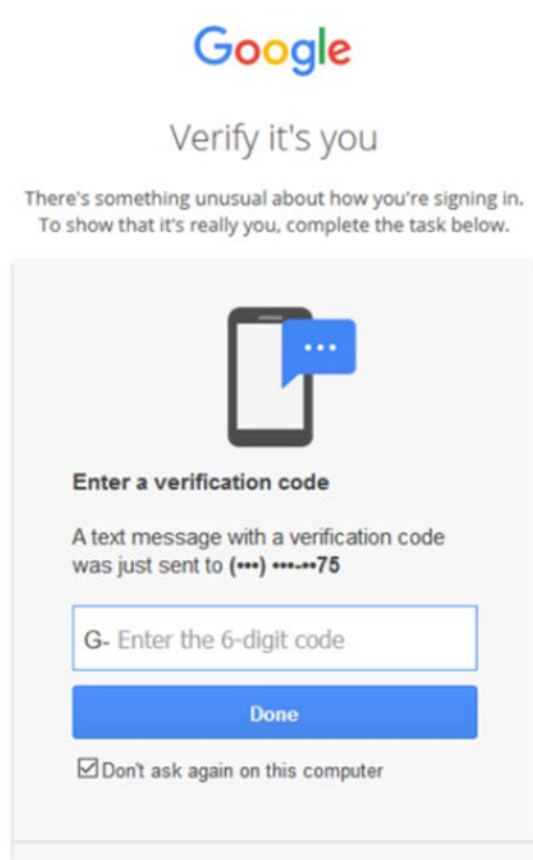

Google
One account. All of Google.
Sign in to continue to Gmail
[redacted]
Password
Wrong password. Try again.
Sign in
Forgot password?

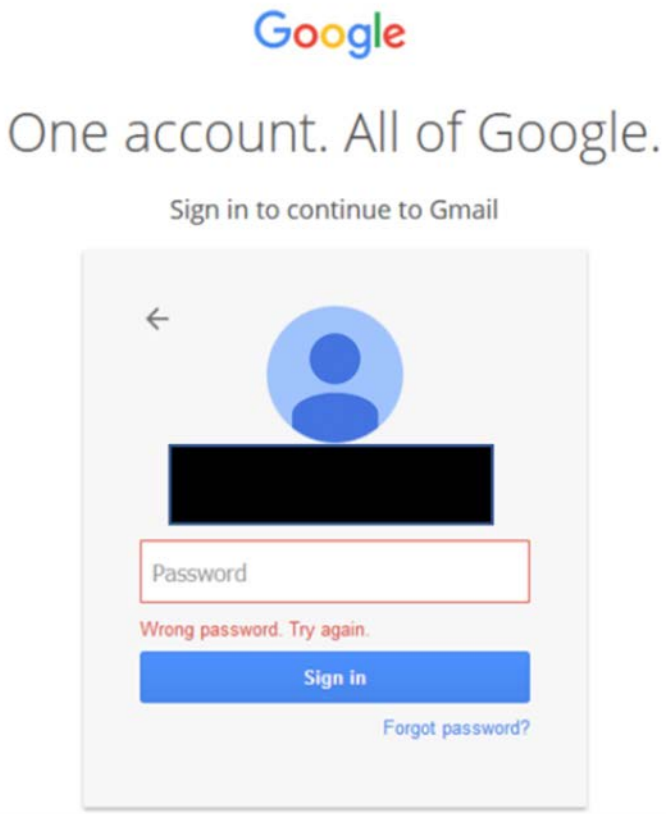

Google
One account. All of Google.
Sign in to continue to Gmail
Password
Wrong password. Try again.
Sign in
Forgot password?


Google
Verify it's you
There's something unusual about how you're signing in.
To show that it's really you, complete the task below.
Confirm the phone number you provided in your security settings: (•••) •••-••75
Enter phone number
Done
Try another way to sign in


Google
One account. All of Google.
Sign in to continue to Gmail
[redacted]
Password
Wrong password. Try again.
Sign in
Forgot password?


Google
Verify it's you
There's something unusual about how you're signing in.
To show that it's really you, complete the task below.
Confirm the phone number you provided in your security settings: (•••) •••-••75
Enter phone number
Done
Try another way to sign in

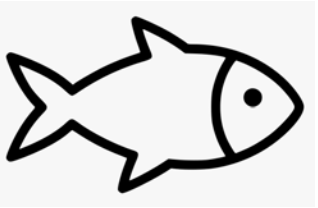

Google
Verify it's you
There's something unusual about how you're signing in.
To show that it's really you, complete the task below.
Enter a verification code
A text message with a verification code was just sent to (•••) •••-••75
G- Enter the 6-digit code
Done
Don't ask again on this computer


Google
One account. All of Google.
Sign in to continue to Gmail
[redacted]
Password
Wrong password. Try again.
Sign in
Forgot password?

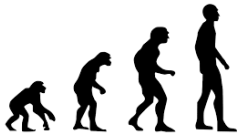
2FA

Targeted attacks were able to bypass 2FA

Most phishing attacks accounted for 2FA in their phishing flow



Phishing attempts that did not anticipate 2FA adapted



One service doubled the price of their contract upon finding 2FA

How large is the market?

How sophisticated are the methods of attack?

How widely used are these services?

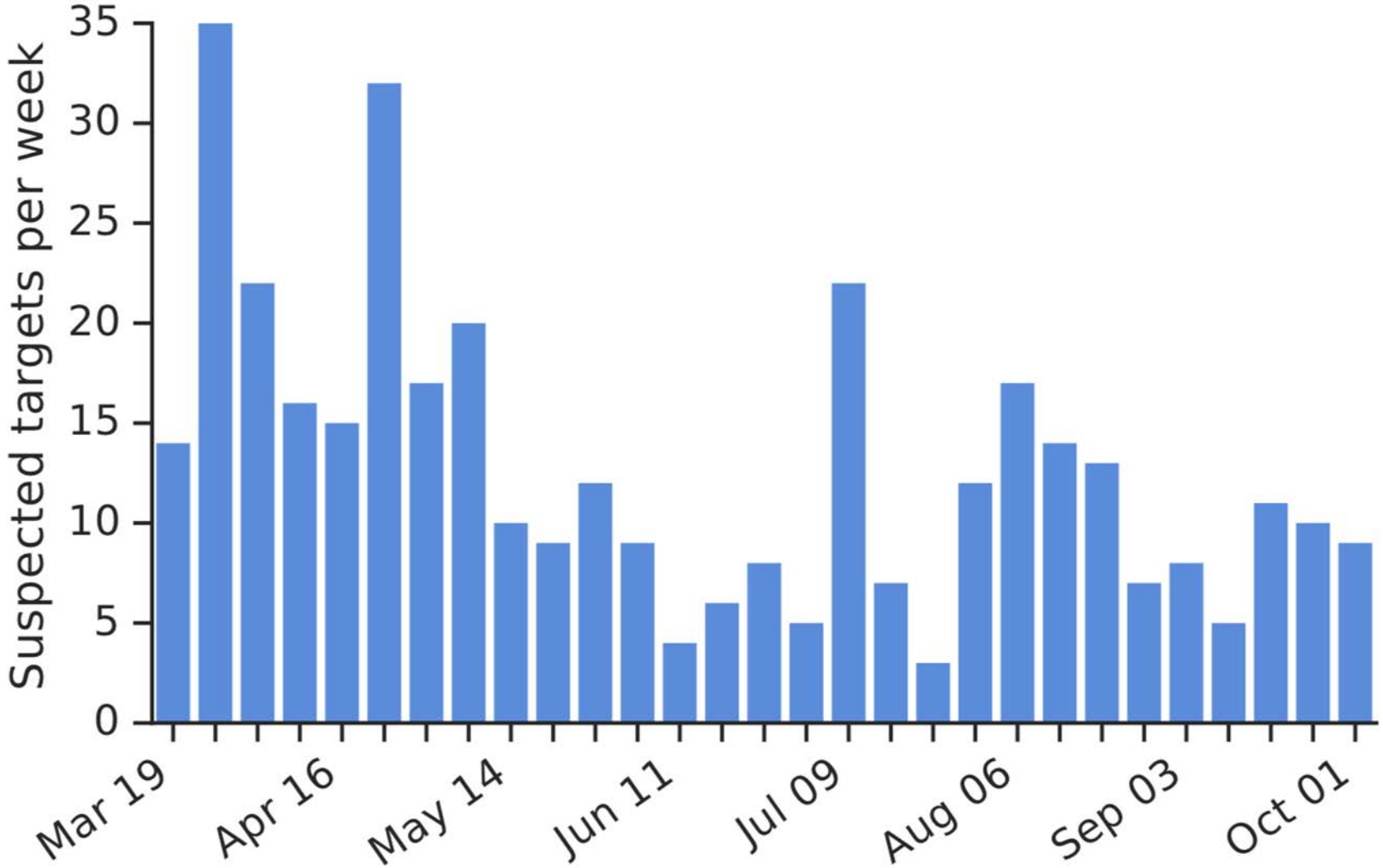
Automation allowed us to fingerprint services

Much of functionality was quick and real-time

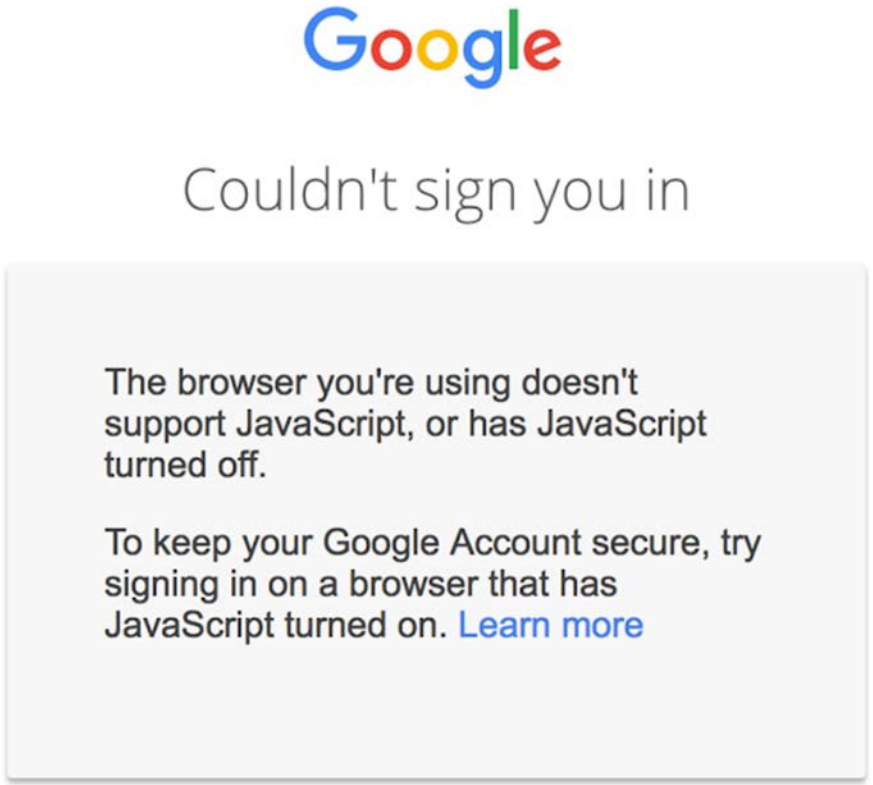
Analyzed metadata of logins to create an fingerprint for three services

Fingerprinting of automated framework allowed us to view reach of services

Hundreds of people are affected by these services



Gmail defenses introduced against MITM phishing



Better protection against Man in the Middle phishing attacks

April 18, 2019

Posted by Jonathan Skelker, Product Manager, Account Security

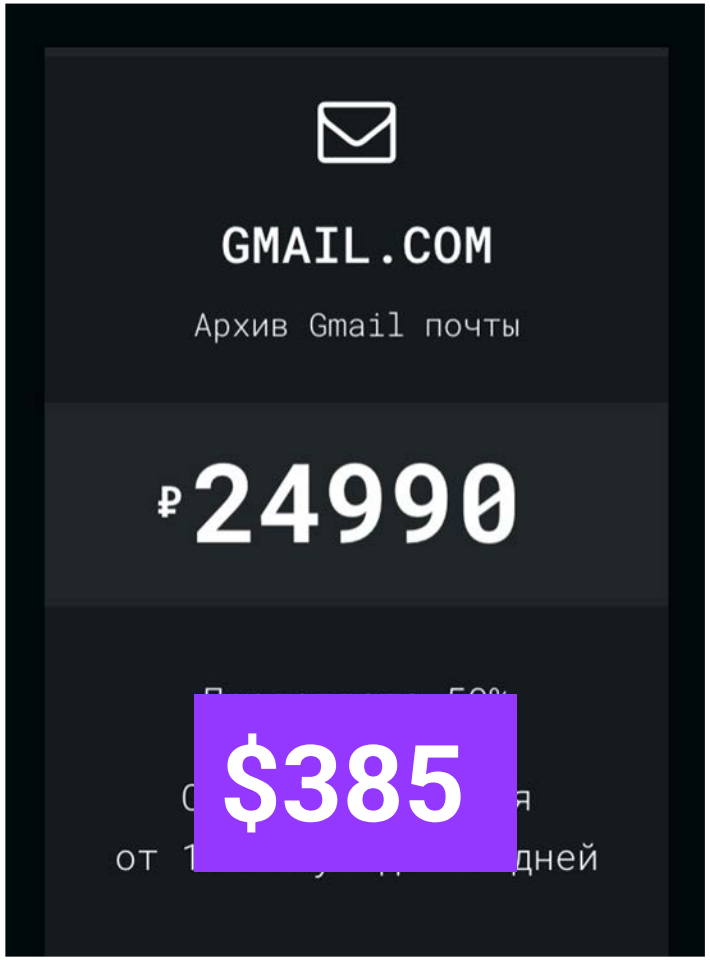
We're constantly working to improve our phishing protections to keep your information secure. Last year, we announced that we would require JavaScript to be enabled in your browser when you sign in so that we can run a risk assessment whenever credentials are entered on a sign-in page and block the sign-in if we suspect an attack. This is yet another layer of protection on top of existing safeguards like Safe Browsing warnings, Gmail spam filters, and account sign-in challenges.

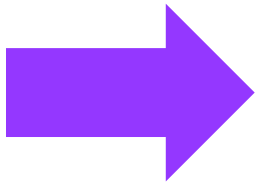
However, one form of phishing, known as "man in the middle" (MITM), is hard to detect when an embedded browser framework (e.g., Chromium Embedded Framework - CEF) or another automation platform is being used for authentication. MITM intercepts the communications between a user and Google in real-time to gather the user's credentials (including the second factor in some cases) and sign in. Because we can't differentiate between a legitimate sign in and a MITM attack on these platforms, we will be blocking sign-ins from embedded browser frameworks starting in June. This is similar to the restriction on webview sign-ins announced in April 2016.

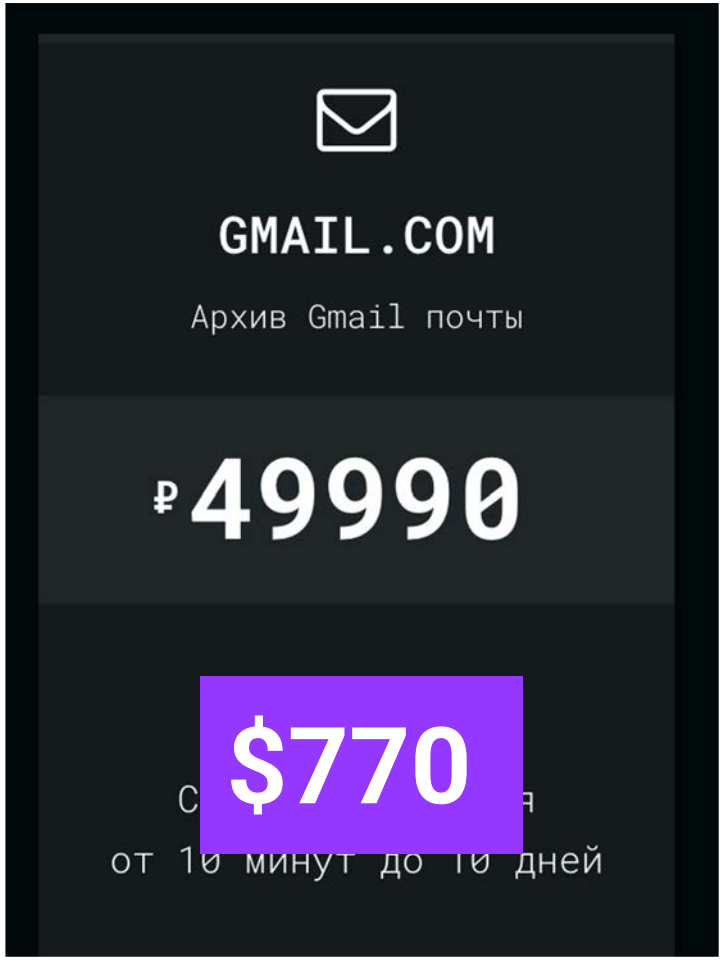
https://security.googleblog.com/2018/10/announcing-some-security-treats-to.html

https://security.googleblog.com/2019/04/better-protection-against-man-in-middle.html

Increase in price for services since study finished

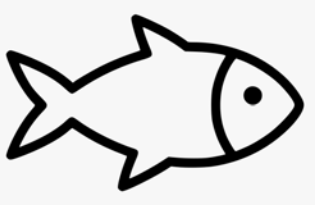






Hack for hire attacker characterization

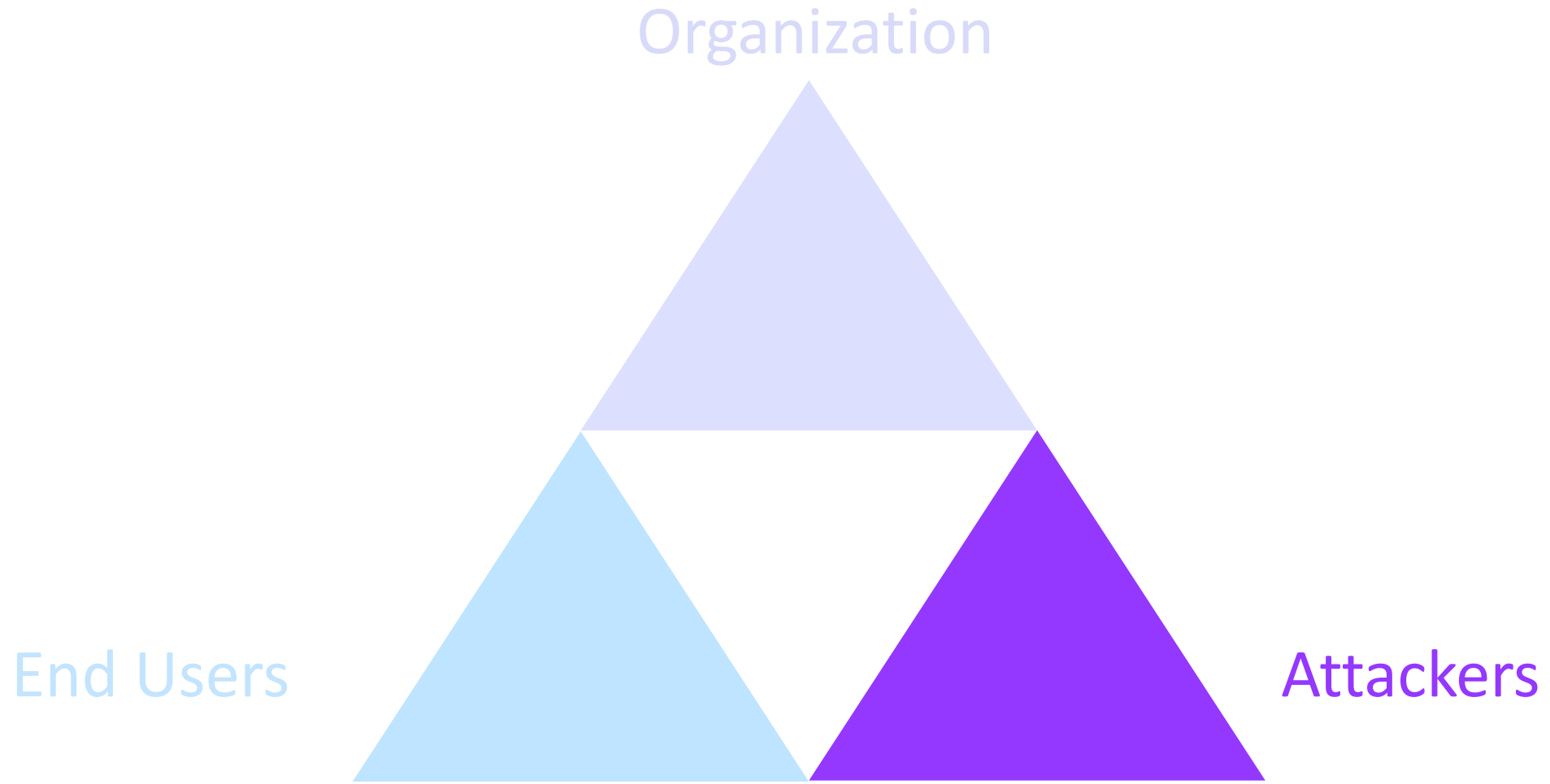
Sophisticated attackers can bypass 2FA via phishing



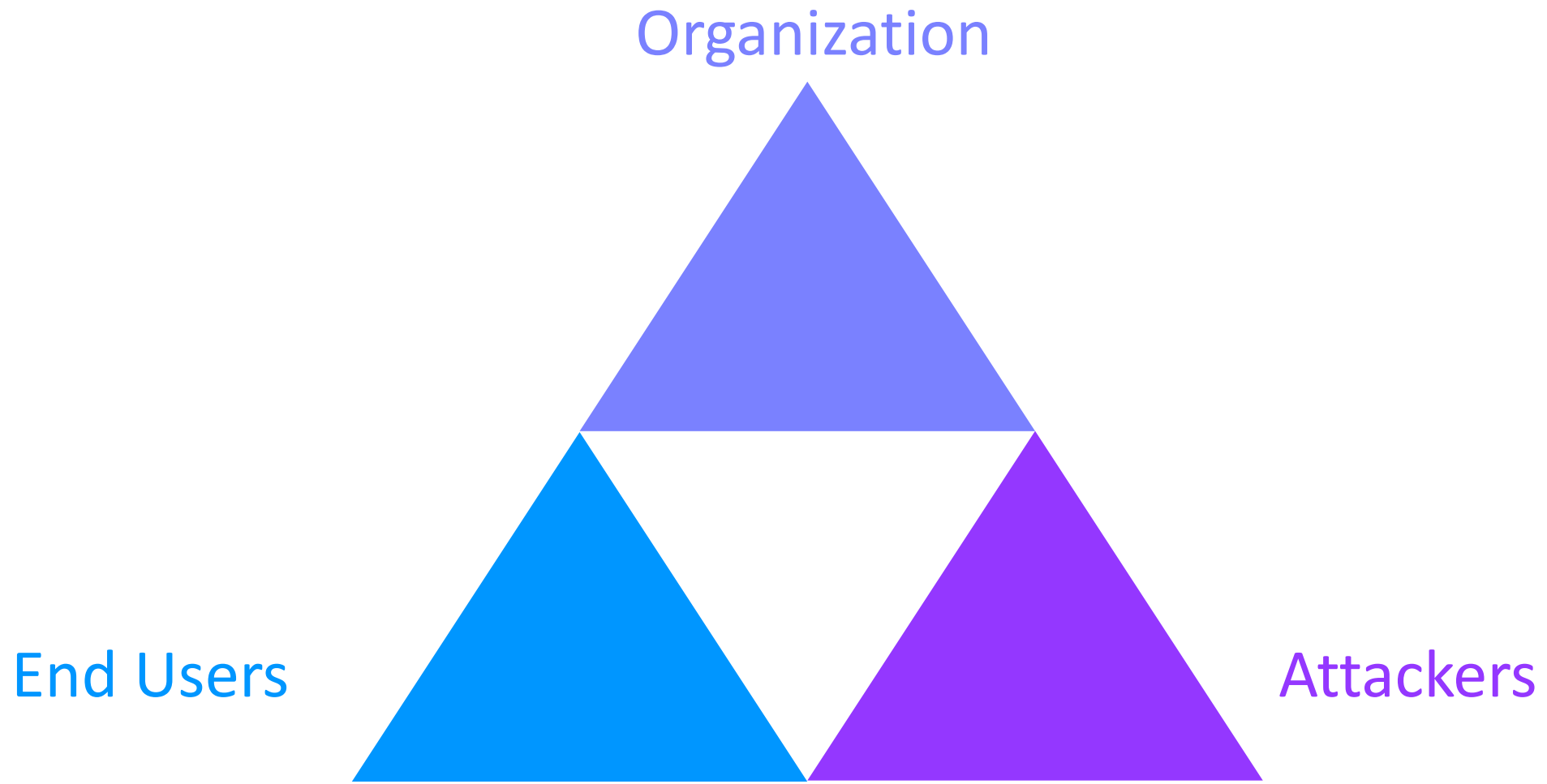
Persistent attacks span up to multiple weeks

Successful services affect roughly 1 in a million Gmail users

Understanding user behaviors to better prioritize security processes



Understanding user behaviors to better prioritize security processes

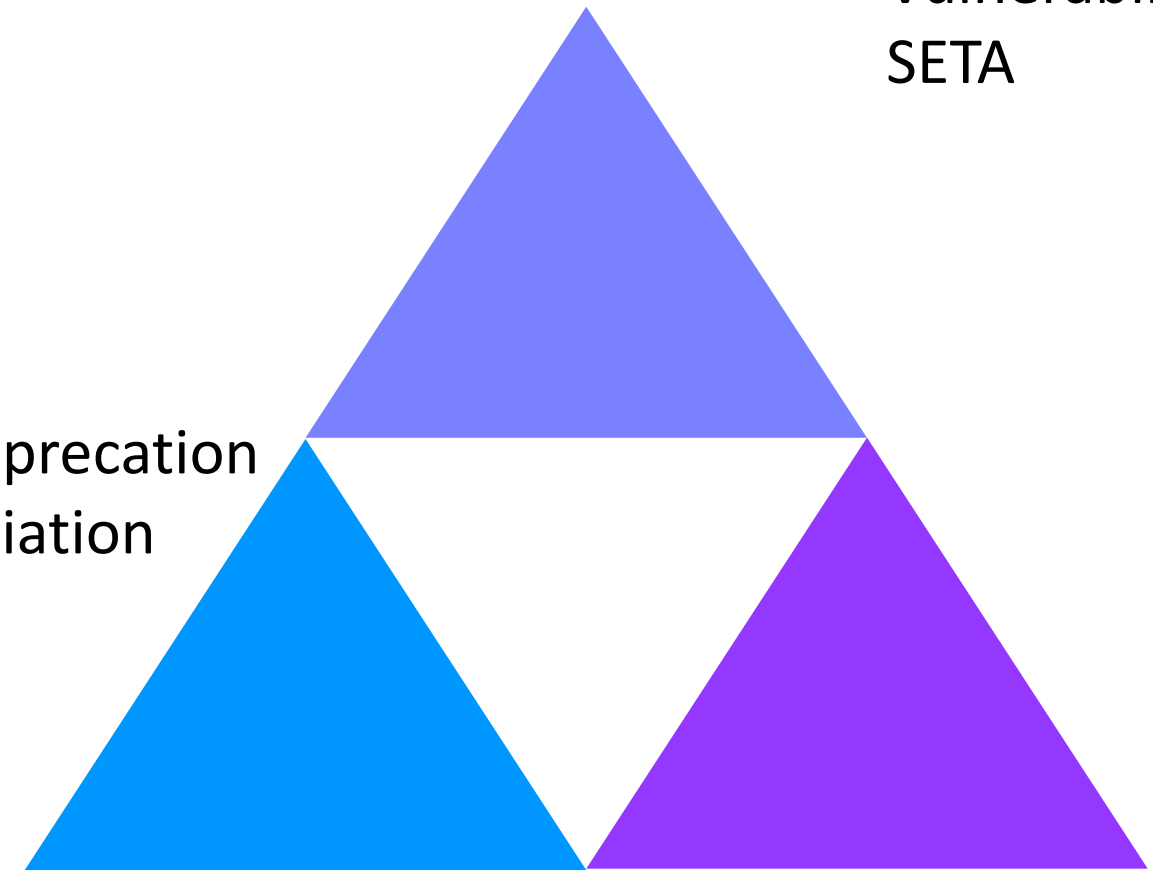


Understanding user behaviors via large-scale empirical measurement can help us better prioritize security processes

Understanding user behaviors to better prioritize security processes

Organization

Training Efficacy
Vulnerability Remediation
SETA



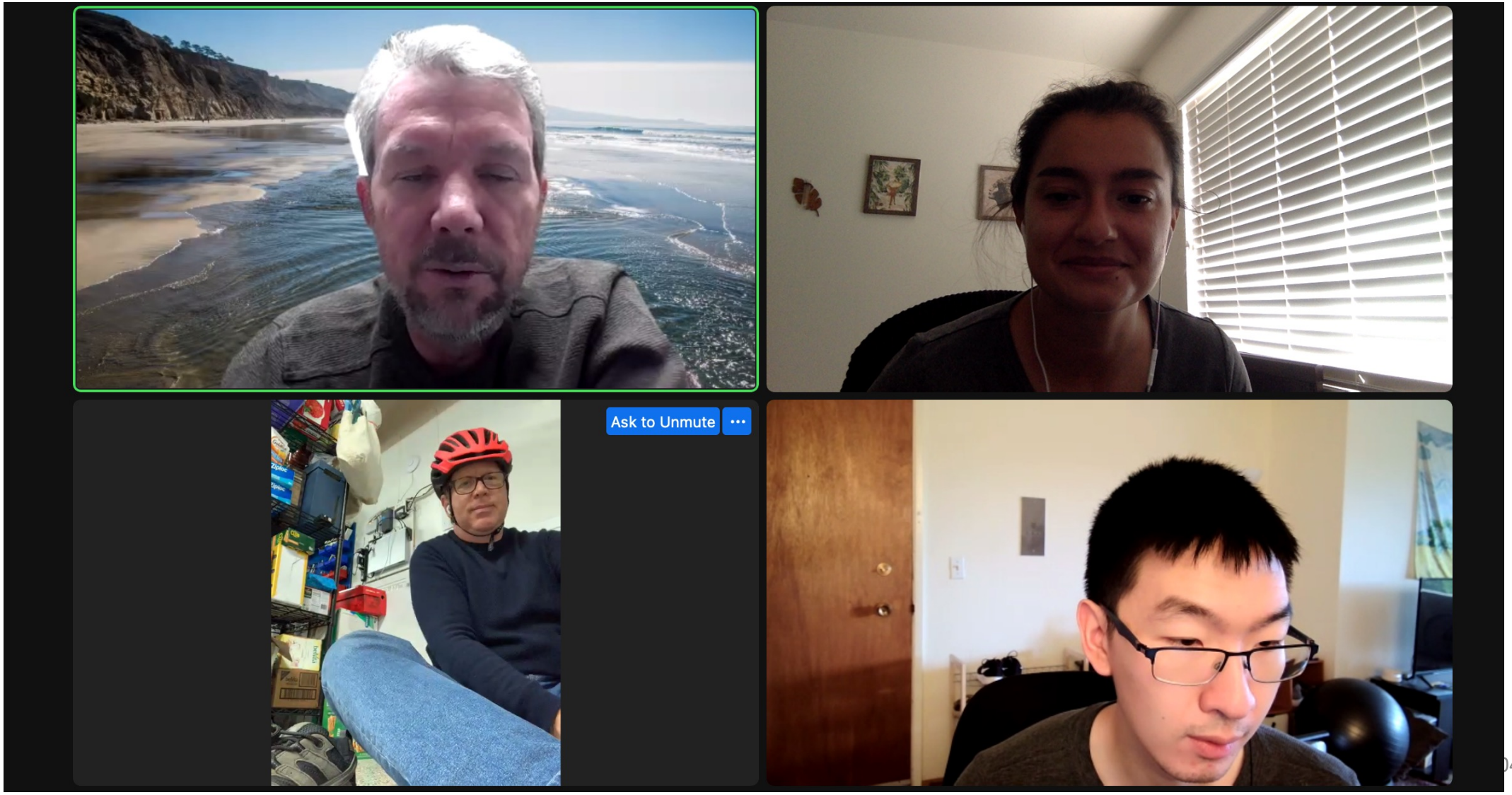
HTTPS longtail
Web Feature Deprecation
Device Differentiation
DPI Risks

End Users

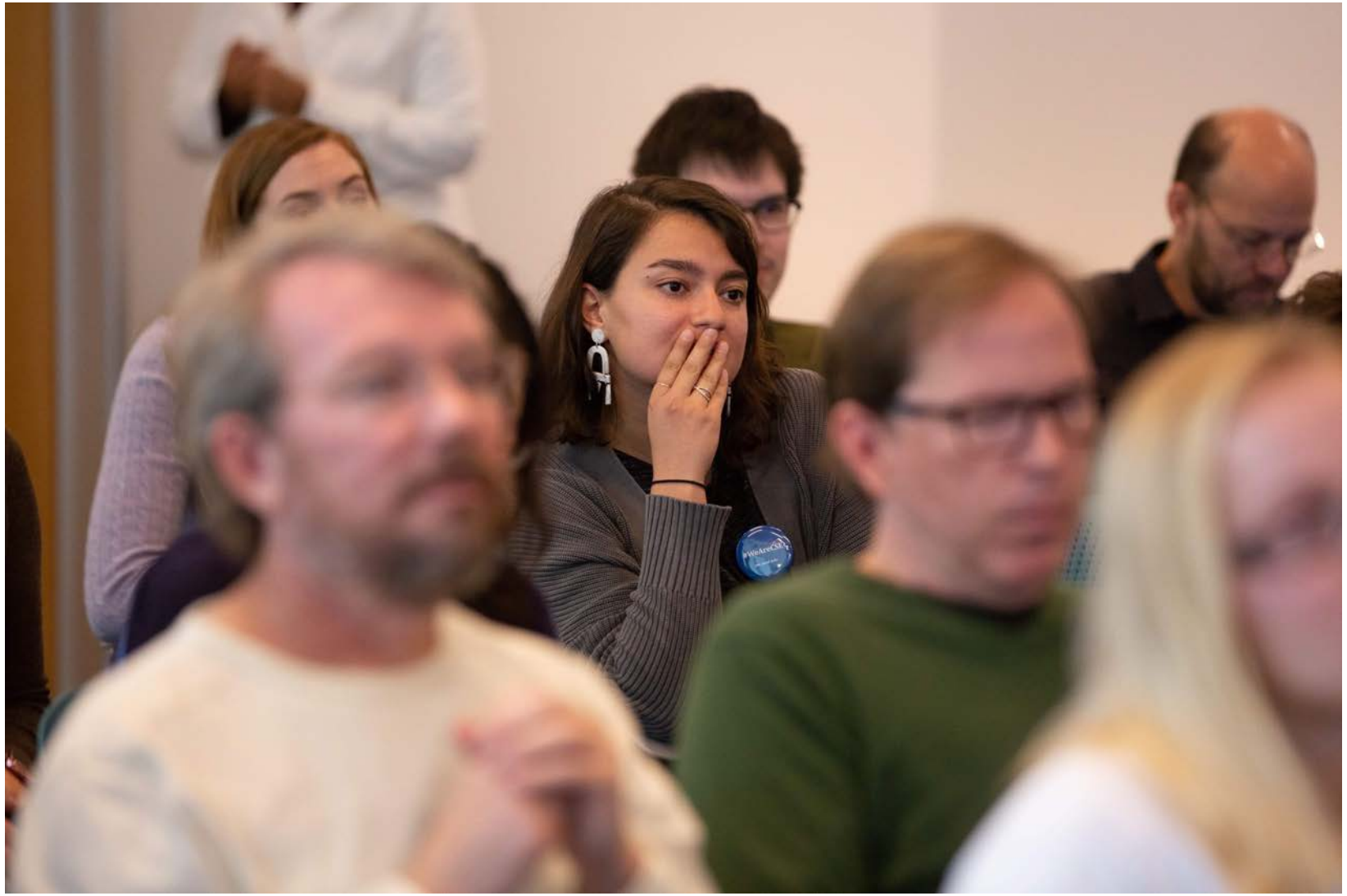
Attackers

Thank you

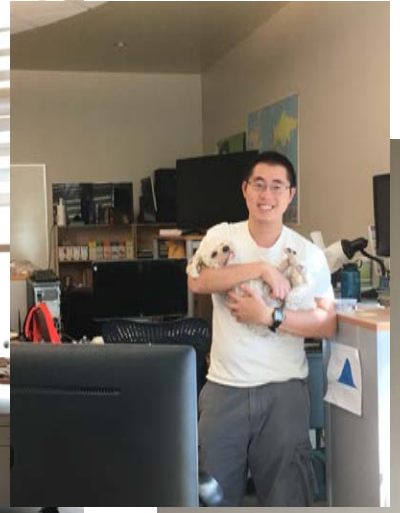
A Counter-Roast

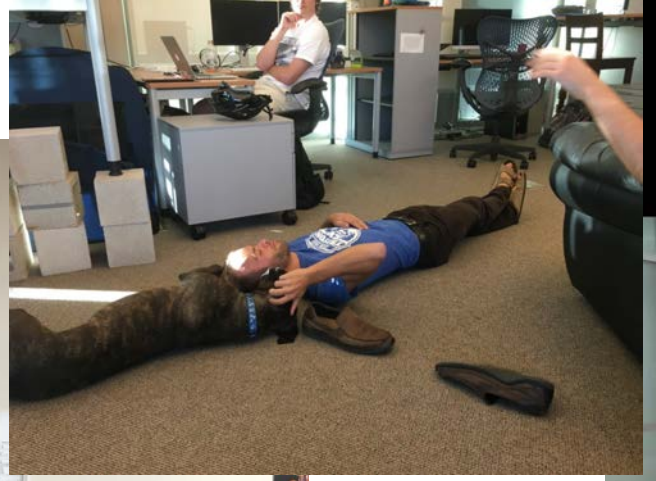


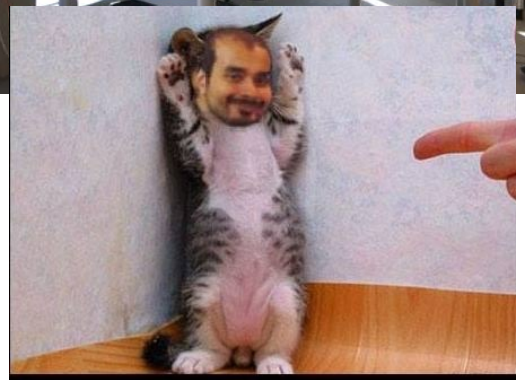
A story



Thank you!!

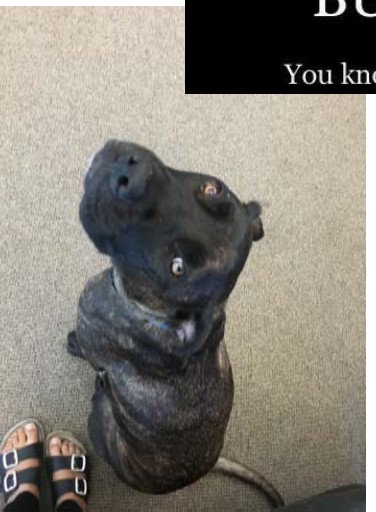






BUSTED

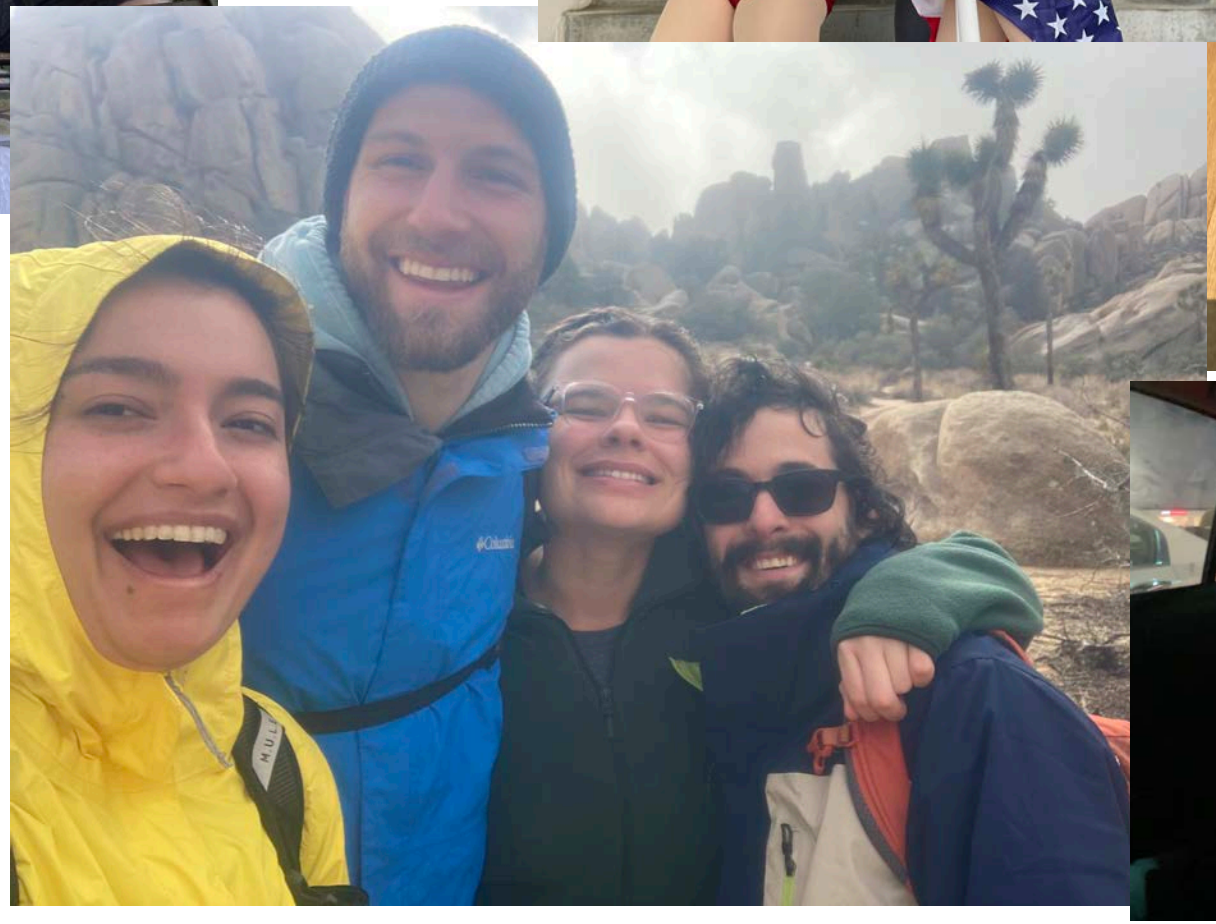
You know what you did.




Google


WE THE PEOPLE


BIKE TOURS



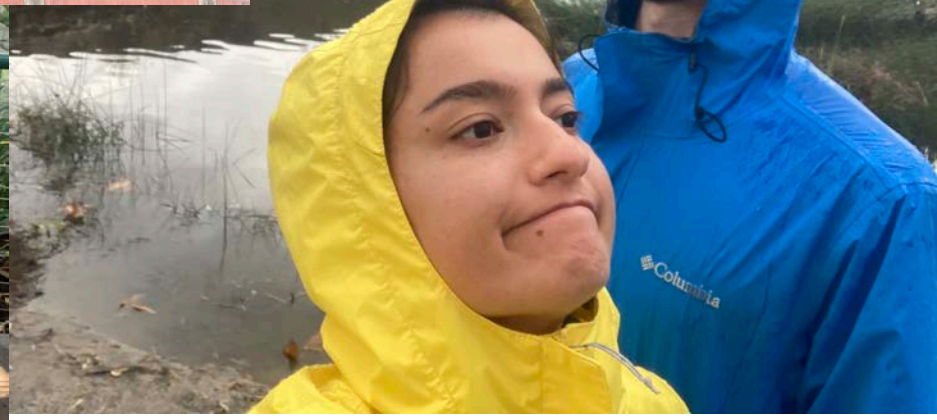

MARVEL STUDIOS
MS MARVEL

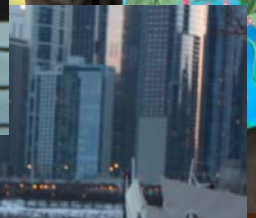

UCSD












Canon
EOS
REBEL

Thank you

Questions?

arianamirian.com

arianamirian28@gmail.com

@arimirian

@amirian@infosec.exchange