Understanding Users' Interaction with Login Notifications (Extended Version)

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Abstract

Login notifications are intended to inform users about recent sign-ins and help them protect their accounts from unauthorized access. The notifications are usually sent if a login occurs from a new location or device, which could indicate malicious activity. They mostly contain information such as the location, date, time, and device used to sign in. Users are challenged to verify whether they recognize the login (because it has been them or someone they know) or to proactively protect their account from unwanted access by changing their password. In two user studies, we explore users' comprehension, reactions, and expectations of login notifications. We utilize two treatments to measure users' behavior in response to login notifications sent for a login they initiated themselves or based on a malicious actor relying on statistical sign-in information. Users feel relatively confident identifying legitimate logins but demonstrate various risky and insecure behaviors when it comes to malicious sign-ins. We discuss the identified problems and give recommendations for service providers to ensure usable and secure logins for everyone.

1 Introduction

To protect accounts from unauthorized access, login notifications are intended to inform users about recent sign-ins. Depending on the service, the notifications are only sent if the login occurred from an *unknown location* or *new device*, which could indicate malicious activity.

Notifications are often delivered via email and include details about the device (browser and OS), approximate location, date, and time of the sign-in. Users need to decide whether the reported login is legitimate or malicious and are recommended to change the password in case the login is unfamiliar. Logins can be confused to be malicious when users *share accounts* and friends or family log in unknowingly. While the notification is intended to protect users and provide a feeling of security, it can also be perceived as burdening and overwhelming by requiring a decision based on technical jargon and highlighting negative consequences.

Previous work [28] focused on challenge-based notifications and studied incident-response information-seeking and mental models about attackers. In contrast, we focus on *granted access* notifications informing users about a recent sign-in and analyze users' comprehension, expectations, and reaction to the notification.

In this work, we collected and analyzed 67 login notifications sent by real-world services and developed a *baseline* notification that we employed in two user studies. In the first study ($n = 220$), we asked participants to imagine having an account they recently have or have *not* signed in to (depending on their treatment) and then showed participants a notification that either contained their current *real* sign-in information or was prefilled with information from an attacker relying on statistical data (i.e., California, USA; Chrome on Windows). The second study ($n = 229$), disguised as a psychological test, let users create an account they had to sign in to during the multi-stage study. Participants then either received a legitimate notification to their email upon signing in themselves (*Legit*) or unexpectedly received a notification prefilled with statistical sign-in information after around one week (*Malicious*). We sought to answer the following questions:

RQ1 *[Comprehension & Reaction] Do users understand why they received the notification and which factors may have caused receiving it? Which actions do users take in response, and is resolving the situation a priority?*

We find that participants correctly understand that "a login" caused receiving the notification. However, they are unaware of or misinterpret the trigger and are thus unsure how to react appropriately. Unique to Study 1, participants either claim they would change the password (Legit) or report they would mistakenly ignore the notification (Malicious). Comparing both studies, we find a large gap between participants' intended and actual behavior regarding password changes.

RQ2 *[Decision-Making & Execution] Do the currently employed notifications help users distinguish malicious and legitimate logins? Which information helps account owners with their decision, and do current notifications appropriately guide users in resolving the situation?*

Based on device and location, participants can correctly attribute notifications caused by their own logins, but they are confused when the notification is unexpected (Malicious) and struggle to identify the correct reaction.

RQ3 *[Perception & Expectation] How do login notifications make users feel? When do they expect notifications to be sent, and how does prior experience affect their decision?*

Notifications about malicious logins evoke (more) negative emotions, but participants who changed their password also felt empowered by taking action to protect their account. Interestingly, more than 90% of the participants expect services to send login notifications because it makes them feel protected.

Our results suggest that login notifications are not, *per se*, a net positive for online account security. We find only $\frac{1}{5}$ of the participants who should have changed their password to protect their account actually did. While participants appreciate when companies decide to monitor their accounts for incidents, services that send notifications for every login can cause warning fatigue. We find malformed login notifications and current anti-phishing advice problematic and give clear recommendations for service providers to improve their notifications. While login notifications can help to reinforce account security, we think that protecting their accounts by identifying malicious logins should not be the sole responsibility of the user and highlight the need for better notifications.

2 Related Work

Next, we outline how our research extends related work.

2.1 Login Notifications & Challenges

Related to our work is a qualitative interview study ($n = 67$) by Redmiles [28]. It explores the account security incident response at Facebook by interviewing users who experienced a login incident. Different from our work, Redmiles focused on "secondary authentication" notifications that prompt users to enter a code to access their accounts. Redmiles interviewed participants from 5 countries and reported on incident-response information-seeking and mental models about attackers. Regarding the notifications' effectiveness, Redmiles identified a lack of key information to be problematic, e.g., the likelihood that the notification is about a legitimate threat. In contrast, our work studies a different notification (see Section 3) and focuses on users' comprehension, expectations, and reaction to the notification and not on regaining access or mental models about attackers. Markert et al. [21] studied administrators' configuration of risk-based authentication (RBA). The predefined notifications were slightly customized, and only few administrators opted to disable them completely. Generally, participants lacked consensus about which information to include. Further aspects were the need for more context and explanation to prevent phishing attacks or the inaccuracy of IP-based location estimation. Wardle [45] measured the time it takes for leaked credentials to be abused. For this, Wardle created accounts on web services, intentionally leaked them online, and then used login notifications, among other signals, to measure the time between the leak of the credentials and their first malicious abuse. A study by Doerfler et al. [6] evaluated the efficacy of login challenges in preventing account takeovers, finding that up to 94% of phishing-rooted hijacking attempts and 100% of automated hijacking attempts can be prevented. Still, Gavazzi et al. [9] found that only about 20% of popular websites employ risk-based measures. Wiefling et al. [48] showed that verification codes sent via email are the de facto standard for login challenges enforced by RBA. In a subsequent study, they demonstrated that providing this code in the subject can reduce the login time [49]. Jubur et al. [14] presented an attack to bypass push-based two-factor authentication (2FA) notifications.

2.2 Security Warning & Notification Design

There is a large body of literature on security warning design [5, 31, 43]. The most prominent applications are notifications in the context of TLS [2, 8], phishing [27], and malware [3], as well as domains like warnings for developers [12] or countering misinformation [15]. For user authentication, there is work on breach notifications [13, 50], password-reuse notifications [11, 38], notifications to promote the use of 2FA [10, 29], or FIDO2 [16], or protect users from using common PINs [20].

While certain design patterns discussed in these works, like the use of opinionated design, proved to be effective for certain applications [8], we did not observe such patterns in login notifications. This is likely owed to the uncertainty of whether a true threat is present. Similarly, the use of alarming language or wording highlighting urgency was low. Interestingly, only a handful of notifications in our analysis (see Section 3) tried to explain why the notification is sent and attempted to address contextual misunderstandings [21, 31]. Personalization was the only best practice strictly applied [10] by referring to "your account" and including the account name to create trust and direct the notification.

3 Login Notifications in the Wild

Login notifications intend to inform users about recent sign-ins and often include technical details such as the login time, used device, or approximate sign-in location. However, they are not sent for every login. While theoretically significant location or device changes trigger notifications, the probabilistic nature involving factors like sign-in history and user behavior makes it difficult to predict when notifications are actually sent. Some services sent notifications for every login, others only in case of significant location and device changes causing a higher risk level. For example, we noticed receiving fewer sign-in notifications if the affected account had two-factor authentication enabled.

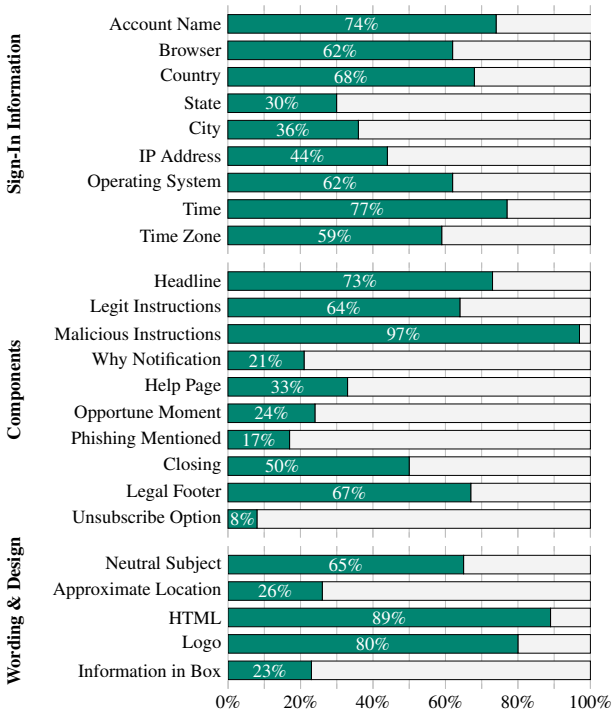

Figure 1: The information included in login notifications for a granted access ($n = 67$) sent by real-world services.

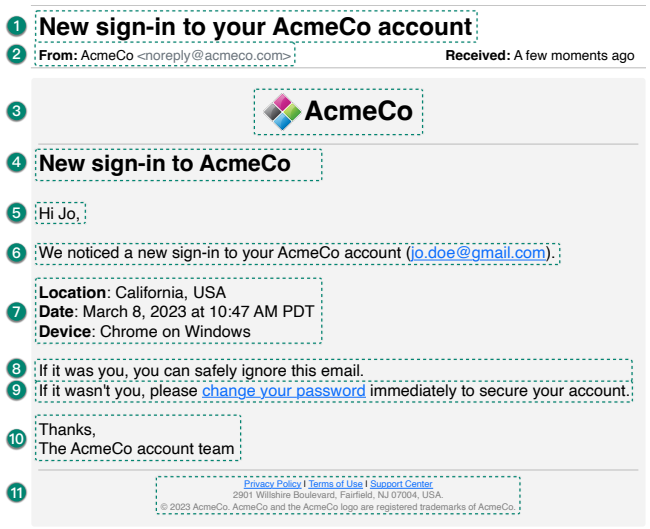

Figure 2: The *baseline* login notification, as used in our user studies, is derived from ($n = 67$) real-world notifications.

3.1 Notification Types

Based on the type of information they convey, services usually distinguish between three different notification types [21]:

(1) **Granted Access:** The notification inform about a *granted access*. Some services send such notifications for every sign-in, while others follow a risk-based approach.
(2) **Additional Challenge:** These notifications inform about a new sign-in attempt for which an *additional challenge* needs to be solved (i.e., insert a code or click a link).
(3) **Blocked Access:** The notification informs users about a *blocked access*, which can happen because the risk-based authentication system ranks the sign-in as too risky.

For the remainder of this work, we focus on the first type, i.e., notifications informing the user about a *granted access*. Sending this type can be done by every organization, as it does not require an advanced risk assessment (i.e., basic logic and the ability to display login details are enough). Moreover, we limited our dataset to email-based notifications. While notifications can also be via other channels, e.g., SMS or push notifications, establishing them requires additional effort.

3.2 Analysis

To find a representative *baseline* notification, we collected more than 80 login-related emails sent by real-world services by actively enumerating over 500 existing accounts. To trigger the notification, we signed in using the Tor browser, which is often classified as suspicious activity, and monitored our inbox. We also searched through account remediation pages [24] and community support forums [4], and learned about them via friends and colleagues, in both cases, we created an account on the service to obtain a notification ourselves. Our collection is limited to the top Tranco list [17] websites (as of June 2023), with about $\frac{1}{3}$ being in the top 100/1,000/50,000 respectively. The dataset is biased towards English language websites (few non-English notifications have been translated).

For analysis, two authors categorized 67 of the emails as *granted access* notifications. They then independently analyzed various aspects: which sign-in information the notifications includes (i.e., login time, location, device), what the main components are (i.e., headline, malicious instructions), salient design and wording decisions (i.e., logo, highlighting of sign-in details, neutral language), and metadata such as sender and subject. We summarize our findings in Figure 1. Please refer to Appendix D and E for the full details.

Sign-In Information As depicted in Figure 1, the majority of notifications included the login 7 *Time* (77%), 5 *Account Name* (74%), 7 *Country* (68%), 7 *Browser* (62%), and 7 *Operating System* (62%). Less frequently, the notifications also included the 7 *Time Zone* (59%) or a login *IP Address* (44%). The small number of notifications including the login *City* (36%) or *State* (30%), is explained by geographical differences between the U.S. and Europe. Notifications about logins in the U.S. mostly focused on states; European notifications often focused on cities.

Components Throughout all notifications, we noted the presence of a 4 *Headline* (73%) that was often (76%) different from the email subject. Another key component is the instructions describing how users should react in response

to receiving the notification. While only 64% provided instructions in the ❽ *Legitimate* case, more than 97% explained how to react in the ❾ *Malicious* case if the user does not recognize the login. The large majority (66%) recommended changing the password. Fewer (high-ranked) web services included a button to report the login as malicious or legit on a separate web page (9%) displaying account remediation steps. Similarly, a small number (9%) suggested to visit the account activity page. Prominent among financial services was the option to contact support (4%). A dedicated *Why Notification* component was included in 21% of the notifications. It primarily creates context and explains to users why they received the notification. It often gives examples of legitimate (i.e., new device) and malicious causes ("someone unauthorized gained access") that might have triggered the notification. 33% included a link to a dedicated *Help Page* (note: *regular* support links in the email footer were not counted).

About 24% of the emails tried to use the *Opportune Moment* to tell the user about other options to secure their account (i.e., enabling 2FA). The dangers of *Phishing* and methods to double-check the legitimacy of the notification were mentioned in 17% of the emails, with the most prominent suggestion to not click the "change password" link and instead sign in to the website by manually pasting or typing in the URL. About half of the notifications included a ❿ *Closing* (50%) text that often thanked the user and included the name of a "{service} account team." A footer with ⓫ *Legal* information was included in 67% of the emails, and an *Unsubscribe* link was present in 8% of the notifications.

Wording & Design Using affinity diagramming, we identified the wording of most email subjects as *Neutral* (65%), with a strong focus on "*New login to {service}*." In some cases it is alarming (23%), like "*Security alert*" or a prompt (9%), like "*Please review this sign in!*." In two cases it was a question (3%), e.g., "*Did you recently sign into {service}*?" Almost all emails (92%) referred to ❻ "your account" to emphasize the importance of the notification. A few services tried to address the inaccuracies of IP-based location estimation by describing it as *Approximate* (26%). Most of the notifications (89%) were sent as *HTML* emails; the rest were sent in plaintext. For a "corporate look-and-feel," 80% of all notifications included a ❸ *Logo*, with an even split between a centered or left alignment. Interestingly, 23% of the emails opted to display the sign-in information in a visually detached box, most likely to draw the user's attention to the login details.

Selecting a Representative Login Notification Our data-driven *baseline* login notification (see Figure 2) includes all components used by at least 50% of the notifications. It uses a neutral subject and a slightly modified headline. We adjusted our email sender, opted for an HTML email, and included a logo. Also, we included the affected account name and referred to "your account." We included the most popular sign-in details, as well as legitimate and malicious instructions for users to take after receiving the notification. As our study sample was U.S.-based, we included the ❼ *State* in the sign-in details. The email also included a closing and footer with fictional legal information.

4 Self-Report Study: Method

This section describes our self-report studies' methodology. We first explain the study structure and treatments. Next, we describe the recruitment process, demographics, limitations, and ethical considerations. This initial self-report study aims to explore tendencies and identify themes to inform the design of the subsequent measurement study.

4.1 Study Protocol

We ran a quantitative online study with the following structure utilizing our baseline notification (see Section 3).

(1) *Consent:* We briefed participants and asked for consent.
(2) *Scenario:* Next, we described the scenario for the study telling participants to imagine that they are Jo Doe (jo.doe@gmail.com) and have an account with the company AcmeCo which is "like other accounts you may have, such as for online shopping or social media." Based on their (randomly) assigned treatment (see Section 4.2), we told participants on a subsequent page to imagine that they recently signed into this AcmeCo account (*Legit*) or have not signed into the account for a while (*Malicious*).
(3) *Notification:* After describing the circumstances, participants saw a login notification sent by AcmeCo (Figure 2). The login information depicted in the notification was either derived from the currently used system (*Legit*) or showed a login from California using Chrome on Windows (*Malicious*). From now on, up to the questions about prior experiences, a two-column layout displayed the notification on the left and the questions on the right.
(4) *Reaction:* To understand how participants felt in reaction to being exposed to the notification, we used I-PANAS-SF [39]. Afterward, we asked participants to list three actions they would take after receiving the notification (**SQ1**), how concerned they would feel (**SQ2**–**SQ3**), and their priority of taking action (**SQ4**–**SQ5**).
(5) *Understanding:* Questions **SQ6**–**SQ9** investigated if participants understand what the notification is telling them and whether it appropriately guides them.
(6) *Expectation:* Next, we asked what participants think would be the consequence of ignoring (**SQ10**–**SQ11**) and if they expect real companies to send similar emails (**SQ12**–**SQ13**), it also contained an attention check **SAC**.
(7) *Prior Experience:* If they have received similar login notifications in the past (**SQ14**), we asked if and why they decided to read them (**SQ15**–**SQ16**) and situations where such notifications helped them (**SQ17**–**SQ18**).
(8) *Demography:* Next, we asked for demographics, including their age, gender identity, education, and any technical background (**SD1**–**SD4**). The study closed by asking participants if they participated honestly.

4.2 Treatments

We used two treatments to cover the cases that can trigger a notification: a *Legit* and a *Malicious* login. While a legit login is initiated by the user (or anyone who was intentionally given access), a malicious login is initiated by an attacker who got hold of the password, e.g., via a breach.

Legit ($n = 110$): To mimic a legit login, participants in this treatment should imagine that they recently logged into their AcmeCo account. The login details for the notification were obtained from the current session, i.e., their operating system and browser (based on the HTTP User-Agent string), as well as state and country derived from the IP address.

Malicious ($n = 110$): Participants in this treatment were told to imagine they had not logged into their AcmeCo account for a while and were all shown a notification for a login from California using Chrome on Windows. These login details were selected as we expect an attacker to know the victim resides in the USA. Logging in from the state with the highest population [40], as well as the browser and operating system with the highest market share [35, 36] minimizes the risk of being detected. We consider more sophisticated attacks [6, 22] that involve relaying login details and spoofing the user's sign-in information out of scope, as it makes recognizing such logins very difficult.

4.3 Recruitment and Demographics

Using Prolific, we recruited $n = 220$ participants, 110 for each treatment. A power analysis ($d = 0.4, \alpha = 0.05, power = 0.8$) yielded 100 as the necessary treatment size to which we added a 10% buffer to account for errors. We required participants to be over the age of 18 and reside in the U.S. to fulfill the assumption of the attacker in the malicious treatment. We did not exclude any participants as all of them passed the attention check (**SAC**) and indicated to have answered honestly; we also did not identify any inconsistencies. The self-report study was compensated with $2.50 and took participants, on average, 12 minutes to complete.

The demographics for the self-report study are depicted in Table 1 in Appendix C. Participants split equally between male- and female-identifying participants; seven identified as non-binary, and four preferred not to disclose their gender. In terms of age and education, 49% of the participants were younger than 35 years, and 50% had a Bachelor's or Master's degree. Lastly, 73% of the participants stated not to have a technical background.

4.4 Limitations

Although we carefully considered various aspects of the study, it has its limitations which we will outline in the following. First, we conducted an online study and asked participants to describe their behavior, opinion, and perception based on a fictitious scenario. As research has shown [46, 47], it is difficult to determine if this reflects reality even if none of the participants indicated to have answered dishonestly at the end of the study. To draw our conclusion based on measured instead of intended behavior and experienced situations, we only used this study to inform the design of a subsequent study to delve further into the topic. Second, the self-report study's sample was comprised of younger and higher-educated participants, which is typical for Prolific or other crowdsourcing platforms. We note that results may change for different populations, which should be investigated in succeeding studies. Third, results may suffer from self-report biases (e.g., social desirability). To mitigate this, we did not explain that this was a study about usability or security. Fourth, like many human-subject studies, there is the potential for a bias in question wording. To circumvent this, we piloted the study and tried to keep the questions short and clear. The full survey instrument can be found in Appendix A. Fifth, we only recruited US-based participants, which can have culture-based influences on the results.

4.5 Ethical Considerations

When the self-report study was conducted, none of the authors worked at an institution with an Institutional Review Board (IRB) that could oversee it. We followed the principles of the Menlo Report [41] "Respect for Persons," "Beneficence," and "Justice." We designed the study to minimize any potential harm while maximizing benefits. At the beginning of the study, we described the study procedure carefully, including all risks, and asked participants for their consent. Participants could withdraw from the study at any point without risking losing their compensation. All collected data were stored and processed in accordance with the General Data Protection Regulation (GDPR).

5 Self-Report Study: Results

Next, we present the results of our self-report study. As self-reported data may be exaggerated and biased, we mostly refrain from reporting exact numbers and only report general trends and themes to address this limitation.

The qualitative coding was done by two of the researchers, who started by separately coding 10% of the answers. Afterward, they agreed on a joint codebook (see Tables 5–8) and used it to code the remaining 90%. The agreement between the two coders for this first study was high ($\kappa = 0.82$). When quoting individual participants, e.g., L61-N, one can derive their treatment (***L**egit* or ***M**alicious*) and password change behavior (*Would **N**ot Change* or *Would **C**hange*). Similarly, we re-use the color codes like A *Was Me* from Figure 3 within the text when referring to participants' explanation.

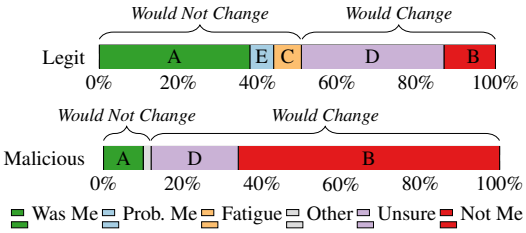

Figure 3: Breakdown (based on **SQ1**), into those who reported they *would* or *would not* change their password.

5.1 RQ1: Comprehension & Reaction

Comprehension Questions **SQ6** and **SQ7** asked participants to describe what the notification is telling them and why they may have received it. All 220 participants correctly described that a new login happened, yet, about a third, both in the legit and the malicious group, assumed that the login must have been abnormal. Some respondents speculated that the device or the location is unknown. Missing cookies, e.g., when using private browsing, were brought up by few participants, and just one person mentioned an unusual login time as a reason. However, all of those deviations may trigger a notification. We further discuss this discrepancy between users' understanding and the actual implementation in Section 8.

Reaction Legit The 110 participants in the legit group split equally between participants who would ignore the notification and those who would change their password (**SQ1**).

The majority of participants who would ignore it argued that they A definitely or E probably received it because they logged in themselves:

"*I live in Texas, use Chrome on Windows, and have just logged into this account. It's probably me.*" (L61-N)

Fewer participants thought it was them causing the notification, but additionally expressed C fatigue:

"*Delete the email because I know I am the person who signed in, [...] I unsubscribe from AcmeCo entirely because I am tired of receiving these emails constantly.*" (L80-N)

Of participants who said they would change their password (unnecessarily), the majority were D unsure whether it was them logging in. They said they would change the password to eliminate the possibility of someone having access:

"*It looks like someone else logged in. [...] Even if I'm not sure, might do this just in case.*" (L87-C)

The remaining B participants were certain that someone else would know their password:

"*I would think my password was compromised.*" (L56-C)

Taking action is a higher priority for participants who said that they would change their password than for those who do not. Likewise, their agreement to **SQ10** saying that "ignoring this email from AcmeCo would have consequences" is also higher.

Generally, the ratings of participants who reported that they would change their password in the legit group are more similar to those participants in the malicious group who reported that they would change their password, which highlights the strong influence of a misinterpreted notification.

Reaction Malicious In the malicious group, the majority described that they would change their password, only a few said they would ignore it. Of the former, B most justified their reaction by (correctly) saying that someone else just logged in:

"*Someone else got into my account, so I need to change the password right away.*" (M56-C)

Again, there are also D participants who expressed some form of uncertainty, yet, in contrast to the legit group, they mostly questioned the legitimacy of the email:

"*I would hover over the email to ensure it wasn't a phishing email [...] after ensuring it was legit and safe, I would change my password*" (M87-C)

Of the participants in the malicious group who said they would ignore it, A most described that it must have been them logging in, misinterpreting the situation:

"*It's safe to assume that my account is not compromised. [. . .] It's good to see that my safety is a concern.*" (M92-N)

Only F few participants argued differently: M25-N mentions phishing, similar to many other participants, but would "send the email to spam" and not do anything else. M51-N, on the other hand, would "ignore it. It is my business, not theirs."

Similar to the legit treatment, the intend to take action in response to the notification was of higher priority for participants who supposed to be compromised than those who did not. Likewise, of those who intended to change their password, the majority *agreed* or *strongly agreed* that ignoring the notification would have consequences.

Summary While users understand that the notification informs them about a new login, their comprehension of potential triggers deviates from what can be actual reasons. We find a tendency to misinterpret the notification: participants either stated they would unnecessarily change the password (*Legit*) or they would mistakenly ignore the notification (*Malicious*). Note this study is limited to self-reported, hypothetical reactions. Thus, we further investigate these findings in the subsequent study (see Section 6).

5.2 RQ2: Decision-Making & Execution

Decision-Making To identify the type of information (*location*, *date*, *device*) participants based their decision on, we specifically checked the open responses. Most participants consider the device as a factor (explicitly the browser or OS). However, responses vary noticeably between the 4 groups. While 4 of 5 participants in the *Legit (Would Not Change)* group mentioned the device when describing how they made their decision, slightly fewer did in the *Legit (Would Change)* group. In the malicious treatment, the device was mentioned less than half of the time by those who would not change and even more seldom by those who stated they would.

Although intuitively the *location* should be the easiest, hence, most popular indicator for identifying the notification's intent, it is only reported as the second most frequent across all groups. Again, participants in the legit *Legit (Would Not Change)* treatment included it most often, followed by *Legit (Would Change)*. In the malicious treatment, 1 in 3 for the *Would Not Change* and *Would Change* groups said the same.

Lastly, only some participants mentioned the *date* and/or *time* in their responses. When comparing the groups, ratios range from a few for the *Malicious (Would Change)* group to about half for the *Legit (Would Not Change)* group, which fits the overall picture: participants in the legit group who expressed not to change their password refer to the login factors the most, followed by the *Legit (Would Change)* and the *Malicious (Would Not Change)* group. The participants who refer to any of the 3 types of information the least are those in the *Malicious (Would Change)* group.

A second view on this is given by **SQ18**, where we asked participants if they ever had a real-world situation in which they learned about an unrecognized login via such a notification. Of those who did, half described that the *location* was the determining factor. Only a few said that the information about the *device* helped them, and only twice it was the *time*.

Execution Question **SQ8** asked participants if the notification explained how to resolve the situation. The majority across all groups *agrees* or *strongly agrees*. When explaining their answer (**SQ9**), most participants focused on how to resolve the situation for a malicious login, even if they do not intend to change their password:

"*It gave me steps to take if this was not me.*" (L41-N)

Another group explicitly mentions both outcomes:

"*It explains to ignore the email if it was me, and change my password if it wasn't.*" (L101-N)

Participants who criticize the notification report that they miss information in some form:

"*Changing my password is the very first line of defense, but I wish there was more information about what steps to take, or further assistance from AcmeCo.*" (M26-C)

This highlights an important aspect, as account remediation usually consists of more steps than just changing the password. Others [23, 44] also observed a lack of advice provided by websites. In Section 8, we discuss the risk that arises from this lack of information.

Lastly, some participants referred to the *change your password* link, which is provided in the notification. Some noted:

"*The steps to take were very clear. It also provided a link to make it easy to change my password if I needed to.*" (L42-C)

Other participants perceived the link negatively, saying that they do not trust it and describe it as bad practice:

"*It shouldn't be suggesting that I click the link in the email as this is a trick often used by scammers.*" (M35-C)

Both positions provide reasonable arguments which come down to a weighting of usability and security. We further contrast both perspectives in Section 8.

Summary Based on the open-ended questions, the *device* and the *location* appear to be influential types of information when participants make their decision. The *Legit (Would Not Change)* group generally refers to login information the most, *Malicious (Would Change)* participants the least. As we identified a mismatch between the responses in the study and real-world experiences, we employ the second study investigating to what extent the different types of information actually drive their decision processes. In terms of the execution, most participants, irrespective of the treatment and the described action, agree that the notification provides them with sufficient information. Participants who commented negatively mentioned a lack of information or disliked the *change your password* link.

5.3 RQ3: Perception & Expectation

Perception Using the PANAS, we investigated how the notifications make participants feel and asked them about their concern (**SQ2**). Participants in the *Malicious (Would Change)* group felt the most positive followed by *Legit (Would Change)*. *Malicious (Would Not Change)* and *Legit (Would Not Change)* ranked the lowest, which shows that participants feel more positive if they do something in reaction to the notification. This may explain why participants (*Legit*) tended to change their password even if it may not be necessary.

The situation for the negative affect is more distinct. Participants in the malicious group who described to change their password feel more negative than those in all other groups. This stark contrast may be explained by the fact that the majority of them report being hacked, while only a few in the *Legit (Would Change)* have a similar assumption and all others just try to "better be safe than sorry." The *Legit (Would Not Change)* and *Malicious (Would Not Change)* group feel less negative, even compared to *Legit (Would Change)*. This aligns with the participant's understanding of the notification as information about their own login.

Participants' responses regarding the concern (**SQ2**–**SQ3**) match the previous observations. The *Malicious (Would Change)* has the highest concern level, with the majority being *moderately* or *extremely concerned*. This is higher compared to *Legit (Would Change)*, where some are *moderately*, and few are *extremely concerned*. Participants who described not to change their password, reported the lowest concern.

Expectation In response to **SQ12**, nearly all participants *agree* or *strongly agree* that notifications should be sent by real companies. They feel that the notifications *protect accounts*, *alert customers*, and show that companies are invested in security. The only negative aspect mentioned was *annoyance*:

"*People who log into the site a lot are going to get spammed. It would be better if they only sent you a notification when they detect a strange login.* " (L32-N)

Still, this is only reported by few participants. Others were not annoyed and reported to receive such notifications *regularly*

(**SQ14**). More than three times as many said they get them *many times*, and the largest portion described to receive them *occasionally*. Similarly, more than half said they read them *always*, some *often*, few *sometimes*. Hence, there appears to be some decline which could be explained by participants differentiating *expected* and *unexpected* notifications:

"*If I signed in from a second device and then received the email, I knew it was me, so I would ignore it. But when I didn't sign in, I would pay attention and read the email.*" (L16-N)

Summary Participants who would change their password have higher positive affect ratings, which may be explained by them securing their accounts. Those that assumed to be hacked also felt most negatively. Participants who reported they would not change their password reacted significantly more indifferent. We use Study 2 to observe participants' feelings when confronted with a real notification. Almost all participants expect services to send login notifications, leaving them feeling protected. They claimed to always read them or at least when the notification arrives unexpectedly. Only a few reported being annoyed by such notifications.

6 Measurement Study: Method

In this second study, we expand on the self-reported results by measuring user behavior on an actual website. The following outlines the protocol, treatments, recruitment, ethics, and limitations.

6.1 Study Protocol

In contrast to Study 1, participants in this study should receive a notification for a concrete account. To resemble a real-world setting, the protocol had to fulfill four criteria: (1) a *real account* gets created, (2) participants are *unaware* that the study is about login notifications, (3) participants receive the notification in their *personal email account*, (4) reactions to login notifications are *measurable*.

For this, we invited participants to take part in a multi-stage study about changes in the cognitive ability of mental rotation over time [34, 42]. This framing allowed us to inform people about the length of the commitment without revealing our interest and justified the account creation on our website. The task also was a strong cognitive distractor that prevented participants from drawing too much attention to the authentication task.

Similar to Study 1, we used 2 treatments and the baseline notification (see Figure 2) adapted to the branding of our study's website: The legit group ($n = 110$) received a notification only after they logged in themselves. The location, date, and device in the notification were derived from the metadata of their login. The malicious group ($n = 119$) received a notification unexpectedly at a time when they had not interacted with the account for multiple days. This resembled a login attempt by a malicious actor. The location ("California, USA") and device ("Chrome on Windows") were selected to have the highest statistical chance of matching any user in our U.S.-based sample [35, 36, 40]. We did not allow mobile devices and used a tracking pixel to see if the email was opened.

Stage 1: The first page on the study's website explained the mental rotation test. To ensure participants would regularly check their email and understand the value of the account, after giving their consent, they saw a privacy notice, which highlighted the importance of the account as it would be used to store the study data, name, and email address. It also explained that the email would be used to send invitations to subsequent stages, and the compensation in form of Amazon gift cards. After the account creation, participants solved 5 mental rotation tests and provided demographic information (**MD1**–**MD4**). At the end, participants in the legit treatment were informed that invitations to Stage 2 would be sent in approx. 7 days; in the malicious group, the note said 14 days.

Stage 2: After 7 days, participants in the legit group received an email inviting them to return to our website to conduct another mental rotation test. To do so, they had to log into their account, which triggered a login notification. Participants in the malicious group expected their next email after 14 days. However, to imitate a malicious login, we sent them an (unexpected) login notification filled with our statistical sign-in data 7 days after they completed the first stage.

Stage 3: For the legit group, invitations to the final Stage 3 were sent 48 hours after they completed Stage 2; in the malicious group, 48 hours after they received a notification for a login they did not initiate. We chose this time frame to give participants enough time to react. After logging into Stage 3, participants were debriefed and told about the purpose of the study. This was followed by our questionnaire (see Appendix B). From then on, the notification we sent was shown on the left side of their screen for reference.

(1) *Email:* First, we asked participants if they remember receiving the notification (**MQ0**); if not, they were forwarded to a different section (see Appendix B). Participants who triggered the tracking pixel in the notification or who changed their password skipped this question.
(2) *I-PANAS-SF:* To learn about the feelings and emotions in reaction to the notification, we again utilized the Positive and Negative Affect Schedule (I-PANAS-SF) [39].
(3) *Reaction:* Next, we asked how thoroughly participants read the notification (**MQ1**) and how and why they chose to react to it (**MQ2a**–**MQ3a**). Participants who changed their password were specifically asked about any other actions (**MQ2b**–**MQ3b**).
(4) *Content & Design:* To better understand the reactions, **MQ4** asked about influencing factors like metadata, content, and design. **MQ5** specifically asked about the helpfulness of the account name, location, date, and device.
(5) *Time & Location:* **MQ6**–**MQ10** investigated the time when and location where the notification was read. With **MQ7**,

we verified if the location, which had been derived automatically, was actually accurate or could have led to confusion, and **MAC2** was an attention check.

(6) *Comprehension & Expectation:* With **MQ11**, we captured if participants understood why they received the notification. **MQ12** and **MQ13** asked participants when they expect real companies to send notifications.

(7) *Prior Experience:* We concluded with three questions covering negative experiences with security incidents (**MQ14**), as well as their opinion on regular (**MQ15**) and event-driven password changes (**MQ16**).

6.2 Recruitment & Demographics

We used Cint for the recruitment of the measurement study, as Prolific could not support all our requirements. For Stage 1, we recruited 625 participants, about 3 times more than the desired number of completions as recommended by the panel provider. After filtering 12 participants who failed the attention check (**MAC1**), 613 participants remained. At the end of Stage 3, we had 252 completions. This high number of dropouts is almost exclusively owed to participants who did not return after the first stage of the study. Lastly, we removed 23 participants as they provided unrelated answers or failed the second attention check (**MAC2**) for a final number of $n = 229$. Stage 1 took, on average, 2.5 minutes and was compensated with $3.00 USD. Stage 3 took, on average, 6 minutes and was compensated with $4.00 USD. Participants in the legit group received an additional $1.00 USD for the completion of Stage 2, which took 2 minutes on average. Regarding the demographics, we observe a shift towards male-identifying participants (65%), the age distribution is diverse, ranging from 14% to 21% for all age groups between 25 and 74. Most participants had a high school (33%), Bachelor's (26%), or trade degree (23%) and did not have a technical background (82%). The full details are given in Table 2 in Appendix C.

6.3 Ethical Considerations

At the time we conducted the measurement study, none of the authors worked at an institution with an IRB. However, we carefully followed the guidelines provided in the Menlo Report, including a risk-benefit evaluation, developing the protocol with peers familiar with conducting user studies, and following the legal requirements. The study included deception and sent a login notification to participants' personal email accounts, which could have caused more anxiety than just imagining to have received a login notification. We actively tried to avoid this situation by conducting our self-report study first. However, as half of the participants stated they would (unnecessarily) change their password, we decided to verify this potentially user-burdening behavior.

To protect participants from unnecessary risks, we implemented several safeguards: i) Our panel provider offered the study only to participants that agreed to studies that might involve deception. ii) The affected spatial reasoning account had no subjective value to the participants and only allowed to access the email address. iii) All participants have been debriefed (also the ones that decided to withdraw early or drop out). In particular, we told them about the true purpose of the study, and in case they belonged to the *malicious* treatment that "This sign-in did not take place; at no time was your account at risk," and asked them whether they prefer to leave the study early (while being fully compensated), which nobody did. iv) We provided an optional contact address and feedback form that we closely monitored (we have not received any complaints). v) We shared a website (also accessible from outside of the study), that participants could visit and share to learn more about login notifications and related account security measures. vi) We created a distinct email account for sending the notifications that applied all state-of-the-art email security features, which can prevent email spoofing attacks. We also allowed participants to reply to the notification and ask for assistance. Finally, all email addresses were only stored encrypted, separated from the study responses, and were deleted after the study in accordance with GDPR.

6.4 Limitations

In addition to the limitations from Study 1, we relied on a controllable artificial account setting for this study which might lack ecological validity. However, only 7 participants mention the non-real-world setting as a reason for not reacting to the notification. We expect more participants to change their password if the notification was sent for an account with a higher subjective value. In regard to the tracking pixel, we tested it with Gmail, Outlook, and Yahoo! and analyzed the web server access log to check if any automated scans may already trigger the pixel. While it was not the case, we cannot rule out that this holds for all scenarios.

7 Measurement Study: Results

Next, we present the results of the measurement study. We have applied the same structure, coding methods, and statistical testing as with our self-report study (see Section 5). Intercoder agreement for this second study was high ($\kappa = 0.77$). The resulting codebook can be found in Table 9–11 in Appendix F. In contrast to Section 5, we will report on exact numbers to provide more detailed insights based on measured user behavior. We will discuss the similarities and difference between the two study findings and their methods in Section 8.

7.1 RQ1: Comprehension & Reaction

Comprehension When asked why they have received the notification (**MQ11**), 85% (93) in the legit and 79% (94) of the participants in the malicious treatment realized that a new

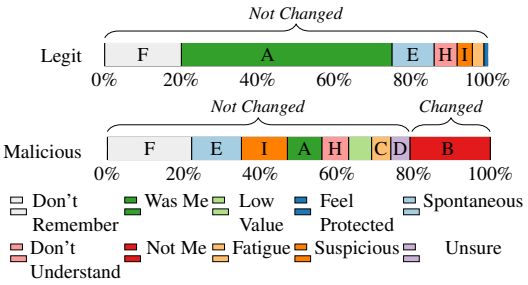

Figure 4: Breakdown of participants (measured), into those participants who *have* or *have not* changed their password.

login happened. Very few who gave a different explanation believed it was a phishing attempt (3; 1%), most simply did not understand what has happened at all (39; 17%):

"*I had no idea, which is why I deleted it.*" (M93-N)

Those in the legit treatment who mapped the notification to a new login usually perceived it as a simple info email (42; 38%), followed by those who saw it as a prompt to review the login (28; 26%). Fewer responses (15; 13%) explicitly mention that the login must have been abnormal. In the malicious treatment, most participants, who understood that a new login happened, described that they were (potentially) compromised (46; 36%). Another 19% (22) perceived it as an informative but non-critical email. The remainder (13; 11% each) either mentioned that the system rated the login as unusual or wants them to review the login.

We observed a lower comprehension (compared to the first study) of what might have caused the notification, especially in the malicious group. One explanation might be the temporal connection between logging in and receiving the notification. From **MQ6**, we know that about two-thirds read it immediately, most of the others within few hours. Hence, participants in the legit treatment had indeed a connection, and their understanding was substantially better. Similarly, we did not observe differences between treatments in the self-report study, where both had identical circumstances. This influence of contextual factors was already observed by prior work on warning design [12, 31] and could be achieved by including a *Why Notification* section. Some websites already do (see Section 3), and we will elaborate on this in the discussion.

Reaction General Out of the total 229 participants, 48 participants, 23 in the legit and 25 in the malicious treatment, F cannot remember the notification. Still, 26 of them triggered the tracking pixel, so they must have at least opened the notification. Among the large majority of participants who saw the login notification (181; 79%), it was very rare that they completely ignored its content. In response to **MQ1**, just 6% said that they only read the subject. About 90% read the notification completely or at least skimmed the body.

Reaction Legit Unlike the self-report study suggested, where half of the participants in legit treatment said they would change their password (see Section 5.1), none in the measurement study actually did. As shown in Figure 4, the majority of participants (60; 55%) explained their reaction in response to **MQ3b** by saying A it was their own login. Another 12, i.e., 11%, described it as a E *spontaneous* reaction, e.g., M42-N: "I just didn't think much of it." Previously, we saw that some participants do not understand what the notification is saying, which was the driving reason for H 6% (6) to ignore it. Finally, we recorded themes aligning with the findings from the self-report study with participants who were I *suspicious* about the legitimacy of the notification (4; 4%), felt C *fatigued* (3; 3%), or G *protected* (3; 3%).

Reaction Malicious In the malicious group, only 26 of the 119 participants, i.e., 22%, changed their password; all of them correctly saying B it was not them logging in. The reasons given by the other 78% (93) in response to **MQ3b** for not changing their password have mostly been given by participants in the legit treatment: E *spontaneous* reaction (15; 13%), notification looked I *suspicious* (14; 12%), or was H *not understood* (8; 7%), C being *fatigued* (6; 5%) or D *unsure* how to react (6; 5%). Finally, there are two justifications that are owed to the study design: participants describing they A logged in themselves although they did not (11; 9%), likely an example of social desirability, and those who assigned a low value to the account (7; 6%):

"*This account has no value, it was not a streaming or banking account or amazon account*" (M74-N)

This justification can be reasonable, but users need to keep in mind that an attacker can also target other accounts that verbatim or partially reused the compromised password [25].

Summary About 80% saw the notification. Participants in the legit treatment who triggered it themselves understood what it was telling them and reacted accordingly. In the malicious treatment where participants did not have this context, only 22% changed their password, and they had more difficulties explaining the circumstances. Hence, the number of password changes in the malicious treatment is substantially lower than expected, while we could not confirm the tendency to unnecessary password changes.

7.2 RQ2: Decision-Making & Execution

Participants in the self-report study said that the notification tells them how to resolve the situation. Hence, we did not further test this. Instead, we will focus on the decision-making process, as participants seem to struggle with determining whether it was them or not, especially for malicious logins.

Helpfulness of Login Information Foremost, we wanted to get more insights into the helpfulness of the displayed login information. We know from the self-report study that information about the *device* and *location* are considered by participants when deciding how to react to a login notification. In Figure 5, we can see that for those in the *Legit* and *Malicious (Change)* group, all information is about equally helpful: 22–35% find the different types *moderately* and 38–62% even *extremely* helpful. Participants in the *Malicious (No Change)*

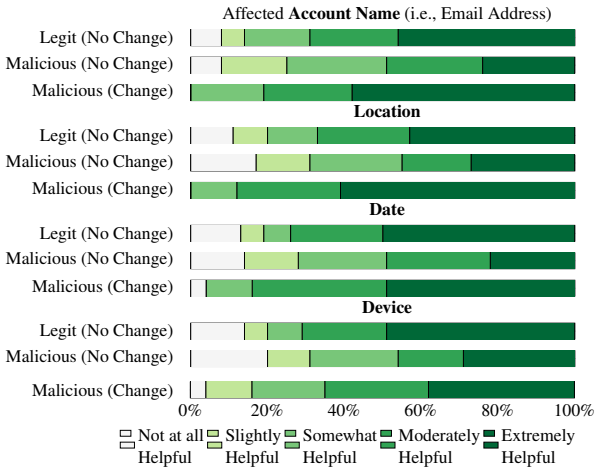

Figure 5: Helpfulness of the details for deciding (**MQ5**).

group, in contrast, appear to have a less distinct opinion as ratings are more equally distributed, ranging from 8–30%. A Kruskal-Wallis test also showed significant differences for all types of information when comparing *Malicious (No Change)* to *Legit* and *Malicious (Change)*, respectively. This uncertainty of participants in the *Malicious (No Change)* group regarding the displayed information aligns with the previous section, where we found that those participants misattributed or did not understand the cause of the notification.

Effect of Other Factors In addition to the already-known influence of the login information, we were also interested in the effect of other exogenous and endogenous factors. Figure 6 gives an overview. Generally speaking, the content (e.g., provided information, instructions, wording) and prior experience in dealing with such notifications had the highest effect on participants' reactions, with 42% expressing a *moderate* or *major effect* on average. Followed by that is the metadata (e.g., sender, subject, time of arrival) with 29%. All other factors seemed to have a less distinct influence, with 18% (appeared to be phishing) to 23% (was expected) of the participants reporting a *moderate* or *major effect*.

When comparing the groups, *Legit* is the one where most participants reported a factor having no effect. The *Malicious (Change)* group, on the other hand, is the one where participants describe the strongest influences of the factors. Using a Kruskal-Wallis test with Bonferroni-correction for pairwise comparisons, we found that the metadata had a significantly higher effect for *Malicious (Change)* participants compared to *Malicious (No Change)* participants ($\chi^2(2) = 6.65, p < 0.05$). The same is true for the email content ($\chi^2(2) = 7.73, p < 0.05$). Thus, to nudge more users to change their password upon receiving potentially malicious login notifications, focusing on designing the content and metadata is vital.

Influence of Negative Experiences Overall, 30% of participants described falling victim to a security breach within the last two years (**MQ14**). In the malicious treatment, 42% of those who changed their password reported prior negative

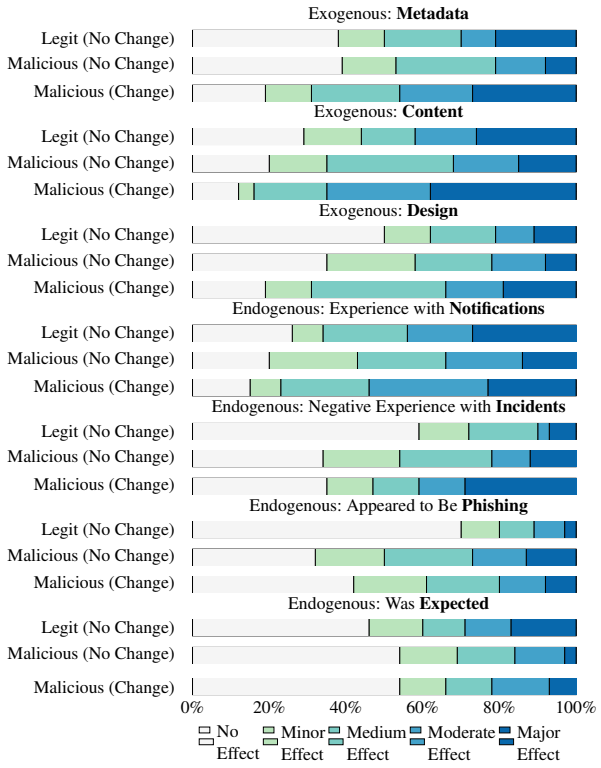

Figure 6: Influence of factors on participants reaction (**MQ4**).

experiences. Only 32% of those who did not change their password said so. The difference is not statistically significant, $\chi^2(2) = 2.61, p = 0.271$ but suggests that prior breach experience increases the likelihood of users changing their password upon receiving a notification.

Summary Based on the first study, we assumed the device and location to be more helpful than the account name and the date. However, when compared side-by-side, we can conclude that all factors are equally essential. What we did observe is that the helpfulness of the information for the *Malicious (No Change)* participants is significantly lower, which further explains the issues of this group when determining what happened. Regarding other factors, the content of the notification, its metadata, and prior experience in dealing with it had the highest effect across all treatments. Negative experience tends to influence the reaction as well; other aspects appeared to be less crucial.

7.3 RQ3: Perception & Expectation

Perception In the self-report study, the PANAS revealed that participants who would change their password felt significantly more positive (M: 15.6, SD: 3.2) but also more negative (M: 12.7, SD: 4.1). Participants who described ignoring the notification scored the lowest. The second study backs up both findings. The average positive *affect* of the *Malicious (Change)* group is 15.0 (SD: 4.5) but only 11.6 (SD: 5.0) and 12.6 (SD: 5.6) for the *Malicious (No Change)* and

Legit, respectively. Using a Kruskal-Wallis test (Bonferroni corrected), we were also able to confirm the significance between the two malicious groups, $\chi^2(2) = 8.29, p < 0.05$. For the negative *affect*, *Malicious (Change)* averages 9.8 (SD: 4.1), *Malicious (No Change)* (M: 8.1, SD: 4.3), and *Legit* (M: 5.7, SD: 1.6). Again, Kruskal-Wallis was used yielding significance between both malicious groups and *Legit* ($p < 0.01$); the comparison between the two malicious groups nearly did, $\chi^2(2) = 5.26, p = 0.0654$.

Expectation More than 90% of the participants in the self-report study expect real-world services to send notifications. Participants who expressed disagreement reported receiving them constantly and being annoyed. Moreover, the second study showed so far that there is a substantial number of participants who have not changed their password although they should, some of them mentioning that it was a spontaneous reaction which this fatigue may also explain. Hence, we used **MQ12** to learn when users expect to receive notifications.

A majority of participants (151; 66%) expressed they want to receive notifications after suspicious account activity. On average, 60% want to be notified if a login takes place from a new device, 47% for logins from a new location, 31% if they have not logged in for a while, and 22% for logins that take place at an unusual time of the day. Only 9% want to receive a login for *every* login, and even less (9; 3%) do not want to receive login notifications at all.

Summary We can confirm that participants who changed their password felt both more positively and negatively, probably because they assumed some form of compromise but also had a sense of achievement after preventing it by changing the password. The other groups had lower scores, aligning with them not expecting any harm.

The self-report study showed that participants expect services to send login notifications. With the new findings, we can further specify this by saying that participants want to be notified after suspicious logins, logins from new devices, and logins from new locations. Fewer participants expect to receive notifications based on temporal deviations.

8 Discussion

Next, we discuss the takeaways and give recommendations.

8.1 Effectiveness of Login Notifications

Above all, we intend to understand if login notifications, as used by numerous services nowadays, achieve their goal of increasing the security of users' accounts. In the case of the malicious logins, we saw that more than 80% in the self-report study and still about 20% of users in the measurement study react to the notification by changing their password. Hence, email notifications can serve as an enhancement to account security, as every additional password change serves the goal of preventing a malicious actor from gaining access.

Still, there are also negative aspects that should be mentioned. For example, one may argue that such notifications are burdening and blaming. If service providers, with all the information about the login history, are uncertain, how should the user be able to determine the legitimacy of a login? Of course, from a service provider's perspective allowing login and hedging it with a notification rather than blocking it makes sense. Still, it highlights the need for robust security measures implemented by service providers themselves [18].

Contrary to concerns about burdening users, it can be argued that users took the appropriate action in the legitimate cases. Therefore, users are not burdened, as they correctly follow the instructions when prompted by a legitimate login notification. Moreover, users tend to feel more protected and satisfied when they receive notifications. The reassurance they provide contributes to a positive user experience and reinforces trust in the service.

Finally, although login notifications are generally beneficial, their implementation has room for improvement. Further research and development should focus on refining notification systems to ensure maximum effectiveness and usability. For example, research on click-through rates of SSL/TLS warnings increased comprehension and adherence by improving warning design [8]. One approach to facilitate appropriate reaction may be to match users' understanding of the login notifications and the actual implementation of these notifications. As we saw in Sections 5 and 7, participants appear to expect and need contextual factors to determine what has caused the notification. Services could adhere to this expectation by including a distinct *Why Notification* component in the notification, e.g., by explicitly saying that a login happened from a previously unseen device. Our initial analysis only found this contextualizing section in about 20% of the notifications. Moreover, services need to provide more steps than just changing the password. Rather, they should initiate a thorough remediation process, including removing unknown sessions, checking related accounts, or enabling 2FA [23, 44].

8.2 Self-Reported vs. Measured Findings

When we compare the findings of the self-report study with the measured behavior, we find that participants' actual reactions differ from the responses in the hypothetical scenario. This is in line with prior work [30] and the main reason why we would encourage measuring behavior, particularly regarding participants' reactions (RQ1) to the notification. Here, we observed the most pronounced difference, with fewer participants actually changing their password than originally anticipated. Prior work suggests that behavior is more correlated if decisions are either made proactively or because users are actively prompted for a decision [47]. Hence, using neutral instead of alarming language in our notification headline and subject can be a contributing factor. In the limitation sections, we have outlined other potential reasons for this observation,

like social desirability biases. Smaller are the differences related to comprehension (RQ1) and decision-making processes (RQ2); identical are those about perceptions and expectations (RQ3). Here, we see the negative affection for the malicious treatment and the more neutral affection for the legitimate treatment in both studies.

8.3 Expectation vs. Fatigue

More than 90% of the participants expect services to send login notifications, and finding a balance between sending them too often and too rarely is crucial. We found that participants want to be notified when a login takes place from a new device or location, but also if a login appears "suspicious," which can be accomplished with advanced logic provided by risk-based algorithms [48,49]. Time-related notifications (i.e., a login after a long or at an unusual time) are less demanded.

For service providers, sending notifications more often than necessary, following a "better safe than sorry"-mentality may be tempting. Yet, for users, this leads to a well-documented phenomenon in the area of security warnings: fatigue [2, 7, 37]. This fatigue is most likely caused by unnecessary login notifications, i.e., those that do not convey a real risk teach users that all notifications are unimportant. The situation is further aggravated by services like Mozilla, Tumblr, Etsy, and others that send notifications for every single login.

8.4 Good Intentions & Questionable Advice

In both studies, about 15% of the participants questioned the legitimacy of the notification. Prior work explains how to best advise users [32], yet, most of the 10 notifications that include information about phishing at all do not follow it.

For example, questionable advice is given by Twitter (and three other major services), which suggests that the presence of a padlock icon will "let you know a site is secure" and that users should check for the presence of "https://" and "{domain}" in the hyperlink. Interestingly, in May 2023, Google announced removing the padlock icon in Chrome, as HTTPS should nowadays be considered the default state [1]. Similarly remarkable, Amazon suggests better copying and pasting the "It wasn't me"-link into a browser, "just to be safe." Spotify advises users to verify the email was sent from "@spotify.com," which is only expedient if the email server and DNS are configured correctly. Related work demonstrated how vulnerable this email ecosystem is [33]. A good example is some of PayPal's advice [26] that explicitly mentions to "not rely on the padlock symbol and the 's' in https." Interestingly, LinkedIn opted to add a security footer message [19] to their login notification that includes the affected user's name and profession to authenticate official emails.

8.5 Recommendations

Below, we give recommendations for service providers.

Include Information in Metadata We found that the metadata is an influential factor, and 75% of the participants paid attention to the email subject. Hence, in addition to the most important information, the subject should already provide context for deciding how to react. Generic clauses, e.g., "Your account has been logged into." as used by Tumblr, do not achieve this, which is why email subjects like "New login to Twitter from {browser} on {OS}" are preferable. Similarly, websites should make use of the email sender's name so that recipients can quickly parse the information about the sender; in our initial analysis, we found 5 services that did not.

Describe What Happened What triggers a notification, e.g., an "unusual login" is often unclear to participants. Services could easily address this issue by explaining what triggered the notification, yet, only 12% of the evaluated emails currently provide examples of common triggers. Explaining the circumstances would also help to create context, which is especially important when users receive unexpected notifications and struggle to assess the situation correctly.

Specify Instructions Notifications need to include instructions for both outcomes, i.e., legit and malicious logins. For the legit case, most services describe to ignore the message. For malicious logins, the recommendation needs to prompt users to visit the website and change or reset the password or, even better, initiate a thorough remediation process. Most services facilitate this by including a link which is a controversial practice. Of course, it simplifies the process, and 10% in our study explicitly appreciated the shortcut. However, also 10% of the participants were suspicious due to the presence of a link and did not change their password. Hence, services should carefully evaluate, including a link.

Provide Comprehensible Details We found that all types of information (account name, location, time, and device) have a positive influence. Still, services should avoid too technical details. Negative examples are sign-ins on smartphones displayed using the model number instead of the name, e.g., "SM-S908B/DS" instead of "Samsung Galaxy S22." Operating systems are also often reported with their full version number, e.g., "iOS 16.0.1." The least recommendable example is the raw User-Agent string, which we found in 4 emails.

Respect Privacy Most services employed tracking technologies in their emails like tracking pixels, URL parameters, and third-party redirects. However, participants reported being concerned and wondered "what else they're tracking." Adhering to a privacy-by-design concept as suggested by GDPR or the California Privacy Act would address this concern. Currently, the only services that do so are those 7 that send plaintext notifications, e.g., Cloudflare, GitHub, or Nintendo.

By addressing the identified areas for improvement, service providers can continue to strengthen account security and foster user trust.

References

[1] David Adrian, Serena Chen, Joe DeBlasio, Emily Stark, and Emanuel von Zezschwitz. Chromium Blog: An Update on the Lock Icon, May 2023. https://blog.chromium.org/2023/05/an-update-on-lock-icon.html, as of June 6, 2023.

[2] Devdatta Akhawe and Adrienne Porter Felt. Alice in Warningland: A Large-Scale Field Study of Browser Security Warning Effectiveness. In *USENIX Security Symposium*, SSYM '13, pages 257–272, Washington, District of Columbia, USA, July 2013. USENIX.

[3] Hazim Almuhimedi, Adrienne Porter Felt, Robert W. Reeder, and Sunny Consolvo. Your Reputation Precedes You: History, Reputation, and the Chrome Malware Warning. In *Symposium on Usable Privacy and Security*, SOUPS '14, pages 113–128, Menlo Park, California, USA, July 2014. USENIX.

[4] Apple, Inc. Apple Support Community: Notification of Sign In with Apple ID, January 2022. https://discussions.apple.com/thread/253581666, as of June 6, 2023.

[5] Lujo Bauer, Cristian Bravo-Lillo, Lorrie Cranor, and Elli Fragkaki. Warning Design Guidelines. Technical Report CMU-CyLab-13-002, Carnegie Mellon University, February 2013.

[6] Periwinkle Doerfler, Kurt Thomas, Maija Marincenko, Juri Ranieri, Yu Jiang, Angelika Moscicki, and Damon McCoy. Evaluating Login Challenges as a Defense Against Account Takeover. In *The World Wide Web Conference*, WWW '19, pages 372–382, San Francisco, California, USA, May 2019. ACM.

[7] Serge Egelman, Lorrie Faith Cranor, and Jason Hong. You've Been Warned: An Empirical Study of the Effectiveness of Web Browser Phishing Warnings. In *ACM Conference on Human Factors in Computing Systems*, CHI '08, pages 1065–1074, Florence, Italy, April 2008. ACM.

[8] Adrienne Porter Felt, Alex Ainslie, Robert W. Reeder, Sunny Consolvo, Somas Thyagaraja, Alan Bettes, Helen Harris, and Jeff Grimes. Improving SSL Warnings: Comprehension and Adherence. In *ACM Conference on Human Factors in Computing Systems*, CHI '15, pages 2893–2902, Seoul, Republic of Korea, April 2015. ACM.

[9] Anthony Gavazzi, Ryan Williams, Engin Kirda, Long Lu, Andre King, Andy Davis, and Tim Leek. A Study of Multi-Factor and Risk-Based Authentication Availability. In *USENIX Security Symposium*, SSYM '23, Anaheim, California, USA, August 2023. USENIX.

[10] Maximilian Golla, Grant Ho, Marika Lohmus, Monica Pulluri, and Elissa M. Redmiles. Driving 2FA Adoption at Scale: Optimizing Two-Factor Authentication Notification Design Patterns. In *USENIX Security Symposium*, SSYM '21, pages 109–126, Virtual Conference, August 2021. USENIX.

[11] Maximilian Golla, Miranda Wei, Juliette Hainline, Lydia Filipe, Markus Dürmuth, Elissa Redmiles, and Blase Ur. "What was that site doing with my Facebook password?" Designing Password-Reuse Notifications. In *ACM Conference on Computer and Communications Security*, CCS '18, pages 1549–1566, Toronto, Ontario, Canada, October 2018. ACM.

[12] Peter Leo Gorski, Yasemin Acar, Luigi Lo Iacono, and Sascha Fahl. Listen to Developers! A Participatory Design Study on Security Warnings for Cryptographic APIs. In *ACM Conference on Human Factors in Computing Systems*, CHI '20, pages 1–13, Honolulu, Hawaii, USA, April 2020. ACM.

[13] Jun Ho Huh, Hyoungshick Kim, Swathi S.V.P. Rayala, Rakesh B. Bobba, and Konstantin Beznosov. I'm Too Busy to Reset My LinkedIn Password: On the Effectiveness of Password Reset Emails. In *ACM Conference on Human Factors in Computing Systems*, CHI '17, pages 387–391, Denver, Colorado, USA, May 2017. ACM.

[14] Mohammed Jubur, Prakash Shrestha, Nitesh Saxena, and Jay Prakash. Bypassing Push-Based Second Factor and Passwordless Authentication with Human-Indistinguishable Notifications. In *ACM Asia Conference on Computer and Communications Security*, ASIA CCS '21, pages 447–461, Virtual Conference, May 2021. ACM.

[15] Ben Kaiser, Jerry Wei, Elena Lucherini, Kevin Lee, J. Nathan Matias, and Jonathan Mayer. Adapting Security Warnings to Counter Online Disinformation. In *USENIX Security Symposium*, SSYM '21, pages 1163–1180, Virtual Conference, August 2021. USENIX.

[16] Leona Lassak, Annika Hildebrandt, Maximilian Golla, and Blase Ur. "It's Stored, Hopefully, on an Encrypted Server": Mitigating Users' Misconceptions About FIDO2 Biometric WebAuthn. In *USENIX Security Symposium*, SSYM '21, pages 91–108, Virtual Conference, August 2021. USENIX.

[17] Victor Le Pochat, Tom Van Goethem, Samaneh Tajalizadehkhoob, Maciej Korczyński, and Wouter Joosen. Tranco: A Research-Oriented Top Sites Ranking Hardened Against Manipulation. In *Symposium on Network and Distributed System Security*, NDSS '19, San Diego, California, USA, February 2019. ISOC.

[18] Xu Lin, Panagiotis Ilia, Saumya Solanki, and Jason Polakis. Phish in Sheep's Clothing: Exploring the Authentication Pitfalls of Browser Fingerprinting. In *USENIX Security Symposium*, SSYM '22, pages 1651–1668, Boston, Massachusetts, USA, August 2022. USENIX.

[19] LinkedIn, Inc. Security Footer Message in LinkedIn Emails, March 2023. https://www.linkedin.com/help/linkedin/answer/a1339250, as of June 6, 2023.

[20] Philipp Markert, Daniel V. Bailey, Maximilian Golla, Markus Dürmuth, and Adam J. Aviv. On the Security of Smartphone Unlock PINs. *ACM Transactions on Privacy and Security*, 24(4):30:1–30:36, September 2021.

[21] Philipp Markert, Theodor Schnitzler, Maximilian Golla, and Markus Dürmuth. "As soon as it's a risk, I want to require MFA": How Administrators Configure Risk-based Authentication. In *Symposium on Usable Privacy and Security*, SOUPS '22, pages 483–501, Boston, Massachusetts, USA, August 2022. USENIX.

[22] Ariana Mirian, Joe DeBlasio, Stefan Savage, Geoffrey M. Voelker, and Kurt Thomas. Hack for Hire: Exploring the Emerging Market for Account Hijacking. In *The World Wide Web Conference*, WWW '19, pages 1279–1289, San Francisco, California, USA, May 2019. ACM.

[23] Lorenzo Neil, Elijah Bouma-Sims, Evan Lafontaine, Yasemin Acar, and Bradley Reaves. Investigating Web Service Account Remediation Advice. In *Symposium on Usable Privacy and Security*, SOUPS '21, pages 359–376, Virtual Conference, August 2021. USENIX.

[24] Netflix, Inc. I Received an Email Stating There Was a New Sign-in to My Account, June 2023. https://help.netflix.com/en/node/100775, as of June 6, 2023.

[25] Bijeeta Pal, Tal Daniel, Rahul Chatterjee, and Thomas Ristenpart. Beyond Credential Stuffing: Password Similarity Models using Neural Networks. In *IEEE Symposium on Security and Privacy*, SP '19, pages 866–883, San Francisco, California, USA, May 2019. IEEE.

[26] PayPal, Inc. PayPal Security Center: How to Identify Fake Messages, June 2023. https://www.paypal.com/us/security/learn-about-fake-messages, as of June 6, 2023.

[27] Justin Petelka, Yixin Zou, and Florian Schaub. Put Your Warning Where Your Link Is: Improving and Evaluating Email Phishing Warnings. In *ACM Conference on Human Factors in Computing Systems*, CHI '19, pages 518:1–518:15, Glasgow, Scotland, United Kingdom, May 2019. ACM.

[28] Elissa M. Redmiles. "Should I Worry?" A Cross-Cultural Examination of Account Security Incident Response. In *IEEE Symposium on Security and Privacy*, SP '19, pages 920–934, San Francisco, California, USA, May 2019. IEEE.

[29] Elissa M. Redmiles, Everest Liu, and Michelle L. Mazurek. You Want Me To Do What? A Design Study of Two-Factor Authentication Messages. In *Who Are You?! Adventures in Authentication Workshop*, WAY '17, pages 1–5, Santa Clara, California, USA, August 2017.

[30] Elissa M. Redmiles, Ziyun Zhu, Sean Kross, Dhruv Kuchhal, Tudor Dumitras, and Michelle L. Mazurek. Asking for a Friend: Evaluating Response Biases in Security User Studies. In *ACM Conference on Computer and Communications Security*, CCS '18, pages 1238–1255, Toronto, Ontario, Canada, October 2018. ACM.

[31] Robert W. Reeder, Adrienne Porter Felt, Sunny Consolvo, Nathan Malkin, Christopher Thompson, and Serge Egelman. An Experience Sampling Study of User Reactions to Browser Warnings in the Field. In *ACM Conference on Human Factors in Computing Systems*, CHI '18, pages 512:1–512:13, Montreal, Quebec, Canada, April 2018. ACM.

[32] SECUSO Research Group, KIT. How to Detect Fraudulent and Phishing Messages, March 2022. https://secuso.aifb.kit.edu/betr-nachrichten-flyer2EN, as of June 6, 2023.

[33] Kaiwen Shen, Chuhan Wang, Minglei Guo, Xiaofeng Zheng, Chaoyi Lu, Baojun Liu, Yuxuan Zhao, Shuang Hao, Haixin Duan, Qingfeng Pan, and Min Yang. Weak Links in Authentication Chains: A Large-scale Analysis of Email Sender Spoofing Attacks. In *USENIX Security Symposium*, SSYM '21, pages 3201–3217, Virtual Conference, August 2021. USENIX.

[34] Roger N. Shepard and Jacqueline Metzler. Mental Rotation of Three-Dimensional Objects. *Science*, 171(3972):701–703, February 1971.

[35] StatCounter. Desktop Browser Market Share Worldwide – June 2023, June 2023. https://gs.statcounter.com/browser-market-share/desktop/worldwide, as of June 6, 2023.

[36] StatCounter. Desktop Operating System Market Share Worldwide – June 2023, June 2023. https://gs.statcounter.com/os-market-share/desktop/worldwide, as of June 6, 2023.

[37] Joshua Sunshine, Serge Egelman, Hazim Almuhimedi, Neha Atri, and Lorrie Faith Cranor. Crying Wolf: An Empirical Study of SSL Warning Effectiveness. In

USENIX Security Symposium, SSYM '09, pages 399–416, San Diego, California, USA, June 2009. USENIX.

[38] Kurt Thomas, Jennifer Pullman, Kevin Yeo, Ananth Raghunathan, Patrick Gage Kelley, Luca Invernizzi, Borbala Benko, Tadek Pietraszek, Sarvar Patel, Dan Boneh, and Elie Bursztein. Protecting Accounts From Credential Stuffing With Password Breach Alerting. In *USENIX Security Symposium*, SSYM '19, pages 1556–1571, Santa Clara, California, USA, August 2019. USENIX.

[39] Edmund R. Thompson. Development and Validation of an Internationally Reliable Short-Form of the Positive and Negative Affect Schedule. *Journal of Cross-Cultural Psychology*, 38(2):227–242, March 2007.

[40] U.S. Census Bureau. U.S. and World Population Clock, June 2023. https://www.census.gov/popclock/, as of June 6, 2023.

[41] U.S. Department of Homeland Security. The Menlo Report: Ethical Principles Guiding Information and Communication Technology Research, August 2012. https://www.caida.org/publications/papers/2012/menlo_report_actual_formatted/, as of June 6, 2023.

[42] Steven G. Vandenberg and Allan R. Kuse. Mental Rotations, a Group Test of Three-Dimensional Spatial Visualization. *Perceptual and Motor Skills*, 47(2):599–604, October 1978.

[43] Meridel Walkington. Designing Better Security Warnings, March 2019. https://blog.mozilla.org/ux/2019/03/designing-better-security-warnings/, as of June 6, 2023.

[44] Kathryn Walsh, Faiza Tazi, Philipp Markert, and Sanchari Das. My Account Is Compromised – What Do I Do? Towards an Intercultural Analysis of Account Remediation for Websites. In *Workshop on Inclusive Privacy and Security*, WIPS '21, pages 1–6, Virtual Conference, August 2021.

[45] David Wardle. How Long Does It Take To Get Owned? Technical Report RHUL–ISG–2019–4, Royal Holloway University of London, March 2019.

[46] Rick Wash, Emilee J. Rader, Ruthie Berman, and Zac Wellmer. Understanding Password Choices: How Frequently Entered Passwords Are Re-Used across Websites. In *Symposium on Usable Privacy and Security*, SOUPS '16, pages 175–188, Denver, Colorado, USA, July 2016. USENIX.

[47] Rick Wash, Emilee J. Rader, and Chris Fennell. Can People Self-Report Security Accurately?: Agreement Between Self-Report and Behavioral Measures. In *ACM Conference on Human Factors in Computing Systems*, CHI '17, pages 2228–2232, Denver, Colorado, USA, May 2017. ACM.

[48] Stephan Wiefling, Luigi Lo Iacono, and Markus Dürmuth. Is This Really You? An Empirical Study on Risk-Based Authentication Applied in the Wild. In *International Conference on ICT Systems Security and Privacy Protection*, IFIP SEC '19, pages 134–148, Lisbon, Portugal, June 2019. IFIP.

[49] Stephan Wiefling, Tanvi Patil, Markus Dürmuth, and Luigi Lo Iacono. Evaluation of Risk-based Re-Authentication Methods. In *International Conference on ICT Systems Security and Privacy Protection*, IFIP SEC '20, pages 280–294, Virtual Conference, September 2020. IFIP.

[50] Yixin Zou, Shawn Danino, Kaiwen Sun, and Florian Schaub. You 'Might' Be Affected: An Empirical Analysis of Readability and Usability Issues in Data Breach Notifications. In *ACM Conference on Human Factors in Computing Systems*, CHI '19, pages 194:1–194:14, Glasgow, Scotland, United Kingdom, May 2019. ACM.

Appendix

A Self-Report Study: Survey Instrument

Scenario Description
In the following survey, you will be asked to imagine that your name is **Jo Doe** (jo.doe@gmail.com). You have an online account with a major company called **AcmeCo** which you **regularly access with all the devices you own**. Imagine that **this account is important to you**, and that it is like other accounts you may have, such as for online shopping or social media.
A Notification from AcmeCo
Imagine, you {**recently signed into** your AcmeCo account. **/ have not signed into** your AcmeCo account for a while.}
In your inbox, you see the following email.

Notification

We displayed an interactive mockup email interface with our baseline notification shown in Figure 2.

I-PANAS-SF
Now we would like to know **how you feel in reaction to the email** shown on the left. The list below consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer on the list. Indicate to what extent you feel this way right now, that is, at the present moment.

	Very slightly or not at all (1)	A little (2)	Moderately (3)	Quite a bit (4)	Extremely (5)
Upset	○	○	○	○	○
Hostile	○	○	○	○	○
Alert	○	○	○	○	○
Ashamed	○	○	○	○	○
Inspired	○	○	○	○	○
Nervous	○	○	○	○	○
Determined	○	○	○	○	○
Attentive	○	○	○	○	○
Afraid	○	○	○	○	○
Active	○	○	○	○	○

Reaction

SQ1 **Please list 3 actions** you might take after receiving this email **and explain why** you might take those actions.
1 Action: _____ Explanation: _____
2 Action: _____ Explanation: _____
3 Action: _____ Explanation: _____

SQ2 I would **feel** _____ **about receiving** this email from AcmeCo.
○ Not at all concerned ○ Slightly concerned
○ Somewhat concerned ○ Moderately concerned
○ Extremely concerned

SQ3 Why?
Answer: _____

SQ4 For me, **taking action in response** to this email from AcmeCo **would be**
○ Not a priority ○ Low priority ○ Medium priority ○ High priority
○ Very high priority

SQ5 Why?
Answer: _____

Understanding

SQ6 In your own words, please **describe what this email is telling** you.
Answer: _____

SQ7 In your own words, please **describe all of the factors that may have caused you to receive this email**.
Answer: _____

SQ8 I feel that this email from AcmeCo explained to me **how to resolve the situation**.
○ Strongly disagree ○ Disagree ○ Neither agree or disagree
○ Agree ○ Strongly agree

SQ9 Why?
Answer: _____

Expectation

SQ10 I feel that **ignoring this email** from AcmeCo **would have consequences**.
○ Strongly disagree ○ Disagree ○ Neither agree or disagree
○ Agree ○ Strongly agree

SQ11 Why?
Answer: _____

SAC Please select 'Agree' as the **answer** to this question.
○ Strongly disagree ○ Disagree ○ Neither agree or disagree
○ Agree ○ Strongly agree

SQ12 I think **real companies should send emails like this one** when necessary.
○ Strongly disagree ○ Disagree ○ Neither agree or disagree
○ Agree ○ Strongly agree

SQ13 Why?
Answer: _____

Prior Experience

SQ14 **I have received emails similar to this one** in the past.
○ Never ○ A few times ○ Occasionally ○ Many times ○ Regularly

*If participant stated to have received similar notifications in **SQ14**:*
We will now ask you about **your personal experiences with similar emails** you have received in the past. **Based on these experiences**, please answer the questions below:

SQ15 I _____ read them.
○ Never ○ Rarely ○ Sometimes ○ Often ○ Always

SQ16 Why?
Answer: _____

SQ17 Have you **ever received a similar email** that helped you to **learn about an unrecognized sign-in**? For example, a sign-in that concerned you.
○ Yes ○ No ○ Don't know

*If participant answered 'Yes' in **SQ17**:*

SQ18 Referring to the situation where a similar email helped you to learn about an unrecognized sign-in. Please **describe the situation**, how you knew that something was wrong, and **how you solved it**.
Answer: _____

Demography

SD1 Select your age.
○ 18–24 ○ 25–34 ○ 35–44 ○ 45–54 ○ 55–64 ○ 65–74 ○ 75+
○ Prefer not to answer

SD2 Which of these best describes your current gender identity?
○ Woman ○ Man ○ Non-binary
○ Prefer to self-describe: _____
○ Prefer not to answer

SD3 What is the highest degree or level of school you have completed?
○ No schooling completed ○ Some high school, no diploma
○ High school graduate, diploma, or equivalent ○ Some college
○ Trade, technical, or vocational training ○ Associate's degree
○ Bachelor's degree ○ Master's degree ○ Professional degree
○ Doctorate ○ Prefer not to answer

SD4 Which of the following best describes your educational background or job field?
○ I have an education in, or work in, the field of computer science, computer engineering or IT.
○ I do not have an education in, nor do I work in, the field of computer science, computer engineering or IT.
○ Prefer not to answer

One More Thing
Please indicate if you've honestly participated in this survey and followed instructions completely. You will not be penalized/rejected for indicating 'No' but your data may not be included in the analysis:
○ Yes ○ No

B Measurement Study: Survey Instrument

Stage 1: Enrollment

Participants solved 5x spatial reasoning tests.

Demography

MD1 Select your age.
○ 18–24 ○ 25–34 ○ 35–44 ○ 45–54 ○ 55–64 ○ 65–74 ○ 75+
○ Prefer not to answer

MD2 Which of these best describes your current gender identity?
○ Woman ○ Man ○ Non-binary
○ Prefer to self-describe: _____
○ Prefer not to answer

MD3 What is the highest degree or level of school you have completed?
○ No schooling completed ○ Some high school, no diploma
○ High school graduate, diploma, or equivalent ○ Some college
○ Trade, technical, or vocational training ○ Associate's degree
○ Bachelor's degree ○ Master's degree ○ Professional degree
○ Doctorate ○ Prefer not to answer

MAC1 Please select 'Agree' as the answer to this question.
○ Strongly disagree ○ Disagree ○ Neither agree or disagree
○ Agree ○ Strongly agree

MD4 Which of the following best describes your educational background or job field?
○ I have an education in, or work in, the field of computer science, computer engineering or IT.
○ I do not have an education in, nor do I work in, the field of computer science, computer engineering or IT.
○ Prefer not to answer

Stage 2: Recall

Participants solved 5x spatial reasoning tests.

Stage 3: Questionnaire

Debriefing

Participants were debriefed and told about the actual purpose of the study.

Email

The individual login notification we sent to the participant is displayed for later reference (see Figure 2, but re-branded to match the SRS study).
If participant has not changed their password.

MQ0 Do you **remember** receiving **this email**?
○ Yes ○ No

*Participants who selected 'No' in **MQ0** were forwarded to **MQ10**.*

I-PANAS-SF

Now we would like to know how you felt in reaction to the email. The list below consists of a number of words that describe different feelings and emotions. Read each item and then mark the appropriate answer on the list. **Indicate to what extent you felt this way when you noticed the email**.

We asked I-PANAS-SF from the Self-Report Study again.

Reaction

MQ1 Did you **read** this **email** when you received it? (email as shown on the left)
○ I did not read it at all ○ I only read the subject but not the body
○ I read the subject and skimmed the body ○ I fully read it

MQ2a In reaction to this email, you decided to change your password. Please **describe** any **other actions** you took.
Answer: _____

MQ3a **Why** did you react this way, i.e., change your password and take the other actions you described.
Answer: _____

If participant has not changed their password.

MQ2b **What** did you do **in reaction** to it?
Answer: _____

MQ3b **Why** did you react this way?
Answer: _____

Content & Design

MQ4 How much did the following **factors influence** your **reaction**?
Answer choice per item: No effect (1) – Major effect (5).
⋈ Email metadata (e.g., sender, subject, time of arrival)
⋈ Email content (e.g., information, instructions, wording)
⋈ Email design (e.g., structure, color, font size)
⋈ Experience in dealing with such emails
⋈ Negative experience with security and privacy incidents (e.g., data breach, identity theft) ⋈ Email appeared to be phishing
⋈ Expected to receive such an email
⋈ Other: _____
Answer choices were randomly ordered.

MQ5 Please rate how **helpful** the following **information** was for **deciding how to react** to this email?
Ans. choice per item: Not at all helpful (1) – Extremely helpful (5).
⋈ Affected account name (i.e., email address)
⋈ Location ⋈ Date ⋈ Device

Time & Location

MQ6 **When** did you read the email?
○ I never read it ○ Immediately after I noticed it
○ Less than 1 hour after I noticed it ○ A few hours after I noticed it
○ One day after I noticed it ○ More than one day after I noticed it
○ I do not remember

*If participant has not selected "Never" in **MQ6**:*

MQ7 **In which US state** have you been when you **read** the **email**?
Dropdown with all 50 US states + District of Columbia
If somewhere outside the USA: _____

MQ8 **Where** did you read the email?
○ At home ○ At work ○ On the go
○ Somewhere else: _____ ○ I do not remember

MAC2 Please select 'Agree' as the **answer** to this question.
○ Strongly disagree ○ Disagree ○ Neither agree or disagree
○ Agree ○ Strongly agree

MQ9 In case you received the email at a **different location or different time**, would your **reaction** to it been any **different**?
○ Yes ○ No ○ Do not know

*If participant selected "Yes" in **MQ8**:*

MQ10 **What** would you have **done differently**, if you had received the email at a **different location or different time**?
Answer: _____

Comprehension

MQ11 In your opinion, **why** have you **received** this email?
Answer: _____

Expectation

MQ12 In your opinion, **when** should real companies **send emails** like this one? (Select all that apply)
☐ Never ☐ After every detected sign-in which suggests that something is suspicious or wrong ☐ After every detected sign-in when I have not signed in for a while ☐ After every detected sign-in from a new device ☐ After every detected sign-in at an unusual time of the day (e.g., in the middle of the night) ☐ After every detected sign-in from a new location ☐ After every detected sign-in ☐ Other: _____

*If participant selected "Never" in **MQ12**:*

MQ13 In your opinion, **why** do you think real companies should **never send emails** like this one?
Answer: _____

Prior Experience

MQ14 Have you had any **negative experiences** with a **security or privacy** incident within the **last two years** (e.g., data breach, identity theft)?
○ Yes ○ No

MQ15 **Regularly changing** my **password** (e.g., every 90 days) **increases** the **security** of my account.
○ Strongly disagree ○ Disagree ○ Neither agree or disagree
○ Agree ○ Strongly agree

MQ16 **Changing** my **password** after it **has been breached increases** the **security** of my account.
○ Strongly disagree ○ Disagree ○ Neither agree or disagree
○ Agree ○ Strongly agree

One More Thing

Please indicate if you've honestly participated in this survey and followed instructions completely. You will not be penalized/rejected for indicating 'No' but your data may not be included in the analysis:
○ Yes ○ No

C Demographics

C.1 Self-Report Study

Table 1: Demographics of the self-report study.

	Male		Female		Other		Total	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Age	105	48	104	47	11	5	220	100
18–24	16	7	9	4	2	1	27	12
25–34	37	17	39	18	6	3	82	37
35–44	25	11	29	13	1	0	55	25
45–54	14	6	14	6	1	0	29	13
55–64	10	5	6	3	0	0	16	7
65–74	2	1	6	3	0	0	8	4
75+	1	0	1	0	0	0	2	1
Education	105	48	104	47	11	5	220	100
High School	14	6	11	5	1	0	26	12
Some College	19	9	20	9	2	1	41	19
Trade	4	2	5	2	0	0	9	4
Associate's	10	5	8	4	2	1	20	9
Bachelor's	36	16	40	18	2	1	78	35
Master's	17	8	14	6	2	1	33	15
Professional	3	1	2	1	0	0	5	2
Doctorate	1	0	4	2	1	0	6	3
Background	105	48	104	47	11	5	220	100
Technical	10	5	39	18	1	0	50	23
Non-Technical	92	42	61	28	8	4	161	73
Prefer not to say	3	1	4	2	2	1	9	4

C.2 Measurement Study

Table 2: Demographics of the measurement study.

	Male		Female		Other		Total	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Age	149	65	79	34	1	0	229	100
18–24	4	2	6	3	0	0	10	4
25–34	17	7	15	7	0	0	32	14
35–44	27	12	17	7	0	0	44	19
45–54	24	10	15	7	0	0	39	17
55–64	35	15	13	6	0	0	48	21
65–74	31	14	11	5	0	0	42	18
75+	11	5	2	1	1	0	14	6
Education	149	65	79	34	1	0	229	100
High School	47	21	31	14	0	0	78	34
Trade	39	17	12	5	1	0	52	23
Bachelor's	34	15	24	10	0	0	58	25
Master's	23	10	10	4	0	0	33	14
Doctorate	4	2	2	1	0	0	6	3
Prefer not to say	2	1	0	0	0	0	2	1
Background	149	65	79	34	1	0	229	100
Technical	10	4	25	11	0	0	35	15
Non-Technical	134	59	53	23	1	0	188	82
Prefer not to say	5	2	1	0	0	0	6	3

D Real-World Notifications: Features

Table 3: Information contained in notifications sent by real-world services.

Rank	Domain	Account Name	Browser	Country	State	City	IP	OS	Time	Time Zone	Instructions Legit	Instructions Malicious
1	google.com	●	○	○	○	○	○	●	○	○	●	●
	workspace.google.com	●	○	○	○	○	●	○	○	○	○	○
2	facebook.com	●	●	●	○	●	○	●	●	●	●	●
6	microsoft.com	●	●	●	○	○	●	●	●	●	●	●
7	twitter.com	●	●	●	●	●	○	●	○	○	●	●
9	instagram.com	●	●	●	○	●	○	●	●	●	●	●
10	cloudflare.com	●	●	○	○	○	●	●	●	●	●	●
13	apple.com	●	○	○	○	○	○	●	●	●	●	●
14	linkedin.com	●	●	●	●	●	○	●	●	●	○	●
15	netflix.com	●	○	●	●	○	○	○	●	●	●	●
17	wikipedia.org	○	○	○	○	○	○	○	○	●	●	●
20	amazon.com	○	●	●	●	○	○	●	●	●	●	●
25	yahoo.com	●	●	●	○	○	●	●	●	○	●	●
32	github.com	●	○	○	○	○	○	○	○	○	●	●
36	pinterest.com	○	●	○	○	○	○	●	○	●	●	●
63	vk.com	○	●	○	○	○	○	○	●	○	○	●
72	mozilla.org	○	○	●	●	●	●	○	●	●	○	●
80	spotify.com	○	○	●	○	○	○	○	●	●	●	●
82	tumblr.com	○	●	●	●	○	●	●	●	○	●	●
83	paypal.com	●	●	●	●	●	○	●	●	●	●	●
97	ebay.com	●	●	●	●	●	○	●	●	●	●	●
99	dropbox.com	●	●	○	○	○	○	●	●	●	●	●
103	csdn.net	●	○	●	○	○	●	○	●	○	○	●
104	imdb.com	●	●	●	●	○	○	●	●	●	●	●
125	soundcloud.com	●	●	●	○	●	●	●	●	●	●	●
155	twitch.tv	●	●	●	●	●	●	●	●	●	●	●
157	etsy.com	●	●	●	●	●	●	●	○	●	●	●
164	booking.com	○	●	●	○	●	○	●	●	●	●	●
171	sourceforge.net	●	●	●	○	○	○	●	●	●	○	●
179	researchgate.net	●	●	●	○	○	○	●	●	○	○	●
180	oracle.com	●	●	●	●	●	●	●	●	●	●	●
186	slack.com	○	●	●	○	○	●	○	●	○	●	●
206	weebly.com	●	●	●	●	●	○	●	●	●	●	●
236	samsung.com	●	○	●	○	○	○	○	●	●	○	●
322	grammarly.com	●	●	●	○	●	●	●	●	●	○	●
328	fiverr.com	●	●	●	○	●	○	●	●	●	○	●
344	snapchat.com	●	○	●	○	●	●	○	●	●	●	●
381	yelp.com	●	●	○	○	○	○	●	●	●	●	●
392	binance.com	●	○	○	○	○	●	○	●	●	○	●
524	netease.com	●	○	●	○	○	●	○	●	○	○	●
541	gitlab.com	●	○	○	○	○	●	○	●	●	●	●
545	atlassian.com	●	●	●	●	●	●	●	●	●	●	●
563	uber.com	○	●	●	○	●	●	●	●	●	○	●
753	airbnb.com	○	●	●	●	○	○	●	●	●	●	●
885	nintendo.com	●	●	●	○	○	○	○	●	○	○	●
924	xing.com	●	●	●	○	○	○	●	●	○	●	●
1205	wayfair.com	●	○	○	○	○	○	●	●	●	●	●
1327	deezer.com	○	●	●	○	●	○	○	●	●	●	●
1387	lyft.com	●	●	●	●	●	○	○	●	○	●	●
1413	battle.net	●	○	○	○	○	○	○	○	●	○	●
2476	1password.com	○	●	●	●	○	●	○	●	●	○	○
2645	porkbun.com	●	○	○	○	○	●	○	○	●	○	●
3179	faceit.com	○	○	●	○	○	●	○	○	○	●	●
3605	plex.tv	●	○	●	●	●	●	○	○	●	○	●
4189	dhl.de	○	○	○	○	○	○	○	○	●	○	●
4250	dashlane.com	○	●	●	○	○	●	●	○	●	○	●
5383	logmein.com	●	●	●	●	●	●	●	●	○	○	●
8544	maxmind.com	○	○	●	●	●	●	○	●	●	●	●
10625	check24.com	●	●	●	○	○	○	●	●	●	○	●
16460	myunidays.com	●	○	○	○	○	●	○	●	●	○	●
16993	n26.com	●	●	●	○	●	●	●	●	●	●	●
19535	neteller.com	●	●	○	○	○	○	●	●	●	●	●
25667	splitwise.com	●	●	○	○	○	○	●	○	●	●	●
27539	decathlon.com	○	●	●	○	○	○	●	●	●	●	●
31988	netatmo.com	●	○	●	○	●	●	●	●	○	●	●
40161	stacksocial.com	●	○	○	○	○	○	○	●	●	●	●
48031	traderepublic.com	●	○	○	○	○	○	●	○	○	○	●

E Real-World Notifications: Email Metadata

Table 4: Sender, email address, and subject of the notifications sent by real-world services.

Rank	Domain	Display Name	Email Address	Subject
1	google.com	Google	no-reply@accounts.google.com	Security alert
	workspace.google.com	Google Workspace Alerts	google-workspace-alerts-noreply@google.com	Alert: Suspicious login
2	facebook.com	noreply	noreply@facebookmail.com	Did you use Facebook from somewhere new?
6	microsoft.com	Microsoft account team	account-security-noreply@accountprotection.microsoft.com	Microsoft account unusual sign-in activity
7	twitter.com	Twitter	verify@twitter.com	New login to Twitter from {browser} on {OS}
9	instagram.com	Instagram	security@mail.instagram.com	New login to Instagram from {browser} on {OS}
10	cloudflare.com	Cloudflare	noreply@notify.cloudflare.com	Your Cloudflare account has been accessed from a new IP Address
13	apple.com	Apple	noreply@email.apple.com	Your Apple ID was used to sign in to iCloud on a {device}
14	linkedin.com	LinkedIn	security-noreply@linkedin.com	{Name}, please verify your new device
15	netflix.com	Netflix	info@mailer.netflix.com	A new device is using your account
17	wikipedia.org	Wikipedia	wiki@wikimedia.org	Login to Wikipedia as {account name} from a device you have not recently used
20	amazon.com	amazon.com	account-update@amazon.com	amazon.com, action needed: Sign-in
25	yahoo.com	Yahoo	no-reply@cc.yahoo-inc.com	Unexpected sign-in attempt
32	github.com	GitHub	noreply@github.com	[GitHub] Please review this sign in
36	pinterest.com	Pinterest	noreply@account.pinterest.com	New login on your Pinterest account
63	vk.com	VK	admin@notify.vk.com	Someone has accessed your account from {OS} through {browser}, {country}
72	mozilla.org	Firefox Accounts	accounts@firefox.com	New sign-in to Firefox
80	spotify.com	Spotify	no-reply@spotify.com	New login to Spotify
82	tumblr.com	Tumblr	no-reply@tumblr.com	Your account has been logged into.
83	paypal.com	service@paypal.com	service@paypal.com	Login from a new device
97	ebay.com	eBay	ebay@ebay.com	A new device is using your account
99	dropbox.com	Dropbox	no-reply@dropbox.com	We noticed a new sign in to your Dropbox
103	csdn.net	CSDN	service@register.csdn.net	[CSDN] Notification of remote login
104	imdb.com	imdb.com	account-update@imdb.com	imdb.com, action needed: Sign-in
125	soundcloud.com	SoundCloud Login	no-reply@login.soundcloud.com	SoundCloud sign-in detected from a new device
155	twitch.tv	Twitch	no-reply@twitch.tv	Your Twitch Account - Successful Log-in
157	etsy.com	Etsy	noreply@mail.etsy.com	{Name}, did you recently sign into Etsy?
164	booking.com	-	noreply@booking.com	New sign in to your account
171	sourceforge.net	SourceForge	noreply@sourceforge.net	Foreign login to your SourceForge.net account
179	researchgate.net	ResearchGate	no-reply@researchgatemail.net	New login from {browser} on {OS}
180	oracle.com	Oracle	no-reply@oracle.com	New Device Login Detected with Your Account
186	slack.com	Slack	feedback@slack.com	Slack account sign in from a new device
206	weebly.com	-	noreply@messaging.squareup.com	New login from {browser} on {OS}
236	samsung.com	Samsung Account	sa.noreply@samsung-mail.com	New sign in to your Samsung account
322	grammarly.com	Grammarly Security	info@security.grammarly.com	New Login to Grammarly
328	fiverr.com	Fiverr	noreply@e.fiverr.com	New login on your Fiverr account
344	snapchat.com	Team Snapchat	no_reply@snapchat.com	New Snapchat Login
381	yelp.com	Yelp	no-reply@yelp.com	New login to your Yelp account ({account name})
392	binance.com	Binance	do-not-reply@ses.binance.com	[Binance] Login Attempted from New IP address {IP} - {time}({timezone})
524	netease.com	NetEase Account Center	passport@service.netease.com	NetEase mailbox account abnormal login reminder
541	gitlab.com	GitLab	gitlab@mg.gitlab.com	gitlab.com sign-in from new location
545	atlassian.com	Atlassian	noreply@am.atlassian.com	Unusual login attempts on your Atlassian account
563	uber.com	Uber	noreply@uber.com	New device sign-in
753	airbnb.com	Airbnb	automated@airbnb.com	Account activity: New login from {browser}
885	nintendo.com	-	no-reply@accounts.nintendo.com	[Nintendo Account] New sign-in
924	xing.com	XING	mailrobot@mail.xing.com	New login on XING: {browser} {OS}
1205	wayfair.com	Wayfair	noreply@wayfair.com	New device sign-in
1327	deezer.com	-	securityteam@deezer.com	Access from new PC
1387	lyft.com	Lyft	noreply@lyftmail.com	New Login
1413	battle.net	Blizzard Entertainment	noreply@blizzard.com	Help us keep your Blizzard Account safe with a security check
2476	1password.com	1Password	hello@1password.com	New 1Password sign-in from {browser}
2645	porkbun.com	Porkbun Support	support@porkbun.com	porkbun.com | account security notice - successful login
3179	faceit.com	FACEIT	no-reply@faceit.com	Login from a new IP
3605	plex.tv	Plex	noreply@plex.tv	New sign-in to your Plex account
4189	dhl.de	-	noreply.kundenkonto@dhl.de	Successful login to your DHL account with a new device or browser
4250	dashlane.com	Dashlane	no-reply@dashlane.com	New device added to Dashlane
5383	logmein.com	LogMeIn.com Auto-Mailer	do-not-reply@logmein.com	LogMeIn Audit Notification - Login from an unfamiliar location
8544	maxmind.com	-	support@maxmind.com	MaxMind Notification: Unrecognized Device Login
10625	check24.com	CHECK24 Accounts	customeraccount@check24.com	New Login to Your Customer Account
16460	myunidays.com	UNiDAYS	no-reply@myunidays.com	Important: UNiDAYS Log-in Notification
16993	n26.com	N26	noreply@n26.com	Action needed: Unusual login to your N26 account
19535	neteller.com	NETELLER	no-reply@emails.neteller.com	New device has been detected
25667	splitwise.com	Splitwise	hello@splitwise.com	New sign-in to your Splitwise account
27539	decathlon.com	DECATHLON Service	noreply@services.decathlon.com	DECATHLON: New login to your account
31988	netatmo.com	Legrand - Netatmo - Bticino	do-not-reply@netatmo.com	Someone has logged into your account
40161	stacksocial.com	StackSocial	shop@email.stackcommerce.com	Account Activity Notification
48031	traderepublic.com	Trade Republic	service@traderepublic.com	Registration from a new device

F Codebook

Table 5: Codebook for **SQ1**, **SQ5**, and **SQ6** used in Section 5.1 RQ1: Comprehension & Reaction.

Code	Freq.	Description	Example
SQ1: Please list 3 actions you might take after receiving this email and explain why you might take those actions.			
Change PW	151	Participant would change the password.	*"Someone else got into my account, so I need to change the password right away."* (M56-C)
Ignore	69	Participant would ignore the email.	*"Ignore the email. It was me that signed in."* (L78-N)
Contact AcmeCo	64	Participant would contact AcmeCo.	*"I would try and contact them and get a solution to this urgent problem."* (M54-C)
Review Activity	59	Participant would check what has been done with the account.	*"I would look for strange activity on the account."* (M47-C)
Review Details	37	Participant would check the shown login information.	*"Check location, date, device. If it is my own location, date, and device, then I can safely ignore this message."* (L12-N)
Prevent Phishing	33	Participant would check the legitimacy of the notification.	*"Check the sender of the email. I would want to be sure the email was legitimate."* (M16-C)
Change Other PWs	25	Participant would change passwords of other accounts.	*"Change passwords for other important accounts as well"* (M87-C)
Check Other Accounts	22	Participant would check the other accounts.	*"I would look to see if other accounts of mine had been compromised."* (M28-C)
Add Additional Security	19	Participant would try to add security measures.	*"Look for additional security options e.g. 2FA"* (L8-C)
Ask Family/Friends	12	Participant would ask family and/or friends if they have used the account.	*"Ask my husband if he signed in."* (L42-C)
Delete Account	10	Participant would consider deleting the account.	*"My account has been taken over, and might as well make a new account and terminate this account."* (M7-C)
Log Out (All) Devices	10	Participant would try to end the session of some or all devices.	*"I would logout all devices if the option is available."* (M61-C)
Remember Recent Logins	9	Participant would try to recall past actions.	*"I will do my best to remember whether I have login recently."* (L71-C)
Verify Old PW	7	Participant would log in to check if the password still works.	*"Check to see if my login still works to see if my password's been changed."* (M16-C)
SQ5: Why? (***SQ4****: For me, taking action in response to this email from AcmeCo would be [Priority Level]*)			
Secure Account	105	Participant would want to secure the account.	*"To make my information secure if it wasn't me logging in."* (M46-C)
It Was Me	37	Participant would know why it was sent.	*"It wouldn't be a priority if I recognize the device, data, and location."* (L1-N)
Serious Consequences	31	Participant would assume that an attacker could cause serious damage.	*"It could have serious consequences."* (M53-C)
Security Is Important	11	Behaving securely is generally important to the participant.	*"Protecting my accounts is important"* (M31-C)
Just Info	8	Participant would see the notification as a heads-up.	*"I assume it's simply a courtesy email."* (L95-N)
Account Is Important	9	The account is important to the participant.	*"This account is important to me, so I want to make sure it's not compromised."* (M83-C)
Annoyed by Notification	4	Participant would be annoyed by the notification.	*"I will not waste my time pursuing something that is not a real security threat to my account."* (L83-N)
Identify Damage	4	Participant would want to understand what happened.	*"I would need to get to the bottom of the notification"* (L37-C)
SQ6: In your own words, please describe what this email is telling you.			
New Login	157	Participant describes that there was a new login.	*"It's alerting me that my account has been signed into."* (L61-N)
Abnormal Login	63	Participant describes that there was a new login which deviates from previous ones.	*"The main factor is a security issue associated with an unknown login to my account."* (L72-N)
Abnormal Login: Device	38	Participant describes that there was a new login from an unusual device.	*"There was a sign in to my account not recognized as me or one of my devices"* (L6-N)
Abnormal Login: Location	15	Participant describes that there was a new login from an unusual location.	*"someone signed in from California and I'm not normally in that area"* (M91-N)
Abnormal Login: Cookies	3	Participant describes that there was a new login without cookies.	*"I just logged in after not logging in for a while, so the cached session was probably expired, and it thought I was a new login."* (M87-N)
Abnormal Login: Time	1	Participant describes that there was a new login at an unusual time.	*"A new sign-in from a different location or a different time signing in."* (L91-N)

Table 6: Codebook for **SQ7** and **SQ11** used in Section 5.1 RQ1: Comprehension & Reaction.

Code	Freq.	Description	Example
SQ7: In your own words, please describe all of the factors that may have caused you to receive this email.			
Hack	134	An unauthorized person logged into the account.	*"There could have been a breach into my account and jeopardized my security."* (M54-C)
New Device	90	Login with a new device.	*"Signing in on a different device than normally used"* (L40-N)
It Was Me	53	Participant logged in.	*"I logged in and triggered the email."* (L20-C)
New Location	32	Login from a new location.	*"Because someone signed into my account from a new location."* (M38-C)
Account Inactivity	12	Login after a longer period of inactivity.	*"I logged in to an account that I haven't tried in a long time and it wanted to give me notice"* (M62-N)
Deleted Cookies	11	Previously set cookies were deleted.	*"I probably have cleared all of my cookies so the site didn't recognize this device and though it was a new device."* (L28-N)
Phishing	11	Notification is a phishing attempt.	*"It is a phishing email... they probably just got a list of everyone who has AcmeCo emails and sent it out to all of them to try to get passwords."* (M25-N)
Unknown Login	9	An unknown login happened	*"The main factor is a security issue associated with an unknown login to my account."* (L72-C)
Shared Account	9	Someone who the account is shared with logged in.	*"If it wasn't me, then it might have been a loved one with my account access."* (L93-C)
Error	8	An error occurred on AcmeCo's side.	*"It could be an error, the email may have been sent to me by a glitch in the system."* (M57-C)
Notifications Enabled	8	The participant opted in to receive such notifications.	*"I have alerts set up to send this notice to me automatically every time my AcmeCo account is accessed (even if it's me who logged in)"* (L41-N)
SQ11: Why? (***SQ10**: I feel that ignoring this email from AcmeCo would have consequences. [Agreement Level]*)			
Someone Has Access	115	An attacker has access to the account.	*"Someone potentially may have hacked my account"* (L6-C)
It Was Me	37	It was the participant logging in.	*"There would be no consequences of ignoring it if the sign-in was me."* (L1-N)
Identity Compromised	36	Own identity could be compromised.	*"My personal info could be stolen and used for nefarious purposes."* (M7-C)
Depends	27	It depends on whether the login was legit or malicious.	*"It depends on whether this was me or not."* (L90-N)
Unclear	9	Participant has no clear opinion on the consequences of ignoring.	*"There is no telling what is happening."* (M94-C)
Compromise Other Accounts	7	Ignoring the notification could also compromise other accounts.	*"Someone else has my account and can use it to steal other accounts associated with this email."* (M11-C)
Lock Out	7	Access to the account could be lost entirely.	*"I feel that someone could get me locked out of my account."* (M28-C)
Just Info	6	Notification is just a heads-up.	*"It is a courtesy email."* (L95-N)
Check Login	5	Login needs to be checked.	*"I should at least ensure there was no fraud."* (L55-C)

Table 7: Codebook for **SQ9** and **SQ18** used in Section 5.2 RQ2: Decision-Making & Execution.

Code	Freq.	Description	Example
SQ9: Why? (***SQ8****: I feel that this email from AcmeCo explained to me how to resolve the situation. [Agreement Level]*)			
Explains Malicious	133	Participant appreciates that instructions for the malicious case are explained.	*"It gives me the option to change my password."* (L41-N)
Explains Both	53	Participant appreciates that instructions for the legit and malicious case are explained.	*"It explains to ignore the email if it was me, and change my password if it wasn't."* (L101-N)
Missing	33	Participant misses information or advice.	*"Changing my password is the very first line of defense, but I wish there was more information about what steps to take, or further assistance from AcmeCo."* (M26-C)
Provides Link	22	Participant appreciates that a link is provided to change the password.	*"The steps to take were very clear and easy to follow. It also provided a link to make it easy to change my password if I needed to."* (L42-C)
Notification Untrusted	10	Participant describes the notification to be untrustworthy.	*"It shouldn't be suggesting that I click the link in the email as this is a trick often used by scammers."* (M35-C)
SQ18: Referring to the situation where a similar email helped you to learn about an unrecognized sign-in. Please describe the situation, how you knew that something was wrong, and how you solved it.			
Malicious	134	It was not the participant signing in.	*"I changed my password for my email once because someone got a hold of it somehow."* (L42-C)
Location	68	Login took place at an unknown location.	*"I knew it because the login happened from a place I did not even visit and immediately changed my password."* (L43-C)
Location: Continent	19	Login took place on a different continent.	*"I received a notification that someone from another continent logged into my account and I immediately knew this was not me."* (L50-C)
Location: Country	17	Login took place in a different country.	*"I received an email that someone logged into my account from another country so I changed my password"* (L69-N)
Location: State	8	Login took place in a different state.	*"I had a login notification from California when I live in Texas. Immediately I knew someone hacked into my account."* (M61-C)
Unexpected	32	Notification came unexpected.	*"I knew something was wrong because I received a sign-in attempt notification from a website I hadn't used in a while, and hadn't even tried signing in to lately."* (M95-N)
Device	17	Login was done with an unknown device.	*"It was my instagram account, I hadn't logged in on that device they described, I changed my password"* (M20-C)
Account Sharing	10	Login was done by someone who the account is shared.	*"My kids sometimes use my accounts - Amazon, Netflix, Disney plus - I ask them to confirm it was them signing in - which is fine."* (L89-C)
It Was Me	10	It was actually the participant logging in.	*"I received a similar email from Amazon about a new sign in. It turned out that I used a new device that it didn't recognize."* (L10-C)
Time	2	Login took place at an unusual time.	*"I knew it was me because the sign in came at a time, and from a location, which did not at all correlate to my real world location, and I dealt with the situation as described in this study - I changed my password and ensured that 2FA was enabled."* (M27-C)

Table 8: Codebook for **SQ3**, **SQ13** and **SQ16** used in Section 5.3 RQ3: Perception & Expectation.

Code	Freq.	Description	Example
SQ3: Why? (***SQ2**: I would feel [Concern Level] about receiving this email from AcmeCo.*)			
Someone Has Access	99	The account is accessed by someone else.	*"Cause someone else is using my account"* (M60-C)
It Was Me	41	Participant knows why it was sent.	*"Because I already know that I just signed in"* (L90-N)
Privacy Invasion	28	Participant mentions the private information which may be saved on the account.	*"i don't want someone to have access to my personal info"* (M39-C)
PW Exposed	13	Participant refers to the risk of an exposed password.	*"Someone is logging into my account which means they have my login info"* (M31-C)
Someone Tried	12	Participant focuses on someone trying to sign into the account.	*"Somebody else tried to log in to my account"* (L85-C)
Only Information	8	Participant sees the notification as a heads-up.	*"It seems like a normal security warning"* (L56-N)
Feeling of Security	5	Participant appreciates the information.	*"Because I like the added security function and appreciate the notice."* (L28-N)
Annoyed	5	Participant is annoyed by the notification.	*"It's not a problem. It is just annoying."* (L32-N)
Phishing	4	Participant sees the notification as phishing.	*"I would feel moderately concerned because it is a phishing email."* (M25-N)
SQ13: Why? (***SQ12**:I think real companies should send emails like this one when necessary. [Agreement Level]*)			
Protect Accounts	111	Notifications are a form of protection.	*"It's helpful and protects the persons data."* (M45-C)
Alert Users	95	Notifications alert users to unknown logins.	*"To alert customers about possible security breach"* (M67-C)
Show Protection	15	Sending notifications shows that companies are security conscious.	*"It shows that they care about users security."* (L22-C)
Annoying	10	Notifications are annoying.	*"These emails are incredibly annoying."* (L90-N)
Quick Action	9	Notifications allow to take a quick action in case something unauthorized happens.	*"You can immediately stop access to your account from people who exhibit criminal behavior"* (M91-C)
SQ16: Why? (***SQ15**: I [Frequency Level] read them.*)			
Account Security	110	Reading the notification assure that the account is secure.	*"Because it keeps my accounts safe and protected by monitoring this."* (L82-C)
Know Sign-in	33	Reading the notification depends on whether the login is known.	*"If I signed in from a second device and then received the email, I knew it was me, so I would ignore it. But when I didn't sign in, I would pay attention and read the email."* (L16-N)
Important	46	Reading the notifications is important.	*"I read them, cos they are important."* (M36C)
Check Details	36	Notification is read to check the login details.	*"Just in case it wasn't me. I look at the date, location, and time to determine."* (L20-N)

Table 9: Codebook for **MQ2a**, **MQ2b**, **MQ3a**, **MQ3b**, and **MQ11** used in Section 7.1 RQ1: Comprehension & Reaction.

Code	Freq.	Description	Example
MQ2a: In reaction to this email, you decided to change your password. Please describe any other actions you took. **MQ2b**: What did you do in reaction to it?			
Nothing	121	Participant did nothing.	*"After I read it, I didn't do anything as it was me who signed in."* (L17-N)
Change PW	26	Participant changed the password.	*"I took no other actions than to change my password as directed because I had not signed in."* (M71-C)
Check Details	10	Participant checked the login details in the notification.	*"I just made sure it was my device, and on the day I accessed"* (L69-N)
Reaction Unclear	10	Participant did not know how to react.	*"I was confused and decided to wait and see."* (M93-N)
Archive Email	6	Participant archived the notification.	*"save it in my personal files in gmail"* (M8-N)
Mark as Spam	4	Participant marked the notification as spam.	*"Put it in my spam folder"* (M25-N)
Understand	4	Participant tried to understand the notification.	*"I thought about it for a couple of minutes and then deleted it."* (M105-N)
MQ3a: Why did you react this way, i.e., change your password and take the other actions you described. **MQ3b**: Why did you react this way?			
Was Me	71	Participant described the own login being the reason.	*"because it was me that logged in"* (L10-N)
Spontaneous	27	Participant reacted spontaneously.	*"I just didn't think much of it"* (M51-N)
Not Me	26	Participant was not the one signing in.	*"Because the wrong state especially the opposite coast is a huge red flag."* (M77-C)
Suspicious	18	Participant questioned the legitimacy the notification.	*"I hadn't logged in and the location was California so I was afraid it was a phishing attempt."* (M107-N)
Don't Understand	14	Participant did not understand the notification.	*"Wasn't sure what it was for"* (L30-N)
Fatigue	9	Participant felt fatigued by seeing the notification.	*"it's good for security but I get these all the time."* (M74-N)
Low Value	7	Account has a low value for the participant.	*"Why should I care if someone accesses my SRS survey?"* (M70-N)
Unsure	6	Participant did not know how to react.	*"I unsure it was me why I received it"* (L40-N)
Feel Protected	3	Participant felt protected by receiving the notification.	*"I was glad that they sent me this in case there was anything out of the ordinary going on."* (L17-N)
SQ11: In your opinion, why have you received this email?			
Inform About Login	64	Notification informed about a new login.	*"Because your system recognized that a device signed into my account."* (L47-N)
Check Login	41	Notification was a prompt to check the login that just happened.	*"To make sure that it was in fact you who had signed in to the account."* (M104-N)
(Potential) Compromise	46	Notification informed about an actual or a potential compromise.	*"My reaction was that someone from California somehow got into my account."* (M116-C)
Don't Know	39	Participant did not know why the notification was sent.	*"I had no idea, which is why I deleted it."* (M93-N)
Unusual Login	28	Notification informed about a login that was somehow unusual.	*"It sounded like someone other than my typical device had logged into my account."* (M45-N)
Security	8	Notification was sent for security reasons.	*"Security purposes."* (L9-N)
Phishing	3	Notification was phishing.	*"I thought it was phishing"* (L30-N)

Table 10: Codebook for **MQ10** used in Section 7.2 RQ2: Decision-Making & Execution.

Code	Freq.	Description	Example
MQ10: What would you have done differently, if you had received the email at a different location or different time?			
Pay More Attention	12	Participant would have payed more attention to the email.	*"I might have taken a closer look at it."* (L56-N)
Change PW	6	Participant would have changed the password.	*"I would have done as the email said and changed my password "* (L104-N)
Contact Support	4	Participant would have contacted the support.	*"Read it very carefully. If anything didn't look right I'd have contacted your organization"* (L19-N)
Panic	2	Participant would have panicked because then someone else would have been signing in.	*"If i was outside I might panic a bit more, or if the email came at a weird or random time"* (L69-N)

Table 11: Codebook for **MQ13** used in Section 7.3 RQ3: Perception & Expectation.

Code	Freq.	Description	Example
MQ13: In your opinion, why do you think real companies should never send emails like this one?			
Feels Like Scam	4	Email notification in the current form feels like scam.	*"I got very concern, since include a link in the email instead of suggesting go to the website."* (M10-N)
Annoying	2	Receiving the email notifications is annoying.	*"They take too much time"* (M107-N)