Prospects for Improving Password Selection

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Abstract

User-chosen passwords remain essential to online security, and yet people continue to choose weak, insecure passwords. In this work, we investigate whether prospect theory, a behavioral model of how people evaluate risk, can provide insights into how users choose passwords and whether it can motivate new designs for password selection mechanisms that will nudge users to select stronger passwords. We ran a user study with 762 participants, and we found that an intervention guided by prospect theory—which leverages the reference-dependence effect by framing selecting weak passwords as a loss relative to choosing a stronger password—causes approximately 25% of users to improve the strength of their password (significantly more than alternative interventions) and reduced the final number of weak passwords by approximately 25%. We also evaluate the relation between user behavior and users’ mental models of hacking and password attacks. These results provide guidance for designing and implementing account registration mechanisms that will significantly improve the strength of user-selected passwords, thereby leveraging insights from prospect theory to improve the security of systems that use password-based authentication.

1 Introduction

User-chosen passwords remain a critical component of security. Many efforts have been made to nudge users towards choosing stronger passwords, including password rules [29] and password meters [17], but these efforts have met with only partial success. Password recipes are ineffective at enforcing strong password choices [29, 63], many password meters are ineffective [11] especially for accounts users consider unimportant [17], and users continue to select and use weak passwords [40]. In this work, we investigate the extent to which insights from cognitive psychology apply to users’ password selection decisions and how those insights might be leveraged to enhance security by nudging users to select stronger passwords.
word selection decisions—i.e., an interaction with negative framing resulted in significantly higher rates of improvement compared to neutral framing \((p < .001)\) or positive framing \((p = .022)\). However, the source-dependence effect did not appear to apply; the phrasing of the prompt (specific of vague) did not have a significant impact on whether user went back and selected a stronger password \((p = .611)\).

To validate the impact of a prospect-driven intervention, we evaluated whether our intervention with negative framing increased the strength of user-selected passwords. We found that the final number of weak passwords (after interacting with the negative framing) was significantly lower than the initial number of weak passwords selected by our participants \((p = .019)\). This result confirms that the reference-dependence effect can be leveraged to enhance security by nudging users to select stronger passwords.

Finally, we investigated whether mental models of security affected how users responded to our interactions. We found that perceptions about who is likely to be targeted by hackers are correlated with password selection decisions. However, password selection decisions were consistent across different mental models of risks associated with password attacks.

Our results suggest that prospect theory can be a helpful model for understanding how users make security decisions—in particular, how users choose passwords. We find that an interaction after users select a preliminary password that leverages a negative framing—i.e., frames continuing with weak passwords as having a negative impact on security relative to improving the password before creating an account—can significantly strengthen passwords and reduce the number of weak passwords that users ultimately select. We believe that this insight from prospect theory can form the foundation for designing and implementing password selection mechanisms that enhance security by nudging users to make better password selection decisions.

2 Background: Prospect Theory

Prospect theory \([28,54–57]\)—first introduced in the 1970s as a critique of the then-dominant expected utility theory \([20,61]\)—is a descriptive model of decision making in the presence of risk. Expected utility theory—which asserts that a principal faced with a choice between two options will evaluate the expected utility of each outcome and then select the option with the higher expected utility—does not accurately predict human behavior observed in many experimental settings.

Prospect theory instead postulates that decisions are comprised of two phases: an editing phase and an evaluation phase. In the editing phase, humans apply a set of simplifying heuristics to reduce the complexity of the decision problem. In the evaluation phase, probabilities and utilities are weighted by a decision weight \(w\) and a subjective value \(\nu\), respectively; example functions capturing empirically-observed behavior are shown in Figure 1. Humans are then presumed to ratio-

![Figure 1: Example functions matching empirically-observed behavior proposed by [57].](image)

1. Isolation Effect: People simplify decision problems by disregarding components shared between alternatives and focusing exclusively on components that distinguish the options.

2. Pseudocertainty Effect: People simplify decision problems by treating extremely likely (but uncertain) outcomes as though they were certain.

3. Reference-dependence Effect: People simplify decision problems by defining outcomes relative to a neutral baseline. The framing of a problem can effect which baseline is used.

4. Certainty Effect: People overweight the probability of outcomes that are certain relative to outcomes that are merely probable.

5. Source-dependence Effect: People have different decision weights depending on the type of risk. For example, people have higher decision weights for contingent risks than for equivalent probabilistic risks (e.g., they prefer an insurance policy that provides certain coverage of specific types of damages to one that provides probabilistic coverage of all types of damages). Similarly, people are ambiguity averse—they prefer to bet based on precisely defined odds rather than on unknown odds.

6. Loss Aversion Effect: People subjectively dislike losses more than they value gains. That is, the value function is steeper for negative values (losses) than for positive values (gains).

More than 40 years later, prospect theory is still widely viewed as the best available model for how people make decisions in the presence of risk. It has been applied as a
Prospect theory has also been applied prescriptively in certain domains to nudge people towards certain “desirable” behaviors, including nudging employees to increase their retirement contributions [53], encouraging teachers to improve student outcomes [21], and incentivizing teams in high-tech factories to increase their productivity [35]. However, prospect-driven interventions have not been uniformly successful: a 2012 study did not see any increase in effort when financial or non-financial incentives for students were framed as losses compared to equivalent incentives framed as gains [26].

3 Methodology

To investigate how well prospect theory effects apply as a descriptive model of password selection, we conducted a user study (n = 762) to evaluate the impact of two prospect theory effects—the source-dependence effect and the reference-dependence effect—on password selection decisions.

3.1 Experimental Setup

We developed an experimental aggregated news site that is accessible only to authenticated users. When visiting for the first time, a user is redirected to the account creation page (Figure 2a). During account creation, the password strength is classified in real time using the zxcvbn password strength estimator [64] as weak, moderate, or strong, and this information is displayed to the user in real-time via a three-level password meter. A password is classified as weak if it has
After initially selecting a password, users who select a strong password are redirected to the home page of the aggregated news site (Figure 2c). Users who select a weak or moderate password are instead presented with an interactive prompt that states that weak (resp., moderate) passwords put their account at risk and asks whether they would like to choose a stronger password (Figure 2b). This prompt was presented using one of two possible framings:

1. **Vague Prompt:** The password you selected is (strength). Would you like to choose a stronger password?

2. **Specific Prompt:** (strength) passwords can be guessed or learned by attackers in (time), which may lead to the loss of personal information, including credit card info, and identity theft. Would you like to choose a stronger password?

Here (strength) is the classification based on the zxcvbn total score of the password the user submitted: weak or moderate. (Recall that users who submit a strong password are authenticated immediately and are not presented with a prompt.) For the specific prompt, (time) is the zxcvbn estimate for how long it would take to crack the password with an offline guessing attack if passwords are hashed and salted using a slow hashing algorithm with a moderate work factor (e.g., bcrypt, scrypt, or PBKDF2).

As shown in Figure 2b, the prompt has two buttons: one to go back (and choose a different password) and one to continue creating the account with the current password. This pair of buttons is labeled with one of three possible framings:

1. **Positive Framing:**
   - **Go Back:** Choose a stronger password to reduce the risks of financial loss and identity theft
   - **Continue:** Create account with current password

2. **Neutral Framing:**
   - **Go Back:** Yes
   - **Continue:** No

3. **Negative Framing:**
   - **Go Back:** Choose a stronger password
   - **Continue:** Ignore potential risks of financial loss and identity theft and create account with current password

Users who elect to continue are redirected to the site home-page. Users who choose to go back stay on the account creation page until they select and submit a second password; they are then redirected to the site home page (no matter how strong their second selected password is).

Each user is pseudorandomly assigned to one of the six prompts and the three framings—based on a hash of their current IP address. For each user, the site logs the strength of their initial password choice, how they interact with the interactive prompt (for users who initially select a weak or moderate password), and the strength of their revised password choice (for users who go back to change their password).

### 3.2 User Study

To evaluate the impact of prospect theory effects on password selection decisions, we conducted a user study with 762 users. Participants were recruited through Amazon Mechanical Turk, and participation was restricted to United States residents who had completed at least 50 HITs with an approval rate of at least 95%. This user study, including all consent forms and survey instruments, was reviewed in advance by the Institutional Review Board (IRB) at our institution and received an IRB exemption approval.

The task was advertised as beta-testing an aggregated news site. Each participant was asked (1) spend 1-2 minutes exploring the website as they would normally behave as an Internet user, (2) enter the unique confirmation code displayed when they visited the site, and (3) complete the follow-up survey questions. Participants who did not enter a valid confirmation code were excluded from the study.

Prior to the start of the task, users were presented with a consent form that informed them about what data would be collected and how that data would be used; only people who consented to these practices participated in the study. To avoid the appearance of collecting any personal information, users were given a username and email address to use on the site.

The follow-up survey contained questions about participants’ mental model of hacking [62] and their views on password security. We also asked basic demographic questions. To ensure validity, we conducted a series of three cognitive interviews and made revisions to clarify the wording of our survey questions. A copy of our final survey instrument is included in Appendix A.

Participants who completed the task and entered a valid confirmation code were compensated $1.20. The median completion time for the full task was 5.15 minutes.

A summary of the demographics of our user study population, along with a comparison to the overall demographics of the United States is shown in Figure 3. We observe briefly that the demographics of our study population differ slightly from the overall demographics of the United States. In particular, our survey population skews significantly younger and slightly more male. Black and African American demographics are slightly underrepresented while Asian and Asian American demographics are slightly overrepresented. Despite these differences, studies conducted with Mechanical Turkers about security and privacy have generally been found to extend to the broader population [44].
3.3 Hypotheses

To explore the impact of prospect-driven interventions on password selection decisions, we identified and evaluated four hypotheses relating to the source-dependence effect, the reference-dependence effect, and users’ mental models.

Source-dependence effect. When presented with the vague interactive follow-up prompt, a user is required to evaluate options in the presence of multiple different sources of risk: in addition to reasoning about how likely it is that an attacker would target this site and/or this user, the user must evaluate uncertainties about how hard it would be for an attacker to guess their password and about what the potential consequence of password compromise might be. When presented with the specific prompt, some of these uncertainties—in particular how hard it would be for an attacker to guess their password and what an attacker might do after they’ve learned a user’s password—are eliminated in favor of more concrete risks.

The source-dependence effect observes that users evaluate different types of risk differently, and in particular that ambiguities are evaluated differently than more concrete risks. We therefore hypothesize that users will evaluate the option to continue with their current (weak or moderate) password more negatively when presented with the specific prompt than with the vague prompt, resulting in stronger password selection after interacting with the specific prompt compared to the vague prompt.

**Hypothesis 1:** Users’ password selection decisions exhibit the source-dependence effect, that is users assigned to the specific prompt conditions are more likely to strengthen their password and less likely to ultimately select a weak password compared to users assigned to the vague prompt conditions.

Reference-dependence effect. In the conditions with positive framing, the option to go back is labeled as “Choose a stronger password to reduce the risks of financial loss and identity theft”. By emphasizing the benefits of going back, this framing implicitly nudges the user to consider the option to continue as the neutral reference point and the option to go back as a choice with higher utility relative to that reference point. By contrast, the negative framing emphasizes the loss of utility (“potential risks of financial loss and identity theft”) associated with continuing with the current password, thereby implicitly nudging the user to treat the option to go back as the neutral reference point and to evaluate continuing as a loss of utility relative to that reference point.

The reference-dependence effect implies that this difference in framing will cause users assigned to a positive framing condition to evaluate the difference between going back (i.e., choosing a stronger password) and continuing (i.e., submitting a weak password) as a positive gain in utility, whereas users assigned to a negative framing condition will evaluate the difference between continuing (i.e., submitting a weak password) and going back (i.e., choosing a stronger password) as a loss of utility. The loss aversion effect suggests that the subjective value function is steeper for (relative) losses than for (relative) gains. We therefore hypothesize that users will evaluate the option to continue with the current (weak) password more negatively in the negative framing conditions than the positive framing conditions—even though the two options have the same absolute utility in all conditions—resulting in better password selection decisions after interacting with the negative framing prompt compared to the neutral and positive framing prompts.

**Hypothesis 2:** Users’ password selection decisions exhibit the reference-dependence effect, that is users assigned to a negative framing condition—which frames going back as the neutral baseline and continuing as a loss relative to that
baseline—are more likely to strengthen their password and less likely to ultimately select a weak password compared to users assigned to vague prompt conditions.

**Mental Models of Hacking.** Our user study concluded with a series of questions about participants’ mental models of hacking and password security. One question we asked was who participants believe were the primary target of password stealing attacks. Drawing on Wash’s taxonomy of hacker mental models [62], we provided three possible answer: hackers target everyone equally, hackers primarily target rich people, and hackers primarily target users with special privileges (e.g., system administrators). We hypothesized that users who believe that hackers target everyone equally will consider themselves to be a more likely target compared to users with other mental models and will therefore be more sensitive to risks associated with password compromise.

**Hypothesis 3:** Users who believe everyone is equally likely to be targeted by a password stealing attack will be more likely to strengthen their password after seeing an interactive prompt and will be more likely to initially choose a strong password.

We also asked participants questions designed to understand how their evaluation of password risks. First we asked how likely they believed a password stealing attack would be to succeed if they selected a weak (resp., moderate, strong) password. We also asked users to select which things a hacker would be able to do if they successfully compromised a users password, given a list of six possibilities. We hypothesized that users’ beliefs about risks associated with passwords would correlate with users’ password selection decisions.

**Hypothesis 4:** Users who believe that weak passwords are more likely to be guessed by attackers or who believe that there are more potential consequences when a password gets compromised will be more likely to strengthen their password after seeing an interactive prompt and will be more likely to initially choose a strong password.

4 Results

To evaluate our hypotheses, we observed which passwords users ultimately selected (after interacting with the prompt) and compared those final password selection decisions to users’ initial password selections.

4.1 Source-dependence Effect

We found that the specificity of the prompt had no significant effect on password selection. Of the users who saw a vague prompt, 15.6% opted to go back and ultimately selected a stronger password, compared to 18.2% of users who saw the specific prompt. This difference, depicted in Figure 4, was not statistically significant ($p = .573$).

This negative result may be an indication that the source-dependence effect does not apply in the context of password selection decisions. However, it is also possible that the language of our prompts was insufficient to transfer uncertainty-based risk into probability-based risk in a manner that would trigger the source-dependence effect. Finally, it is possible that many of our users simply did not read the prompt, precluding the possibility of observing statistically significant effects due to the source-dependence effect.

Regardless of the underlying mechanism, these results suggest that utilizing more specific language about the nature of risks due to weak passwords—including notifying users of how long it would take an attacker to crack a password—is not an effective way to nudge users to select stronger passwords.

4.2 Reference-dependence Effect

We did find that the framing of the options had a significant effect on password selection decisions. Approximately 25% of users improved the strength of their password when presented with the negative framing, a significantly higher rate of improvement than the neutral framing ($p < .001$) or positive framing ($p = .022$). These results are depicted in Figure 5.

To confirm that an interaction with negative framing significantly improves password strength, we also tested whether this intervention reduces the number of weak passwords selected by users. Among users assigned to conditions with negative framing, the number of weak passwords ultimately selected was significantly lower than the number of weak passwords selected initially ($p = .019$). In contrast, the positive and neutral framings showed no significant reduction in the
number of weak passwords ultimately selected. These results are depicted in Figure 6.

These results confirm that the reference-dependence effect occurs in the context of password selection decisions. While further work will be required to validate this result in real-world systems, prior work has found that the results of password studies conducted online generally do extend to real-world systems [18]. The insight that reference-dependence effects impact users’ password selection decisions therefore provides guidance for how authentication mechanisms designers can prescriptively enhance security: by adding a confirmation page and framing the option to go back and select a strong password as the “neutral baseline” (and framing the option to continue with a weak or moderate password as a loss of utility relative to that baseline), we can effectively nudge users to enhance the security of their accounts by selecting significantly stronger passwords.

4.3 Mental Models

In our follow-up survey, we asked about users’ mental models of hacking in order to explore whether there was a correlation between how users thought about password hacking attacks and how users responded to our interactive prompts.

Hacking Targets. We asked users to identify who they thought hackers would target during a password-stealing attack: everyone equally, primarily rich people, or primarily privileged users (e.g., system administrators). We found that 70.7% of participants believed that hackers target everyone equally, and anyone is equally likely to have their password stolen, 12.3% of participants believed that hackers primarily target rich people, and 15.4% of participants believed that hackers primarily target privileged accounts (e.g., system administrators). These results are depicted in Figure 7.

A small number of participants opted instead to provide a free-form response. Some of these responses identified the primary targets as “gullible people” and “weak links”. Other responses provided more nuanced variants of the options provided, e.g., “It depends on the hacker. Botnets attack everyone while social engineering attacks focus on special privileges.” or identified all of the above as the best description of who is likely to be the target of a password stealing attack.

Users who believed that hackers primarily target administrators during such attacks were significantly less likely to improve the strength of their password after exposure to the interactive prompt compared to users who believed that every-
Figure 8: Perceptions of how likely a password guessing attack is to succeed based on the strength of a user’s password.

one is targeted equally ($p = .044$). We believe this difference occurs because users with this mental model are less likely to believe they will be the target of an attack. To our surprise, users who believed that hackers primarily target rich people were actually more likely to improve the strength of their password compared to users who believed that everyone is targeted equally ($p = .040$) and were also significantly more likely to initially select a strong password ($p = .011$). This may be due to the fact that Americans consistently underestimate income inequality [15, 41, 42] and the income of top earners relative to the median worker [30], and thus may consider themselves to be a high-priority target if they hold that mental model.

Risk Evaluation. We also asked survey participants to rate how likely a password guessing attack would be to succeed if a user selected a weak password, a moderate password, or a strong password. We found that 88.6% of participants considered a weak password to be somewhat or very likely to be successfully attacked, compared to 63.9% of participants for a moderate and 21.8% of participants for a strong password. These responses, which are depicted in Figure 8, were statistically significantly different between all the different password strengths ($p < .001$). They suggest that most users believe that stronger passwords are in fact less likely to be vulnerable to password guessing attacks. However, there was no significant correlation between whether a user believed stronger passwords had less risk and whether that user improved the strength of their password after seeing the interactive prompt ($p = .873$).

We then asked users to identify what a hacker would be able to do if they successfully learned the user’s password. Participants were asked so select all applicable choices from a provided list of six possible consequences; they could also enter a free-form response. We found that 43.0% of respondents selected all six options from the list of possibilities provided, with nine of those participants also adding a seventh free-form answer. These results, depicted in Figure 9, suggest that many users believe there are lots of potential negative consequences due to (successfully) password hacking attacks.

Figure 9: Password selection decisions as a function of number of negative consequences of password compromise.

However, there was no significant correlation between the number of consequences a participant selected and how likely they were to improve their password or between the number of consequences they selected and how likely they were to initially select a strong password.

These negative results suggest that the reference-dependence effect applies uniformly across different risk assessments. They therefore imply that a prescriptive intervention that leverages this effect is likely to enhance security for many different classes of users, regardless of how well-informed they are about the risks associated with compromised passwords.

5 Discussion and Limitations

These results suggest that it may be possible to significantly improve the strength of user-selected passwords by leveraging insights from prospect theory—in particular the reference-dependence effect—through a negatively framed interactive prompt after users select an initial password. However, further work will be required to validate these results and to ensure that the potential benefits to security outweigh any potential harms.

Ecological Validity. The major limitation of this work arises from the fact that we recruited Amazon Mechanical Turk users to select passwords for an experimental account rather than conducting the study using an authentication system for real accounts. Prior work has found that Mechanical Turk users select slightly weaker passwords in experimental settings compared to users selecting passwords for real accounts. For example, one study found that 44.0% of users selected guessable passwords for their real account compared
While follow-up work will be needed to validate the reference-dependence effect—or to bad security practices—such as writing passwords and leaving them in accessible locations. Furthermore, prior work has found that results from laboratory and online studies about passwords correspond to patterns in behavior for real accounts [18]. While follow-up work will be needed to validate the reference-dependence effect for real accounts and to investigate whether it predicts behavior for different types of accounts (e.g., important and unimportant accounts), we hypothesize that this effect will extend to real-world password selection decisions.

Memorability. The risk of account compromise due to password cracking and other attacks is not the only risk that users consider when selecting a password: users also need to weigh risks associated with other factors such as memorability. Forgetting a password is inconvenient in the best case; in the worst case it can cause users to lose access to accounts. Future work will be required to determine the effect of framing on the memorability of passwords that users select.

Concerns about memorability might motivate users to employ memory-assistance techniques. This could lead to improved security practices—such as increased adoption of password managers—or to bad security practices—such as writing down passwords and leaving them in accessible locations. Further work will be required to evaluate the impact of framing on these other password-related practices.

Ethical Considerations. Leveraging the reference-dependence effect through negative framing of decisions has the potential to enhance security by encouraging users to adopt stronger passwords. However, this effect is an example of nudging [1]. While nudging is often associated with the class of UI design elements known as dark patterns [8, 9, 13, 23], which nudge users to make decisions that are inimical to their interests, nudging can also be used towards making decisions that the mechanisms designer views as “better”, a form of nudging sometimes called soft paternalism [19, 31, 47, 52]. Since nudging inherently leverages subconscious patterns in human behavior, care and consideration will be required to ensure that any precriptive application of nudging and prospect theory effects with real-world impact—including leveraging the reference-dependence effect to improve password selection—is handled ethically and responsibly.

6 Related Work

Improving Password Selections. Given the prevalence of password-based authentication, a large body of work has been dedicated to the problem of improving users’ password selection decisions.

Early work on estimating password strength generally focused on entropy-based metrics [32]. However, entropy has since been criticized as being a poor measure of password guessability [29, 63, 64]. More recent efforts use dictionaries of words and leaked passwords and/or variants of words in those dictionaries (e.g., L33t-style substitutions) to define classes of weak or prohibited passwords [22, 38, 64].

Studies have found that users exhibit misconceptions about password strength [59], which has resulting in increasing adoption of password meters across the most popular websites [17]. In general, having a password meter improves password strength, especially for accounts that users consider important [17]. However, some websites continue to use metrics that rely on entropy-based metrics and are thus ineffective and enforcing strong password selections [63]; one study found that most password meters on websites are ineffective [11]. Careful calibration is also required to ensure that usability considerations don’t undermine the benefits of a password meter; meters that are too strict can annoy users, while meters that are too lenient fail to exhibit the benefits of stronger password selections [58].

Applications of Prospect Theory to Security. Despite the success of prospect theory in economics, there has been limited work applying prospect theory to security decisions, and only in limited domains. Verendel [60] developed a prospect theory model for decisions about buying versus skipping security protections (e.g., anti-virus software), although that work did not include any experimental validation. Schroeder [48] conducted a lab-based survey of IT officers in the U.S. military and found that prospect theory predicted hypothetical decisions about investment in information security. Sawicka and Gonzalez [46] explored the extent to which prospect theory can explain behavioral dynamics in IT-based work environments; they found the model matched choices observed in a short experimental run, but that it was not likely to account accurately for behavior over longer time periods. Sanjab et al. [45] explored how the decision weight function and value function impact principals’ decisions in adversarial games in the context of attacks on Unmanned Aerial Vehicles (UAVs); they found that these subjective functions led to the adoption of riskier strategies which cause delays in delivery. Most recently, Qu et al. [43] investigated the reference-dependence effect of risk factors on password strengths.
effect and the pseudocertainty effect in the context of two-factor authentication; they found that both effects explained whether or not users choose to enable two-factor authentication for a game in a laboratory setting. However, other security decisions—notably including password selection—have not been previously studied.

Applications of Prospect Theory to Privacy. In 2007, Acquisti et al. posited that several prospect theory effects—notably ambiguity aversion—might significantly impact privacy decision making [2]. Follow-up work found that people were more willing to sell personal information than to buy back previously-disclosed information [3, 24], and that the framing of notice affected whether or not users disclosed personal information in a survey [4]. Chloe et al. [12] also found that visual signals of an app’s trustworthiness were affected by framing, with positively framed signals proving more effective at influencing user opinions about the trustworthiness of an app. More recent work has looked at developing and validating a theory for how context and personality affect decisions about disclosing personal information [5] and at the mechanism-design problem of how to calibrate noise in privacy-preserving mechanisms [36, 37].

7 Conclusion

In this work, we explore the extent to which two effects identified in the prospect theory literature—the source-dependence effect and the reference-dependence effect—apply to users’ password selection decisions, and we evaluate the feasibility of leveraging these effects to enhance security. We conduct a user study with 762 users to explore the impact of these two effects. Although source-dependence has no significant effect on password selection, we find that the reference-dependence effect does. By employing a negative framing in a follow-up interactive prompt, we can nudge 25% of users to increase the strength of their selected password. This effect appears to be consistent across different mental models of password risks.

Further work will be required to validate the reference-dependence effect for real-world accounts, and careful consideration will be required to ensure that framing and any other nudging effects are employed ethically. Nonetheless, these results suggest a path forward that will enhance system security by nudging users to adopt significantly stronger passwords.

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A Survey Questions

1. How strong was the password you chose when you created your account on the site?
   - Strong
   - Moderate
   - Weak

2. How much do you agree with the statement: A hacker would be likely to try to hack this site.
   - Completely agree
   - Somewhat agree
   - Neither agree nor disagree
   - Somewhat disagree
   - Completely disagree

3. How much do you agree with the statement: A hacker would be likely to successfully guess the password I used on this site.
   - Completely agree
   - Somewhat agree
   - Neither agree nor disagree
   - Somewhat disagree
   - Completely disagree

4. Is the password you used on this site a password that you also use on other sites?
   - Yes
   - No

5. How common are password stealing attacks?
   - Extremely common
   - Somewhat common
   - Neither common nor uncommon
   - Somewhat uncommon
   - Extremely uncommon

6. How could hackers potentially learn your password? Choose all that apply.
   - It is impossible for a hacker to learn my password.
   - If I accidentally download a virus, a malicious app, or a malicious attachment.
   - If I visit a sketchy or malicious website.
   - If I accidentally click on a phishing link and enter my credentials on a fake website.
   - If a hacker (or a program run by a hacker) guesses my password on the website.
• If a hacker steals the files storing all passwords for the website.
• Other: ____________________

7. How likely would it be for a password stealing attack to succeed if you use a weak password?
• Extremely likely
• Somewhat likely
• Neither likely nor unlikely
• Somewhat unlikely
• Extremely unlikely

8. How likely would it be for a password stealing attack to succeed if you use a moderate password?
• Extremely likely
• Somewhat likely
• Neither likely nor unlikely
• Somewhat unlikely
• Extremely unlikely

9. How likely would it be for a password stealing attack to succeed if you use a strong password?
• Extremely likely
• Somewhat likely
• Neither likely nor unlikely
• Somewhat unlikely
• Extremely unlikely

10. Do you think upgrading your passwords can prevent password guessing?
• Yes
• Maybe
• No

11. What could a hacker do if they successfully learn your password? Choose all that apply.
• They could cause bugs (viruses can cause computers to crash, quit applications, erase important system files).
• They could steal personal and financial information from individual computers, and send the information to criminal.
• They could resell personal information.
• They could display annoying visual images on computers (a skull, advertising popups, or pornography).
• They could control the computer and use the computer to send information to others.
• They could use the computers to cause problems for third parties.
• Other: ____________________

12. Which of the following are likely to try to steal passwords? Choose all that apply.
• A young computer geek who wants to show off or explore the internet
• Criminals
• Organizations and institutions
• Other: ____________________

13. Which of the following best describes who is likely to be the target of a password stealing attack?
• Hackers target everyone equally, and anyone is equally likely to have their password stolen
• Hackers primarily target rich people
• Hackers primarily target people with special privileges (e.g. system administrators)
• Other: ____________________

14. What is your current age?
• 18-24
• 25-34
• 35-44
• 45-59
• 60-74
• 75+

15. What is your gender?
• Man
• Woman
• Non-binary person
• Other: ____________________

16. Choose one or more races that you consider yourself to be:
• White
• Black or African American
• American Indian or Alaska Native
• Asian
• Pacific Islander or Native Hawaiian
• Other: ____________________

17. Do you consider yourself to be Hispanic?
• Yes
• No