Effect of Cognitive Effort on Password Choice

Thomas Groß
Newcastle University, UK

Kovila P.L Coopamootoo
Newcastle University, UK

Amina Al-Jabri
Newcastle University, UK

ABSTRACT

This paper reports on a lab experiment with 100 subjects which is the first to investigate the impact of cognitive effort and depletion on the choice of user passwords. Two groups of 50 subjects each were asked to generate a password. One group was cognitively depleted, the other was not. Password strength was measured and compared across groups. We find that subjects who are cognitively depleted create worse passwords than undepleted subjects. Surprisingly, subjects who report mild cognitive exertion create better password than undepleted subjects. We are interested in discussing how cognitive effort impacts authentication as well as how to negotiate the cognitive demands of password procedures to best support users.

1. INTRODUCTION

The Limited Strength model [2] states that cognitive effort is a limited resource. Once depletion is reached subsequent decisions are impeded. We hypothesize that cognitive depletion impacts a wide range of security behaviors and, hence, investigate as a first step how password choice differs between depleted and undepleted users. Two groups of 50 subjects each—one artificially depleted, the other not—were asked to generate a password. Password strength was measured and compared across groups. A linear regression showed that depletion level, personality traits and mood, predict password strength, with an overall adjusted $R^2 = .206$. The depletion level was the strongest predictor of password strength ($p = .001$, importance 0.371). Participants reporting slight effortful exertion created significantly better passwords than the undepleted control group. From the observation that the user's capacity to create strong passwords is diminished under depletion, we learn that cognitive effort is indeed necessary for password creation. At the same time, it is surprising that slight exertion of cognitive effort prior to the password creation leads to stronger passwords. This research is the first in-depth analysis of the impact of cognitive effort and depletion on password creation. Our findings open up new avenues for usable security research.

Symposium on Usable Privacy and Security (SOUPS) 2016, June 22–24, 2016, Denver, Colorado.

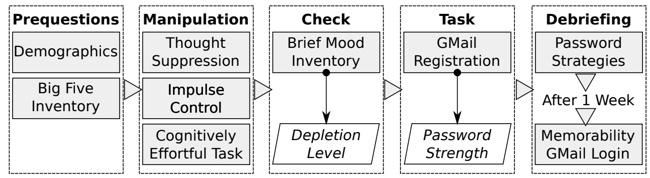

Figure 1: Experiment structure with cognitive depletion as manipulation.

2. METHOD

The sample consisted of international university students, $N = 100$, mostly non-computer science background, of which 50 were women. The mean age was 28.18 years ($SD = 5.241$) for the 83 participants who revealed their age.

The experiment group was artificially depleted, the control group was not. The control group completed non-depleting equivalents of the tasks with similar length and flavour. Cognitive depletion was induced via (a) a *thought suppression task* in which participants were shown the photo of a white bear and asked not to think of the white bear [7], (b) an *impulse control task* in which participants first learned a habit of crossing out all letters 'e' in a statistical text, followed by a new rule of crossing out all letters 'e' unless they are adjacent to a vowel, (c) a *cognitively effortful Stroop task* [5] in which the name of a color (e.g., 'red') is printed in a color not denoted by the name (incongruent color and name).

Previous research observed that personality traits such as impulsiveness impacts susceptibility to phishing. We further hypothesized that personality traits impact password strength as covariate. The procedure depicted in Figure 1 consisted of (a) pre-task questionnaires for demographics and personality traits (Big Five Inventory, BFI), (b) a manipulation to induce cognitive depletion, (c) a manipulation check on the level of depletion, (d) password entry on a mock-up GMail registration page, and (e) a debriefing and memorability check one week after the task with a GMail login mockup.

3. RESULTS

We use two-tailed tests at a significance level of .05.

3.1 Manipulation Check

We introduce a manipulation check, because induced cognitive depletion will differ across participants [3] depending on their beliefs. We use a brief mood inventory (BMI) as manipulation check and, thereby, follow a method of Baumeis-

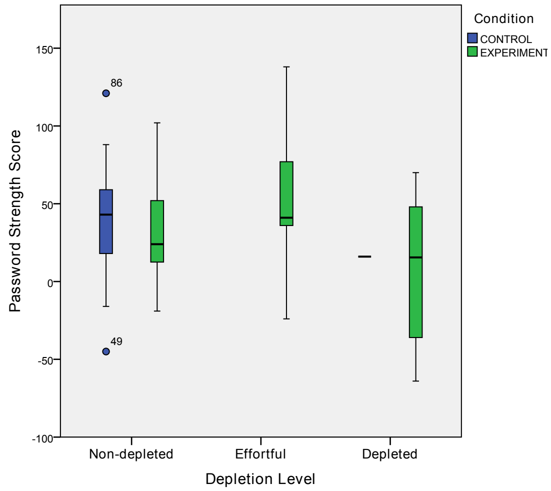

Figure 2: Password strengths by experiment condition and depletion level.

ter's research [6], including the dimensions (a) excited, (b) thoughtful, (c) tired, (d) happy, (e) worn out, (f) sad, (g) angry, (h) calm, rated with 5-point Likert-type items from strongly disagree to strongly agree. A comparison across groups on tired and worn out suggested that the manipulation was successful (Mann-Whitney U, two-tailed, tired: $U = 368, Z = -6.299$, significance $p = .000 < .05$; wornout: $U = 669$, $Z = -4.145$, significance $p = .000 < .05$). The effect size of the manipulation is large ($r = 0.63$) for feeling tired and is medium to large ($r = 0.42$) for feeling worn out.

3.2 Password Strength Score

The impact on the password strength score was analyzed with a multi-predictor forward stepwise linear regression. The linear regression had an accuracy of an adjusted $R^2 = .206$.

3.2.1 *Effect of Depletion Level*

The automated data preparation of the regression grouped tiredness into three classes: disagree and neither agree nor disagree, slightly agree, strongly disagree. We call this classification *depletion level* and label the classes as non-depleted, effortful, and depleted.

The depletion level was the most important predictor in the regression (significance $p = .001 < .05$, importance= 0.371). The effortful level, that is only slightly depleted, had a coefficient of 50.65 (significance $p = .000 < .05$). The non-depleted level had a coefficient of 31.62 (significance $p = .006 < .05$). Figure 2 shows password strength by condition and depletion level.

3.2.2 *Effects of Mood.*

BMI Thoughtfulness and Calmness had significant effects. Strong disagreement to thoughtfulness implied stronger passwords (significance $p = .018 < .05$, importance = 0.251, coefficient 40.072). Strong disagreement to calmness implied stronger passwords (significance $p = .012 < .05$, importance = 0.172, coefficient 38.799).

3.2.3 *Effects of Personality Traits.*

Of the Big Five personality traits, the BFI Agreeableness score was the most important predictor on the password strength (significance $p = .025 < .05$, importance = 0.137, coefficient 14.649), where higher agreeableness significantly implied stronger passwords. The BFI Extraversion was a notable yet non-significant negative predictor on password strength (significance $p = .108 > .05$, importance = 0.069, coefficient -11.538).

4. DISCUSSION

We applied the methodology of previous depletion studies [2, 1, 6] to a ubiquitous security context. Compared to undepleted states, we observe that strong depletion leads to weaker passwords, whereas mild cognitive exertion leads to stronger passwords. This finding corresponds with Kahneman's observation that initial effort during an activity introduces a bias towards exerting further cognitive effort [4] and also with Selye's arousal curve, an inverse U-shaped relation showing optimum human performance under moderate stress. However, we did not find significant effects of the user's password strategies, such as the reuse of passwords.

5. CONCLUSION

This study is the first to show that cognitive effort is necessary for the creation of strong passwords, that cognitive depletion implies weaker passwords than in an undepleted state and that mild cognitive effort implies better passwords than in an undepleted state. Our results highlight the importance of human cognition in security research. In addition, our findings suggest the need for new design paradigms for password policies and HCI interventions to support the user's password creation such as making password systems less effortful.

Acknowledgment

This work was supported by the EU FP7 Project FutureID (GA n°318424) and the EPSRC Research Institute in Science of Cyber Security (RISCS; EP/K006568/1 ChAISe).

6. REFERENCES

[1] Baumeister, R., Bratslavsky, E., Muraven, E., and Tice, D. Ego depletion: is the active self a limited resource? *Personality and social psychology 74* (1998), 1252–1265.

[2] Baumeister, R. F., Vohs, K. D., and Tice, D. M. The strength model of self-control. *Current directions in psychological science 16*, 6 (2007), 351–355.

[3] Job, V., Dweck, C. S., and Walton, G. M. Ego depletion is it all in your head? implicit theories about willpower affect self-regulation. *Psychological science* (2010).

[4] Kahneman, D. *Thinking fast and slow.* Farrar, Strauss, 2011.

[5] Stroop, J. R. Studies of interference in serial verbal reactions. *Journal of experimental psychology 18*, 6 (1935), 643.

[6] Tice, D. M., Baumeister, R. F., Shmueli, D., and Muraven, M. Restoring the self: Positive affect helps improve self-regulation following ego depletion. *Journal of Experimental Social Psychology 43*, 3 (2007), 379–384.

[7] Wegner, D. M., Schneider, D. J., Carter, S. R., and White, T. L. Paradoxical effects of thought suppression. *Journal of personality and social psychology 53*, 1 (1987), 5.