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Jun Zhang

Dezhi Wu

Nicholas Brown

Paul Benjamin Lowry

Gregory D. Moody

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Jun Zhang*
University of Science and Technology of China
jzhang90@ustc.edu.cn

Dezhi Wu*
University of South Carolina
dezhiwu@cec.sc.edu

Nicholas Brown[1] &
Paul Benjamin Lowry[2]
Virginia Tech
[1]nichb15@vt.edu
[2]Paul.Lowry.PhD@gmail.com

Greg Moody
University of Nevada Las Vegas
greg.moody@unlv.edu

*Co-first authors

ABSTRACT

Smartphone users often find mobile security notifications (MSNs) to be annoying and intrusive. MSNs are security warnings displayed on mobile interfaces designed to protect mobile phone users from security attacks. Traditionally, users are forced to choose between "Yes" ("Accept") or "No" ("Ignore" or "Deny") decisions in response to MSNs. However, in practice, to make MSNs less intrusive, a new "Remind Me Later" button is often added to MSNs as a third option. Consequently, this "Remind Me Later" option causes new problems of deferred security coping behaviors. In other words, hesitant users do not take appropriate actions immediately when security threats take place. Grounding our theoretical basis on choice deferral and dual-task inference, we designed two experiments to understand the key factors affecting users' deferred security coping decisions in a three-option MSN scenario ("Yes", "No", "Remind Me Later"), to determine which MSN message and design features facilitate immediate security coping.

Keywords

Mobile security notification, MSN, deferred coping, choice deferral, HCI, dual-task interference.

INTRODUCTION

Due to the increasing number of malware apps in Android and iOS app stores, security incidents are taking place more frequently on mobile devices. These mobile security threats lead to increased security risks to organizations allowing employees to bring their own devices to work. More commonly, employees are working from home using personal mobile devices to remotely access key organizational assets. This flexibility to work remotely enables business productivity and enhances sustainability; but it also imposes substantial security risks to cyberinfrastructure and key business assets, making mobile security increasingly challenging and crucial for today's business environment.

A considerable proportion of users are unaware of security threats and do not know how to appropriately protect their mobile devices when security attacks take place (Allam, Flowerday and Flowerday, 2014; Goode, 2010; Mylonas, Kastania and Gritzalis, 2013). In practice, mobile security notifications (MSNs) are widely used to protect users with low security awareness from cyberattacks. When potential threats such as malware or unauthorized access to private data are detected, the mobile operation system or antimalware app pushes MSNs to users' mobile screens.

In a classic *two-option* design of MSNs, users are given two options to respond to MSNs: "Yes" (i.e., "Accept") or "No" (i.e., "Ignore" or "Reject"). By clicking the "Yes" button on MSNs, users are instructed to navigate to a security setting page to take the recommended actions to cope with a security threat. In contrast, clicking the "No" button enables users to resume their ongoing primary tasks on their mobile devices without taking any *coping actions* to deal with a security threat. Coping actions include protective behaviors, where users comply with the recommendations included in MSNs, and maladaptive behaviors, where users reject or ignore the recommendations included in MSNs.

However, the two-option MSN response does not provide flexible options for users who intend to properly respond to MSNs but cannot take immediate coping actions due to the important nature of their ongoing, critical primary task they must perform on their mobile devices. Inherently, this classical two-option MSN design has a limitation and does not allow users to effectively handle use cases for a *deferred coping response*—that is, the choice to respond to an MSN at a later, more opportune time.

Ultimately, the purpose of MSNs is to help users ensure a secure mobile computing environment, however, such pop-

up MSNs have been shown to annoy users. MSNs can easily interrupt the usual cognitive flow of a user's *app use activities* (Jenkins, Anderson, Vance, Kirwan and Eargle, 2016; Ochs, 2014; Warner, Miller, Jennings, Lundsgaarde, Pincetl, Robinson Jr, Sommers and Childress, 1998; D. Wu, Moody, Zhang and Lowry, 2020). App use refers to the activity or task a user performs on a mobile device. The recommended security measures will often interrupt users' primary tasks, and it is likely for users to form resistant attitudes toward interruptive MSNs and possibly refuse to comply with the MSN recommendations. This phenomenon is conceptualized as *MSN disregard* or *MSN rejection* in prior studies (Jenkins et al., 2016). Similarly, when users accept the recommendations, this is conceptualized as *MSN acceptance*.

To minimize users' psychological reactance toward MSNs, user interface (UI) developers provide a *three-option design of MSN*, whereby a "remind me later" option is added to the traditional two-option design (Clayton, 2007; Fagan, Khan and Nguyen, 2015; Johnson and Spielmann, 2010). The "remind me later" option gives users the flexible choice to defer immediate decision making and can be effective in alleviating users' psychological reactance and improving his or her app use experience. This is especially useful in scenarios where users do not want to be interrupted from their current app use. Conversely, the "remind me later" option leads to the new problem of *deferred security coping*, given that mobile security measures are not implemented immediately. The following two figures present an example interface design of the two-option MSN (Figure 1) and three-option MSN (Figure 2).

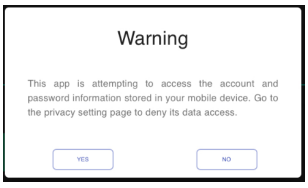

Figure 1. Two-Option MSN

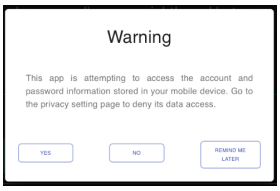

Figure 2. Three-Option MSN

In practice, we observe a paradox between user experience and immediate security coping behaviors: The system developers provide a "remind me later" option to reduce the intrusiveness of MSNs to ensure positive user experiences, however, the preferred choice is a user's immediate security coping to minimize security threats and risks. In this study, we aim to understand this paradox through the following research questions:

- **RQ1:** What are the critical design factors that can predict the possibility of MSN acceptance and MSN rejection?
- **RQ2:** In which app use scenarios are users more likely to engage in deferred coping with MSNs?
- **RQ3:** How can we improve the design of MSNs to reduce unnecessary deferred security coping behaviors in three-option MSN displays?

LITERATURE REVIEW ON CHOICE DEFERRAL

In this section, we provide a literature review on the factors that contribute to choice and decision deferral outcomes, both of which relate to deferred coping.

Choice deferral "refers to the observation that, when faced with decision problems [where multiple alternative choices are provided] people sometimes choose none of the options available to them" (Gerasimou, 2016, p. 296). Specifically, when a three-option MSN is presented on users' mobile interfaces, users can follow the recommendation by initiating security measures immediately by clicking the "Yes" (i.e., "Accept") button. We term the "Yes" option as a primary or recommended *immediate security coping option*. Second, users can choose to simply disregard the MSN by clicking the "No" (i.e., either "Ignore" without any attention or "Deny" with intention) button; we term it as the *alternative or compromise option*. Third, when users feel that it is difficult to make an immediate decision between primary and alternative options, they can intentionally click the "Remind Me Later" button to engage in the choice deferral decision-making process.

The fundamental reason for individuals to defer their decisions to make a choice is that "choosing requires trade-offs" (Dhar, 1997a; Etkin and Ghosh, 2018, p. 209). When a user struggles in deciding the trade-offs among alternatives, choice deferral is likely to happen. Based on this fundamental assumption, researchers have identified a variety of factors that influence choice deferral, some of which are summarized as follows.

Lack of dominance and the difficulty in making a decision. Li, Ye and Yang (2017) suggest that one of the major antecedents of choice deferral is lack of dominance. Specifically, a primary choice is not clearly superior to alternative choices, and when a dominant choice is unavailable, the difficulty in making a decision increases. Users, in turn, will exert more effort in evaluating the alternative choices and may ultimately defer their decisions.

Attractiveness of the decision outcomes and the alternative options. Similarly, according to Dhar (1997b), Dhar and Nowlis (1999), and Nagpal and Krishnamurthy (2008), if multiple alternative choices are equally attractive to a user, then it is hard for him or her to select a primary option that is superior among the alternatives. Furthermore, choice deferral is more likely to occur when multiple options are attractive than when they are unattractive (Chatterjee and Heath, 1996; Nagpal and Krishnamurthy, 2008).

Choice overload and information overload. Too many alternatives or options can overwhelm decision makers (Li et al., 2017; Pilli and Mazzon, 2016). People have limited cognitive resources to process the information; thus, when the consideration to choose among alternatives overwhelms the decision maker, "decision-making can become difficult" (Li et al., 2017, p. 835). Li et al. (2017) point out that complex designs and procedures in the user

interface interaction can similarly increase users' perceived information overload, which can further contribute to a user's choice deferral.

Time pressure. Similarly, the time resources for evaluating the alternatives are also limited. Findings on the relationship between time pressure and choice deferral are mixed. According to Dhar and Nowlis (1999) and Godinho, Prada and Garrido (2016), under time pressure consumers tend to make much faster decisions and engage in fewer choice deferral actions. However, the effects of time pressure exist only when the degree of choice conflict is high. According to Hahn, Lawson and Lee (1992), time pressure increases the perceived cognitive overload of decision makers, further contributing to choice deferral. Moreover, Heuvel et al. (2012) suggest that in an environment where the responsibility of decision making is highly accountable, decision makers under time pressure tend to avoid making immediate decisions.

Based on these existing findings, we elaborate why choice deferral can occur in the MSN context, and explain how MSN designs can be improved to reduce users' choice deferral decisions.

HYPOTHESIS DEVELOPMENT

We propose a set of hypotheses to address our three research questions. Specifically, we propose H1-H2 to address RQ1, H3-H4 to address RQ2, and H5 to address RQ3.

MSNs with better argument quality that facilitate MSN acceptance

Persuasive messages with better argument quality can increase the likelihood of persuasion success (Liu, Burton-Jones and Xu, 2014). According to protection motivation theory (PMT), messages should effectively increase users' protection motivations to comply with MSNs (Posey, Roberts and Lowry, 2015; Vance, Siponen and Pahnila, 2012). PMT suggests that threat-appraisal and efficacy-appraisal components can be incorporated into MSN messages to increase their argument quality. Formally, the threat-appraisal component in MSNs describes threat vulnerability and severity and why users should decide to cope immediately. The efficacy-appraisal component explains how to implement the recommended security measures in a feasible manner. With the inclusion of these two components into the content design of an MSN and with the resultant improved message argument quality, users are likely to form stronger protection motivations against security threats.

H1: MSNs with better argument quality are likely to increase users' MSN acceptance.

Task attributes that lead to MSN rejection during the app use

Maladaptive rewards refer to the intrinsic and extrinsic rewards of not complying with persuasion attempts embedded into security messages (Hassandoust and Techatassanasoontorn, 2020; Posey et al., 2015). In the context of MSNs, the major maladaptive reward of rejecting MSNs is that the usual workflow of user's current app use activities can continuously flow without being interrupted by the security coping tasks suggested by MSNs. As such, by clicking the "No" or "Ignore"/ "Deny" button immediately, users can resume their primary app tasks. Hence, if users are highly engaged in their primary app-use activities or have stronger intrinsic motivation to continuously use the app, the maladaptive rewards would be higher.

Compared with users in non-hedonic tasks (typing, reading articles), users in hedonic app-use tasks (playing game, watching hedonic videos) are highly aroused and intrinsically motivated (Paul Benjamin Lowry, Gaskin, Twyman, Hammer and Roberts, 2013; Paul Benjamin Lowry, Gaskin and Moody, 2015; J. Wu and Lu, 2013). As a result, users are less willing to stop their app use when performing their hedonic tasks, and thus the associated maladaptive rewards of rejecting MSNs are greater. Therefore, we propose:

H2: Users in hedonic app use tasks, compared with those in non-hedonic tasks, are more likely to reject MSNs.

Conflicts in trade-offs between security and user experience that lead to choice deferral

In addition to accepting or rejecting an MSN, a third option, "Remind Me Later," is presented to users. When a dominant option is unavailable, users will be more hesitant to make an immediate decision. Consequently, choice deferral is more likely to occur in situations where all options are equally attractive (Chatterjee and Heath, 1996; Nagpal and Krishnamurthy, 2008). Thus, when the app-use tasks are as attractive as security behaviors, users are more likely to engage in choice deferral.

H3: In situations where the protection motivations and maladaptive rewards are both high, users are more likely to engage in choice deferral.

Better design of MSNs that reduces choice deferral

Choice deferral is largely determined by the trade-offs between multiple options available to the users. Further, prior research suggests choice deferral is contingent upon environmental settings (e.g., emotional state, time pressure, and cognitive overload) when and where the decision is made.

MSNs usually contain detailed information about potential threats and the recommended actions to cope with the threats. For a user, processing these details can easily induce cognitive overload. If MSNs can be designed in a way to better structure the information, it is less likely they will defer their security coping decisions. Thus,

H4: MSNs with a better interface structure can lower information overload and reduce users' choice deferral.

Moreover, difficulties in making trade-off decisions and time pressure in processing the information of alternative options can increase individuals' cognitive overload (Hahn et al., 1992). In practice, MSNs are often delivered to users at inopportune times that trigger a high degree of dual-task interference (DTI) (Jenkins et al., 2016). We argue that such MSNs with high DTI will lead to an increase in users' cognitive overload. It is more challenging for users to make an appropriate decision when MSNs appear during a period that users are performing their primary app-use tasks. Thus, we hypothesize:

H5: MSNs delivered during low DTI time periods can lead to less choice deferrals, compared with MSNs delivered during high DTI time periods.

METHDOLOGY

To examine our three proposed research questions and five hypotheses, we plan to conduct two controlled user experiments.

Study 1

A 2 (high vs. low MSN argument quality) *2 (high vs. low mobile task interactivity) *2 (hedonic vs. non-hedonic app-use scenarios) lab experiment will be used to validate H1-H3.

The argument quality of MSN content is manipulated by the threat-appraisal and efficacy-appraisal components in the MSN messages. To manipulate the high vs. low task interactivity and hedonic vs. non-hedonic app use scenarios, we create a series of mobile app-use task scenarios during which MSNs will be delivered to users. We use active game playing as the high interactive *hedonic* task, watching a hedonic video as the low interactive *hedonic* task, typing a paragraph as the high interactive *non-hedonic* task, and reading an article as the low interactive *non-hedonic* task.

Study 2

In Study 2, we explore how MSN delivery time affects users' MSN choice deferral decision-making processes. In the app use scenario, a 2 (high vs. low information overload) *2 (high vs. low DTI) factorial controlled experiments will be conducted to validate H4 and H5.

Information overload will be manipulated by the different interface structures of MSNs. For users in the high DTI condition, MSNs will be displayed at random times during the primary mobile app task. In the low DTI condition, MSNs will be displayed after the completion of the first mobile app task. As for the data collection process, when users respond to MSNs, their selections will be recorded in our database.

Finally, we will conduct post-experiment surveys in both studies to measure users' subjective perceptions of perceived argument quality of MSN, perceived task interactivity, level of intrinsic (hedonic) motivation in app use, protection motivation, perceived maladaptive rewards of non-compliance, perceived information overload, and perceived task interference.

EXPECTED CONTRIBUTIONS

We expect to significantly contribute to the MSN design in human-computer interaction (HCI) field by delineating more trade-off boundary conditions to further understand users' security deferred coping behaviors to effectively respond to highly threatening MSNs. Understanding users' security compliance behaviors in choice deferral conditions can significantly enrich the current information security (ISec) literature. Our planned series of empirical studies are expected to have both solid theoretical and practical implications to both HCI and ISec research domains.

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