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Bonnie Anderson
Brigham Young University

Anthony Vance
Brigham Young University

Brock Kirwan
Brigham Young University

Jeffrey Jenkins
Brigham Young University

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Research in Progress

Bonnie Brinton Anderson
Brigham Young University, Provo, Utah, USA {bonnie_anderson@byu.edu}

Anthony Vance
Brigham Young University, Provo, Utah, USA {anthony.vance@byu.edu}

C. Brock Kirwan
Brigham Young University, Provo, Utah, USA {kirwan@byu.edu}

Jeffrey Jenkins
Brigham Young University, Provo, Utah, USA {jeffrey_jenkins@byu.edu}

ABSTRACT

Users remain a weak link in computer security due, in part, to their level of security message disregard. We examine how dual-task interference (DTI) influences fine motor control in the brain in response to security messages, allowing us to develop measures of DTI using mouse-cursor tracking and mobile indicators (e.g., accelerometer and geolocation data) for desktop and mobile devices, respectively.

Keywords: user security behavior, security messages, dual-task interference, fMRI, eye tracking

INTRODUCTION

Neuroscience has shown that the brain cannot perform even simple tasks simultaneously (e.g., responding to a security message in the middle of another task) without significant performance loss. This limitation of the human cognitive system is known as dual-task interference (DTI) and occurs even when tasks are "neither intellectually challenging nor physically incompatible" (Pashler 1994, p. 220).

Given this cognitive limitation, it is not surprising that research has consistently shown that users respond poorly to interruptive security messages (Bravo-Lillo et al. 2011; Egelman et al. 2008; Felt et al. 2015). However, despite the clear implications of DTI, little research has examined how to improve the effectiveness of security messages by minimizing the extent to which they interrupt another task. While some security messages require immediate attention (e.g., web browser SSL or malware warnings), others are not attached to a specific event, such as a software update, privacy preferences, or other protective prompts

This research addresses an important gap in the fields of information security and neuroscience. Although neuroscience research has found that some aspects of fine motor control are affected by multitasking (Dux, et al. 2006; Filmer, et al. 2013), it is currently unknown how DTI in the brain influences fine motor control such as mouse and touchpad movements. These physiological movements have been demonstrated to provide robust evidence of cognitive activity, such as attention and task engagement processing (Anderson et al. 2015; Welsh and Elliott 2004). By correlating fMRI and mouse-tracking data, this proposal aims to develop measures of DTI collected via users' interaction with the user interface (UI) that software can use to predict periods of low DTI when users are available to respond appropriately to security messages.

Users remain the weak link in computer security, partly because of their inability to appropriately respond to security messages. The insights gained from this proposal can inform the design and evaluation of messages to effectively help users respond to security threats and thus enhance the information security of individuals, organizations, and society.

Security Messages and DTI

An active research stream has examined the effectiveness of a variety of security messages. These messages are crucial in situations in which threats cannot be designed away, such as when contextual decisions by the user are required (Bravo-Lillo, et al. 2011). Unfortunately, experimental research has consistently shown that security messages are disappointing in their effectiveness (Wu et al. 2006). Dhamija et al. (2006) found that 68% of participants ignored or *clicked through* browser SSL warnings without hesitation and that only 4% of participants can recall the language of SSL warnings.

However, evidence shows that security messages are improving, partly by addressing the criticisms of previous studies (Egelman, et al. 2008). In their field study work, Akhawe and Felt (2013) found that users adhered to 91% and 77% of Firefox and Chrome malware and phishing warnings, respectively. The results were less positive for SSL warnings: Firefox users adhered to 67%, and Chrome users adhered to 30%. However, by designing the warning to clearly indicate the recommended option, Felt et al. (2015) increased the Chrome SSL adherence rate to 62%. Because of the large disparity in results based on warning design, Akhawe and Felt called for more research that pays "attention to improving security warnings" (2013, p.14).

DTI is a powerful theoretical lens for explaining why interruptions impact and are impacted by concurrent tasks. It explains performance decrements in a variety of contexts, including searching concurrently for multiple pieces of information (Navon and Miller 1987), and switching attention between tasks (Szameitat et al. 2011). Normally, people are not aware of tasks interfering with each other unless the two tasks are cognitively difficult or physically incompatible. However, studies demonstrate that when people are involved in even simple cognitive tasks, they cannot process information or perform behaviors related to other tasks as quickly or as effectively (e.g. Duncan and Coltheart, 1987). DTI occurs as cognitive functions are still engaged in the primary task while responding to security messages.

The security literature suggests this effect, as security messages often interrupt users while they conduct other tasks on a computer (West 2008). Specifically, Yee suggests that "interrupting users with prompts presents security decisions in a terrible context: it teaches users that security issues obstruct their main task and trains them to dismiss prompts quickly and carelessly" (Yee 2004, p. 49). One reason users may choose to dismiss warnings quickly and carelessly within this context is that it is cognitively difficult for them to switch between performing their primary task and optimally addressing the security warning (Bravo-Lillo et al., 2011)

The Influence of DTI on Fine Motor Control

Recent research using fMRI shows that neural activation specific to DTI can differ depending on the types of tasks involved (Salo et al. 2015). While much research has focused on the brain regions associated with cognitive processing and control that are influenced by DTI, it is also apparent that regions associated with motor control are impacted. It is theorized that response selection, or the communication of a chosen response to a motor action, contributes to the decrease in reaction time observed in multitasking (Dux et al. 2006). Specifically, areas of the posterior lateral prefrontal cortex (pLPFC) have been shown to be involved in a slowing of response selection (Dux, et al. 2006; Filmer, et al. 2013). When the pLPFC is inhibited by transcranial direct current stimulation, individuals respond significantly slower in a multitasking paradigm ((Filmer et al. 2013). We wish to better understand the role of brain regions involved in fine motor movement and response selection under DTI in the context of security. Further, we propose using these fine motor differences as indicators of DTI that software can observe as users naturally interact with the UI using a mouse or a mobile device. Using the capabilities built-in to mobile devices that can capture fine motor control will allow us to optimize DTI and security messages.

PRIOR WORK

In an fMRI experiment preliminary to this proposal, we scanned participants while they performed two tasks: a primary working memory task and a secondary task responding to security messages. We observed significant activation in the medial temporal lobe (MTL), including the hippocampus, while subjects were in the low-DTI conditions. When participants engaged in the high-DTI condition, fMRI activation in the MTL decreased relative to both the warning-only and the low-DTI conditions. An analysis of individual differences showed that the degree of fMRI activation difference between the low- and high-DTI conditions correlated with participants' adherence in the high-DTI condition. This suggests that the MTL activation differences we observed were the neural correlates of adherence to the security message when DTI was high. In another experiment using Amazon Mechanical Turk, we were able to show that security message adherence increased when the security messages were displayed at low DTI times.

METHODOLOGY

In the proposed experiment, we will recruit participants from our university campus community that have successfully completed the MRI medical screening form to ensure participant safety. The participants will complete the working memory and security message tasks similar to our earlier study. However, instead of completing each condition in a separate block, a modified block design will be used. In a pseudo-random order, the participants will complete one, two, or three trials in a row of low-DTI, high-DTI, memory-only, and security message-only trials. Trial sequence will be optimized such that each condition follows every other condition an equal number of times. Participants will complete an fMRI scan broken into three blocks of approximately seven minutes each and will respond using an MR-compatible touchpad developed for this experiment. The MR-compatible touchpad will allow us to simulate mobile device use while in the scanner.

EXPECTED CONTRIBUTION

By correlating fMRI data of regions of the brain responsible for fine motor control with mousing and mobile indicators, we expect to develop measures of DTI that can be captured as users naturally interact with the software UI. Previous research has shown that mouse tracking data can serve as a robust indicator of cognitive processing (Anderson et al. 2015; Welsh and Elliott 2004). However, it is currently unknown how DTI influences fine motor movements. Establishing these measures would constitute a substantial contribution to the DTI neuroscience literature and the HCI literature on user interruptibility (Mark et al. 2012). Ultimately we anticipate that the findings from this study will help us understand how to measure DTI and predict DTI so we are able to time security messages warnings to be displayed to users at a time when they are most likely to to understand the message and act appropriately in response to the warning.

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