Exploring How Cognitive Differences Impact Behavior and Performance in The Face of IT Interruptions

Research in Progress

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ABSTRACT

While IT interruptions have improved users' performance in the workplace and everyday life by providing them with timely information, numerous studies have reported their negative effects on users' performance and behavior. In an attempt to understand how users' cognitive capabilities affect their performance and behavior in the face of IT interruptions, we propose that the three main executive capabilities of users' brains (Inhibition, Updating, Shifting) predict distinct performance and behavioral outcomes. The Inhibition capability predicts the likelihood that users get distracted by irrelevant IT interruptions while it improves their performance on the main task. Updating and Shifting capabilities positively impact users' performance on both the interrupting and the main tasks. An experiment is designed where users are observed while performing a primary task while being interrupted by two types of IT interruptions (relevant versus irrelevant). Potential contributions are discussed.

Keywords

IT interruptions, Brain Executive Functions, User Performance.

INTRODUCTION

Information technology devices have become inseparable entities in our lives by supporting various cognitive activities such as finding a route on the map, using calendars, and managing documents. Although there are numerous benefits of using information and communication technologies (ICT) such as increasing creativity (Elsbach & Hargadon, 2006) and providing timely information (Jett & George, 2003) for users, there are serious concerns about their potential negative influence on human's cognition, emotion, and behavior (Wilmer, Sherman, & Chein, 2017). ICT devices use push notifications to attract users' attention and inform them of either relevant information (e.g., work-related email from a colleague) or irrelevant ones (e.g., an unimportant social media notification). The adverse effects of interruptions have prompted researchers from Information Systems (IS) and HCI fields to investigate the determinants of such impact and designing interruption management systems (Mehrotra & Musolesi, 2017).

IS research has examined the effects of several interruption characteristics on user performance (Addas & Pinsonneault, 2015); however, the impact of cognitive differences among users on their behavior and performance is rarely studied. For instance, IS research has uncovered the influence of task complexity (Speier, Vessey, & Valacich, 2003), congruence between main and interrupting tasks (Addas & Pinsonneault, 2018), interrupting task modality (Lu et al., 2013), and interruption presentation (Speier et al., 2003) on performance (Addas & Pinsonneault, 2018), behavior (Jenkins, Anderson, Vance, Kirwan, & Eargle, 2016), and affect (Barley, Meyerson, & Grodal, 2011). Individual difference factors such as demographics (Speier et al., 2003), personality (Bertolotti, Mattarelli, Mortensen, O'Leary, & Incerti, 2013), and working memory capacity (Foroughi, Malihi, & Boehm-Davis, 2016) have also been studied as moderators of the abovementioned links. Although the current research on interruptions informs us of how performance and behavior are affected by interruptions characteristics, it is not yet clear why individuals behave and perform differently in response to different types of interruptions (e.g., distractions from a mobile device or an important email). For instance, it is essential to understand why one user may be distracted more easily while showing a higher level of performance on the interrupting task compared to another user. In this study, we argue that the difference in behavior and performance can be attributed to the cognitive differences among users.

To understand the roots of variation in performance and behavior, we rely on the literature on Executive Functions (EF) – a set of general purpose control mechanisms that the brain uses to coordinate thought and action (Miyake et al., 2000). A widely accepted classification of the EFs suggests that there are three main EFs, namely *Inhibition* (i.e., overriding an automatic response), *Shifting (i.e., task switching)* and *Updating (i.e., working memory)* (Hofmann, Schmeichel, & Baddeley, 2012). There is evidence that people have different EF capabilities (EFC) (Del Missier, Mäntylä, & Bruine de Bruin, 2010). For instance, one user may exhibit high shifting EFC while having low inhibition EFC. Another user may show low shifting EFC where they are not able to efficiently switch between tasks while having high inhibition EFC helping them to ignore distractions.

This study has two main goals: (1) uncovering the role of users' executive functions in handling interruptions; and (2) understanding the effect of EFC on users' behavior and performance in the face of IT interruptions. An experiment is designed in which two types of IT interruptions (relevant versus irrelevant) are presented to the users while they perform a memory task. We examine how users' three EF capabilities affect their performance on both the main and the interrupting tasks as well as the likelihood that they are distracted by the irrelevant interruptions.

The remainder of this paper is organized as follows. In the next section, the literature on IT interruptions and executive functions is reviewed. Subsequently, the research model including six hypotheses are proposed. Then the research methodology is explained. Finally, we present the potential contributions of this research for both theory and practice.

LITERATURE REVIEW

IT interruptions are defined as "perceived, IT-based external events with a range of content that captures cognitive attention and breaks the continuity of an individual's primary task activities" (Addas & Pinsonneault, 2015). IT interruptions can be classified based on different factors such as the initiating entity, recipient, relevance, or structure (Addas & Pinsonneault, 2015; Brixey, Walji, Zhang, Johnson, & Turley, 2004). The initiating entity determines where the source of the interruption (e.g., system generated or from another user). The recipient dimension determines the entity who receives the interruption (e.g., doctor or nurse in a healthcare setting). The structure dimension describes whether the interruption is actionable or informational. Finally, the relevance factor distinguishes between two types of interruptions: IT intrusions versus IT interventions (Addas & Pinsonneault, 2015). The former are interruptions that are perceived by users as not being relevant or important, while the latter refers to interruptions that are perceived as important or relevant to users.

IS research on interruptions has mostly dealt with examining how different IT interruption characteristics (e.g., the timing or relevance of the interruption) influence users' cognition, affect, behavior, and performance. Speier et al. (2003)) suggested that interruptions improve users' performance on simple tasks while impairing performance on complex ones. The potential disruptive effect of interruptions on performance depends on the timing of such interruptions as well. For instance, switching to interruptions in the middle of a primary task rather than at task breaks significantly reduce users' performance (Iqbal & Bailey, 2005). Although most research on IT interruptions is devoted to identifying their negative effects on performance and methods to alleviate it, Addas and Pinsonneault (2018)) suggested that IT interruptions (Emails in their study) that are congruent to users' jobs increase their performance. The influence of interruptions on affective states such as annoyance, anxiety, stress, and frustration have been investigated (Bailey & Konstan, 2006; Tams, Thatcher, & Grover, 2018; Zijlstra, Roe, Leonora, & Krediet, 1999). For instance, Bailey and Konstan (2006)) found that interruptions that occur during the primary task execution elevate the sense of annoyance and anxiety in users. Users' may exhibit undesired behavior such as regularly checking their cell phone, which disrupts the flow of their activities and reduces their performance (Sarker, Kabir, Colman, & Han, 2016).

Individual difference factors range from demographic variables such as age and gender (Speier et al., 2003) to cognitive differences such as working memory capacity (Foroughi et al., 2016). Attentional inhibition was studied as a mechanism through which aging affects technostress (Tams et al., 2018). The authors suggested that the inhibitory effectiveness of the human brain declines with age, which makes them less able to ignore interruptions. As users' cognitive load increases with the frequency of IT interruption, the effectiveness of the inhibitory mechanism moderates this relationship. Their results show that in facing interruptions, users with higher inhibitory ability experience less cognitive load compared to those with lower inhibitory power. Another study by Foroughi et al. (2016) investigated the effect of working memory capacity on the number of errors following interruptions. The results showed a negative relationship between users' working memory capacity and the number of errors they made following the interruptions. Despite the significance of executive functions in coordinating individuals' attention and behavior, it has not been studied either as a theoretical lens or as an individual difference factor.

Executive functions (EF) are a set of general purpose cognitive control functions that coordinate the thoughts and actions of humans (Miyake et al., 2000). EFs provide a means for self-regulating behavior (Hofmann et al., 2012). There are several classifications of EFs (Toplak, West, & Stanovich, 2013); however, there is consensus among researchers that the three main executive functions are: monitoring and updating of working memory representations (Updating), inhibition of prepotent responses (Inhibition), and shifting of mental sets (Shifting) (Hofmann et al., 2012; Miyake & Friedman, 2012; Miyake et al., 2000). These three EFs are basic in the sense that they lay at a lower level of cognition compared to high-level EFs (e.g., planning) (Miyake et al., 2000).

The *Updating* function refers to the active monitoring and rapid addition/deletion of working memory contents (Miyake et al., 2000). The *updating* EF is closely linked to the working memory concept (Smith & Jonides, 1997), which plays a crucial role in retrieving information from memory and guarding goal related information (Miyake & Friedman, 2012). The *Inhibition* EF denotes the ability of humans to deliberately override a dominant, automatic, or prepotent response (Miyake et al., 2000). This function is involved in instances where users break habits such as automatically checking their cell phones upon receiving a notification. The *Shifting* EF handles the task switching function, which includes disentangling attentional resources from one task and focusing on a second task (Miyake et al., 2000). Both the *Updating* and *Inhibition* EFs are essential for performing the task at hand because they are responsible for retaining goal related information and guarding cognitive resources against distractions respectively. However, the *Shifting* EF determines the efficiency and effectiveness of one's working memory in switching between tasks (Hofmann et al., 2012).

HYPOTHESES DEVELOPMENT

The research model proposed in Figure 1 links the EFC dimensions (*Inhibition*, *Updating*, and *Shifting*) to user behavior (being distracted) and performance (main task and interrupting task).

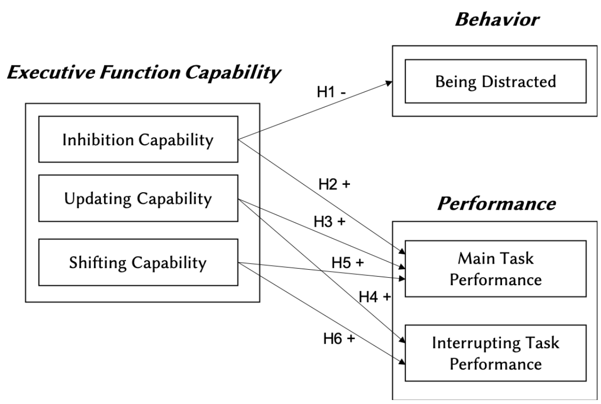

Figure 1. Research Model

We use the self-regulation perspective of executive functions proposed by Hofmann et al. (2012) to justify the effect of EFC on behavior and performance. Self-regulation is defined as humans' goal-directed behavior (Carver & Scheier, 2004). The framework proposes distinct mechanisms by which EFs support self-regulatory thinking and action.

The first hypothesis relates the inhibition EFC to the likelihood that a user is distracted by IT interruptions. Inhibition EF supports the self-regulatory mechanism of actively suppressing an automatic or habitual behavior (Hofmann et al., 2012). This mechanism is crucial for controlling interfering information and concentrating on the main task. Inhibition EF supports users in overriding an automatic behavior of attending to an interrupting stimulus. Therefore, we expect that users who have strong inhibition EFC are more capable of ignoring irrelevant IT interruptions (i.e., IT intrusions). Thus:

H1: The *Inhibition* EFC is negatively associated with the behavior of "being distracted" by IT intrusions.

The inhibition EF guards the goal related information against external interferences (Altamirano, Miyake, & Whitmer, 2010). Users who have high inhibition EFC are able to keep the irrelevant information to the main task at hand away from cognitive resources; increasing the efficiency and effectiveness of working memory to perform the main task. Therefore:

H2: The *Inhibition* EFC is positively associated with the users' performance on the main task.

The *Updating* EF is linked to two self-regulatory mechanisms that are critical for performing both the main task and the interrupting task: (1) activating goal related standards of the current task (Kane, Bleckley, Conway, & Engle, 2001) and (2) top-down direction of attention (Hofmann et al., 2012). To perform both the main and the interrupting tasks, the *Updating* EF loads goal related information into the working memory and constantly adds/deletes information to finally complete these tasks. The efficiency of this process is dependent on an individuals' inhibition EFC. Thus:

H3: The *Updating* EFC is positively associated with the users' performance on the main task.

H4: The *Updating* EFC is positively associated with the users' performance on the interrupting task.

The shifting EF represents one's ability to disengage from the current task and reengaging to focus on the interrupting task (Hofmann et al., 2012). In other words, it determines the flexibility of working memory resources in switching from one task to another. Every time users switch from the main task to the interrupting task, and vice versa, the effectiveness and efficiency of this transitory episode depends on the *Shifting* EF. Users who have weak *Shifting* EF take longer time to disentangle their attentional resources from the current task and focus on the interrupting task. In switching back from the interrupting task to the main task, the *Shifting* EF again is required to moving attentional resources back to the main task. Therefore:

H5: The *Shifting* EFC is positively associated with the users' performance on the main task.

H6: The *Shifting* EFC is positively associated with the users' performance on the interrupting task.

METHODOLOGY

An experiment is designed with a one between subject factor (EFC) with three dimensions (Inhibition, Updating, and Shifting). Each EFC dimension has two levels (Low, High), which gives eight levels of the EFC capability factors in total. To simulate a real work environment where users receive both relevant and irrelevant interruptions during their work, our experimental design includes two types of interruptions. IT intrusions (i.e., irrelevant or unnecessary) accompany a 1 kHz tone while a 5 kHz tone is played when an IT intervention (i.e., relevant or necessary) occurs.

There are several criteria for selecting the *Memory Task* as our experimental task: (1) it must be cognitively demanding so that a moderate or heavy load is imposed on users' working memory resources (2) concentration is required to perform the task such that interruptions can potentially be distracting and harmful (Spira & Feintuch, 2005) (3) it has been used and validated before in the IT interruption literature (Tams et al., 2018). In the memory task, a set of faced down cards are presented to the subjects. On each turn, the participant can select two cards in a row, which reveals the symbols behind them. If the symbols do not match, the cards return to their face-down positions. Once partcipants find a matching pair, the cards remain face-up. As suggested by Tams et al. (2018)), we use equations and answers instead of symbols in order to increase the difficulty of the game. In this version of the *Memory Task*, participants are asked to find the matching *equation* and *answer* pairs (e.g., "11*5" and "55"). At the start of each turn, the cards are randomized.

Interruptions appear randomly on four locations on the screen while participants perform the main task. They include multiple choice math questions (e.g., 45+36). Interruptions disappear if the participant (a) clicks on any of the multiple choice buttons (i.e., the participant chooses an answer) or (b) clicks on the *close* icon on the top right of the interruption window. Otherwise, they remain for 15 seconds and then disappear. Interruptions come at random points in time (starting from 20 seconds after the beginning of the main task). The time interval between interruptions is randomly selected from 5 to 15 seconds intervals (excluding the 15 seconds required for the interruption to disappear). The task is implemented in MATLAB version 2019a using the *App Designer* tool.

Inhibition, Updating, and Shifting EFCs are measured using Dot Counting, Flanker, and Set Shifting computerized tests respectively. We use the EXAMINER test battery (Kramer et al., 2014) to run the tests and calculate the combined scores for each EFC dimension.

The performance on the main task is measured using two criteria: 1- the number of clicks on the cards (the fewer the number of clicks the higher the performance) and 2- the time to complete the main task. Two measures are also used to capture the interrupting task performance: 1- number of right/wrong answers to the multiple choice questions (interventions) and 2-average time to answer the multiple choice questions (only the right answers are considered). To measure the number of times participants are distracted by intrusions, we count the number of times they respond to the multiple choice questions (regardless of the correctness of the answer they provide).

Participants watch an introductory video clip that introduces the experiment. Then they perform the eight EFC tasks that determine their measure of EFC. Participants are then instructed on how to perform the main task and how to distinguish between IT intrusions and IT interventions. They are informed that they will be compensated with $20 at the end of the experiment. However, they can receive a $5 or $10 bonus depending on how well they perform on the main task and the interrupting tasks (the two criteria of completion time and number of errors are used to determine bonus level). This bonus scheme was included to ensure that participants have sufficient motivation to score well on the main task. After they finish the main task, the score is automatically calculated and presented to participants . Prior to any data collection ethics approval was received from the ethics board at the authors' university.

CONCLUSION

This paper is expected to have several contributions. First, it explains how the three main EFs (i.e., Inhibition, Updating, and Shifting) play vital roles in coordinating users thought and action in response to IT interruptions. Second, it explains the difference in users' behavior and performance in the face of IT interruption based on cognitive differences. Third, since there is evidence that EF capabilities can be improved through practice (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008), our research provides a basis for how IT users can improve their performance in a high IT interruption environment. Fourth, our study contributes to the IT interruption management literature (Mehrotra & Musolesi, 2017) by explaining why users' behavior and performance differ in response to interruptions. This individual difference factor could be used to personalize Interruption Management Systems (IMS) to increase their effectiveness. These systems prioritize interruptions based on their characteristics to identify opportune moments (i.e., the period when users' attention can be interrupted with a minimal adverse effect on their performance). Nonetheless, the current IMS have not yet considered the cognitive differences among users. We believe that the EFC capabilities construct can further personalize such systems and increase their efficiency in enhancing users' performance.

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