INFORMATION TECHNOLOGY INDUCED ATTENTIONAL SWITCHING EFFECTS ON INHIBITORY CONTROL

by

Deven M. Christopher

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This thesis was prepared under the direction of the candidate's thesis advisor, Dr. Monica Rosselli, Department of Psychology, and has been approved by the members of her supervisory committee. It was submitted to the faculty of the Charles E. Schmidt College of Science and was accepted in partial fulfillment of the requirements for the degree of Master of Arts.

SUPERVISORY COMMITTEE:

Monica Rosselli, Ph.D.
Thesis Advisor

Summer Sheremata, Ph.D.

Robin Vallacher, Ph.D.

Teresa Wilcox, Ph.D.
Chair, Department of Psychology

Ata Sarajedini, Ph.D.
Dean, Charles E. Schmidt College of Science

Khaled Sobhan, Ph.D.
Interim Dean, Graduate College

November 13, 2018
Date

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ABSTRACT

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Deciding what information we attend to has implications on our ability to remain valuable and productive in our respective academic and economic domains. This study investigated if attentional switching due to information technology interruptions would deplete resources in a unique way and impair performance on a response inhibition task. Three groups were compared on the Simon task after participants either did or did not receive interruptions during a self-regulation task. Unexpectedly, a larger Simon effect was found for participants who did not receive interruptions.

These results conform to previous evidence showing sustained directed attention may result in depletion and effect subsequent inhibitory control. Although not supporting predictions, these results may provide a basis for further research, particularly because younger generations are developing in a more connected world than preceding generations. By understanding these differences, younger generations may better adapt to technological advances and leverage them to their advantage.

DEDICATION

This manuscript is dedicated to my family, particularly my best friend and husband, Scott, whose confidence has guided me through every moment, and to my daughters, Memphis Eve and Sofia Reese, my sunshine and star. I also dedicate this work to my dad, my first best friend.

INFORMATION TECHNOLOGY INDUCED ATTENTIONAL SWITCHING EFFECTS ON INHIBITORY CONTROL

TABLES

INTRODUCTION

Attentional switching, defined as switching back and forth between more than one task or goal within a limited period, is the foundation for a type of goal interference: interruptions (Gazzaley & Rosen, 2016). Goals are plans that guide actions; they aid individuals in deciding how to respond to incoming external events (Gazzaley & Rosen, 2016). Goal interference can be defined as an externally generated event that uses cognitive resources to process information that is not directly related to a primary task or goal (Kraushaar & Novak, 2010). An interruption, an externally generated event which is engaged in as a simultaneous, secondary goal or task, may require greater effort than maintaining directed attention toward a primary task (Addas & Pinsonneault, 2015; Falkinger, 2008; Kahneman, 1973; Kaplan & Berman, 2010; O'Conaill & Frohlich, 1995). The current study investigates whether the particular type of goal interference that interruptions present (in the context of attentional switching) could have effects that extend beyond a primary task, namely, to subsequent tasks or goals that require inhibitory control. A primary task is used to simulate a goal; to guide participants actions and aid them in deciding how to respond to interruptions.

The effort expended by attentional switching induced by interruptions may uniquely deplete an individual's resources. Although there is a developing acknowledgement of resource depletion, the field lacks a general framework for identifying the resource and understanding why a range of seemingly unrelated acts draw from this common resource [i.e., why one act of volition depletes volitional power for a

second unrelated act (Kaplan & Berman, 2010; Inzlicht & Gutsell, 2007)]. What is clear is that when an individual performs a task that requires directed attention, performance on the task immediately following is impaired due to fewer available resources (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Tice, Baumeister, Shmueli, & Muraven, 2007; Vohs, Baumeister, & Ciarocco, 2005; Webb & Sheeran, 2003). Resources susceptible to depletion are shared between executive functioning and self-regulation (Vohs et al., 2008), and studies identify a range of behaviors affected as a result of resource depletion (Gailliot et al., 2007; Inzlicht & Gutsell, 2007; Kaplan & Berman, 2010). If attentional switching induced by interruptions results in a greater or more rapid depletion of resources, it is important to investigate the potential ramifications of performance on subsequent volitional acts, including inhibition.

How we adapt to technological advances and leverage them to our advantage by deciding what information we attend to at any moment in time has substantial implications on our ability to remain valuable and productive in our respective academic and economic domains. An aspect in which attentional switching can be observed is with the ubiquitous use of technology. Information technology (IT) communicates and directs information via computers, networks, and other physical devices (e.g., smartphones and tablets) to create, process, and exchange electronic data (Khan, 2013). IT research defines information as data that is meaningful to the recipient and is of value in current or potential actions or decisions (Davis & Olson, 1984). IT enables the continuous connectivity often necessary to achieve goals by providing a means through which we accrue valuable information needed to accomplish our work. However, our computers and smartphones also induce attentional switching by facilitating a multitude of

interruptions in the form of emails, text messages, app notifications, RSS feeds, and social networks, making it increasingly difficult to maintain directed attention toward a primary task.

Resource Depletion and Interruptions

There are several explanations as to why IT interruptions may uniquely deplete an individual's resources. Research has shown interruptions manipulate and often divert attention involuntarily. IT interruptions are often unplanned, as well as the process they activate, and may involve an unseen cost in the form of anxiety. Finally, IT interruptions require additional decisions to be made by the individual.

IT interruptions divide attention. Engaging in more than one task at a time may result in a more rapid depletion of resources. An individual who receives an IT interruption while working on a primary task is required to divide their attention between the task at hand and the incoming interruption. According to attention allocation perspective, attention is a limited, divisible resource, which comes from a limited pool of attentional capacity (Kahneman, 1973). Wickens (2002) uses the term "resources" to connote something that is limited and can be allocated. To "invest capacity," to "pay attention," and to "exert effort" are all expressions used interchangeably with "resources" concerning an implicit underlying reservoir (Hagger, Wood, Stiff, & Chatzisarantis, 2010) of limited availability that facilitates goal performance (Wickens, 1980; Kahneman, 1973). Therefore, if individuals choose to divide their attention between working on a primary task and an incoming IT interruption, they may inadvertently exert a higher degree of effort and deplete their resources more quickly than if they had maintained directed attention on their primary task. The current study requires

participants in an IT interruptions group (IT group) to divide their attention between tasks.

IT interruptions are unplanned. Because task demands are increased by interruptive external events (Addas & Pinsonneault, 2015; Kahneman, 1973), an individual may experience a greater depletion of resources if their attention is diverted involuntarily by way of an IT interruption. Kahneman (1973) subdivides attention into directed and involuntary. Involuntary attention, related to level of arousal, is more automatic, mostly stimulus-driven, and less goal-directed (Kaplan & Berman, 2010). Surprising stimuli, which automatically attract attention, necessitate a greater effort of processing than do familiar stimuli (Falkinger, 2008; Kahneman, 1973). O'Conaill and Frohlich (1995) define interruptions as unscheduled. Therefore, externally generated events, such as interruptions which arrive and are unplanned or surprising, may also require more significant effort than maintaining directed attention on a primary task. The interruptions in the current study's IT group arrive at intervals unexpected by the participants.

IT interruptions activate a process. González and Mark (2004) maintain that it is not interruptions, but the entire process of frequent attentional switching (such as an alert of an email while working) that may result in a depletion of resources. After attending to an email, an individual may become aware (through the message content) of a number of additional tasks that need to be performed (Siu, Iverson, & Tang, 2006; Thomas et al., 2006; Tyler & Tang, 2003; Whittaker & Sidner, 1996; Whittaker, Bellotti, & Gwizdka, 2006; Whittaker, Bellotti, & Cwizdka, 2007). In addition, many emails cannot be discarded in a single session, but require multiple actions, as well as input or

decisions from others (Thomas et al., 2006), further increasing task demands. Heavy demands such as these, which are often placed on an individual due to repeated IT interruptions, can deplete resources (Kaplan & Berman , 2010). Further, the effort an individual expends is not only on the interruption, but after the interruption has been attended to, the process of reorienting to the primary task once it has been revisited. The additional time it takes to reorient back to the primary task after the interruption is classified as a disruption cost (Mark, Gudith, & Klocke, 2008). Mark, González, and Harris (2005) report that after an interruption, it took individuals approximately 25 minutes to return to the original task. Jackson, Dawson, and Wilson (2003) report that email caused 96 interruptions in an eight-hour day with an added hour and a half of recovery time per day. Although these results are convincing, much of the data presented here are the results of detailed fieldwork observation and are not easily replicated. After attending to an IT interruption, the current study instructs participants to reorient to their primary task as quickly and efficiently as possible.

IT interruptions may lead to anxiety. IT interruptions can produce anxiety in several circumstances: if an individual works faster to compensate for time lost due to being interrupted; if an individual becomes aware that even if they work faster, they will not have enough time left to complete their primary task; or if, when their time to complete the task ends, the task is still incomplete. Bailey, Konstan, and Carlis (2001) investigated the effects of interruptions on anxiety by designing an experiment in which an interruption was a peripheral task presented to a user while performing a primary task. One of the key findings of their work was that a user experiences a greater increase in anxiety when a peripheral task interrupts their primary task than when it does not. The

authors also found that when they interrupted a user during a document-editing task, the user completed the task faster than when they performed the same task without interruption. Additional studies have confirmed this finding and have also shown, as intrusions accumulate throughout the day, individuals do not necessarily exhibit decrements in performance; however working faster (Mark et al., 2008) in order to avoid productivity loss (tasks left incomplete) may be accompanied by feelings of anxiety. Glass, Singer, and Friedman (1969) concluded that adapting to unpredictable stress (such as an inability to complete tasks) involves a "psychic cost," suggesting a depletion of resources (Baumeister et al., 1998). Even if an individual shifts efficiently between a primary task and an IT interruption, they may not resume a suspended primary task in enough time to complete it (Iqbal & Horvitz, 2007). One study reports 41% of interruptions resulted in the discontinuation of the interrupted work entirely (O'Conaill & Frohlich, 1995). As the literature shows (Bailey et al., 2001; Baumeister et al., 1998; Glass et al., 1969; Iqbal & Horvitz, 2007; Mark et al., 2008; O'Conaill & Frohlich, 1995), anticipated productivity loss may contribute to anxiety felt by individuals who experience repeated IT interruptions. Therefore, the current study has been designed in such a way that participants do work faster to compensate for time lost after being interrupted, they do realize (due to IT interruptions) that they will not have enough time to complete their primary task, and when the time cap is up, they must leave their primary task incomplete.

IT interruptions generate additional decision making. Extensive active decision making has been shown to reduce self-control and result in poorer performance on subsequent acts of inhibition (Speier, Vessey, & Valacich, 2003). Choosing is more depleting than merely establishing preferences (Vohs et al., 2008), and this may be

another key in the literature as to why IT-induced attentional switching may uniquely deplete resources. If one-third of interruptions contain requests for action, with each of these requiring an assessment of whether and when the message content should be attended to [right away, at a later moment, or not at all (Siu et al., 2006)], an individual who continues to manage an increasing accumulation of minor decisions may be inadvertently lowering their threshold for self-control (Goleman, 2013). The greater demands on their attention could leave them susceptible to poorer decision making if, when faced with a truly significant decision toward the end of a day, they are not able to control impulsive actions because they have not retained enough energy to inhibit distractions or lower reflexive behaviors (Hartman & Miguel, 2017). The current study requires participants in an IT group to make decisions in order to complete their primary and secondary tasks.

As this review of the literature has shown, an individual may be interrupted through email and instant messaging over a combined seven times during any given hour and there are many studies providing explanations as to why this may result in resource depletion. However, the research thus far has not connected or combined the findings to investigate the role IT may play on acts of succeeding volition. Therefore, this project includes variables and measures that have not been linked before when investigating this field and simulates the process of frequent attentional switching during a typical work day in an IT group to elucidate any costs to subsequent acts of volition.

Current Study

Although previous research on self-regulation and executive-functioning have identified a critical resource that is central to that domain and is susceptible to depletion,

that tasks administered in these studies interact with each other (suggesting they may share a common resource), and that initiating self-regulation activity seems to impair subsequent volitional control significantly, none have however, tested the process of frequent attentional switching as a source of depletion and what effects it may have on subsequent acts of executive function (Gailliot, et al., 2007; Kaplan & Berman, 2010; Muraven & Baumeister, 2000; Vohs & Heatherton, 2000; Vohs et al., 2008). González and Mark (2004) identified a gap in the existing knowledge in this field, declaring an explicit lack of studies focusing on the role of IT and attentional switching. Despite increasing dependence on IT for every aspect of daily life, not only for use in the workplace, but also for education, tracking fitness and health, and keeping in touch socially, very little is known about the consequences of IT related interruptions.

The following were considered when investigating the costs of IT-induced attentional switching: (1) the expenditure of attentional resources and how these resources may be depleted more rapidly when attention is diverted involuntarily from a primary task to engage in one or more secondary tasks, and (2) how the process of IT-induced attentional switching and consequent resource depletion may have consequences that extend beyond the primary task. The current study aims to achieve ecological validity by simulating a typical working environment, applicable to either a business or academic setting, and help close the gap in the existing knowledge in this field by investigating whether attentional switching between two or more tasks due to IT interruptions results in the depletion of resources of limited capacity, and due to depletion, impairs performance on an ostensibly unrelated task that measures response inhibition.

An inability to inhibit socially inappropriate responses could pose repercussions (Levitin, 2015), especially for younger generations and for those who are increasingly more comfortable with switching attention between multiple technologies. Ophir, Nass, & Wagner (2009) designed a series of experiments to study distinctions between the information processing styles of heavy media multitaskers (HMMs) and light media multitaskers (LMMs). Results showed heavy media multitaskers (HMMs) performed worse on a test of task-switching ability. To identify HMMs, a questionnaire-based media multitasking index was developed to determine the mean number of media a person simultaneously consumed (HMMs were one standard deviation or more above the mean on this index). The authors examined the HMMs' abilities regarding the allocation of attention to environmental stimuli and their entry into working memory, the holding and manipulation of stimulus and task set representations in working memory, as well as the control of responses to stimuli and tasks. HMMs showed a reduced ability to filter out interference from irrelevant stimuli and irrelevant task sets (task-switching). The authors suggest attentional switching facilitated through technology, a growing social trend, places new demands on cognitive processing, in particular attention allocation, further stating HMMs use a "breadth-biased profile of cognitive control" necessary to manage multiple input streams (Ophir et al., 2009).

Although attentional switching between technology devices is commonplace [some individuals average more than four switches per minute (Brasel & Gips, 2011)], many adults aim to implement strategies in order to limit the amount of media streams they consume at any one time. However, that may not be the case for younger generations (and for the future, as youth continue to mature). Analyses of responses from 1,319

Americans from three generations revealed a clear generational effect; recent generations, identified as "Net Geners," switch their attention due to technology more than older generations. Net Geners find attentional switching to be easier (Carrier, Cheever, Rosen, Benitez, & Chang, 2009) and claim they switch their attention between tasks more efficiently than past generations. Notwithstanding, research thus far does not support this claim; during complex tasks, task switching eliminates cues needed to effectively perform the task (Gupta, Li, & Sharda, 2013) leading to performance degradation.

If, as the results Ophir et al. (2009) indicate, there is a growing trend to information technology processing, and that trend is rapid switching between tasks, and if IT-induced attentional switching results in a greater or more rapid depletion of resources, it is important to investigate any consequences to performance on subsequent volitional acts. Because a reduced ability to filter out interference from irrelevant stimuli (Ophir et al., 2009) due to attentional conflict impairs complex task performance (Gupta et al., 2013), resolving the conflict between attentional switching and goal performance seems essential for all individuals, from office workers to students and teachers. The current study investigates participants with a mean age of 21.56, supplying one of the first studies to investigate this phenomenon in a sample consisting primarily of traditional college-age students and thereby providing some of the first results indicating whether or not todays Net Gen college students (who have grown up with widespread access to technology) are developing a greater digital literacy (Oblinger & Oblinger, 2005) than have older generations, and if this has enriched them with an ability to switch their attention more efficiently.

The present study tested two hypotheses. If IT induced attentional switching depletes participants in the IT group more than it does for participants in the PT group, performance on the Simon Task (a task which measures inhibitory control) is expected to be impaired. Performance on the inhibitory task is expected to be impaired in the interruptions group. The first hypothesis will examine the Simon effect (i.e., reaction time measured by subtracting the mean reaction time of correct congruent trials from the mean reaction time of correct incongruent trials). A larger Simon effect is expected for participants in the IT group than for participants in the PT group. The second hypothesis will examine the proportion correct of incongruent test trials (second dependent variable). Participants in the IT group are expected to have significantly less proportion of correct incongruent test trials than participants in the PT group.

Because attention allocation perspective posits that attention is a limited, divisible resource that comes from a limited pool of attentional capacity (Kahneman, 1973), and because task demands are increased by interruptive external events (Addas & Pinsonneault, 2015; Kahneman, 1973), participants in the IT interruptions group are expected to have poorer performance on the Simon Task, which measures response inhibition, than participants in the process time (PT) or control (C) group.

METHOD

Participants

One-hundred-and-seventy-seven participants (120 women, 57 men, $M_{age} = 21.56$, age range: 18-40 years) who were enrolled in Psychology courses at Florida Atlantic University (FAU) were recruited through the FAU Subject Pool. Participation was also received from Psychology courses at FAU in which professors provided extra credit for participating in research. An additional twenty-six participants were tested, but were excluded for not completing the Simon task correctly (e.g. the participants used the arrow keys instead of the shift keys during the Simon task and therefore did not complete the task) (4), if they were over the age of forty (3), or if they were diagnosed ADHD (Jurado & Rosselli, 2007; Mullane, Corkum, Klein, & McLaughlin, 2009) (17). No other exclusion criteria were observed. An analysis of outliers was made resulting in the removal of two cases (Hoaglin & Iglewicz, 1987; Hoaglin, Iglewicz, & Tukey, 1986). For the main analysis, the sample size was appropriate to achieve a power of .8 ($\alpha = .05$) to detect a medium effect. Participants were recruited with a cover story. They were told that the purpose of the study was to investigate how people carryout tasks in an office space for business and academic settings. Participants were randomly assigned to one of three conditions (three levels of the independent variable): an IT interruptions group (IT), a process time group (PT), or a control group (C). There were no significant differences in age, levels of education, handedness, or demographics across groups. After the experiment was conducted, participants were debriefed and told that the study was

investigating the effects of IT induced attentional switching on subsequent acts of inhibitory control (see Table 1).

Table 1

Participant Demographics

		3 Groups								
		Control			Interruptions			Process		
		N	Mean	SD	N	Mean	SD	N	Mean	SD
Gender	Male	17			19			21		
	Female	45			34			41		
Handedness	Right	55			48			60		
	Left	7			5			2		
Age			21.53	3.61		21.17	3.33		21.92	4.81
Years of Edu.			14.10	1.29		14.02	1.45		13.90	1.39

Note. From kindergarten to grade 12 was counted as 13 years of education, while any education beyond that was greater than 13.

Materials and Procedure

Materials

Basic Information Form. This form includes questions regarding demographic and educational information.

Reaction time task. As a baseline measure, Inquisit's Simple Visual Reaction Time Task was used to measure reaction time to a visual presented stimulus.

Primary task. For the self-regulatory task HabitE pages one and two were selected. This task consists of two pieces of paper each containing nonsense Placeholder Text (created in the software program, InDesign). The second page is printed in an lighter shade of gray.

Inhibitory Control task. The Simon Task (Simon, 1969) is founded on stimulus–response compatibility. The task measures selective response inhibition: the aptitude to inhibit interference between competing actions. The Simon effect (reaction time

measured by subtracting the mean reaction time of correct congruent trials from the mean reaction time of correct incongruent trials) is when individuals respond more accurately and faster when stimulus and response features match. This is the case even when the location information is irrelevant to the task (Simon, 1969). According to information-processing theory, the three steps of decision making are stimulus identification, response selection, and response execution by the motor response. The Simon effect provides insight into the response selection stage. During the response selection stage, an individual uses a rule to translate the relevant stimulus dimension (usually shape or color) to the correct left or right response. However, the location dimension of the stimulus (its position on the screen) overlaps with the relevant stimulus dimension (left or right). Therefore, the irrelevant location dimension of the stimulus activates the corresponding response consequently interfering with an individual's ability to make a response to the non-corresponding side. As a result, same-side responses are more accurate and faster than opposite-side responses.

Survey. The survey included questions which asked the participants how much they enjoyed contributing to the experiment, how much anxiety they felt throughout the duration of their participation, if they thought page one and page two of the HabitE task was difficult, and if they detected any pattern to the interruptions they received (the final question applied to the IT group only). Participants responded to all survey items using a 5-point Likert scale [from 1 = *not at all* to 5 = *a tremendous amount* (see Table 5, for Survey results)].

Laptop. IT interruptions, the Simple Visual Reaction Time Task and the Simon Task were delivered on a Dell Inspiron 5000 15.6 inch 16:9 1080p IPS screen.

Procedure

In a between-subjects design, participants were randomly assigned to one of three conditions (three levels of the independent variable): an IT interruptions group (IT), a process time group (PT), or a control group (C). After providing informed consent, participants completed a basic information form and a simple visual reaction time task to use as a baseline. In the IT interruptions group (IT), participants were interrupted with four secondary tasks while attempting to complete an immersive task, primary task (HabitE). In a process time group (PT), participants were not interrupted while completing HabitE, rather they completed the four secondary tasks (delivered as interruptions in the IT group) in a block of time (process time) prior to engaging in immersive time. Participants in a control group (C) were not interrupted while completing HabitE. After completing HabitE, participants in all three groups completed the Simon task, a task which measures the ability to inhibit interference between competing actions (selective response inhibition). Each participant completed the HabitE pages followed by the Simon task in the same order. The dependent variables are the Simon effect and the proportion correct of incongruent test trials. Finally, at the conclusion of the experiment, all participants completed a survey.

Self-Regulation. For all three conditions, the current study chose, as the primary task or goal, a self-regulation task. Several studies indicate self-regulation tasks and executive-functioning tasks interact with each other (suggesting they may share a common resource) (Vohs et al., 2005), that the resource is finite in capacity (Kahneman, 1973), and that this shared resource is susceptible to depletion (Tice et al., 2007). For the purposes of the current study, the self-regulation task was chosen particularly to simulate

the type of immersive task that any number of workers, students, or teachers are required to complete. Most of the decisions we make and actions we perform each day may feel like they stem from our well-considered options (Duhigg, 2013), but a study found that more than 40% of those actions are habits rather than conscious decisions (Neal, Wood, & Quinn, 2006). An important form of self-regulation is when an individual forms a habit and then breaks it. For this reason, an immersive, increasingly complex, primary task [referred to in the current study as "HabitE" (Tice et al., 2007)] was selected for the experimental design.

HabitE. HabitE consists of two pages of printed text (two columns per page) and necessitates directed attention for twenty-five minutes (this includes orientation to the rules and a ten-minute per page time limit). First, participants were provided with a paper copy of HabitE page one and instructions for the first set of rules. With a pencil, they crossed out the letter "e" each time it appeared on the first page of text. The instructions given to participants stressed speed and accuracy. For up to 10 minutes, participants worked on HabitE page one to develop a habitual response of marking every "e." Addas and Pinsonneault (2015) state rapid switching between competing tasks depletes attentional resources especially when tasks are complex. Therefore, after participants have completed page one and have developed the habit of crossing out every "e," they are given HabitE page two. Page two of this immersive, increasingly complex, primary task requires participants to override their habit of crossing out every "e." The instructions for HabitE page two are based on a more complex rule (Tice et al., 2007) and ask the participants to cross out every "e" *except* if it is adjacent to another vowel, or one letter removed from another vowel. Again, the instructions stressed speed and accuracy. Thus,

the second page required participants to override (in some instances, on a case by case basis) their habitual response of marking every "e." To determine whether participants followed instructions, the HabitE pages were scored for accuracy *amount* (see Table 3, for HabitE results). On both pages, a percentage of the number correctly crossed out "e's" and "e's" left uncrossed (that should have been crossed) were recorded. Participants in group C completed the HabitE pages free of interruptions (without a laptop present on the desk).

The device used to time the participants while they completed their immersive task beeped at the five minute mark (halfway through the allotted time to complete each page). The participants were made aware that the timer would beep half way through their ten minutes, and they were instructed to ignore the beep and keep working on the task until the entire ten minutes was complete. When the timer beeped half way through their allotted time, participants who were interrupted became aware that they would not be able to complete their primary task before the ten minutes was over (because they were not yet half way completed with the page). As stated, anticipated productivity loss may contribute to anxiety (Bailey et al., 2001). Therefore the current study was designed so that the participants would become aware (before the time they were given to complete the task) that they would be unable to complete the primary task (see Table 3 and 4, for HabitE results).

Immersive time. The time individuals spend engaging in the self-regulation task can be understood as immersive time. Immersive time is defined as working on a project independent of other people or "hands-on" time (Chamas, 2016). HabitE was chosen as the primary task for the current experiment because, in any given day, an individual in

either an office or academic setting encounters a need for immersive time to accomplish a task: a time to write, think, experiment, or explore. For the purposes of the current study, the 20 minutes that participants spend completing HabitE page one and two is meant to simulate this type of task.

Information Technology Interruptions. Addas and Pinsonneault (2015) define IT interruptions as IT-based external events with a range of content that captures cognitive attention and breaks the continuity of focus on a primary task. In a typical day, one study found individuals spent an average of only three minutes working on a primary task before they were interrupted and consciously switched their attention (González & Mark, 2004). In a field study over the course of two weeks, Iqbal and Horvitz (2007) found that interruptions came from emails and instant messaging 4.28 and 3.21 times per hour, respectively. Two interruption subtype categories include informational intrusions and actionable intrusions (Addas & Pinsonneault, 2015). Informational intrusions are processed at the cognitive level (Wickens, 2002). They are one-way informational elements (e.g. email; instant messaging; pop-up displays) or task-irrelevant events (e.g. general reminders; announcements; status updates; notifications). Actionable intrusions draw attentional resources at the behavioral response level by requiring action (e.g. conducting online discussions; responding to information requests). They lead to task switching or simultaneous interactions (Barley, Meyerson, & Grodal, 2011), often requiring additional decision-making effort (Speier et al., 2003), and are typically more demanding than those that only provide information (Kahneman, 1973). Dabbish, Kraut, Fussell, and Kiesler (2005) estimate one out of every three messages workers receive contain requests for action, which result in attentional switching. The current study

investigates the independent variable, IT interruptions, in the form of informational and actionable intrusions.

The participants in the Interruptions group (IT) are interrupted four times while they attempt to complete their primary task (HabitE). Because this experiment is meant to simulate a typical period of time for an individual in an office or academic setting, the current study considers the four interruptions as four secondary tasks. In the Interruptions group (IT), these four unplanned (Falkinger, 2008), IT-based external events capture the participants cognitive attention and break the continuity of their focus on their primary task (Addas & Pinsonneault, 2015). By dividing the participants attention in this way (Kahneman, 1973), the current study is designed to investigate whether the four interruptions (secondary tasks) activate a process (González & Mark, 2004) that leads to anxiety (Bailey et al., 2001; Glass et al., 1969) and depletes resources necessary for the participants to perform well on the Simon task (a task which measures inhibition).

IT Group. Participants in the IT group completed HabitE page one and page two with two interruptions (one informational intrusion and one actionable intrusion) arriving at minute four and minute eight during each ten-minute per page time limit. The interruptions were delivered on a laptop that was placed within reach in front of their working space as they attempted to complete the HabitE pages. Referring to Jackson et al. (2003), participants assigned to the IT group faced the obstacle of reorienting themselves back to their immersive task once revisited. In addition, referring to Mark et al. (2008), participants in IT also had to contend with any anxiety caused by productivity loss due to IT interruptions. They did not have enough time to complete their immersive task [measured using HabitE pages one and two (Addas & Pinsonneault, 2015)].

PT Group. Participants in the PT group completed the four secondary tasks (presented as two informational and two actionable intrusions in the IT group) on a laptop during a block of time referred to as process time. Next, they completed the HabitE pages free of interruptions without a laptop present on the desk. This divergent arrangement of time included the secondary tasks delivered as interruptions in the IT group; however, it placed the secondary tasks prior to immersive time rather than throughout. The purpose of the third group is to investigate whether attentional switching or additional secondary tasks are contributing to depletion.

Process time. Process time is defined as time allotted for quick decisions, short interactions, or small management projects that enable continuity of workflow for those an individual is working with (Chamas, 2016). In the process time group, the same secondary tasks used to interrupt the IT group are completed in a block of time prior to completing the primary task. Asking the participants to complete the secondary tasks (the informational and actionable intrusions presented in the IT intrusions group) together in a block of time (process time) prior to completing the primary task (HabitE pages one and two: immersive time) should be understood as simulating an individual checking their email or returning phone calls first thing in the morning and then spending 25 minutes to two hours working on an immersive project. Process time is most effective when it happens before an individual begins immersive time (Chamas, 2016) and, as previously stated, IT research defines information as data that is meaningful to the recipient and is of value in current or potential actions or decisions (Davis & Olson, 1984). Therefore, the process time in the PT group is placed prior to immersive time. It is reasonable to imagine if an email is left unattended, one that would have taken a few seconds to answer

when it was received, but because of a delayed reply, it could cost an opportunity or create extra work.

It is important to indicate that, for the PT group, the secondary tasks (which were interruptions to participants in the IT group), may no longer be depleting, as the attentional switching between the primary task and interruptions is eliminated. The secondary tasks in the PT group are four sequential process tasks, which are completed prior to the primary task (HabitE). This is an extension of ecological validity the current study aspires to achieve, and a significant element to consider, because many individuals most likely do not have the luxury of working a full eight-hour workday free of connecting with others or receiving information through IT.

Control Group. A third group completed the primary task (immersive time, HabitE) without interruptions or any additional secondary tasks.

Response Inhibition. Response inhibition, the ability to suppress automatic behaviors in response to external stimuli that interfere with goal-driven behavior is fundamental to individual functioning (Congdon et al., 2010; Mostofsky & Simmonds, 2008; Evenden, 1999), a critical aspect of attentional selectivity, and important in decreasing goal interference (Gazzaley & Rosen, 2016). Self-regulation activity (such as HabitE) seems to significantly impair subsequent volitional control suggesting the energy available to an individual is expended during the initial act (Gailliot, et al., 2007; Muraven & Baumeister, 2000; Vohs & Heatherton, 2000; Vohs et al., 2008). After having exerted self-regulation, an individual appears to have less resources to draw upon to reach a subsequent goal (Baumeister et al., 1998; Vohs & Faber, 2007). The current study investigates IT interruptions and their effect on an individual's inhibitory processes.

Response inhibition is characterized by the ability to suppress a prepotent or habitual response to environmental contingencies (Congdon et al., 2010). The concept of interference within response selection (i.e., response conflict) can be assessed using the Simon task (Simon, & Berbaum, 1990), an established paradigm used to measure response inhibition. The current study investigates the dependent variables by utilizing the Simon task, which alternatively to the Stroop task, represents a language-independent method of assessing interference inhibition (Coderre, Van Heuven, & Conklin, 2013).

Simon Task. Next, participants completed the Simon task, by which twos dependent measures were assessed. The Simon task was completed on a laptop, administered through Millisecond's Psychological Testing software, Inquisit. Each trial began with a fixation cross in the center of the screen that remained visible for 800-ms and was followed by a 250-ms blank interval. At the end of the interval, a red or blue square appeared on either the left or right side of the screen and remained on the screen for 1,000-ms if there was no response. Participants were instructed to press the left shift key when they saw a blue square and the right shift key when they saw a red square. Response timing began with the onset of the stimulus, and the response terminated the stimulus. There was a 500-ms blank interval before the onset of the next trial. Congruent conditions occurred when the red box appeared on the right side of screen or when the blue box appeared on the left side. Incongruent conditions, or forced interference, occurred when the red box appeared on the left side of screen or when the blue box appeared on the right side. The task consisted of 28 experimental trials, 14 congruent and incongruent trials each, presented in random order.

RESULTS

The current study tested two hypotheses. If IT induced attentional switching depleted participants in the IT group more than it did for participants in the PT group, a larger Simon effect was expected for participants in the IT group than for participants in the PT group. To examine the first hypothesis, a one-way analysis of variance (one-way ANOVA) showed a significant group effect over the means of the Simon effect (i.e., reaction time measured by subtracting the mean reaction time of correct congruent trials from the mean reaction time of correct incongruent trials), $F(2, 174) = 4.479$, $p = .013$, $\eta_p^2 = .049$. Tukey post hoc tests revealed that there was a significant increase in the Simon effect between the process time group and the control group, $p < .05$. No significant differences were found between the interruptions and control group or between the interruptions and process time group (see Table 2).

Table 2

Simon Task Performance

	3 Groups					
	Control *n* = 62		Interruptions *n* = 53		Process *n* = 62	
	Mean	SD	Mean	SD	Mean	SD
RT congruent	378.10	61.49	380.06	67.10	366.36	58.29
RT incongruent	394.16	59.36	399.93	64.48	403.89	70.14
Simon Effect	16.05	44.83	19.87	41.93	37.53	40.13
Proportion correct of incongruent	.94	.07	.92	.09	.93	.07

Note. Simon effect (reaction time measured by subtracting the mean reaction time of correct congruent trials from the mean reaction time of correct incongruent trials) in milliseconds.

The second hypothesis examined the proportion correct of incongruent test trials. Participants in the IT group were expected to have significantly less proportion correct of incongruent test trials than participants in the PT group. To examine the second hypothesis, a one-way analysis of variance was conducted to assess the mean group effect over the means of the proportion correct of incongruent test trials (for the Simon Task). No significant group effect was found, $F(2, 174) = .601$, $p = .549$, $\eta_p^2 = .007$. There were no significant differences in incongruent test trials between the interruptions group, the process time group, or the control group (see Table 2).

To examine the performance on the self-regulation task (HabitE), one-way analysis of variance was conducted to assess the mean group effect over the means of the scores on HabitE between three groups (the IT interruptions, the process time group, and

the control group). No significant group effect was found, $F(2, 173) = 1.02$, $p = .364$, $\eta_p^2 = .012$. There were no significant differences in the mean scores on the self-regulation task between the interruptions group, the process time group, or the control group (see Table 3).

Table 3

HabitE Results

	3 Groups					
	Control *n* = 62		Interruptions *n* = 53		Process *n* = 62	
	Mean	SD	Mean	SD	Mean	SD
HabitE score	.80	.21	.76	.24	.74	.26

Finally, the current research investigated the results of the survey given to all participants at the conclusion of the experiment. The survey asked questions such as how much anxiety they felt due to their participation and if they thought page two of the HabitE task was difficult. Participants responded to all survey items using a 5-point Likert scale (from 1 = *not at all* to 5 = *a tremendous amount*). In the PT group, 77.4% rated their anxiety as "Not At All" or "A Little Bit" compared to 72.2% of those in the IT group. When asked if page two of the task was difficult, 46.8% of participants in the PT group selected "Quite A Bit" or "A Tremendous Amount" compared to 35.2% of participants in the IT interruptions group (see Table 4).

Table 4

Survey Results

		3 Groups		
		Control	Interruptions	Process
How much did you enjoy participating in this experiment?	Not At All	0.0%	0.0%	1.6%
	A Little Bit	8.2%	1.9%	8.1%
	Somewhat	24.6%	25.9%	33.9%
	Quite A Bit	54.1%	63.0%	48.4%
	A Tremendous Amount	13.1%	9.3%	8.1%
Did you feel anxiety due to your participation in this experiment?	Not At All	36.1%	24.1%	37.1%
	A Little Bit	37.7%	48.1%	40.3%
	Somewhat	18.0%	18.5%	16.1%
	Quite A Bit	4.9%	7.4%	4.8%
	A Tremendous Amount	3.3%	1.9%	1.6%
Was page one of the task difficult?	Not At All	54.1%	51.9%	59.7%
	A Little Bit	32.8%	29.6%	24.2%
	Somewhat	11.5%	14.8%	14.5%
	Quite A Bit	1.6%	3.7%	1.6%
	A Tremendous Amount	0.0%	0.0%	0.0%
Was page two of the task difficult?	Not At All	4.9%	3.7%	9.7%
	A Little Bit	23.0%	20.4%	22.6%
	Somewhat	26.2%	40.7%	21.0%
	Quite A Bit	32.8%	25.9%	40.3%
	A Tremendous Amount	13.1%	9.3%	6.5%

Note: 2.8% of the participants in the IT group correctly detected and described the pattern to the interruptions they received.

DISCUSSION

The objective of the present study was to investigate if attentional switching due to IT interruptions would deplete resources in a unique way and impair performance on a task used to assess inhibitory processing. Three groups were compared on the Simon inhibitory control task after participants either received (IT), or did not receive (PT), interruptions during a self-regulation task. The PT group completed four secondary tasks (the same tasks which interrupted participants in the IT group) in a session of time identified for the purposes of the current study as "process time." Then, the PT group completed the self-regulation task uninterrupted in a block of time identified as "immersive time." Participants in the control condition completed the self-regulation task without secondary tasks. Unexpectedly, the results indicated a marginally significant increase in the Simon effect for participants in the PT group rather than the IT group, $p = .069$. The Simon effect in the current studies' sample was similar to previous studies with corresponding age groups (Salvatierra & Rosselli, 2010). No significant differences were found between groups by comparing the means of the proportion correct of incongruent test trials. Taken together, these results suggest IT induced attentional switching does not deplete participants in the IT group more than it does for participants in the PT group. Specifically, these results conform to previous evidence which suggest sustained directed attention results in depletion and diminished performance on subsequent acts of inhibition. The current data does not support the notion that the

particular type of goal interference interruptions present (in the context of attentional switching) has effects extending beyond a primary task, namely, to subsequent tasks or goals requiring inhibitory control.

Instead of finding the predicted increased Simon effect for participants who received interruptions, the current study found diminished performance (by measuring the means of the Simon effect) for participants who were not interrupted. These findings could be interpreted in several ways. First, the results may be consistent with the notion that Net Generation college students (who have grown up with technology) are developing a greater digital literacy (Oblinger, & Oblinger, 2005) than older generations and are enriched with an ability to switch their attention more efficiently because information technology is woven throughout their daily lives.

The results of the current study could also be interpreted by considering that younger generations have commonly used instant messaging (IM) as a major communication tool and this communication preference may reveal a perception gap between generations. Sixty-eight percent of young people between the ages of 18 to 29 have reported texting “a lot” (Newport, 2014, p.2). Texting among 18- to 24-year-olds has continued to increase and exceed texting among previous generations, while their use of e-mail and phone calls has gone down (Shapira, 2010, p.4). When considering older generations text less (47% among 30- to 49-year-olds and 26% among those ages 50 to 64 report texting “a lot”), this preference over email and phone calls could infer younger generations think instant messaging increases productivity and actually reduces interruptions due to shorter, faster conversations. This sustained trend has been reported to explain that Net Geners use IM as a major communication tool [74% of teenagers

compared to 44% of online adults (NetDay, 2003)] and use the word "talk" to describe IM, rather than consider it technology (Oblinger & Oblinger, 2005). Therefore, because younger generations are so accustomed to using IM, pop-ups (including those which delivered the IT interruptions during the current studies' experiment) may blend into the background, may not appear surprising or unplanned (Falkinger, 2008; Kahneman, 1973; O'Conaill & Frohlich, 1995), and therefore may not produce anxiety.

Another detail the current study explored for insight into the results was regarding the claim Net Geners have made of switching their attention due to technology more efficiently than older generations (Carrier et al., 2009). During IT switching, an individual engages in attentional conflict between the interruption and the primary task and this could increase an individual's arousal level (e.g. anxiety) and facilitate performance on a simple task (Gupta et al., 2013). The current study, with a sample consisting primarily of traditional college-age students, examined the performance on the self-regulation task and found no significant differences in the mean scores on the self-regulation task between the three groups. Perhaps because of the low levels of anxiety reported in each of the experimental groups (approximately 75% of participants in the PT and IT group rated their anxiety as "Not At All" or "A Little Bit"), there were not significant differences found between groups based on the scores calculated for HabitE.

An explicit lack of studies focusing on the role of IT and attentional switching has been identified (González & Mark, 2004), and much of the data which has been collected to investigate IT interruptions are the results of detailed fieldwork observation (Jackson et al., 2003; Mark et al., 2005). In addition, prior work has not investigated the role of IT interruptions as a source of resource depletion (Baumeister et al., 1998; Tice et al., 2007;

Vohs et al., 2005; Webb & Sheeran, 2003). Therefore, the present study was designed to simulate a typical work day by including IT interruptions (delivered during a self-regulation task) and investigate if they would deplete resources and result in diminished performance on the Simon task. The data collected in the current study supports the abundance of results which show that when an individual performs a task that requires directed attention, performance on the task immediately following is impaired due to fewer available resources (as was seen in the PT group).

Limitations

The current study has several limitations. First, only one inhibitory task was used as a dependent measure. The Simon task is an established paradigm thought to assess one subcomponent of response inhibition [i.e., the concept of interference within response selection (Simon & Berbaum, 1990)], however there are additional tasks which have been utilized to assess other subcomponents, including action cancelation and action withholding. These additional subcomponents can be measured by the Stop-signal (SST) task and the Cued Go/No-Go (GNG) task (Schachar et al., 2007). Subprocess of behavioral inhibition may affect goal-directed behavior. It is not clear whether one particular inhibitory subcomponent would be better suited at assessing the effects of IT induced attentional switching. Including dependent variables measured by these two additional tasks could have corroborated the current studies results. Also, although the participants did not know when the interruptions would arrive, they were instructed to attend to the pop-ups on the screen in front of them. In this way, the interruptions used in the task may or may not have appeared "unplanned." In addition, further explanations of the results could have been investigated by collecting data from the participants which

indicated whether or not they considered themselves to be gamers (which could affect reaction time), the time of day they were scheduled to participate (to assess how long the participant had been awake), or how many hours of sleep they received the night before. Finally, analysis of the current data could have taken into consideration whether or not the participants were employed in addition to taking classes, and each participants familiarity with information technology, to explore if there were differences across groups.

Future Directions

Future research could focus on several areas including generational differences, the complexity of the task used in the experiment, and how people could recover from depletion. Regarding generational differences, researchers could explore if there is a particular age group most impacted by the release of the first iPhones in 2007. It appears reasonable to investigate, based on the results of the current study, the possibility that maintaining directed attention toward a primary task (Addas & Pinsonneault, 2015; Falkinger, 2008; Kahneman, 1973; Kaplan & Berman, 2010; O'Conaill & Frohlich, 1995) may require more effort and may be more depleting for those participants college age and younger. Insights obtained from the current study's survey could be incorporated into future research. Specifically, a clear look at the level of difficultly rated for the self-regulation task. According to Social Facilitation Theory, arousal facilitates easy tasks but reduces performance on complex tasks (Sanders, G. S., 1981; Zajonc, R. B., 1965). As previously stated, the levels of anxiety were quite similar between the experimental groups. However, when asked if page two of the task was difficult, more participants in the PT group selected "Quite A Bit" or "A Tremendous Amount" than participants in the

IT interruptions group. According to distraction conflict theory (DCT), attentional conflict impairs complex task performance (Gupta et al., 2013), therefore the perceived complexity of the task may have contributed to the results and future tasks could be more demanding in an IT interruptions condition. Participants could be asked to recall information seen during the pop-ups or select IT interruptions could be ignored.

Future studies could also make adjustments to the self-regulation task (HabitE). Perhaps if more levels of complexity were added to the task (which extend beyond concentration) a participants resources would be further depleted. For example, the text (rather than being simply "place holder" text) could have meaning. Then, participants could be asked to answer questions pertaining to the meaning of the text provided. In addition, it could prove helpful to introduce methods to measure working memory. In this way, rather than interruptions, it may be discovered that the secondary tasks could be considered "mental breaks." Manipulating the HabitE task could open the door for future experimentation in other ways as well. In addition to English, the text could be translated into another language such as Spanish. This could provide a means to explore the effects of bilingualism on such a task and if there are any differences to an individual's performance when crossing out "e's" in their first or second language. In addition, analysis of the self-regulation task could include comparing the errors between page 1 and page 2, as well as changes in errors in over time. If more errors are recorded towards the end of HabitE page 2, rather than the beginning of the page, analysis of their reaction times could also be included for insights into the results. Therefore, different degrees of difficulty for the self-regulation task could be measured to understand if one arrangement was more effective (or more depleting) than another.

Finally, future studies could also investigate how to induce a positive mood state capable of counteracting depletion and improving self-regulation. Attention Restoration Theory (ART) proposes a potential approach to facilitating recovery of resources (Kaplan, 1995, 2001); directed attention might recover if it is allowed to rest. Therefore in addition to sleep, the use of involuntary attention, such as what is encouraged when an individual immerses themselves in natural environments (e.g., a park or garden), could put less drain on attentional capacity (Kaplan & Berman, 2010). Mood management strategies such as casual video game (CVG) play and meditation could also be candidates for this line of research. Russoniello, O'Brien, & Parks (2009) found changes in EEG and heart rate variability (HRV) consistent with autonomic nervous system relaxation in participants after playing Bejeweled II. Tang et al. (2010), reported that after 11 hours of integrative body-mind training (IBMT), participants showed structural changes around the anterior cingulate cortex, a part of a neural network involved in error monitoring and development of self-control.

In conclusion, although not supporting predictions, the current study's results may provide a beginning point for further research, specifically because younger generations are developing in a more connected world than preceding generations. By understanding these differences, younger generations may better adapt to technological advances and leverage them to their advantage which could have substantial implications on their ability to remain valuable and productive in their respective academic and economic domains.

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