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The Relations among Executive Functions and Users' Perceptions toward Using Technologies to Multitask

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ABSTRACT

In this research, we examined the influence of information processing abilities (i.e., executive functions) on users' perceptions about technologies. Borrowing the literature from psychology discipline, we explained how individual's working memory capacity (WMC), focus, and flexibility skills influence cognitive absorption, perceived ease of use, and perceived usefulness in the context of technologies multitasking. We also integrated a micro-level measure (n-Back task to measure WMC) and macro-level measures (self-report questionnaire) in this present study. The results revealed that individual's information processing mechanism influences the degree of his or her cognitive absorption when he or she engages in more than one task or technology simultaneously or sequentially. An individual is likely to experience high degree of cognitive absorption if he or she is able to balance the focus and flexibility. Furthermore, we found that WMC is positively associated with perceived ease of use. Together, perceived ease of use and cognitive absorption influence perceived usefulness.

Keywords

Focus, Flexibility, WMC, Cognitive Absorption.

INTRODUCTION

In the information age, new technologies, new ways of working, and an increasing availability of information could significantly affect productivity growth, and specifically the productivity of workers in information-intensive industries (Aral, Brynjolfsson and van Alstyne, 2007). Juggling multiple tasks (multitasking) with technological devices is a common practice at home, at school, at work, and even during meetings (Adler and Benbunan-Fich, 2011). This new skill has also been identified as a new job requirement in information systems (IS) fields such as 911 operators and managerial positions at some telecommunication companies. While the demand to perform multiple tasks in the workplace is increasing, little is known about the information processing abilities involved in multiple task situations. For example, a survey conducted by Davenport (2005) reported that 51% of knowledge workers do not feel that they are in control of information flow, and 41% believe that their organization does not offer them assistance in dealing with the situation.

With the extensive use of IS especially in work setting, therefore, it is necessary to understand how users actually multitask using the systems. Cognitive scientists have investigated multitasking in a variety of experimental paradigms, ranging from task-switching (e.g., switching cost paradigm—Allport and Wylie, 2000) and inhibition (e.g., backward inhibition paradigm—Arbuthnott, 2005) to understand the executive control processes that underlie multitasking. Unfortunately, experimental psychologists are far from agreeing on which theory best explains this interference and they continue to postulate new models (Konig, Buhner and Murling, 2005). In this research, we do not attempt to criticize or compare these theories neither we attempt to integrate all of the different theories. We should note that there are many other paradigms as to the basic set of executive functions that are too numerous to discuss in this context. Though these different paradigms may agree or disagree on how goals direct the executive controls, they have the same agreement that executive systems are responsible for handling the situations that require the inhibition of irrelevant stimuli and involve shifting and attention. Thus, instead of debating which paradigms best explain the phenomena under study, we believe these different paradigms may help shed light on the relationship between goals, attention, and cognitive functions.

One phenomenon in IS field that has received much intention from IS researchers is the concept of flow. When an individual entered the state of flow, he or she is likely to use the unconscious thought process to achieve the optimal experience that occurred when his or her interaction with the system (Csikszentmihalyi, 1990). However, information processing underlying the state of flow when individuals engage in multiple tasks or technologies remains unclear. The present research explore these hypotheses by examining to what extent the balance between two executive functions—*focus and flexibility*—is related to individuals' perception about using technologies to support multitasking. Although there many other suggestions as to the basic set of executive capacities that are too numerous to discuss in this context, we do not attempt to argue here that all elements of attention are related to multitasking. This is not the case. Rather, we suggest that any adequate

executive need to be able to focus attention, to divide attention between two important targets or stimulus streams, and to switch between tasks (Baddeley, 2012). In other words, in order to successfully perform multitasking, one should be able to maintain their focus and flexibility functions.

The objectives of this current study are twofold. First, we examined the influence of information processing abilities (i.e., executive functions) on users' perceptions about technologies. To this extent, we explained the phenomena in question through the lens of executive functions (e.g., Baddeley, 2012; Miyake, Friedman, Emason, Witzki, Howarter and Wager, 2000) to explain how individual's WMC, inhibition, and switching skills influence his or her perception about how easy, useful, and enjoyable the system is when it comes to multitasking. Second, we integrated a micro-level measure (n-Back task to measure WMC) and macro-level measures (self-report questionnaire) in a single research program. By achieving these objectives, we expect to shed light on a new understanding of how executive functions may explain IS use.

LITERATURE REVIEW

Attention and Executive Functions: Conscious or Unconscious Process?

The ability to engage in volitional behaviors is often considered a unique human ability, and people have long assumed that this volition behaviors and consciousness are intimately related (Dijksterhuis and Aarts, 2010). However, recent research has shown that people often engage in behaviors without the presence of their consciousness awareness (e.g., Bijleveld, Custers and Aarts, 2009). Unconscious thought is defined as "a cognitive process that takes place while conscious attention is directed elsewhere (Dijksterhuis and Aarts, 2010). While conscious thought is dependent on conscious capacity, which is low, unconscious thought tends to process larger amounts of information and it can therefore lead to relatively good decisions on complex matters (Bos and Dijksterhuis, 2011).

Although executive functions have been long associated with conscious processes, and hence are implicated in volitional behavior, the new evidence shows that goals modulate attention processes irrespective of the conscious or unconscious source of the activation of the goal (Dijksterhuis and Aarts, 2010). Executive functions play a significant role in determining focus of attention, dividing attention between two important targets or stimulus streams, and switching between tasks (Baddeley, 2012). Miyake et al. (2000) identified three basic control functions of the central executive: (1) *inhibition*—one's ability to deliberately inhibit dominant, automatic, or prepotent responses when necessary; (2) *shifting*—shifting back and forth between multiple tasks, operations, or mental sets; and (3) *updating*—updating and monitoring of working memory representation. A core theoretical argument of Miyake and colleagues' framework is that individual differences in executive functions reflect both similarity and diversity of each component. In other words, the inhibition, shifting, and updating functions are partially distinct, however, they are also partially interdependent in their functions. These three constructs are likely to share some common task requirements, particularly the maintenance of goal pursuit (Miyake et al., 2000). In our research model we used the term of inhibition or focus, flexibility, and WMC to refer to the three executive functions respectively. The balance between focus and flexibility is crucial for goals to do their work properly (Dijksterhuis and Aarts, 2010).

The State of Flow

Flow occurs when the balance between challenges and skills exceeds the average level of typical experience. Such that, one's involvement in the task becomes automatic and spontaneous and there is little awareness of the self-other than what one is doing (Fullagar and Kelloway, 2009). Drawing upon the concept of flow, Agarwal and Karahanna (2000) proposed a new construct named "cognitive absorption" to describe the state of flow when individuals engage in technology related tasks. They defined cognitive absorption as "*a state of deep involvement with software*" (p. 673). They proposed five dimensions of cognitive absorptions: (a) temporal dissociation—the inability to register the passage of time while engage in interaction; (b) focused immersion—the experience of total engagement where other attention demands are ignored; (c) heightened enjoyment—the pleasurable aspects of the interaction; (d) control—the user's perception of being in charge of the situation; and (e) curiosity—the extent the experience arouses an individual's sensory and cognitive curiosity (p. 673).

RESEARCH MODEL

Building upon the theories presented in the previous section, we proposed two major hypotheses in this present study. First, individual's information processing mechanism influences the degree of his or her cognitive absorption when he or she engages in more than one task or technology simultaneously or sequentially. Second, WMC of an individual determines his or her perception whether using electronic devices (e.g., phone, computer) are easy or not. Working memory system consists of a limited capacity system that provides the temporary storage and manipulation of information that is necessary for performing a wide range of cognitive activities (Baddeley, 2012). Because WMC differs from one to another person, it may also constraints comprehension more for some people to another. The proposed research model is illustrated in figure 1.

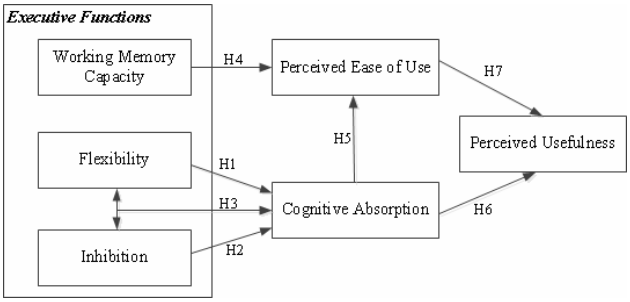

Figure 1. Research Model

Hypotheses Development

The shifting process involves the omission of irrelevant task sets (e.g., to be encountered stimuli, the required responses, and the cues used to indicate which task is the relevant one in the current trial) and the subsequent active engagement of a relevant task set (Miyake et al., 2000). Task-switching is associated with switching cost (Allport and Wylie, 2000). However, this switching cost can be reduced by preparation or practice. Once this process becomes automatic, they are likely to experience cognitive absorption. Thus, we test:

H1: Flexibility function is related to cognitive absorption.

Agarwal and Karahanna (2000) indicated that when an individual is in the state of flow, all of his or her attentional resources are focused on a particular task, thereby reducing the level of cognitive burden associated with the task. Cognitive absorption is also characterized with the absence of distraction (Csikszentmihalyi, 1990). The inhibition function itself involves the prevention of attentional resources being allocated to task-irrelevant stimuli and responses using attentional control (Miyake et al. 2000). In other words, an individual will enter a state of flow if he or she is able to inhibit the irrelevant stimuli that exist in the external environment. Therefore,

H2: Inhibition function is related to cognitive absorption.

As mentioned previously, the balance between focus and flexibility is crucial in performing complex tasks. Dijksterhuis and Aarts (2010) indicated that rewards and requirements associated with goals are likely to motivate the person to achieve them. Studies of selective visual attention tasks have shown that the balance between focus and flexibility is modulated by the presence of positive affect or reward (Dijksterhuis and Aarts, 2010). In the technology adoption literature, perceived enjoyment is viewed as a reward derived through the use of the technology (Venkatesh, Thong and Xu, 2012). Perceived enjoyment, one dimension of cognitive absorption, has been identified as an intrinsic motive that drives individuals to use technology due to hedonic benefits derived from the use of the technology (Venkatesh et al., 2012). Thus, given the cognitive absorption represents intrinsic motivation, we hypothesize that:

H3: The interaction between inhibition and flexibility function is positively related to cognitive absorption, such that, individuals higher in both inhibition and flexibility function are likely to experience higher cognitive absorption.

WMC represents the third function of executive controls (i.e., updating function) (Miyake et al., 2000). Previous studies have shown that the executive component of the WMC system is specifically responsible for the covariation between WMC measures and higher order cognition (Kane and Engle, 2003). Davis, Bagozzi and Warshaw (1989) have suggested that perceived ease of use is a key determinant of technology adoption at the early stage of project implementation. At this initial stage, IS users tend to process new information that requires them to consciously maintain their goal by allocating more memory resources. Thus, all thing being equal, individuals who have higher WMC are likely to perceive the use of technologies to multitask is easier than those who have lower WMC.

H4: Working memory capacity is positively associated with perceived ease of use.

The relations among cognitive absorption and two main predictors of IS adoption (i.e., perceived ease of use and perceived usefulness) has been established by Agarwal and Karahanna (2000). Agarwal and Karahanna argued that confidence and a state in which an individual is driven by intrinsic motivation will together enhance perceptions of a lower cognitive burden. Thus:

H5: Cognitive absorption is positively associated with perceived ease of use.

Similarly, Agarwal and Karahanna (2000) indicated that a state of cognitive absorption is expected to influence perceived usefulness through the heightened enjoyment. In other words, when individuals voluntarily engage in using particular systems and enjoy it, they may perceive that the systems are useful. Therefore, we hypothesize:

H6: Cognitive absorption is positively associated with perceived usefulness.

Consistent with the technology acceptance model (Davis et al. 1989), we also hypothesize that perceived ease of use is positively associated with perceived usefulness.

H7: Perceived ease of use is positively associated with perceived usefulness.

RESEARCH METHODOLOGY

Study Context and Sample

We test our model in the context of using technologies or electronic devices (i.e., smartphones, computer, laptop, tablet) to perform multitasking. To test our hypotheses, we collected data using Amazon Mechanical Turk (MTurk) technique. A total of 102 usable responses were collected.

Operationalization of Research Variables

We used the n-Back task as a measure of working memory capacity. The stimulus material was adapted from Jaeggi, Studer-Luethi, Buschkuehl, Su, Jonides and Perrig (2010) (see Jaeggi et al., 2010 for details). To measure inhibition, flexibility, perceived usefulness,

perceived ease of use, and cognitive absorption, we used self-report measures. Measures were adapted from prior literature when they were appropriate. A single factor test showed that there is no evidence of a single factor accounting for more than 50% of the variance, suggesting that common method bias is not a significant threat in this research (Podsakoff, MacKenzie, Lee and Podsakoff, 2003).

Data Analysis

We used Ordinary Least Square (OLS) to analyze the data.

RESULTS

We assessed the reliability of each individual item by inspecting the loading of each item on its corresponding construct. All measures satisfied the measure of reliability (reliability greater than .5 on EFA). The Cronbach's alpha values at the construct level exceed the .70, indicating the measures are reliable. The confirmatory factor analysis also shows that scales used in this study met the criteria of internal validity. Though several items exhibit score loadings less than .7 on their respective constructs, all of these constructs exhibit good internal consistency as evidence by their composite reliability scores (>.08) (Fornell and Larcker 1981). Supporting discriminant validity, all indicators should load more higher on their corresponding construct than on other constructs in the model.

The Assessment of Regression Model

The results of regression analysis are presented in figure 2. All of our proposed hypotheses were supported.

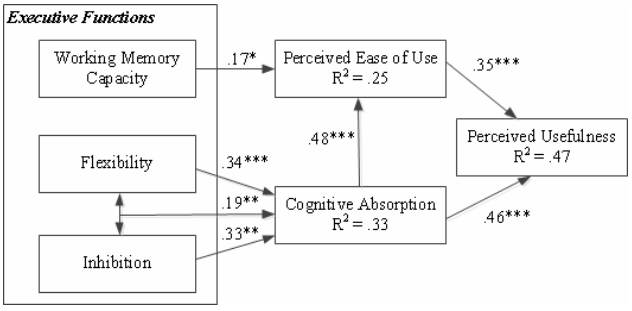

Figure 2. Regression Results

DISCUSSION, IMPLICATIONS, AND CONCLUSION

Information workers often must perform multiple tasks at the same time, either in parallel or sequential order (Czerwinski, Horvitz and Wilhite, 2004). Our findings revealed that focus and flexibility are the two main predictors of cognitive absorption when an individual engage in multitasking. Whilst previous research indicated that performing two tasks concurrently typically requires attentional control to coordinate processing on the two tasks in addition to the demands of each task separately (Miyake et al., 2000), we built our study on the assumption that the multitasking process can take place under unconscious state of mind. The present findings reveal that the balance between focus and flexibility has an implication on how people experience the state of flow then they use technologies to multitask. These results suggest that, even when people are asked to work on more than one task, as long as they are able to maintain the balance between the two executive functions—focus and flexibility—they would encounter less challenge to enter the state of flow. The issue is also to understand what can aid people in switching tasks, that is, which can help them to successfully move to another task and concentrate on that ongoing task.

The findings also indicated that WMC is associated with perceived ease of use. Our working memory system consists of a limited capacity system that provides the temporary storage and manipulation of information that is necessary for performing a wide range of cognitive activities (Baddeley, 2012). Thus, individuals who have higher WMC are likely to perceive that multitasking is easier than those who have lower WMC. Consistent with the findings of Agarwal and Karahanna (2000), we found that cognitive absorption is positively associated with both perceived ease of use and perceived usefulness. These findings suggest that individuals in the state of flow perceive that technologies are ease to use and useful in their work. Further research may be necessary to investigate how to measure cognitive absorption using micro-level data.

Though our study used a micro-level task to measure WMC and measured its relationship with higher level measures, we did not include the micro-level of analysis of focus and flexibility. The limitation of IS research in exploring unconscious process of information processing can also be tied to the research instrument. That is, information processes can happen very quickly, say less than .25 to .5 seconds, and occur simultaneously in parallel (Cowan, 1988). By using both micro-level and macro-level of analysis, we suggest that the interpretation of research findings can be generalized to practical contexts with less subjective bias than purely using self-report measures.

Practically, the findings of this research may give some ideas of the relationship between executive functions and perceptions about technology use. Though there is no doubt that multitasking may increase the stress level among knowledge workers, this research showed that multitasking also depends on the ability of an individual to balance the focus and flexibility of his or her cognitive function. Ophir, Nass and Wagner (2009) found that heavy multitaskers performed worse on a test of task-switching ability. However, we argue that this result is inconclusive. Ophir et al. did not consider the executive systems of technology users. Moreover, lack of balance between focus and flexibility could be another reason to explain the findings. That is, heavy multitaskers could be higher on flexibility skill, whereas light multitaskers could be higher on inhibition skill. Further research is

needed to investigate the balance between focus and flexibility using micro-and macro-levels of analysis.

This study also provides additional information for designing user interface tools to facilitate the balance between focus and flexibility. By saving users' WMC, they may perceive that technologies are easier to use and, in turn, they would be able to allocate more capacity on their work. The findings suggest that applications for organizing tasks and remembering the task presentation would be beneficial for users who might be dealing with multitasking in their workplace.

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