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# HELPING OLDER WORKERS REALIZE THEIR FULL ORGANIZATIONAL POTENTIAL: A MODERATED MEDIATION MODEL OF AGE AND IT-ENABLED TASK PERFORMANCE[1]

**Stefan Tams**
Department of Information Technologies, HEC Montréal,
Montréal, Québec, CANADA {stefan.tams@hec.ca}

*Evidence shows that older users have lower performance levels for IT-enabled tasks than younger users. This is alarming at a time when the workforce is rapidly aging and organizational technologies are proliferating. Since the explanation for these lower performance levels remains unclear, managers are not sure how to help older users realize their full potential as contributors to organizational success. The research model presented here identifies the declining information-processing speed of older workers as the cause of their reduced capacity to perform IT-enabled tasks. According to the model, IT experience and IT self-efficacy reduce the negative impacts of this decline, whereas IT overload and the effort cost of IT use aggravate them. To test the model, data were collected using three complementary studies. The results supported the model and indicated five ways that organizations can help older users improve their capacity to perform IT-enabled tasks. Additional data collected in interviews with human resources directors confirmed the relevance of these solutions.*

**Keywords**: System use outcomes, task performance, systems design, information processing, age, older users, experience, self-efficacy, overload, effort cost

## Introduction

Changes in cognitive abilities that occur with age have a significant impact on IT-enabled task performance. This is a crucial issue for organizations in many countries because of two current trends: (1) the rapid aging of the workforce and (2) the spectacular increase in the use of workplace IT (Ghasemaghaei et al. 2019; Tams et al. 2014; OECD 2019). With populations aging fast, the number of older workers is expected to rise at a sharply increasing rate during the next 30 years (OECD 2011, 2013).

At the same time as the workforce has been aging, the IT used to accomplish work tasks has become more complex and increasingly difficult to use (Ayyagari et al. 2011). For example, organizational software systems like Microsoft Excel are often more complicated after upgrades or new features are added to them or after they are integrated with new applications (Tian and Xu 2015). As a general rule, increased system complexity creates more information processing demands (Browne et al. 2007). To perform tasks competently, users not only have to process large amounts of task-related information, they also have to process ever-increasing amounts of information to navigate the system and use an increasingly diverse range of features (Ahuja and Thatcher 2005). Thus IT-enabled tasks such as reviewing financial data using Excel (Serrano and Karahanna 2016) now place exceptionally high information processing demands on users.

These greater processing demands are especially taxing for older workers who have to perform IT-enabled tasks (Tams et al. 2014). Research in fields like human–computer interaction

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and psychology has shown that older users frequently have lower task performance levels than younger ones (Wagner et al. 2010). This points to a causal connection between age and IT-enabled task performance.

The negative effect of age on IT-enabled task performance is an important discovery. Age has become a key demographic variable and an important independent variable in IS research because increasing numbers of older workers have IT-intensive jobs that require them not only to react to information but also to analyze and create it (Erlich and Bichard 2008; Venkatesh et al. 2003). IT-enabled task performance has likewise become a key issue and a crucial dependent variable in IS research because it is the main outcome of system use (Goodhue and Thompson 1995; Serrano and Karahanna 2016; Zhang and Venkatesh 2013) and because it has a direct impact on organizational productivity (DeLone and McLean 1992).

However, the precise connection between age and IT-enabled task performance remains unclear. Researchers have failed to provide an adequate explanation of this connection for three main reasons. First, user age is a nascent area of IS research (Tams et al. 2014), so that with almost no literature to build on, a new study has the difficult task of laying the foundations of the entire inquiry. Second, past work has used IS theories and theories from cognitive psychology to study age effects. For example, it has drawn on the UTAUT (Brown et al. 2010) and on social cognitive theory (Lam and Lee 2006) to study IT adoption by older persons. Since age is outside the scope of these theories, researchers cannot use them to develop a precise explanation of what causes the observed age effects. Finally, although IS researchers clearly understand that task performance cannot be studied without taking into consideration users, they have tended to focus on tasks and technologies and have not addressed the issue of user age directly (Serrano and Karahanna 2016).

Therefore, it is time to make user age a central theoretical and practical concern by asking the following research question:

> *RQ: How, why, and under what conditions does a user's age impact his or her IT-enabled task performance?*

This question points to three interrelated issues that require investigation. The first issue is the cause of the lower task performance of older users. Until now, research has focused on the direct effect of age on task performance, that is, on the general connection between these two constructs. This approach has mostly led to broad speculations that fail to provide an adequate theoretical frame for conducting a thorough scientific examination of the effects of age on IT-enabled task performance. Therefore, the first objective of the present investigation is to develop a more detailed explanation of older users' lower performance levels for IT-enabled tasks. To do so, it will be necessary to use mediation concepts to identify and analyze the mechanism through which age impacts IT-enabled task performance.

The second issue is the problem of how to help older users improve their performance. As Tams et al. (2014) have argued, an explanation of why older users have lower performance levels than younger users has limited value if it provides no indication of how to help them improve. Thus the second objective of the present investigation is to determine whether IT-related individual differences such as having more IT experience can mitigate the problem of older users' lower performance levels. Addressing this issue will require moderated mediation analysis.

The third issue has to do with the factors that can worsen the impact of age on IT-enabled task performance. If managers do not understand these factors, then they can unintentionally create work conditions that exacerbate this impact. Therefore, the third objective of the present investigation is to examine whether IT-related individual differences such as being more vulnerable to IT-enabled overload can aggravate the problem of older users' lower performance levels. Addressing this issue will also require moderated mediation analysis.

The article is structured as follows. The next section reviews theories of cognitive aging and shows that the theory of processing speed provides the best lens for examining the connection between age and IT-enabled task performance. The subsequent section uses this theory to develop the hypotheses. The "General Method" section reports on three complementary studies that were conducted to test the hypotheses. The final section discusses the implications of the results and indicates avenues for future research.

## Theoretical Background

The literature has given insufficient attention to the theoretical interrelationships between cognitive aging (i.e., age-related changes in cognitive abilities), IT-enabled task performance, and IT-related individual differences (Tams et al. 2014). A few studies have examined the intersection of two of these areas of research. For example, Serrano and Karahanna (2016) looked at the connection between user capabilities and task performance. However, no study has considered the intersection of all three areas, even though doing so would likely make it possible to provide a much more complete explanation of age-related impacts on IT-enabled task performance (see Figure 1).

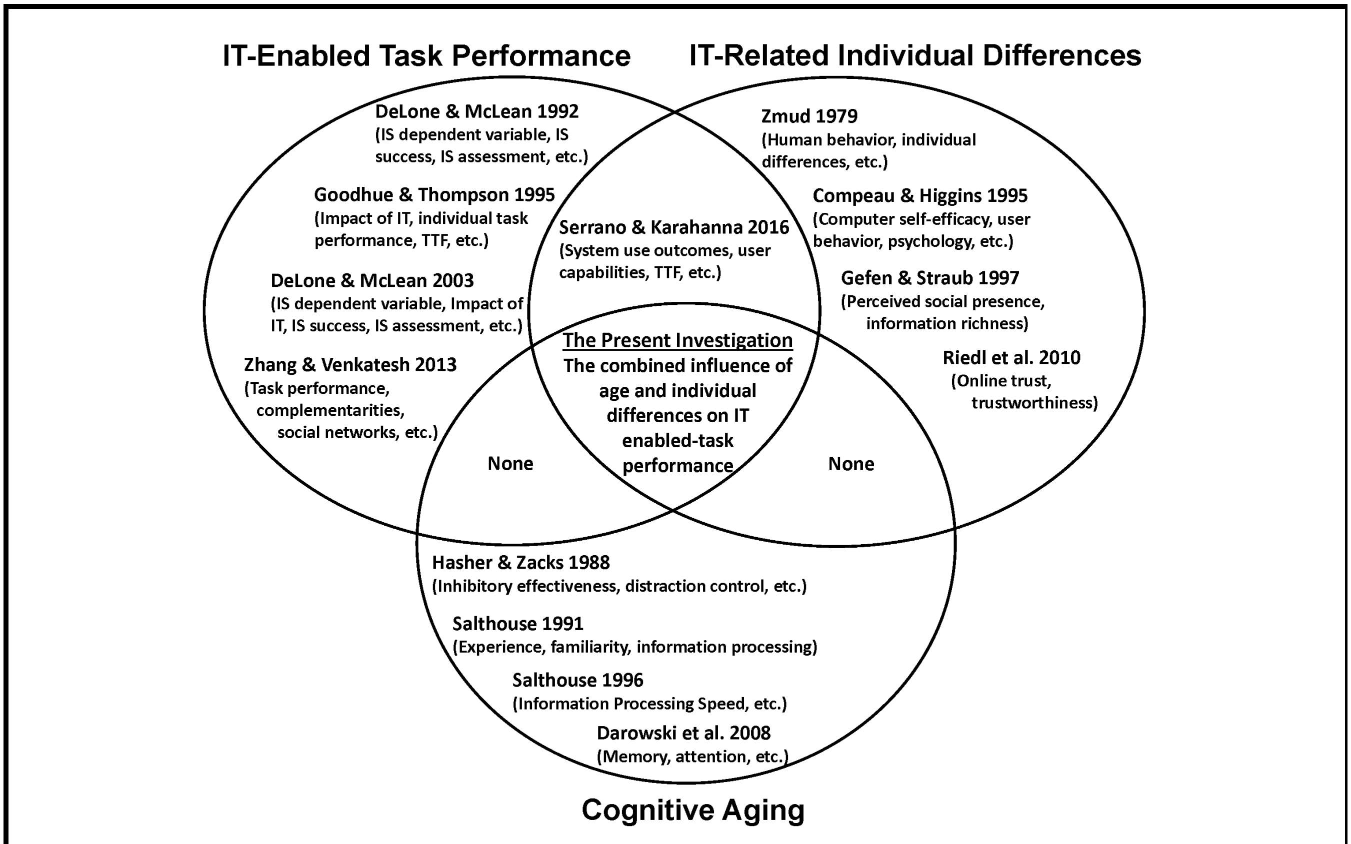



**Figure 1. Illustrative Studies in the Context of the Present Investigation**

During the past 50 years, researchers have developed three fundamental explanations of cognitive aging: the theory of processing speed, the theory of inhibitory deficits, and the theory of limited resources (Park and Festini 2017). All three theories provide important insights into age-related declines in cognitive abilities, but when they are evaluated using the approach recommended by Truex et al. (2006) for applying theories from other fields to IS research, it becomes clear that the theory of processing speed, with its focus on the relation between age differences and cognitive performance (Salthouse 1996, 2016, 2000), offers the best lens for investigating the impacts of user age on IT-enabled task performance. The theory has age as its independent variable and performance on cognitive tasks such as IT-enabled reporting as its dependent variable (Salthouse 1996). Moreover, it has been used successfully in a wide variety of research contexts (Park and Festini 2017), and it has made it possible to explain differences in cognitive performance related to age with great precision and consistency (Smith 1996).

As for the theory of inhibitory deficits and the theory of limited resources, they primarily focus on attentional control in the presence of task-irrelevant information and on the allocation of attentional resources (Smith 1996). The theory of inhibitory deficits acknowledges that task performance can suffer when task-irrelevant information is present, but it pays no direct attention to task performance as an outcome variable. Similarly, the theory of limited resources is more useful for identifying the limited resource—working memory capacity—than for analyzing task performance; in addition, it has led to conflicting findings (Park and Festini 2017). This confirms that the theory of processing speed is the theory that focuses the most directly on task performance and the one that provides the most conceptually interesting approach to the problem of age-related reductions in IT-enabled task performance.

Moreover, the underlying assumptions of the theory of processing speed do not conflict with the theoretical foundations of IS research. One of its key underlying assumptions is that as the time pressure and the number of information processing demands associated with a task increase, processing speed becomes more and more relevant to task performance. This means that the greater the time pressure and the higher the number of processing demands associated with an IT-enabled task, the more likely it will be possible to develop an adequate explanation of user performance by introducing a model based on the theory of processing speed.

The central thesis of the theory of processing speed is twofold. First, as adults become older, the speed with which they process information decreases, and second, this decrease leads to reduced cognitive performance (Salthouse 1996). Recent IS research has introduced the notion of "touchpoints of age": the points or areas where age has an impact on IT use and on use-related outcomes like task performance (Tams et al. 2014, p. 286). The touchpoint of age examined in the present investigation is information processing speed. The impact of this touchpoint of age on task performance is investigated using IT-related individual difference variables as moderators.

The moderators are identified using Wickens' Human Information Processing Model (Wickens et al. 2004). Wickens' model, which is based on research in cognitive psychology, addresses information processing in general and has not been previously applied to the study of age-related impacts on IT-enabled task performance. Emerging from the same area of research, this model is a useful complement to the theory of processing speed because it identifies four moderators of information processing that are specifically relevant to IT-enabled work and that IS research has established as relevant to managers and systems designers: experience, self-confidence, cognitive load, and effort cost.

According to Wickens' model, it is mainly experience that facilitates the extraction of meaning from information. Since processing speed also impacts the perception of information, this suggests that it is essential to examine the interaction between experience and processing speed. Interestingly, the theory of processing speed indicates that experience is an important moderator of the relationship between age and performance (Salthouse 2000). Wickens et al. (2004) argue that thought and decision-making play a key role in information processing. They maintain that thought is linked to self-confidence because the latter can foster positive thinking and change the cognitive representation of future events. In their discussion of decision-making, they emphasize that it involves considering the anticipated effort required to undertake an activity and the cost associated with this effort. They call this type of cost an "effort cost" because it is related to the mental effort required to engage in a behavior such as using an IT. It is also important to mention that they point to the detrimental effects of cognitive load, especially cognitive overload, on the performance of information processing tasks.

In line with Wickens' model, IS researchers have been treating experience as a moderator variable for a long time, particularly in their models of IT acceptance and use (Taylor and Todd 1995). They have also recognized the importance of the other three constructs. Self-efficacy, the basis of self-confidence, is a key factor for IT use (Compeau and Higgins 1995), and cognitive load, especially cognitive overload, is a critical contributor to technostress (Ayyagari et al. 2011). As for effort cost, to the extent that it is directly related to cognitive effort, it hinders the adoption of new systems and impedes user compliance with information security policies (Bulgurcu et al. 2010; Polites and Karahanna 2012). The indirect effect that age has on IT-enabled task performance by way of processing speed is moderated by these four concepts. This is the topic of the next section.

Experience and self-efficacy have to be examined as mitigators. Although these two constructs are generally related to each other (Compeau and Higgins 1995), they can be examined separately to obtain a more nuanced understanding of the effect of age on IT-enabled task performance because they involve different aspects of information processing: perception in the case of experience and thought in the case of self-efficacy (Wickens et al. 2004). Experience helps users develop new abilities, whereas self-efficacy motivates them to make a greater effort. Since these two constructs interact with processing speed in different ways, investigating them as separate moderators makes it possible to examine the factors mitigating the impact of age on IT-enabled task performance more thoroughly and to provide practitioners with more detailed guidance on how to reduce this impact.[2]

In line with the recommendations of Keen (1980), the research model presented here does not focus on specific technologies. On the contrary, the goal is to present a universal model that applies to IT in general. Once this model has been validated, context-specific versions of it can be developed to take account of particular technologies. Although this approach has disadvantages for context-specific research, it should allow IS scholars to build a cumulative research tradition for issues related to technology and aging.

[2]The approach used is driven by theoretical as well as practical considerations, but it is clear that using the same model to analyze the moderating effects of both experience and self-efficacy may cause multicollinearity. Alternatively, if they are analyzed in separate models, there is a risk of spurious effects. In either case, the conclusions drawn about the individual effects may be somewhat imprecise. Nevertheless, based on McGrath (1981) I argue in the "Limitations" subsection of this article that the theoretical and practical benefits of including all four moderating variables in the theoretical model outweigh the importance of trying to avoid these potential statistical problems. In this article, I hypothesize the effects of the four moderators individually and test them using separate models because my goal is to examine the individual influence of each moderator on the effect of age on IT-enabled task performance rather than the combined influence of multiple moderators. For example, I examine the moderating effect of IT experience as a whole rather than the effect of the unique dimension of IT experience that is unrelated to IT self-efficacy. The approach that I chose alleviates the risk of multicollinearity, although the risk of spurious effects remains. This issue is discussed in more detail in the "Methods" subsection.

## Development of the Research Hypotheses

Using the theory of processing speed and Wickens' moderators, a moderated mediation model is developed for the IT-related individual differences moderating the indirect effect that age has on IT-enabled task performance by way of processing speed. The first step is to conceptualize the causal link between age and IT-enabled task performance (Research Objective 1). This baseline model is then refined by elucidating the mitigating and aggravating factors that managers and systems designers need to consider when they seek to control age-related impacts on IT-enabled task performance (Research Objectives 2 and 3). These mitigating and aggravating factors moderate Path *b*, the second stage in the mediation process. This means that the moderation operates on the effect that processing speed has on IT-enabled task performance (see Figure 2). There are two reasons that Path *a*, the first stage of the mediation process, is not moderated. First, there is no theoretical reason to assume that specific IT-related individual differences moderate age-related impacts on general cognitive abilities such as processing speed. Second, given that Path *a* is a foundational premise of the model, examining the moderators of Path *a* is a less useful way to develop a parsimonious research model.

### *Research Objective 1: Information Processing Speed as a Touchpoint of Age (Mediation)*

When applied to IT-enabled task performance, the theory of processing speed can be used to formulate the hypothesis that age leads to reductions in processing speed that hamper performance on IT-enabled tasks. This section clarifies the fundamental implications of the theory of processing speed and specifies the hypotheses that formalize a baseline model whose focus is Hypothesis 1c.

The effect of age on the speed of information processing is well documented. Information processing speed normally declines with increased age due to losses in gross brain volume and reductions in cerebral blood flow (Park and Festini 2017). The slower speed is connected to the gradual slowing of the transmission of neural impulses that occurs as human beings age (Salthouse 2000). These documented negative effects of age make it plausible to assume the following hypothesis:

*H1a: Age affects information processing speed negatively.*

According to the theory of processing speed, a normal age-related decrement in the speed that human beings execute even simple cognitive processes leads to the gradual decline of more complex intellectual abilities (Salthouse 1996). Thus the performance levels for cognitive tasks tend to decrease as the persons performing these tasks become older. This is especially true if the tasks require information integration and manipulation, as is the case in most IT-enabled work.

Two factors cause this reduction in cognitive performance: the limited time mechanism and the simultaneity mechanism (Salthouse 1996). The limited time mechanism slows the speed of information processing with the result that less information processing is completed in a given period of time. When this occurs, the level of cognitive performance is necessarily lower (Salthouse 1996). As for the simultaneity mechanism, it has to do with the fact that human beings often need to process different pieces of information simultaneously in order to see connections between them and understand their relevance. Doing so becomes more difficult if the initial processing operations take too long and the later operations that make them meaningful are not performed soon enough. When this occurs, a smaller amount of relevant information is available and higher order processes such as abstraction and information integration are impaired (Salthouse 1996). Simultaneously managing multiple streams of information also becomes more difficult, and this can lead to problems with multitasking.

Both mechanisms are relevant to the performance of IT-enabled tasks because the latter are characterized by a fast work pace and concurrent processing demands (Ahituv et al. 1998; Browne et al. 2007). IT-based work creates information overload, a situation where users are "forced to work faster to cope with increased processing requirements" (Ragu-Nathan et al. 2008, p. 421; Hinz et al. 2016), and where the negative impact of the limited time mechanism on the performance of IT-enabled tasks can be even greater. Moreover, to perform these tasks in organizations, it is often necessary to use a multitude of devices (e.g., a desktop computer and a smartphone) and applications (e.g., MS Excel, SAP, and Outlook). As a result, users often have to manage large numbers of concurrent processing demands at the same time, which means that the simultaneity mechanism comes into play.

These arguments show that the theory of processing speed and the predictions that it makes possible are applicable to the performance of IT-enabled tasks. At the same time, it is also important to stress that age-related declines occur earlier and are more pronounced for the performance of cognitive tasks that involve visual–spatial information processing as opposed to auditory or tactile information processing (Salthouse 2000). This means that declines in processing speed can be especially pronounced for IT-enabled tasks, where information is usually

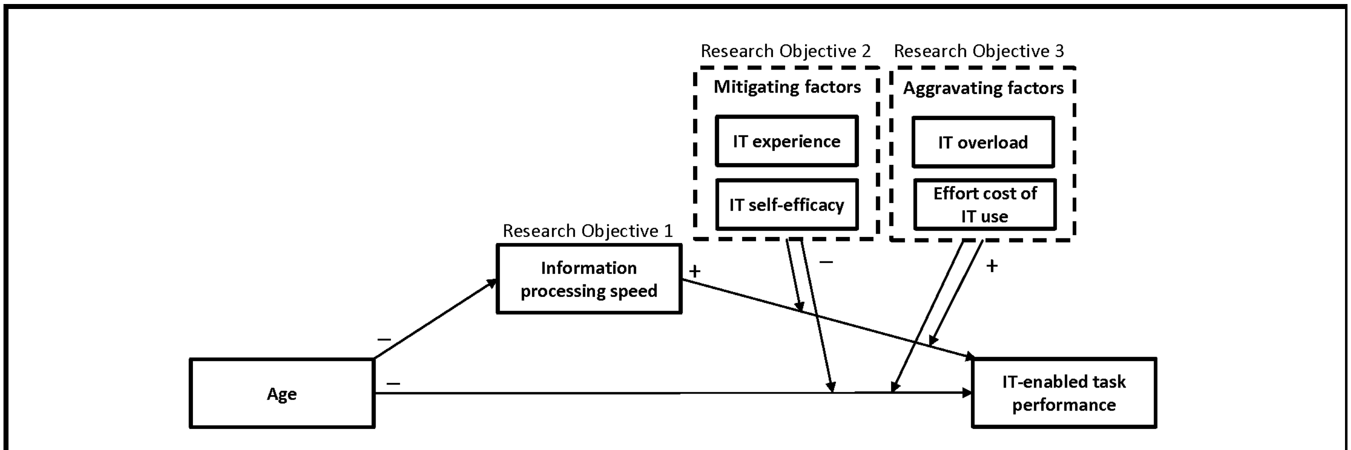



**Figure 2. Research Model**

presented in the two-dimensional visual space of a computer screen. The negative impact that slower information processing has on IT-enabled task performance clearly indicates that information processing speed is essential to the successful performance of IT-enabled tasks. Therefore, it is plausible to assume the following hypothesis:

> *H1b:* *Information processing speed affects IT-enabled task performance positively.*

The causal order of the constructs must also be taken into account, for age cannot be expected to cause decrements in IT-enabled task performance directly. As Salthouse (1996) points out, it is the reduction in information processing speed that causes declines in performance, and it is age that causes this reduction. Thus information processing speed is conceptually closer to performance than age is, and it plays the fundamental role of mediating the effect of age on performance (Luszcz et al. 1997).

The framework of proximal and distal individual differences can be used to examine the causal order of the constructs more closely (Luszcz et al. 1997). Depending on whether they are cognitive or noncognitive predictors, individual differences such as age and processing speed can be either proximally or distally connected to task performance (Luszcz et al. 1997; Salthouse 1991). Processing speed is a cognitive predictor, but age is a demographic characteristic of users, which makes it a noncognitive predictor (Luszcz et al. 1997). Cognitive predictors such as processing speed are proximally connected to task performance, whereas noncognitive predictors such as age are distally connected to it. This conclusion can be inferred from research demonstrating that cognitive predictors substantively reduce or even eliminate age-related performance variance and that noncognitive ones are not nearly as effective in this regard (Luszcz et al. 1997).

This means that proximal cognitive predictors, especially processing speed, can mediate the impact of a more distal noncognitive predictor like age on performance (Luszcz et al. 1997; Salthouse 1996). For the present investigation, it is essential to see that processing speed qualifies as a touchpoint of age and that this opens up the possibility of a more precise explanation of the impact of age on IT-enabled task performance. With a view to developing this explanation, it is plausible to assume the following hypothesis:

> *H1c:* *Information processing speed mediates the negative effect of age on IT-enabled task performance.*

## *Research Objective 2: Mitigating Factors (Second Stage Moderated Mediation)*

According to the theory of processing speed, factors in the task environment can mitigate the performance problem for older adults (Salthouse 2000). Wickens' Human Information Processing Model identifies two factors that have this mitigating effect: experience and self-efficacy. These two mitigating factors help older users circumvent information processing constraints because they facilitate the development of compensatory cognitive skills and beliefs that enhance the ability of these users to maintain a normal level of task performance.

### IT Experience as a Mitigating Factor

The main compensatory skills that IT experience helps users develop are parallel processing and memory extension (Ericsson and Charness 1994). Users develop the ability to do parallel processing because their experience allows them to anticipate the complexity of navigating with certain system features and the difficulty of navigating when disruptive events such as system failures occur. As a result, they can begin processing subsequent stimuli before they have finished processing earlier stimuli, and this makes processing constraints like reduced processing speed relatively unimportant for their task performance. Sweller (1994) makes a similar point using cognitive load theory, which posits that experience refines and makes automatic the schemata in working memory that link related pieces of information, leading to the gradual replacement of resource-intense cognitive processes by more efficient automatic ones that are less affected by processing constraints.

Experience also allows persons to use long-term memory as an extension of short-term memory (Ericsson and Kintsch 1995). This memory extension makes it possible for them to do more mental work. Thus they can perform IT-enabled tasks more efficiently, even when they are faced with an extremely high number of information processing demands. Just as the well-known saying "practice makes perfect" implies, users generally begin to improve their performance levels after they have had a significant amount of experience with the various aspects of their task environment.

In IT-based work, experience—the amount of time that persons have spent using IT over the course of their lives (Taylor and Todd 1995)—is especially relevant to task performance. The preceding discussion of the two compensatory cognitive skills that experience helps users to develop, parallel processing and memory extension, suggests that IT experience improves their ability to do mental work with IT and to manage multiple information processing demands at the same time. Thus, by reducing the impact that the limited time and simultaneity mechanisms have on their task performance, IT experience should help older users overcome their processing limitations. It is therefore plausible to assume the following hypothesis:

> *H2a:* *As mediated by information processing speed, age has an indirect effect on IT-enabled task performance that is weaker when the user has more IT experience.*

### IT Self-Efficacy as a Mitigating Factor

Self-efficacy refers to the belief in one's ability to succeed in specific situations or to accomplish certain tasks. When persons have this belief, it has a fundamental impact on their cognitive functioning and on their ability to perform tasks (Bandura 1993). Indeed, the positive relation between self-efficacy and performance has been established in many fields of research, including IS (Compeau and Higgins 1995; Marakas et al. 1998).

It seems clear that self-efficacy should provide a buffer against the negative impacts of cognitive declines in older adults, including declines in their processing speed. Persons with high levels of self-efficacy are strongly motivated, and this leads them to exert greater cognitive effort when they process information (Bandura 1989; Salthouse et al. 2004). Moreover, they usually set higher goals for themselves and make firmer commitments to achieving these goals (Bandura 1993). By contrast, persons with lower levels of self-efficacy tend to dwell on the difficulty of performing tasks and on the adverse consequences of failure. This undermines their cognitive functioning and their overall effort to perform by diverting their attention from the execution of a task to concerns about potential problems. In a word, it causes them to make poorer use of their cognitive abilities (Bandura 1989).

To determine how age affects IT-enabled task performance, it is essential to take into consideration IT self-efficacy, the belief that persons have in their ability to use IT effectively to accomplish work tasks (Compeau and Higgins 1995). If older users have greater IT self-efficacy, they will be motivated to make a greater effort while processing information to perform IT-enabled tasks, and this additional effort will compensate for their declining processing speed. They will be able to process information faster, and they will find it easier to manage multiple cognitive demands at the same time. This suggests that by reducing the negative impact of the limited time and simultaneity mechanisms, IT self-efficacy should provide a buffer against the negative effect that declining processing speed has on task performance. Therefore, it is plausible to assume the following hypothesis:

> *H2b:* *As mediated by information processing speed, the indirect effect of age on IT-enabled task performance is weaker when the user has higher levels of IT self-efficacy.*

## *Research Objective 3: Aggravating Factors (Second Stage Moderated Mediation)*

According to Wickens' Human Information Processing Model, information processing constraints can be aggravated by cognitive overload and effort costs (Wickens et al. 2004). In this section, these two aggravating factors are used to develop specific hypotheses about IT-enabled task performance.

### IT Overload as an Aggravating Factor

IT overload occurs when users feel overburdened by an excessive number of IT demands (Choi and Lim 2016). It is relevant to the investigation of the effects of age on task performance because it is increasingly common in contemporary work environments. Indeed, the pressure to keep up with ever-evolving IT often compounds the pressure to perform work duties (Ahuja and Thatcher 2005). Hence it is no surprise that more and more users complain of IT overload (Ragu-Nathan et al. 2008).

For the present investigation, it is important to note that IT overload can aggravate problems related to slow information processing. Since it is connected to the sheer volume of IT demands, IT overload should primarily impact the limited time mechanism, although it may also influence the simultaneity mechanism. IT can add task-performance steps that overtax the cognitive abilities of users trying to accomplish a task. This can worsen the impact of the limited time mechanism on their performance because when users have less time to accomplish a task, their slower processing speed becomes more problematic. Moreover, the task-performance steps added by an IT can force users to change their work habits to adapt to the technology, slowing them down and causing them to make mistakes, with the result that the impact of the limited time mechanism is strengthened. In addition, IT-based work often involves tight schedules that reinforce the limited time mechanism. Of course, if an IT does not overtax the cognitive abilities of users by limiting the time available to accomplish tasks, then the limited time mechanism may have little or no impact and even users with slower information processing speed may perform well. This suggests that it is plausible to assume the following hypothesis:

> *H3a:* *As mediated by information processing speed, the indirect effect of age on IT-enabled task performance is stronger when there are higher levels of IT overload.*

### The Effort Cost of IT Use as an Aggravating Factor

As an aggravating factor, the effort cost of IT use is related to the nature of cognitive demands. When the latter have a high degree of complexity, the cognitive effort required to manage this complexity becomes an aggravating factor for task performance. For example, at many organizations Microsoft Excel is becoming more complicated because of mergers and acquisitions that increase the number of interconnected spreadsheets (Worstall 2013). These interconnected spreadsheets are often confusing and force users to make more cognitive effort. In general, it is complex technologies and features that create effort costs related to the mental exertion required to use them (Wickens et al. 2004).

Thus it is essential to examine the construct "effort cost of IT use," which refers to the cognitive effort required to use IT. Since this effort is related to the complexity of IT demands, it should primarily impact the simultaneity mechanism, although it may also influence the limited time mechanism. The simultaneity mechanism is relevant because effort cost can lead to a deflection of processing resources. If the task environment imposes an additional cognitive demand such as the use of a complex IT, this redirects users' processing resources to the technology, causing them to concentrate on the technology rather than on the task at hand. This deflection of processing resources can interact with the processing speed of users and negatively impact their task performance by disrupting task-related processing. When the latter eventually resumes, the information from earlier processing operations is no longer readily available. As a result, the information processed before the deflection cannot be integrated with the information processed after the deflection to the same degree. This suggests that the effort cost of IT use should strengthen the impact of the simultaneity mechanism on performance. It is therefore plausible to assume the following hypothesis:

> *H3b:* *As mediated by information processing speed, the indirect effect of age on IT-enabled task performance is stronger when the effort cost of IT use is higher.*

## General Method

Three complementary studies were conducted. Study 1 was performed in a controlled laboratory environment to establish the internal validity of the results. It tested the baseline model (Research Objective 1 → Hypotheses 1a-1c) as well as the mitigating factors (Research Objective 2 → Hypotheses 2a and 2b). Study 2 was based on a large-scale survey conducted to accomplish two objectives. The first objective was to establish the external and ecological validity of the results of Study 1, and the second one was to test the aggravating factors (Research Objective 3 → Hypotheses 3a and 3b). Study 3 consisted of a survey designed to extend the findings of Study 2 to a population of users who work with one specific technology. This made it possible to highlight the specific role of information systems in the relation between age and task performance.

## Study 1

Since the goal of Study 1 was to control the variables as closely as possible in order to maximize internal validity, it had to be conducted in a laboratory. It was a correlational study rather than a true experiment because age cannot be manipulated. This means that age was an experimental selection. Consistent with past research, the participants were university students and older persons from the community who were recruited through university contacts. At the time of the study, all of the older persons who participated in it were active users of IT and living independently. In addition, all of them reported being healthy, mentally alert, and physically active. The students and the older persons were invited to come to the laboratory to participate in an experiment so that relevant data could be obtained on the relation between age and IT-enabled task performance.

### Study 1: Task

To test the model, it was essential to have the participants perform an information processing task (Salthouse 1996, 2016). The selected task was one in which the participants had to search for matching pairs of symbols in a matrix of computer-generated cards. In a limited amount of time, they had to find the matching pairs by memorizing the individual symbols and their location in the matrix. To perform this task, they had to process a significant amount of information because each matching pair of symbols consisted of an equation and its result, for example, "7*12" and "84." This meant that this IT-enabled task required cognitive resources related both to memory and to information processing; as a result, it could be used to investigate a model of IT-enabled task performance framed either by the theory of limited resources or by the theory of processing speed, the focus of the present investigation.

Requiring IT-enabled information processing, the task highlighted an important form of the IT artifact: "technology as an information processing tool" (Orlikowski and Iacono 2001, p. 124). Moreover, it is important to stress that the participants performed the task in an IT-enabled environment, clearly an appropriate context for studying IT-enabled task performance. After performing the task, the participants were asked to respond to various questions so that data could be obtained on measures such as their age, their processing speed, and the mitigating factors.

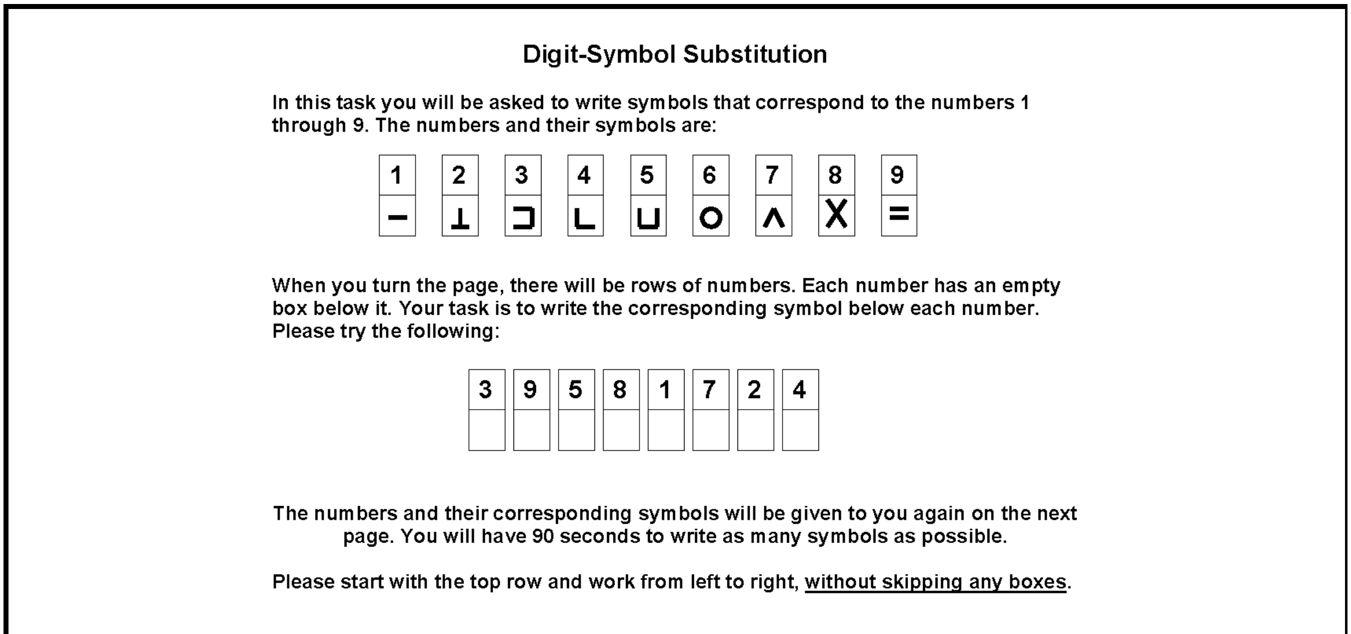
### Study 1: Measures

*Age*. In IS research and in research on processing speed, age has mainly been operationalized by comparing younger and older users chronologically (Morris et al. 2005; Salthouse et al. 2004). In line with this tradition, age was operationalized in Study 1 using an experimental selection with two groups, one made up of younger participants and one made up of older ones. Consistent with the theory of processing speed, participants between the ages of 18 and 25 were defined as younger and those between the ages of 60 and 85, as older (Salthouse 1992b). These definitions were also consistent with the fact that retirement-aged persons now make up the fastest growing part of the workforce in OECD countries, there being a dramatic increase in the numbers of workers older than 65 in these countries (OECD 2019). Moreover, many of these retirement-aged persons hold IT-heavy positions at organizations. It has even been reported that some H&R Block employees working in tax accounting are over 80 years old (AccountantsDaily 2015).

*Processing speed*. The most widely accepted test for information processing speed is the Digit Symbol Substitution Test (Salthouse 1996, 2016). This test is performed with a code table that has pairs of digits and symbols and rows of double boxes. The top box contains a digit, and the bottom box is empty. Using the code table, the participant has to write in the bottom box the symbol that is associated with the digit in the top box (see Figure 3). The participant's processing speed is determined by the number of correct symbols that he or she writes in 90 seconds (Salthouse 1996). The test is objective with wide support for its accuracy, and it has a test–retest reliability of 0.82 (Salthouse 1992a).

*IT-enabled task performance*. Task performance refers to the extent to which task output is effective in meeting task objectives (Burton-Jones and Straub 2006). The task objective in Study 1 was to match as many pairs of equations and results as possible within the allotted time. Therefore, task performance was measured as the number of successfully matched pairs of equations and results achieved within the allotted time.

*Mitigating factors*. As previously mentioned, the two mitigating factors considered were IT experience and IT self-efficacy, the first referring to the amount of time that persons have spent using IT over the course of their lives (Harrison and Rainer 1992), and the second referring to the belief that persons have in their ability to use IT effectively to accomplish tasks (Compeau and Higgins 1995; Marakas et al. 1998). For Study 1, a three-item scale for generalized computer experience was adapted from prior research (Harrison and Rainer 1992) as a measure for evaluating IT experience (see Appendix A), and Compeau and Higgins' (1995) original 10-item measure was used to evaluate generalized computer self-efficacy (see Appendix A).



**Digit-Symbol Substitution**

In this task you will be asked to write symbols that correspond to the numbers 1 through 9. The numbers and their symbols are:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|
| – | ⊥ | ⊐ | L | ⊔ | O | ∧ | X | = |

When you turn the page, there will be rows of numbers. Each number has an empty box below it. Your task is to write the corresponding symbol below each number. Please try the following:

| 3 | 9 | 5 | 8 | 1 | 7 | 2 | 4 |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

The numbers and their corresponding symbols will be given to you again on the next page. You will have 90 seconds to write as many symbols as possible.

Please start with the top row and work from left to right, without skipping any boxes.

**Figure 3. Participant Instructions for the Digit–Symbol Substitution Test**

*Control variables*. All of the participants in Study 1 were required to follow the same procedure in the same laboratory. Using techniques such as emitting white noise, the laboratory was controlled to eliminate extraneous distractions. In addition, the sex, the health, the education, and the task-related self-efficacy of the participants were used as control variables. These variables have been linked to cognitive performance in general and to performance on IT-enabled tasks in particular (Salthouse 2000; Serrano and Karahanna 2016; Zhang and Venkatesh 2013).

## Study 1: Analysis and Results

The survey instrument demonstrated good measurement properties. The alphas were 0.74 for IT experience and 0.96 for IT self-efficacy. This means that they exceeded the recommended threshold of 0.71 (Nunnally 1978). The average variance extracted (AVE) exceeded 0.50 for both constructs: 0.62 and 0.61 respectively (Fornell and Larcker 1981), and the square root of each construct's AVE was larger than the inter-construct correlations. A total of 128 subjects participated in the study, one half of them, younger persons, and the other half, older persons. The average age was 21 for the younger participants (SD = 1.7), and 71 for the older ones (SD = 6.0). Close to 50% of the participants were male (47%), and most participants were in good health (with a mean of 3.8 on a 5-point scale). The majority of them were college-educated (with a mean of 5.2 on an 8-point scale) and engaged several times a month in mental activities like doing crossword puzzles (with a mean of 3.25 on a 5-point scale).

All the mediation hypotheses (H1a-H1c) and moderated mediation hypotheses (H2a and H2b) were formally tested using PROCESS, Version 3, for conditional process analysis in SPSS (Hayes 2015, 2018a). The tests were conducted with a 95% confidence interval and 5,000 bootstrap resamples in SPSS v25. In line with Hayes (2018a), the choice of PROCESS models was guided by theory and prediction. To provide a baseline estimate of the indirect effect of age, Hypotheses 1a-1c are concerned with mediation alone; therefore, they were tested using PROCESS model 4 (see Figure 4), which excludes moderating variables in order to produce an overall estimate of the indirect effect.

Moderated mediation hypotheses H2a and H2b nuance the explanation of the indirect effect of age by treating the moderators separately. This makes it possible to analyze the overall moderating effect of each one. Thus each one was tested individually by estimating a separate instance of Model 15. The latter produces an Index of Moderated Mediation that determines whether the moderated mediation effect is significant (Hayes 2018a, 2018b). This index is a direct test of the hypotheses because it excludes other moderators. For example, in the case of H2a, Model 15 probes the overall moderating effect of IT experience irrespective of the level of IT self-efficacy. By contrast, other models such as Model 17 generate an Index of Partial Moderated Mediation that partials

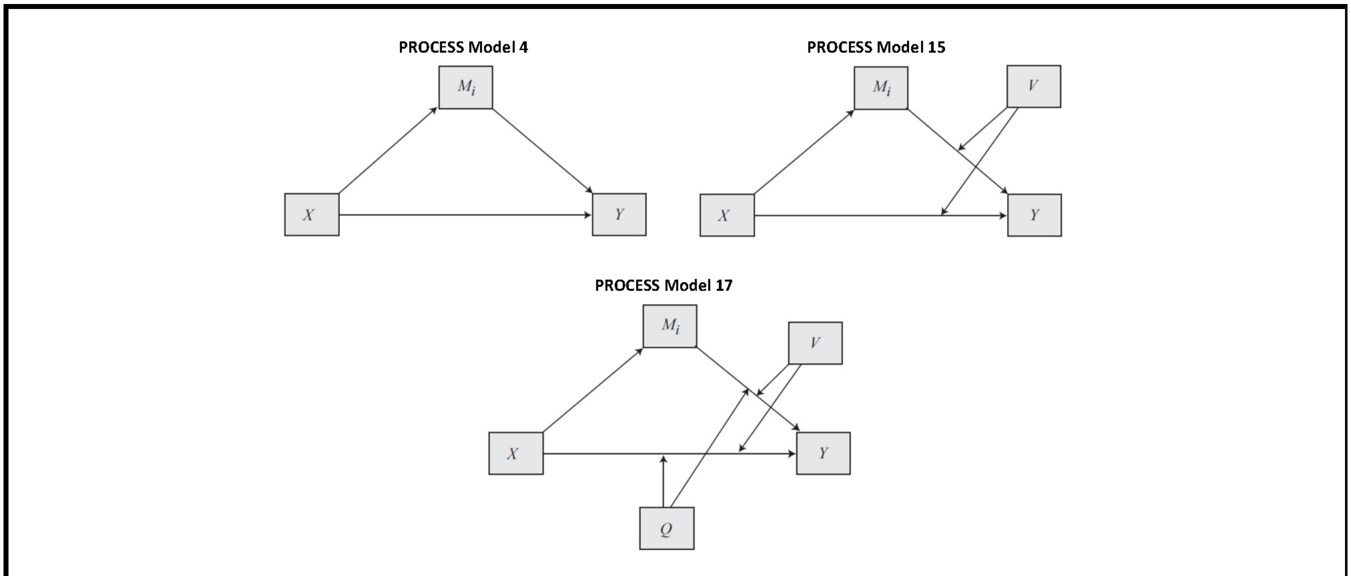



**Figure 4. Comparison of PROCESS Models (Hayes 2018a)**

out the variance associated with IT self-efficacy when the moderating effect of IT experience is calculated (see Figure 4). Partialing out this variance changes the meaning of the regression coefficient of IT experience in a manner that may run counter to the hypothesis. For example, contrary to what was hypothesized, it could show that IT experience moderates the indirect effect among users who have low levels of IT self-efficacy.

Model 15 essentially multiplies the effect of age on processing speed by the effect of processing speed on IT-enabled task performance at different levels of each moderator. By examining the moderators separately, Model 15 also makes it possible to avoid multicollinearity that might otherwise arise from related moderators such as IT experience and IT self-efficacy (see Footnote 1). In line with Hayes (2015, 2018a), the conditional indirect effect that age has on IT-enabled task performance, by way of information processing speed moderated by IT experience, can be expressed as follows:

$$f\left(\hat{\theta} \mid IT\ experience\right) = \hat{a}\left(\hat{b}_1 + \hat{b}_2 * IT\ experience\right) \quad (1)$$

This indirect effect depends on IT experience to the extent that the interaction coefficient $\hat{b}_2$ is different from zero. The indirect effect moderated by IT self-efficacy can be expressed as follows:

$$f\left(\hat{\theta} \mid IT\ self-efficacy\right) = \hat{a}\left(\hat{b}_1 + \hat{b}_2 * IT\ self-efficacy\right) \quad (2)$$

All of the hypothesis tests included the control variables, and the results supported the hypotheses. First, in support of H1a, age was found to have a significant negative effect on processing speed ($\beta$ = -.7022, SE = .0781, LL = -.8570, UL = -.5474, p < 0.001). Second, in support of H1b, processing speed was found to have a significant positive effect on IT-enabled task performance ($\beta$ = 0.2567, SE = .0823, LL = .0936, UL = .4198, p < 0.01). Finally, in support of H1c, age was found to have a significant negative indirect effect on IT-enabled task performance by way of processing speed ($\beta$ = -.1803, SE = .0612, LL = -.3002, UL = -.0626, p < 0.05).

The results of the moderated mediation tests provided a significant positive index of moderated mediation for H2a. Thus age was shown to have a positive moderated indirect effect on IT-enabled task performance by way of the interaction of processing speed and IT experience (Index = .1003, SE = .0478, LL = .0087, UL = .1992, p < 0.05). This finding supported H2a. The model effect size was 65%, the F-statistic, 21.37, and the p-value, less than .001. The results also provided a significant positive index of moderated mediation for H2b. Specifically, age was shown to have a positive moderated indirect effect on IT-enabled task performance by way of the interaction of processing speed and IT self-efficacy (Index = .1052, SE = .0499, LL = .0023, UL = .2014, p < 0.05). This finding supported H2b. The model effect size was 66%, the F-statistic, 22.07, and the p-value, less than .001. Table 1 presents the conditional indirect effects that age has on IT-enabled task performance by way of processing speed at different values of each moderator.

**Table 1. Conditional Indirect Effects at Different Values of the Moderators**

| Moderator | Level[a] | Indirect Effect[b] | SE[c] | LLCI[d] | ULCI[e] | Zero Included?[f] |
|---|---|---|---|---|---|---|
| IT experience | Low | -.2531* | .0707 | -.4032 | -.1241 | No |
| | Mean | -.1510* | .0612 | -.2746 | -.0321 | No |
| | High | -.0488 | .0849 | -.2179 | .1146 | Yes |
| IT self-efficacy | Low | -.2779* | .0738 | -.4251 | -.1286 | No |
| | Mean | -.1738* | .0602 | -.2923 | -.0563 | No |
| | High | -.0698 | .0817 | -.2353 | .0910 | Yes |

[a]Low = The conditional indirect effect at low levels of the moderator (one standard deviation below the mean).
Mean = The conditional indirect effect at an average level of the moderator (at the mean).
High = The conditional indirect effect at high levels of the moderator (one standard deviation above the mean).
[b]Standardized, *$p < 0.05$.
[c]SE = Standard Error; [d]LLCI = Lower Limit Confidence Interval; [e]ULCI = Upper Limit Confidence Interval.
[f]"No" means that zero is not included in the confidence interval and that the indirect effect is significant.

The pattern in Table 1 shows the roles that IT experience and IT self-efficacy play as moderators of the indirect effect of age on IT-enabled task performance. Specifically, the negative indirect effect that age has on IT-enabled task performance by way of processing speed is significant when these moderators are at low and average levels. However, this negative indirect effect is insignificant at high levels of these moderators. This pattern demonstrates that IT experience and IT self-efficacy provide a buffer against the negative consequences of age-related declines in information processing speed.

### Study 1: Discussion

Study 1 provided evidence that age reduces IT-enabled task performance because it is accompanied by declines in the speed of information processing. Study 1 also showed that this negative indirect effect is offset by high levels of the two mitigators: IT experience and IT self-efficacy.

Consistent with prior research, Study 1 used two discrete age groups (younger persons and older persons) in order to make possible rigorous distinctions in the age variable. However, these two age groups represent specific periods at the opposite ends of human life, and it may be the case that more information would be obtained if age were observed as a continuous variable. To address this issue, another study was conducted that assessed age more comprehensively.

## *Study 2*

Study 2 was a large-scale survey that replicated the results of Study 1 in a real-world setting. It made it possible to extend these results by testing the aggravating factors (Research Objective 3 → Hypotheses 3a and 3b) and the mitigating factors (Research Objective 2 → Hypotheses 2a and 2b).

### Study 2: Sample

In line with the recommendations of Lowry et al. (2016), a market research company was hired to collect data from persons of varying ages who use organizational IT. The market research company in question was Qualtrics. For Study 2, quality assurance mechanisms were used to verify that the respondents took the survey seriously. In particular, three requests were embedded in the survey for quality assurance. One of them was worded as follows: "For this particular question, please select the response option 'moderately disagree.'" Only respondents who selected the option "moderately disagree" were allowed to continue completing the survey. All others were redirected to the end of the survey, and their responses were discarded.

To satisfy the sample frame requirements, two screening questions (SQ) were developed. The first one (SQ1) was designed to assess whether the respondents fit the study context: "At the organization where you are employed, do you currently use Information Technology (IT) to accomplish your work tasks?" The second one (SQ2) was designed to create a psychological contract with respondents to ensure that they took the survey seriously: "Do you commit to providing honest answers to the questions in this survey?" Prospective respondents who satisfied the sample frame requirements by answering the two questions appropriately were allowed to participate in the study. Those who did not satisfy them were not allowed to participate in it. In total, there were 7,164 prospective respondents, all of whom lived in the United States. However, 4,499 of them were screened out because they did not respond "yes" when asked SQ1, and 180 of them were screened out because they did not respond "I will provide honest answers" when asked SQ2. In addition, 1,465 prospective respondents were eliminated because they failed one of the three quality assurance questions. This left a total of 1,020 responses that satisfied the sample frame requirements and the various quality assurance mechanisms. Qualtrics was paid US$7.00 for each completed response.

In line with the sample specifications, the average age of the respondents was 45, the minimum age of a respondent being 18 and the maximum age, 75. Most of the respondents (89.9%) work in tertiary industries (services), although some (6.7%) are employed in secondary industries (manufacturing) and some (3.4%) in primary industries (raw materials). Example job titles include "nurse" (49 respondents), "accountant" (59), "office clerk" (49), and "sales representative" (73).

While answering the survey questions, the respondents were asked to focus on the IT that they use the most frequently for work-related tasks. The survey referred to this technology as "this IT." For 45% of the respondents, "this IT" was Function IT like Word that is used to perform discrete tasks (for categories of information systems, see McAfee 2006). For 39% of them, it was Network IT like Outlook that facilitates interactions with others. Finally, for 16% of them it was Enterprise IT like SAP that supports entire business processes. On average, the respondents used "this IT" to perform about 70% of their work tasks (with a mean of 5 on a 7-point scale).

### Study 2: Measures

The measures were adapted from prior research whenever possible. Appendix A details the scales that were used. In line with Tams et al. (2014), age was measured in three essential ways:

1. As a grouping variable that segmented the respondents into different age groups based on their chronological age, a measure analogous to the one used in Study 1.

2. As a continuous variable of chronological age.

3. As a variable of perceived cognitive age.

The first two measures are based on the actual number of years that the respondents have lived. They are straightforward, objective measures of life length. By contrast, cognitive age is a subjective measure (Tams et al. 2014) because it refers to age as a state of mind based on how old respondents perceive themselves to be. The chronological and the cognitive measures of age complement one another as objective and subjective determinations of how old respondents are (Tams et al. 2014).

Following Bandura (2006), information processing speed was examined by constructing a three-item measure of processing speed self-efficacy. When processing speed cannot be evaluated directly through an objective test like digit symbol substitution, self-efficacy constitutes a valid proxy (Salthouse et al. 2004). To ensure content validity, the item content was based on the phenomenon described in the IS literature as information overload, the situation where users are exposed to more information than they can process efficiently (Hinz et al. 2016). To ensure the quality of the measurement properties, card sorting exercises and a pilot test were used. The pilot test was conducted with a sample of 130 persons who use organizational IT and showed that the measure had good properties. The alpha and the AVE were 0.95 and 0.65 respectively, with item loadings of 0.776, 0.818, and 0.823. Moreover, in the pilot test the square root of the AVE was greater than the correlations between the measure and related ones.

In line with Harrison and Rainer (1992), IT experience was measured as the amount of experience with the IT used the most at work. Following Compeau and Higgins (1995) and Marakas et al. (1998), IT self-efficacy was measured as the belief that respondents have in their ability to use the IT effectively. The measures for IT overload, effort cost of IT use, and task performance were adapted from Choi and Lim (2016), Bulgurcu et al. (2010), and Tsai et al. (2007). As control variables, the sex, the conscientiousness, and the task experience of the respondents were used because these variables have been shown to impact cognition and performance on IT-enabled tasks (Salthouse 2000; Serrano and Karahanna 2016; Tsai et al. 2007; Zhang and Venkatesh 2013). Since the respondents held jobs in different sectors of the economy and used different types of organizational IT, it was also necessary to control for the industry and for the type of IT used at work.

### Study 2: Analysis and Results

A psychometric analysis confirmed that the survey instrument had good reliability and construct validity (see Appendix B). Thus it was possible to proceed with the hypothesis testing, for which the same analytical approach was used as in Study 1. To test H1a-H1c, PROCESS model 4 was used again. H2a can be expressed by Equation (1), and H2b, by Equation (2); therefore, to test them, PROCESS model 15 was used again. The latter was also used to test H3a and H3b, which can be expressed as follows:

$$f\left(\hat{\theta} \mid IT\ overload\right) = \hat{a}\left(\hat{b}_1 + \hat{b}_2 * IT\ overload\right) \quad (3)$$

$$f\left(\hat{\theta} \mid Effort\ cost\ of\ IT\ use\right) = \hat{a}\left(\hat{b}_1 + \hat{b}_2 * Effort\ cost\ of\ IT\ use\right) \quad (4)$$

It is important to note that the hypothesis tests included the control variables. Table 2 presents the results obtained for H1a-H1c for the three measures of age. These results were consistent, H1a-H1c being supported for all three measures.

In line with the results of Study 1, the results of the moderated mediation tests in Study 2 provided a significant positive index of moderated mediation for H2a across all three measures of age. Therefore, there was consistent evidence that age has a positive moderated indirect effect on performance by way of the interaction of processing speed and IT experience (see Table 3). The same held true for IT self-efficacy, the other mitigating factor in the model. This finding supported H2a and H2b. As for the aggravating factors, there was evidence that across all three measures, age has a negative moderated indirect effect on performance by way of the interaction of processing speed and IT overload. This finding supported H3a. However, there was limited evidence that the effort cost of IT use moderated the indirect effect of age on IT-enabled task performance. At a level of .1 the results for H3b were only marginally significant. Thus it was necessary to conclude that H3b was not supported.

Table 4 presents the conditional indirect effects that age has on IT-enabled task performance by way of processing speed at different values of the mitigators and aggravators. The pattern in Table 4 confirms the roles that IT experience and IT self-efficacy play as mitigators. The negative indirect effect that age has on IT-enabled task performance by way of processing speed is significant when these mitigators are at low and average levels, but it is insignificant when they are at high levels. This demonstrates that IT experience and IT self-efficacy provide a buffer against the negative consequences of age-related declines in information processing speed. This pattern holds for all three measures of age, a finding in line with the theoretical standpoint of the present investigation. The pattern in Table 4 also confirms the roles that IT overload and the effort cost of IT use were hypothesized to play in the model. Specifically, the negative indirect effect is small when these aggravators are at low levels, but it gradually increases as these aggravators change from low or average levels to high levels.

### Study 2: Discussion

For Study 2, an additional sample of working adults of varying ages was used to replicate and extend the results of Study 1. Study 2 demonstrated that the results of Study 1 extend to real-world settings and that the indirect effect that age has on IT-enabled task performance by way of processing speed is stronger for higher levels of the two aggravating factors: IT overload and the effort cost of IT use.

Moreover, H3b was supported at the .1 level of significance but not at the .05 level, which means that there was some evidence to support it but not enough to reject the null. It is possible that for the specific technologies like Microsoft Word used by the respondents, the effort cost was not sufficiently high to produce the hypothesized effects, but for the moment this is only speculation. One of the goals of the third study was to replicate the results of Study 2 to clarify this issue.

## *Study 3*

Study 3 was a survey designed to add specificity to the investigation by replicating the results of Study 2 for a sample of users who have the same job position and who work with the same technology.

### Study 3: Sample

Data were collected from 250 accountants of varying ages who use Microsoft Excel to perform their work tasks. A sample population of accountants was used because accounting work requires information processing that depends on the use of IT. Excel was selected as the target technology because it is designed to support accounting functions such as budgeting, preparing financial statements, and creating balance sheets. Qualtrics, the market research company that was hired to collect the data for Study 2, was also hired to collect the data for Study 3. In addition, the same quality assurance mechanisms and screening questions (SQ1 and SQ2) were used. To ensure that the desired sample frame was directly targeted, Qualtrics was asked to send the survey only to accountants, and screening questions related to the respondents' profession and their use of Excel were added (SQ3 and SQ4).

In total, there were 2,919 prospective respondents, all of whom lived in the United States. However, 67 of them were screened out because they did not respond "yes" when asked SQ1, and 2 others, because they did not respond "I will provide honest answers" when asked SQ2. Another 2,449

**Table 2. Findings for Research Objective 1 across Different Measures of Age**

| Hypothesis | Measure of Age[a] | Coefficient[b] | SE[c] | LLCI[d] | ULCI[e] | Zero Included? |
|---|---|---|---|---|---|---|
| H1a | Age group | -.1984** | .0319 | -.2611 | -.1357 | No |
| | Continuous age | -.2096** | .0319 | -.2722 | -.1470 | No |
| | Cognitive age | -.2064** | .0310 | -.2672 | -.1455 | No |
| H1b | n/a | .1703** | .0310 | .1095 | .2311 | No |
| H1c | Age group | -.0345* | .0088 | -.0532 | -.0194 | No |
| | Continuous age | -.0364* | .0090 | -.0556 | -.0204 | No |
| | Cognitive age | -.0337* | .0089 | -.0531 | -.0182 | No |

[a]Age group = Chronological age measured through a grouping variable (6 groups, see Appendix A).
Continuous age = Chronological age measured as a continuous variable (see Appendix A).
Cognitive age = Perceived/subjective age (see Appendix A).
[b]Standardized coefficients. H1a and H1b = direct effects, H1c = indirect effect, *p < 0.05, **p < 0.001.
[c]SE = Standard Error, [d]LLCI = Lower Limit Confidence Interval, [e]ULCI = Upper Limit Confidence Interval

**Table 3. Findings for Research Objectives 2 and 3 across Different Measures of Age**

| Hypothesis | Measure of Age | Index of Moderated Mediation[a] | SE[b] | LLCI[c] | ULCI[d] | Zero Included? | Model Effect Size | Model F-Statistic[e] |
|---|---|---|---|---|---|---|---|---|
| H2a (IT experience) | Age group | .0176* | .0071 | .0042 | .0330 | No | 19% | 19.25* |
| | Continuous age | .0192* | .0075 | .0054 | .0342 | No | 19% | 19.11* |
| | Cognitive age | .0196* | .0074 | .0060 | .0351 | No | 18% | 18.17* |
| H2b (IT self-efficacy) | Age group | .0144* | .0073 | .0009 | .0296 | No | 19% | 20.23* |
| | Continuous age | .0154* | .0076 | .0008 | .0307 | No | 19% | 20.02* |
| | Cognitive age | .0154* | .0076 | .0012 | .0311 | No | 18% | 18.89* |
| H3a (IT overload) | Age group | -.0168* | .0067 | -.0307 | -.0050 | No | 20% | 21.56* |
| | Continuous age | -.0179* | .0072 | -.0337 | -.0052 | No | 20% | 21.13* |
| | Cognitive age | -.0163* | .0072 | -.0321 | -.0041 | No | 19% | 20.16* |
| H3b (Effort cost of IT use) | Age group | -.0120 | .0066 | -.0254 | .0002 | Yes | 18% | 18.65* |
| | Continuous age | -.0126 | .0070 | -.0271 | .0003 | Yes | 18% | 18.39* |
| | Cognitive age | -.0114 | .0072 | -.0264 | .0018 | Yes | 17% | 17.28* |

[a]Standardized, *p < 0.05.
[b]SE = Standard Error, [c]LLCI = Lower Limit Confidence Interval, [d]ULCI = Upper Limit Confidence Interval, [e]*p < 0.01.

**Table 4. Conditional Indirect Effects at Different Values of the Mitigators and Aggravators**

| Measure of Age | Level of IT Experience | Indirect Effect[a] | SE[b] | LLCI[c] | ULCI[d] | Zero included? |
|---|---|---|---|---|---|---|
| **Mitigator: IT Experience** | | | | | | |
| Age group | Low | -.0523* | .0131 | -.0804 | -.0289 | No |
| | Mean | -.0314* | .0085 | -.0497 | -.0165 | No |
| | High | -.0105 | .0107 | -.0337 | .0940 | Yes |
| Continuous age | Low | -.0560* | .0133 | -.0834 | -.0321 | No |
| | Mean | -.0332* | .0086 | -.0509 | -.0178 | No |
| | High | -.0104 | .0114 | -.0338 | .0106 | Yes |
| Cognitive age | Low | -.0541* | .0133 | -.0829 | -.0303 | No |
| | Mean | -.0308* | .0085 | -.0490 | -.0158 | No |
| | High | -.0075 | .0111 | -.0310 | .0130 | Yes |
| **Mitigator: IT Self-Efficacy** | | | | | | |
| **Measure of Age** | **Level of IT Self-Efficacy** | **Indirect Effect** | **SE** | **LLCI** | **ULCI** | **Zero Included?** |
| Age group | Low | -.0442* | .0129 | -.0712 | -.0217 | No |
| | Mean | -.0282* | .0087 | -.0467 | -.0131 | No |
| | High | -.0088 | .0120 | -.0339 | .0131 | Yes |
| Continuous age | Low | -.0468* | .0133 | -.0752 | -.0228 | No |
| | Mean | -.0297* | .0089 | -.0483 | -.0141 | No |
| | High | -.0091 | .0123 | -.0350 | .0134 | Yes |
| Cognitive age | Low | -.0448* | .0132 | -.0740 | -.0217 | No |
| | Mean | -.0277* | .0087 | -.0471 | -.0128 | No |
| | High | -.0069 | .0121 | -.0327 | .0153 | Yes |
| **Aggravator: IT Overload** | | | | | | |
| **Measure of Age** | **Level of IT Overload** | **Indirect Effect** | **SE** | **LLCI** | **ULCI** | **Zero Included?** |
| Age group | Low | -.0143 | .0081 | -.0311 | .0011 | Yes |
| | Mean | -.0326* | .0083 | -.0499 | -.0177 | No |
| | High | -.0509* | .0133 | -.0792 | -.0272 | No |
| Continuous age | Low | -.0148 | .0086 | -.0331 | .0016 | Yes |
| | Mean | -.0344* | .0087 | -.0522 | -.0189 | No |
| | High | -.0539* | .0142 | -.0843 | -.0288 | No |
| Cognitive age | Low | -.0140 | .0086 | -.0317 | .0024 | Yes |
| | Mean | -.0317* | .0088 | -.0505 | -.0170 | No |
| | High | -.0494* | .0142 | -.0807 | -.0252 | No |
| **Aggravator: Effort Cost of IT Use** | | | | | | |
| **Measure of Age** | **Level of Effort Cost of IT Use** | **Indirect Effect** | **SE** | **LLCI** | **ULCI** | **Zero Included?** |
| Age group | Low | -.0200* | .0095 | -.0406 | -.0033 | No |
| | Mean | -.0335* | .0085 | -.0517 | -.0188 | No |
| | High | -.0470* | .0129 | -.0748 | -.0245 | No |
| Continuous age | Low | -.0211* | .0099 | -.0418 | -.0033 | No |
| | Mean | -.0352* | .0087 | -.0540 | -.0200 | No |
| | High | -.0494* | .0133 | -.0782 | -.0259 | No |
| Cognitive age | Low | -.0203* | .0099 | -.0416 | -.0025 | No |
| | Mean | -.0331* | .0087 | -.0520 | -.0179 | No |
| | High | -.0459* | .0135 | -.0747 | -.0230 | No |

[a]Standardized, *$p < 0.05$.
[b]SE = Standard Error, [c]LLCI = Lower Limit Confidence Interval, [d]ULCI = Upper Limit Confidence Interval

were screened out because they did not satisfy the additional sample requirements for Study 3 (SQ3 and SQ4). Finally, 151 prospective respondents were eliminated because they failed to respond to one of the three quality assurance questions correctly. In the end, a total of 250 responses satisfied the sample frame requirements and the various quality assurance mechanisms. Qualtrics was paid US$23 for each completed response. The average age of the respondents was 46, the minimum age of a respondent being 19 and the maximum age, 75. On average, the respondents used Microsoft Excel to perform about 70% of their work tasks (with a mean of 5 on a 7-point scale).

### Study 3: Measures

In Study 3, the same measures were used as in Study 2, but they were adapted to fit the Excel context (see Appendix A for the full scales). As control variables, the sex, the conscientiousness, and the task experience of the respondents were used because these variables have been shown to impact cognition and performance on IT-enabled tasks (Salthouse 2000; Serrano and Karahanna 2016; Tsai et al. 2007).

### Study 3: Analysis and Results

A psychometric analysis confirmed that the instrument had good reliability and construct validity (see Appendix C). To test the hypotheses, the same analytical approach was used as in Studies 1 and 2 (see Equations (1)–(4) above). Table 5 presents the results obtained for H1a-H1c for the three measures of age. These results were consistent, H1a-H1c being supported for all three measures.

In line with the results of Studies 1 and 2, the results of the moderated mediation tests in Study 3 provided a significant positive index of moderated mediation for H2a across all three measures of age. Therefore, there was consistent evidence that age has a positive moderated indirect effect on performance by way of the interaction of processing speed and IT experience (see Table 6). The same held true for IT self-efficacy, the other mitigating factor in the model. This finding supported H2a and H2b. As for the aggravating factors, there was evidence that across all three measures, age has a negative moderated indirect effect on performance by way of the interaction of processing speed and IT overload. The same held true for the effort cost of IT use, a finding that supported H3a and H3b.

Table 7 presents the conditional indirect effects that age has on task performance by way of processing speed at different values of the mitigators and aggravators. The pattern in Table 7 confirms the roles that IT experience and IT self-efficacy play as mitigators. The negative indirect effect that age has on IT-enabled task performance by way of processing speed is significant when these mitigators are at low levels, but it gradually decreases as these mitigators move from low or average levels to high levels. This demonstrates that these mitigators provide a buffer against the negative consequences of age-related declines in information processing speed. This pattern holds for all three measures of age. The pattern in Table 7 also confirms the roles that IT overload and the effort cost of IT use were hypothesized to play in the model. The negative indirect effect that age has on task performance by way of processing speed is insignificant when these aggravators are at low levels, but it worsens as these aggravators increase from low or average levels to high levels.

### Study 3: Discussion

Study 3 demonstrated that the results from Study 2 extend to a population of users who have the same job position and who work with the same specific technology. Thus Study 3 highlighted the specific role of information systems in the relation between age and IT-enabled task performance.

In Study 3, support was found across all three measures of age for the claim that the effort cost of IT use is an aggravating factor. In Study 2, the corresponding hypothesis was not supported, so that it was reasonable to speculate that the results may have occurred because the effort cost related to using the technologies was not sufficiently high. It is possible that stronger support was found for H3b in the Study 3 dataset because—consistent with the theoretical standpoint of the present investigation—Microsoft Excel requires users to make a greater mental effort. For various reasons, Excel can be more cognitively demanding than technologies such as Microsoft Word. For example, using Pivot tables in Excel can be more demanding than using simple grids in Word because it requires processing input parameters and outputs. This explanation of the differences observed in Studies 2 and 3 is consistent with the assumption that the higher the number of information processing demands associated with an IT-enabled task, the more likely it will be possible to develop an adequate explanation of user performance by introducing a model based on the theory of processing speed. It also suggests that there may be a three-way interaction between information processing speed, the effort cost of IT use, and the type of IT used to perform work tasks. This possibility should be explored in future research.

**Table 5. Findings for Research Objective 1 across Different Measures of Age**

| Hypothesis | Measure of Age | Coefficient[a] | SE[b] | LLCI[c] | ULCI[d] | Zero Included? |
|---|---|---|---|---|---|---|
| H1a | Age group | -.2553** | .0754 | -.4039 | -.1067 | No |
| | Continuous age | -.3220** | .0765 | -.4727 | -.1713 | No |
| | Cognitive age | -.2408** | .0682 | -.3752 | -.1064 | No |
| H1b | n/a | .1205** | .0591 | .0040 | .2370 | No |
| H1c | Age group | -.0291* | .0181 | -.0697 | -.0009 | No |
| | Continuous age | -.0408* | .0213 | -.0864 | -.0048 | No |
| | Cognitive age | -.0291* | .0176 | -.0689 | -.0010 | No |

[a]Standardized coefficients, H1a and H1b = direct effects, H1c = indirect effect; *p < 0.05, **p < 0.001.
[b]SE = Standard Error, [c]LLCI = Lower Limit Confidence Interval, [d]ULCI = Upper Limit Confidence Interval

**Table 6. Findings for Research Objectives 2 and 3 across Different Measures of Age**

| Hypothesis | Measure of Age | Index of Moderated Mediation[a] | SE[b] | LLCI[c] | ULCI[d] | Zero Included? | Model Effect Size | Model F-Statistic[e] |
|---|---|---|---|---|---|---|---|---|
| H2a (IT experience) | Age group | .0745* | .0308 | .0232 | .1446 | No | 26% | 10.76* |
| | Continuous age | .0935* | .0339 | .0370 | .1697 | No | 27% | 10.98* |
| | Cognitive age | .0710* | .0276 | .0241 | .1321 | No | 27% | 11.00* |
| H2b (IT self-efficacy) | Age group | .0404* | .0234 | .0051 | .0965 | No | 24% | 9.50* |
| | Continuous age | .0531* | .0261 | .0111 | .1122 | No | 25% | 9.95* |
| | Cognitive age | .0407* | .0205 | .0071 | .0885 | No | 25% | 9.88* |
| H3a (IT overload) | Age group | -.0296* | .0173 | -.0689 | -.0009 | No | 24% | 9.67* |
| | Continuous age | -.0372* | .0207 | -.0808 | -.0010 | No | 24% | 9.72* |
| | Cognitive age | -.0296* | .0168 | -.0663 | -.0012 | No | 24% | 9.68* |
| H3b (Effort cost of IT use) | Age group | -.0309* | .0167 | -.0681 | -.0035 | No | 24% | 9.43* |
| | Continuous age | -.0360* | .0194 | -.0792 | -.0029 | No | 25% | 9.96* |
| | Cognitive age | -.0329* | .0163 | -.0684 | -.0062 | No | 25% | 9.97* |

[a]Standardized; *p < 0.05.
[b]SE = Standard Error, [c]LLCI = Lower Limit Confidence Interval, [d]ULCI = Upper Limit Confidence Interval
[e]*p < 0.01.

**Table 7. Conditional Indirect Effects at Different Values of the Mitigators and Aggravators**

| Measure of Age | Level | Indirect Effect[a] | SE[b] | LLCI[c] | ULCI[d] | Zero Included? |
|---|---|---|---|---|---|---|
| **Mitigator: IT Experience** | | | | | | |
| **Measure of Age** | **Level of IT Experience** | **Indirect Effect[a]** | **SE[b]** | **LLCI[c]** | **ULCI[d]** | **Zero Included?** |
| Age group | Low | -.0657* | .0274 | -.1279 | -.0219 | No |
| | Mean | -.0194 | .0172 | -.0583 | .0086 | Yes |
| | High | .0409 | .0283 | -.0069 | .1026 | Yes |
| Continuous age | Low | -.0874* | .0296 | -.1520 | -.0355 | No |
| | Mean | -.0292 | .0207 | -.0745 | .0076 | Yes |
| | High | .0465 | .0342 | -.0126 | .1226 | Yes |
| Cognitive age | Low | -.0650* | .0246 | -.1184 | -.0222 | No |
| | Mean | -.0208 | .0160 | -.0578 | .0054 | Yes |
| | High | .0366 | .0262 | -.0109 | .0923 | Yes |
| **Mitigator: IT Self-Efficacy** | | | | | | |
| **Measure of Age** | **Level of IT Self-Efficacy** | **Indirect Effect** | **SE** | **LLCI** | **ULCI** | **Zero Included?** |
| Age group | Low | -.0515* | .0283 | -.1161 | -.0070 | No |
| | Mean | -.0161 | .0176 | -.0540 | .0170 | Yes |
| | High | .0193 | .0255 | -.0250 | .0774 | Yes |
| Continuous age | Low | -.0705* | .0324 | -.1423 | -.0167 | No |
| | Mean | -.0240 | .0221 | -.0709 | .0166 | Yes |
| | High | .0224 | .0311 | -.0344 | .0908 | Yes |
| Cognitive age | Low | -.0517* | .0261 | -.1111 | -.0104 | No |
| | Mean | -.0161 | .0175 | -.0552 | .0145 | Yes |
| | High | .0195 | .0240 | -.0249 | .0704 | Yes |
| **Aggravator: IT Overload** | | | | | | |
| **Measure of Age** | **Level of IT Overload** | **Indirect Effect** | **SE** | **LLCI** | **ULCI** | **Zero Included?** |
| Age group | Low | -.0062 | .0192 | -.0459 | .0312 | Yes |
| | Mean | -.0308* | .0180 | -.0709 | -.0010 | No |
| | High | -.0580* | .0275 | -.1196 | -.0108 | No |
| Continuous age | Low | -.0124 | .0235 | -.0597 | .0339 | Yes |
| | Mean | -.0432* | .0211 | -.0892 | -.0061 | No |
| | High | -.0774* | .0318 | -.1472 | -.0205 | No |
| Cognitive age | Low | -.0069 | .0185 | -.0466 | .0279 | Yes |
| | Mean | -.0314* | .0176 | -.0695 | -.0020 | No |
| | High | -.0586* | .0269 | -.1179 | -.0123 | No |
| **Aggravator: Effort Cost of IT Use** | | | | | | |
| **Measure of Age** | **Level of Effort Cost of IT Use** | **Indirect Effect** | **SE** | **LLCI** | **ULCI** | **Zero Included?** |
| Age group | Low | .0020 | .0222 | -.0437 | .0474 | Yes |
| | Mean | -.0292* | .0180 | -.0695 | -.0006 | No |
| | High | -.0604* | .0268 | -.1196 | -.0161 | No |
| Continuous age | Low | -.0045 | .0267 | -.0576 | .0508 | Yes |
| | Mean | -.0407* | .0215 | -.0878 | -.0041 | No |
| | High | -.0770* | .0313 | -.1477 | -.0258 | No |
| Cognitive age | Low | .0035 | .0199 | -.0376 | .0449 | Yes |
| | Mean | -.0297* | .0173 | -.0686 | -.0013 | No |
| | High | -.0628* | .0273 | -.1234 | -.0175 | No |

[a]Standardized; *$p < 0.05$.
[b]SE = Standard Error, [c]LLCI = Lower Limit Confidence Interval, [d]ULCI = Upper Limit Confidence Interval

## General Discussion

In the literature on cognitive aging, there is a general consensus that one overall factor—processing speed—mediates performance differences related to age (Park and Festini 2017; Smith 1996). Taking this fundamental finding as its starting point, the present investigation has sought to provide a parsimonious account of age-related differences in IT-enabled task performance.

### Implications for Researchers

The present investigation contributes to the literature on IS use by responding to calls for more research on the effects of age on the outcomes of IS use (Ghasemaghaei et al. 2019; Tams et al. 2014). Although prior research has improved understanding of age-related impacts on these outcomes, it has not developed an in-depth explanation of how and under what conditions age affects them. Using the theory of processing speed, the present investigation offers an improved model for studying the relationship between age and IT-enabled task performance as an outcome of IS use. The investigation identifies the speed of information processing as an underlying influential mechanism and shows that although it does not provide a complete explanation of the effect of age on IT-enabled task performance, it is a key mediating variable (Salthouse 2016; Smith 1996). The investigation also shows that the effect of age on IT-enabled task performance depends on IT experience, IT self-efficacy, IT overload, and the effort cost of IT use, all of which act as boundary conditions (see Figure 5).

The present investigation also contributes to the literature on IT-enabled task performance by answering calls for more empirical work on the impacts of user characteristics on task performance outcomes (DeLone and McLean 1992; Serrano and Karahanna 2016). In particular, it shows that although task performance is more challenging for older users, there are viable ways to control the performance impacts of age.

Moreover, the present investigation contributes back to the reference literature on cognitive aging by making valuable additions to processing speed theory. It demonstrates that the indirect effect of age through processing speed on task performance depends on experience, self-efficacy, overload, and effort cost. Whereas experience has been validated earlier as a moderator of this indirect effect (Salthouse 2000), the other three moderators have not been considered previously.

### Research Implications for Practitioners

According to Robey and Markus (1998), the theory underlying a research project should contain action levers that practitioners can use to manage issues through direct interventions in the real world. In the model presented here, it is the mediating and moderating variables that indicate the action levers. When these variables were examined in informal discussions with experts, four initial action levers for practitioners were identified: (1) IT training, (2) faceted search engines, (3) tag-based interface navigation, and (4) consistent mappings between interface components. To ensure that these four action levers are relevant and that when used together they address task performance issues for older users effectively, their practical relevance and their comprehensiveness were vetted with experienced practitioners, as recommended by Rosemann and Vessey (2008) and by Toffel (2016).

#### Methods

To vet these action levers with practitioners, a two-step approach was used. The first step was to conduct semi-structured interviews with five human resources directors who were recruited for these interviews through university contacts. Each of these HR directors was paid CAN$150 to do an interview. The interviews had the threefold objective of assessing the practical relevance of the four initial action levers, refining them, and making useful additions to them. The second step was to collect survey data from an additional sample of 15 HR directors recruited by Qualtrics using a custom recruitment option. Qualtrics was paid US$240 for each completed response. The survey had the twofold objective of assessing the practical relevance and the comprehensiveness of the final set of action levers.

#### Interview Results

The interview participants confirmed the importance of the dependent and independent variables, and they helped refine the four initial action levers. For example, Participants 1 and 2 said that IT training should be conducted face-to-face instead of online. This recommendation was added to the description of the IT training action lever. Participant 4 provided insight into how tag-based interface navigation, which had been proposed as an important systems design change, could be applied in practice.

To identify other relevant action levers, the interview participants were asked whether other levers should be added to

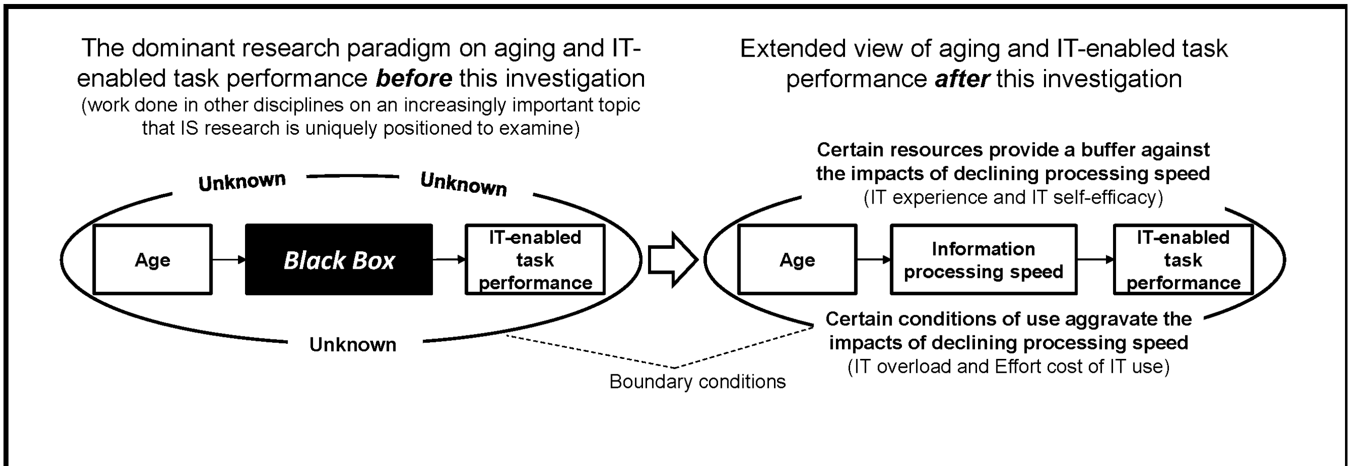



**Figure 5. Main Value Added of This Investigation: Specifying How and Why (Processing Speed, the Mediator) and under What Conditions (the Moderators) Age Impacts IT-Enabled Task Performance**

the initial four. Most of the participants said that no additional levers were necessary. However, Participant 5 made the useful recommendation that a fifth instrument should be added to the practitioner toolbox: pairing older workers with expert users for informal coaching. This recommendation was followed, bringing the number of actions levers to a total of five.

The participants also indicated that the findings are the most relevant in industries where IT evolves quickly and where low voluntary turnover means that workers grow older over the course of their careers at a single firm (Interview Participants 4 and 5). For example, the findings were considered more important by Participant 5, who works in an industry with low voluntary turnover, than they were by Participant 4, who works in an industry with high voluntary turnover.

### Survey Results

The survey respondents confirmed the importance of the dependent and independent variables. Most of them maintained that managing the job performance of employees who use IT for their work is a “high priority” (with a mean of 6 on a 7-point scale). They also indicated that managing an aging workforce is a “high priority” (with a mean of 6 on a 7-point scale). Moreover, they confirmed that the five action levers are comprehensive so that it is not necessary to add to them.

Most of the respondents found each of the five final action levers “very relevant” (with a mean of 6 on a 7-point scale). One exception was the use of faceted search engines (Action Lever 5 in the final validated list). On average, the respondents found this action lever “relevant” (with a mean of 5) as opposed to “very relevant.” A series of one-sample t-tests confirmed that the respondents found each of the five final action levers significantly more relevant than the baseline of “moderately relevant” (with a mean of 4) that is assumed here ($p < .001$).

The respondents also ranked the five final action levers in terms of their importance as research implications for practitioners. Each of the action levers in the final validated list is discussed below as a research implication in accordance with its position in this ranking.

### Final Validated List of Research Implications for Practitioners

*Implication 1 (IT training)*: Managers need to develop resources to help their aging employees compensate for cognitive decline. IT experience and IT self-efficacy are two especially important resources that managers should focus on. User training is a particularly effective strategy in this regard because it can be used to develop both of these resources at the same time (Marakas et al. 1998). The training should be conducted face-to-face instead of online because human interaction is important to older workers. Indeed, they often find it reassuring (Interview Participants 1 and 2). In addition, it should be performed directly on the job to make it easier for older workers to apply the skills that they learn to their job tasks (Interview Participant 2). Moreover, older workers should be retrained in the use of the same software in the event that major system changes occur. For example, when the structure of the ribbon in MS Office changes drastically, they should be retrained (Interview Participant 3). This increases the likelihood that older users will continue to have high performance levels all the way until retirement.

*Implication 2 (mentorship)*: Interview Participant 5 suggested that mentorship programs pairing older workers with expert users, who can provide system-related advice and on-the-job coaching, would be a useful way to help older workers remain productive IT users. Compared with regular training initiatives or with IT help services at organizations, mentorship offers the advantage of being more informal and friendly, and more focused on the specific needs of individuals. This means that it may make older workers feel more comfortable about seeking advice, especially when they are frustrated by their inability to perform well after system changes.

*Implication 3 (consistent mappings)*: The results of the present investigation also suggest that introducing more consistent mappings between the various interface components would reduce the impact of declines in processing speed. More consistent mappings help reduce the effort cost of IT use so that processing speed becomes less important for task performance. This is because they allow users to interact with a system on the basis of pattern recognition, which is facilitated by consistency (Czaja and Sharit 1998). By contrast, if users—especially older ones—are required to learn exceptions, this increases their cognitive burden and slower processing speed becomes more problematic. For example, at a large restaurant chain the food labels used in the computerized menu are often inconsistent with those used in the recipes, and this hampers performance (Interview Participant 4).

*Implication 4 (navigation type)*: Older workers would also benefit from interfaces that use tags instead of spatial metaphors such as folders. Spatial metaphors generate an additional cognitive burden for older users because spatial abilities decline with age, aggravating the task performance problem for older users. For example, the large restaurant chain mentioned above has transformed the way orders are taken by giving iPads to its waitstaff, but the food items that customers order are often hidden in complex folder hierarchies such as Menu/Dinner/Appetizer/Finger Food. Particularly for older employees of the restaurant chain, navigating these complex hierarchies impedes performance (Interview Participant 4). By contrast, a tag-based interface would take full advantage of the greater vocabulary of older workers (Pak et al. 2009), who are often more familiar with the keywords used during the performance of their job tasks (Interview Participant 4).

*Implication 5 (faceted search engines)*: The results of the present investigation also indicate that introducing faceted search interfaces would be a useful change to systems design. Popular search engines like Google Search provide users with a list of results that they have to read sequentially in order to judge the relevance of each one. When a large number of results are obtained, this can be a tedious process, especially for older users. A faceted search interface groups results into a few broad categories that it generates dynamically from page metadata (Castellanos et al. 2020). Users can choose one of these categories and then search for more specific results within it. This approach greatly reduces the amount of information processing required for information search tasks, making slower processing speed less problematic. However, this implication mainly applies to organizations such as accounting firms and law firms where employees have to perform knowledge work (Interview Participant 4).

Although the effectiveness of these action levers was not directly tested—which means that it constitutes an avenue for future research—there was a consensus among respondents that these levers could significantly improve the task performance of older users by reducing the importance of information processing speed for work tasks. As guidelines these levers were seen as "extremely useful" (Survey Respondent 3) because they highlight ways of making older workers into full-fledged members of the team who have useful knowledge and skills to help accomplish essential work tasks.

## Limitations

Since IT experience and IT self-efficacy are not completely independent (Compeau and Higgins 1995), investigating them together in the same model may cause multicollinearity. Moreover, the issue of multicollinearity may also arise for IT overload and the effort cost of IT use. However, it is important to note that the effect of each moderator was tested separately to address this issue. Conversely, the approach used in the present investigation may have masked spurious effects because the results do not show whether the moderating impact of IT self-efficacy was confounded by that of IT experience, or vice versa. This dilemma occurs because the moderators selected for the model are likely to be related to each other in the real world. These moderators were selected because one of the main objectives of the investigation was to provide more detailed guidelines to practitioners (McGrath 1981). Investigating both IT experience and IT self-efficacy makes it easier to determine whether ability and effort can moderate the effect that age has on IT-enabled task performance independently of each other. This issue is important to practitioners because in IT-based work, ability and effort do not necessarily have the same relevance. In IT-based work where ability is more important than effort, IT self-efficacy is less relevant to performance than IT experience, but in IT-based work where performance is primarily a function of effort, IT self-efficacy is more relevant to performance than IT experience (Marakas et al. 1998). Therefore, if only one of these two moderators had been examined, the guidelines proposed to practitioners would have been more limited in scope.

In addition, common method variance could threaten the validity of the results. PROCESS relies on ordinary least squares regression, and one weakness of this type of analysis is its sensitivity to bias in the estimation of the effects of random measurement errors (Hayes et al. 2017). However, since relevant procedural remedies were incorporated in the research design, method bias was alleviated. This conclusion is consistent with the observation of numerous interaction effects in the research because method variance attenuates these effects and makes them more difficult to detect (Conway and Lance 2010). Moreover, one of the measures of age used in the research was objective (chronological age) rather than perceived (cognitive age), and this reduces the likelihood of method variance even more. Finally, it is important to note that consistent results were obtained using three different measures for age, a clear indication that the findings are not measurement specific.

## Future Research

Following Bacharach (1989) and other theorists who maintain that the primary goal of a theory is to answer the questions how, why, and when (i.e., under what conditions) a phenomenon occurs, the present investigation has examined the structure of the relation between age and IT-enabled task performance using the concepts of mediation and moderation. To extend the results of the present investigation, researchers should follow two lines of inquiry:

*The development of a taxonomy of the cognitive aging mechanisms that mediate impacts related to age*: Consistent with past research indicating that

> most of the individual differences in performance are attributable to how quickly one can carry out the relevant operations rather than to variations in the amount of knowledge or in other cognitive abilities (Salthouse 1996, p. 407),

the present investigation has focused on information processing speed as a mediator. Yet it is possible that there are other age-related factors that influence performance. Although they only consider task performance indirectly, the theory of inhibitory deficits and the theory of limited resources may be able to enhance the predictive power of the model developed in the present investigation (Salthouse 1996; Smith 1996). According to the theory of inhibitory deficits, older persons have greater difficulty ignoring interruptions than younger persons, so that interruptions can disrupt their task-related processing more easily (Hasher and Zacks 1988). Given that interruptions constantly occur in IT-based work (Ayyagari et al. 2011), future research could attempt to determine whether inhibitory deficits mediate the relation between age and IT-enabled task performance.

As for the theory of limited resources, it is mostly concerned with the allocation of attentional resources (Craik and Byrd 1982). Its basic assumption is that deeper encoding processes require more attentional resources and that performing encoding under divided attention conditions is particularly difficult. According to the theory, encoding processes are less efficient in older persons because the latter have greater difficulty with divided attention and this reduces their working memory capacity. Future research could attempt to determine whether working memory capacity mediates the relation between age and IT-enabled task performance.

Nevertheless, with such strong evidence that processing speed is the primary factor responsible for the impact of age on IT-enabled task performance, researchers are very unlikely to find that inhibitory deficits and working memory capacity are more than secondary factors. Processing speed has been consistently used to predict the most variance in measures of cognitive performance, and it has been shown to mediate most working memory effects (Smith 1996). Moreover, its importance is not restricted to specific use contexts such as those in which workers have to manage frequent interruptions. That being said, the development of a complete taxonomy of the cognitive mechanisms that mediate impacts related to age requires the careful investigation of secondary factors.

*The development of context-specific versions of the model that focus on particular technologies*: The present investigation has developed an abstract model of age and IT-enabled task performance that is independent of specific technologies. Notwithstanding the validity of proceeding in this way from a theoretical standpoint, there is no doubt that abstract theory can seem vague and insubstantial from the perspective of practitioners (Gill and Bhattacherjee 2009). In addition, it may appear to provide fewer insights to researchers interested in more situated action (Mingers et al. 2013). On the other hand, abstract theory has two advantages. First, a theoretical model such as the one presented here should remain meaningful even as technology changes. Second, IS scholars can derive context-specific versions of such a model that relate to particular technologies. In this sense, the theoretical model presented here has the potential to foster a cumulative research tradition focusing on issues related to age and IT-enabled task performance.

To adapt this model for the study of specific technologies, IS researchers could follow the approach developed by Truex et al. (2006). For example, decision support systems (DSS) researchers interested in examining how age affects decision performance could develop a DSS-specific version of the model. In addition to assessing the fit between the model and the focal DSS phenomenon, they would need to show how using the model could contribute to cumulative theory in DSS research. Moreover, they would have to adapt the generalized constructs to the specific context of DSS by developing precise definitions and measures for DSS experience, DSS self-efficacy, DSS overload, and the effort cost of DSS use. To this end, they could adapt the Excel-related scales that were used in Study 3 to the specific context of DSS, or they could use NeuroIS approaches and methods such as EEG and heart rate variability. These approaches and methods could be used to complement DSS-specific survey measures in order to explain additional variance in decision performance (Dimoka et al. 2012; Müller-Putz et al. 2015; Riedl and Léger 2016).

## Conclusion

The present investigation has focused on information processing speed and its interactions with IT-related individual differences as the explanation for age-related variations in IT-enabled task performance. It is hoped that the investigation will lead to more work in this area to help older users realize their full organizational potential. At the same time, it is essential to emphasize that the findings hold for older users in general, not for all older users. Most importantly, they should not be interpreted as encouraging any kind of discrimination against older users.

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## *About the Author*

**Stefan Tams** holds the Professorship in Technology and Aging at HEC Montréal, Canada, where he is an associate professor of information systems. His current research interests focus on the roles of age and stress in IT use. His work has appeared in several scientific journals, including *MIS Quarterly*, *Journal of the Association for Information Systems*, *Journal of Strategic Information Systems*, *International Journal of Electronic Commerce*, and *European Journal of Work and Organizational Psychology*, among others.

# Appendix A

## Measurement Items for Principal Constructs

**Table A1. Study 1 Scales**

| Construct | Scale | |
|---|---|---|
| | **Item #** | **Item** |
| **IT experience** (Harrison and Rainer 1992; Taylor and Todd 1995; Venkatesh et al. 2003) | Exp1 | I have experience in using computers. |
| | Exp2 | I have used computers a lot. |
| | Exp3 | Please indicate how many years of hands-on computer experience you have. |
| **IT self-efficacy** (Compeau and Higgins 1995; Marakas et al. 1998) | I could complete a job using the computer … | |
| | SE1 | … if there was no one around to tell me what to do as I go. |
| | SE2 | … if I had never used a package like it before. |
| | SE3 | … if I had only the software manuals for reference |
| | SE4 | … if I had seen someone else using it before trying it myself. |
| | SE5 | … if I could call someone for help if I got stuck. |
| | SE6 | … if someone else had helped me get started. |
| | SE7 | … if I had a lot of time to complete the job for which the software was provided. |
| | SE8 | … if I had just the built-in help facility for assistance. |
| | SE9 | … if someone showed me how to do it first. |
| | SE10 | … if I had used similar packages before this one to do the same job. |

**Table A2. Study 2 Scales**

| Construct | Scale: Item # | Scale: Item |
|---|---|---|
| **Age**<br>(Barak and Schiffman 1981; Ghasemaghaei et al. 2019; Morris et al. 2005; Salthouse et al. 2004; Tams et al. 2014) | **Age group (Chronological age measured through a grouping variable)**: | |
| | ( ) 21-24 ( ) 25-34 ( ) 35-54 ( ) 55-60 ( ) 61-65 ( ) 66+ | |
| | **Continuous age (Chronological age measured as a continuous variable)**: | |
| | Please indicate your precise age in number of years<br>(Data Validation: Must be numeric, Whole numbers only, Positive numbers only) | |
| | **Cognitive Age (Perceived/subjective age)**: | |
| | CA1 | I feel as if I am in my … 20's, 30's, 40's, 50's, 60's, 70's, 80's, or 90's |
| | CA2 | I look as if I am in my … |
| | CA3 | My health is as though I am in my … |
| | CA4 | My interests are mostly those of a person in his/her … |
| | CA5 | I do most things as if I am in my … |
| **Processing speed self-efficacy**<br>(Bandura 2006; Hinz et al. 2016; Salthouse 1996) | IPS1 | I have the ability to handle even large amounts of information efficiently. |
| | IPS2 | I have the ability to deal efficiently with even vast amounts of information. |
| | IPS3 | I have the ability to process even vast amounts of information efficiently. |
| **Task performance**<br>(Tsai et al. 2007) | Over the past month … | |
| | Perf1 | … I have completed all of my assigned tasks very effectively. |
| | Perf2 | … I have performed my work very well. |
| | Perf3 | … I have fulfilled my work responsibilities very effectively. |
| **IT experience**<br>(Harrison and Rainer 1992) | Exp1 | I have worked with this IT for a long time. |
| | Exp2 | I have a great deal of experience with this IT. |
| | Exp3 | I have been exposed to this IT for a long time. |
| **IT self-efficacy**<br>(Bandura 2006; Compeau and Higgins 1995; Marakas et al. 1998) | SE1 | I have the ability to be very good at using this IT. |
| | SE2 | I have the ability to excel at using this IT. |
| | SE3 | I have the ability to perform very well when using this IT. |
| **IT overload**<br>(Ahuja and Thatcher 2005; Choi and Lim 2016) | Overload1 | I feel overloaded due to this IT. |
| | Overload2 | I feel pressured due to this IT. |
| | Overload3 | I am forced by this IT to do more work than I can handle. |
| **Effort cost of IT use**<br>(Bulgurcu et al. 2010) | Cost1 | Using this IT is cognitively demanding. |
| | Cost2 | Using this IT requires a lot of mental effort. |
| | Cost3 | I have to be very concentrated when I use this IT. |

| **Table A3. Study 3 Scales that Differ from Those Used in Study 2** | | |
|---|---|---|
| | **Scale** | |
| **Construct** | **Item #** | **Item** |
| **IT experience** (Harrison and Rainer 1992) | Exp1 | I have worked with Excel for a long time. |
| | Exp2 | I have a great deal of experience with Excel. |
| | Exp3 | I have been exposed to Excel for a long time. |
| **IT self-efficacy** (Bandura 2006; Compeau and Higgins 1995; Marakas et al. 1998) | SE1 | I have the ability to be very good at using Excel. |
| | SE2 | I have the ability to excel at using Excel. |
| | SE3 | I have the ability to perform very well when using Excel. |
| **IT overload** (Ahuja and Thatcher 2005; Choi and Lim 2016) | Overload1 | I feel overloaded due to Excel. |
| | Overload2 | I feel pressured due to Excel. |
| | Overload3 | I am forced by Excel to do more work than I can handle. |
| **Effort cost of IT use** (Bulgurcu et al. 2010) | Cost1 | Using Excel is cognitively demanding. |
| | Cost2 | Using Excel requires a lot of mental effort. |
| | Cost3 | I have to be very concentrated when I use Excel. |

In Study 2, *this IT* referred to the IT that respondents used the most frequently for work-related purposes. In Studies 1, 2 and 3, all the measures were standardized using Zscores to account for the different distributions associated with the different scale anchors that were used (Cohen et al. 2003).

# Appendix B

## Psychometric Testing for Study 2

Evaluating the quality of the survey instrument involved estimating the reliability as well as the convergent and discriminant validity of the construct measures. The statistics were obtained through a factor analysis using Maximum Likelihood Extraction and Promax rotation,[3] and SPSS® 25.0 was used to calculate them. Seven factors were specified for extraction because the items for seven different constructs had to be analyzed. Internal consistency (reliability) is represented by Cronbach's coefficient alpha. Satisfactory values exceed 0.70 (Nunnally 1978). All alphas exceeded this threshold (see Table B1).

**Table B1. Quality Criteria and Descriptive Statistics for Construct Measures**

| Construct | Number of Items | AVE[a] | Alpha | Mean | SD |
|---|---|---|---|---|---|
| Cognitive age | 5 | 0.67 | 0.91 | 2.61 | 1.14 |
| Processing speed | 3 | 0.87 | 0.95 | 4.98 | 1.34 |
| Task performance | 3 | 0.79 | 0.92 | 6.21 | 0.99 |
| IT experience | 3 | 0.80 | 0.93 | 5.57 | 1.46 |
| IT self-efficacy | 3 | 0.82 | 0.94 | 5.64 | 1.14 |
| IT overload | 3 | 0.78 | 0.91 | 2.84 | 1.52 |
| Effort cost of IT use | 3 | 0.69 | 0.87 | 4.28 | 1.49 |

[a]Average Variance Extracted

The convergent validity of a construct is considered satisfactory when its AVE is at least 0.50, and the discriminant validity of a construct is considered adequate when the square root of the AVE is larger than the inter-construct correlations (Fornell and Larcker 1981). All AVE values exceeded 0.50 (see Table B1), and the square root of each construct's AVE was higher than the correlations between that construct and all others (see Table B2). These results indicate good construct validity.

**Table B2. Inter-construct Correlations***

| Construct | Cognitive Age | Processing Speed | Task Performance | IT Experience | IT Self-Efficacy | IT Overload | Effort Cost of IT Use |
|---|---|---|---|---|---|---|---|
| Cognitive age | **0.821** | | | | | | |
| Processing speed | -0.164 | **0.930** | | | | | |
| Task performance | 0.024 | 0.275 | **0.887** | | | | |
| IT experience | 0.049 | 0.285 | 0.192 | **0.896** | | | |
| IT self-efficacy | -0.043 | 0.436 | 0.296 | 0.609 | **0.908** | | |
| IT overload | 0.072 | -0.086 | -0.222 | -0.178 | -0.312 | **0.882** | |
| Effort cost of IT use | 0.184 | -0.003 | -0.033 | 0.065 | -0.034 | 0.437 | **0.831** |

*Diagonal elements in bold are square roots of the Average Variance Extracted

Construct validity receives additional confirmation when the items load above 0.50 on their associated constructs and when the loadings within constructs are higher than those across constructs (Fornell and Larcker 1981). Table B3 presents the loadings for this study. Visual inspection of these loadings and cross-loadings further confirms that all constructs had good convergent and discriminant validity.

[3]In contrast to orthogonal rotation methods such as Varimax, oblique rotation methods like Promax account for inter-correlations between the factors (Tabachnick and Fidell 2007). Since the present investigation tests a research model in which the constructs are inter-correlated, Promax is used. The near-zero cross-loadings reported in Tables B3 and C3 are an expected outcome of using Promax. Please note that the cross-loadings are higher but acceptable when Varimax is used.

| Table B3. Item Loadings and Cross-Loadings | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Item** | **Cognitive Age (CA)** | **Information Processing Speed (IPS)** | **Task Performance (Perf)** | **IT Experience (Exp)** | **IT Self-Efficacy (SE)** | **IT Overload (Overload)** | **Effort Cost of IT Use (Cost)** |
| **CA1** | 0.855 | 0.010 | 0.008 | 0.032 | -0.023 | 0.021 | -0.002 |
| **CA2** | 0.845 | -0.002 | 0.043 | 0.032 | -0.023 | -0.030 | 0.007 |
| **CA3** | 0.813 | -0.030 | -0.011 | -0.030 | 0.024 | 0.009 | 0.023 |
| **CA4** | 0.748 | 0.019 | -0.010 | -0.026 | 0.023 | 0.016 | -0.010 |
| **CA5** | 0.839 | 0.001 | -0.031 | -0.013 | 0.008 | -0.014 | -0.019 |
| **IPS1** | 0.011 | 0.899 | 0.008 | 0.012 | 0.017 | 0.003 | -0.005 |
| **IPS2** | 0.000 | 0.958 | -0.011 | -0.001 | -0.004 | 0.000 | 0.004 |
| **IPS3** | -0.012 | 0.933 | 0.006 | -0.017 | -0.005 | 0.001 | 0.000 |
| **Perf1** | 0.017 | 0.008 | 0.906 | 0.003 | -0.022 | -0.001 | 0.006 |
| **Perf2** | -0.016 | -0.010 | 0.894 | -0.030 | 0.008 | -0.010 | 0.014 |
| **Perf3** | -0.003 | 0.005 | 0.861 | 0.028 | 0.017 | 0.010 | -0.018 |
| **Exp1** | 0.026 | -0.002 | 0.010 | 0.948 | -0.070 | -0.002 | 0.002 |
| **Exp2** | -0.021 | 0.022 | 0.000 | 0.875 | 0.057 | -0.004 | -0.005 |
| **Exp3** | -0.013 | -0.025 | -0.011 | 0.864 | 0.059 | 0.008 | 0.001 |
| **SE1** | -0.005 | 0.019 | -0.001 | 0.077 | 0.838 | -0.001 | 0.007 |
| **SE2** | 0.017 | -0.016 | -0.006 | -0.018 | 0.977 | 0.003 | 0.008 |
| **SE3** | -0.004 | 0.013 | 0.010 | 0.007 | 0.902 | -0.010 | -0.014 |
| **Overload1** | 0.009 | -0.004 | 0.003 | -0.038 | 0.033 | 0.864 | 0.039 |
| **Overload2** | -0.019 | -0.033 | 0.015 | 0.006 | 0.015 | 0.971 | -0.030 |
| **Overload3** | 0.014 | 0.044 | -0.021 | 0.034 | -0.057 | 0.803 | 0.008 |
| **Cost1** | 0.034 | 0.019 | -0.008 | 0.016 | 0.009 | 0.025 | 0.752 |
| **Cost2** | -0.007 | 0.003 | -0.019 | 0.019 | -0.008 | -0.010 | 0.935 |
| **Cost3** | -0.026 | -0.022 | 0.030 | -0.035 | 0.001 | -0.001 | 0.795 |

# Appendix C

## Psychometric Testing for Study 3

To evaluate the quality of the survey instrument, the same approach was used as in Study 2. All alphas exceeded the recommended threshold of 0.70 (see Table C1).

**Table C1. Quality Criteria and Descriptive Statistics for Construct Measures**

| Construct | Number of Items | AVE[a] | Alpha | Mean | SD |
|---|---|---|---|---|---|
| Cognitive age | 5 | 0.72 | 0.93 | 2.69 | 1.04 |
| Processing speed | 3 | 0.89 | 0.96 | 4.93 | 1.22 |
| Task performance | 3 | 0.77 | 0.91 | 6.23 | 0.85 |
| IT experience | 3 | 0.72 | 0.89 | 6.57 | 0.62 |
| IT self-efficacy | 3 | 0.86 | 0.95 | 6.06 | 0.86 |
| IT overload | 3 | 0.85 | 0.94 | 1.98 | 1.09 |
| Effort cost of IT use | 3 | 0.72 | 0.88 | 4.37 | 1.33 |

[a]Average Variance Extracted

All AVE values exceeded 0.50 (see Table C1), and the square root of each construct's AVE was higher than the correlations between that construct and all others (see Table C2).

**Table C2. Inter-construct Correlations***

| Construct | Cognitive Age | Processing Speed | Task Performance | IT Experience | IT Self-Efficacy | IT Overload | Effort Cost of IT Use |
|---|---|---|---|---|---|---|---|
| Cognitive age | **0.850** | | | | | | |
| Processing speed | -0.224 | **0.944** | | | | | |
| Task performance | 0.037 | 0.223 | **0.878** | | | | |
| IT experience | 0.099 | 0.265 | 0.261 | **0.848** | | | |
| IT self-efficacy | -0.164 | 0.442 | 0.257 | 0.494 | **0.928** | | |
| IT overload | -0.089 | -0.105 | -0.218 | -0.187 | -0.174 | **0.921** | |
| Effort cost of IT use | 0.057 | 0.045 | 0.086 | 0.002 | 0.011 | 0.369 | **0.846** |

*Diagonal elements in bold are square roots of the Average Variance Extracted

Table C3 presents the loadings for this study. Visual inspection of these loadings and cross-loadings further confirms that all constructs had good convergent and discriminant validity.

**Table C3. Item Loadings and Cross-Loadings**

| Item | Cognitive Age (CA) | Information Processing Speed (IPS) | Task Performance (Perf) | IT Experience (Exp) | IT Self-Efficacy (SE) | IT Overload (Overload) | Effort Cost of IT Use (Cost) |
|---|---|---|---|---|---|---|---|
| CA1 | 0.843 | 0.016 | -0.007 | 0.024 | -0.021 | 0.002 | -0.004 |
| CA2 | 0.807 | -0.067 | -0.051 | 0.118 | -0.036 | -0.013 | 0.065 |
| CA3 | 0.854 | 0.024 | -0.059 | -0.029 | 0.026 | -0.033 | 0.005 |
| CA4 | 0.827 | 0.092 | 0.017 | -0.005 | -0.046 | 0.037 | -0.029 |
| CA5 | 0.914 | -0.062 | 0.082 | -0.092 | 0.056 | 0.016 | -0.024 |
| IPS1 | 0.030 | 0.933 | -0.010 | -0.002 | -0.002 | 0.006 | -0.018 |
| IPS2 | 0.013 | 0.968 | 0.018 | -0.024 | 0.014 | -0.007 | 0.042 |
| IPS3 | -0.032 | 0.931 | 0.001 | 0.027 | -0.019 | 0.003 | -0.016 |
| Perf1 | 0.024 | 0.059 | 0.865 | -0.019 | 0.030 | 0.037 | -0.041 |
| Perf2 | 0.011 | 0.001 | 0.916 | -0.003 | 0.006 | -0.049 | 0.052 |
| Perf3 | -0.050 | -0.048 | 0.852 | 0.043 | -0.035 | 0.004 | -0.008 |
| Exp1 | 0.019 | -0.038 | 0.055 | 0.889 | -0.005 | 0.048 | -0.021 |
| Exp2 | -0.013 | 0.090 | -0.055 | 0.755 | 0.140 | -0.025 | -0.007 |
| Exp3 | -0.002 | -0.024 | 0.009 | 0.893 | -0.070 | -0.021 | 0.018 |
| SE1 | -0.054 | 0.058 | -0.032 | -0.028 | 0.898 | 0.014 | -0.005 |
| SE2 | 0.019 | -0.038 | 0.020 | 0.023 | 0.948 | 0.015 | 0.018 |
| SE3 | 0.014 | -0.023 | 0.010 | 0.016 | 0.937 | -0.024 | 0.000 |
| Overload1 | -0.025 | -0.014 | -0.009 | 0.029 | -0.042 | 0.933 | 0.027 |
| Overload2 | -0.022 | -0.008 | 0.015 | -0.032 | 0.026 | 0.967 | 0.016 |
| Overload3 | 0.053 | 0.023 | -0.012 | 0.010 | 0.019 | 0.859 | -0.031 |
| Cost1 | 0.071 | 0.002 | 0.017 | 0.009 | 0.073 | -0.012 | 0.789 |
| Cost2 | -0.039 | 0.007 | -0.005 | -0.004 | -0.060 | -0.017 | 0.927 |
| Cost3 | -0.022 | 0.000 | -0.008 | -0.013 | 0.004 | 0.040 | 0.816 |