Human Error in Information Security: Exploring the Role of Interruptions and Multitasking in Action Slips

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Abstract. Breaches of cyber-security often arise unintentionally from the human user such as when switching between subtasks or external interruptions, disrupting the flow of work and leading to action slips in the execution of a task procedure [1, 2]. There has been little research into the perceived effects of task interruption and switching on computer-based tasks when such action slips can potentially compromise information security. Semi-structured interviews were conducted on nine university employees who regularly handle sensitive information, designed to identify which features of information-sensitive computer-based tasks are the most susceptible to disruption. Potential sources of human error in were identified with task interruption judged to be more likely than multitasking as a source of error. The interview findings will serve as the basis of experimental investigations into how disruptions in the flow of a task procedure can cause action slips that may compromise the handling of sensitive data. Well-informed empirical work in the area of Cyberpsychology is critical to understanding the processes involved, and to guiding potential solutions rooted in human-machine interface design and human computer interaction.

Keywords: Cyber security · Information security · Human error · Interruption · Cyberpsychology

1 Introduction

Interventions to improve information security have largely involved technological safeguards (e.g., improved firewalls and anti-virus software), but there is also increasing acknowledgement of the role of the human user in interacting with and maintaining the effectiveness of these defense mechanisms [3]. Even when adequate training has been provided, omissions, inaccuracies, and other mistakes can arise from temporary lapses of attention [1, 2]. Such slips can contribute to breaches in information security. Although information-sensitive settings have received little scrutiny, it seems likely that such errors are more common in the presence of workplace stressors

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such as workload, interruption/distraction or fatigue [4, 5] sometimes arising indirectly as a result of poor work organization or low staffing levels [6]. This study is concerned with understanding how the particular requirements of handling sensitive data, both in terms of the types of task undertaken and the stressors that are at play, contribute to errors and delays.

The suggestion that settings that constitute high attentional load—high cognitive demand, multiple overlapping tasks, unexpected task interruptions—could leave the worker vulnerable to action slips or time costs, is also supported by the cognitive psychology literature. In laboratory studies, performance deficits (e.g., increased reaction time and/or error rates) are reliably documented when alternating between two tasks relative to performing the same two tasks individually [7]. Such effects are typically attributed to an attention bottleneck [8]. The execution of one task is significantly slowed by the temporal proximity of another because the cognitive system is incapable of planning and responding to two tasks at the same time. It seems reasonable to expect that in settings involving information security such loads may be high due to multitasking and that these will lead to effects on efficiency and accuracy that will have material consequences.

The effects of switching between tasks can be distinguished from those involving task interruption. This involves the temporary suspension and subsequent resumption of a primary task in order to attend to an unexpected secondary activity. Interruptions are commonplace in the modern work environment which is attended by a plethora of emails, phone calls, text messages and face-to-face interruptions that are likely to break up the flow of an ongoing task. This can result in a time cost in resuming the primary task [9–11], and/or forgetting to execute an action after interruption [2, 12–14]. The Memory for Goals model of interruption [15] interprets these effects in terms of activation and decay, such that a goal will diminish in activation when suspended by an interruption, either to the extent that it is forgotten, or that a time cost is incurred to reactivate the suspended goal. Even in cases when a user attempts to defer an interruption to a more convenient time, the very action of momentarily engaging with the interrupter for a few seconds (e.g., by telling a colleague that they will be able to help at a later point), can be enough to derail their train of thought, causing procedural errors [1] and/or a time cost at resumption [9, 10].

There has been little experimental work examining the effects of multitasking and interruption with a focus on information security. One study demonstrated how users are more prone to cyber vulnerabilities (e.g., less accurate in sorting between legitimate and phishing emails) when multitasking (completing an online survey simultaneously on the other half of the computer screen [16]). Another study required participants to make a security judgment about which applications to install on a phone, and found that malicious applications were more likely downloaded when multitasking [17]. In addition to a tendency to be less cautious with potentially malevolent cyber material, it is conceivable that multitasking and interruptions could contribute to another risky cyber behavior: accidental disclosure of secure information. Many jobs now involve information that has limitations on circulation (within and/or outside the organization), whether it is company material under embargo, internal memos or emails, or the demographic, financial, or occupational health details of employees. Privacy breaches are always a possibility, for example, in information omission, commission, or the

mis-timing of disclosure, such as violating an embargo. Given what we know about attention and human information processing, it is likely that action slips with material security consequences are more likely when employees are multitasking and when interruptions occur [2, 12].

The literature indicates that human error is by far the weakest link in cyber security, whether due to a lack of knowledge about secure policies and procedures ('mistakes') or due to unintentional errors in the execution of routine procedures ('action slips'). Prevailing theories of attention predict that suspending a task at crucial moments when goals and plans must be coordinated for impending action will necessarily result in slower task performance and more frequent errors. While increasing awareness and understanding of potential vulnerabilities in the cyber domain might improve workflows, investigating the types of action slips that can lead to a breach in security and ways in which they can be minimized is imperative. We therefore interviewed employees who regularly work with sensitive information to gain insight into the work-tasks they usually perform, and their view of how multitasking and interruptions affect their performance at work. The knowledge gained from these interviews can in due course be applied to the design of novel laboratory studies aimed at quantifying the costs of workflow disruption in terms of time and accuracy.

The aims of the study were to 1) identify information-sensitive computer-based tasks that are the most susceptible to disruption; 2) understand the characteristics of task interruption and/or multitasking in the context of information-sensitive computer-based tasks, and 3) from the perspective of individuals working with sensitive information, understand how task interruption and/or multitasking may affect performance.

2 Method

Nine employees of a large UK university were each interviewed separately. To be included in this sample, participants needed to handle sensitive information when performing computer-based tasks as part of their work role (e.g., Professional Services staff working in areas such as IT, finance, research administration and/or governance, human resources). They were given £10 for their participation and completed the study before or after work or during unpaid breaks. Interviews were semi-structured, with two interviewers present, and typically lasted about 45 min. Transcribed interviews were subjected to a thematic analysis, with the qualitative data coded following the systematic process highlighted by [18].

3 Results

3.1 Computer-Based Primary Task

The first theme to emerge was that of the everyday computer-based tasks in which that participants engaged, with subthemes regarding the type and nature of the task. In all cases, the most common task that involved the handling of sensitive data was either entering information into a database, or responding to emails that contained sensitive

information. The type of sensitive information dealt with commonly involved either health/well-being (e.g., occupational health reports, counselling referrals), financial (e.g., student hardship, staff payroll), or demographic details of staff/students (e.g., date of birth, addresses, passport number). Participants described in depth the nature of the tasks carried out, detailing the precise steps to be performed (e.g., entering information, comparing, verifying, saving, attaching, sending, advising), and in many cases it emerged that there were clear procedural steps that had to be undertaken to complete the task. Regarding the cognitive processes engaged in completing the task, all nine participants mentioned memory (e.g., a mental list of checks to be done, or remembering details from one database to be able to cross reference with another), and five specifically mentioned procedural memory (e.g., having to consciously remember the order of steps in a particular procedure). Also frequently-mentioned was attention (e.g., vigilance for error, or attention switching between different sources of information), judgment, problem solving, and decision making.

The second theme concerned the factors that could hinder performance when completing the computer-based task. Seven participants talked about task interruption as an environmental constraint, with face-to-face interruptions being the main source (most often colleagues, but sometimes other walk-in enquiries). Participants described how interruptions can be completely unpredictable in terms of their occurrence (e.g., happening when in the middle of something), and their duration (e.g., distraction could be momentary, or could take time away from the main task for a long period). Three participants mentioned background sound as a constraint (particularly in an open-plan office), and five participants said that high workload and the associated time pressure could impact their performance.

The third theme evolved around the types of errors that could arise during the handling of sensitive information. Data-input errors were most likely to occur, such as typographical errors (e.g., a wrong number in financial details), misspelling of names, error in date-of-birth format (British vs American), or inputting information into the wrong table/column. Some participants mentioned that procedural omissions could be made, for example, after arranging a student appointment, forgetting to log that information into the database; forgetting to file a paper copy; or forgetting to add an email attachment. Errors could also take the form of an unintended distribution of sensitive information. For example, one participant reported inputting information into templates, but sometimes not removing all the previous student's details so that their details are unintentionally sent out to others. Another participant described how there are different levels of disclosure for different people (e.g., counsellors, academic staff, students' parents) and how distribution could be directed incorrectly and without adequate consent for that sharing. Three participants mentioned email-based errors that could result in revealing sensitive information to unauthorized recipients (e.g., forgetting to remove information in the email trace when forwarding, or sending to an unintended recipient with a similar email address).

3.2 Understanding Characteristics and Effects of Task Interruptions

Participants were next asked specifically whether their performance on the computer-based task was ever affected by the need to multitask or was on occasion interrupted.

Although participants did report multitasking (e.g., switching between different sources of information to complete a task), all reported that their performance was more negatively affected by interruption. Interruptions were perceived as being unpredictable, often out of their control, frequently associated with their own sense of urgency, and, as one participant put it "takes me out of the loop of what I was doing". In contrast, multitasking was perceived as self-initiated and necessary for task completion. Questions then followed that aimed to understand in greater depth the characteristics and effects of interruptions when performing an information-sensitive computer-based task.

The majority of participants reported that the initiating source of an interruption was most often auditory (six cited face-to-face interruptions as most likely, and two mentioned phone calls). Only one participant rated email interruption as being most distracting. When elaborating on interruption source, participants reported that by its nature face-to-face interruption was almost impossible to ignore and needed immediate acknowledgement so as not to appear rude (they were perceived as being urgent). Even if this interaction was only momentary (e.g., a quick query, or to schedule a more convenient time to engage properly), the temporary stopping of their prior task led them to lose track of their place in the task or lose the thread of what they had been doing. Phone interruptions were viewed as needing to take priority over any computer-based event, although one participant noted that their response to the telephone was not as immediate as that to a colleague interrupting in person. In contrast, emails could more easily be deferred so that ongoing tasks were not disrupted, and some participants reported turning off notifications and only checking emails periodically. While the initiating source of interruptions were auditory, the majority of participants (8 out of 9) reported that the actual interrupting task needing to be carried out was almost always computer-based (e.g., looking up information on a database).

Participants were asked to rate the frequency of interruptions occurring during a busy and quiet working period on a 5-point scale (1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Quite Often, 5 = Almost Always). Interruptions during busy work periods were judged to occur 'quite often' (mean rating = 4.00, SD = 0.87), but only 'sometimes/rarely' during quieter times (mean = 2.39, SD = 1.11). Using a 5-point scale to attempt to quantify the effects of interruption, it was clear that participants felt that interruptions were sometimes – quite often disruptive to their ongoing task (mean = 3.56, SD = 0.68), and could sometimes have a negative impact (mean = 3.17, SD = 0.70).

Participants were asked to provide an example of when they felt an interruption had contributed to a negative outcome. Various errors occurred after being interrupted such as inputting the wrong details, inputting information into the wrong part of a table, or omitting an item/section of information due to loss of concentration. One participant recounted being distracted while sending an email, and put multiple addresses into 'cc' rather than in the blind field so that individual identities were revealed to others on the list. Another participant had intended to remove 'cc' on an email but was interrupted and forgot to do so when they returned to the email, and subsequently confidentiality was compromised.

In addition to errors, participants described the time costs of interruption. This could comprise the extra time taken retracing previous actions in order to pick up the

thread of what they had been doing, or in terms of unnecessary repetition (e.g., one participant reported duplicating processes unintentionally as they had forgotten they had already been done). If an error has been made in programming for example, it can take time to locate and rectify that error before being able to continue. As a further negative effect, some participants commented that interruptions increased workload and stress especially at busy times.

4 Discussion

4.1 Summary of Findings

The computer-based tasks that the University employees most often performed when handling sensitive data were responding to emails and inputting/retrieving information from databases. These all required a number of task steps and would tend to place demands on memory (particularly procedural memory) and attention (e.g., switching between sources to gather information). Users engaged in both multitasking and task interruptions on a frequent basis, but while multitasking was accepted as 'part of the job', interruptions were regarded as unwelcome and disruptive. The cost of interruption was either in terms of time (e.g., rechecking when resuming the task), or errors, due to not checking when resuming the task (e.g. inputting/typing errors, or failing to execute an intended action, particularly checking procedures). When checks were not made, this could result in sensitive information being logged incorrectly or distributed to an unintended or unauthorized recipient. Face-to-face questions were seen as more urgent and therefore more likely to interrupt the ongoing task than emails that could be more easily deferred. When deferring face-to-face interruptions, participants reported that the flow of their task had been disrupted. The quantitative data analysis demonstrated that interruptions were perceived as being frequent, disruptive, and as having a negative impact on performance.

4.2 Recommendations

While the current interviews provided information regarding the nature, characteristics and effect of interruptions on performance, well-designed empirical work is essential to better understanding the processes involved. Interruptions were frequently mentioned as being disruptive to procedural tasks—characterized by the requirement to complete several steps, sometimes in a particular order—with participants reporting losing track of what they had already done and what they were about to do. As the basis for assessing action slips in the handling of sensitive information, we recommend using a procedural task and particularly one that mimics the inputting of data. Participants frequently mentioned that slips could occur in the sending of emails, and so in our lab we have recently developed a procedural task that is based around this ecologically valid task context.

Auditory-initiated interruptions (face to face or telephone) were viewed as 'more interrupting' than their visually-initiated counterparts (such as emails), due to a sense of perceived urgency and social etiquette in responding to another person. Future research

could assess whether the auditory modality is more attention-grabbing than the visual modality within a laboratory setting. Moreover, it would be useful to further investigate the utility of deferring an interruption. The interviews revealed that interruptions do not need to be long to be perceived as disruptive, although it may be modulated by the overall long-term level of demand.

The information gleaned from these interviews can help form the basis of experimental tasks to investigate how disruptions in the flow of a task procedure can cause action slips that may compromise the handling of sensitive data. Well-informed empirical work is critical to improving understanding of cognitive processes and subsequently to inform interruption handling strategies. Furthermore, such research can contribute to technological solutions rooted in human-machine interface design that will be critical to supporting users within dynamic and multitasking environments, and ultimately to reduce the incidence of unintentional security breaches.

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