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The many faces of information technology interruptions: a taxonomy and preliminary investigation of their performance effects

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Abstract. *Despite the growing importance of information technology (IT) interruptions for individual work, very little is known about their nature and consequences. This paper develops a taxonomy that classifies interruptions based on the relevance and structure of their content, and propositions that relate different interruption types to individual performance. A qualitative approach combining the use of log diaries of professional workers and semi-structured interviews with product development workers provide a preliminary validation of the taxonomy and propositions and allow for the discovery of a continuum of interruption events that fall in-between the extreme types in the taxonomy. The results show that some IT interruptions have positive effects on individual performance, whilst others have negative effects, or both. The taxonomy developed in the paper allows for a better understanding of the nature of different types of IT interruption and their consequences on individual work. By showing that different types of interruptions have different effects, the paper helps to explain and shed light on the inconsistent results of past research.*

Keywords: IT interruptions, taxonomy, individual performance, interviews, log diaries

INTRODUCTION

Whilst information technology (IT) enables continuous connectivity and provides important organisational benefits, it also produces unintended consequences such as triggering work interruptions. IT interruptions are frequent and have important impacts on work. They are estimated to cost managers 10 min of each work hour (O'Conaill & Frohlich, 1995), and they create more than 70 suspensions per day for office workers, with each needing between 1 min (Jackson *et al*., 2003) and 24 min (Hemp, 2009) for primary task resumption.

Despite their importance, IT interruptions rarely appear in information systems research, and our understanding about this phenomenon is limited. Much of the extant literature does not

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explicitly define IT interruptions (or general work interruptions). Studies conceptualising interruptions have drawn heavily on distraction conflict theory (Baron, 1986; Speier *et al*., 2003; Gupta *et al*., 2013a;) that defines interruptions as external, unpredictable events that create attentional conflict between the competing demands of the interruption and primary task. Attentional conflict increases arousal, which improves performance on simple tasks and reduces it on complex tasks. This theoretical lens has improved our understanding of contextual factors that influence performance, such as the interrupter's hierarchical level (Gupta *et al*., 2013a), the interruption's presentation format (Speier *et al*., 1997) and perceived task complexity (Speier *et al*., 2003; Gupta *et al*., 2013a). However, distraction conflict theory distinguishes different interruption contexts but not different types of interruptions based on their actual contents (e.g. what an interruption message is about).[1] Similarly, several taxonomies exist that conceptualise interruptions based on distinguishing attributes (Latorella, 1999; McFarlane, 2002; Brixey *et al*., 2004; Rukab *et al*., 2004), yet these do not take into account the content of the interruption.

Unpacking IT interruption content overcomes a limitation of distraction conflict theory, which considers all interruption as competing with the primary task. Instead, the content of some interruption messages may provide useful and relevant information that helps the receiver in completing his or her primary task (Gupta *et al*., 2013a). Furthermore, distinguishing IT interruptions based on content may better explain the inconsistent findings in the literature, which associate interruptions to both negative (e.g. (Speier *et al*., 1997; McFarlane, 2002; Kapitsa & Blinnikova, 2003;)) and positive (e.g. (Ang *et al*., 1993; Robertson *et al*., 2004)) task performance outcomes.

Hence, there is evidence suggesting that a systematic conceptualization of IT interruptions based on content allows us to distinguish interruption types and better understand their performance effects. This paper addresses the following questions: *What are the different types of IT interruptions*? *How do the different types resemble or differ from each other with respect to their performance consequences*? We conceptualise IT interruptions and develop a taxonomy that classifies IT interruption types according to their content range and the way they direct attention relative to the primary task. Drawing upon the attention allocation perspective from psychology, we develop propositions that link different IT interruption types to performance outcomes. We provide a preliminary test of the taxonomy through empirical work that combines log diaries and in-depth semi-structured interviews.

This research makes three contributions. Firstly, our taxonomy distinguishes different IT interruptions types and serves as a foundation for further research. Secondly, we empirically test the taxonomy and use it to help explain the inconsistent findings in the literature by relating interruption type to variations in performance. Finally, a third contribution is the discovery of hybrid IT interruptions that fall in-between the extreme interruption types and that have unique effects on performance. This extends the traditional focus on IT interruptions in the context of singular, artificially manipulated tasks (e.g. (Cutrell *et al*., 2000; McFarlane, 2002; Adamczyk & Bailey,

[1]Other theories are dominant in interruptions research such as the goal activation model (Altman & Trafton, 2002) and the interruption coordination framework (McFarlane, 2002). However, those theoretical frameworks focus on interruption management rather than on conceptualising interruptions or examining their different contents.

2004;)) to a broader context where individuals are working on real, interdependent tasks nested in larger projects.[2]

TAXONOMY OF IT INTERRUPTIONS

Most literature on IT-based work interruptions did not define interruptions nor consider their content (see Table 1 for a summary of studies). Building upon the existing work, we define IT interruptions as *perceived*, *IT-based external events with a range of content that captures cognitive attention and breaks the continuity of an individual's primary task activities*. IT interruptions are a subset of work interruptions where technology creates the interruption (e.g. system failure) or mediates a human-created interruption (e.g. email; SMS; instant messaging). For IT-mediated interruptions, three technology features can significantly influence attention: *multimodal notification alerts*, *parallelism* and *reviewability*. Firstly, the actual IT-mediated interruption (e.g. email message) is often preceded by an initial alert notification that provides *multimodal cues* (e.g. sound; popup; icon display in the system tray). These alerts increase attentional demands and provide a strong trigger to switch rapidly to the interruption content (Middleton, 2007). Secondly, *parallelism* allows individuals to handle multiple interaction threads simultaneously, which taxes attention (Iqbal & Horvitz, 2007; Dennis *et al*., 2008). Thirdly, *reviewability* (ability to view message repeatedly after alert occurrence) reminds one of the interruption content and maintains attention on it (Barley *et al*., 2011).

Several interruption taxonomies exist. Brixey *et al*., (2004) developed a data-driven taxonomy of interruptions in the healthcare context. Whilst the taxonomy identifies several useful categories covering the interruption process from the interruption initiator to the interruption outcomes and management techniques, it does not directly address the content of the interruption nor relate it to primary tasks.[3] Also, the taxonomy only considers interruptions representing *secondary* tasks and ignores relevant interruptions. Similarly, McFarlane, (1997) and Latorella's, (1999) taxonomies do not focus on interruption content and its effects on task performance, because their purpose was to classify the interruption context to design systems that support interruption management. Finally, Rukab *et al*., (2004) developed a taxonomy based on activity theory to classify interruptions in distributed team environments. It classifies the primary and interruption tasks but without identifying whether the interruption content is related or unrelated with the primary task. Also, the taxonomy only considers interruptions prompting task switches and not other types of content (e.g. interruptions providing or requesting information).

[2]Whilst others (e.g. (Cutrell *et al*., 2000); (Czerwinski *et al*., 2000)) also examine the performance effects of relevant vs. irrelevant interruptions, our study differs in several ways: developing a taxonomy based on content dimensions; focusing on tasks nested in projects; focusing on performance efficiency and effectiveness to address the mixed empirical results; and examining technology's features and relating them to the performance effects.
[3]One of the categories, *Reason to Interrupt*, only partly addresses content by establishing whether the interruption is aimed at requesting information, switching tasks or power/control.

Table 1. IT interruptions in prior studies of work interruptions

Interruption type/subtype*		Definition of interruption (Authors)
Intrusion	System (system properties)	• No definition (Dabbish & Kraut, 2004; Dabbish & Kraut, 2008)
	System (system availability)	•No definition (Zellmer-Bruhn, 2003)•An event that diverts attention from primary task (France *et al*., 2005)
	Informational	•No definition (Cutrell *et al*., 2000; Czerwinski *et al*., 2000; Bailey *et al*., 2001; Miller, 2002) •An event that breaks the user's attention on the current task to focus on the interruption temporarily (p. 910) (Ho & Intille, 2005) •An event within the notification system prompting transition of attention focus from a primary task to a notification (McCrickard *et al*., 2003)
	Actionable (communicative)	•No definition (Dabbish & Kraut, 2004; Dabbish & Kraut, 2008) •A certain event that interferes with work process and results in the cessation and suspension of human activity (Kapitsa & Blinnikova, 2003) •Events that result in the cessation and postponement of an ongoing task (Zijlstra *et al*., 1999)
	Actionable (material)	•No definition (Bailey *et al*., 2001; McFarlane, 2002; Zellmer-Bruhn, 2003; Adamczyk & Bailey, 2004; McDaniel *et al*., 2004; Gievska *et al*., 2005; Bailey & Konstan, 2006; Iqbal & Horvitz, 2007; Ratwani *et al*., 2007; Monk *et al*., 2008) •A certain event that interferes with work process and results in the cessation and suspension of human activity (Kapitsa & Blinnikova, 2003) •Discrete event during which attention is abruptly redirected to process information that is irrelevant to the ongoing main task (Oulasvirta & Saariluoma, 2004) •Externally generated, randomly occurring, discrete event that breaks continuity of cognitive focus on a primary task (Speier *et al*., 1997) •Uncontrollable, unpredictable stressors that produce information overload, requiring additional decision-making effort. It breaks attention on primary task and turns it toward the interruption, if only temporary (p. 772–773) (Speier *et al*., 2003) •Events that result in the cessation and postponement of an ongoing task (Zijlstra *et al*., 1999) •An event that diverts attention from primary task (France *et al*., 2005)
	Unspecified	•A disruptive event (initiated by a human actor) that impedes progress toward accomplishing organisational tasks (Carton & Aiello, 2009) •A synchronous interaction that was not initiated by the subject, was unscheduled and resulted in the recipient discontinuing their current activity (O'Conaill & Frohlich, 1995)
Intervention	Informational	•No definition (Earley *et al*., 1990; Ang *et al*., 1993; Miller, 2002)
	Actionable (communicative)	•No definition (Okhuysen & Eisenhardt, 2002; Woolley, 1998)
	Actionable (material)	•No definition (Cutrell *et al*., 2000; Czerwinski *et al*., 2000; Okhuysen & Eisenhardt, 2002)

*Because *content* is not explicitly conceptualised in these studies, we qualitatively assessed the studies' methodologies to classify the studies by content relevance (intrusions and interventions; first column) and content structure (informational, actionable and system; second column). Inter-rater agreement for this classification was 88%.

In sum, whilst existing taxonomies deliver useful categories, a new taxonomy is needed to explicitly classify IT interruptions based on their content. Our taxonomy builds on our conceptualisation of IT interruptions and combines two content-based dimensions: content relevance for primary activities and content structure.

Dimensions of the taxonomy: content relevance and content structure

Our taxonomy includes the content relevance dimension because it may explain variations in task performance (Cutrell *et al*., 2000; Czerwinski *et al*., 2000; Gievska *et al*., 2005). We epitomise this dimension through two interruption categories that we adapt from the literature: IT intrusions and IT interventions. IT intrusions are defined as *perceived*, *IT-induced or IT-mediated external events that are irrelevant to performing primary task activities*. These events disrupt and divert attention from primary activities (cf. (Jett & George, 2003)). Most studies in Table 1 focused implicitly on intrusions. IT interventions are defined as *perceived*, *IT-mediated external events that reveal a discrepancy between performance expectations and actual performance of primary task activities*. This definition builds on Jett and George's, (2003) *discrepancy interruptions* and literatures on feedback (Ilgen *et al*., 1979) and control (Campion & Lord, 1982). Interventions are relevant for primary task activities because they direct attention toward the source of discrepancy (Jett & George, 2003). They disrupt an individual's ongoing behaviour and motivate a behavioural change to reduce the discrepancy (Jett & George, 2003).

The second dimension, content structure, is important because interruptions with different structures may have different antecedents (Kettinger & Grover, 1997) and consequences (Dabbish *et al*., 2005). IT interruptions can be system-generated (system interruptions with no explicit content) or mediated by the system (i.e. human-generated). The latter include two content types: *informational* and *actionable*. Interruptions with informational content involve one-way dissemination of information and require processing primarily at the cognitive level (e.g. a pop-up display showing stock news announcements). Actionable interruptions require processing primarily at the behavioural response level whether in the form of communicative action (e.g. email discussion over a project proposal) or material action (e.g. email requesting a sales report). This dimension thus views the structure of the interruption content as a basis for activating different cognitions and actions.

IT interruption subtypes

The combination of the two dimensions yields a 2 × 3 taxonomy with five IT interruption subtypes (see Figure 1 for descriptions/examples).[4] On the succeeding paragraphs, we elaborate on each component of the taxonomy. The literature summarised in Table 1 is used to illustrate each subtype.

Informational intrusions

This category reflects one-way informational elements disseminated via IT (e.g. email; instant messaging; pop-up displays) that relate to personal/social contexts, general work or other contexts that fall outside of the primary activities domain. Unlike fleeting distractions,

[4]Note that the 2 × 3 taxonomy is missing one theoretical category. This is because we did not find a conceptually coherent category for *system interventions*. Whilst the literature identifies interventions that are directly generated by the system (Ang *et al*., 1993; Earley, 1988), these interruptions do not represent a separate category because they typically represent feedback on task performance and thus overlap with informational interventions.

Content relevance of the interruption		Content structure of the interruption: Informational	Actionable	System
Intrusion (irrelevant)	Description	IT-mediated interruptions involving the processing of information that is relevant to an individual's secondary (non-primary) task activity	IT-mediated interruptions involving the execution of two-way communicative actions or material actions that are relevant to an individual's secondary (non-primary) task activity	IT-induced interruptions involving system property issues or lack of availability of system resources, which disrupt an individual's current flow of work in his or her primary task activity
	Example(s)	• *Pop-up display interrupting an individual's browsing task with unrelated notifications on sports scores, stock quotes, and weather reports (McCrickard et al., 2003)*	• *Electronic message that interrupts an individual performing a text editing task with a request for contact information from a directory (communicative action) (Kapitsa & Blinnikova, 2003)* • *Digital prompt triggering a switch from the execution of a text editing task to a task that requires summarizing short video clips (material action) (Adamczyk & Bailey, 2004)*	• *Computer or diagnostic malfunction that interrupts the work of a physician (France et al., 2005)*
Intervention (relevant)	Description	IT-mediated interruptions involving the processing of information that is relevant to an individual's primary task activity	IT-mediated interruptions involving the execution of two-way communicative actions or material actions that are relevant to an individual's primary task activity	N/a
	Example(s)	• *Computer-mediated feedback delivered to an individual while participating in a mockup recruitment session (Ang et al., 1993)*	• *Electronic message requesting to share information and question others during a group problem-solving task (communicative action) (Okhuysen & Eisenhardt, 2002)* • *Instant messaging alert instructing an individual about how to organize websites during a web search task (material action) (Cutrell et al., 2000)*	

Figure 1. Taxonomy of IT interruptions.

informational intrusions capture and divert attention from primary activities. They are processed mostly at the cognitive level via mental activities such as information organisation and evaluation, information retrieval (Wickens, 2002), comparing with prior experiences, idea generation, problem-solving and decision-making. Examples include task-irrelevant events such as general reminders (Ho & Intille, 2005), announcements (Bellotti *et al*., 2005), status updates (Dabbish & Kraut, 2004) and notifications (Cutrell *et al*., 2000; Czerwinski *et al*., 2000).

Actionable intrusions

Like informational intrusions, actionable intrusions represent human-generated, task-irrelevant electronic messages. However, they differ in that they draw attentional resources at the behavioural response level (i.e. they require communicative or material action; cf. (Goldkuhl, 2001)). Communicative action involves responding or engaging in ongoing communication. When the intrusion triggers material action, the response is physical, such as working on other tasks, managing resources or otherwise intervening in the external environment. Hence, actionable intrusions lead to task switching and, with the diffusion of multiple communication media at work, possibly to multiple simultaneous interactions (Cameron & Webster, 2013).

Dabbish *et al*., (2005) argued that a third of all email messages contain requests for action that cause people to shift attention and take on new tasks. Actionable intrusions were frequently examined (see Table 1). Examples of communicative actions include conducting online discussions (Ducheneaut & Bellotti, 2001; Bellotti *et al*., 2005) responding to information requests (Ducheneaut & Bellotti, 2001) amongst others (e.g. (Kettinger & Grover, 1997; Zijlstra *et al*., 1999; Kapitsa & Blinnikova, 2003;)). Material action responses include task switching prompts delivered via various modalities such as pop-up displays (Adamczyk & Bailey, 2004), instant messaging systems (e.g. (Iqbal & Horvitz, 2007; Ratwani *et al*., 2007)) and PC applications (e.g. Speier *et al*., 1997; McDaniel *et al*., 2004).

System intrusions

System intrusions are induced by technology. They include system property issues and the lack of availability of system resources. System property issues arise when the system's features are novel or discrepant from expectations, interrupt the current workflow and divert attention away from the primary task toward the system's interface (Louis & Sutton, 1991). Examples include systems that are slow, unreliable, difficult to use, loaded with features, demand constant attention or fit poorly with the task. At a higher level of disruption, system resources may become unavailable because of system glitches, breakdowns or upgrades.

We include system intrusions because they are consistent with our conceptualization of IT interruptions. They typically do not have an explicit content. Whilst they disrupt the primary task (i.e. break its continuity), they also capture attention and divert it from the primary task. Indeed, system property issues were found to consume attentional resources and divert them from primary task activities toward the system and its features (Karr-Wisniewski & Lu, 2010). Similarly, system failures draw attention and interrupt individuals as they attempt to figure out how to deal with the failure. Instead of focusing on the primary task, they divert attention to issues such as uncertainty over the breakdown duration, work that piles up during the breakdown, assessing the breakdown's performance implications, thinking of ways to get back to the task (e.g. contacting IT support; self-help) and/or performing other tasks until system resumption. Moreover, our classification of system failures as work interruptions follows other research that has treated these disruptions in a similar fashion (e.g. (France *et al*., 2005; Gupta *et al*., 2013b)). In sum, we believe that system intrusions that occur during the performance of the primary task can be classified as interruptions that break task continuity and capture and divert attention. As such, they are different from mere task disruptions that do not capture and divert cognitive attention. They are also different from distractions that represent fleeting phenomena that do not fully capture attention.

Informational interventions

Informational interventions reflect one-way informational elements that are disseminated via IT tools (e.g. email; instant messaging; pop-up displays) and that are directly relevant to performing primary task activities. They typically reveal information about a discrepancy between expected and actual primary task performance, which may help individuals resolve such discrepancies (Kluger & DeNisi, 1996). Individuals process the information about the discrepancy and engage in problem-solving (cognitive processing) to reduce the gap. As an example, Ang *et al*., (1993) examined a computer-mediated feedback delivered to 72 individuals whilst participating in mockup recruitment sessions and found that such interventions enable them to better realign their focus on the recruitment tasks.

Actionable interventions

Actionable interventions are IT-mediated events that are relevant to primary activities, and are usually designed to reduce discrepancies in performing such activities. They include

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communicative action and material action responses. Communicative actions are two-way interactions, communications and discussions between the interruption target working on a primary task and other individuals or team members within or outside the organisation. For example, Okhuysen and Eisenhardt, (2002) designed an intervention that led members of a work group to question others. This created opportunities for discussing important task issues and focused their attention on closing discrepancies in their task performance. The other behavioural response, material action, occurs when the intervention directs individuals to execute actions that are related to primary activities. Cutrell *et al*., (2000) examined instant messaging alerts that instructed individuals about how to organise websites in their web search task. Okhuysen and Eisenhardt, (2002) gave instructions to manage time properly. This created a discrepancy-seeking mode and stimulated group members to improve their time management.

PEPERFORMANCE EFFECTS OF IT INTERRUPTIONS: AN ATTENTION ALLOCATION PERSPECTIVE

To further develop our theorization, we explore – using the attention allocation perspective from psychology – the consequences of different IT interruption subtypes on individual performance. Given the limited prior theoretical work and the exploratory nature of the study, we focus on the three subtypes that are expected to have the most important effects on performance: actionable intrusions, actionable interventions and system intrusions. The effects of interruptions are expected to be most salient when they mobilise attention and trigger high levels of arousal (Kahneman, 1973; Weick, 1990). Events requiring action are typically more demanding than those that only provide information (Kahneman, 1973). Hence, we focus on actionable intrusions and interventions, because they both expose individuals to informational content, and ask them to act upon such content (Kahneman, 1973). We also focus on system intrusions because: (a) they impose sizable cognitive demands and increase arousal through blocking attention from the main work that can adversely affect performance; and (b) they represent the only category in the taxonomy that is generated by the system's activity.

Performance effects of system intrusions, actionable intrusions and actionable interventions

The attention allocation perspective posits that attention is a scarce, divisible resource that is deployed from a limited pool of attentional capacity to process information cues and meet task demands (Kahneman, 1973). Task demands are increased by interruptive events in the environment, such as tasks occurring in quick succession (Kahneman, 1973). Such rapid task switching triggers interferences that overload attentional resources: capacity interference (when demands exceed capacity) and structural interference (when the two competing tasks have similar structures, such as both being perceptual). Task switching also decreases performance efficiency because of the switching costs to coordinate and allocate resources to multiple competing activities (Kahneman, 1973) and performance effectiveness (e.g. missing or forgetting key information; reduced performance accuracy) as a result of attention contraction (i.e. dismissing cues used for task processing) (Easterbrook, 1959; Kahneman, 1973; Speier *et al*., 2003). In sum, rapid switching between competing tasks depletes attentional resources needed for efficient/effective task performance, especially when tasks are complex.[5]

Whilst much of the attention allocation research focuses on attention shortage from task switching, it has also been recognised that attentional capacity may be elastic because of external events that stimulate attention, increase capacity and mobilise previously untapped resources (Kahneman, 1973). This notion has been developed in mindfulness research (Langer, 1989) that suggests that task-pertinent events (e.g. performance reviews) motivate individuals to switch to more 'mindful' states of cognitive processing (Langer, 1989; Louis & Sutton, 1991). Such mindful states induce individuals to pay more explicit attention to their tasks, actively attend to new information, become open to different points of views and heedfully relate their actions to those of others they are collaborating with (Langer, 1989). In short, this leads to expansion of attentional capacity, which benefits task performance.

We draw on these insights on attentional contraction and expansion to link IT interruption subtypes to individual performance. When IT intrusions occur, the limited attentional capacity is diverted and spread over the primary task and the unrelated interruption tasks. This increases cognitive load and leads individuals to contract attention that had been devoted to their primary task. Individuals attend to a narrower range of cues needed to execute the primary task, which may compel them to dismiss critical cues that are needed for effective task execution (Speier *et al*., 1997). Upon resuming the primary task, individuals are also subject to heavy temporal switching costs (Monk *et al*., 2008).

Conversely, with IT interventions, focal attention expands on the primary task as individuals switch to a mindful processing mode (Jett & George, 2003). Attention is mobilised around the source of the inconsistency. Individuals engage in a 'bottom-up consideration of the actual details and facts surrounding [the] situation' ((Jett & George, 2003), p. 503). Because the interrupting stimulus is task-oriented, attentional expansion does not lead to diversion or distraction but rather to active thinking about resolving the problem at hand. Our propositions examine the link between the three interruptions subtypes and two dimensions of performance: time-based efficiency and effectiveness (i.e. work quality and learning) (O'Leary *et al*., 2011).

Effects of system intrusions and actionable intrusions on efficiency

Time-based efficiency comprises a *structural* dimension reflecting the work time that is consumed by the interruption, and a *cognitive* dimension representing the temporal switching costs of attention diversion (Monk *et al*., 2008). For the *structural* effect, system intrusions block time from the primary task whilst the system is down or not fully functional. Users typically cannot control the intrusion's timing to occur at opportune moments. France *et al*., (2005) found that

[5]It has been shown that for simple tasks (i.e. tasks relying on a limited number of cues) and/or less demanding interruptions, performance may not diminish and may even improve because of cue elimination (Kahneman, 1973); (Speier *et al*., 1997). But when tasks are complex and/or intrusions are intense, attention contraction results in eliminating cues that are needed to effectively perform the task, which leads to performance degradation (Gupta *et al*., 2013a); (Speier *et al*., 1997).

computer malfunctions interrupted physicians in the emergency department and reduced their efficiency. Actionable intrusions also consume work time and channel it to unrelated tasks and push the primary task behind (O'Conaill & Frohlich, 1995; McFarlane, 2002).

Regarding the *cognitive* effect, actionable intrusions incur temporal costs from switching between demanding interruptions and primary task activities and going through a process of cognitive suppression/activation of relevant cues. Firstly, switching to intrusive tasks significantly increases their completion time because it requires activating new tasks with new demands whilst suppressing information from the unfinished primary task (Bailey *et al*., 2001; McFarlane, 2002). Secondly, it is cumbersome to retrieve previously stored cues and resume the interrupted tasks (Oulasvirta & Saariluoma, 2004). Significant resumption lags have been reported (e.g. (Ratwani *et al*., 2007; Monk *et al*., 2008)), and one study found the average recovery time from a single email intrusion to be 64 s (Jackson *et al*., 2003). Thirdly, completing the primary task is likely to take longer upon resumption because of cognitive and emotional loads that remain unreleased. An experiment by Bailey and Konstan, (2006) quantified those effects at 3–27% more time, and others supported such effects (e.g. (Iqbal & Horvitz, 2007; Speier et al., 1997)). Whilst in theory, individuals could work faster to compensate for the lost time; extant research found that frequent interruptions create a feeling of "time famine" that leaves individuals unable to get their work done on time (Perlow, 1999).

Proposition 1. System intrusions are detrimental to individuals' efficiency because they divert attention and consume time that should have been dedicated to primary activities.

Proposition 2. Actionable intrusions are detrimental to individuals' efficiency because they: (a) divert attention and consume time dedicated to primary activities; and (b) fragment attention between primary tasks and non-primary activities, which incurs cognitive switching costs.

Effects of system intrusions and actionable intrusions on effectiveness

Effectiveness is made up of *quality* and *learning* (O'Leary *et al*., 2011). Both system intrusions and actionable intrusions are expected to debilitate work quality. For instance, system feature issues (e.g. slow, complex or unresponsive systems) may interfere with effective completion of tasks as a result of fragmenting attention and diverting it from primary activity. Research on awareness systems shows that system interfaces providing too much information interrupt work and decrease its quality (Dabbish & Kraut, 2004; Dabbish & Kraut, 2008).

Actionable intrusions are also expected to decrease work quality. Whilst individuals are naturally inclined to constantly scan the environment for new stimuli and engage in several tasks at a time, effective multitasking ability is severely restricted by shrinkage in the range of cue utilisation (Easterbrook, 1959) and capacity and structural interferences on cognitive attention (Kahneman, 1973; McFarlane, 2002). Frequent task switching fragments attention, increases errors and generally hampers work quality. These effects are expected to be more pronounced because of the *parallelism* feature of technology that taxes attention and fragments it amongst multiple fragmented threads of interaction. Research shows that when tasks are complex, frequently occurring actionable intrusions decrease decision accuracy of both the primary and interruptive tasks (Speier *et al*., 1997). Similar results were echoed in other contexts (McFarlane, 2002; Speier *et al*., 2003; Bailey & Konstan, 2006).

Proposition 3. System intrusions and actionable intrusions are detrimental to individuals' work quality because they divert attention from primary task activities.

System intrusions and actionable intrusions also hamper individuals' *learning* about their primary tasks because they reduce the time available to integrate new information and they create cognitive and capacity interferences that affect memory retrieval. A study of online trainees found that system intrusions (i.e. error messages and network issues) inhibited self-regulation and learning, leading trainees to forget some key declarative and procedural aspects of their training material (Sitzmann *et al*., 2010). Similarly, actionable intrusions impel individuals to unload parts of their working memories to act upon the interruptions and then resume the interrupted task. This hampers information retrieval and thus learning (McDaniel *et al*., 2004; Oulasvirta & Saariluoma, 2004).

Proposition 4. System intrusions and actionable intrusions are detrimental to the learning of individuals about their primary tasks because they divert attention from primary activities.

Effects of actionable interventions on efficiency

Because actionable IT interventions are by definition events that refocus attention on the primary task, they do not entail switching costs between primary and secondary tasks. However, such events may still deplete work time, as workers faced with an intervention channel their attention toward making sense of the event, redoing the work or coming up with ways to improve performance and close the gap if a discrepancy was identified by the intervention. Evidence was found that actionable interventions in simulated decision-making tasks have a detrimental effect on information processing efficiency (Szalma *et al*., 2006).

Proposition 5. Actionable interventions are detrimental to individuals' efficiency because they disrupt their work and prompt them to act upon the content of the intervention (e.g. redo the work; design and implement corrective action strategies).

Effects of actionable interventions on effectiveness

Actionable interventions are expected to enhance work quality and learning. Firstly, consistent with the notion of mindfulness, they focus attention on discrepancies and motivate individuals to spend efforts to learn about and effectively close the gaps (Kluger & DeNisi, 1996; Okhuysen & Eisenhardt, 2002; Zellmer-Bruhn, 2003). Secondly, they provide information that helps recognise areas of improvement and complete the task effectively (Woolley, 1998; Jett & George, 2003). Thirdly, they trigger a mindful cognitive state that helps individuals close task performance discrepancies by orienting them to the present and enabling them to integrate new information and stimuli from multiple sources (Langer, 1989). Individuals then actively and reflectively process the task information into new and meaningful ways rather than rely on pre-existing knowledge representations (Ilgen *et al*., 1979; Jett & George, 2003; Langer, 1989).

Because the actionable intervention is mediated by technology and thus has limited social contextual cues compared with a face-to-face intervention, this creates a buffer that maintains the individual's attention on correcting the task discrepancy rather than divert it to situational issues (Ang *et al*., 1993). This also motivates one to embrace the feedback provided by the intervention without fear of negative evaluation and other situational interferences that occur in a face-to-face environment, which increases the success likelihood (Ang *et al*., 1993; Kluger & DeNisi, 1996; Earley, 1988). Furthermore, IT's *reviewability* feature allows individuals to repeatedly consult and review the message, which can maintain their motivation and focus on closing the discrepancy and improving their performance. This capability is reinforced by the wide diffusion of mobile computing, which allows the content of such interventions to be reviewed anytime and anywhere.[6]

In support of these effects, it was found that IT-generated interruptions providing feedback on investment decisions enhance the value of subjects' stock portfolio and their information search quality (Earley *et al*., 1990). These results were stronger for actionable interventions (directive and strategy-shaping feedback about investing) than for informational ones (notifications about portfolio performance). Another study of software developers found that actionable interventions (electronic software bug notifications) that were negotiated enhance task prediction accuracy and learning (Robertson *et al*., 2004). Developers actively sought explanations of the bugs on the system and became more engaged in fixing them.

Proposition 6. Actionable interventions are beneficial to individuals' (1) work quality and (2) learning, because they reorient attention to areas of discrepancy in primary task performance, and motivate and direct individuals toward reducing the discrepancies.

METHOD

Our empirical study aimed at validating the entire taxonomy, exploring the performance effects of the three IT interruptions subtypes for which we developed propositions and uncovering any missing categories through an inductive analysis. The unit of analysis is the interruption subtype. We focused on individuals working in project environments. This context is interruption-intensive, broader than the isolated task context, and involves distinct boundaries for understanding IT interruptions and their impacts.

Data were collected through a primarily qualitative approach to provide rich insights in the nascent area of IT interruptions and to capture actors' experiences in their natural working

[6]We are indebted to an anonymous reviewer for providing insights regarding this point.

environments. We collected the data from two independent samples and through two methods: log diaries and semi-structured interviews. Combining these two methods achieved data source- and data type triangulation and the use of insights from one method (log diaries) to focus the interviews on the key issues identified. These methods were deemed more appropriate than direct observation. Firstly, many IT interruptions are ephemeral and less amenable to observation without obstructing the participants. Secondly, participants may respond differently to the interruption (e.g. ignore it) if the researcher is physically present (cf. (Yin, 2009)). Thirdly, log diaries and interviews may provide more insights on behavioural outcomes that can be remote from the immediate observable context of the interruption events.

Log diaries

Five professionals working in project environments (two project managers, two software developers and a law professional) and nine university professors participated in the log study. Professors added diversity to the sample and provided an interruption-rich context. Participants were provided with an online logbook (previously pilot-tested) on which they were asked to record the IT interruptions they experienced during their workday. To mitigate recall bias, they were asked to record each event promptly after its occurrence.

The log included open-ended questions to describe the primary activity that was interrupted and the interruption event (interruption source, technology medium, topic, etc.). Additionally, we presented closed-ended statements to measure the interruptions' content relevance, content structure and duration. We also included Likert-type statements to measure the perceived performance outcomes (efficiency and effectiveness) associated with each interruption entry in the log. These measures were previously validated (Addas & Pinsonneault, 2013). The log had a simple, nonobstructive design to facilitate completion and reduce disruptive effects on attention. It was limited to a single page that we asked to respondents to print and keep handy to avoid switching screens, which diverts attention and consumes time. Printing the log also enabled prompt recording of events in the case of a system outage (a system intrusion). In our analysis, we only used the data of those who responded to the log during what they considered a typical workday (93% of total). In all, 61 interruption events were recorded.

The first author classified the IT interruption subtypes by combining two components: the interruption's content relevance and its content structure. Content relevance was measured by a closed-ended question asking respondents to specify whether the interruption was entirely unrelated (intrusion), entirely related (intervention) or somewhat related to the primary activity. Content structure was measured by asking respondents to specify whether the interruption provided information (informational), requested a reply (communicative action), required switching to a new task (material action) or had no specific content. The classified subtypes were then validated by qualitatively assessing the respondents' descriptions of their primary tasks and interruption events. If the closed-ended responses were not consistent with the open-ended descriptions, the interruption event was reassigned to the appropriate category based on the qualitative description (this occurred in only two cases). The final classification was further validated through an expert judge who separately classified the interruption events by assessing the qualitative descriptions and the provided definitions of the interruption subtypes. This generated a hit ratio score of 91% (see online Appendix 1).[7] The performance effects of IT interruption subtypes were analysed via simple descriptive statistics (means, standard deviations and frequencies) because of the exploratory nature of the study and the small sample size.

Interviews

To complement the log diary data, we interviewed individuals in new product development (NPD) teams who work on multiple tasks and multiple projects in an interruption-intensive environment. To obtain contextual information about the sites, company documentations, such as project documents, company newsletters and websites/blogs, were examined. Prior to data collection, two qualitative methodology experts were consulted on the interview questions, which resulted in revising and/or changing the flow of some questions. Additionally, the questions were pilot-tested with two NPD professionals, and that resulted in further refining the questions and the overall data collection strategy.[8]

We controlled retrospective bias by selecting knowledgeable informants, reminding them to report on current/recent project activities, inquiring about general interruption patterns rather than specific events and conducting the log study for external validation and data triangulation. Impression management bias, generated from asking performance-related questions, was controlled via: (a) triangulating data; (b) selecting informants from different hierarchical levels, functional areas, organisations and industries (see Table 2); (c) assuring informants that their responses were confidential and would not be used for any evaluation purposes or decisions; and (d) adopting a stance of emphatic neutrality during the interviews (Patton, 2002).

The interviews were semi-structured, in-depth and lasted about 1 h each. Follow-up contacts were made with some informants to clarify ambiguous information and/or elicit new information. We targeted individuals in NPD units via a heterogeneity sampling approach (Patton, 2002) to capture as many interruption subtypes as possible and to see whether common patterns are robust across a heterogeneous sample. We varied our sample selection across the following attributes: task interdependence, job role, product type (physical/digital) and experience level. Team members were screened for current or recent involvement in NPD projects and the use of IT in NPD activities. Participation letters were sent to the key persons explaining the study goals, participation requirements, ethical procedures and benefits from participating in this project. The final list of participants includes 21 individuals from the NPD units of 8 organisations (referred to as Alpha, Beta, Gamma, Delta, Epsilon, Zeta, Eta and Theta). The interviewee list is shown in Table 2, which illustrates the heterogeneity criteria in columns and the individual cases in rows.

To analyse the data, we first recorded, transcribed, coded and summarised each interview in a contact summary sheet. The first author coded each interview statement for evidence of the interruptions subtypes and their effects on performance. A research assistant coded a subset of the interview. An agreement rate of 86% was achieved between the two coders. Disagreements were arbitrated by a senior scholar specialising in this domain. During coding, we remained

[7]The hit ratio score is the ratio of the correct item placements to total item placements across all construct categories.
[8]The interview guide is available from the authors upon request.

open to finding divergent patterns and/or rival outcomes in the data (Patton, 2002). Next, we reconciled the data with the theoretical dimensions defined a priori (IT interruptions types and performance consequences) by constructing chains of evidence (see online Appendix 2 for a sample evidence chain). An analytic induction approach (Patton, 2002) was also used to see whether additional subtypes would emerge from the data.

RESULTS

Evidence of IT interruption subtypes

We found evidence of the existence of all IT interruption subtypes. Table 3 summarises the results from the log diaries and shows that all types of interruptions identified based on the literature were supported in the empirical study. IT intrusions occurred more frequently than interventions (37 vs. 8 occurrences) but had shorter durations on average (19 min vs. 65 min). Of these, actionable interventions had the longest average durations (78 min). These findings were also supported by the interview data (see Table 4 for the main quotes).

Interestingly, 11 of the 14 log participants reported interruptions that did not fall into our categorization. These events are related to primary activities but not to the focal ones being conducted (16 occurrences or 26% of all interruption events; see Table 3). For example, a university professor, whilst writing a paper for a journal, was interrupted by an email from a colleague about another research project they were working on together. Similarly, a marketing analyst, whilst creating a renewal proposal for a client, was interrupted by an email from the client about a data mismatch issue. On average, participants spent less time on these events (13 min) than on intrusions (19 min) and interventions (65 min).

These interruption events are now explored further in the interviews with NPD project members to better understand their nature and consequences on performance.

Informational intrusions

Informational intrusions were mostly manifested with NPD project members being copied on emails that were irrelevant to their work. Some perceived such interruptions as attempts to keep them in the loop (e.g. Assistant Product Designer, Epsilon; see also quote Q1, Table 4), whilst others perceived them as documentations disseminated to deflect responsibility; a ‘cover your own back’ phenomenon (VP Development & Distribution, Zeta), or a way to ‘avoid facing the issues’ (NPD manager, Beta; see also Q2). Other times, project members were interrupted with notifications from others who faced problems with their work (Q3).

Actionable intrusions

We also found evidence of actionable intrusions, such as information requests (communicative action), that impinged on project work. These were typically initiated by people from other departments and often by superiors (Q4 and Q5). Whilst some intrusions occurred through other media (Q6, Q7 and Q8), most came through email. Email’s *multimodal alert* feature made it difficult to resist interrupting one’s work to handle these information requests despite their lack of relevance to the primary task. A lead developer from Alpha complained the following:

Table 2. List of interviewees and companies

Company	Job role		Product		Team size		Task interdependence		Experience	
	NPD manager	Other team members	Digital	Physical	Small	Large	Moderate	High	Low	High
Alpha	—	Software development team lead	Software solutions for NPD	—	5	—	Moderate (pooled or sequential)	—	—	10 years
	—	Software developer 1							—	17 years
	—	Software developer 2							—	12 years
	—	Quality assurance specialist							5 years	—
Beta	Integrated product team manager	—	—	Gas turbine engines for power generation	—	200	—	High (reciprocal or team)	4 years	—
	—	Technical lead/vibrations specialist							—	8 years
Gamma	—	VP marketing analysis	Web analytics software	—	—	13	—	High (reciprocal or team)	1 year	—
	—	Product strategist			6	—	—	High (reciprocal or team)	½ year	—
	Product manager 1	—			2	—	—	High (reciprocal or team)	—	20 years
	Product manager 2	—			6	—	—	High (reciprocal or team)	½ year	—
Delta	CTO	—	Software for system testing devices	Semi-conductor testing devices	—	10	Moderate (pooled or sequential)	—	—	8 years
	—	Senior member of technical staff			5	—			—	8 years

	—	Senior software developer			2	—			3 years	—
Epsilon	—	Assistant product designer	—	Denim Jeans	3	—	—	High (reciprocal or team)	2 ½ years	—
Zeta	VP, development and distribution	—	Film productions and interactive digital media	—	5	—	Moderate (pooled or sequential)	—	—	11 years
	—	Distribution and marketing manager							1 ½ years	—
	—	Director, post-production							—	12 years
Eta	—	Software engineer 1	Web-based machine translation software	—	—	20	Moderate (pooled or sequential)	—	2 years	—
	—	Software engineer 2	Web-based productivity software		4	—	Moderate (pooled or sequential)	—	2 ½ years	—
	—	Software engineer 3							½ year	—
Theta	Head of planning and NPD	—	Bank deposit accounts	—	3	—	Moderate (pooled or sequential)	—	1 year	—
Total	6	15	6	3	10	4	6	6	12	9

Description of organisations:
•Alpha: a small Canadian company that develops engineering software solutions supporting product designers in the process of NPD.
•Beta: a large, global engine maker. The individuals we interviewed were part of a team involved in developing gas turbine engines for industrial power generation and oil and gas mechanical drive applications.
•Gamma: a small developer of Web analytics software with a large, international customer base.
•Delta: a small Canadian team of engineers that develop test solutions for a broad range of high-speed semiconductor device interfaces.
•Epsilon: a global manufacturer of Denim Jeans. We interviewed an individual within a small team of three designers.
•Zeta: a Canadian company that specialises in international film productions and interactive digital media.
•Eta: the international arm of a global, multinational corporation that makes a broad range of computing solutions. We interviewed three software development engineers.
•Theta: a subsidiary of a large, European bank that develops financial solutions.

Table 3. Results of log diaries

Interruption type/ subtype		Number of occurrences	Example of primary task description	Example of interruption description	Average duration⁺	Performance efficiency		Performance effectiveness				
						Efc1	Efc2	Eff1R	Eff2R	Eff3	Eff4	Eff5
Intrusions	System	11	Sending email to the student giving detailed feedback on their project	The webmail logs you out automatically after 10 minutes and when I pressed “send” the sign in page appeared again and the email text was lost	36.81 (22.50)	2.18 (0.87)	2.36 (1.03)	0.82 (0.60)	1.73 (0.90)	1.55 (0.69)	1.64 (0.92)	2.09 (0.83)
	Informational	*8*	*Preparing for classes*	*Email from staff about a new school policy for requesting IT services*	*7.88 (6.64)*	*3.43 (0.98)*	*3.57 (0.79)*	*2.57 (1.40)*	*2.63 (0.74)*	*1.50 (0.76)*	*1.63 (0.92)*	*2.00 (1.00*
	Actionable	18	I was on a phone call with main partner	SMS from relative for feedback on a personal subject	12.06 (12.22)	2.47 (0.94)	2.53 (1.18)	1.41 (1.18)	1.11 (0.58)	1.17 (0.38)	1.33 (0.49)	1.29 (0.47)
Aggregate intrusions		**37**	**-**	**-**	**18.51**	**2.59**	**2.70**	**1.49**	**1.62**	**1.35**	**1.49**	**1.68**
Interventions	*Informational*	*2*	*Investigating with client navigational issues on his website*	*Chat message from colleague with link to competitor’s website that shows how we could deal with these issues*	*25.00 (7.07)*	*3.50 (0.71)*	*4.00 (0.00)*	*4.00 (0.00)*	*4.00 (0.71)*	*5.00 (0.00)*	*4.50 (0.71)*	*5.00 (0.00)*
	Actionable	6	Reading a paper for my research project	Email from co-author with an attached revision for the paper. I stopped the reading activity and worked on the paper as per the comments and suggestions.	77.83 (148.65)	3.80 (0.45)	4.40 (0.89)	4.33 (0.82)	4.17 (0.41)	4.00 (0.63)	3.83 (0.75)	4.00 (1.10)
Aggregate interventions		**8**	**-**	**-**	**64.63**	**3.73**	**4.30**	**4.25**	**4.13**	**4.25**	**4.00**	**4.25**
Hybrids	*Informational*	*7*	*Creating a renewal proposal for client*	*Email from client on an issue pertaining to another project (data mismatch)*	*14.43 (11.86)*	*3.40 (089)*	*3.60 (0.89)*	*3.20 (1.79)*	*2.86 (1.21)*	*3.00 (1.15)*	*2.57 (1.13)*	*2.00 (1.41)*
	Actionable	9	Meeting with financial manager	Phone call from important client to discuss a client issue	12.44 (9.42)	3.44 (1.13)	3.44 (1.51)	3.00 (1.41)	2.22 (1.20)	3.00 (0.87)	2.78 (1.09)	1.89 (0.93)
Aggregate hybrids		**16**	**-**	**-**	**13.31**	**3.42**	**3.51**	**3.09**	**2.50**	**3.00**	**2.69**	**1.94**
Aggregate interruptions		**61**	**-**	**-**	**23.19**							

Note: The numbers shown under the closed-ended statements (greyed cells) represent the mean responses on 5-point Likert-type scales (standard deviations in parentheses). The rows in italics represent the subtypes for which no performance propositions were developed.
⁺Average duration shown in minutes.
Proxy measures for performance:
•Efc1: After this interruption, I switched back to my primary activities without losing the flow (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).
•Efc2: After this interruption, I reengaged quickly in my task (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).
•Eff1R: Handling this interruption made me feel overwhelmed (1 = not at all; 2 = slightly; 3 = somewhat; 4 = moderately; 5 = extremely).
•Eff2R: Interruption made me forget things related with primary activities (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).
•Eff3: Interruption revealed critical information that helps me do my primary activities (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).
•Eff4: Interruption motivated me to better do my primary activities (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).
•Eff5: Interruption sensitised me to new ways of doing my primary activities (1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree).
R= Reverse scale items.

> *You are focusing on your work, and then you hear that sound: ‘Ding’… and the notification… and the buzzing in your pocket. Someone wants you to help with whatever they are doing. Then it starts all over… This takes your attention away, but for some reason you still keep checking them.*

System intrusions

Some members experienced system intrusions as features interfering with NPD tasks (e.g. slow system or system not working as planned; Q9). Most system intrusions, however, related to the lack of availability of resources due to system crashes (Q10 and Q11). Consistent with our theoretical arguments, informants confirmed that system intrusions are interruptions that consume and divert attention rather than being mere task disruptions (e.g. see Q10).

Informational interventions

Project members – especially in high interdependence teams (e.g. Gamma; Epsilon) – received feedback highlighting discrepancies in their primary activities. This was often via email about product issues at the pre-launch stage (Q12) or via Twitter notifications from customers who provided real-time feedback about product features, issues and limitations (Q13).

Actionable interventions

Actionable interventions involved multidirectional exchanges with coworkers and customers (communicative action), which refocused attention on task discrepancies (see Table 4, shaded cells). For example, project members described collaborations on shared workspaces that changed the way development work was done (Q14 and Q15). A member from Zeta referred to email discussions with customers that stimulated work changes (Q16). Project members also received email interventions that triggered material actions (Q17), which frequently came from customers requesting changes in product features (Q18 and Q19).

Performance effects of IT interruptions

The log results on IT interruptions' performance effects are shown in Table 3 (shaded cells). Participants indicated that intrusions had negative effects on both performance efficiency (average of 2.65 on a scale of 5) and effectiveness (1.53/5). In contrast, interventions had a positive effect on efficiency (3.99/5)[9] and on effectiveness (4.18/5). The data also suggest that actionable and system intrusions have relatively similar negative effects on efficiency (averages of 2.50 and 2.27, respectively; weighted average 2.41) and on effectiveness (averaging 1.26 and 1.57; weighted average 1.38). Their effects seem stronger than informational intrusions on efficiency (3.50) and on effectiveness (2.07). Whilst the negative effects of actionable interventions seem slightly lower than the effect of informational interventions both on efficiency (4.10 vs. 3.75) and on effectiveness (4.07 vs. 4.50), it is difficult to generalise this result because there were only two cases of informational interventions.

Furthermore, we conducted a comparative analysis between academics and working professionals. IT-mediated intrusions seemed to be more disruptive to the efficiency of working professionals' jobs as compared with the jobs of academics (2.67 vs. 3.63 for informational; 1.92 vs. 3.36 for actionable). For system intrusions, the opposite seemed true, with academics reporting lower efficiency (1.83 vs. 2.44). Regarding effectiveness, IT-mediated and system intrusions were only slightly more disruptive to working professionals. IT interventions seemed to have very similar (positive) effects on the two job categories.

Overall, the results seem consistent with our theoretical arguments that actionable and system intrusions and actionable interventions will have negative effects on efficiency and

[9]We measured only the cognitive dimension of efficiency, because the log is at the level of individual events rather than the project level. Hence, the proposed negative structural efficiency effects of interventions cannot be tested with the log diaries.

Table 4. Data supporting the IT interruptions taxonomy

Interruption type / subtype		Supporting evidence from interviews
Intrusions	Informational	**Q1** *Many of the emails I get do not have any value for my projects, just emails circulating within the company. Some of them are HR-related […] They can really be disruptive if too many are flying around.* (Software developer 1, Alpha)
		Q2 *I am copied on emails that have no relevance to my work or are at a level that I do not need to know. For instance, sometimes you manage a project and there might be a technical issue that arises but that issue could be easily resolved within the technical people and you do not necessarily need to know about it but people still tend to copy you because they think you need to be aware or they want to show that they are actually working on it. But to me it is being an annoyance because it just distracts me and I do not need to know about it.* (NPD manager, Beta)
		Q3 *It is basically always about the same pattern so let us say some machine is not working and somebody cannot access a certain machine on a remote site, and they send emails to everybody and the person who probably knows something about it replies to everybody. When you get those notifications, you kind of hope that it stops at a certain point. You're back doing your task and then BOOM: another notification, another, another! It goes on and on. This kind of stuff takes my attention away and distracts me from the main programming tasks.* (Team lead, Alpha)
	Actionable (communicative action)	**Q4** *Should I focus more on developing and running the programs for vibration tests on our engines, or on answering the constant emails from our other departments about HR stuff, corporate issues, company events, or what have you? I think the answer is clear. Even when the information they ask from me is available or easy to get, these emails disturb the engineering process that is involved in vibration testing.* (Vibrations specialist, Beta)
		Q5 *Because I report directly to the CEO so I have to handle a lot of emails about things that have nothing to do with product development. I do this on a daily basis several times. I would stop immediately what I am doing and then go back to it after I have finished or responded or taken action or made plans for whatever else it was that required for my attention.* (Head of Planning and NPD, Theta)
	Actionable (material action)	**Q6** *I need to report numbers to Finance and to the board on the membership of our clients. This is also interrupting to the development work [...] [I] have to go myself in Excel, play with the columns and numbers, and craft something that is going to finally make sense.* (Product manager 2, Gamma)
		Q7 *From time to time we are definitely asked to shift to different things. For example, we have to fill up some kind of online logbook journal. It is kind of a nuisance and a distraction for developers to do extra documentation work; especially that it is not directly related to the project.* (Software developer 1, Alpha)
		Q8 *Well I am working on a Jean design and then I get an email: "Oh, I am meeting a buyer and I am missing some information. Can you prepare a presentation that includes so, so and so and have it ready in the next hour?" So that is a major annoyance because first of all it is something that was not provided beforehand, was unplanned and I will be doing it as a favor because it's not really part of my work.* (Assistant product designer, Epsilon)
	System	**Q9** *Yes, the IT infrastructure gives us some hiccups from time to time. And it might be annoying and slowing down the overall process […] [The IT department] make processes and features to suit their own people not vice versa.* (Software developer 2, Alpha)
		Q10 *I work a lot with Photoshop for example to design posters which we send to the television networks. There have been several instances where I will work on something and my entire computer will freeze or crash. Oh God! Photoshop is a big one that hinders the flow of my work.* (Distribution & Marketing manager, Zeta)
		Q11 *We experience system failures and network failures. Those are bad interruptions. If you are for example fixing something on a remote machine and the network is down, the task is completely blocked and you have to figure out another way to connect to this machine.* (Software engineer 1, Eta)
Interventions	Informational	**Q12** *Ok so for example, last night my quality control colleague sent me the status of the 2 modules we were debugging: […] "On module 1, here is the symptom that was reported; "Here is the chain of the circuit"; "Here is where I found the problem in that chain". "--- Next module: this is the symptom that you described"; "Here is what I found";"--- thanks, [name]."* (Senior member of technical staff, Delta)
		Q13 [Referring to 'Tweets' and Blog comments from clients who are using a beta product undergoing development]: *It helps me understand what people do with my product and how to use it, and sometimes what are the limitations or what are the feature that people want. People comment and it is great that you get an answer so fast.* (Product Manager 1, Gamma)
	Actionable (communicative action)	**Q14** *We have a shared workspace and we integrate our codes with each other. This electronic environment gives us the opportunity to provide feedback on each other's work. So while working on a particular task, other developers can interrupt me with feedback and discussions that help to improve the code and catch errors and so on. (Software developer 2, Alpha)*
		Q15 [Referring to email interactions between developers that relate to current project work]*: To me these are the best emails because they are always geared towards improving what I am actually doing now because that is really my job. When it is something about development stuff before release, it is usually where I am most present, you know [...] It is not a problem for me because they are issues that needs to be addressed and it is part of my daily work [...] So these interruptions help the actual work.* (Product strategist, Gamma)
		Q16 *We mostly get information-based feedback by email on stuff we work on so when it comes back it is feedback you know, like 'The tape is ok but why did you do this?' It is mostly discussions that trigger a change, you know, like 'We have a problem with the tape, there is this and this. What's your take on that?'* (Distribution & Marketing manager, Zeta)
	Actionable (material action)	**Q17** *Some of the emails we receive may be related to some pending issue in our decision. Like for example in the web development world we usually depend on some graphic work that should be delivered from graphic designers, so every now and then I receive some emails about those new web site designs, those new icons. 'I think those icons should better be placed like this. What do you think? Try them on the existing work and give us our opinion'; these sorts of things. In this case these emails interrupt you because they make you change your perspective.* (Software engineer 2, Eta)
		Q18 *Well, most interruptions like that would be changes in the required specifications or in the features. So you are developing a feature and they [email you] "No, instead of taking one 32-bit register, we need two or three" [...] This interruption allows me to just adjust some expectation about the way I am working on the product* (Senior software developer, Delta)
		Q19 [Referring to email feedback received during a design task]: *It is not interruption; it is positive disruption. Because merchandisers would email us and tell us that is the feedback we are getting from the retailers, and we need to change this. So basically even while you are working on something, you get feedback, you have to re-organize your entire focus, re-categorize, redirect, realign.* (Assistant product designer, Epsilon)

effectiveness and that actionable interventions will have a positive effect on effectiveness. We further explore these results through interviews with NPD project members. Table 5 provides the key quotes from the interviews that illustrate and examine the effects observed in the logs.

Table 5. Data supporting propositions on system intrusions, actionable intrusions and actionable interventions

			Proposition support						
Supporting evidence			P1	P2	P3	P4	P5	P6a	P6b
Intrusions	System	**Q1** [Referring to system migration from C++ to Python]: *It took two months of start-up issues where you assign some tasks to the developers and they started doing them but they were distracted by either having to support the old code or by having to learn the new code*, *so what happened is the project slipped by I would say by 8 weeks because of that*. (CTO, Delta)	√						
		Q2 *Well from my point of view whenever such a thing* [*breakdown of network server*] *happens my first thought is that because I am responsible for the schedule and the momentum of the project so if I do not deliver on a certain date that means it gets rescheduled to some other date and that means my project is being postponed*. (NPD manager, Beta)	√						
		Q3 *Software and network failures are not very frequent*, *but when it happens it can become a blocker and it take a lot of time to be resolved. This time is project time. I can't work on a project if I don't have access to the resources*. (Software engineer 3, Eta)	√						
		Q4 [Referring to a meeting with the CEO where she was demonstrating product features]: *Then the system is crashed and you cannot do anything so you find yourself completely handicapped and we have just to wait until the system goes back online*. (Head of planning and NPD, Theta)	√						
	Actionable	**Q5** [*Some tasks*] *really require all your attention. You have to be inside the problem* […] *you cannot do it by slices and have to do it as a whole* […] *For example*, *last week I was working on a complex issue*, *using analytic geometry on the drafting system in order to change multiple system parameters that are all linked together. I was interrupted by other non-related email tasks and this made me forget the mental state in which I was. I was not deep into the problem anymore. I was taken out of it and had to spend more time to return to the same point*. (Software developer 2, Alpha)		√					
		Q6 *Yeah*, *that can be something major too because you are working on something in the middle and then you have to switch to other stuff* [referring to computerized tasks that are not related to the project work of test automation] *and when you come back you probably have to restart from the beginning so that is double*. (Quality assurance specialist, Alpha)		√					
		Q7 *When we are developing a new banking product a lot of the tasks require deep focus. So when you get distracted by your computer to do other stuff*, *then you have to start the process all over again mentally in order to reach the stage where you were previously. It often takes about half an hour after a long interruption just to recover mentally and*		√					

(Continues)

Table 5. *(Continued)*

Supporting evidence			Proposition support						
			P1	P2	P3	P4	P5	P6a	P6b
		be back into the mood and in the environment where you left off. (Head of Planning and NPD, Theta)							
		Q8 [Referring to emails that prompt switching to tasks unrelated to vibration testing]: *Vibration testing is a complex process. You have to simulate the vibration environment, measure the pressure waves, the input signals, do the modal analysis. If I keep being pulled to doing other tasks that are required by our other departments, this raises the likelihood that errors will be committed in my work* (Vibrations specialist, Beta)			√				
		Q9 *Part of our work entails mathematical problem-solving tasks. When I am doing complex mathematical tasks, such as analytical geometry, being constantly interrupted by emails, SMSs, phone calls that all require you to do tasks that have nothing to do with what you are doing can really affect how you understand and tackle these problems. For some problems that can be solved in one day if I really concentrate, I can spend one month and not find a solution*. (Software developer 2, Alpha)			√	√			
		Q10 [Referring to effects of emails that prompt switching to tasks unrelated to developing new movies]: *Yeah, I think it is definitely flow especially because it is a very creative process and you know with music and everything coming in I sort of look at it as one piece. When you are interrupted with other tasks you sort of break the piece into separate pieces which I do not think sometimes works as well for certain movies. I think it sometimes impacts creatively how we can work and what we get out*. (Director of post-production, Zeta)			√				
		Q11 *When I am struggling to meet the deadlines and then my email keeps telling me 'No, do this instead', I can become overwhelmed, forget stuff, and make wrong decisions. It's not worth it, especially since many of those things that interrupt us are not even part of the development projects*. (Distribution and marketing manager, Zeta)			√	√			
Interventions	Actionable	**Q12** [Referring to customer feedback on product features that are being launched]: *The merchandisers would actually e-mail us* […] *and if it is something they want to have in this pant in this colour where they need me to initiate one more colour, it is not a big deal. It is already my task-at-hand to which I need to add something so I just work on it. But then if it is something major then we would have to stop and redesign. Redesigning is a major task because that involves other people. It involves bringing the contractor and communicating the change with the technical designer. Then I have to update an Excel sheet with the specifications. So if the feedback involves a total overhaul of something, it is like a ripple effect where you have to involve more and more people. And they have to come back to you*					√		

(Continues)

Table 5. *(Continued)*

Supporting evidence	Proposition support						
	P1	P2	P3	P4	P5	P6a	P6b
because you want to change this but to change that, this would delay things (Assistant product designer, Epsilon)							
Q13 [Referring to 'Tweets' and Blog comments from clients who are using a beta product undergoing development]: *Well from the customers' perspective I guess if they are complaining from something relating to the product it is negative in the sense that it takes time and work to address their concerns, but it is positive in the sense that they are telling me about something to be fixed, which will help me improve the product.* (Product manager 1, Gamma)					√	√	
Q14 *Yeah, a new thing that we are also doing now is that when we work on a new project, we get emails from our internal departments providing feedback that can help us improve our product offering. In fact, it is usually good feedback because they filter information from the clients and they come up with something that is essential to the product or which we should focus on.* (Product manager 2, Gamma)						√	
Q15 *The emails that contain feedback about the tasks I am doing can help me in a lot of ways. They can help me see things that are open in the project, help me create the big picture, re-prioritize what I am doing, and be more attentive to the important issues. When the feedback is negative I may be disappointed for a while but I am also motivated to get it working. It helps me see the problems and fix them.* (Software engineer 3, Eta)						√	
Q16 [Referring to customer email feedback on product features that are being launched]: *Most of the requests for change are positive because customers open your eyes to things that take your product to the next level and align it with the market* […] *So these emails are interruptive but also positive in the sense that they help you give people what they want and make people happy. And of course your own performance is tied to that.* (Assistant product designer, Epsilon)						√	
Q17 [Referring to email interruptions about bug fixes for products under beta release]: *The good part of this is that you get to find these bugs early before release so you can fix them. This improves the quality of your work and preserves the image of the company as a whole in front of the end-users.* (Software engineer 2, Eta)						√	
Q18 [Referring to Q17 in Table 4 (email feedback on website design icons)]: *You are provided with new ideas like in this case a new way to place the icons, and this makes you change some of the code in order to try out these new designs in your work. You have to make it fast and prepare for the next deployment or the next release so these emails are good because they help you to learn how to do something in a different and better way.* (Software engineer 2, Eta)							√

Performance effects of system intrusions and actionable intrusions

Consistent with the log results, the interview data show that IT intrusions decrease individual performance and that technology's *parallelism* feature contributes to these effects (e.g. see Q9, Table 5). As another example, a Software Developer from Eta complained the following:

> *You know why our performance is affected*? *I'll tell you*. *We get interrupted all the time*. *Here I am*, *coding away*, *and then* '*Ding*'! *An email from some developer I don't even work with*, *asking for help. Before I have a chance to answer*, *a text message pops up about some other unimportant issue*; *and so on*, *and so forth*. *How can you focus on coding in this environment*?

Efficiency effects. System intrusions decreased efficiency by *consuming additional project time* (see Table 5). This occurred primarily through three interrelated patterns: (a) increasing task completion time; (b) task/project delays; and (c) task blocking. In the first pattern, individuals spent more time than planned to complete their primary project tasks. For example, Zeta's Distribution and Marketing Manager experienced system freezes when creating posters for film projects: '[If] it is a big picture it can take up to 10 minutes and then every time I save, it will be another 5 minutes…'. In some cases, significant increases in task completion time also led to the second pattern, namely task/project delays. For example, Delta's Chief technology officer (CTO) identified productivity issues that led to project slippage when developers migrating from C++ to a Python system continue supporting the old development tasks (Q1, Table 5). In other cases, task/project delays occurred independently because of intrusions compelling project members to prioritise and reschedule project tasks (Q2). Regarding the third pattern, we found that some project tasks could become completely blocked through the onset of system intrusions (Q3 and Q4).

The interviews indicate that *temporal switching costs* were incurred from actionable IT intrusions. Whilst system intrusions could also create such switching costs, this occurred in the relatively uncommon cases of long-lasting interruptions. For example, a software developer from Alpha incurred switching costs when he returned to his project tasks after spending half a day trying to resolve system issues and then having to figure out where he left off. By contrast, even brief actionable intrusions could trigger switching costs, owing to the interference generated by cognitively demanding secondary tasks. Project members reported that the problem was one of being taken away from project tasks that required deep focus, having to suppress cues associated with the tasks left behind to perform the interruptive tasks and then having to reactivate cues associated with the task to be resumed (Q5, Q6 and Q7). Individuals described the effects of such interruptions with terms such as 'losing the flow' (Director of post-production, Zeta), 'ramp-up time' (Senior software developer, Delta) and the difficulty to 'be back into the mood' (Head of planning and NPD, Theta). Such switching costs were especially salient with complex primary tasks (Software developer 2, Alpha), complex interruptive tasks (CTO, Delta) and creative tasks that require continuous flow (Director of post-production, Zeta).

In sum, the data show that both efficiency dimensions (structural and cognitive) were adversely affected by IT intrusions. A question that remained was how the effects of such events that occurred at the task level accumulated to a more aggregate level and influenced the individual's project work. We found four mechanisms through which system and actionable intrusions affect an individual's overall project efficiency: (a) accumulation over time; (b) accumulation over chains of activities; (c) accumulation over interruption phases; and (d) ripple effects across tasks. Firstly, detrimental effects on efficiency accumulated with increased intrusion frequency. As an NPD manager (Alpha) remarked, 'two minutes from one email, two minutes from another, so it adds up'. Secondly, effects accumulated over chains of activities set off by the initial interruption. An informant from Alpha said that email intrusions '[keep] on bouncing back and forth and the email becomes way too long. It just becomes a chain of email activity'. This is consistent with the prior research that conceptualises interruptions as clusters of activities following an initial attention switch (Okhuysen & Eisenhardt, 2002). Thirdly, intrusion costs accrued over response phases (McFarlane, 2002; Okhuysen & Eisenhardt, 2002) (e.g. some informants mentioned that just reading the email affected their productivity before even reacting to the message). Finally, there were ripple effects of the intrusions caused by task interdependency. As noted by an informant from Theta, 'it [system intrusion] ends up creating backlogs in other aspects of the product that are dependent on this being finished'. Based on the preceding analysis and the evidence summarised in Table 5, P1 and P2 are supported.

Effectiveness effects. Actionable intrusions debilitated performance *quality* and *learning*. System intrusions were not as cognitively demanding and did not explicitly insist on action. One informant stated that 'system issues like network failures and these sorts of interruptions have a time impact for sure, but they don't really affect the quality of work' (Software engineer 3, Eta). When system intrusions decreased quality, it was primarily due to the tools themselves being unavailable or not working properly (e.g. quality control tool defect) rather than their interruptive nature that interferes with the functioning of primary activities.

These negative effects required several facilitating conditions. Intrusions needed to reflect task switches that were unanticipated, demanding and insistent on action. Also, they needed to interrupt complex project tasks requiring deep focus (Q8 and Q9) and to occur at points in the task where no closure had been reached (Q10). With such mechanisms in place, actionable intrusions overwhelmed individuals as they juggled attention back and forth between the primary project tasks and the intrusions whilst having to suppress and reactivate cues that were associated with those tasks. This led to various performance problems, such as cognitive load (Q11), errors (Q8 and Q11), wrong decisions (Q11), lower ability to find solutions (Q9), decrease in creative output (Q10), decreased levels of understanding (Q9) and forgetfulness (Q11). This evidence – combined with the evidence in Table 5 – partially supports P3 and P4 (informants did not envision quality and learning effects for system intrusions).[10]

Performance effects of actionable interventions

Actionable interventions improved effectiveness but at the cost of efficiency. Several informants noted this trade-off (e.g. Table 5, Q13). A software developer from Alpha stated the following:

[10]Whilst the log results show a negative effect of system intrusions on effectiveness, this does not sufficiently support P3 and P4, given the small effect size relative to actionable intrusions, the small sample size, and the lack of support by the interview data.

> *Time and quality, they are connected* […] [*Actionable interventions*] *help you to fix the bug step-by-step and achieve a very good quality of code, but you lose on your time-to-market.*

Moreover, the *reviewability* feature of technology, which can be leveraged by mobile computing, is a strong contributor to the improved effectiveness effect. Delta's CTO observed the following:

> *One good thing about these* [*interventions*] *when they come* via *email is that you get a full record of the conversation so you always refer back to it. You can see it anywhere and anytime you wish, because you also have it on your Smartphone. And when you see a file and you see a description, it helps you limit the range of the problem and this helps a lot throughout the process.*

Efficiency effects. Actionable interventions did not influence the *cognitive dimension* of efficiency, because they did not switch attention to non-project activities. However, by aiming at improving primary task performance, they *consumed additional project time* as individuals dedicated time and effort to closing the discrepancy. This depended on the magnitude of the discrepancy. For small discrepancies, such as changing the colour of a product (Table 5, Q12) or the location of an icon (Q18), no significant effects on efficiency were reported. Conversely, larger discrepancies took more time to resolve (Q12 and Q13). They increased task completion time and/or introduced task/project delays as project members made sense of the discrepancy revealed by the intervention, and responded to the intervention to close the discrepancy. Firstly, efficiency decreased as individuals had to reflect and consciously think about what brought about a particular discrepancy. For example, a Product Manager in Gamma reported the following:

> *While the web analytics tool was still under development, we got some customer feedback on our Twitter site that told us the product was not capturing analytical data about their website visitors in the right way. We had no idea what was causing this and it took a while to troubleshoot. I had to freeze development for a while until this issue was fixed before releasing the next product iteration.*

Secondly, efficiency deceased as individuals mustered solutions to close the discrepancy. This often involved several iterations with clients and/or other stakeholders, and it sometimes required changes in planning or implementation strategy (Q12). Hence, P5 is supported.

Effectiveness effects. Actionable interventions enabled project members to improve their *work quality*, which translated to the final product being launched. Quality improved by interrupting individuals' ways of working and triggering a more mindful information processing mode. Three mindfulness mechanisms were salient: (a) informational; (b) motivational; and (c) reflective. Firstly, interventions provided critical information that reveals a discrepancy in some aspect of individuals' task performance, typically relating to product issues or features, and reoriented them toward the gap (Q14). Secondly, actionable interventions motivated and stimulated individuals to close the discrepancy (Q15). Thirdly, they triggered a more reflective information processing mode in which individuals became sensitised to new possibilities and integrated them into a better product solution (Q16).

New product development project members also reported learning benefits (Q18). Again, the *reviewability* feature was salient when members used specific IT tools to manage the interventions, such as bug reporting tools. Firstly, individuals used the feedback system as a knowledge repository, which helped cue their memories and effectively reuse knowledge from past interactions with the issue. Once interrupted with bug fixing requests for products they were developing, individuals could search the system's database for information that helped them better learn about the bug and ways to fix it. A Product Manager from Gamma stated the following:

> *The interaction with* [*name of tool*] *is very effective*; *it is like a super-notebook*. *It is an interruption I guess*, *but it is very positive because if it is not recorded you will probably forget the details*. *The list never gets lost and the tracking is very accurate*. *So we can go in there*, *search for an issue*, *find out the history*, *and through the process of fixing this issue we can actually relate it to the source code that was changed during the process*. *It is very powerful*.

Secondly, individuals used the system as a troubleshooting guide. As such, interruptions with product bugs were presented in visually and/or textually stimulating ways, which led them to better learn how to trace the problem, limit its range and address it in a step-by-step manner.

> *In the system there is a description of when and how it happens*; *like the customer was doing this operation with that file and the file is normally attached in the system and I can open it in my system and look what is going on there*. *So we have like breakpoints*; *control points where we can execute the program step-by-step*, *and I can qualify whether I am I right or not*. *So I find that the problem happened exactly in this place*. (Software developer 2, Alpha)

Hybrid interruptions: a continuum between intrusions and interventions

As we highlighted earlier, interruption events emerged from the log that could not be classified as intrusions or interventions (see Table 3). We further explored this phenomenon in the interviews. We discovered that between the two extreme types of the taxonomy, there is a continuum of interruption events that we refer to as *hybrid interruptions*.[11] Some of the events on this continuum concern interruptions that are relevant to the focal project, whilst others relate to the tasks within other projects in the individual's project portfolio. Hybrid interruptions are a mix of intrusions and interventions. They are partly intrusions because they divert attention from the focal primary tasks and partly interventions because they focus attention on other core areas of the individual's project portfolio. Attention is switched to process useful information on project issues

[11]We thank an anonymous reviewer for providing this insight on hybrid interruptions as a continuum of events.

(informational hybrid interruptions) or to execute communicative or material actions related to tasks within the project portfolio (actionable hybrid interruptions). For an interruption to be considered a hybrid, its content needs to focus on tasks other than the focal primary task, but it must also provide feedback that can be imported by individuals back into the primary task or to other tasks that fall within their project portfolio (see interview evidence in Table 6).

Informational hybrid interruptions

Project members described IT-mediated interruptions (mostly emails) that diverted attention from the focal primary tasks yet contained useful information about other NPD tasks from the current or from other projects. These consisted mostly of (1) status updates and information on NPD projects and (2) competitive intelligence. For example, some members provided internal updates, feedback and inspiration about product development issues (Q1 and Q2, Table 6). Others were external updates about competitors and market trends (Q2 and Q3).

Actionable hybrid interruptions

Actionable hybrid interruptions came mostly via email. Some interruptions focused on communicative actions (e.g. technical discussions about technologies and competition, Q5; information requests about past or future projects, Q6). Others elicited material actions relating to non-focal NPD tasks that were part of the focal project (Q7 and Q9) or other projects in the portfolio (e.g. software bug fixing requests, Q8 and Q10).

Exploring the performance effects of actionable hybrid interruptions

Because the extant literature focuses on interruptions to isolated tasks, it does not provide a solid ground from which to develop performance propositions for hybrid interruptions that affect tasks embedded in interrelated projects. Hence, we develop these propositions inductively. The log results (Table 3) show that the performance scores of actionable hybrid interruptions (3.44 for efficiency; 2.58 for effectiveness) fall in-between those of actionable intrusions (2.50; 1.26) and actionable interventions (4.10; 4.07). The scores are also closer to intrusions on the effectiveness dimension and to interventions on the efficiency dimensions. This seems to support the notion that these events are a hybrid of intrusions and interventions. Furthermore, the interview results show that actionable hybrid interruptions entail trade-offs between efficiency and learning, and influence the quality both positively and negatively (see Table 7 for key quotes).

Efficiency effects

Unlike the two extreme types, actionable hybrid interruptions exhibited no net negative effects on the structural dimension of efficiency. This is because whilst individuals shifted attention from the focal primary task and thus increased task completion time, this was offset by efficiencies resulting from load balancing because attention shifted to other tasks in the current project or project portfolio. There was thus no net increase in total project time. As a product designer from Epsilon observed on email interruptions concerning other tasks in the project portfolio,

Table 6. Data supporting the IT interruptions taxonomy – hybrid interruptions

Interruption type / subtype	Supporting evidence from interviews
Informational hybrid interruptions	**Q1** *I would say 30% of them* [referring to email interruptions] *provide some extra additional information for the project. Not just necessarily related to the current project but related to overall development* […] *They are work-related*. (Software developer 1, Alpha)
	Q2 *We would get interruptions that are for example inspirational. So we will get emails with pictures*: '*Oh, check this out! This is something happening*'. *So it does interrupt from the task I am working on at the moment but it is also part of the greater picture. This is sort of the direction we have so we have to look into it*. (Assistant product designer, Epsilon)
	Q3 *There are several email interruptions that provide updates on development stuff. Not necessarily stuff I am currently working on.* '*Have you seen these guys; how they do pricing? Have you seen these guys or the features?*' (Product strategist, Gamma)
	Q4 […] *you cannot focus on a contract which needs focused attention when you have a constant stream of email information coming in, even if that information is still about project-related stuff* […] (VP, Development and distribution, Zeta)
Actionable hybrid interruptions (communicative action)	**Q5** *A part of the interruptions I face come as emails with technical discussions that help me know about the competition, know about the existing new technologies and what people say about them* […] *These interactions are like forum discussions. One of us finds something new released so he posts it, we reply, everyone puts their opinion, we try it out, we suggest how we can do something better than the competition, all these kinds of things*. (Software engineer 2, Eta)
	Q6 [Referring to email interruptions about past or future projects]: *These things are mostly information requests, about what we have, what we do not have, when something will be completed, the format that it will be completed in, people looking for work trying to get on to the show*, etc. […] *Basically it is information about what is going on with the other shows so I am current on everything that is happening*. (Director of post-production, Zeta)
Actionable hybrid interruptions (material action)	**Q7** *Email is a big issue because we get a lot of emails on project-related stuff. I get everyday maybe 30/40 emails and all of them require attention. It is not like easy one-liners; you have to research and talk to people so for example if you are doing a task-at-hand, there is a lot of interruptions because you have to leave what you are doing and then go address that issue and that may involve communicating with retailers / merchandisers, researching 2 or 3 files electronically, emailing people up, you know.* (Assistant product designer, Epsilon)
	Q8 *Other email interruptions would be for products that are already released. So recent example we did integration with Google Analytics. So recently we get an email from* [product name] *clients saying that the data just doesn't make sense*. '*How come I am not seeing this data?*' […] *So if I get that then I will leave the stuff I am working on, go spend some time trying to investigate this, or I escalate again*. (Product strategist, Gamma)

(Continues)

Table 6. *(Continued)*

Interruption type / subtype	Supporting evidence from interviews
	Q9 [Referring to email interruptions]: *In some cases they can change the thing I am doing right now. You are working on this component and you have to switch to this component because it is urgent* […] *Sometimes you do not have the time or the luxury to look what you have actually done or to hibernate your state before switching to another state*. (Software engineer 1, Eta)
	Q10 *If for example you work on two big projects, one that is released and people are using it all the time and you are working on your next project, and all of a sudden they discover a failure or some problem in the released project, this will completely interrupt you from the current task you do. You have to jump back to the released project to fix this problem because it is used right now*. (Software engineer 1, Eta)

They help you do your work on this project or on other projects […] *So if you think about what is my task at hand, I am doing something so all that is sort of interrupting and taking time from what I am doing but this is also part of the bigger picture of what I am supposed to be doing*.

We found that project members incurred *temporal switching costs*. Firstly, they had to find themselves back in the primary task after switching attention to other projects or project components (Q1 and Q2, Table 7). Secondly, there were losses from switching to new projects that interjected their current task flow (Q3). Thirdly, project members (e.g. Zeta's Director of Post-Production) described temporal costs due to switching from the main task to tasks that were performed in the past such as backtracking to resolve issues about previously released movies. Some credited these switching costs to technology's *parallelism* feature.

At one point we were working with a single lead customer and at the same time we were getting demands for new features from other customers, and it was always emergencies. The amount of interruptions was incredible. It was coming from everywhere at the same time: telephone, e-mail, Excel sheets, everything […] *Our overall response time became slower to our customers and even to our own tasks because of the constant back and forth distraction*. (CTO, Delta)

Effectiveness effects

Actionable hybrid interruptions both benefitted and harmed individuals' *work quality*. For example, bug fix request emails provided insights on fixing product performance discrepancies (Q5, Q6, Q7 and Q8). Like actionable interventions, this effect played out via informational (Q5 and Q6), motivational (Q9) and reflective (Q7) mechanisms. However, project members also indicated that the intrusive nature of actionable hybrid interruptions increases cognitive load and debilitates quality (Q4), especially for creative work. Zeta's Post-Production Director found interruptions from other projects to break the creative flow of music production, which needed to be considered as one piece.

Table 7. New propositions for actionable hybrid interruptions

Supporting evidence		P7	P8a-b	P9
		Propositions suggested		
Actionable hybrid interruptions	**Q1** *With many email requests about other projects this can really distract you from your actual project and it takes time to find yourself back in*. (Software engineer, Eta)	(−)		
	Q2 *Here we have a lot, a lot, a lot of such email interruptions* [*relating to already released products*] *for a small company I find. You are running like a chicken without a head, you know. So it's just stuff like 'Using this tool, it is not working. Why?' Then you stop what you are doing and investigate* […] *I feel I get nothing done in the day, and then I struggle to get back into the high-level thinking. It is really hard to wear different hats all the time*. (Product strategist, Gamma)	(−)		
	Q3 *When the deadline is coming around and we suddenly get an email that ends up becoming another project on board everything stops. If I am juggling too much on my plate, everybody burns out* […] *My output ends up not being in the same timely fashion as if I did not have that application deadline and the market next week and a deliverable due tomorrow. It will also slow down the flow of my work*. (Distribution and Marketing manager, Zeta)	(−)		
	Q4 [Referring to same event as Q3]: *Of course the quality of my work will probably not be as strong as if I only had to work on the application or if I only had to work on the market* […] *When I am exhausted and I am overworked and just completely overwhelmed of course it will affect the quality.* (Distribution and Marketing manager, Zeta)		(−)	
	Q5 *Normally this kind of interruption when we get emails about bugs in released products is good. Yeah, it helps the quality of your performance because some of the issues might not be related to your immediate work* [*but*] *to other work or a third-party product that you plug yourself into. Normally web development has to be done and tested across all the browsers* […] *So when I get a bug like that it helps me gain the perspective of how that browser or that third-party software behaves and helps me enhance our product to support it in the future more across the different browsers*. (Software engineer 2, Eta)		(+)	
	Q6 [Referring to an interruption where she had to split attention between tasks comprising testing different product features]: *But I would also say that sometimes this would help the quality of the job. Because in your mind when you only work on a particular task, you probably have no knowledge for potential problems. But if you work on another one and they are similar and you get idea and you double check, so it gives you new knowledge that you can apply*. (Quality assurance specialist, Alpha)		(+)	(+)
	Q7 [Referring to email interruptions with bug fix requests]: *All of this, the purpose of it is to make the product better and by better I define that as clients like it better. So any disruptions that come from the client that you have to solve or react to enhancement so it forces a lot of thinking… forces you to*		(+)	(+)

(Continues)

Table 7. *(Continued)*

Supporting evidence	Propositions suggested P7	P8a-b	P9
evaluate what a client wants, then it corrects your thinking as you may have gone off […] *for a couple of months and maybe the market's moved a little bit and this allowed you to Litmus-test it*. (VP Marketing Research, Gamma)			
Q8 *Feedback on released products is always good, you know? Yes, it interrupts the tasks I am doing, but it also makes for better quality of my work for the next and other product releases and for new product iterations; enhancing the product and responding to clients' needs you know* […] *Many projects we do have commonality in terms of the user experience, usability comments, and stuff like that. So the next time around when you do another product you're like 'Aha!'* (Product strategist, Gamma)		(+)	(+)
Q9 [Referring to the effects of email interruptions about bugs in released products]: *It actually makes you in a way motivated to go back and discover the bug because in many cases it is your own bug so it puts your mind in an urgent state that wants you to completely leave the task you do and do the context switching we were speaking about and go back and fix it* […] *So it makes you motivated and it puts you in a learning mode*. (Software engineer 1, Eta)			(+)
Q10 [Referring to email interruptions triggering switching to other projects]: *Definitely I think as I do more and more you sort of build a better mousetrap and I become more efficient. I learn the tricks on how to get it done more efficiently. Although every project is different and it is always different people so there is different politics, which make it complicated, but there is a lot of crossover between the projects. I get the same request for three different projects and I have to figure out which is the best way to address all these requests. They are slightly different but they pertain to a lot of the same information. So there are ample opportunities for learning from these interruptions across projects*. (Director of Post-Production, Zeta)			(+)
Q11 [Referring to email interruptions relating to other projects in the portfolio]: *It is learning all the time. Even in urgent tasks. For example, if you are in the middle of development and the testing engineer emails you to request something for another project, this interrupts you, but it also may trigger something in your mind and you look at the issues from a different perspective. So these interruptions they widen your perspectives and your vision. That is the learning opportunity. Going ahead with this may open issues that you did not really consider in your core components even*. (Software engineer 1, Eta)			(+)

Like actionable interventions, actionable hybrid interruptions provided *learning opportunities* by orienting attention toward discrepancies and motivating individuals to learn new ways to close such discrepancies (Q9). Beyond these simple learning effects, they also allowed for cross-learning amongst NPD tasks and projects (Q6, Q8, Q10 and Q11).

Project members attached different values to the trade-offs between efficiency losses and learning gains. One product manager from Gamma reported that the time losses –

which were emphasised by the *parallelism* feature of the technology – were not worth the gain in learning.

> [Referring to bug fixes for other projects]: *For* [*a single issue we got so many interruptions*]: *an online meeting*, *two conference calls and 16 emails*. *And that is still ongoing*. *This is all just about a single customer issue for a free product*! […] *Some lessons learned yes but is it worth the time investment*? *I don't think so*.

A software engineer from Eta expressed the opposite value.

> [Referring to email interruptions about bugs in released products]: *It may affect my* [*time*] *performance but it is worth it*. *In an organization like* [*company name*], *if you fix some urgent bug you learn from it and you take credit for it and you may get your time reallocated to do whatever was delayed*.

We revisited the literature to provide theoretical grounding for our inductively developed propositions on actionable hybrid interruptions. Whilst these interruptions have not been studied explicitly, we found some evidence from adjacent literatures supporting their effects. For example, O'Leary *et al*., (2011) suggested that multiple team membership variety increases context switching, which is conducive to learning as a result of accessing new and diverse inputs that could be immediately integrated into primary task contexts. However, they also suggested that time losses resulting from switching to different task (and team) contexts decrease productivity. Furthermore, Miller, (2002) studied the group members working on a simulated radar control task who were given critical task-related information that was only needed for a future subtask. He found these interruptions to negatively influence productivity in terms of decision time as subjects had to 'start over' after the interruption whilst having mixed effects on the quality (accuracy) of the decision. We formulate the following propositions:

Proposition 7. Actionable hybrid interruptions are detrimental to the efficiency of NPD project members because they fragment attention between the primary task and other project activities, which incurs cognitive switching costs.

Proposition 8a. Actionable hybrid interruptions are beneficial to the work quality of NPD project members by enabling them to obtain insights about how to fix performance discrepancies.

Proposition 8b. Actionable hybrid interruptions are detrimental to the work quality of NPD project members by breaking the flow of their development work.

Proposition 9. Actionable hybrid interruptions are beneficial to the learning of NPD project members, because they (1) reorient their attention to areas of discrepancy in the performance of their primary tasks and (2) enable learning across NPD tasks and projects.

Summary of results

We found a preliminary support for our IT interruptions taxonomy and the propositions linking three IT interruption subtypes to individual performance. As shown in Table 8, which summarises the results of the deductive and inductive analyses, the two intrusion subtypes decreased efficiency (system intrusions influenced only the project time dimension). Additionally, actionable intrusions were detrimental to quality and learning. Conversely, actionable interventions improved performance outcomes, albeit whilst consuming additional project time. The effects of hybrid interruptions fell in-between the extreme types. Specifically, they decreased efficiency, enabled various types of learning within and across projects and produced both beneficial and detrimental effects on quality.

DISCUSSION AND CONCLUSION

Contributions and implications for theory

This paper makes three contributions: conceptualising IT interruptions and developing a content-based taxonomy of IT interruptions; using the taxonomy to preliminarily examine the effects of IT interruptions subtypes on individual performance; and uncovering a new continuum of hybrid interruptions. We discuss these contributions and their resulting implications on the succeeding paragraphs.

Taxonomy of IT interruptions

Information systems research on IT interruptions is limited. Also, most existing studies do not conceptualise IT interruptions and/or do not classify them into separate categories. This is

Table 8. Summary of effects

	Efficiency			
Interruption type/ performance effect	Structural costs	Cognitive switching costs	Quality	Learning
System intrusions	Detrimental: project time consumption (P1 supported)	No effect	No effect (P3 partially supported)	No effect (P4 partially supported)
Actionable intrusions	Detrimental: project time consumption (P2a supported)	Detrimental: fragments attention (P2b supported)	Detrimental: more errors (P3 partially supported)	Detrimental: memory retrieval issues (P4 partially supported)
Actionable interventions	Detrimental: project time (P5 supported)	No effect	Beneficial: fix discrepancies (P6a supported)	Beneficial: learn about discrepancies (P6b supported)
Actionable hybrid interruptions	No effect	Detrimental: fragments attention (P7)	•Beneficial: fix discrepancies (P8a) •Detrimental: more errors; loose creative flow (P8b)	Beneficial: learn about discrepancies; cross-learning (P9)

problematic because IT interruption types can entail different characteristics and outcomes. This study conceptualised IT interruptions and classified them into a taxonomy by combining two content-based dimensions. The taxonomy provides a consistent understanding of the nature and effects of the different IT interruptions subtypes. This improved understanding has a direct implication for researchers to not view IT interruptions as a monolithic, mostly negative event. Additionally, it enhances their ability to accumulate and integrate past findings on IT interruptions. The taxonomy also creates a foundation for future research by serving as a useful tool for the systematic examination of various IT interruption subtypes and their nomological network (antecedents; consequences; moderation/mediation effects).

Finally, our taxonomy creates the foundation upon which IT interruptions and their impacts can be quantified, by providing an appropriate content domain for developing operational measures. For example, IT intrusions and interventions can be operationalised by asking survey respondents about the content relevance of emails (or text messages) that interrupt their primary tasks. To operationalise the content structure, respondents can be asked to report the incidents in which the interrupting emails require them to read (informational), respond to (communicative action) or act upon (material action) the incoming email. Researchers can use this operationalisation to relate specific properties of the IT interruption subtypes to individual performance and other outcomes. Such quantification of our taxonomy provides an important extension of our work by allowing researchers to develop and use these measures to tap into the nomological network surrounding the IT interruption taxonomy.

Performance effects of IT interruptions

To further assess the efficacy of our taxonomy, we designed an empirical study to establish the existence of the taxonomy subtypes and provide initial insights into the relative effects of some subtypes on individual performance. We found that IT interruption subtypes have different effects on performance depending on the particular content of the event, its relation to the primary task and the performance measures used. Our framework can be enhanced and refined and applied to other organisational contexts (e.g. managerial work).

We also showed that technology features can shape the effects of IT interruptions. Firstly, our results show that slow, complex or buggy systems create an IT-induced intrusion that draws attention away from the task and negatively affects performance. Secondly, for human-generated interruptions, technology can play a role through three material features: *multimodal alerts*, *parallelism* and *reviewability*. As our results suggest, the first two features are especially salient for IT intrusions by intensifying their effects and overloading cognitive attention. Conversely, *reviewability* takes a more dominant, positive role with IT interventions, and its effects are reinforced via mobile computing technologies. Thirdly, we also found that for IT interventions, the IT medium can limit social contextual cues and maintain attention on performing/adjusting the task-at-hand rather than divert it to situational issues. A software developer from Alpha said the following:

> *It really makes a difference whether you receive the task feedback by email or face-to-face. You have to understand that the quality of the technical solutions can depend on the style of the manager. When there is a problem in your code you really want to fix it, but if the*

product manager puts too much attention to it, you will turn to self-defense mode rather than focus on the problem and its solution. When the situation is handled face-to-face, there are often many emotions involved. You become nervous. There is also the issue of pride. But when the feedback interruption comes in an email or through a bug fixing software, you can better concentrate on actually fixing the bug.

Finally, another effect of the technology is the broadcasting feature of email that increases the frequency of interruptions. Several informants told us about the large number of informational intrusions they received in the form of irrelevant emails that were copied on as a way for the senders to 'cover their own backs'.

Hybrid interruptions as the 'grey' side of IT use

Existing information systems research mostly considers the *bright* side of intended IT usage. Through this research, we focus on the unintended aspects of such usage as characterised by IT interruptions. With the help from our taxonomy and insights from attention allocation theory, we showed that IT interruptions can have both a *bright* side (IT interventions) and a *dark* side (IT intrusions). But as with many social phenomena, reality is more complex and presents us with a *grey* side that is reflected by hybrid IT interruptions. These interruptions emerged from the data were found to be very prevalent and were in fact part of the job description in dynamic environments where individuals constantly shift attention amongst related project tasks. As we argued, the hybrid interruptions entail both positive and negative performance consequences.

In this paper, we distinguished IT intrusions, IT interventions and hybrid interruptions in terms of the interruptive event's relation to the primary tasks within an individual's project portfolio (see Figure 2). Because prior research examined singular primary tasks (i.e. there were no non-focal primary tasks), the hybrid interruptions continuum was concealed because any interruption that was unrelated to the primary task being performed was considered an intrusion. By adjusting the lens to the project level, this research provides a more nuanced perspective and articulates a continuum of hybrid interruptions (the B circles in Figure 2) that are related to non-focal primary activities. This suggests that it is critical to conceptualise IT interruptions within the context of the interrupted individual. Stated differently, interruptions are in the 'eye of the beholder'. Whilst in prior research, interruptions largely occurred in the context of isolated tasks and were artificially imposed; this study suggests that an individual's task boundaries have a direct influence on how one perceives the nature and consequences of one's interruptions. If one's task responsibilities are defined too narrowly, many interruptions that are not directly related to such tasks will be perceived as intrusions. By expanding the task's boundaries, intrusions take on a more extreme position outside of the project's boundaries, and a new continuum of *hybrid* interruptions appears in-between intrusions and interventions.

Consequently, whether a given interruption has a positive or negative consequence will depend on specifying the individual's task boundaries and performance domain (e.g. whether performance is assessed for an individual task or for an overall project). One implication of this is for researchers to consider interruptions at a broader level such as the project level, as well as to potentially adopt an interpretive view of IT interruptions (i.e. to consider them as socially constructed events rather than objective artefacts manipulated in the laboratory).

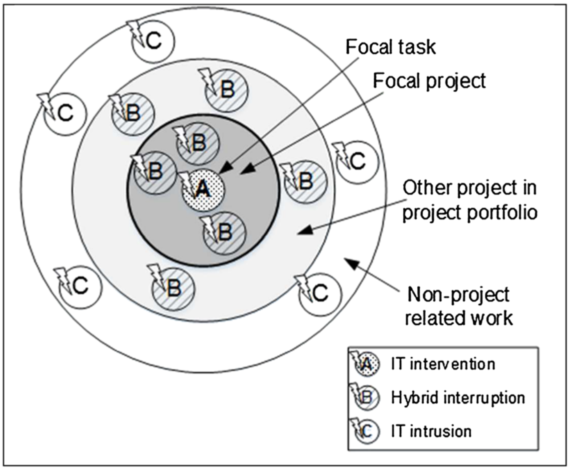

Figure 2. Representation of the different types of IT interruptions.

Our results must be interpreted with caution, as they apply within the context we studied, which involved complex, interdependent tasks that are embedded in larger projects. For some simple tasks, some informants welcomed intrusions and perceived no negative effects from them. This also applied to some tasks with very low dependence on other tasks (which occurred rarely) in which case intrusions provided a chance for some individuals with particular cognitive styles to take time away from the task and find inspiration when reaching an impasse. Moreover, task interdependence allowed us to observe the cross-learning effects of IT interventions. Finally, whilst our log study shows robust results of IT interventions across the two job categories but that the two categories differed with respect to which IT intrusion subtypes were more disruptive to efficiency, these results must also be viewed cautiously because of the small number of participants from each category.

Implications for practice

Our results have important practical implications. Firstly, without a well-developed taxonomy, it is difficult for managers to understand how the myriad IT interruptions that occur in their organisations resemble or differ from each other. Evidence shows that for most managers and professionals, interruptions have a negative connotation (Hemp, 2009). Our taxonomy alerts managers that not all interruptions are equal, and enables them to differentiate between various IT-based interruptions. This framework becomes especially valuable when quantified, as we suggest in the previous section. Consequently, managers can precisely measure various interruption properties in the units (e.g. frequencies and durations of informational/actionable intrusions and interventions). Such precise measurement is a first step to understanding the different types of IT interruptions that occur and their differential impacts on performance.

A second contribution of our work for managers is the realisation that interruptions (both intrusions and interventions) mean that individuals will take more time to complete their tasks. However, it is important to note that the time lost because of intrusions is not compensated by gains in quality or learning. In fact, intrusions are also detrimental to both quality and learning. On the contrary, whilst interventions also mean that efficiency is reduced, they are associated with gains in learning (i.e. fixing discrepancies) and in quality of work. This suggests that from an individual performance perspective, managers should try to limit or control the occurrence of intrusions as much as possible whilst leveraging the benefits of interventions at minimal efficiency costs. Simple tactics to deal with intrusions such as asking individuals to clearly indicate when they can and when they should not be interrupted can help alleviate the negative effects of intrusions. For example, some organisations have institutionalised the notion of 'quiet time' (e.g. (Perlow, 1999)) to make sure that tasks requiring intense, uninterrupted attention (e.g. complex, creative tasks) would not be interrupted. Alternatively, asking individuals to deal with interruptions in batch rather than in real time can limit the negative effects of switching costs inherent to intrusions. If the context of work makes it difficult to prevent intrusions, managers and workers can organise their tasks to minimise the effects. For example, individuals facing frequent IT intrusions can try to subdivide their tasks in such a way that their components have low interdependence. This would reduce the task switching and resumption costs. Similarly, to get the benefits of IT interventions and limit their effects on efficiencies, managers can create time periods when feedback provision is likely to be critical, but the efficiency lost is likely to be minimal, for example at the junction of two tasks.

Thirdly, our results alert managers to the important role played by technology's features. For example, intrusions become all the more disruptive because of IT's parallelism and multimodal alerts features. By contrast, because of its reviewability feature, using IT media to deliver interventions may be quite effective in situations where individuals need to be reminded of the feedback content and/or require a full record of the content to use it for knowledge access or reuse. Using IT media as a source of feedback interventions can also limit social contextual cues, which may be beneficial in situations where the feedback is sensitive or emotionally charged, to maintain attention focus on the intervention content. However, managers need to be aware that this may not always be desirable, as IT-delivered interventions also mean that there is a loss of face-to-face interaction with managers and other sources of feedback. Managers need to know how to manage the trade-offs between these gains and losses that likely depend on various factors such as the style and mood of the feedback provider/recipient, the nature of the interruption and task, etc. This also has implications for designing feedback mechanisms to contain technology and/or face-to-face components (or both) based on the characteristics of the task and individual.

Fourthly, our results invite managers to align their interruption management policies to the evaluation systems they use (i.e. whether employees are compensated for individual tasks or projects, a portfolio of projects or their overall work). For example, when employees are compensated more for individual output (e.g. (Perlow, 1999)), managers can use some of the tactics we described earlier for controlling intrusions to their individual employees. But when it is more important to evaluate the overall work output rather than individual tasks, managers can adopt a more tolerant policy allowing individuals to be interrupted by information requests that are less relevant for them but important for the overall work. Managers' choice of how to evaluate performance can thus influence how IT interruptions are perceived by individuals.

Limitations and future research

This paper has limitations that create opportunities for future research. Firstly, our method is subject to biases (e.g. recall bias; impression management). As described earlier, we applied multiple steps to limit their effects in the interviews and log responses. Another source of bias in the log is due to the act of filling the log, which may be seen as an actionable interruption. We limited the effects of this bias by designing a short, simple, non-obstructive log, which we asked the respondents to print to limit attention switching. Moreover, by asking the respondents to record interruptions promptly upon occurrence, this likely resulted in slightly increasing total interruption duration whilst reducing total interruption frequency (i.e. less overall net disruptive effect).

Secondly, our finding that intrusions are always negative points to a limitation of our approach, which focuses on a specific level of analysis (the individual level), and a particular context (individuals working on complex interdependent project tasks). Indeed, research at the dyadic level found that some intrusions (e.g. information requests) have positive effects on the interrupter (e.g. information seeker) (e.g. (Dabbish & Kraut, 2004)). Similarly, intrusions may have positive consequences in other organisational contexts, such as in low latency situations involving real-time fraud detection, when timely information is valued. As the work context and how we deal with technology evolve, interruptions will need to be studied at broader levels of analysis (e.g. the organisational level) using broader theoretical and/or contextual perspectives. This can further enhance our understanding of the various costs and benefits of IT interruptions and their net effects on organisation performance.

Thirdly, we provided a preliminary test of the taxonomy by directly relating IT interruption subtypes to individual performance. However, the relationships between these constructs are probably much more complex. As this emerging area matures, it will become important to extend and refine our framework by applying it within a more complete nomological network. One way of achieving this is to develop a research model that links our IT interruption subtypes to individual performance whilst including the mediating and moderating factors. One potential mediating factor may be subjective workload that is increased by IT intrusions (Adamczyk & Bailey, 2004) and that in turn may debilitate individual performance as overloaded individuals with limited attentional resources become obliged to dismiss task relevant cues (Kahneman, 1973). As for moderating effects, it will be important to address potential factors that relate both to the interruption source (e.g. position power; cf. Gupta *et al.*, 2013a) and the interruption target (e.g. perceived control; cf. (Cameron & Webster, 2013)).

Fourthly, our research can be extended by comparing IT interruptions with other related phenomena, such as non-IT interruptions (e.g. face-to-face) and IT distractions created by the environment, and by unpacking the source of the interruption (e.g. manager vs. coworker; cf. (Gupta *et al.*, 2013a)). These extensions can shed more light on the IT interruptions and their impacts and how their effects resemble or differ from those of related events.

Other areas for future research remain. One important area concerns the role of mobile computing that likely complicates the effects of IT interruptions. For example, it is possible that mobile computing may reduce the frequency and impacts of IT intrusions because many such intrusions can be handled in non-work hours. For interventions, mobile devices may enhance the positive effects by leveraging the *reviewability* feature and allowing individuals to maintain focus on closing the discrepancy anywhere and anytime (as our results suggest). For hybrid interruptions, mobile computing allows individuals to accomplish project-related tasks in non-official work hours, but individuals may not have undivided attention during those hours. More research is needed to uncover the corresponding effects on performance.

A final research avenue is to investigate the performance effects of IT interruption subtypes across job categories. Our initial log study results, which must be interpreted cautiously, indicate that IT-mediated intrusions may be more disruptive to the efficiency of working professionals, whereas IT-induced intrusions may be more disruptive to academics' work efficiency. The former result may suggest that academics are better multitaskers than working professionals, which needs to be theoretically and empirically examined. The latter result may be due to the fact that most working professionals in our sample were product developers who worked in team environments and who – unlike the academics – had access to team coordination mechanisms to mitigate the effects of system failures and issues. For example, some informants identified two such strategies: resource sharing (using the system resources of coworkers, if they were running) and task shifting (reallocating employee to other project-related tasks that do not require the missing or dysfunctional resources).

The framework proposed in this paper represents a step toward a better understanding of the multidimensional phenomenon of IT interruptions and their various effects on individual performance. It is hoped that this research provides an impetus for further research in this important yet underresearched domain.

REFERENCES

Adamczyk, P.D. & Bailey, B.P. (2004) If not now, when? The effects of interruption at different moments within task execution. In: Proceedings of the CHI Conference on Human factors in Computing Systems, Vienna, Austria.

Addas, S. & Pinsonneault, A. (2013) Electronic messaging interruptions and individual performance: a tale of two interruption types, working paper.

Ang, S., Cummings, L.L., Straub, D.W. & Earley, P.C. (1993) The effects of information technology and the perceived mood of the feedback giver on feedback seeking. *Information Systems Research*, **4**, 240–261.

Bailey, B.P. & Konstan, J.A. (2006) On the need for attention-aware systems: measuring effects of interruption on task performance, error rate, and affective state. *Computers in Human Behavior*, **22**, 685–708.

Bailey, B.P., Konstan, J.A. & Carlis, J.V. (2001) The effects of interruptions on task performance, annoyance, and anxiety in the user interface. In: Proceedings of the 8th IFIP International Conference on Human-Computer Interaction (INTERACT 2001), Tokyo, Japan.

Barley, S.R., Meyerson, D.E. & Grodal, S. (2011) E-mail as a source and symbol of stress. *Organization Science*, **22**, 887–906.

Baron, R.S. (1986) Distraction-conflict theory: progress and problems. *Advances in Experimental Social Psychology*, **19**, 1–40.

Bellotti, V., Ducheneaut, N., Howard, M., Smith, I. & Grinter, R.E. (2005) Quality versus quantity: e-mail-centric task management and its relation with overload. *Human–ComputerInteraction*, **20**, 89–138.

Brixey, J.M., Walji, M., Zhang, J., Johnson, T.R. & Turley, J. P. (2004) Proposing a taxonomy and model of interruption. In: Proceedings of the 6th International Workshop on Enterprise Networking and Computing in the Healthcare Industry (Healthcom 2004), Odawara, Japan.

Cameron, A.-F. & Webster, J. (2013) Multicommunicating: juggling multiple conversations in the workplace. *Information Systems Research*, **24**, 352–371.

Campion, M.A. & Lord, R.G. (1982) A control systems conceptualization of the goal-setting and changing process. *Organizational Behavior & Human Performance*, **30**, 265–287.

Carton, A.M. & Aiello, J.R. (2009) Control and anticipation of social interruptions: reduced stress and improved task performance. *Journal of Applied Social Psychology*, **39**, 169–185.

Cutrell, E.B., Czerwinski, M. & Horvitz, E. (2000) Effects of instant messaging interruptions on computing tasks. In: Proceedings of the CHI Conference on Human Factors in Computing Systems, The Hague, Netherlands.

Czerwinski, M., Cutrell, E. & Horvitz, E. (2000) Instant messaging: effects of relevance and time. In: Proceedings of HCI, Sunderland, UK.

Dabbish, L.A. & Kraut, R.E. (2004) Controlling interruptions: awareness displays and social motivation for coordination. In: Proceedings of the ACM Conference on Computer Supported Cooperative Work, Chicago, IL.

Dabbish, L.A. & Kraut, R.E. (2008) Research note - awareness displays and social motivation for coordinating communication. *Information Systems Research*, **19**, 221–238.

Dabbish, L.A., Kraut, R.E., Fussell, S. & Kiesler, S. (2005) Understanding email use: predicting action on a message. In: Proceedings of the SIGCHI conference on Human factors in computing systems, Portland, OR.

Dennis, A.R., Fuller, R.M. & Valacich, J.S. (2008) Media, tasks, and communication processes: a theory of media synchronicity. *MIS Quarterly*, **32**, 575–600.

Ducheneaut, N. & Bellotti, V. (2001) E-mail as habitat: an exploration of embedded personal information management. *Interactions*, **8**, 30–38.

Earley, P.C. (1988) Computer-generated performance feedback in the magazine-subscription industry. *Organizational Behavior and Human Decision Processes*, **41**, 50–64.

Earley, P.C., Northcraft, G.B., Lee, C. & Lituchy, T.R. (1990) Impact of process and outcome feedback on the relation of goal setting to task performance. *Academy of Management Journal*, **33**, 87–105.

Easterbrook, J.A. (1959) The effect of emotion on cue utilization and the organization of behavior. *Psychological Review*, **66**, 183–201.

France, D.J., Levin, S., Hemphill, R., Chen, K., Rickard, D., Makowski, R., *et al.* (2005) Emergency physicians' behaviors and workload in the presence of an electronic whiteboard. *International Journal of Medical Informatics*, **74**, 827–837.

Gievska, S., Lindeman, R. & Sibert, J. (2005) *Examining the qualitative gains of mediating human interruptions during HCI*. In: Proceedings of the 11th International Conference on Human-Computer Interaction, Las Vegas, NV.

Goldkuhl, G. (2001) Communicative vs material actions: instrumentality, sociality and comprehensibility. In: Proceedings of the Sixth International Workshop on the Language-Action Perspective on Communication Modelling (LAP 2001), Montreal, Canada.

Gupta, A., Li, H. & Sharda, R. (2013a) Should I send this message? Understanding the impact of interruptions, social hierarchy and perceived task complexity on user performance and perceived workload. *Decision Support Systems*, **55**, 135–145.

Gupta, A., Sharda, R., Dong, Y., Sharda, R., Asamoah, D. & Pickering, B. (2013b) Improving rounding in critical care environments through management of interruptions. *Decision Support Systems*, **55**, 516–527.

Hemp, P. (2009) Death by information overload. *Harvard Business Review*, **87**, 82–82.

Ho, J. & Intille, S.S. (2005) Using context-aware computing to reduce the perceived burden of interruptions from mobile devices. In: Proceedings of the CHI Conference on Human Factors in Computing Systems, Portland, OR.

Ilgen, D.R., Fisher, C.D. & Taylor, M.S. (1979) Consequences of individual feedback on behavior in organizations. *Journal of Applied Psychology*, **64**, 349–349.

Iqbal, S.T. & Horvitz, E. (2007) Disruption and recovery of computing tasks: field study, analysis, and directions. In: Proceedings of the CHI Conference on Human Factors in Computing Systems, San Jose, CA.

Jackson, T., Dawson, R. & Wilson, D. (2003) Reducing the effect of email interruptions on employees. *International Journal of Information Management*, **23**, 55–65.

Jett, Q.R. & George, J.M. (2003) Work interrupted: a closer look at the role of interruptions in organizational life. *Academy of Management Review*, **28**, 494–507.

Kahneman, D. (1973) Attention and Effort. Prentice Hall, Englewood Cliffs, NJ.

Kapitsa, M. & Blinnikova, I. (2003) Task performance under the influence of interruptions. In: Operator Functional State: The Assessment and Prediction of Human Performance Degradation in Complex Tasks, pp. 323–329. IOS Press, Amsterdam, Netherlands.

Karr-Wisniewski, P. & Lu, Y. (2010) When more is too much: operationalizing technology overload and exploring its impact on knowledge worker productivity. *Computers in Human Behavior*, **26**, 1061–1072.

Kettinger, W.J. & Grover, V. (1997) The use of computer-mediated communication in an interorganizational context. *Decision Sciences*, **28**, 513–555.

Kluger, A.N. & DeNisi, A. (1996) The effects of feedback interventions on performance: a historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin*, **119**, 254–284.

Langer, E.J. (1989) Mindfulness. Addison-Wesley, Reading, MA.

Latorella, K.A. (1999) Investigating interruptions: implications for flightdeck performance, *Industrial Engineering Department*, Unpublished Doctoral Dissertation, State University of New York, NASA Center for AeroSpace Information (CASI).

Louis, M.R. & Sutton, R.I. (1991) Switching cognitive gears: from habits of mind to active thinking. *Human Relations*, **44**, 55–76.

McCrickard, D.S., Catrambone, R., Chewar, C.M. & Stasko, J.T. (2003) Establishing tradeoffs that leverage attention for utility: empirically evaluating information display in notification systems. *International Journal of Human-Computer Studies*, **58**, 547–582.

McDaniel, M.A., Einstein, G.O., Graham, T. & Rall, E. (2004) Delaying execution of intentions: overcoming the costs of interruptions. *Applied Cognitive Psychology*, **18**, 533–547.

McFarlane, D.C. (1997) Interruption of people in human-computer interaction: a general unifying definition of human interruption and taxonomy, In *NRL Formal Report*Naval Research Laboratory, Washington, DC.

McFarlane, D.C. (2002) Comparison of four primary methods for coordinating the interruption of people in human-computer interaction. *Human-Computer Interaction*, **17**, 63–63.

Middleton, C.A. (2007) Illusions of balance and control in an always-on environment: a case study of BlackBerry users. *Journal of Media & Cultural Studies*, **21**, 165–178.

Miller, S.L. (2002) Window of opportunity: using the interruption lag to manage disruption in complex tasks. In: Proceedings of the 46th Annual Meeting of the Human Factors and Ergonomics Society, Baltimore, MD.

Monk, C.A., Trafton, J.G. & Boehm-Davis, D.A. (2008) The effect of interruption duration and demand on resuming suspended goals. *Journal of Experimental Psychology*, **14**, 299–313.

O'Conaill, B. & Frohlich, D. (1995) Timespace in the workplace: dealing with interruptions. In: Proceedings of the CHI Conference on Human Factors in Computing Systems, Denver, CO.

Okhuysen, G.A. & Eisenhardt, K.M. (2002) Integrating knowledge in groups: how formal interventions enable flexibility. *Organization Science*, **13**, 370–386.

O'Leary, M.B., Mortensen, M. & Woolley, A.W. (2011) Multiple team membership: a theoretical model of its effects on productivity and learning for individuals and teams. *Academy of Management Review*, **36**, 461–478.

Oulasvirta, A. & Saariluoma, P. (2004) Long-term working memory and interrupting messages in human-computer interaction. *Behaviour & Information Technology*, **23**, 53–64.

Patton, M.Q. (2002) Qualitative Research and Evaluation Methods. Sage Publications, Thousand Oaks, CA.

Perlow, L.A. (1999) The time famine: toward a sociology of work time. *Administrative Science Quarterly*, **44**, 57–81.

Ratwani, R.M., Andrews, A.E., McCurry, M., Trafton, J.G. & Peterson, M.S. (2007) Using peripheral processing and spatial memory to facilitate task resumption. In: Proceedings of the 51st Annual Meeting of the Human Factors and Ergonomics Society, Baltimore, MD.

Robertson, T.J., Prabhakararao, S., Burnett, M., Cook, C., Ruthruff, J.R., Beckwith, L. & Phalgune, A. (2004) Impact of interruption style on end-user debugging. In: Proceedings of the CHI conference on Human Factors in Computing Systems, Vienna, Austria.

Rukab, J.A., Johnson-Throop, K.A., Malin, J. & Zhang, J. (2004) A framework of interruptions in distributed team environments. *Studies in Health Technology and Informatics*, **107**, 1282–1286.

Sitzmann, T., Ely, K., Bell, B.S. & Bauer, K.N. (2010) The effects of technical difficulties on learning and attrition during online training. *Journal of Experimental Psychology: Applied*, **16**, 281–292.

Speier, C., Valacich, J.S. & Vessey, I. (1997) The effects of task interruption and information presentation on individual decision making. In: Proceedings of the 18th International Conference on Information Systems, Atlanta, GA.

Speier, C., Vessey, I. & Valacich, J.S. (2003) The effects of interruptions, task complexity, and information presentation on computer-supported decision-making performance. *Decision Sciences*, **34**, 771–797.

Szalma, J.L., Hancock, P.A., Dember, W.N. & Warm, J.S. (2006) Training for vigilance: the effect of knowledge of results format and dispositional optimism and pessimism on performance and stress. *British Journal of Psychology*, **97**, 115–135.

Weick, K.E. (1990) Technology as equivoque: sensemaking in new technologies. In: Technology and Organizations, Goodman, P.S. & Sproull, L.S. (eds.), pp. 1–44. Jossey-Bass, San Francisco, CA.

Wickens, C.D. (2002) Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science*, **3**, 159–177.

Woolley, A.W. (1998) Effects of intervention content and timing on group task performance. *Journal of Applied Behavioral Science*, **34**, 30–46.

Yin, R.K. (2009) Case Study Research, Design and Methods. Sage Publications, Newbury, CA.

Zellmer-Bruhn, M.E. (2003) Interruptive events and team knowledge acquisition. *Management Science*, **49**, 514–528.

Zijlstra, F.R.H., Roe, R.A., Leonora, A.B. & Krediet, I. (1999) Temporal factors in mental work: effects of interrupted activities. *Journal of Occupational and Organizational Psychology*, **72**, 163–185.

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