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You’ve got email! Does it really matter to process emails now or later?

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Abstract Email consumes as much as a quarter of knowledge workers’ time in organizations today. Almost a necessity for communication, email does interrupt a worker’s other main tasks and ultimately leads to information overload. Though issues such as spam, email filtering and archiving have received much attention from industry and academia, the critical problem of the timing of email processing has not been studied much. It is common for many knowledge workers to check and respond to their email almost continuously. Though some emails may require very quick responses, checking emails almost continuously may lead to interruptions in regular knowledge work. Managing email processing can make a significant difference in an organization’s productivity. Previous research on this topic suggests that perhaps the best way to minimize the effect of interruptions is to process email frequently for example, every 45 min. In this study, we focus on studying email response timing approaches to optimize the communication times and yet reduce the interruptive effects. We investigate previous recommendations by performing a two-phase study involving rigorous simulation experiments. Models were developed for identifying efficient and effective email processing policies by comparing various ways to reduce interruptions for different types of knowledge workers. In contrast to earlier research findings, results indicate that significant productivity improvements could be achieved through the use of some email processing policies while helping attain a balance between email response time and task completion time. Findings also suggest that the best policy may be to respond to email two to four times a day instead of every 45 min or continuously, as is common with many knowledge workers. We conclude by presenting many research opportunities for analytical and organizational IS researchers.

Keywords Email management · Interruption · Performance · Simulation modeling

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1 Introduction

Emails have become increasingly necessary for communicating and exchanging information as we have migrating towards always-on and geographically dispersed but digitally connected workplaces. The benefits of using emails and the associated productivity gains are well documented in the literature. However, managers and researchers are now beginning to see the flip side of excessive reliance on emails. For example, Weber (2004) in his MIS Quarterly editorial recognizes the need for better understanding of problems associated with email. Still another editorial note (Whittaker et al. 2005) calls for more research on preparing email for new business realities.

One challenge, among several others, that knowledge workers are facing is managing the high volume of emails on a timely basis, in the most efficient and effective manner. Due to increased volumes, workers are spending more time on emails than they did in the past. A survey of 840 organizations reports that 47% of their workers spend 1–2 h, and 34% spend more than 2 h on any given workday processing email (American Management Association 2004). This is causing several problems. First, it leads to a perception of a shortage of time thereby resulting in information overload (Dennings 1982; Markus 1994; Berghal 1997; Jackson et al. 2003). Second, it leads to bounded rationality as knowledge workers have limited time and resources available to make decisions and complete their tasks, since too many emails are vying for the knowledge workers' attention. Many policies aimed at reducing email overload have been suggested. These policies usually involve eliminating any unnecessary email transmissions. This is typically accomplished with filtering software or could take the form of policies limiting the use of the carbon copy field. Implementing prioritization schemes so that time sensitive messages receive their proper attention is yet another strategy employed.

In this study we focus on policies that look at the timing of email processing. Knowledge workers often use audible and visual notifications such as messengers and have the tendency to respond to messages as soon as emails arrive (Jackson et al. 2003). This often results in the interruption of ongoing tasks. Jackson's study suggests that although the time lost due to each email interruption may be small, the cumulative effect can become sufficiently large given that an organization is comprised of several knowledge workers, each receiving dozens of emails in need of processing each day. To cope up with this, Jackson et al. (2003) suggested that knowledge workers limit the checking of email messages to once every 45 min. The impact of email interruptions is more likely to be felt by the receivers of email, rather than the senders, because senders usually originate new emails during their naturally occurring breaks or at times that suit them.

One frequently touted benefit of email is its asynchronous nature or the ability to process messages at a convenient time. We are often instead using it much like any synchronous communication tool such as the telephone or chat. By using email like a telephone, knowledge workers lose the key benefit of email (its asynchronous nature) and accept additional interruptions to other important activities. That being said, a tradeoff clearly exists between interruptions and potentially slow responses.

The prime issue that we consider in this study is what timing-based email processing policies enable knowledge workers to *effectively* allocate their attention. We hope to bring to light policies that mitigate the negative impact of email interruptions (non-value added time resulting from interruptions to workflow) without significantly compromising the time required to resolve email messages.

Ideally we may think of knowledge workers as self-learning agents who will determine the ideal email processing policy from their past experience but, as is evident from several recently published reports and studies, this does not seem to be the case. Perhaps most knowledge workers act as irrational agents by processing emails as soon as they arrive, in spite of being aware of the interruptions! This is similar to the example of driving too fast. Even though people are aware that driving fast is irrational and dangerous. However, they still drive fast. Controlled driving can help reach the destination safely but with a tradeoff in terms of time. By selecting a specific time frame or frames dedicated to email, and not answering email outside of this time frame, can we control email's interruptive nature, without compromising on our ability to resolve email messages in a timely manner?

The argument here is not that knowledge workers should refrain from processing emails as they lead to interruptions. Another argument is that knowledge workers do not feel they are being interrupted by emails, since emails are very much a part of their regular tasks and that much of the work is facilitated through emails. The issue that we are trying to address in this study is the following. Irrespective of how well emails get woven into the fabric of our always-on, geo-dispersed work environment, knowledge workers still have to switch between tasks and emails and therefore spend unproductive time resuming interrupted tasks once email processing is complete. We are trying to consider possible solutions to reduce this time loss, given that knowledge workers do not have much control over the number of incoming emails.

An important caveat here is that we are not looking into different polychronic behaviors exhibited by knowledge worker. Highly polychronic knowledge workers see interruptions as positive influence and their performance improves as a result of interruptions in contrast with workers exhibiting low polychronicity (Hall and Hall 1990). The non-value added time that we aim to minimize usually remains constant for each email interruption across all knowledge workers irrespective of whether they are highly polychronic or not. Though it would be interesting to investigate the performance differences demonstrated by knowledge workers having different polychronic inclinations, it is not the goal of this study. Also, we restrict the scope of this study to those knowledge workers who spend significant amounts of time processing their emails. Specifically, we explore the following research questions in this study:

> **Research question 1:** Are there email processing policies that will enable a balance between email response time and task completion time?
> **Research question 2:** Will fewer interruptions result in significantly more efficient work completion?

Research question 3: Will fewer interruptions significantly lower the numbers of hours worked daily?

Research Question 4: To what extent will achieving a fit between email arrival patterns and email processing patterns influence the success of given email processing policies?

We adopt a computational modeling approach and simulate the work environment of a knowledge worker and compare different timing-based processing policies. The following section provides a literature review. The 3rd section describes the research questions and hypotheses. The 4th section provides the model details with an accompanying appendix for technical details. The 5th and 6th sections summarize the results. Finally, the 7th section provides discussion, limitations and future work.

2 Literature review

Interruptions have been defined in several ways. Jett and George (2003), in their literature review on interruptions provide a generic definition. Interruptions are defined as incidents or occurrences that impede or delay organizational members' progress on work tasks. They propose four major types of interruptions: (1) intrusion, (2) break, (3) distraction and (4) discrepancy. An intrusion is normally viewed from a time management perspective and is defined as an unexpected and unscheduled encounter that interrupts the flow and continuity of an individual's work, thus bringing that work to a temporary halt (Jett and George 2003). It appears that the above description could describe email's intrusive effect on knowledge workers. Another definition from the theory of distraction describes an interruption as "an externally generated, randomly occurring, discrete event that breaks the continuity of cognitive focus on a primary task" (Corragio 1990).

Although some research on interruptions has been done within disciplines including IS, human-computer interaction (HCI), management, and cognitive psychology, we still have more to learn. Much of the related research has focused on either interface design or the impact of interruptions on task performance. For example, research within the field of human-computer interaction (HCI) has been mainly focusing on developing interfaces to reduce interruptions and cognitive overload and (e.g., McFarlane 2002). Authors who have studied the interruptive nature of technologies such as email and instant messaging on primary task performance suggest that the intensity of the interruption effect depends upon the point at which the primary task gets interrupted (e.g., Cutrell et al. 2000; Czerwinski et al. 2000; Speier et al. 1999, 2003). Interruptions had less of an impact when a task was interrupted during an earlier processing stage. For example, a task that is interrupted during its planning phase will have a smaller penalty attached to it than a task that is interrupted during later stages, typically called the execution and evaluation phases (Czerwinski et al. 2000). Recently, research in HCI has also studied the problems of email. An entire special issue of *HCI Journal* focuses on redesigning and reinventing email (Whittaker et al. 2005). Duchenaut and Watts (2005) propose taxonomy for future work on email systems. Other efforts are focusing on developing and designing emails for the 21st century (Kerr and Wilcox 2004). None of these studies have looked at the time based policies that could be used to mitigate the impact of email interruptions.

Knowledge workers live in an environment that is constantly interrupted by email (Ducheneaut and Bellotti 2001). When an email arrives randomly, additional time is needed to switch from a current work medium to the email medium. This time is referred to as switching time (Cutrell et al. 2000; Czerwinski et al. 2000) or more commonly as interruption lag (Trafton et al. 2003). Jackson and colleagues (2001 and 2003) found that a knowledge worker takes an average of 1 min and 44 s to react to a new email by activating the email application. After processing the email, the knowledge worker has to spend a small amount of time before fully resuming the interrupted task. This time is primarily spent on recollection and reengaging in the task that was interrupted. This recovery time is also referred to as resumption lag (Trafton et al. 2003) and has been reported to be around 64 s per email interruption (Jackson et al. 2003). Although this time component may appear to be small, because of the large number of messages arriving every day, the cumulative interruption and resumption lags become large, and hence increase the knowledge worker's non-value-added time of a knowledge worker (Jackson et al. 2003).

Jackson and colleagues (2001 and 2003) performed several studies to understand the role of email as an interrupter in organizations. They suggest that the overall interruption effect of email is more than that caused by phone calls. Ironically, the frequency of interruptions can be controlled by controlling the time frame(s) during which interruptions are allowed to occur. Thus, it is possible to reduce the effect of interruptions by scheduling the hours during which email is processed. Jackson et al. (2003) suggests that knowledge workers should check email every 45 min. However, the Jackson studies do not consider several work environment characteristics such as different content complexities of emails or different arrival patterns. These factors may moderate the influence of the timing of email processing on knowledge worker performance. There is a need to study the effect of interruptions caused by emails in a more detailed and elaborate manner. The following section describes the first phase of our study's experiment.

3 Research framework

3.1 Phase I experiment

The research model for this phase of the study is illustrated in Fig. 1. Three performance measures that are evaluated in the study include (1) percent increase in knowledge worker utilization, (2) average email response time, and (3) average task completion time. Utilization is used as a measure of a knowledge worker's information overload in this study. It is defined as the probability of a knowledge worker being in a busy state (Her and Hwang 1989). The percent increase in utilization reflects the non-value added time spent by knowledge worker on a given day due to interruptions.

Work environment can be influence by several characteristics such as primary and secondary task characteristics, sender receiver distance, task complexity, etc. (Te'eni 2001). We chose two work environment characteristics, namely dependency on email communication, and email arrival pattern. Based on the survey conducted by American Management Association (2004), we categorize knowledge workers, on the basis of their dependency on email communication, into four different types: very high users of email, high users, low users, and very low users. "Very high" users spend an average of 4 h per workday processing email, "high" users 3 h, "low" users 2 h and "very low" users 1 h. "Very high" and "high" users of email typically represent workers with a higher need for communicating at work, e.g. executives, CEOs, distribution and marketing managers, sales personnel, marketing managers, workers at geographically dispersed organizations, etc. "Low" and "very low" users of email are knowledge workers with less communication requirements, e.g. office assistants, analysts, programmers, etc.

Emails often follow different arrival patterns in different environments. Figure 1 shows two different email arrival patterns. A time stationary exponential distribution is representative of work environments where emails arrive at a rate that remains roughly constant throughout the workday, whereas a non-stationary arrival pattern is found

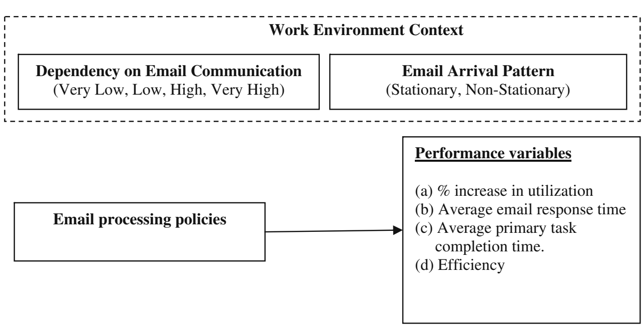


Fig. 1 Research model for the phase I and phase II experiment

in those environments where the arrival pattern varies with the time period.

There is a lack of consensus among research studies that have been conducted to identify the best email processing policy. Jackson et al. (2001 and 2003) have proposed that email should be processed no more than every 45 min to increase employee productivity at the workplace. Another study (Venolia et al. 2001) argues that processing email once per workday is a better policy than continuous processing. Besides the lack of general agreement among prior research findings, the three policies mentioned above do not represent the broad spectrum of policies that a knowledge worker might be able to use in efficiently managing email and primary tasks.

According to the Single-Resource theory (Kahneman 1973), frequently diverting resources such as the attention of a knowledge worker to a secondary task (email) decreases the performance on the primary task. This theory suggests segregating the time during which emails and other tasks are given higher priority for processing, thereby reducing the interaction between the two, can potentially reduce the number of interruptions. Interruption-related literature also confirms that whenever an interruption occurs, switching time (interruption lags) and recall time (resumption lag) is spent before the interrupted task is resumed. As explained in the previous section, when the frequency of interruptions increases, the cumulative resumption and interruption lags increases as well thereby delaying the completion of the primary tasks. This further justifies that controlling the time-frame within which email is allowed to interrupt can reduce the number of interruptions, thereby reducing the cumulative switching and recall time. Such controls also allow for better attention allocation, which is a scarce resource in modern organizations (Davenport and Beck 2000).

To establish such a time-frame, we introduce the notion of "email hour" slots. The total knowledge work hours in a particular workday can be split into two categories: one, during which email is given the highest priority, termed as "email-hour" slots and the other, during which primary tasks are given the highest priority, termed "non-email hour" slots. By adjusting the length of each email-hour slot and varying the number of such email-hour slots in a particular work day, we may be able to reduce the number of interruptions without adversely affecting the primary task completion times as well as email response times.

Perlow (1999) qualitatively studied the effects of the frequency and timing of interruptions on individual and group productivity of knowledge workers. This study found that neither continuous interruptions nor perfect synchronization between interrupting and interrupted tasks is good for effective time management. This leads us to believe that both extremes are not good for knowledge workers' performance and that the optimal policy is somewhere in the middle. Zijlstra et al. (1999) also found that interruptions could cause people to perform a primary task more quickly, but postulated that the relationship between interruptions and task performance would be an inverted U-shape, indicating that the cumulative effect of interruptions at some point does have a negative effect on primary tasks. A controlled interruption policy such as processing emails twice or four times a day will likely keep a better balance between email response time and task completion time than a continuous email processing policy and once-a-day email processing policy. Hence, the research question is:

> **Research question 1:** Are there email processing policies that will keep a balance between email response time and task completion time?

Hypothesis 1(a) For different email arrival patterns (stationary and non-stationary), processing emails two or four times a day will result in significantly higher email response time and low primary task completion time than with continuous email processing.

Hypothesis 1(b) For different levels of dependency on email communication (Very High, High, Low, Very Low) processing emails two or four times a day will result in significantly higher email response time and low primary task completion time than with continuous email processing.

Hypothesis 2 Processing emails two or four times a day will result in significantly less increase in worker utilization (due to interruptions) than with continuous email processing.

3.2 Phase II experiment

The second phase of experiment contributes differently from first experiment phase in that it models a different type of knowledge worker, different performance measures, and it takes different approaches to modeling the knowledge work environment, including modeling attention as an entity. Phase I experiment studies email policies' effects on utilization, email response time, and task completion time. Phase II considers a different type of knowledge worker—project managers who primarily handle complex tasks and are rarely, if ever "caught up." Instead of utilization, which implies that the knowledge worker experiences some "caught up" time, this study considers knowledge worker efficiency and the total amount of time needed by the knowledge worker to complete a daily threshold of work. Efficiency is defined as the knowledge worker's productive time at work divided by the knowledge worker's total time at work. Second phase also allows for one type of email message to always take priority over other email messages, so that all email need not interrupt the knowledge worker—just those in need of urgent resolution. The modeling approach is different as well. Rather than modeling the knowledge worker as a server, this phase models a knowledge worker's attention as an entity that flows from one area of focus to another. Modeling knowledge worker attention as an entity is described in the following section. Additionally, emails with different priorities were also modeled during this phase. Email that require urgent attention are of highest priority (priority-1) whereas emails not defined as urgent must be processed within either one business day (priority-2) or within 1 week (priority-3).

We learn from Speier et al. (1999, 2003) that interruptions can adversely affect complex tasks. We learn from Trafton et al. (2003) that interruptions can cause waste in worker productivity in the form of both interruption and resumption lags. Jackson et al. (2003) gives further evidence of the existence of these lags and approximations for the durations of these lags. By eliminating email interruptions, knowledge worker efficiency should improve.

> **Research question 3:** Will fewer interruptions result in more efficient work completion? Productive time includes working on both primary work and email. Total time includes primary work and email work as well, but also includes time wasted in interruption and resumption lags. Specifically, will the proposed email processing policy significantly improve knowledge worker efficiency?

Hypothesis 3 Dividing non-priority email work into two specific time frames (Scheduled Attention-2) will result in significantly greater efficiency when compared to processing email continuously.

> **Research question 4**: Will fewer interruptions lower the numbers of hours worked daily?

Hypothesis 4 Holding email hours twice daily (Scheduled Attention-2), will result in significantly fewer total hours worked daily when compared to processing email continuously (Continuous Attention).

> **Research Question 5**: To what extent will email arrival patterns influence the success of given email processing policies?

Just as we would schedule employees during the busiest times of day, it is intuitive that scheduling email hours *during* periods of rapid email arrival rates should allow for prompt resolutions.

Hypothesis 5 Email hours scheduled during peaks in arrival patterns (Scheduled Attention-2P and Scheduled Attention-4P) will have significantly shorter resolution times when compared to email hours not scheduled during peaks in arrival patters (Scheduled Attention-2 and Scheduled Attention-4).

4 Model formulation

In this section, we will briefly describe the conceptual development of the model, the stages of interruptions within knowledge work environment, and different email processing policies. The policies that were compared in phase I and II are described in Table 1.

Although the timely processing of all primary tasks is of importance to a knowledge worker, email processing cannot be indefinitely ignored as email could facilitate the sharing of information that is necessary for completion of primary tasks. We implement email processing policies by establishing email hours. The continuous email processing policy implies that every working hour is an email hour. An email arriving during email-hours will interrupt other ongoing primary tasks, because the highest priority is given to email.

During non-email hours, primary tasks have the highest priority and email cannot preempt a primary task. The manner in which any new knowledge object will be handled is contingent upon three things: when it arrived (during email hours or non-email hours), whether it is email or a primary task, and what is the length of the (email or primary task) queue? An email that arrives during email hours will take priority over any other task.

Whenever an interruption occurs, additional time is spent on switching from one task to another (for example, moving from one medium to another and activating the email application). This nonproductive time is referred to as an interruption lag. Processing of an interrupted primary task is resumed once the processing of the interrupt (email) is complete, some time is needed to recall the work done on previously interrupted work. This nonproductive time is referred to as a resumption lag. An email arriving at a time during which the knowledge worker is idle does not cause any interruption. Similarly, if a task arrives during an email-hour slot, then it waits in the queue till the remaining emails have been processed. During non-email hours, an email is processed only if there are no primary tasks in need of processing, because primary tasks are given the highest priority during non-email hours.

Various email types that differ from each other on the basis of content, complexity, and arrival rate were modeled, bringing greater realism to the model. For example, some email messages require longer processing time than others due to their complexity. Phase I model also considered various email characteristics and types. Five different email types were modeled (see Appendix I, Table A.1). These include spam (type 1), priority email (type 2), and informative email (type 3). Emails that require response were further categorized into two additional types: those with service times that do not change based on the age of the email (type 4), and those with service times dependent on the age of email (type 5). Type 5 email service times change as a function of the time for which they remain unanswered. This type of email, if it waits a while, requires no action. This could result from someone else on the message recipient list responding or other circumstances resulting in resolution of the email.

Phase II experiments modeled two separate entities. First, a knowledge worker's flow of attention is modeled. "Attention" represents the focus of the knowledge worker's mental efforts. "Flow of attention" implies that the knowledge worker's attention shifts between different areas of focus. Second, the flow of email messages is modeled separately from the flow of knowledge worker attention. Upon arrival in the knowledge worker's inbox, the email message must wait for the knowledge worker's attention. The delay incurred by the email message is dependent upon the priority of the email message, and the knowledge worker's email processing strategy. Email messages are prioritized according to urgency, and queued accordingly.

Table 1 The email processing policies

Processing strategies	Descriptions
Continuous attention (C)	This processing strategy requires processing email as they arrive (giving first priority to email).
Scheduled attention-1 (C1)	This processing strategy requires holding email hours once daily, every morning.
Scheduled attention-2 (C2)	This processing strategy requires holding email hours twice daily.
Scheduled attention-2P	This processing strategy requires holding email hours twice daily, during two peak email arrival periods.
Scheduled attention-4 (C4)	This processing strategy requires holding email hours four times daily.
Scheduled attention-4P	This processing strategy requires holding email hours four times daily, during four peak arrival periods.
Scheduled attention-6 (C6)	This processing strategy requires holding email hours six times daily.
Jackson attention (C8)	This processing strategy requires holding email hours every 45 min.

Priority-1 (urgent) email messages immediately gain the attention of the knowledge worker provided that the knowledge worker is not idle (at lunch or gone for the day), and all priority-1 email messages having arrived earlier have been processed. Non-urgent email messages gain the attention of the knowledge worker under differing circumstances depending on the knowledge worker's email processing strategy. If the knowledge worker employs a "continuous" email processing strategy, then an email is processed after all email of higher priority have been processed and after all email of equal priority having arrived earlier have been processed. If the knowledge worker employs a "scheduled attention" email processing strategy, then non-priority email messages must wait for a specific time or times during the day during which the knowledge worker processes non-priority email messages. During these time periods an email is processed after all email of higher priority have been processed and after all email of equal priority having arrived earlier have been processed.

Upon starting the workday, the knowledge worker will begin with his or her primary work, unless the specific email processing strategy calls for processing email at this time. For example, email hours could be scheduled for first thing in the morning. Before the primary work takes place, the knowledge worker must take time to again familiarize with the work that is to be performed (the resumption lag). The primary work continues until one of four things happen. First, an urgent email message could interrupt the knowledge worker. Second, the knowledge worker may break for lunch; third, the knowledge worker's email processing strategy may dictate that it is time to process non-urgent email messages. And fourth, the knowledge worker may have completed a given level of work and leave for the day.

Appendix II describes the mathematical model supporting the phase I and II simulation models.

5 Research method

Due to the time-length and the nature of the policies being compared, it is extremely difficult to conduct this study as an experimental or field study with enough control. Hence, a simulation-based computer experiment was chosen to study this problem. Axelrod (2003) describes simulation as a way of doing 'thought experiments' and as a technique that can give surprising 'emerging' results due to due to presence of various interactions among entities that are often difficult to anticipate. Computer simulation has been used as a method for theory development and investigation (Hans-Joachim et al. 2001; Peschl and Scheutz 2001; Di Paolo et al. 2000) and can be used to conduct virtual experiments (Winsberg 2003).

Numerous simulation models representing different types of work environments were developed and run for phase I and II in order to compare the performance of various types of knowledge workers under different email processing policies. Our approach of building a series of simulation models in this study is based upon the guidelines postulated by Chwif et al. (2000): *"divide your model into parts and model each part separately creating a series of simpler models instead of one 'huge' one" and "only after you validate, analyze and have the results, add more complexity if you feel it is really necessary."*

Phase I experiments were based on the parameters listed in appendix I (Table A.2). All tasks in Phase I followed an exponential inter-arrival time distribution. Simulation models representing each scenario described in appendix I (Table A.2) were run for all five policies. Thus, in Phase I, 90 simulations were run for the duration of 500 days with a warm-up time of 50 days. The warm-up time was determined externally by analyzing the data using Welch's method (Welch 1983). Sixteen different work scenarios were implemented and compared in this phase. Thus, 80 different simulation models were replicated 20 times and run for 500 days with a warm-up time of 50 days, leading to generation of 1,600 data points. Collected data were analyzed using Multivariate Analysis of Variance (MANOVA) in order to control the experiment-wide error rate. The different email processing policies comprise the independent variable. Similarly, within phase II experiments, simulations of each processing policy were performed and performance measures were collected. The collected data included six performance measures: Efficiency, Hours-Worked, and the Email-Resolution-Time for each of the four priorities of email message. Each model was run for 90 days with a warm-up time of 30 days and for 20 replications. The warm-up period was obtained using Welch's method.

6 Results

6.1 Results of phase I experiment

Figure 2 (a) shows that the percent increase in utilization of the knowledge worker using the once-a-day (C1) policy is 2% for very low email dependency, whereas it is 5.7% for very high email dependency. For four-times-a-day (C4) policy, the percent increase in utilization varies from 3% to 5% for very low to high dependency on email. With Continuous policy (C), the percent utilization increased the most for all levels of dependency (8–15%). Figure 2 (b) shows that percent utilization increased from 4% to 14% as we moved from C1 to C for time-stationary arrivals and increased from 3.7% to 11.5% on moving from C1 to C for non-time stationary arrivals. C1, C2 and C4 performed

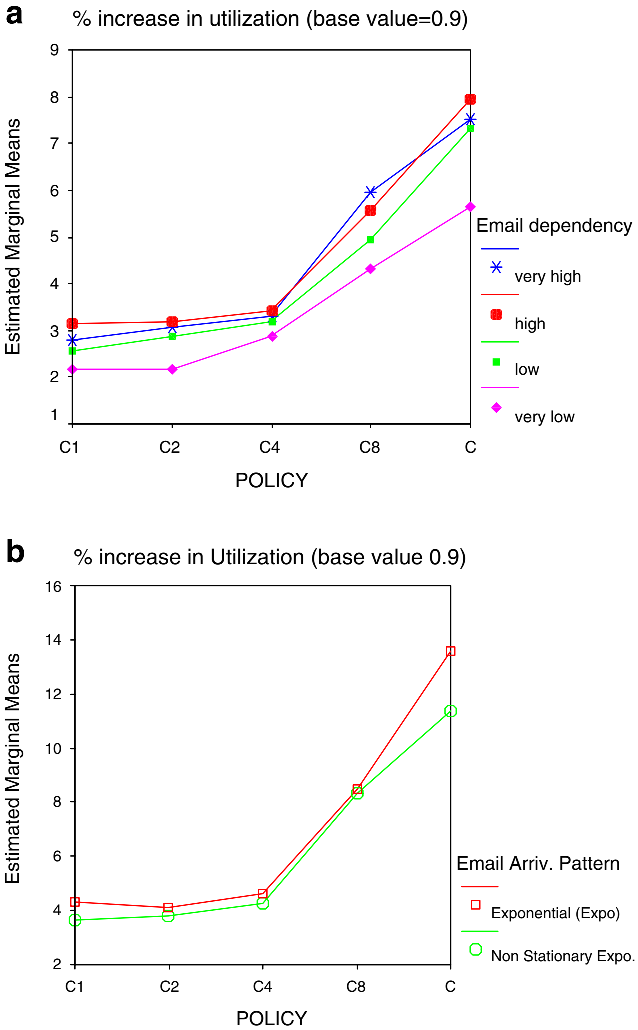


Fig. 2 (**a**): Effect of policy x email dependency on percent increase in utilization. (**b**): Effect of policy x email arrival pattern on percent increase in utilization

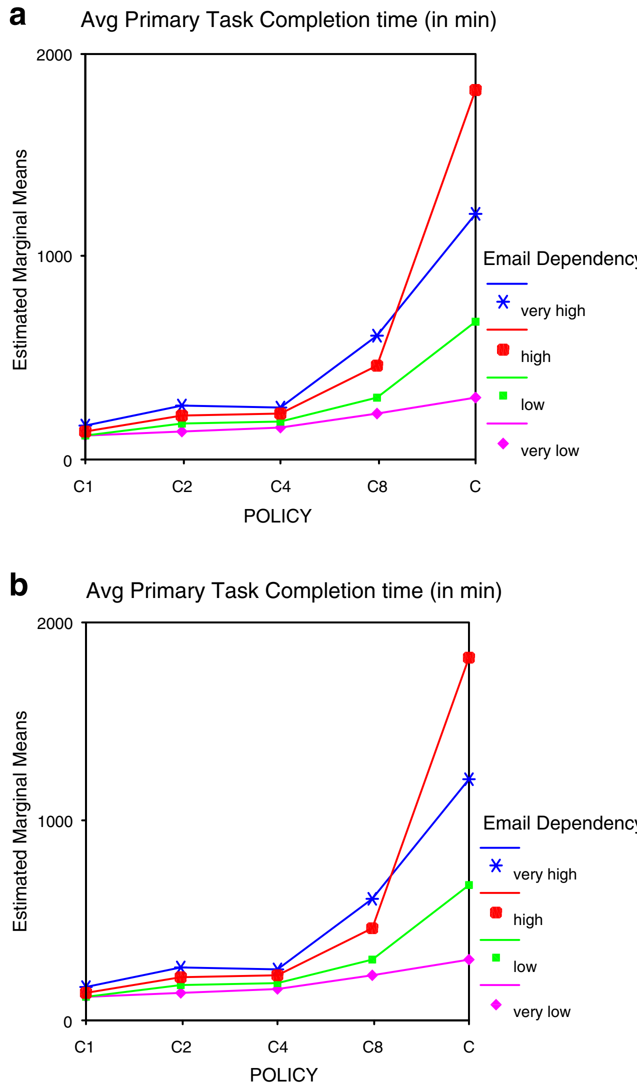


Fig. 3 (**a**): Effect of policy x email dependency on additional time spent. (**b**): Effect of policy x email arrival pattern on additional time spent

better than C8 and C. Figure 3(a) and (b) describe the effect of policy on additional time spent per day due to interruptions across various levels of email dependency and arrival patterns.

For the C1 policy, the cost of interruptions in terms of time varies from 10 to 20 min. For C4, it varies from 12 to 22 min, and for the C policy, it varies from 35 min to an hour. Figure 4 shows the impact of various policies on email response time across various levels of email dependency. The C1 policy showed the longest average wait time (250–370 min) whereas the C policy showed the smallest wait time (15–20 min) for all levels. Similar patterns appeared across various levels of content complexity and email arrival patterns and hence those figures are not shown here. The average primary task completion time increased substantially during the use of C (200 min) and C8 (700 min), whereas for C1, C2 and C4 policies, it was

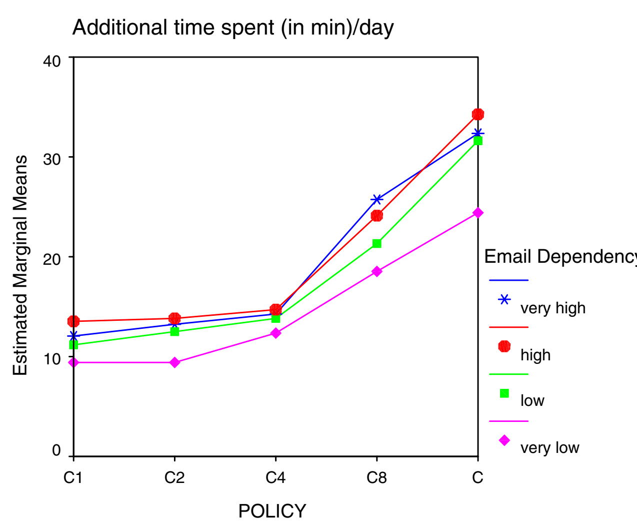


Fig. 4 Effect of policy x email dependency on email response time

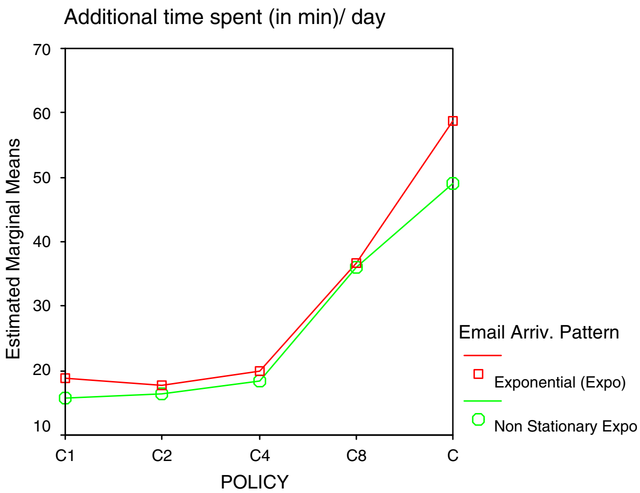


Fig. 5 Effect of policy x email dependency on primary task completion time

between 30 min and 100 min (Fig. 5). The same behavior was noted across different email dependency levels and email arrival patterns. Hypotheses 1(a, b) and 2 were found to be significant at the significance level of 0.05.

6.2 Results of phase II experiment

Table 2 summarizes the results of the MANOVA model.

The email processing policy was found to have a significant effect (α=0.001). All of the email processing policies were compared across multiple performance measures. Tests for differences between groups (email processing policies) were performed using the Bonferroni approach for adjusting alpha to account for inflation of the overall type I error rate resulting from multiple performance measures.

Hypothesis 3 was supported. The expected gains in efficiency were found to be statistically significant (α=0.001).

Hypothesis 3 Dividing non-priority email work into two specific time frames will result in significantly greater efficiency when compared to processing email continuously.

The efficiency that resulted from the Scheduled Attention-2 processing policy was 97.35%, indicating that less than 3% of the knowledge worker's work day was wasted on interruption and resumption lags. The Continuous email processing policy resulted in efficiency of 94.34%, a mean difference of roughly 3%. What can a knowledge worker do with 3% of their time back? 3% of a 9 h day corresponds to roughly 16 min per day. 16 min per day corresponds to an hour and 20 min per week, or around 69 h per year. Consider the knowledge workers used in this case study who are billed out at $300–$400 per hour. Considering an organization with dozens or hundreds of knowledge workers, the cost of email interruptions adds up! But it need not. Choosing the Scheduled Attention-2 processing policy achieved efficiency without adversely affecting the successful resolution of email messages.

Hypothesis 4 was not supported. The Scheduled Attention-2 email processing policy resulted in an average daily total hours worked of 10.5524, while the Continuous email processing policy resulted in an average daily total hours worked of 10.0095. The difference was statistically significant (α=0.001), however the direction of the difference was not as expected. The explanation is of interest, however.

Hypothesis 4 Holding email hours twice daily will result in significantly fewer total hours worked daily when compared to processing email continuously.

In light of efficiency, considerably more work is being accomplished with the Scheduled Attention-2 email processing policy. The Scheduled Attention-2 email processing policy results in an average of 10.2728 productive hours daily (10.5524 * 97.35%). The Continuous email processing policy results in an average of 9.4430 productive hours daily (10.0095 * 94.34%). Consider a project requiring 160 h of work. Using the Continuous email processing policy, the project could be completed in approximately 17 work days. If the knowledge worker instead employed the Scheduled Attention-2 processing policy, the project could be completed within roughly 15.5 work days. With the Scheduled Attention-2 processing policy, email has a tendency to hold the

Table 2 Multivariate tests

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's trace	1.000	87739879.955(a)	6.000	502.000	.000
	Wilks' lambda	.000	87739879.953(a)	6.000	502.000	.000
	Hotelling's trace	1048683.824	87739879.953(a)	6.000	502.000	.000
	Roy's largest root	1048683.824	87739879.953(a)	6.000	502.000	.000
Strategy	Pillai's trace	4.591	137.677	72.000	3042.000	.000
	Wilk's lambda	.000	744.819	72.000	2736.980	.000
	Hotelling's trace	507.821	3528.889	72.000	3002.000	.000
	Roy's largest root	426.365	18013.910(b)	12.000	507.000	.000

a Exact statistic

b The statistic is an upper bound on F that yields a lower bound on the significance level

Table 3 Scheduled attention-2 (pattern and no pattern), email resolution times for both priority-2 and priority-3 email messages

	Scheduled attention 2 pattern		Scheduled attention 2 no pattern	
Priority 2 email	Mean	3.5226	Mean	3.6419
	Median	2.2690	Median	3.1322
	Min	.0012	Min	.0007
	Max	22.3474	Max	22.5887
Priority 3 email	Mean	2.3879	Mean	4.0288
	Median	1.6391	Median	3.2893
	Min	.0010	Min	.0086
	Max	23.2022	Max	23.8542

knowledge worker at work for longer hours. With Continuous processing, you are more or less always caught up. With the Scheduled Attention-2 email processing policy, the "email hours" are scheduled in the morning and at the end of the day. The knowledge worker will often stay late catching up on the day's email processing needs.

Scheduled Attention-2 might be especially effective for the knowledge worker who is facing a deadline or who is more concerned with getting things done than going home at a particular time. Alternatively, Scheduled Attention-2 could be tweaked to process email a bit earlier in the day in hopes of always being caught up by the end of the day. As indicted in Table 3 below, the mean resolution times for priority-2 email messages do not support hypothesis 5. The difference between 3.5226 h (Scheduled Attention-2—with pattern) and 3.6419 h (Scheduled Attention-2—no pattern) is not statistically significant.

Hypothesis 5 Email hours scheduled during peaks in arrival patterns will have significantly shorter resolution times when compared to email hours not scheduled during peaks in arrival patterns.

However, the mean resolution times for priority-3 email do support this hypothesis (2.3879 h is a statistically significant shorter resolution time than 4.028 h (α= 0.001)). The schedule for processing email according to arrival patterns is based on the *total* arrivals of email of both priority-2 and priority-3.

Priority-3 email messages more closely matches the scheduled email hours, causing the mean resolution time to be shorter with priority-3 emails than the priority-2 email messages. An analysis of frequency distributions, Fig. 6, indicates that with respect to priority-3 email, scheduling email hours during peaks in arrival patterns prevents a bimodal distribution of resolution times. If the knowledge worker were to adopt two specific "email hours" during his or her day, selecting email hours that coincide with email arrivals can improve the resolution time of a good many of the priority-3 email that are processed. Priority-3 emails are those email that do not require a particularly prompt response (within 1 week), so the result may be seen as less important. However, all things being equal, faster resolutions are desirable.

Hypothesis 5 also considers the mean resolution times of priority-2 and priority-3 email messages resulting from the Scheduled Attention-4 (no pattern) and the Scheduled Attention-4 (with pattern) email processing policies described in Table 4.

The mean resolution times for priority-2 email do not support this hypothesis (2.7862 and 2.5445 h are not different statistically). The mean resolution times for priority-3 email do not support the hypothesis either (1.9202 h is not statistically different from 1.9236 h). An analysis of frequency distributions, Figs. 7 and 8 below reveal little difference in the two alternative email processing policies.

7 Discussion, limitations, and implications for future research

Figure 2 (a, b) illustrate the variation of percent increase in utilization of the knowledge worker due to interruptions with respect to the policy used. The graphs show that percent increase in utilization first decreases and then increases after reaching a certain minimum value. The percent increase in utilization reaches lowest values at C4 and C2, thus providing the answer to RQ1.

Length and the number of the email-hour slots, and the time gap between email-hour slots in a particular policy impacts the number of interruptions and the resulting increase in overload. The C1 policy comprises a single email-hour slot of 3 h. Since the length of the single email-hour slot is relatively long in C1, the probability of any new email arriving and leading to an interruption is rather high during the three hour duration. The length of each email-hour slot in C4 is relatively small (approx. 45 min). Due to the shorter email-hour slots in the C4 policy, the email queue builds up. The primary tasks are,

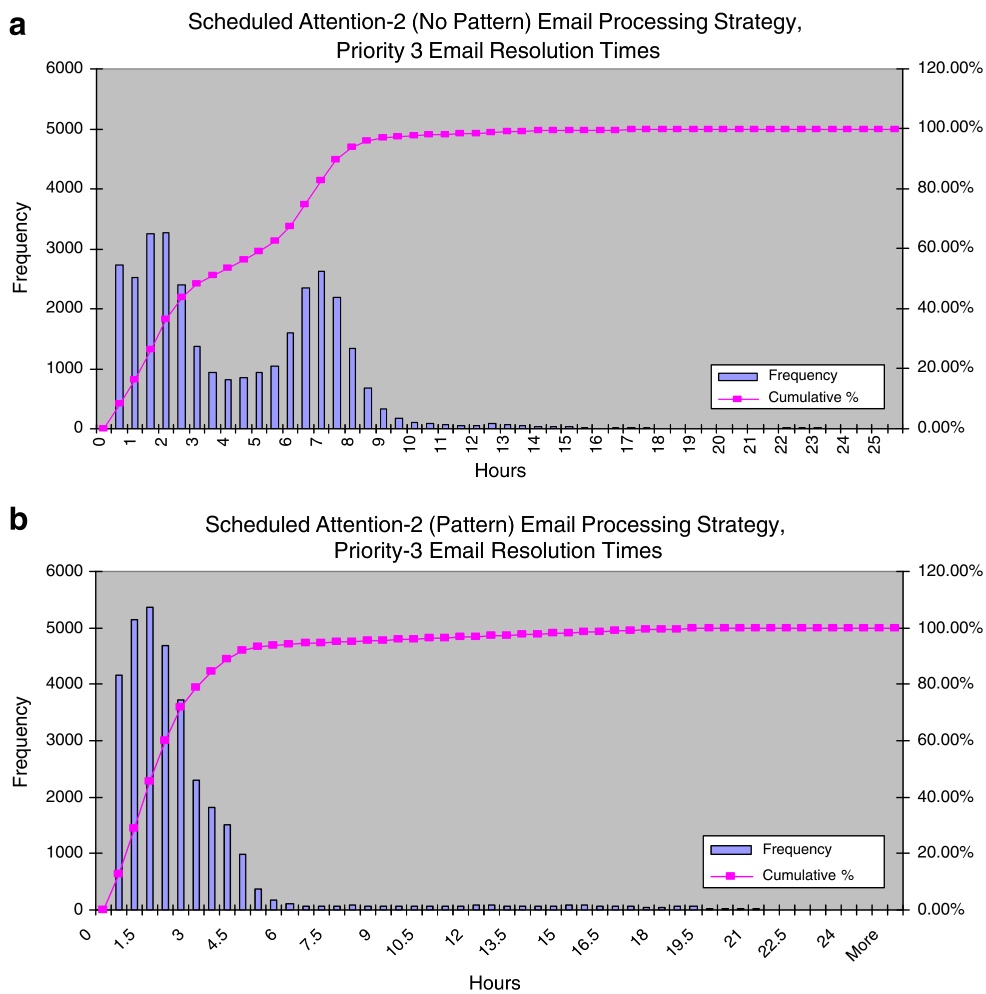


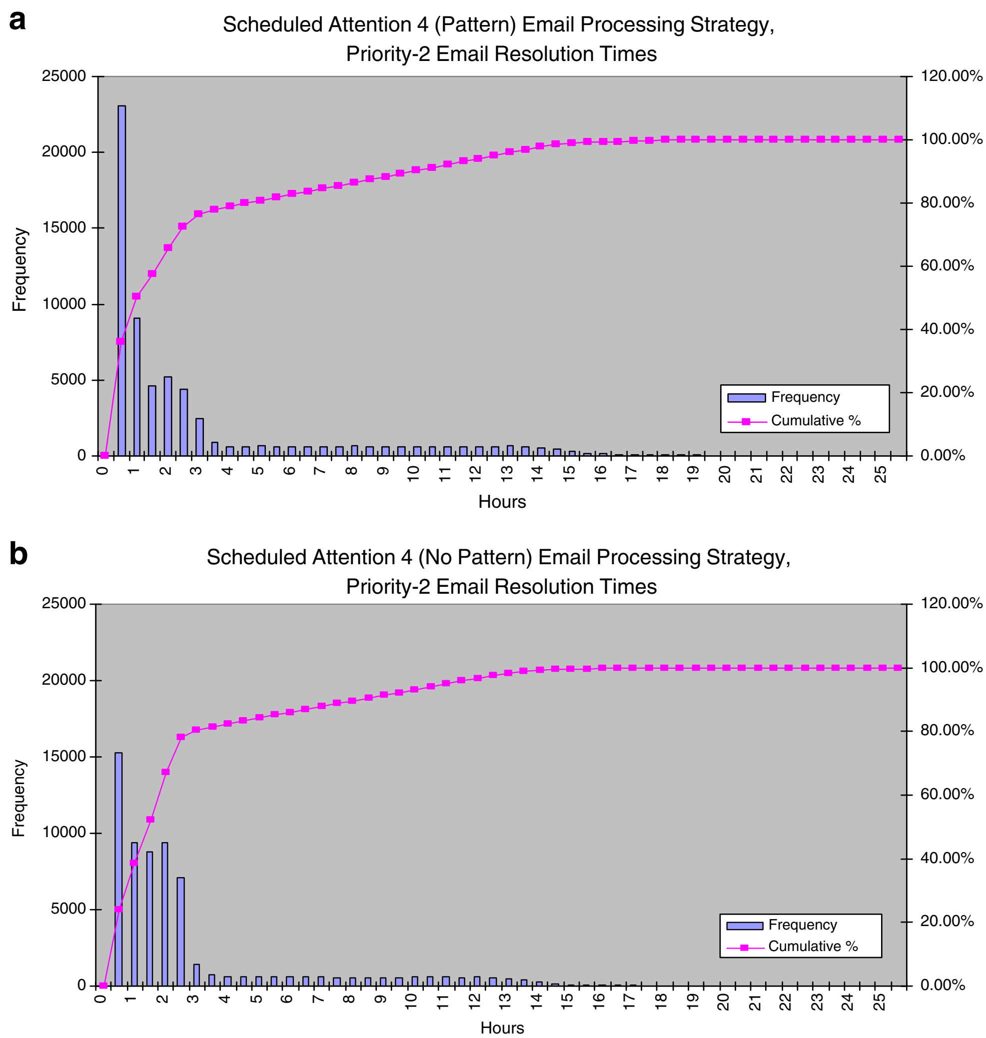
Fig. 6 Scheduled attention-2 (pattern and no pattern), email resolution times for priority-3 email messages

thus, less likely to be processed during these email-hours. Assuming the same rate as other cases, fewer emails arrive during this time, leading to reduced interruptions. Thus, the probability of interruption due to a newly arrived email is also small, implying smaller cumulative resumption and interruption lags. On the other hand, as the number of email-hour slots increases such as in C8, the frequency of email processing increases. The likelihood of primary task processing also increases leading to an increase in interruptions. In the continuous policy, the length of each email-hour slot approaches zero whereas the number of email-hour slots approaches infinity. The priority is always rendered to email. Hence, the number of interruptions increases, leading to an increase in the cumulative sum of interruption lag and resumption lag in the continuous policy.

Table 4 Scheduled attention-4 (pattern and no pattern), email resolution times for priority-2 and priority-3 email messages

	Scheduled attention-4 pattern		Scheduled attention-4 no pattern	
Priority 2 email	Mean	2.7862	Mean	2.5445
	Median	0.9759	Median	1.4184
	Min	0.0009	Min	0.0010
	Max	21.1193	Max	17.7263
Priority 3 email	Mean	1.9202	Mean	1.9236
	Median	1.3045	Median	1.3236
	Min	0.0014	Min	0.0023
	Max	21.1648	Max	17.9526

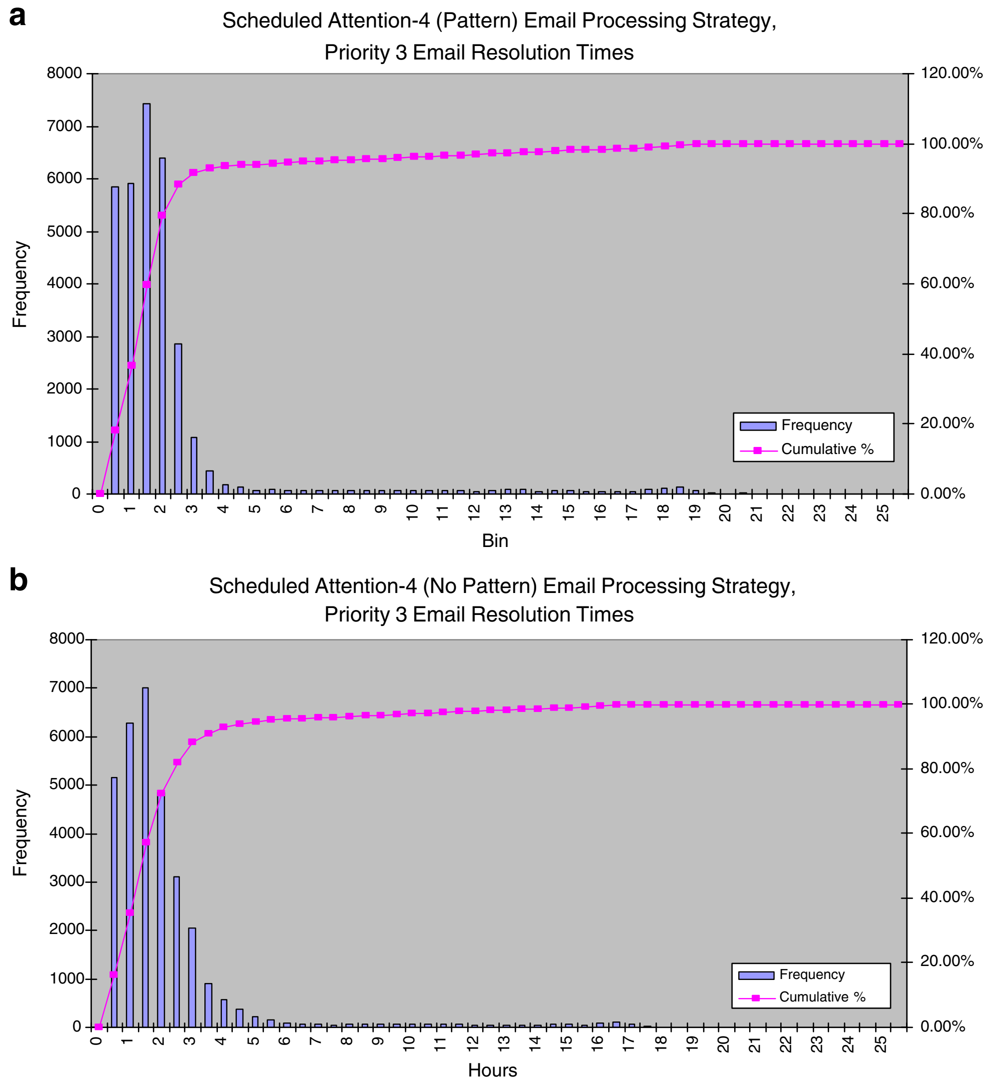
Fig. 7 Scheduled attention-4 (pattern and no pattern), email resolution times for priority-2



The experiments also modeled different complexity levels of email. The variation in primary task completion times across policies is a result of the interaction between three different factors. The most important factor is the number of interruptions that occur during the use of a particular policy. Second is the number of email-hour slots that a particular policy comprises, and third, to a lesser extent, is the time interval between consecutive email-hour slots. In phase I and II, Scheduled attention policies such as two times a day, four times a day performed better than continuous email processing for primary tasks. The difference can be attributed to a large number of interruptions that occur while using the C policy in comparison to C4 and C8. The increase in the number of interruptions clearly affected the cumulative sum of the interruption lag and the resumption lag, leading to a rise in the overall task completion time. The gap between the completion times of primary tasks further widens from C4 to C due to an increase in the number of email-hour slots and also due to the reduction in the time interval between email-hour slots as we move from C4 to C. Thus C2 and C4 performed better than all other policies for all types of primary tasks and email because the number of interruptions was least in these policies.

The mean response time for email decreases with the increase in the number of email-hour slots. The logical explanation is that as the gap between the consecutive email-hour slots becomes smaller from C1 to C8 and completely vanishes in C, email gets processed more quickly, resulting in the reduction in average email response time. What is less obvious, however, is that the marginal reduction in email response times between C4 and C8 or C come at a high cost in terms of increases in other task completion times. The same results are seen in the second experiment. These experiments also revealed that scheduled attention policies (C2 andC4) outperformed C8 and C in balancing the primary task completion time and email response time for all work environments and for all levels

Fig. 8 Scheduled attention-4 (pattern and no pattern), email resolution times for priority-3



of email dependencies, email arrival patterns, email complexities, and email arrival rate.

This study provides numerous insights into the impact of interruptions looks into the problems of email overload and interruptions, simultaneously. The approach undertaken by the authors required the development of complex simulation models to represent human information processing and validating them using the procedure suggested by Sargent (2003). However, known validity and generalizibility issues are associated with any simulation-based study. Another limitation of this study is related to the issue of sample size and power. With simulation, sample size is generally inflated due to the need for running a large number of replications so that variability of stochastic output is reduced. This gives more artificial power to the sampling experiment. Hence, statistical significance of results should not be overemphasized in a simulation based study. Rather, researchers should pay careful attention to the practical significance of the results.

Some assumptions have to be made when developing simulation models. However, these assumptions provide opportunities for future work as well. For example, the impact of different time zones on email arrival pattern was not modeled in this study. This becomes an important topic for study given the recent proliferation of virtual communities and the heavy outsourcing of knowledge work to foreign offices that operate under different time zones.

In the current study, we assumed that all the interruptions caused by email are harmful and delay the processing of primary tasks. In an information-sharing context, not all email can be associated with a negative cost. Some email may actually speed up completion of other tasks at hand. Some internally generated email (a message from a project partner) may have a reward associated with it. Thus, more comprehensive simulation scenarios should be designed in future studies. One of the underlying assumptions of this study is that recall time increases with the increase in the time that has been spent on processing before an interruption occurs. Further research needs to be done where the resumption lag varies non-linearly with the fraction of task completed when the interruption occurs.

The current study has focused on the individual knowledge worker. Future research may study the problem at the network level. It would be interesting to see how the performance of policies changes when a network of knowledge workers is studied. Studies should be conducted to account for a greater number of discrete policies that are not just time or frequency based. Future replications based on independently developed models, and experimental or field studies should be conducted to further validate our results. Perhaps not impossible, but it is very difficult to get human subjects for studies where such policies can be dictated to be used by participants all day for several days. Several economic and accounting or cost based approaches can also be taken to study the same problems, since the extra time spent in task processing can be treated as cost in terms of time.

Future research needs to be pursued that will help establish a research framework for studying email processing policies. For example, factor such as individual characteristics cannot be easily modeled using simulation and alternate approaches could be used to study it. One of the limitations of this study is that it does not consider the behavioral differences between knowledge workers. Our findings suggest what a knowledge worker should ideally do; but these policies need not always behave in the same manner if the behavioral aspects are to be considered. For instance, some workers like variety and work more efficiently with interruptions than others do. So instead of C4, C policy may turn out to be optimal in this case. Various personality and cognitive styles should be considered in any future work to study this problem. As pointed out by Weber (2004) in his recent MIS Quarterly editorial note, tremendous research opportunities exist in email research.

The results of this study contribute to the understanding of email overload and interruptions in an information-processing environment and contradict some of the suggestions made in earlier research. A concrete recommendation from earlier research is that continual or high frequency email processing is not the best policy to reduce the interruption effect of email. This study shows that checking email two to four times a day is a better policy in the work environments studied. These policies tend to reduce the overload due to interruptions and at the same time attempt to achieve an optimum balance between primary task completion time and email response time. We found that a good policy is not to have too few (C1) or too many (C8 and C) email priority hours. The optimal number is somewhere in the middle i.e. C2 to C4.

Through this study, we illustrate how simulation can serve as a very useful tool for analyzing the phenomenon of email overload and interruptions. This study also shows that simulation can provide enormous advantages in studying a problem for which data collection becomes a major challenge due to the site unavailability, where field or experimental studies are difficult to conduct, and where human subjects cannot be utilized easily.

In future studies, simulation may be combined with qualitative data analysis for initial theory development purposes (Peschl and Scheutz 2001). We encourage IS researchers to use simulation along with qualitative and quantitative methodologies as their vehicle for conducting research, for initial theory development, extension, and verification. Finally, this study has important practical significance for those geographically dispersed and service organizations where knowledge workers are spending large amounts of time on processing email such as in contact centers, virtual teams, and marketing firms.

Developing organizational wide policies to encourage users to check their emails on a scheduled basis rather than continuously could save an organizations thousands of hours each year. Such schedules can also be implemented by scheduling deliveries of emails to the users' email boxes periodically rather than continuously. It is also conceivable to develop policies that are appropriate for different classes of users. Further work is necessary to validate the results of this study in industry and to develop implementation mechanisms.

Appendix I

Table A.1 Email types, processing time of email and primary task

Notation	Email/task type	Discrete arrival percentage	Processing time (min)
1	Priority email	5%	Expo(10)
2	Spam	5%	Expo(0.5)
3	Informative email	20%	Expo(5)
4	Email with non-diminishing service time	55%	Ref. Table A.2
5	Email with diminishing service time	15%	Ref. Table A.2
	Primary task		Expo (6)

Table A.2 Parameters used in experiment phase I

S #	Type 4 email (E) Processing Time (PT)	Type 5 E PT (min)	Total email PT per day	Avg. email arrival rate	Primary task (P) arrival rate /day	E utilization (Util)	P util	Min (E+P)Util
1	5	5	1	12	62	0.125	0.775	0.9
2	15	15	1	5	62	0.125	0.775	0.9
3	5	5	1	12	62	0.125	0.775	0.9
4	15	15	1	5	62	0.125	0.775	0.9
5	5	5	2	24	52	0.25	0.65	0.9
6	15	15	2	10	52	0.25	0.65	0.9
7	5	5	2	24	52	0.25	0.65	0.9
8	15	15	2	10	52	0.25	0.65	0.9
9	5	5	3	36	42	0.375	0.525	0.9
10	15	15	3	15	42	0.375	0.525	0.9
11	5	5	3	36	42	0.375	0.525	0.9
12	15	15	3	15	42	0.375	0.525	0.9
13	5	5	4	48	32	0.5	0.4	0.9
14	15	15	4	20	32	0.5	0.4	0.9
15	5	5	4	48	32	0.5	0.4	0.9
16	15	15	4	20	32	0.5	0.4	0.9

Appendix II. The mathematical model

Notation

i	type of email message	i=1,2..I {i=1 for SPAM, i=2 for Irrelevant, i=3 for Read only, i=4 for Reply}
j	urgency (priority) of message	j=1,2..J {j=1 for Urgent (Priority-1), j=2 for within Business Day (Priority-2), j=3 for within 1 week (Priority-3), j=4 for Irrelevant}
k	category of processing need	k=1,2..K {k=1 for <1 min, k=2 for 1–10 min, k=3 for >10 min}
d	day	d=1,2..D
s	sequence number	s=1,2..S
t	time period of day	t=1,2..T {t=1 for 8:00 a.m. until 10:00 a.m., t=2 for 10:00 a.m. until 12:00 p.m., t=3 for 12:00 p.m. until 2:00 p.m., t=4 for 2:00 p.m. until 4:00 p.m., t=5 for 4:00 p.m. until 6:00 p.m., t=6 for 6:00 p.m. until 8:00 a.m.}

X	email processing strategy employed
λ_{ijkt}	arrival rate of email messages of type i, urgency j, processing need k, occurring during time period t
P_{kds}	random variable that represents the processing time required for email of type k, occurring on day d, having sequence number s
p_{kds}	E(P_{kds})
$f_{kds}{}^{P}(\mathrm{x})$	probability density function (pdf) of P_{kds}
R_{ds}	random variable that represents the resumption lag occurring on day d, sequence number s
r_{ds}	E(R_{ds})
$f_{ds}{}^{R}(\mathrm{x})$	pdf of R_{ds}
L_{ds}	random variable that represents the interruption lag occurring on day d, sequence number s
l_{ds}	E(L_{ds})
$f_{ds}{}^{L}(\mathrm{x})$	pdf of L_{ds}
Q_d	random variable that represents the threshold of productive work (email processing and primary work) to be completed on day d
q_d	E(Q_d)
$f_d{}^{Q}(\mathrm{x})$	pdf of Q_d
Wq_{js}	email's wait in the queue (time spent waiting for the knowledge worker's attention) for email of urgency j having sequence number s
Ws_{js}	email's wait in the system (email resolution time) for email of urgency j having sequence number s $Ws_{js} = Wq_{js} + P_{kds}$
$\overline{W}s_{js}$	mean email resolution time for email of urgency j $\overline{W}s_j = \sum_s Ws_{js}/S$
Y_d	total email processing occurring on day d $Y_d = \sum_k \sum_s P_{kds}$

Z_d total amount of primary work completed on day d

G_d total lag time occurring on day d

$$G_d = \sum_s L_{ds} + \sum_s R_{ds}$$

H_d total hours worked by the knowledge worker on day d

$$H_d = Y_d + Z_d + G_d$$

$\overline{H}$ mean hours worked by the knowledge worker

$$\sum_d H_d / D$$

E_d knowledge worker efficiency occurring on day d

$$E_d = (Y_d + Z_d)/H_d$$

$\overline{E}$ mean knowledge worker efficiency

$$\sum_d E_d / D$$

Q_d threshold of productive work (email processing and primary work) to be completed on day d

$$Q_d <= Y_d + Z_d$$

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