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ABSTRACT

Almost a necessity for communication, email consumes significant portions of knowledge workers' time in today's organizations. Though issues such as spam, 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 emails almost continuously. Though some emails may require very quick responses, continuous email checking may lead to workplace interruptions and overload. This study presents a framework for studying email response timing approaches to minimize the communication times and yet reduce the interruptive effects. A rigorous analysis of the effective and efficient email processing policies, in a series of two-phase simulated virtual experiments, is performed by comparing various ways to reduce interruptions for various work settings. Findings suggest that managing email processing can make a significant difference in workplace productivity.

Keywords

Email Management, Interruption, Performance, Modeling and Simulation

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 one to two hours, and 34% spend more than two hours 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 such as prioritizing, filtering, etc. that are aimed at reducing email overload have been suggested.

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 minutes. 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. 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 sacrificing our ability to resolve email messages in a timely manner? The issue that we are trying to address in this study is that 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 only 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. 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: Are these policies robust across different email work environments?

Research question 3: Will fewer interruptions result in significantly more efficient work completion?

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

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 third section describes the research questions and hypotheses. The forth section provides the model details with an accompanying appendix for technical details. The fifth and sixth sections summarize the results. Finally, the last section provides discussion, limitations and future work.

LITERATURE REVIEW

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 seconds 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 seconds 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, 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 minutes. 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.

RESEARCH FRAMEWORK

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.

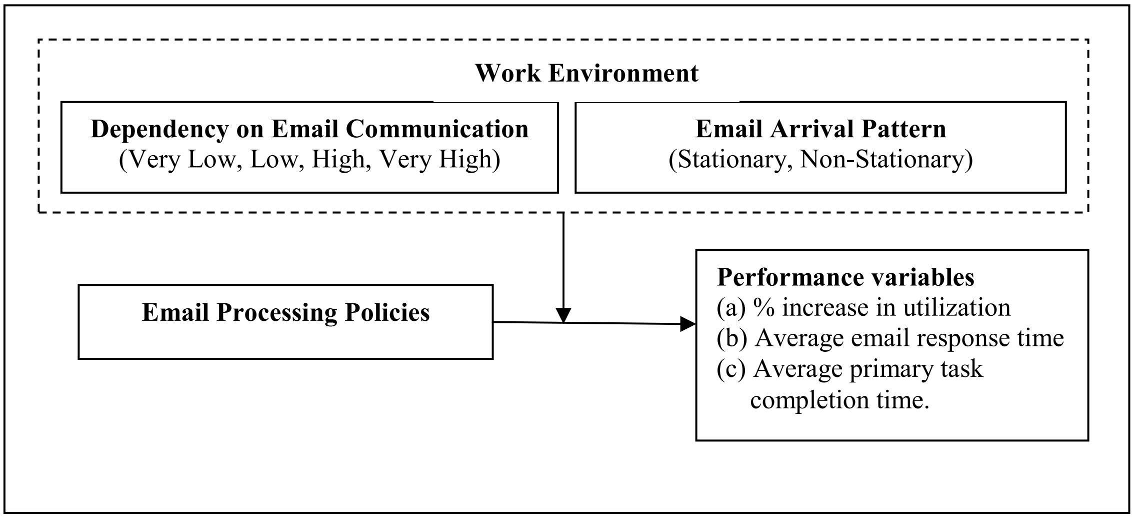


Figure 1: Research Model for the Phase I Experiment

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 categorized 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 four hours per workday processing email, "high" users three hours, "low" users two hours and "very low" users one hour. Emails often follow different arrival patterns in different environments as shown in fig.1. 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 in those environments where the arrival pattern varies with the time period.

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. This 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. 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. 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. 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?

> ***Hypotheses 1:*** *A controlled interruption policy such as processing emails twice or four times a day (middle policies) 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.*

Research question 2: Are these policies robust across different work environments and types of knowledge workers?

Hypotheses 2a: *The performance of policies will not change with a change in email dependency of work environment.*

Hypotheses 2b: *The performance of policies will not change with a change in email arrival pattern.*

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. This phase 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. 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.

We learn from Speier, et al. (1999, 2003) that interruption lags can adversely affect complex tasks. Jackson (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? Efficiency is defined as the knowledge worker's productive time at work divided by the knowledge worker's total time at work. 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).*

MODEL FORMULATION

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

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-4 (C4)	This processing strategy requires holding email hours four times daily.
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 minutes.

Table 1. The Email Processing Policies

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. 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.

These models considered various email characteristics and types. Five different email types were modeled in phase I models. These include spam (type 1), priority email (type 2), 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.

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. 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. 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.

RESEARCH METHOD

Numerous simulation models representing different types of work environments were developed and run in order to compare the performance of various types of knowledge workers under different email processing policies. In order to preserve simplicity within the models and to restrict the focus of the model, the simulation experiments were conducted in two phases. All tasks in Phase I followed an exponential inter-arrival time distribution and modeled five email policies. Sixteen different work scenarios were implemented and compared in this phase. 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. Collected data were analyzed using Multivariate Analysis of Variance.

RESULTS

Fig. 2 (a) shows that, for very low to very high email dependency, the percent increase in utilization of the knowledge worker varies from 2 to 5.7 percent using the once-a-day (C1) policy, 3 to 5 percent for four-times-a-day (C4) policy, and 8 to 15% with Continuous policy (C). Fig 2 (b) shows that percent utilization increased from 4 percent to 14 percent as we moved from C1 to C for time-stationary arrivals and increased from 3.7 percent to 11.5 percent on moving from C1 to C for non-time stationary arrivals. Figures 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. From Fig. 4 and 5, we see that the cost of interruptions in terms of time varies from 10 to 20 minutes for the C1 policy, 12 to 22 minutes for C4 for C4 policy, and 35 minutes to an hour for the C policy.

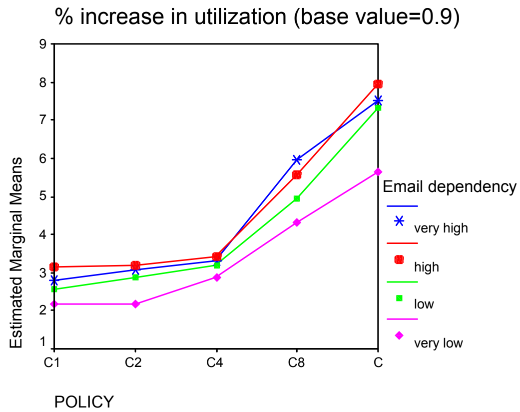


Figure 2(a): Effect of Policy x Email dependency on percent increase in Utilization.

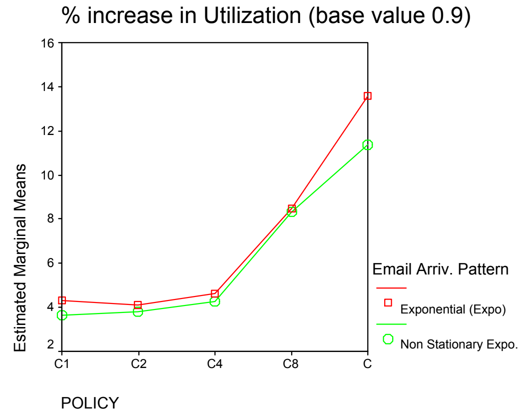


Figure 2(b): Effect of Policy x Email arrival pattern on percent increase in Utilization.

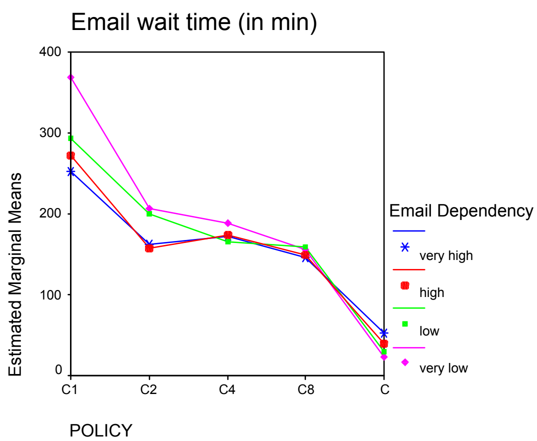


Figure 3(a): Effect of Policy x Email dependency on Additional Time Spent

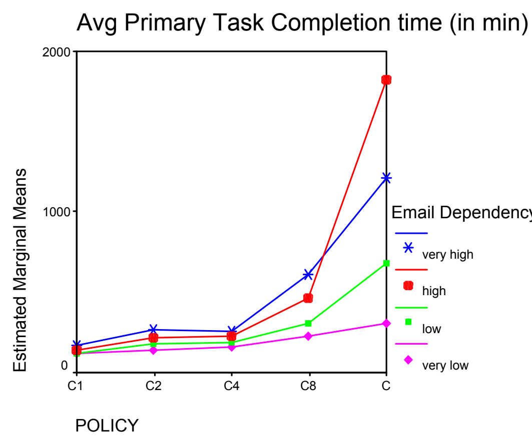


Figure 3(b): Effect of Policy x Email arrival pattern on Additional Time Spent.

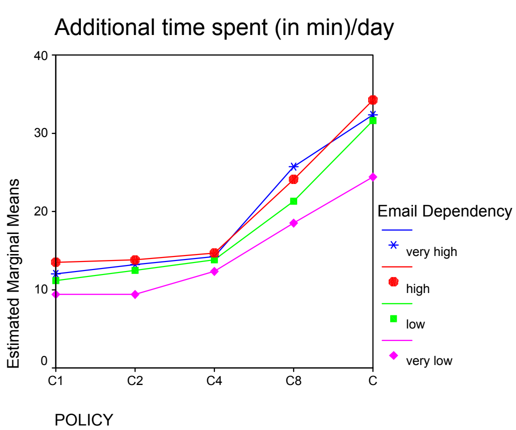


Figure 4: Effect of Policy x Email dependency on Email Response Time

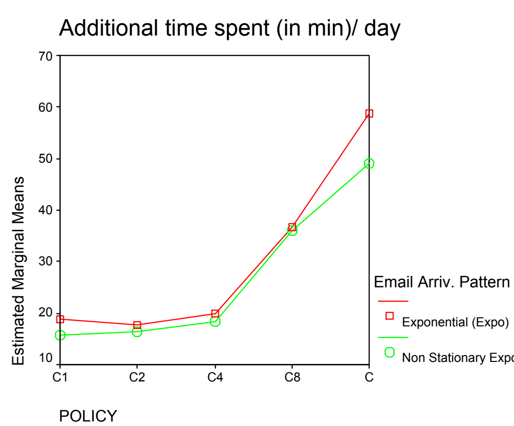


Figure 5: Effect of Policy x Email dependency on Primary Task Completion Time

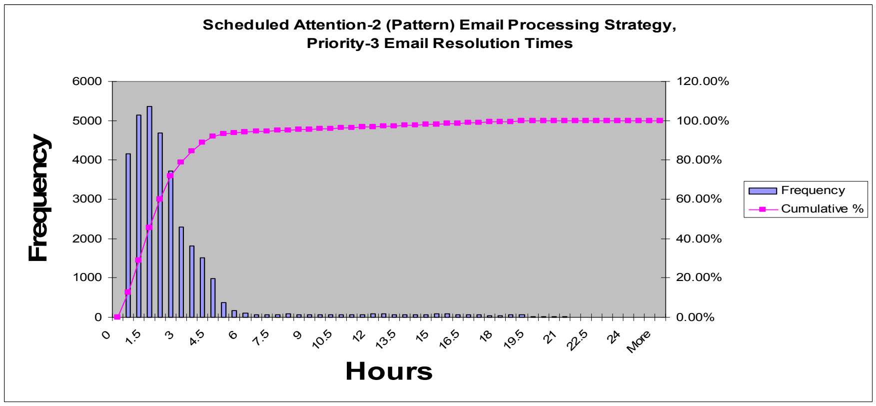
Fig. 4 shows the impact of various policies on email response time across various levels of email dependency. The C1 policy showed the longest average wait time (250 to 370 min) whereas the C policy showed the smallest wait time (15 to 20 min) for all levels. The average primary task completion time increased substantially during the use of C (200 min) and C8 (700 min), whereas for C1, C2 and C4 policies, it was between 30 min and 100 min (Fig. 5). Therefore, hypotheses 1 and 2 were found to be significant at the significance level of 0.05.

The email processing policy was found to have a significant effect ($\alpha = 0.001$). Hypothesis 2(a) was supported. The expected gains in efficiency were found to be statistically significant ($\alpha = 0.001$). 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 while the continuous email processing policy resulted in efficiency of 94.34%. Hypothesis 3 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 ($\alpha = 0.001$), however the direction of the difference was not as expected. As indicted in Table 2 below, the mean resolution times for priority-2 email messages do not support hypothesis 4. The difference between 3.5226 hours (Scheduled Attention-2 – with pattern) and 3.6419 hours (Scheduled Attention-2 – no pattern) is not statistically significant.

	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

Table 2. Scheduled Attention-2 (Pattern and No Pattern), Email Resolution Times for Both Priority-2 and Priority-3 Email Messages

However, the mean resolution times for priority-3 email do support this hypothesis (2.3879 hours is a statistically significant shorter resolution time than 4.028 hours ($\alpha = 0.001$)).



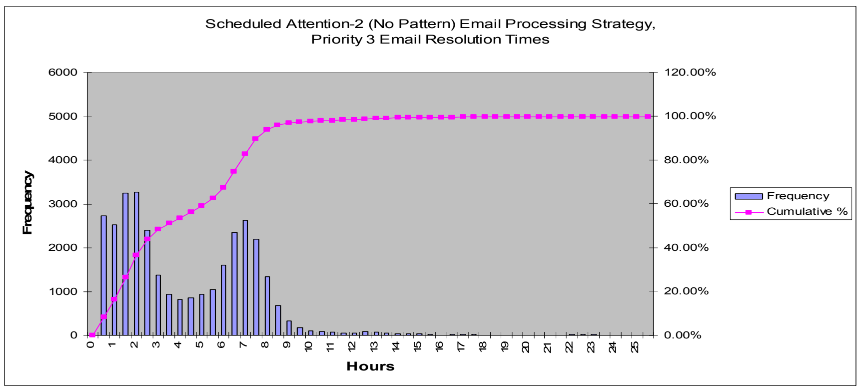


Figure 6. Scheduled Attention-2 (Pattern and No Pattern), Email Resolution Times for Priority-3 Email Messages

DISCUSSION, LIMITATIONS, AND IMPLICATIONS FOR FUTURE RESEARCH

Results illustrate the variation of percent increase in utilization of the knowledge worker due to interruptions with respect to the policy used. The percent increase in utilization reaches its lowest values at C4 and C2, thus providing the answer to research question1. The 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. When all the email get processed during this email-hour slot, the worker starts processing a primary task and continues to do so until another email arrives. The C1 policy comprises a single email-hour slot of three hours. 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 (45 min). Due to the shorter email-hour slots in the C4 policy, any email that arrives during non-email hours waits in the queue. 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 decreases 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.

This study provides numerous insights into the impact of interruptions and investigates the problems of email overload and interruptions, simultaneously. However, known internal and external validity issues are associated with any simulation-based study. Another limitation of this study is related to the issue of sample size and power. 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. Another underlying assumption of this study is that recall time increases with the increase in the time that has been spent on processing before an interruption occurs. The current study has focused on the individual knowledge worker. Future research may study the problem at the group 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 such as C3, C6, etc. 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.

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 Jackson policy (C8) is 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. The performance of each policy was evaluated across numerous measures and under varying work conditions to access the robustness of policies. 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. This result also highlights the value of using simulation to study a complex IS phenomenon.

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.

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