

The Cost of Email Use in the Workplace: Lower Productivity and Higher Stress

ABSTRACT

While email has been shown to be beneficial in the workplace, studies have reported that extensive email use can bring costs. In this study we investigate exactly how time spent on email might be related to perceived productivity and stress in the workplace. We conducted a mixed methods approach using computer logging, biosensors and daily surveys with 40 information workers in their *in situ* workplace environments for two workweeks. We found that the more time employees spent on email, the lower was their perceived productivity and the higher their level of stress. The relationship between email use and productivity was mediated by a difficulty in focusing. We also found an effect of users' email-checking habits: people who primarily check email in response to email notifications reported lower productivity compared to those who self-interrupt to check email. We discuss the implications of our results for improving organizational email practices.

Author Keywords

Email; sensors; productivity; workplace; stress; interruptions; in situ study

ACM Classification Keywords

H.5.3 [Information Interfaces and Presentation (e.g., HCI)]: Group and Organization Interfaces; K.4.m [Computers and Society]: Miscellaneous.

INTRODUCTION

In today's information driven world, email continues to be a ubiquitous communication medium on both organizational and personal levels [5, 11, 40]. Email has been shown to be very useful for assigning and communicating to do's [5], for coordinating and assigning tasks amongst colleagues [47], for task management and archiving information [47], and for storing, retrieving and sharing information easily [40]. Research has also shown that communications in

corporate organizations happen mostly through email [11].

However, it is well established by numerous studies, both quantitative and qualitative, that email leads people to feel cognitively overloaded, e.g., [3, 5, 10, 41]. The popular press has documented this concern: a search in the Google newspaper archives has produced over 166,000 news articles on the sole topic of email overload in the workplace. Sherry Turkle reflects this sentiment in describing how "*we don't do email, our email does us*" [44]. Users continually complain about getting too much email to keep up with [5, 10, 48]. While having good organizational skills can facilitate email management [34], such skills are not universal and their lack may lead to a number of negative outcomes.

Studies on email management practices in the workplace have shown that the time employees spend in managing email comprises a significant portion of their daily activities. A 2012 report from the McKinsey Global institute shows that 28% of employee's workweeks are spent on reading, composing or responding to email [33]. Also, given the culture of reliance on email for information exchange in organizations, people also tend to frequently check email, either triggered by notifications or self-interruptions in anticipation of incoming information [18]. While email is intended to be a tool to benefit communications in the workplace, it is not clear whether extensive engagement in email interactions adversely affects productivity.

The goal of our study is to understand how email usage is related to people's workplace experience in their real work environments, in particular focusing on its relationship with productivity and stress. Though little research has given attention to email and productivity, some findings show that email, coupled with face-to-face interactions, in fact positively impacted productivity [27]. Prior studies have also shown email usage to be associated with increased stress [20, 26]. The relationship between email usage, productivity, and stress in the workplace is complex and not well explored in the literature due to its challenging nature.

While many studies have typically relied on self-reports of email usage, e.g., [10], research shows that such subjective measures grossly overestimate the time spent on information technology [8]. To obtain a more reliable measure of participants' email use, we continuously logged our participants' computer activity as they conducted their

normal work tasks. Our research questions called for a mixed methods approach, so we combined computer activity logging with physiological data and daily surveys, where we measured affective and cognitive parameters of 40 information workers for about two work weeks in their *in situ* workplace environments.

Our findings show that email duration has a negative impact on workers' perceived productivity and stress, and that the first relationship is mediated by difficulty in focusing. We also found some evidence that email-management habits can alleviate some of the negative effects: specifically, people who chose when to self-interrupt to interact with email assessed their productivity higher at the end of the day compared to those who reacted to external interruptions from email notifications.

To the best of our knowledge, our study is the first *in situ* multi-method investigation of email activity, workplace outcomes and well-being. Our results lay ground for the future theoretical exploration of these effects, and provide valuable practical lessons for organizations and knowledge workers.

RELATED WORK

Email usage in the workplace: an overview

Research suggests that people do spend quite a bit of time checking their email over the course of the day. Renaud et al. [36] logged six users and found that they checked email on average 36 times per email session. Other studies found that users check their email around 74 times a day, or 11 times per hour [27], that 84% of the users keep their email up in the background at all times, and 64% of users used notifications to access email at least some of the time [36]. Czerwinski et al. [9] found that email accounted for 24% of the tasks information workers reported performing in a daily diary study. Fisher et al. [15] reported an average of 87 emails per day, while Mark et al. [27] found that users in a logging study spent an average of 34 minutes, 31 seconds per day on email, when analyzed across multiple email clients and websites. Jackson et al. [20] discovered that 70% of all emails received were opened within 6 seconds of their receipt, and it took an average of 64 seconds to resume the task that the email interrupted. Obviously, these disparate estimates could be due to a variety of factors, such as culture, location, sensing mechanisms, instructions, and so on. The bottom line is that people are checking and dealing with their email quite a lot, which in turn could have a variety of repercussions.

Benefits of email in the workplace

Multiple studies have shown that continual email engagement is not unwarranted: email provides many benefits in the workplace [5, 47]. As such, it is not really an option for users to totally "opt out", though this has been shown to be beneficial for reducing stress [29]. Mano and Mesch [26] found email to be helpful in speeding up communication and benefiting performance in the

workplace. In their review of email handling, Ducheneaut and Watts [12] examined email from three different perspectives: email used as a "filing cabinet", a communications production facility and simply as a communications genre. So email certainly has been shown repeatedly to be a multidimensional tool potentially benefiting workplace productivity.

Cost of the ubiquity of email: overload and stress

Despite its usefulness, email research does show that the ubiquity of email has its costs. Researchers identified a number of factors that can contribute to the feeling of email causing cognitive overload, including a lack of clarity of email requests [41], the work being demanded in the emails [41], poor email management strategies [10], a loss of control [3], problems keeping track of email threads [5], interruptions due to email [30] and social pressure to respond (quickly), especially if the sender is higher up in an organizational chain [3, 41]. Email generally imposes more costs on the recipient than the sender, especially when information is requested or when work is delegated to the recipient [10].

Effect of email on productivity

Few studies have addressed the relationship of email use to productivity. Communication technology overload as a broad measure was found to negatively correlate with productivity [23]. Email overload though did show a negative relationship with productivity [37]. Mano and Mesch [26] found that the number of email messages people received increased perceived workplace effectiveness. Yet since only about 30% of received email requires action [5] and since it was found that 32% of emails remain unread [17] this raises the question of what other aspects of email use might affect productivity. It has been proposed that the time and effort spent monitoring and responding to email could adversely affect productivity [5].

Potential effects of email on stress and well-being

While some research has shown that having good organizational skills can help with managing email while mobile (creating a feeling of being "on top of it" [34]), not all information workers have such good organizational skills, which can contribute to stress.

Many studies have shown how debilitating stress is to good health, e.g. [26, 36]. Stress leads to cardiovascular disease, back and shoulder injuries, weight gain, higher cholesterol, high blood pressure and gastrointestinal problems, just to name a few health consequences [2]. This is problematic because while most people are aware of their stress levels, not all have positive stress coping skills [2].

It is possible that better management of email interactions could alleviate this stress emanating from email overload. One study had users turn off their email for a week while they wore heart rate monitors to measure heart rate variability (HRV, a validated measure of stress/depression) [29]. This was in comparison to a baseline period while

doing email as usual while also wearing the HRV sensors. Results showed that HRV signals revealed less stress when the email was turned off, even though other communication channels like the phone, instant messaging, etc., were still available to be used. So while abstinence from email might not be a possibility, tools and user interface designs for protecting a stressed user from the onslaught of email could be an important contribution to productivity and health in the workplace.

Duration of time on email: productivity and stress

Thus, research indicates email as a double-edged sword. While it certainly holds benefits and has become an essential component of the workplace, it also imposes costs. Some claims of email's costs are that it lowers productivity and increases stress. Some studies have made the connection that time on email leads to stress by arguing that time spent on email creates additional work for the user which in turn elevates stress [43]. These claims are based on the idea that time spent on email creates more add-on work for people due to its affordances. Communication is easier and faster via email than written notes and thus creates more messages that people must spend time at, not only in responding to, but also in organizing and filing [5]. Also, as it is easy for the sender to make requests and delegate work [10] this creates new tasks which the recipient may not view as critical to work--some of which must be conducted through email [29]. Email creates interruptions which involves extra work for users to reorient back to the task at hand [20].

Other claims are that the time spent on email extends the workday which leads to stress, e.g. [32]. Stress has also been attributed to the volume of email that people receive [10], and Barley [3] in fact found a positive correlation with time spent on email and number of incoming emails. Thus, we might expect that more time on email would lead to stress.

Yet the few studies that have looked at the relationship of time on email and stress have found contradictory results. In a year-long study of college students, hours of email use per week were negatively associated with stress [42]. Yet other workplace studies found that the amount of time employees spent on email was positively correlated with feeling overloaded [3, 39]. In fact, in one study email was the only communication tool to which the participants attributed as causing stress [3]. All of these studies involved self-reports which have been found to not accurately reflect actual time with ICT usage [8].

Other studies have examined consequences of email use and its effect on productivity using surveys. While not specifically studying email, Karr-Wisniewski [23] found a general measure of communication technology overload to be negatively related to productivity. Sevinc and D'Ambra [37] found a negative relationship of email overload and perceived productivity. A loss of productivity with email use has been explained as people spending time continually

monitoring their email, taking time away from other activities [5]. People reported being lost in email 23% of the time, often due to diversions [17], which could increase their time on email without feeling productive.

Yet with the exception of the study of Barley et al. [3] who used self-reports, studies have not directly measured the relationship of time spent on email and its effect on productivity and stress. We find this surprising as a fair amount of research documents that email comprises a significant portion of the day and descriptive accounts have been provided on the amount of time people spend on email and the number of email checks people typically do [9, 15, 20, 27, 36]. There is also a large amount of research discussing reasons for email overload, e.g. [3, 5, 10, 11, 12, 47, 48]. Yet these two streams of research have not been well linked together and direct measures of stress have not been used.

As email use comprises a significant portion of the day we feel that a time measure of email use is important to consider. To our knowledge, research has not examined the association of time spent on email using objective measures, with effects it might have on the workplace experience. In this paper we ask whether the amount of time on email impacts productivity and stress. If so, what form does this relationship take?

RESEARCH QUESTIONS

Despite the numerous studies that have documented feelings of email overload, it is important to consider that email not only increases the incoming stream of information and tasks, but also provides more structured support for communication and coordination, which may be vital to accomplishing tasks related to work. Thus, while overall people might complain of the influx of email, the tool itself in different ways can help people accomplish their work. Therefore, the relationship of time spent on email and effects on productivity is not so clear-cut. We are interested in how the length of time spent on email is related to people's cognitive and affective states in the workplace. However, people can have different styles of checking email: either by being triggered to check through email notifications or checking on their own. These styles of checking email could affect the frequency of checking email as well as the duration of time people spend on email. We focus on investigating the following research questions.

RQ1. Checking email: Type of interruptions

In the 1980's, Miyata and Norman [35] distinguished between two types of interruptions: *external* interruptions that are triggered by an external source such as a phone call or email notification, and *internal*, or *self* interruptions where a person chooses of their own volition to interrupt their current behavior to do another activity. Interruptions, documented to be disruptive in work and requiring a recovery time, e.g., [30, 38, 16], could have an impact on the workplace experience, for example, affecting a person's ability to focus [21]. A person's style for checking email,

whether externally or self-driven, could affect other aspects of their email usage, such as the daily time they spend on email. With respect to email, we refer to external interruptions specifically as those from email notifications, and self-interruptions as originating from one's self. Jin and Dabbish [21] found a number of reasons that trigger self-interruptions, such as when people needed information, when they remembered to do something else, a desire to take a break, or merely habit. How both external and self-interruptions affect the time spent on email, as well as the frequency of checking email, has not been well explored in the literature. Further, it has not been studied how external and internal interruptions to check email might affect productivity and stress.

There are numerous reasons documented in studies on why people frequently check email, for example, to keep up with information so as not to miss out on something timely [3] and the power of social norms and pressures to respond quickly [29]. As a first step in this study we ask how a person's style for checking email, in terms of being triggered by external notifications or self-interruptions, might be related to their email usage. If such a relationship exists, then a person's email-checking style could help explain their time spent on email. We therefore begin by investigating the following research questions.

RQ1a. How is interruption type, i.e. email checking triggered primarily by either external or self interruptions, associated with email duration in the workplace?

RQ1b. How is interruption type, i.e., email-checking, triggered primarily by either external or self interruptions, associated with frequency of checking email in the workplace?

RQ2. Productivity

An important aspect of the workplace experience that could be affected by email is one's assessment of their productivity. One reason for feeling overloaded from information, according to Eppler and Mengis [14] in their review, can be attributed to when the demands on time to deal with information are greater than the amount of time available. Investing time to manage email takes time away from other activities. Interruptions from email were found to take time from other more crucial tasks in the workplace [26]. Thus, dealing with email could lead people to feel that they are compromising engagement in other types of work which could be more productive for them. For example, time spent on dealing with email might be taking time away from writing a report or producing a presentation. Further, the cognitive effort of dealing with the costs of email as we discussed earlier (responding to, filing, organizing email; continually monitoring the inbox, recovering from interruptions) could also adversely affect perceived productivity. On the other hand, as a large proportion of email use concerns task management [5], it might be expected that work on email could lead to a sense of increased productivity. Often tasks originate in email [5]

and dealing with email could be a way of accomplishing tasks. Thus, it is an open question how the time spent on email might affect productivity. The time involved in dealing with messages (reading, responding, filing, etc.) could relate to productivity, but another perspective of email usage is the number of checks of the inbox that people do. This leads us to our second set of research questions:

RQ2a. How is email checking, primarily triggered by either external or self interruptions, associated with assessed productivity in the workplace?

RQ2b. How is time spent on email associated with assessed productivity in the workplace?

RQ2c. What distribution best characterizes the relationship of email duration and productivity for people?

RQ3. Stress

Stress is another aspect of the workplace experience that could be related to the duration of time that people spend working on email. When a threshold of a person's resources to deal with information is exceeded, then this can lead to stress and anxiety [14]. Some studies show that email usage is, indeed, negatively related to stress: when email was deliberately cut off for a period of five days in a workplace, people became significantly less stressed as measured by their heart rate variability [29]. In another study, participants who were instructed to check their email as much as possible experienced more stress than when they were asked to check it minimally [25]. However, the latter case did not study natural email behaviors for the participants. A relationship of stress and email could be due to different factors. For example, in his study of email use, Barley et al. [3] found that informants reported anxiety in not being able to keep up with their inbox, which could result in missing critical information. However, though stress has been found to decrease in the absence of email [29], the exact pattern of relationship between stress and the duration of email use is not known. We thus ask our third set of research questions:

RQ3a. How is email checking, triggered primarily by either external or self interruptions, associated with stress in the workplace?

RQ3b. How is time spent on email associated with stress in the workplace?

RQ3c. What distribution best characterizes the relationship of email duration and stress for people?

METHOD

Procedure and participants

We conducted a mixed methods *in situ* study with 40 participants (20 females, 20 males). Participants were volunteers working in a research division of a large corporation, and represented different job roles:

administrative support, engineering, and management. Participants were compensated with a \$250 gift card.

Participants were asked to be in the study for 10 full business days. However, some participants were in the study longer than 10 days, due to technical problems or scheduling issues. During the study period, physiological data was collected from a heart rate monitor worn around the chest during all waking hours. Their computer activity at work was also logged during all business hours. Prior to the beginning of the study, we met with participants individually to explain the study procedure, install the software, and to instruct them on how to use the heart rate monitors. Participants were instructed to work as they normally would throughout the workday.

In addition, we administered a pre-study survey with a number of demographic, work, and stress measures. Participants were also sent an evening daily questionnaire, where they reported their ability to focus, and perceived productivity for that day.

All volunteers were assured that their data would be kept private and aggregated, that no content would be associated with their information, and that they would remain anonymous. Upon completion of the study, one of the researchers interviewed all the participants to confirm that they followed the study protocol as instructed, and to learn about any unusual circumstances that could have had an effect on the data provided by the participants.

Measures

Table 1 shows a summary of measures. We detail them as follows.

External/Self interruptions were measured in the post-study interview by the following question: *I check email: 1) Always when triggered by an external notification and never on my own; 2) Much more often when triggered by an external notification than on my own; 3) About half the time when triggered by an external notification, half the time on my own; 4) Much more often on my own than when triggered by an external notification, 5) always on my own and never when triggered by an external notification, and 6) I don't have email notifications.* The Interruption Type measure was categorized into three levels: (1) responses 1 and 2 were combined into "External interruptions" (**External**), (2) response 3 was "Half the time external, half the time self" (**Equal**) and (3) responses 4, 5, and 6 were combined into a measure of "Self interruptions" (**Self**).

Email Duration Proportion was measured as the ratio of the time spent on email interactions and total time spent on computer interaction. We normalized this measure per person. Time spent on email was logged automatically via custom-built Windows Activity Logging software. This logging software tracks every open application, which window is in the foreground, and whether the user is interacting with that window (with mouse, keyboard, touch, etc.). We measured the total duration of email client use.

Email duration was defined as the number of seconds that the email client was in the foreground window, ending when the user either changed windows or the computer had no keyboard or mouse activity for a period of five minutes. As participants at times might not be using their computer for various reasons (e.g., they might be at a meeting), we used only those hours of data when the computer was used (i.e., the logging data showed that computer duration was greater than zero for that hour).

Email Checks was measured as the number of separate times that the email client switched to the foreground. We constructed a ratio of number of daily email checks over total daily seconds of computer duration and normalized per person.

Productivity was measured by six items included in the daily end of day survey: *"How much did you accomplish today based on what you had planned to accomplish?"*, *"How efficient do you feel you were today in performing your work?"*, *"How satisfied were you in what you accomplished today"*, *"How effectively do you feel you managed your time today?"*, *"How would you evaluate the quality of the work you did today"*, and *"Overall, how productive do you feel you were today?"*. All responses were measured on a 7-point Likert scale, with 1=not at all, and 7=extremely. The item dimensions were highly correlated (with correlations ranging from .68 to .94), so we combined them additively to construct an index measure of Productivity.

Focus Difficulty was assessed at the end of each day with one global Likert-scale item: *"It was difficult for me to concentrate today"* (1=strongly disagree, 7=strongly agree). The question was asked as a part of the daily end of day survey.

Stress level was determined from the continuous stream of cardiovascular data measured by digital heart rate monitors that participants wore during all waking hours for the entire duration of the study. We used the Zephyr HXM BT (bluetooth) heart rate monitor. A custom-built mobile phone application pulled the data from the Zephyr Heart Monitor, and uploaded that data into Azure cloud storage. Stress was estimated based on heart rate variability (**HRV**) – a well-validated indicator of mental stress that is used extensively in research and clinical studies (see [1] for a review). HRV is a measure of variations in intervals between consecutive heartbeats. We used the RMSSD as a measure for calculating HRV (see [45]). Perhaps counter-intuitively, the relationship is inverse, so that the lower the RMSSD measure, the higher the amount of stress, as the body is regulating itself through the sympathetic nervous system. Stress was measured to the second and then for each hour we computed the average level of stress for that hour.

The RMSSD was computed each second based on the variance over the prior 5 minutes. For each hour then, we compared the average RMSSD along with email duration

Measure	Description
Email duration	The proportion of seconds spent daily/hourly on email compared to total computer duration.
Email checks	Counts of daily/hourly unique visits to the email client.
Interruption type	People's reported preference for external interruption or self-interruption for checking email (using notifications or not)
Productivity	Measured in end-of-day survey based on six dimensions using Likert scale; Composite measure created.
Focus difficulty	Measured in end-of day survey using Likert scale.
Stress	Measured by worn heart rate monitors using RMSSD.
Baseline stress	Perceived Stress Scale [7] in general survey
Job characteristics	Job demands, job decision latitude from JCQ [22], in general survey

Table 1. Summary of measures used.

and number of email checks. HRV has been used in other *in situ* empirical studies, e.g. [29]

Baseline stress was measured in the pre-study survey based on the Perceived Stress Scale (PSS) [7]. The PSS consists of 14 items and measures an individual's subjective evaluation of their chronic life stress. It has demonstrated reliability and validity and was recommended for use as an outcome measure of stress [7].

Job characteristics. Email is a communication tool, and an employee's job role significantly affects the amount and the dynamics of its usage. For example, a person with administrative support duties may process hundreds of messages a day and have his email client constantly in the foreground of the computer screen, whereas an engineer may have her email closed, and only check email during short scheduled breaks. To control for such differences, we took into account our participants' job roles. Instead of using a rather broad taxonomy of job titles, we relied on two fundamental dimensions suggested by Karasek in his Job Content Questionnaire: job demands, and job decision latitude [22]. Job demands is an index measure computed from five items such as "My job requires working very fast", "I am not asked to do an excessive amount of work" (1=strongly disagree, 4=strongly agree). Job decision latitude is the cumulative measure of an employee's skill discretion and decision-making authority, and is measured by nine items such as "My job requires a high level of skill"

and "I have a lot to say about what happens on my job". Participants answered these questions as a part of the pre-study survey.

Analyses

For the analyses of daily data, we used only full days of window logging (the time of the study setup sometimes resulted in partial days of data collection), used weekday data (i.e., during the work week) and used only days when the computer usage was greater than zero. For the analyses of hourly data (investigating the relationship of email and stress), we used only weekday data, and looked at average stress (based on RMSSD) and average email use for each hour during the hours of 9 am to 5 pm, which is when most participants were in the workplace. We also used only those hours of data when the computer was used (i.e., when the logging data showed that computer duration was greater than zero for that hour).

For our analyses we used Linear Mixed Models (LMM) to account for the correlated data within subjects (repeated measures on days, or on hours). We ran LMM in SPSS using random and fixed effects.

RESULTS

Overview of results with email

The total hours of data collected for window logging was 1981.5, with an average of 49.5 hours of computer screen data logged per participant. The average number of weekdays with window activity logged per person (i.e., excluding Saturdays and Sundays) was 12.4 days.

Table 2 shows that the average daily time spent by our participants on the computer (averaged over work days) is about four and a half hours. Our 40 participants averaged almost one and a half hours per day of time on email and checked their email on average 77 times per day. 30.8% of our participants reported primarily checking email due to external notifications, 28.2% reported checking email about half due to external notifications, and half on their own, and 41.0% reported primarily checking email on their own, and not due to external notifications. Frequency of Checking Email is highly correlated with Email Duration: $r=.75$, $p<.0001$.

	Mean	SD	Median	Range
Total computer duration	4 hr 34 min	2 hr 23 min	4 hr 28 min	3 min - 13 hr 59 min
Total email duration	1 hr 23 min	40.49 min	1 hr 6 min	0 - 7 hr 54 min
Email checks	77.27	63.52	58.0	1 - 408

Table 2. Daily averages of different computer usage. N=40.

Job characteristics

Regression analyses with job characteristics as independent variables and Email Duration as the dependent variable showed that there is no significant relationship with Job Decision Latitude and average amount of time on email: $F(1, 38)=2.57, p<.12$. However, there is a significant relationship of Job Demands with average duration of email use: $F(1, 38)=7.40, p<.01$. The higher one's job demands, the more time one spends on email. The frequency of checking email is negatively correlated with Job Decision Latitude $F(1, 38)=4.45, p<.04$. There is also a strong trend for Job Demands to be positively correlated with email checking: $F(1, 38)=3.58, p<.07$.

Thus, the more decision latitude people have in their jobs, the less they check email. The higher employees' job demands are, the more time they spend on email and the more often they check email. We used Job Demands along with Job Decision Latitude as controls in our subsequent email analyses.

RQ1. Interruption Type: External and self interruptions

Our first research question examined how a person's style of checking email (whether they primarily check due to external or self interruptions) is associated with their email checking frequency and their email duration.

RQ1a. Checking Email

Using LMM, with Interruption Type as an independent variable and Email Checks as a dependent variable, we found no significant relationship: $F(2, 28)=.42, p<.66$.

RQ1b. Email duration

Using LMM, with Interruption Type as an independent variable and Email Duration as a dependent variable, we found no significant relationship: $F(2, 27)=.24, p<.79$.

Therefore, regardless of whether people self-initiate when they want to interact with email, or whether they check email due to an external trigger, it bears no relationship with the amount of time they actually spend on email nor on the frequency of checking of email. Interruption Type may still have varying effects on productivity and stress – which we explore in the following analyses.

RQ2. Email and productivity

We next examine how email is related to information workers' self-assessed productivity at the end of the day. We rescaled our additive index measure of productivity (based on 6 dimensions of 7-point Likert scales), so that the scores ranged from -18 to 18, $M=3.6, SD=7.1$.

RQ2a. Checking email

We first tested a model examining the number of times checking email daily with end of day productivity assessment. We included Email Checks and Interruption Type as independent variables in the model. A LMM analysis was done and coefficients and test statistics are shown in Table 3, using controls of job characteristics. Email Checks was not significantly related to Productivity. However, Interruption Type is significantly associated with

Productivity		B	t	Df	p
Email Checks		-.43	-.81	224	.42
Interruptions	External	-5.15	-2.63	33	.01
	Equal	-.62	-.31	30	.76
	Self ¹	--	--	--	--

Table 3. Model of Interruption Type and number of Email Checks with productivity. ¹ = the parameter is set to zero because it is redundant, i.e., coefficients are relative to Self Interruptions.

Productivity	B	t	df	p
Email duration	-.98	-279	227	.006

Table 4. Model of email duration with productivity, controlled for by job characteristics.

Productivity: $F(2,31)=3.62, p<.04, M_{\text{External}}=23.58, SE=1.61, M_{\text{Equal}}=28.11, SE=1.54, M_{\text{Self}}=28.73, SE=1.20$. We conducted a Bonferroni pairwise comparison on Interruption Type and the results showed a significant difference between External and Self types of interruptions, $p<.04$. The interaction of Interruption Type and Email Checks was not significant. Job Demands was positively related to productivity: $F(1, 34)=5.89, p<.02$ and Job Decision Latitude was not significant. Thus, participants who reported that they primarily check email on their own (Self) reported the highest assessed productivity.

RQ2b. Email Duration

We next examined how email duration during the day might be associated with end of day productivity assessment. We normalized Email Duration per person because some individuals might habitually rate their productivity higher than others. As shown in Table 4, Email Duration is negatively related to Productivity, controlling for job characteristics. Job Demands is positively related to daily Productivity: $F(1, 34)=6.10, p<.02$. The effect of Job Decision Latitude was not significant.

RQ2c. Distribution of Email Duration

How are daily Email Duration and Productivity related? As we had no a priori expectation of the form of the relationship, we tested different models using regression analysis. We used normalized Email Duration per person. We found that the best fitting curve is a quadratic relationship: $F(2, 252) = 4.22, p<.02, \beta_1 = -1.21, \beta_2 = -.15$. In other words, for each individual, there appears to be an optimal amount of time that one spends on email vis-a-vis productivity. Too little time and too much time on email is associated with a lower assessed productivity. The actual optimal amount varies by person yet the significant quadratic relationship suggests that this overall pattern characterizes our participants' use of email.

Explaining email duration and productivity

Our results of email duration could be due to the fact that some people consider themselves as more productive when using email than others. Even though we normalized by person and controlled for job characteristics, it is still possible that some workers, more than others, may view their time on email as accomplishing work and therefore feel more productive the longer their email use. To check this notion, we compared the ten participants with the highest average daily productivity ratings (averaged over the days in the study) with the ten participants with the lowest average daily productivity ratings to see if email duration differed. An independent t-test showed that there was no significant difference between the two groups (Mean Email Duration high group = 3425.60 sec, s.d.=2348.64; Mean Email Duration low group = 3158.50, s.d.=2243.82), $t(18)=.26, p<.80$). Similarly, there was no significant difference between the two groups in average daily Email Checks: $t(18)=.93, p<.37$. Therefore, though some people rate their productivity higher than others, this rating does not reflect different email durations nor amount of daily email checking between the groups. The relationship of email duration and productivity rather varies within people, i.e. when each person spends more time on email relative to their mean usage, then their productivity assessment declines (and vice versa).

RQ3. Email and stress

We next examined the relationship of email and stress. As described in the methods section, stress is measured by RMSSD, based on the heart rate captured by the worn heart rate monitors. Recall that the value of RMSSD is inversely related to one's stress level: the *lower* the RMSSD value, the *higher* the stress.

RQ3a. Checking email

We first tested the relationship of Email Checks with stress. For the independent variable, we used Email Checks per hour and the dependent variable was average RMSSD for that same hour, for the work hours of 9 to 5. We also included the independent variable of Interruption Type. A LMM analysis was done and results are shown in Table 5, using controls of job characteristics and PSS scores, a measure of general baseline stress (see description in Measures section). We found no relationship of Interruption Type with stress nor an interaction. However, we found a strong trend, that the more times a person checks email that hour, the higher is their level of stress for that hour.

RQ3b. Email Duration

We next examined the relationship of email duration with stress, comparing email duration per hour (normalized per person) with average RMSSD for that same hour, during

Stress	B	t	df	p
Interruption Type	-1.62	-.54	24	.59
Email Checks	-.58	-1.88	831	.06

Table 5. Model of interruptions type and number of email checks with stress. The RMSSD value is inversely related to stress.

Stress	B	t	df	p
Email Duration	-.81	-3.16	1249	.002

Table 6. Results of model of email duration with stress. Email duration is measured in seconds. The RMSSD value is inversely related to stress.

the work hours of 9 to 5. We controlled for PSS scores and job characteristics. The results in Table 6 show that Email Duration is significantly positively associated with Stress. The longer one spends on email, the higher one's stress. PSS scores and job characteristics were not significantly related to average RMSSD.

RQ3c. Distribution of Email Duration and Stress

To examine the form of the relationship of Email Duration and Stress more closely, we ran a regression analysis of the fixed effects with Stress (avg. RMSSD/hour) as the dependent variable and Email Duration/hour as the independent variable. A cubic relationship shows a better fit than a linear or quadratic model: $F(3, 1323)=29.86, p<.0001, \text{adj. } R^2=6.1$. Fig. 2 illustrates that a low amount of email duration is associated with the least amount of stress, a moderate amount of email duration with a moderate amount of stress, and a high amount of email duration with the highest stress.

Thus, in sum we found that total Email Duration was positively significantly associated with Stress when we examine the data on an hourly basis. Further, the relationship of Email Duration and Stress each hour followed a cubic relationship: a low amount of email was related to the lowest amount of stress, but stress increased steeply, moderate email usage was related to a moderate amount of stress in a relatively flat curve, and a high amount of email duration was related to a steep increase in stress.

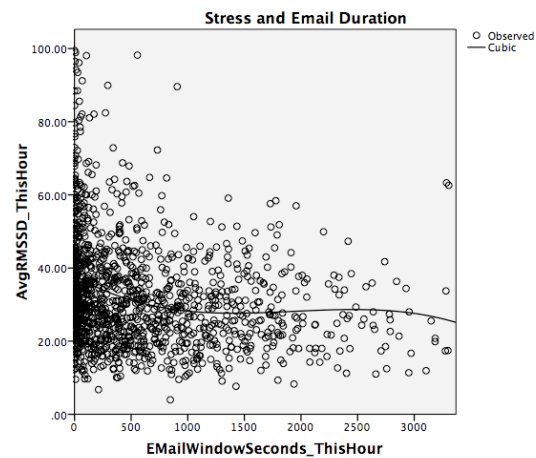


Figure 1. Relationship of Email Duration and Stress based on hourly data. The lower the value of RMSSD (stress), the higher the stress.

MODELS OF EMAIL DURATION

To provide a better understanding of our results, we tested models to see whether the relationship of email duration on productivity and stress might be mediated by another factor.

Email and productivity

Our data is correlational. We hypothesized that email duration could affect one's assessment of productivity due to email affecting one's ability to focus on work in general. In the next section we first explain our reasoning for choosing focus difficulty as a mediating influence.

Focus difficulty as a mediating variable

First, we examine the reliability of the measure of Focus Difficulty. At the end of each day we measured Focus (see section on Measures). A higher value on the focus measure indicates more difficulty in focus. As a check on this measure, we looked at the relationship of Focus with people's logged switching behavior between computer screens. Following the computer screen switching measure used in [27], we divided computer switches into two categories: those of switching *between* applications, and those of switching *within* applications (of which about 95% were switching among Internet sites). We expected that low focus should be correlated with switching Internet sites (i.e., surfing), but that switching between applications should not be associated with focus difficulty. We reasoned that switching rapidly between Internet sites could be a reflection of a lack of focus. We also reasoned that switching between applications involves switching between different work projects, and as work requires focus, this should not reflect a lack of focus. Indeed, using LMM, we found a significant positive correlation of low focus and switching within applications (i.e., primarily switching Internet sites): $F(1, 233)=7.61, p<.006, B = 2.59$. The higher the frequency of switching, the more difficulty in focus. However, there was no significant correlation with application switching, as we expected: $F(1, 241)=.09, p<.77, B = -.35$.

We also examined the relationship of daily Email Checks with difficulty in Focus. A LMM shows a significant positive correlation: $F(1, 221)=66.98, p<.0001, B = -.37$. Thus, the more times one checks email daily, the more difficulty one reports in focusing for that day. Thus, these results are consistent with what we would expect the focus measure to correlate with.

However, why would we expect Focus Difficulty to be a mediator of Email duration on Productivity, and not Email duration as a mediator of Focus difficulty on Productivity? Working on email is a form of multitasking [5, 9]. Barley [3] found a significant positive correlation of number of emails received and time spent on email. Thus, we can expect that the more time people spend on email, the more different emails people must attend to. When people are handling different emails, they are switching among different topics. But it is not only the different topics that people manage but also different activities as Bellotti et al.

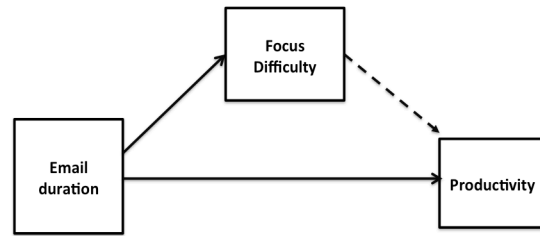


Fig. 2. Theoretical model of Email Duration as a predictor of Productivity, mediated by Focus Difficulty.

[5] discovered: reading, scanning, filing, writing, etc. Thus, we would expect that the longer one spends on email, the more one is shifting their attention to different contexts and activities. As cognitive shifts are associated with a difficulty in concentrating [49], we expect that dealing with email should lead people to experience a difficulty in focusing. This in turn could impact productivity. Also, email involves handling incoming email, but also keeping track of threads, which requires concentration [5]. Dabbish et al. [10] found that emails that are unanswered and left for later work remain in people's attentional focus—much like the Zeigarnik effect would predict [51]. The Zeigarnik effect refers to the idea that unfinished tasks remain in people's attention.

It was shown that prior to doing email people develop a preparatory state of being focused [27]. People use cognitive resources to attend to email as it requires different operations [5] and the response time is generally quite fast (6 seconds) [20]. Using cognitive resources to deal with email can affect people's ability to focus on other important work items. Though people may be initially focused before doing email, combined with the multitasking and task activities that email requires, along with the cognitive expenditures in dealing with interruptions, we expect that doing email expends cognitive resources. Using cognitive resources makes it more difficult to allocate resources to

Variable		Coefficient (SE)	t	df	P
Email duration -->Productivity		-.98(.35)	-2.79	227	.006
Email ->Focus		.20 (.10)	2.12	235	.04
Focus ->Productivity		-1.75 (.21)	-8.21	237	.0001
Email+ Focus ->Productivity	Email	-.65(.32)	-2.06	225	.041
	Focus	-1.70(.21)	-7.93	236	.0001

Table 7. Effect of Focus Difficulty as a mediator variable of Email Duration on Productivity (see model in Fig. 2).

attention focus [49]. Thus, time spent on email, which involves different operations, shifting to different contexts, and responding and recovering from interruptions, could impact one's ability to focus on their work, affecting productivity. Therefore, we test the directionality of this path model with Focus Difficulty as a mediator for email duration.

Fig. 2 shows a theoretical model. We tested the model using LMM, with Focus Difficulty as a mediator variable. The relationship was controlled for by job characteristics.

Coefficients of the effects of the mediator variable on Productivity are shown in Table 7. The results in Table 7 show that Focus Difficulty *fully* mediates the effect of Email Duration on Productivity, because: 1) Email Duration has an effect on Productivity, 2) Email Duration has an effect on Focus Difficulty, 3) Focus Difficulty has an effect on Productivity, controlling for Email Duration, and 4) Email Duration shows no significant effect on Productivity, when controlling for Focus Difficulty. To test the effects of the mediator variables we conducted a Sobel test [4], which reveals if the inclusion of the mediator in the model significantly lowers the effect of the independent variable. The Sobel test confirms that Focus Difficulty is a significant mediator of Productivity (Sobel statistic = -1.94, $p < .05$). Thus, our hypothesized tested model shows the effect of Email Duration on Productivity is significantly mediated by Focus Difficulty: the longer time one spends on email, the more difficult it is to focus. The more difficult it is to focus, the lower the assessed productivity.

Email and stress

We next tested a theoretical model to see whether the relationship of Email Duration and stress might also be mediated by Focus Difficulty. We hypothesized that an inability to focus could lead people to feel more stressed. Why do we expect in our model that email causes stress as opposed to stress leading people to do more email? Email has been shown experimentally to cause stress [29] and in qualitative studies to produce stress [3]. The stress from email has been attributed to different factors. Barley [3] found in interviews that email is associated with a loss of control, and pressure, due to social norms for people to respond quickly to emails. We also know that that research shows that people are interrupted frequently to do email

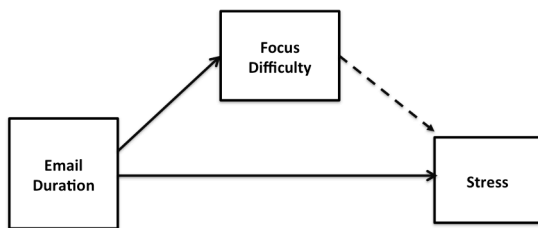


Fig. 3. Theoretical model of Email Duration as a predictor of Stress, mediated by Focus Difficulty.

Variable		Coeff (SE)	t	df	p
Email duration					
-->Stress		-81(.25)	-3.16	1249	.002
Email ->Focus Diff		.04(.03)	1.27	1900	.20
Focus Diff ->Stress		-.17 (.23)	-.76	1039	.45
Email+ Focus Diff - >Stress	Email	-.84(.27)	-3.07	1023	.002
	Focus Diff	-.16(.23)	-.69	1037	.49

Table 8. Effect of Focus Difficulty as a mediator variable of Email Duration on Stress (see model in Fig. 4).

[27, 36] and that interruptions cause stress [25]. Again, since it has been shown that people are in a state of high focus *before* doing email [27], we expect that the activities involved in email (e.g. switching task contexts, managing and organizing email, recovery from interruptions) should deplete those resources, cf [49]. These results informed our model to use the directionality that more time on email should lead to stress, as opposed to higher stress leading people to do more email. Following our same previous argument that email depletes cognitive resources, leading people to have more difficulty in focus [49], we also expect that difficulty in focus could lead to increased stress.

Fig. 3 shows the theoretical model we tested, with Email Duration predicting Stress, and with Focus Difficulty as a mediator variable, based on the hourly data. We used LMM, and controlled for job characteristics and PSS score (as a baseline for stress).

Coefficients of the effects of the mediator variable on productivity are shown in Table 8. The results in Table 8 indicate that Focus Difficulty is not a significant mediator of the effect of Email Duration on Stress. A Sobel test confirms that including Focus Difficulty as a mediator in the model does not affect the relationship of Email Duration with Stress: Sobel statistic = -.65, $p < .52$. Thus, our hypothesized model of Email Duration on Stress is not mediated by Focus Difficulty.

DISCUSSION

While studies of email use generally involve self-reports, we used a mixed methods approach with more sophisticated measures, where email usage was logged *in situ* in the workplace, and participants' internal states were captured via physiological measures and self-reports. This enabled us to not only examine email usage based on the objective logged data, but to also complement our analysis with measures of participants' cognitive and affective states.

We found that when an individual spends more time on email during the workday, it is significantly related to lower assessed productivity at the end of the day. We also found a positive correlation between time on email and fluctuating momentary stress based on hourly data. We tested

theoretical models to explain these relationships and found that the difficulty in focusing on work mediated the relationship between email duration and productivity. However, we did not find such a relationship between email duration and stress. Overall, email duration is associated with a feeling of lower productivity and higher stress. These relationships exist irrespective of individuals' job characteristics [22]: how demanding their work role is and how much latitude they have in making decisions.

Whereas it has been measured that people are in a state of focus before doing email [27], when email duration over the course of the day is considered, we found a positive association of time on email with a difficulty in focusing. Email duration could affect a difficulty in focusing due to a number of operations involved in doing email (e.g. [5, 48]), as well as in task switching when doing email [5]. Checking email is disruptive to a task as one switches attention to attend to the email and then one must exert effort to reorient back to the task.

But why would focus difficulty not affect stress? One clue can be found in the Yerkes-Dodson curve [50], which shows that increased arousal can improve performance, but only up to a point. This curve describing the relationship of arousal and performance follows an inverted U-shape. We tested whether stress might also be related to focus difficulty in this U-shaped form. A regression based on the fixed effects alone indeed shows a significant quadratic relation of stress affecting focus: $F(2, 1800) = 3.17, p < .04$. A low and high level of stress is associated with high difficulty in focusing; a moderate amount of stress is associated with less difficulty in focusing. When people are bored (low stress) or highly stressed, it could be difficult to focus. Thus, following the Yerkes-Dodson relationship, some amount of stress might be conducive to enabling people to focus better. A theoretical framework representing various attentional states also suggests that a state of 'Focus' involves high engagement, and high challenge which could induce some stress [28].

There has been quite a lot of interest in the field of CSCW around the role of interruptions on work, both externally triggered and self-initiated. However, to our knowledge, no one has explored how email usage patterns of people who self identify as being more prone to self interrupt or to react to external notifications affects their productivity or stress. The fact that our study found no differences between primarily external and self-interruption styles of checking email, on email duration and frequency of checking, could be due to the fact that people who prefer to react to external email notifications may do so rapidly, while people who self-interrupt may do so more frequently [18]. We found a significant correlation where people who preferred to self-interrupt to check email assessed their productivity as higher. Interruptions involve a significant recovery time to reorient back to an interrupted task [19, 36]. Perhaps people who self-interrupt have more control over when to take a

task break, making it easier to reorient back on task, and thus leading to a higher feeling of productivity. However, we found no association of interruption style with stress, which suggests that while self-interruptions may lead people to feel more productive, they do not lead to less stress.

Our results build on other studies of email use that find that email use is associated with a feeling of cognitive overload [3, 5, 10, 41]. Overload has been attributed to poor email management strategies [10, 48], coordination challenges that email introduces [5], the work that email invites [3], and social pressures to respond [3, 41]. Our study is unique as we found a relationship of the amount of time that people spend in the workday on email with lower productivity. In our theoretical model, we found focus difficulty to be a mediator of email duration on productivity. This finding is consistent with that found by Hanrahan and Pérez-Quñones [17], that the more time on email, the more opportunities there are for diversions within the email client. Iqbal and Horvitz [19] found that if one switched from an ongoing task to check email it took over 9 minutes to return to the interrupted task, where diversions extended beyond the email client. While email use certainly saves people time and effort in communicating, it also comes at a cost. Future research could examine more carefully exactly what types of workplace activities might be traded off with email use.

While other studies have found an association of email use with stress, our study is different. Cutting off email in the workplace has been found to lower stress [29] as was asking participants to check email as much as they could [25]. Neither of these conditions is realistic for the workplace--until we invent a better replacement, email will not go away. Our study instead examined *in situ* naturalistic workplace behavior. The fact that we found that time on email is associated with higher stress, across all job roles, suggests implications for organizations. Stress is detrimental in the workplace [2]; any intervention that can decrease stress would be beneficial.

Our findings can benefit organizations. Less time spent on email is associated with a higher feeling of productivity and less stress. Cutting down on email time could improve the health and well-being of employees. First, we suggest that organizations make a concerted effort to cut down on email traffic. Organizations could use a pull channel or wikis for much organizational information, reducing the volume of emails. Second, while email batching has been proposed as a solution to better manage email, e.g. [29], our results provide extra support for this idea. If people know to expect email at specified times each day, they may consolidate their email management time and likely spend less time overall on email with less frequent checking and consequently fewer interruptions. Third, while self-discipline can be a challenge, perhaps if employees are made aware that their time on email can lead to a less

positive mood and stress, this could be a motivation to restrict email time.

We found that email is related to several phenomena that could explain the workplace experience yet our data is correlational which does not imply causality. One way to support causality is to find converging evidence for a phenomenon. Our results on stress certainly are consistent with other studies that have shown a positive relationship of email and stress, e.g., [3, 29]. We have additionally shown that the *duration of time* spent on email also is associated with stress. It is also possible that the causality works in the opposite direction. For example, it is possible that people may first assess themselves as unproductive (i.e. at the beginning of the day), and as a result may then engage in more time on email. We find that this argument is not convincing. First, people were asked to assess their productivity at the end of the day, and we assume that they were considering an overview of how productive they felt throughout the day, *assessed at that end of day moment*. Email duration was measured throughout the day. There is thus a time relationship of email duration during the day along with a productivity assessment at the end of the day. Second, numerous studies have documented the varied activities that email involves that can produce knock-on effects for more peripheral work, e.g. [3, 5, 11, 47, 48]. However, controlled experiments would be needed to disentangle the causality.

Why then do people spend time on email if it is associated with feeling less productive and more stressed? Numerous studies have highlighted the benefits of email. There are social reasons [3], people feel that they need to keep on top of email to get critical information [29], there are social norms to respond (quickly) [3, 41], power dynamics in the workplace, and a host of other reasons. Thus, in our current workplace environment, we need email, but it comes at a cost.

Limitations

Our study has several limitations. We looked at the time duration of email and the checking frequency but did not look at the content of the email. For example, email that assigns tasks or that is from one's superior might lead to higher stress than other types of email, e.g., personal email. Thus, as we did not assess the characteristics of the email we cannot make inferences into how these characteristics might affect overload and the workplace experience.

We deliberately bounded our study to email use in the workplace. We did not examine email usage outside of the workplace hours, and individuals could use time outside of the workplace to manage emails that they could not get to during the day, cf [6]. This is a topic for future research.

Despite the fact that we made every effort to gain an accurate measure of email use through logging, we cannot capture email use 100%. If people look away from their email, the logger does not capture this. However, mouse or

keystroke activity did serve as a check that email was being used, so we are reasonably confident that we have a good representation of email use. Further, objective logging of email is far more accurate than self-reports, which many studies rely on [cf 8].

Also, some of our participants used phones to read email and our Windows Activity logger did not work on phones. However, all participants reported to us that their primary way of accessing email was on their laptops or desktops, which we logged.

Our participants were from a single workplace. Although they were in a variety of job roles and their job characteristics expanded across a wide range, we must be careful when generalizing this across other workplaces. Professional context could also play a role in email use [6]. Our results apply to large organizations involving information work. The information workers in our study were highly educated, having at least a bachelor's degree, so we can only generalize the results to similar people.

As we move into an era of Big Data analytics (we consider our data using computer logging and stress tracking "small" Big Data), varied questions of correlation and causation arise. Again, correlation does not imply causality so we cannot ascertain the direction of the relationships that we found. Whereas laboratory studies enable the manipulation of variables to assess causation, *in situ* tracking enables the capture of real world IT usage from multiple perspectives. We feel that the two methods are complementary: tracking studies can identify phenomena that can be later followed up in the laboratory.

CONCLUSION

Email is clearly an important part of the work life of information workers. An accumulating body of empirical research as well as anecdotal evidence shows that the benefits of email use come at a cost, however, of impacting users' well-being. Our study contributes to this body of research by focusing on the relationship between email use and two key variables important to the workplace experience: productivity and stress. Our results benefited from capturing email usage from both external measures and internal user perspectives, which enabled us to investigate fairly nuanced *in situ* experiences. As the development of measurement techniques continues to expand, we expect them to reap deeper understandings of people's *in situ* workplace experiences. We hope that our study can spark future research directions for email management systems that can benefit work with less cost to the user, as well as for improving organizational practices.

ACKNOWLEDGMENTS

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