Email Duration, Batching and Self-interruption: Patterns of Email Use on Productivity and Stress

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ABSTRACT

While email provides numerous benefits in the workplace, it is unclear how patterns of email use might affect key workplace indicators of productivity and stress. We investigate how three email use patterns: duration, interruption habit, and batching, relate to perceived workplace productivity and stress. We tracked email usage with computer logging, biosensors and daily surveys for 40 information workers in their *in situ* workplace environments for 12 workdays. We found that the longer daily time spent on email, the lower was perceived productivity and the higher the measured stress. People who primarily check email through self-interruptions report higher productivity with longer email duration compared to those who rely on notifications. Batching email is associated with higher rated productivity with longer email duration, but despite widespread claims, we found no evidence that batching email leads to lower stress. 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

How do patterns of email use affect the workplace experience? In today's information driven world, email continues to be a ubiquitous communication medium on both organizational and personal levels [5, 10, 40]. Communication in corporate organizations happens mostly through email [10]. Email has been shown to be very useful for assigning and communicating to do's [3], for coordinating and assigning tasks amongst colleagues [47], for task management and archiving information [47], and for storing, retrieving and sharing information easily [40].

However, it is well established by numerous studies that email leads people to feel cognitively overloaded, e.g. [2, 3, 9, 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 as "*we don't do email, our email does us*" [44]. Research studies have documented concerns from users about the challenge of keeping up with email [3, 9, 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 reveals that 28% of an employee's workweek is 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 [17]. Yet it remains an open question how the effects of extensive engagement in email interactions affects people's workplace experience. In particular, 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.

In this paper, we explore email usage, in terms of how people check email (self-interrupting or by using notifications), the time spent on email, and temporal patterns of checking email (batching or continual), and how it affects productivity and stress. While many studies have typically relied on self-reports of email usage, e.g. [9], research shows that such subjective measures grossly overestimate the time spent using information technology [7]. To obtain a more reliable measure of participants'

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email use, we continuously logged our participants' computer activity as they conducted their normal work tasks. Our research questions called for using varied methods, so we combined computer activity logging with physiological data and daily surveys, where we measured affective and cognitive parameters of 40 information workers for 12 days in their *in situ* workplace environments. This research is part of a larger project, HealthSense, to study the wellbeing of information workers in the workplace.

Our findings show that some patterns of email use are associated with lower perceived productivity and higher stress. The longer daily duration spent on email, the lower the assessed productivity and the higher the stress. With high email use, people who chose when to self-interrupt to deal with email, and "Batchers", people who cluster email use, assessed their productivity higher at the end of the day compared to those who check email triggered by email notifications, and to those who check email consistently. To our knowledge, our study is the first *in situ* multi-method investigation of email activity, workplace outcomes and stress. Our results lay ground for 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 spend quite a bit of time checking their email daily. Studies found that users check their email around 11 times per hour [26], that 84% of 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 [35]. Czerwinski et al. [8] found that email accounted for 24% of the tasks information workers reported performing in a daily diary study. Fisher et al. [14] reported an average of 87 emails received per day, while Mark et al. [26] found that users in a logging study spent an average of 34.5 minutes per day on email. Jackson et al. [19] 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 interrupted by email. Obviously, these disparate estimates could be due to a variety of factors, such as culture, workplace, and measurement technique. The bottom line is that people are using 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 [3, 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 [28]. Mano and Mesch [25] found email to be helpful in speeding up communication and benefiting performance in the workplace. Email supports both information management and communication [11]. So email certainly has been shown repeatedly to be a multifaceted tool potentially benefiting workplace productivity.

Cost of the ubiquity of email in the workplace

Despite its usefulness, research does show that the ubiquity of email has its costs. A number of factors have been identified that 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 [9], a loss of control [2], problems keeping track of email threads [3], interruptions due to email [30], and social pressure to respond (quickly), especially if the sender is higher up in the organizational hierarchy [2, 41]. Email generally imposes more costs on the recipient than the sender, especially when information is requested or when work is delegated [9]. Nevertheless, despite the purported costs, email still remains a primary communication mode in the workplace.

Effect of email on productivity

Because of the benefits offered by email in the workplace as well as the corresponding costs, the relationship between email use and productivity is complex. As such, few studies have addressed the relationship of email use to productivity. A broad measure of communication technology overload was found to negatively correlate with productivity [22] as did a more specific measure of email overload [37]. On the other hand, the number of email messages received increased perceived workplace effectiveness [25], even though research shows only about 30% of received email requires action [3]. Also, since 32% of emails remain unread [16], this raises the question of what other aspects of email use might affect productivity.

Loss of productivity with email use has been explained as due to the time spent continually monitoring email, taking time away from other activities [3]. People have reported being lost in email 23% of the time, often due to diversions [16], which could increase their time on email without feeling productive. While these studies provide insight into the different ways people interact with email, there have been no studies quantifying how different email usage behaviors might affect productivity.

Effect of email on stress

Studies show that email usage is, indeed, negatively related to stress [28]. In one study users were asked to 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) [28]. Compared to a baseline period with email use, the HRV signals revealed less stress when email was turned off, even though other communication channels like the phone, instant messaging, etc., were still available to be used. In another study, when participants were instructed to limit the frequency of checking their email, they experienced less stress [23]. People have also reported anxiety in not being able to keep up with their inbox, which could result in missing critical information [2].

Some studies have argued that time spent on email creates additional work for the user which in turn elevates stress [43]. Though without empirical support, 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 it creates more messages that people must spend time with, not only in responding to them, but also in organizing and filing [3]. Also, as it is easy for the sender to make requests and delegate work [9], this creates new tasks which the recipient may not view as critical to work--some of which must be conducted through email [28]. Email creates interruptions which involve extra work for users to reorient back to the task at hand [19], and which could lead to stress. In one study email was the only communication tool to which stress was attributed [2].

Other claims are that stress is due to the time spent on email which extends the workday [32] and to the volume of email received [9]: a positive correlation was found with time spent on email and number of incoming emails [2].

However, it could be not just the duration of time alone that has an effect on the workplace experience but the email management strategies that people employ. The research streams of email duration, interruptions, and email overload have not been well linked together to understand how experience with email affects the workplace experience. Further, studies have either been in the laboratory, done with surveys, or *in situ* without the use of objective measures of stress. Our work builds on previous studies relating email overload to lower productivity [22, 37]. Whereas communication and email overload have been examined, we look at particular email usage patterns and how they might affect productivity. Similarly, our study also builds on the work relating email to stress [23, 28]. No one has examined how duration of time on email might affect stress and whether strategies of self-interruptions to check email or batching email could reduce stress.

RESEARCH QUESTIONS

Despite the documented studies 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. One reason for feeling overloaded from information can be attributed to when the demands on time to deal with information are greater than the amount of time available, cf [13]. 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 [25]. 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. On the other hand, as a large proportion of email use concerns task management [3], it might be expected that work on email could lead to a sense of increased productivity. Often tasks originate in email [3] and dealing with email could be a way of accomplishing tasks.

Thus, it is an open question how specifically different patterns of email use might correlate with productivity and stress. Based on a review of the literature, we selected the following email usage patterns to examine: duration of time on email, types of interruptions, and temporal patterns of checking email.

Email duration. As email use comprises a significant portion of the day, we feel that a measure of email duration is important to examine. Yet the few studies that have looked at the effects of spending time on email 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 workplace studies found that the amount of time employees spent on email was positively correlated with feeling overloaded [2, 39]. Except for the study of Bradley et al. [4], who found no relation of email duration with stress, these studies involved self-reports which have been found to inaccurately reflect actual time with computer usage [7].

Yet with the exception of the study of Barley et al., [2] who also 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 [8, 14, 19, 26, 35]. A large amount of research also has addressed reasons for email overload, e.g., [2, 3, 9, 10, 11, 47, 48]. Yet these streams of research have not been well linked together and there is a lack of research using objective measures of duration of time spent on email to examine its association with productivity and stress in the workplace. We examine whether the amount of time spent on email is associated with productivity and stress.

Interruption types. We examine how a person's habits of email checking, triggered primarily by email notifications or by self-interruptions, might affect productivity. Interruptions, documented to be disruptive in work and requiring a recovery time, e.g., [30, 38, 15], could have an impact on the workplace experience. People can check email in different ways: by primarily relying on notifications or by primarily checking on one's own (and not waiting for, relying on, or reacting to notifications), or using both strategies. These different strategies may be associated with different productivity or stress levels in the workplace. For example, if one primarily checks email on their own, this could reflect better coordination of time, leading one to feel more productive. There may also be an interaction with one's interruption habit for checking email and the amount of time one spends on email. Whereas the time involved in dealing with messages (reading, responding, filing, etc.) could relate to productivity, it is an open question whether relying on email notifications or

checking on one's own might be associated with productivity and stress.

Batching behavior. Restricting email use to certain times of the day has been presented as a solution for email management [28, 36]. The popular media is abound with claims that using email at set times during the day will reduce stress and increase productivity, e.g. [24]. The argument for restricted use, termed "batching email", is that setting aside times to do email should reduce interruptions, leaving the rest of the day to focus on other work. This could potentially increase perceived productivity and reduce stress. In a study where people adopted a once-a-day email strategy, their time on email was significantly reduced though it did not affect stress [4]. Another study that asked people to restrict their email use to set times did find though that it lowered stress [23]. Yet in a survey study of email use, it was found that checking email as it arrives was associated with lower cognitive load compared to checking email at defined times [9]. The claims about batching email, though widespread, remain unsupported due to conflicting results. In this research question, we will first investigate whether we can identify profiles that characterize whether people primarily restrict email use to certain times of the day or rather use it continually throughout the day. We will then examine whether batching email is associated with productivity and stress.

Our research questions on workplace productivity are:

RQ1a. How is time spent on email associated with assessed productivity in the workplace?

RQ1b. How is interruption type, primarily checking email triggered by notifications or by self, associated with assessed productivity in the workplace?

RQ1c. How is batching email associated with assessed productivity in the workplace?

Our research questions related to workplace stress are:

RQ2a. How is time spent on email associated with stress in the workplace?

RQ2b. How is interruption type, primarily checking email triggered by notifications or by self, associated with stress in the workplace?

RQ2c. How is batching email associated with stress in the workplace?

METHOD

Procedure and participants

We conducted an *in situ* study with 40 participants (20 females, 20 males). Participants were volunteers working in a research division of a large corporation, and worked in different job roles: administrative support, engineering, and management. Participants gave informed consent and were compensated with a $250 gift card.

Participants were asked to be in the study for 10 full business days; however due to technical problems or scheduling issues, participants averaged 12 study days. During the study period, physiological data to measure stress was collected from a heart rate monitor worn around the chest during all waking hours. Computer activity at work was 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 a daily evening questionnaire, where they reported their 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, detailed as follows.

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).

Interruption Type was 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 two levels: responses 1 and 2 were

combined into "External interruptions" (**External**), and responses 4, 5, and 6 were combined into a measure of "Self interruptions" (**Self**). Participants who gave response 3 (half external/half self) were not used in the analysis.

Batching behavior. In detailed visual inspection of plots of the data for each participant, of their email duration over the day, we noticed distinct patterns. Some participants tended to cluster or "batch" their email use, usually in 2 or 3 times per day. Others showed a distinct pattern of checking email more or less continuously throughout the day. Still a third group showed a mixed strategy, where sometimes they would "batch" their email and sometimes check it continually. We divided participants into different groups as follows. We first calculated, for each hour of work that day, the percentage of their total daily email use. For example, if a person used email continually throughout the day, and worked 10 hours, then the expected value of email duration for each hour should be 10% of the total. For an 8-hour day, the expected value would be 12.5% of the total. Based on our inspection, observing that many people had 3 peaks of usage, we took the sum of the 3 highest hours of email duration for each person, normalized it by the hours of work that day, and then calculated what proportion of total daily email was done in those hours. For example, for a 10-hour day, we would expect that the proportion in 3 hours would be 30% if a person checked email evenly. But if they batched email, they may use 60% of their total email duration in 3 hours. Based on carefully inspecting the distribution of the entire sample, we used a cut-off criteria of selecting participants whose 3 highest hours of email use comprised 50% or more of their total email use. We used this criteria to create a user Profile of "Batchers". Based on a visual coding of the data by two independent coders, the rest of the participants were coded as "Consistents" (where email use was fairly consistent over the workday), and "Mixed strategy" where users used a mix of batching and consistent strategies. The two independent coders were in 100% agreement. The profile counts were as follows: Batchers: 11, Consistents: 23, Mixed: 6. Figures 1a and 1b illustrate profiles of a "Batcher" and a "Consistent" checker.

We thus created three Profiles of users: "Batchers", whose pattern of email use was to cluster email use in two or three hour periods, "Consistents", whose pattern of email use was fairly consistent throughout the day, and "Mixed", whose email use was a mixed strategy.

Email Checks was measured as the number of separate times that the email client switched to the foreground.

Productivity. In information work, an objective measure of productivity is difficult to obtain. Performance reviews (e.g. bi-annual) could provide a measure but these are not fine-grained enough to look at the relationship with daily email use. We constructed an index of productivity using six dimensions 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.

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 (root mean square of successive differences) 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

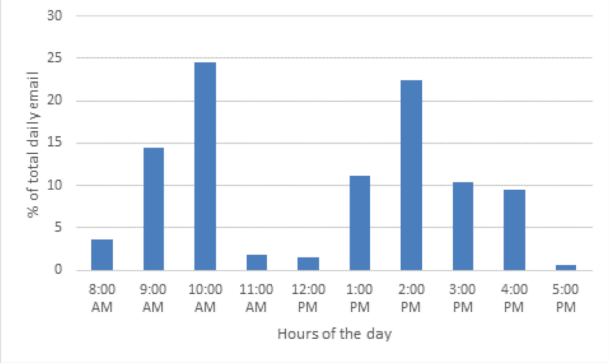

Figure 1a. Data of a user who batches email use. Y-axis shows percentage of daily email done in that hour

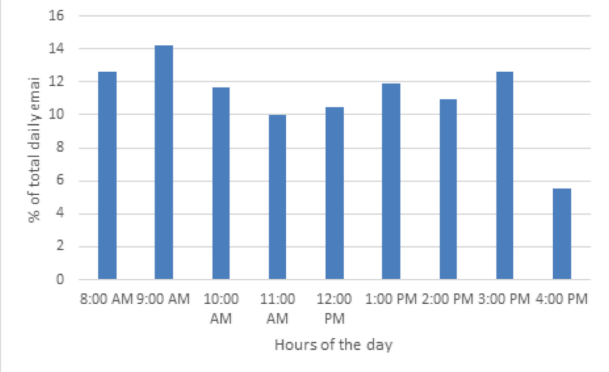

Figure 1b. Data of a user who consistently checks email.

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 and number of email checks. HRV has been used in other *in situ* empirical studies, e.g. [28].

Control variables

We used the following control variables in our study.

Job characteristics. Email is a communication tool, and an employee's job role may significantly affect the amount and 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 [21]. 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, 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 in the general survey.

Productivity Software duration was measured based on the logging data. It is possible that a person's productivity assessment could be based on the amount of time that is spent using software that supports task features: e.g. writing documents, doing analyses, creating presentations, or coding software. We thus controlled for the daily duration of productivity software use. We measured the total duration of use of applications that were coded as "productivity software": the most commonly used applications in this category were Word, Excel, Powerpoint, Visual Studio, Matlab, and OneNote. Productivity software duration was defined as the number of seconds that these applications were 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.

Baseline stress was measured in the pre-study survey based on the Perceived Stress Scale (PSS) [6]. Because we are measuring fluctuating stress (with HRV), we used the PSS score as a baseline measure of stress to control for, as it measures a global level of stress. 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 has been recommended for use as an outcome measure of stress [6].

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 (use of email notifications) or self-interruption for checking email
Batching behavior	Based on the daily distribution of email use, described above
Productivity	Measured in end-of-day survey based on six dimensions using Likert scale; Composite measure created
Stress	Measured by worn heart rate monitors using RMSSD
Control Variables	
Job characteristics	Job demands, job decision latitude from JCQ [21], in general survey
Productivity software	The proportion of seconds spent daily/hourly on productivity software compared to total computer duration
Baseline stress	Perceived Stress Scale [6] in general survey

Table 1. Summary of measures used.

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 patterns 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-Effects 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. For RQ1, a LMM for Productivity was based on including independent variables of Email Duration, Interruption Type, Batching Type, and control variables. We used a random intercept for participants; all other factors in the model were entered as

	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.

fixed effects with no random components. For RQ2, a LMM for HRV (Stress) was based on including the same independent and control variables as RQ1, with the same fixed and random 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 (External), 41.0% reported primarily checking email on their own (Self), and 28.2% reported checking email about equally due to external notifications and on their own. Thirty-four participants had email notifications enabled. An ANOVA showed no significant difference in average Email Duration between Self and External: $F(1, 25)=.11$, $p<.75$. Consistents had significantly longer average Email Duration compared to Batchers and Mixed strategy: $F(2, 37)=6.09$, $p<.005$ and checked email daily significantly more often: $F(2, 37)=6.13$, $p<.005$. Frequency of Checking Email is highly correlated with Email Duration: $r=.75$, $p<.0001$.

Job characteristics

Regression analyses showed no significant relationship of Job Decision Latitude predicting average Email Duration: $F(1, 38)=2.57$, $p<.12$ but there is a significant negative correlation with frequency of checking email: $F(1, 38)=4.45$, $p<.04$. There is a significant relationship of Job Demands predicting average Email Duration: $F(1, 38)=7.40$, $p<.01$ and a strong positive trend with frequency of email checking: $F(1, 38)=3.58$, $p<.07$. Thus, the higher employees' job demands are, the more time they spend on email and the more often they check email. The more decision latitude people have in their jobs, the less they check email. Job Demands and Job Decision Latitude were controls in our subsequent email analyses.

RQ1. Email use patterns and productivity

We next examine how email is related to information workers' self-assessed productivity at the end of the day. Productivity was the dependent variable. Our productivity index measure (based on 6 dimensions of 7-point Likert scales) ranged from 6 to 42, M=27.43, SD=7.52. Independent variables were Email Duration, Interruption Type, and Batching Behavior. We entered interaction terms of Interruption Type x Email Duration and Batching Behavior x Email Duration. Results for RQ1a, RQ1b and RQ1c are shown in Tables 3a and 3b. Control variables of Job Demands, Job Decision Latitude, and Productivity software duration were not significant. Between subjects variance was 21.79, SE=2.76, and within-subjects variance was 23.03, SE=9.07.

RQ1a. Email Duration

Email Duration is significantly negatively related to Productivity: the more time spent on email for that day, the lower the assessed productivity for that day (Table 3b).

RQ1b. Interruption Type

There were no main effects of Interruption Type. However,

Productivity		F	df	p
	Intercept	2.12	1, 20	.15
RQ1a	Email duration	14.08	1, 135	.001
RQ1b	Interruption Type	2.32	1, 19	.14
RQ1c	Batching Type	.08	2, 23	.92
Interrupt Type x Email Dur		7.80	1, 131	.006
Batching Type x Email Dur		3.05	2, 128	.05

Table 3a. Model of Email use patterns with Productivity: tests of fixed effects of Email Duration, Interruption Type and Batching Behavior.

Productivity	Coeff (SE)
RQ1a: Email duration	-5.18 (1.30)***
RQ1b: Interruption Type: Self [1]	3.45 (2.26)
RQ1c: Batching Type: Consistent[2]	1.11 (2.80)
RQ1c: Batching Type: Batching[2]	.84 (3.10)
Self Interruption x Email Duration[1]	2.64 (.95) **
Consistent x Email Duration[2]	2.06 (1.26)
Batching x Email Duration[2]	3.33 (1.35) *

Table 3b. Coefficients and SE of fixed effects in Table 3a. ***p<.001, **p<.01, *p<.05. [1]External-interruptions is the reference category; [2]Mixed strategy is the reference category.

there was a significant Interruption Type x Email Duration interaction. As Email Duration increases, productivity is rated highest by those who check email on their own compared to those who primarily rely on email notifications

RQ1c. Email Batching behavior

Batching behavior as a main effect was not significantly related to Productivity. However, there was a significant interaction of Batching behavior and Email Duration. Batchers rate their productivity higher at high email durations in relation to a mixed strategy.

Explaining email duration and productivity

Even though the main effect of Email Duration shows a negative relationship with Productivity, the interaction results show interesting patterns of Self-interrupters and Batchers rating their productivity *higher* with more time spent on email compared to the reference groups. The results of Email Duration could be due to some people considering themselves to be more productive when using email than others. Even though we normalized by person and controlled for job characteristics and productivity software, 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 all 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, $t(18)=.26$, $p<.80$). 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, the relationship of email duration and productivity rather varies *within* individuals, i.e., when a person spends more time on email relative to their mean usage, then their productivity assessment declines (and vice versa).

RQ2. Email use patterns and stress

We next examined the relationship of email usage patterns and stress. As described in the methods section, stress is measured by HRV, based on the heart rate captured by the worn heart rate monitors. Recall that the value of HRV is inversely related to one's stress level: the *lower* the HRV value, the *higher* the stress. Email duration was compared with average HRV (using the measure of RMSSD) for that same hour, during the work hours of 9 to 5. Results are shown in Table 4a and 4b. For all analyses, we controlled for Job Demands, Job Decision Latitude, and baseline stress, as measured by the Perceived Stress Scale (PSS) instrument [6]. Control variables were not significant. Between subjects variance was 83.09, SE=4.01, and within-subjects variance was 129.10, SE=43.64.

HRV (Stress)		F	df	p
	Intercept	.46	1, 19	.51
RQ2a	Email Duration	6.76	1, 858	.009
RQ2b	Interruption Type	2.04	1, 19	.17
RQ2c	Batching Type	1.30	2, 19	.30
Interrupt Type x Email Dur		2.61	1, 859	.11
Batching Type x Email Dur		.72	2, 859	.49

Table 4a. Model of Email use patterns with HRV: tests of fixed effects of Email Duration, Interruption Type and Batching Behavior.

HRV (Stress)	Coeff (SE)
RQ2a: Email duration	-2.07 (.69)**
RQ2b: Interruption Type: Self [1]	-6.89 (4.82)
RQ2c: Batching Type: Consistent[2]	-9.13 (5.68)
RQ2c: Batching Type: Batching[2]	-2.26 (7.53)
Self Interruption x Email Duration[1]	1.12 (.69)
Consistent x Email Duration[2]	.80 (.70)
Batching x Email Duration[2]	.68 (.99)

Table 4b. Coefficients and SE of fixed effects in Table 4a. **p<.01. [1]External-interruptions is the reference category; [2]Mixed strategy is the reference category. Note that the *lower* the value of HRV, the higher the stress.

RQ2a. Email Duration

Email Duration is significantly associated with Stress. The longer one spends on email that hour, the higher is one's stress for that hour (Table 4b).

RQ2b. Interruption Type

Interruption Type did not show a significant relationship with Stress as a main effect nor was there a significant interaction with Email Duration.

RQ2c. Email batching behavior

Batching behavior was neither significant as a main effect on Stress, nor was there a significant interaction of Batching behavior and Email Duration on Stress.

DISCUSSION

There has been increasing interest in HCI on the role of interruptions in work, both externally triggered and self-initiated. However, to our knowledge, no one has explored the relationship of email usage patterns of duration of time on email, interruption habits (notifications or self-interruptions), and batching behavior, and how they relate to perceived workplace productivity or stress.

While studies of email use generally involve self-reports, we used an 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 objective logged data, but to also complement our analysis with measures of participants' cognitive and affective states.

Email duration showed significant effects both with productivity and stress. When an individual spends more time on email during the workday, it is significantly related to lower assessed productivity and higher stress, after controlling for job characteristics. Our findings of email duration build on results of Hanrahan and Pérez-Quiñones [16], in that the more time on email, the more opportunities there are for diversions within the email client. Iqbal and Horvitz [18] found that it took over nine minutes to return to an interrupted task from checking email, when diversions extended beyond the email client. More diversions from one's task-at-hand could lead one to feel less productive and more stressed.

Though we did not study cognitive overload per se, our results with Email Duration and stress also build on other studies of email use that find that email use is associated with a feeling of cognitive overload: due to poor email management strategies [9, 48], coordination challenges that email introduces [3], the work that email invites [2], and social pressures to respond [2, 41].

We found that different email use patterns interact with duration of time on email and were associated with perceived productivity and stress. Participants who primarily checked email of their own volition reported higher productivity at days' end with higher email duration, compared to those who primarily check email through notifications. One reason could be that people who primarily self-interrupt to do email could feel that they have more agency in their work, i.e., by choosing when to interrupt, they could feel more productive. Also, interruptions involve a significant recovery time to reorient back to an interrupted task [18, 35]. Perhaps people who self-interrupt have more control over when to take a task break, e.g. gearing their interruptions to natural break points in tasks [18] making it easier to resume an interrupted task, thus leading to a higher feeling of productivity. Those who check email on their own may be better at adapting their use of email based on the state of their ongoing tasks.

Many claims in the popular media tout that batching email should lead people to be more productive and feel less stress. Our study found some support for these claims for productivity but only with high email use. One explanation could be that there are diminishing marginal returns for checking consistently. Perhaps as time spent on email increases, consistently checking ends up wasting time, providing less relevant information relative to the time invested. At high email durations, batching may yield better returns and may be perceived as more efficient. This relationship warrants further examination. However, contrary to claims that batching email can reduce stress, we found no evidence in our study to suggest this.

Personality: exploring email usage patterns

Our results raise the question of why batchers and self-interrupters feel more productive at high email volume. Although it was not one of our primary research questions, we opted to explore this post facto, and wondered whether we might be able to explain users' choice of email strategies based on individual differences. As a first step, we explored personality, since we had collected scores on the Big 5 personality traits [29] in the general survey.

Specifically, we expected that Consistents (non-Batchers) and Self-interrupters might score higher on the Conscientiousness trait of the Big 5 personality test [29], as it describes people who are careful and vigilant. We did not find differences with Self and External Interruption Types. However, in comparing Batchers with Consistents, we found that Consistents score significantly higher in the Conscientiousness personality trait: ($F(1, 32)=12.97$, $p<.001$. Using logistic regression, the Nagelkerke R^2 showed that Conscientiousness explains 36.8% of the variance of Batching/non-Batching behavior. This exploratory result suggests that different email management strategies could be related to personality differences, worth further exploration.

Implications for organizations

Our study is unique in that we found a relationship with increasing time that people spend on workday email and higher stress. Cutting off email in the workplace has been found to lower stress [28] as was limiting the frequency of checking email [23]. Neither of these conditions is realistic for the workplace given social norms [2]. Our study instead examined *in situ,* naturalistic workplace behavior. Until we invent a better replacement, email will not go away.

While email use certainly saves people time and effort in communicating, it also comes at a cost. Our results suggest implications for organizations: spending longer time on email may have detrimental effects in the form of workplace stress [2]. Any intervention that can decrease stress is beneficial. Future research could examine more carefully exactly what types of workplace activities might be traded off with email use. Of course many factors of email can influence productivity and stress in the workplace. For example, receiving timely and relevant information, the job role of the sender, and the tone of the received email can all influence productivity and stress. Our study is a first step in providing evidence that suggests that reducing time on email could be beneficial.

Our findings can benefit organizations. Cutting down on email time (associated with higher assessed productivity and less stress) could improve the health and the wellbeing 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 email. Second, while batching does not offer benefits for short durations on email, it may be a good strategy for those who expect to

receive a large volume of email, as it will result in fewer interruptions (volume is shown to be correlated with duration [2]). Third, while self-discipline can be a challenge, perhaps if employees are made aware that time on email can lead to stress, this could motivate them to restrict email time. Tools and user interface designs for protecting stressed users from the onslaught of email could contribute to improving workplace productivity and health.

Notes on causality

We found that patterns of email use is related to some aspects of 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 are consistent with other studies that have shown a positive relationship between email and stress, e.g., [2, 28]. We have additionally shown that the *duration of time* spent on email is associated with stress. Of course, it is also possible that the causality works in the opposite direction. For example, 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 assessed 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 the day moment*. There is thus a time relationship of email duration measured throughout 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 lead to extra peripheral work, e.g. [2, 3, 10, 47, 48]. However, controlled experiments would be needed to disentangle the causality.

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. As correlation does not imply causality 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 captures real world IT usage from multiple perspectives. We feel the two methods are complementary: tracking studies can identify phenomena that can be then tested in the laboratory.

Limitations

Our study has several limitations. We looked at the time duration of email and the checking patterns but did not look at the content of the email, as our field site did not allow this. 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, we cannot make inferences into how email content might affect overload and the workplace experience. This remains as future work but obviously could have privacy implications.

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 [5]. This is again 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 [7]. 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 [5]. 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.

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 [2], the need to keep on top of email to get critical information [28], there are social norms to respond (quickly) [2, 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.

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' wellbeing. 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 (logging and physiological) 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, and that can improve organizational practices.

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