Stress and Multitasking in Everyday College Life: An Empirical Study of Online Activity

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ABSTRACT

While HCI has focused on multitasking with information workers, we report on multitasking among Millennials who grew up with digital media--focusing on college students. We logged computer activity and used biosensors to measure stress of 48 students for 7 days for all waking hours, in their *in situ* environments. We found a significant positive relationship with stress and daily time spent on computers. Stress is positively associated with the amount of multitasking. Conversely, stress is negatively associated with Facebook and social media use. Heavy multitaskers use significantly more social media and report lower positive affect than light multitaskers. Night habits affect multitasking the following day: late-nighters show longer duration of computer use and those ending their activities earlier in the day multitask less. Our study shows that college students multitask at double the frequency compared to studies of information workers. These results can inform designs for stress management of college students.

Author Keywords

Multitasking; stress; computer logging; *in situ* study; biosensors; Millennial generation; social media

ACM Classification Keywords

H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces; K.4.m [Computers and Society]: Miscellaneous.

INTRODUCTION

The field of HCI has in recent years taken a strong interest in multitasking as a research topic. A number of *in situ* studies focusing on information workers have shown the extent to which people switch activities while using digital media, e.g. [8, 12, 17, 27, 28]. However, a generation of young people, raised amidst the rapid development of the Internet, is now transitioning to college and the workforce--

many will become information workers. This group, born after 1980 and often referred to as the Millennial generation or digital natives [4, 13], has received a great deal of research attention on their digital technology use, e.g., in terms of its purpose for them [19], and their skills [13]. Yet even as information and communications technology (ICT) grows more integral to young people's lives, a question remains as to how this generation—immersed in ICT since childhood—manages their online behavior. While research has shown that information workers multitask to a great extent, e.g. [12], how does a generation that grew up with the Internet compare?

As research continues to reveal more insights about multitasking behavior, a relationship between stress and multitasking has begun to emerge, e.g. [26]. If indeed stress is associated with multitasking, or more broadly, ICT usage, then this has important consequences, as stress has been linked to mental and physical health problems [29]. Among Millennials, stress can degrade academic performance [2]. However, with some exceptions [38, 39], research has not addressed how and to what extent ICT use might be associated with stress in these young people.

In this paper, we investigate the detailed ICT usage of a sample of the Millennial generation. We report the extent to which they multitask and how this behavior is associated with stress. Using a mixed methods approach of sensors, biosensors, and daily surveys, we measured the behaviors and stress of 48 college students for seven days each in their *in situ* environments during their waking hours, where they perform their normal routines as students—amidst the interruptions, the distractions, and the social milieu in their daily lives.

STRESS AND MULTITASKING WITH MILLENNIALS

Multitasking refers to handling two or more tasks concurrently. Though the ability to actually process multiple streams of information simultaneously depends on many factors, e.g., the complexity of information (for a review see [36]), multitasking with ICT refers to the constant switching of computer windows, where attention to content changes, often at a rapid rate [12]. Some research suggests that high multitaskers may have different characteristics than low multitaskers. Constant switching involves flexibility in attention, which has been associated with positive affect [18]. High multitaskers may also process information differently: research suggests they have

less control over focusing their attention and may be more susceptible to environmental distractions [34].

Detailed studies of ICT usage in the workplace have consistently found high levels of multitasking among information workers [8, 27], showing they switch events (both online and offline) about every three minutes on average [12]. Focusing on computer window switching alone showed that switching occurred even more frequently: about once every 1.6 minutes [28]. Switching events can be due to external interruptions, from digital media or physical interactions [17], or from self-interruptions, for example, switching computer windows to another website [12].

It is debated, whether, having grown up with the Internet, Millennials have an innate competence to multitask [4]. In fact, compared to older generations, Carrier et al. [6] found that the Millennial generation used more different media at the same time (e.g. listening to music while reading). In a diary study of college students, participants reported doing multiple tasks during Internet use more than with academic reading, watching television, or recreational reading [30]. A survey study found that a majority of college students used instant messaging (IM) during schoolwork (93%), non-computer activities (93%) and computer activities (97%) [11]. One study found that students reported checking Facebook on average seven times a day, averaging 26 minutes per day [23].

The above results thus suggest that it is common for Millennials to work on multiple tasks at the same time, using different media. With ICT, the multitude of social media sites provide ample opportunities for switching. Our focus is on examining the extent to which young people switch their attention when using ICT.

Stress, ICT usage and multitasking
Stress is a part of life for most college students. A national survey in 2013 found that 82.8% of students reported feeling overall stress during the last year [2]. Stress has been attributed to a number of factors, e.g. exams, demands on time, and financial pressures [35]. Stress occurs when one perceives that they do not have the ability to cope with the demands of a situation [23].

There is reason to believe that ICT usage might contribute to stress for college students. In laboratory environments, stress has been shown to be related to computer work-related stressors [16] as well as interruptions from digital media [26]. In the workplace, a major source of interruptions associated with stress was found to be email [28]. Others have argued that ICTs (such as email) create a feeling of overload which contributes to stress [3]. Yet social media use might alleviate stress: one study showed that interacting with strong, but not weak, social ties on Facebook reduces stress [5].

However, studies linking ICT usage and stress among Millennials are sparse and show mixed results. In a prospective survey study, high ICT usage was associated with prolonged stress when measured one year later [39]. However, in a later study, high ICT usage without breaks was found to be associated with current, but not prolonged stress, and only for young women [38].

One explanation for these discrepancies in results is methodological; they are based on self-reports and people have been shown to be poor estimators of their ICT usage [7]. Further, studies of stress to date have mostly deployed a variety of self-report scales, confounding the comparisons (for a review, see [35]).

The relationship between stress and ICT usage for college students may be related to contextual factors of college life. One particular behavior in college life that could affect ICT usage and stress, and that has received much research attention, is the prevalence of staying up late. According to [33], the age group of 19-29 (which our study involves) goes to sleep later than any other age cohort, averaging midnight. Of this age cohort, 60% use their laptops within the hour in which they go to bed [33] and weekday Facebook activity increases until around midnight [11]. Young people who are so-called "evening types" stay up late and tend to report attention problems as well as emotional difficulties [31]. A large survey found that staying up later was associated with decrements in performance the next day [24]. It is thus possible that late night activity affects stress and ICT use the next day and we examine this.

Thus, though multitasking with ICT has been investigated with information workers, to our knowledge no study has examined the relationship of multitasking behavior and stress of this particular Millennial generation group: college students. Given the wide choice of new media technologies, and considering that their use could be associated with stress, we examine multitasking behavior in the real-world situated environment of college life.

RESEARCH QUESTIONS
To investigate the nature of multitasking, ICT usage, and how it might be associated with stress in this user group, we break down this broad question into the following research questions.

Q1. *Multitasking behavior*. Given the high frequency with which information workers switch tasks in the workplace, (e.g. [8, 12, 27, 28]), to what extent do Millennials, having grown up with the Internet, multitask online? In this research question we consider two aspects of online multitasking that have been addressed with information workers (see [28]): 1) how long do people attend to an application or website before switching?, and 2) how frequently do people switch their attention between applications and websites? As attentional differences were found in heavy and light multitaskers [34], we also examine

whether such differences also occur in the applications and websites used.

Q2. *Stress and ICT usage.* Although some recent studies have examined longitudinal effects of technology use on stress in Millennials through self-reports [38, 39], none have explored this relationship with specific ICT usage to understand what might be associated with stress. For college students in particular, there may be a number of stressors in their lives (e.g. college courses, grades); yet it is also possible that ICT usage may be associated with stress. As with information workers, interruptions and distractions from the Internet and social pressures to keep up with social media communications could be associated with higher stress [3, 26]. Alternatively, connections to others afforded by social media could lower stress levels amidst the day-to-day stresses of college life [10]. We investigate the relationship between ICT usage and stress.

Q3. End of day activity, stress and ICT usage. Much attention has been given to how sleep habits and late night activity of college-age students affect performance, health, e.g. [33], and well-being, e.g. [38, 39]. But how does the time that students end their activities for the day relate specifically to stress, multi-tasking and computer usage on the following day? It is possible that late night "evening types" [31] may have different ICT usage patterns than non "evening types." While our data collection did not permit analyzing the amount or quality of sleep, our measures allow us to examine the relationship of time of end of day activity with the following day's stress and ICT use.

RESEARCH SETTING AND METHODOLOGY

This study was conducted at a large public university on the U.S. west coast. A total of 48 undergraduates (27 male and 21 female) were recruited for the study from undergraduate classes, resident communities, and snowball sampling. Their majors included computer science, engineering, social sciences, biological and physical sciences, and humanities, with ages ranging from 18 to 26; the mean age was 19.6. The average age when participants started using a computer was 9.4 and using the Internet, 10.8. The median college year was sophomore. Their GPAs ranged from 1.6 to 3.8.

We conducted an *in situ* observational study where data was collected on each participant for seven days during their waking hours. The study used a mixed methods design: computer logging, the wearing of heart rate monitors, daily surveys, a general survey, and a post study interview. We also conducted experience sampling and cell phone logging, not presented in this paper. This study design is informed by other studies using precision tracking of online behavior with logging and sensors, e.g. [28]. While ethnographic approaches can capture rich, contextual data, there is a tradeoff in obtaining precise, to-the-second detail of online usage that sensors can provide. As our interest was in capturing fine-grained computer activity, we opted for this approach.

Computer logging. Computer activity was logged using Kidlogger (kidlogger.net), freeware Windows computer logging software. The software generated one log record each time a user opened a new window or switched between already opened windows. A window can be an application or a web browser tab. Each log record includes the starting time and duration of the active window, the name of the application and a URL if the window is a web browser tab, and idle time. Timestamps are to the second. Only time spent in the window that was currently in use was measured. In other words, if a webpage is open in the background while the user is actively using Excel in the foreground, our software only counted the Excel time, not the webpage time. The logging software was installed on Day 1 and recorded for the entire duration of the weeklong study.

*Heart rate monitors (**HRM**).* To measure stress, participants wore a digital HRM, the Polar RS800CX wristwatch receiver and chest strap sensor, for the 7-day study duration during all waking hours. Heart rate variability (**HRV**) is considered a valid indicator of mental stress and is used extensively in research and clinical studies (see [1, 25] for reviews). HRV refers to the variations in instantaneous heart rate and R-R (intervals between consecutive beats). The recommended measure for calculating HRV is to use the standard deviation (sd) of the normal-to-normal heart beat [25]. Contrary to intuition, the *lower* the measure of HRV (i.e. the lower the sd in R-R), the higher the amount of stress is experienced. The sympathetic nervous system, a subsystem of the autonomic nervous system, responds to stress (the body responds to stressful circumstances by regulating itself). The HRV measures the fluctuations in the autonomic nervous system. Thus, when a person is relaxed, HRV is higher, as the body is not regulating itself. Even if HRV is changed by mild exercise, it returns to the baseline state very rapidly [25]. HRV was found to measure mental stress during computer usage in a laboratory study [16]. A lowering of HRV has been associated with increase in factors related to stress (e.g., anxiety [41]). With ICT use, it has been shown that when people do not use email, their stress, as measured by HRV, is lowered [28].

Survey measures. Participants completed an end-of-day survey in which they rated their mood according to a PANAS scale, (**PANAS-EOD**) a well-validated measure of mood [40] (this measures two dimensions: positive and negative affect). They noted the classes they attended, their productivity, and how influenced they were by deadlines. A general survey asked for demographic information, academic background and status, a general PANAS measure, technology habits and attitudes.

Procedure. On Day 1 of the study, participants came to a campus laboratory where the computer logging software was installed on their devices. Participants who also had desktop computers were given software installation instructions. Participants were also provided with a HRM

and were instructed to wear the heart rate monitors all their waking hours, except when they swam, showered, or did exceptional strenuous activity. They were told to take off the HRMs when ready for bed.

Because the HRMs stored only 2-3 days of data, participants were asked to meet with researchers 1-2 times during the week of their data collection. During these meetings, researchers downloaded the data, confirmed that the HRM and logging software were functioning properly, and reminded participants to complete the daily surveys.

Semi-structured interviews were conducted on Day 7. We asked participants about their general experiences during the study, their technology and social media habits, their various projects and responsibilities, and how technology could reduce their stress and improve productivity and mood. Participants were compensated $100 for the study. HR data from the remaining days and both laptop and desktop computer logs were obtained on Day 7.

RESULTS

Overview of data collected
Of 48 participants, two (one female, one male) were excluded from the analysis. For one, our logging software was blocked by anti-virus software in their computer from the second day. Another was noncompliant, using another personal computer and not recording HR.

We used Polar ProTrainer 5 software to do error correction on the HRM data, on beats per minute (bpm). We then calculated R-R intervals, and took the sd of R-R intervals in 15-minute intervals, yielding an HRV measure. Some HR signals, such as a flat bpm or wild fluctuations, can be due to a loose chest strap or temporary technical malfunction. We eliminated such data: 20 full days of HR data from 9 participants and 32 segments of data ranging from 2-5 hours from 19 participants. The computer log data was matched by timestamps with the HRV data in 15 minute time units.

We collected a total of more than 1350 hours of computer logs from 46 participants, excluding computer idle time; of these, 108 hours are logs of desktop use, the rest are of laptop use. We captured 117,559 computer window switches, and recorded 3,064 hours of heart rate reading, yielding over 15 million samples of heart rates. We received 306 end-of-the-day surveys. Full days of computer usage are analyzed for most analyses; partial days are excluded due to days of set up and finish. Most participants reported in the exit interviews that the week of study was representative of a typical week in a school quarter; nine mentioned the week was atypical (e.g. more or less computer use, more stress), because of midterm and final examinations.

Overview of ICT use
In this section we present an overview of computer usage: duration by type of online activity, and how activity and stress change throughout the day. Two coders independently coded the computer logs of the top 421 most frequently visited URLs (based on at least 20 visits). Coding was based on the name of the application used and the domain name of the website if it was a URL. The coders iteratively developed 10 website categories. Out of the 421 URLs, there were disagreements in 34 of these URLs. After discussion, the coders reached consensus for all 421 URLs.

The coded categories of websites were 1) *Social media:* Facebook, Twitter, Tumblr, Wikipedia, etc.; we further separated the social media group into two sub-groups: Facebook (**FB**) and Other Social Media (**Other SM**); 2) *Email*: includes web mail 3) *Academic* (**Acad**): related to courses, e.g. the university course management system, academic writing sites; 4) *Web information services* (**Web Serv**): search engine and information management such as Google, dropbox, file sharing; 5) *Gaming*: game community sites, browser-based gaming (e.g. esea.net, twitch.tv); 6) *News*: e.g. nytimes.com, cnn.com; 7) *Entertainment*: music, video, anime sites, etc.; 8) *Business*: e.g. banking, payment sites; 9) *Shopping*: e.g. Amazon.com, ebay.com; and 10) *Miscellaneous* sites.

Overview of computer use by category
Table 1 shows the average daily time in each category of activity. Based on full study days, participants averaged 4 hours, 40 min. of computer usage daily, with the highest amount over nine hours, and the lowest, about 18 minutes. Social media (FB + Other SM) is the highest category of website use, averaging 84 minutes daily. Daily Internet usage in our sample is almost an hour longer than that found in other studies [10, 30]. FB usage in our study is higher than previous studies [10, 23].

For the rest of our analyses, we focus on Social media, (FB and Other SM), Email, Acad and Web Serv. We chose

		Mean	SD	Max	Min
Total Computer		4:40:34	2:15:27	9:18:47	0:18:07
Total Internet		3:44:08	1:57:39	8:42:01	0:16:30
Social Media	FB	0:42:01	0:43:35	2:46:11	0:00:00
	Other SM	0:42:37	0:41:17	3:39:26	0:00:00
Email		0:12:23	0:9:40	0:43:26	0:00:00
Web Serv		0:10:53	0:13:14	0:59:60	0:00:00
Academic		0:21:54	0:18:51	1:10:50	0:00:00
Gaming		0:06:19	0:14:07	1:01:28	0:00:00
Entertainment		0:09:11	0:10:48	0:39:37	0:00:00

Table 1. Means and SD of daily time spent in different computer activities (H:MM:SS). N=46.

these categories because: 1) a number of studies have focused on the use of Facebook among undergraduate students (for a review, see [14]) and on academic performance (e.g. [22]). These studies showed conflicting results, suggesting more exploration on the relationship between FB use and academic activities; and 2) other studies (e.g. [21]) have reported that the most frequently visited sites by students are the university's learning management system, Google, email and FB, which fall into each of our chosen categories.

Overview of computer use and stress throughout the day
To see how stress varies over the course of the day with computer and Internet usage, we divided our data into one-hour time units and within each hour, computed an average over all participants, for all full days. Fig. 1 shows that computer usage is heavy and rises from 2 p.m. to early morning the next day; there is a consequent similar rise in use of SM, FB, and email through evening. Stress (as measured by HRV which is *inversely* related to stress level) is comparatively low in the morning (about 7 a.m.), and increases through the rest of the day. Thus, as computer usage rises, stress rises as well. Later we will account for individual differences in stress.

Q1. Multitasking: Switching behavior
Our first research question asks the extent to which this user group multitasks. One measure of multitasking is the duration of viewing a computer window before switching to another [12, 28]. The results for overall usage show that when participants are on their computers, the average time on any computer window (before switching to another window) is 47.9 seconds (sd=16.47). In terms of switching, participants switch more than 1.2 times per minute on average when they use their computers.

	Heavy Users	Light Users	Heavy MT	Light MT
FB	**1:18:58 (0:18:56)***	**0:12:12 (0:03:55)***	0:54:58 (0:18:36)	0:18:29 (0:07:27)
Other SM	**1:15:24 (0:19:04) ***	**0:09 :19 (0:02:31) ***	**0:53:09 (0:10:05) ***	**0:22:35 (0:06:55) ***
Email	**0:16:30 (0:03:16)**	**0:08:30 (0:02:31)**	0:15:43 (0:03:09)	0:11:22 (0:04:18)
Acad	0:18:28 (0:02:51)	0:11:53 (0:04:00)	0:26:37 (0:05:40)	0:25:01 (0:08:28)
Web Serv	0:13:54 (0:05:26)	0:06:14 (0:02:05)	0:13:06 (0:05:17)	0:07:06 (0:03:11)
PANAS (positive)	**29.2 (2.29)***	**36.6 (1.32)***	**26.9 (2.24)***	**34.6 (1.87)***
GPA	2.97 (.15)	2.90 (.19)	**3.16 (.55)***	**2.66 (.54)***

Table 2. Means (SE) of daily total durations for Heavy/Light users and multitaskers (MT). H:MM:SS. *=p<.05, ***=p<.001.

Heavy and light multitaskers and users
We next compared heavy and light computer users and multitaskers (**MT**) (Table 2). Based on a histogram of average daily computer duration, we chose the ten heaviest (h:mm:ss) (mean=7:43:09, sd=1:01:40) and ten lightest (mean=1:30:57, sd=0:47:55) users. To identify heavy and light multitaskers, based on a histogram of average daily window switching frequency, we chose the ten highest and ten least frequent switchers. On average, light MT switch 0.8 times per minute (sd=0.15) and heavy MT switch 2.1 times per minute (sd=0.22). We find that Heavy Users use FB and Other SM significantly more than Light Users.
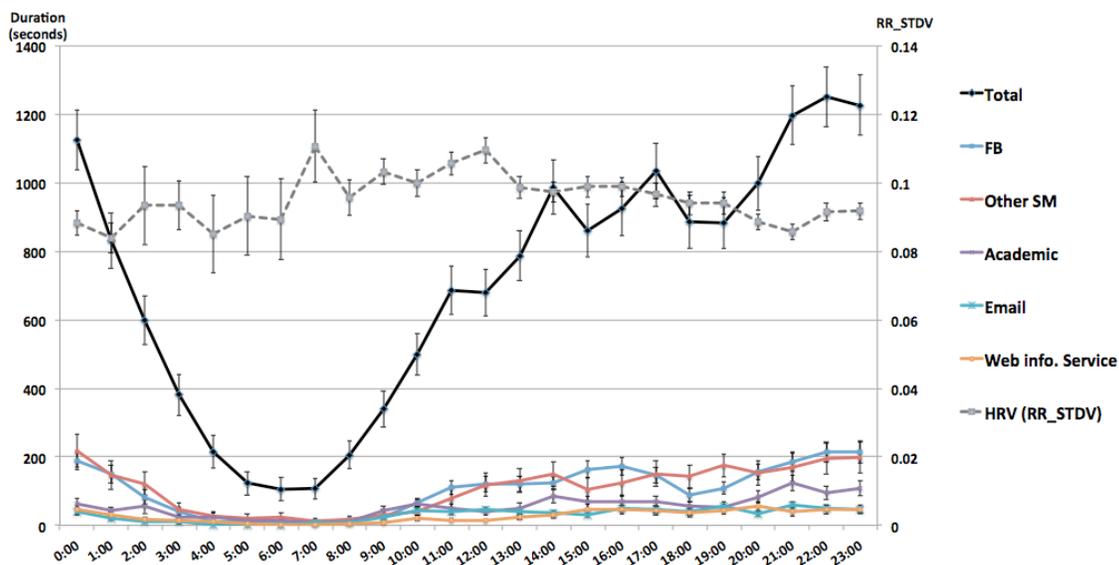
Fig. 1. Avg. duration of different online activities and stress (as measured by HRV) over 24 hours. The right axis shows HRV. Note the HRV measure is inversely related to stress. Error bars are SE.

Heavy MT use Other SM more than Light MT. Light Users and Light MT show the highest positive affect, based on the PANAS positive scores. However, Heavy MT have significantly higher GPAs than Light MT. We found no differences in HRV, and durations of Email, FB, and Acad site usage.

Q2. Stress and ICT use
To examine what online activity might be associated with stress in the Millennials, we developed a model using HRV as a dependent measure. We used measures collected from our log data and surveys as independent variables. The data was segregated into 15-minute time units throughout the day.

To account for the fact that our data was correlated within participants (each person was observed for 7 days), we ran a linear mixed model in SPSS using random and fixed effects, to account for the nested interdependence (of measures within subjects). We had no a priori conception of what variables might be associated with stress; therefore, we entered our target variables, durations of Acad, FB, Other SM, Email, Total Computer Usage and counts of Window Switches (in the 15-min. unit). We also included age of first Internet use as this could be associated with online activities and stress. We controlled for gender, age, and other variables that could affect stress: year in school, week of the academic quarter, GPA (self-reported), whether in class, and number of course credits. To test gender effects, we looked at all 2-way interactions with gender. To correct for lack of normality, we did a log transformation on these variables: Academic, FB, Other SM, and Email.

As SPSS does not provide an automatic model building procedure for linear mixed models, we built the model by hand using a backward elimination procedure as in stepwise regression, where we started with all variables in the model and then eliminated variables until we found the best fitting model based on the BIC criterion[1]. Table 3 shows the beta coefficients for the best fitting model for stress. None of our control variables were significant.

The model shows a direct relationship between computer duration and stress; as time spent on the computer increases, stress increases. With more window switches, the higher the stress. However, the more time spent on FB, Other SM, and Acad, the lower the stress. The older the age when participants first adopted the Internet, the lower is the stress. Email duration was not significant.

An R^2 statistic for linear mixed models must account for the variance explained by both the fixed and random effects;

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[1]In linear mixed models, Schwarz's Bayesian Criterion (BIC), a well-established measure of model selection, is used to find the best fitting model [37]. The lower the score, the better the fit of the model. As the BIC number is not meaningful by itself we do not report it here.

	β	F	df (num, den)	p
Computer duration	-.007	71.71	1, 5394	.0001
Window Switches	.-014	25.78	1, 5384	.0001
Other SM	.007	38.43	1, 5411	.0001
FB	.004	7.82	1,5414	.005
Acad	.003	7.33	1, 5406	.007
Age first Internet	.01	6.38	1, 42	.015

Table 3. Model for stress, as measured by HRV. The higher the HRV value, the *lower* the stress. Beta coefficients of log-transformed variables are adjusted for interpretability.

however, there is no standard method for specifying an R^2 in these models [9]. However, we can provide an estimate of the R^2 using fixed effects alone. We therefore ran a general linear model including only fixed effects which yielded an R^2 value = 10.3%. This value will *underestimate* the amount of variance explained by not including random effects (participants), but it will provide a reasonable estimate since the random effects are not large. The variance inflation factors for all variables in Table 3 range from 1.0-1.29, indicating that multi-collinearity is not a problem. We note that the beta coefficients for the model are low.

Q3. Activity the night before: stress, and ICT use
In this research question we investigate whether the time that one ends activity for the day is related to stress and ICT usage the *next* day. Participants were instructed to wear the HRMs all waking hours and to take them off before they went to bed. We considered the later timestamp (computer activity ceasing or when the HRM was taken off) as a measure we call 'end of day activity'. While we cannot ascertain when participants went to sleep, we can calculate a precise time (i.e. the later timestamp) of when online activity ended and when the HRM was taken off. This could be a reasonable proxy for close to the time when participants went to sleep. To reduce error even further, we grouped the timestamps estimating end of day activity into three wide time bins. Informed by the average time that college students go to bed (midnight) [33], we used this as one cutoff point. We also used 2 a.m. as our second cutoff point following Monk et al's classification of "evening types" [31]. We created three time intervals: before midnight, 12 a.m.-2 a.m., and after 2 a.m. Single days of four people who removed their HRMs early in the evening were excluded from the analysis. We only used data from nights before weekdays, and excluded Friday and Saturday nights as they may have different late night activity patterns [31].

Using a linear mixed model to account for the correlations within participants, we compared the difference in means of the following variables, measured the *following* day: HRV, Computer Duration, Total window switches, and duration of FB, Other SM, Acad, and positive and negative affect (from the end of the *following* day PANAS measure). Our grouping variable was End of Day activity in the three categories, mentioned above. Table 4 shows the results. Means reported are all within 15 minute time units. We controlled for year in college, age, credit units, GPA, and week in the academic quarter. For HRV, Computer Duration, and Acad, none of the controls were significant. For Window Switches, credit units $(F(1,30)=9.51, p<.004)$ and week of the quarter $(F(1,30)=12.55, p<.001)$ were significant.

We see a pattern with end of day activity (**EOD**) and some variables. While HRV does not differ in general for EOD, there is a significant Gender x EOD interaction. Males who end their activity the latest (after 2 a.m.) have the highest stress the next day, whereas females who end their activity the earliest (before midnight) have the highest stress the next day (note a higher HRV means lower stress). Males use the computer significantly later than females $F(2,3653)=3.10, p<.05$. Those who end their activity the latest (after 2 a.m.) spend the longest duration on the computer the following day, and also do the most window switches. Those who end their activity the earliest for the day spend the most time the next day on academic sites. The participants with highest positive affect the next day (as measured by the PANAS- EOD) are those who end their activity between midnight and 2 a.m. Those with the highest negative affect (PANAS-EOD) are the ones who end their activity the earliest. There is no difference in durations of FB or SM.

Qualitative analysis of interviews
We analyzed the post-study interview data with open-coding to identify themes to explain our participants' multitasking behavior and their stress.

One theme we identified, expressed by four participants, was that constant switching was habitual, or a routine. One student (P29) described: "*It's just encoded or something.*" Related to this was the notion of wanting to do "something" on digital media, as P14 explained, "*…to make myself feel like I'm not wasting time.*" However, this habit to "always be occupied" can cause sidetracking or completely losing track of time, e.g., "*all of a sudden, stuff happens and the next thing you know, an hour has passed and you've been on Youtube*" (P12). P41 reflected on the times when his friends are unproductive, explaining that "*it's usually not something that they intend to do, but something they find themselves doing.*"

Another theme that emerged, reflected by ten participants, was regarding social media as a "reward system," for example: "*I got a little bit of work done and I should*

Dependent variable		EOD: Time activity ended previous day			
		Before 12 a.m.	12 a.m. - 2 a.m.	After 2 a.m.	F (df), p
HRV: (EOD x Gender)	M	.085 (.002)	.088 (.001)	.077 (.001)	F(3,28)=4.12 p<.02
	F	.073 (.001)	.092 (.002)	.080 (.001)	
Computer duration (sec.)		604.84 (22.67)	569.12[1] (17.79)	612.20[1] (18.08)	F(2,24)=4.21, p<.03
Win switches (counts)		14.38[1] (1.41)	12.78[1] (1.08)	15.23 (1.1)	F(2,39)=3.40, p<.04
FB (sec.)		82.89 (18.12)	72.25 (12.82)	68.88 (13.33)	F(2,37)=.572 p<.57
Other SM (sec.)		90.53 (24.87)	104.08 (18.70)	90.08 (19.36)	F(2,41)=.32, p<.73
Acad (sec.)		87.64[1] (14.74)	24.77[1] (10.46)	54.14 (10.89)	F(2,47)=7.45 p<.002
Positive affect		26.51 (1.45)	29.77[1] (1.14)	25.45[1] (1.19)	F(2,38)=8.57 p<.001
Negative affect		21.54[1] (1.44)	17.61[1] (1.07)	18.31 (1.14)	F(2,40)=3.36 p<.05

Table 4. Means (SE) of variables the day after EOD. Means for computer usage are within 15 min. time units. 1=Bonferroni pairwise differences of means at p<.05.

reward myself, and there is this constant switching between my reward and my studying" (P42), and "*[t]hat's just the cycle. That's pretty much how I write all my essays*" (P37). Five participants expressed contradictory attitudes towards social media, e.g.: "*I feel that [multitasking with social media] increases my productivity. But it also increases distraction time. It's a little trade off"* (P18).

Our participants expressed conflicting attitudes towards social media. For some, integrating it into a study routine is beneficial because it provides a platform for academic purposes, helps reduce stress, or provides a break from inefficient studying. However, a total of 26 people commented that they use social media more excessively than they want to, or would like to limit the use of social media for they lost track of time, procrastinated, and avoided work as a result. For example, P18 told us: "*Because I spend so much time on social network sites every day and play games on it, I'll have to work at night, and that increases my stress.*" Thus, though our study shows that social media is associated with lower stress, the interview comments suggest that the participants' relationship with social media is far more complex.

DISCUSSION
Our study provides two main contributions. First, our methodology enabled us to gain precision data to describe multitasking behavior and ICT usage of Millennial age

college students in a real-world context over multiple days. With the exception of [22], studies of duration of ICT use for college students are based on self-reports. However, as shown by [7], self-reported estimates of time in ICT use are overstated by 32% compared to logged computer usage. Second, in contrast to self-reported measures of stress, we used biosensors to directly measure stress of college students in their *in situ* environments. Therefore, our measures, both in terms of duration and frequency, provide a fairly accurate portrayal of multitasking behavior in our sample as they were taken over a range of contexts for seven days.

Returning to the debate of whether growing up with the Internet has influenced multitasking behavior [4], our study suggests that college students multitask at a greater frequency compared with study results of information workers in the workplace. We found that college students in our sample spent shorter durations on average per computer window (47.9 sec.) compared to what Mark and Voida [28] found (75.5 sec.) with information workers--about 2/3 less time. We also found that college students switched at double the frequency with computer windows –1.25 times a minute—whereas information workers switched .62 times a minute in the workplace [28]. Our results contribute to the debate on "digital natives" and multitasking, suggesting that they do multitask to a greater extent than "digital immigrants." However, further research is needed to examine whether the higher rate of computer window switching may be situational, age-related, or even cultural.

We found that the more time students spent on the computer, the higher was their stress. We also found a positive relationship between window-switching frequency and stress. Yet more time spent on FB, Other SM, and academic sites is associated with lower stress. Even after controlling for a range of potential stressors in college life, there emerged a relationship between stress and computer usage. We cannot attribute causality to this relationship. It may in fact be that computer usage in general, and for the particular sites visited, is a *reflection* of stress in young people rather than a driver of stress [3]. There may also be underlying covariates that are associated with both factors. For example, a person may have a stressful lifestyle and their computer usage could be associated with their lifestyle.

Our data suggest that staying up late is associated with higher levels of multitasking, in terms of window switches. Half of our sample (23) were remarkably consistent in their habits of staying up after 2 a.m. The longer duration of late-nighters' total computer usage the next day could be due to the fact that they simply have more waking hours. There may also be a number of factors associated with late night activity and computer usage; these warrant further research. For example, longer computer duration and low positive affect could possibly be associated with behavior due to

late-night patterns, such as attentional difficulties, as found by [31].

Whereas Ophir et al. [34] found that heavy and light multitaskers show attentional differences, our results show where these differences lie with ICT usage. Heavy multitaskers spend a longer duration of time on social media sites compared to light multitaskers. Further, in contrast to studies that show that positive affect is associated with attentional flexibility [18] (a behavior needed in multitasking), we found that light multitaskers (as well as light users) have higher positive affect. One explanation for the difference could be that though in the laboratory positive affect promotes attentional flexibility, in a real-world context (as in our study), over a sustained period of time high multitasking may lead to a lower positive affect, due for example, to accumulated stress.

Our finding of an association between ICT usage and stress are consistent with the earlier study of Thomée et al. [39] but not their later study [38]. The differences could be due to our direct biophysical measures of stress whereas these prior studies used self-reports. We also build on results reported in HCI. Stress has been associated with email [28]; we show it is also associated with overall computer usage. The results of [26] found that external interruptions increased stress. However, in our study, participants experienced both internal, as well as external, interruptions; it is not clear to what extent self-interruptions also contribute to stress. Moreover, we show that for college students ICT use is an additional source of stress to other known stressors, e.g. academic performance or financial pressures [35].

How can we explain the relationship of multitasking and stress? One explanation could be cognitive load. Jeong and Fishbein [20] propose that the tasks that people choose to work on at the same time (e.g. listening to music and reading) are determined by the tasks' cognitive load. People prefer to combine tasks with cognitive loads that do not exceed a threshold of their attentional resource limitations. Stress occurs when this threshold is exceeded: when one perceives they do not have the ability to cope with current task demands [23]. An example is when people feel that they cannot keep up with incoming online information and experience a loss of control, which has been reported with email use [28]. Some participants reported in the interviews that their switching behavior was "encoded" which suggests it has become habitual. Laboratory research suggests that if our brains cannot process information that rapidly, as occurs with habitual task-switching, then this in turn could lead to stress [32]. Switching windows frequently to a completely different site (e.g. from Facebook to an academic site) could also increase cognitive load, as one needs to continually reorient.

There are several reasons why social media use might be associated with lower stress. Switching to a social media site can provide a break from work, or what our participants

in the interviews called a "reward system." Social media can also provide connections to others which could reduce stress; communicating with strong ties was shown to be associated with relieving stress [5]. Conversely, excessive use of social media along with a consequent increase in task switching may lead to procrastination or distraction from work, which could in turn be associated with higher stress. Future studies could examine more precisely how social media use is associated with stress, e.g. in amount or purpose of use.

Considering the widespread experience of stress in college life [2], our study has implications for stress management. A first step in management is identifying the context associated with stress. We envision an interface that informs users when a threshold of computer usage or switching is exceeded that affects stress. This interface could help users identify individual patterns of ICT usage associated with stress. This is a step towards helping people change those patterns to reduce stress.

In the interviews, we asked how technology could reduce stress and increase productivity. Six consistent late nighters (who ended their days after 2 a.m. for the majority of the study days) want limited use of social media; another seven late nighters want to have an organizer to help manage their time. Those who ended their days earlier did not express interest in such assistance.

Our participants in general felt positive about the study, rating their participation on average 5.57 (1= extremely negative, 7=extremely positive). Some commented that the data collection did not interfere with their daily routine. Some participants checked their computer log files during the study; they reported being much more aware of their excessive multitasking habits and how much they "overdose on social media."

Limitations
Our study had several limitations. We installed the computer logging software on one personal laptop per participant. We could not capture the time spent on other personal laptops (if any) or public computers in school libraries or computer labs. Thus, it is likely that we underestimated the overall computer use in students' life. Also, end of day surveys were sent via email (though done online), thus potentially increasing their email use.

For our third research question, we estimated end-of-day time using the later of computer logging data or HR recording. It is possible that participants did not immediately go to sleep after taking off the heart rate monitor or stopping computer use. Thus, though we feel that our logging and HRM timestamps, along with our wide time bins, can give a reasonable estimate close to when participants went to bed, it might be earlier than the actual time. Thus, we refer to this measure as "end of day" activity rather than "time to sleep." In a future study, we will directly ask participants when they went to bed.

A few participants mentioned slight changes of behavior because of the study. For example, one mentioned less FB use because he did not want to "look bad" to us; another mentioned not going to the gym as often because of the HRM. But we think the effect is very limited because most participants informed us of no change of their daily routine at all. Further, we believe that observing a participant for a week *in situ* can average out any potential "performance" effect.

CONCLUSIONS
Although our study found that increased use of computers (both in terms of window switching and duration) were associated with increased stress, our results suggest that *type* of computer activity may be correlated with lower stress. Social media use was found to coincide with less stress, echoing other studies that suggest the socio-emotional benefit of using social media, e.g. [10]. Higher use of academic sites was also correlated with less stress. Future studies might further explore the relationship among college students' computer time spent on task, stress, and performance. Additionally, our study identified a variety of computer usages. The fact that late night use predicted more window switching and longer use the following day may indicate that some students simply consume more media. However, the finding that participants who ceased activity earliest had the most negative affect (and for females, the highest stress), suggests that differing computer usage may be related to a student's ability to cope with stressors.

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