Sleep Debt in Student Life: Online Attention Focus, Facebook, and Mood

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ABSTRACT

The amount of sleep college students receive has become a pressing societal concern. While studies show that information technology (IT) use affects sleep, here we examine the *converse*: how sleep duration might affect IT use. We conducted an *in situ* study, and logged computer and phone use and collected sleep diaries and daily surveys of 76 college students for seven days, all waking hours. We examined effects of sleep duration and sleep debt. Our results show that with less sleep, people report higher perceived work pressure and productivity. Also, computer focus duration is significantly shorter suggesting higher multitasking. The more sleep debt, the more Facebook use and the higher the negative mood. With less sleep, people may seek out activities requiring less attentional resources such as social media use. Our results have theoretical implications for multitasking: physiological and cognitive reasons could explain more computer activity switches: related to less sleep.

Author Keywords

Multitasking; sleep; productivity; computer logging; *in situ* study; sensors; social media; Facebook; mobile phone; mood

ACM Classification Keywords

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

INTRODUCTION

"O magic sleep! O comfortable bird,
That broodest o'er the troubled sea of the mind...."

John Keats, in Endymion, 1818

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This reflection on sleep by the poet Keats was written almost 200 years ago. Yet in our current digital age, the topic of sleep (or lack thereof) is as important as ever, widely discussed in the academic community as well as in the popular press. One dominant theme has been how people rarely get enough sleep--the term "sleep debt" is actively discussed in the public sphere. Sleep deprivation can have serious consequences, leading to errors in the workplace [23], accidents [2], and even to falling asleep involuntarily at critical times, such as while driving [2]. However, how sleep deprivation might affect how people use information technology (IT) has yet to be explored.

Considering the current tendency of information workers and students to be online and accessible for interruptions much of the day (and night), the relationship of IT use and sleep is an important issue. Over the last decade, there has been discussion of how constant connectivity is associated with multitasking [32], interruptions [12], and checking email [32], during what might normally be sleeping hours, disrupting or shortening sleep.

In human-computer interaction (HCI), attention has been given to prototypes and apps that provide novel ways to measure sleep [3, 11, 24], including sensing social data [38]. In other fields, although studies suggest that IT use might interfere with sleep, cf [1], there have not yet been studies showing the *converse*: how sleep duration might affect IT use. Why is it important to consider how sleep might affect IT use? First, if a connection between sleep duration and IT use is indeed found, then this would point to the notion of sleep as a variable that should be considered in HCI research, particularly as it relates to user performance with digital media. Second, this research could identify specific computer behaviors that are present when people are lacking sleep, which could prevent human error. Third, such research could inform the design of technological interventions that might lead people to improve their sleep habits, e.g. by recognizing and informing about digital media behaviors that might be impacted by sleep deprivation.

The purpose of this study is to examine how sleep might affect IT use. Rather than rely on laboratory settings, we conducted an *in situ* study to capture real world contingencies that could play a role in the relationship between sleep and IT use. Sleep deprivation in young people, especially college students, has been given much attention, particularly on how sleep is affected by technology use (cf 1, for a review). As a first step to studying this converse relationship, we examine how technology use is affected by sleep duration with college students. Our results show that with less sleep, students perceive higher work pressure and productivity, spend shorter durations of time focusing their attention online, increase their time on Facebook, and experience more negative mood. These results contribute to the growing body of research examining the relationship of sleep and IT use.

SLEEP AND INFORMATION TECHNOLOGY USE

Sleep Duration and Performance

Lack of sleep is linked to numerous negative cognitive and health outcomes [23]. Lack of sleep can lead to reduced memory and cognitive functioning [23, 30], poor academic and work performance [23, 43], and safety risks such as falling asleep while operating vehicles [2]. Sleep deprivation and its effects remain prevalent among the US adult population, with 37% of adults aged 20-39 years reporting less sleep than the recommended 7-9 hours per night [11]. Those people who stay up late or who are categorized as “evening types” report attentional and emotional problems [35].

Sleep debt

Sleep debt is the cumulative loss of, and consequent pressure for sleep, that results from an inadequate amount of physiologically normal sleep [51]. Sleep debt can accrue in a variety of ways including going to bed later but keeping wake time the same, having untreated sleep disorders, or experiencing external sleep disturbances. Since people vary in the amount of sleep they need, sleep debt is based on the “*cumulative hours of sleep loss with respect to the subject-specific daily need for sleep*" [51]. Numerous studies have found sleep debt to impact a host of outcomes such as mood [18], weight gain [4], performance [42], and health [29].

College Students and Sleep Duration

Young adults may be particularly at risk for sleep disturbances and deprivation [6]. Lack of sleep is prevalent among college students, especially women [8]. Poor sleeping habits have negative impacts on undergraduate physical and mental health as well as academic performance such as lower test scores and grade point averages [43, 49]. Poor sleep quantity and quality, which include late nights, earlier wakeup times [49], and irregular sleep-wake patterns [28] are associated with lower academic performance, suggesting that routines around sleep, in addition to sleep amount, affect college students.

Constant availability via mobile phones and the Internet may lead to sleep disturbances. For example, among a sample of young people, smartphones were often used before bed and caused frequent sleep interferences [25]. Among adolescents, IT use tends to stretch late into the evening with negative effects on sleep as well as on academic performance [9]. Thus, while there is mounting evidence that IT use consequently affects sleep, no one has looked at the opposite relationship, which we explore in this study.

Sleep and Social Media Use

Increasingly, research has documented how social media might contribute to sleep deficiencies, largely from people staying awake to stream videos, peruse profiles, and chat online [39, 50]. However, studies are lacking on how sleep duration might affect social media and computer usage. Such relationships are quite plausible. Social media is often viewed as a lightweight activity [52] with socializing, escape, and distractions being common reasons people report for using social media [1, 47]. There is evidence of an association between more time on social networking sites and less effortful thinking [55]. Thus, sleep deprived individuals who are online may likely engage in less cognitively demanding and more distracting activities such as social media use.

Sleep and Multitasking

A number of studies have examined multitasking, or activity switching, while working with digital media, [e.g. 12, 19]. Multitasking can occur by switching attention not only among computer screens but also between devices [22]. These studies have often pointed to the role of interruptions (from external sources or oneself) [19], email [32], or habitual behavior [19] in influencing multitasking. Although not as thoroughly explored, sleep may also affect technology use and multitasking. For instance, one study found that those who ended their daily activity and went to sleep earlier tended to multitask less the next day [33]. This suggests that perhaps sleep patterns might be associated with attention shifting.

Studies of sleep deprivation and attention have found insufficient sleep to result in decreased visual and auditory attention [20]. Less sleep could thus contribute to less cognitively taxing behaviors while on the computer such as having less persistent attention with more switching of focus between windows and applications. This alteration in attention also applies to task switching [17]. It is quite plausible that similar low-attention behaviors, due to less sleep, could occur while on the computer as well. Thus, less sleep could contribute to higher online multitasking in the following ways. It could lead to more frequent switching of attention to different computer screens. This switching could be due to more self-interruptions, which comprise almost half of all interruptions in the workplace and can lead to task switches [12, 19]. Self-interruptions could be due to higher distractibility, and lack of sleep could make people more prone to distraction and thus more likely to switch focus from their current task at-hand.

RESEARCH QUESTIONS

In contrast to prior studies, which focused on how IT use affects sleep, we look at the converse: how sleep duration might affect how people use IT. While numerous studies point to the detrimental effects of having less sleep [23, 30, 43, 49], amount of sleep could also affect IT use. Further, while we expect sleep debt to be related to sleep duration, there are differences. One night of short sleep may affect some performance measures the next day and not others. However, sleep debt represents an accumulation of the effects of loss of sleep. In other words, consistently sleeping shorter than one's ideal amount could accumulate and produce effects on different variables than sleep duration. We thus examine sleep duration the night before and sleep debt with different variables. The following are our research questions and hypotheses.

RQ1: What are the impacts of sleep on college students' perceptions of productivity and work pressure? Before examining sleep effects on IT use, we begin by looking at related experiences to sleep duration. Decades of research have shown that sleep and health are related and that deficits in sleep can lead to personal and fiscal costs [23]. Studies of worker productivity and sleep patterns have found that decreased sleep leads to reduced memory, cognitive functioning, and work performance [30]; and for college students, sleep deficits result in lower academic performance [43, 49]. Conversely, when students are well rested, they tend to perform better academically and exercise more [5]. Thus, we explore whether less sleep duration the night before is associated with higher subjective work pressure and lower perceived productivity. We hypothesize that:

H1: Students with shorter sleep duration the night before will have higher perceived work pressure the next day.

H2: Students with shorter sleep duration the night before will rate their productivity to be lower the next day.

RQ2: Is sleep related to college students' multitasking on the computer? Surveys of college students have found high association between online computer use and sleep deficits for that evening [37]. Other research shows that longer duration of focus on the computer is related to less stress [32]. Coupling these patterns with evidence that decreased sleep reduces attention and focus [26], computer behavior when people had less sleep might involve more switching and less focused attention. A higher frequency of switching on the computer has been considered as a measure of higher multitasking [32]. In other words, from a fine-grained perspective it is an indicator of switching attention between different activities as screens and content change. Thus, we expect that less sleep should be associated with higher multitasking, as reflected by shorter attention duration on any computer screen. Thus, we expect that:

H3: Students with shorter sleep duration the night before will have shorter focus duration on computer windows the next day.

RQ3: Is sleep debt associated with Facebook use? Social media consumption (as opposed to production) is often lightweight, requiring little effort and often serving as a quick break (see [52]). As such, it is not surprising that youth report using social media for such things as distraction, a way to fill time, and as a mechanism for socializing [47]. Further, college students who use social media, especially social networking sites like Facebook, report feeling a need to check these sites regularly to stay connected to others [48]. This is consistent with other research that suggests that Facebook use is habitual [13]. We would not expect social media habits like Facebook use to change so easily after one night of sleep loss but rather would expect to see changes over longer term sleep loss accumulation (i.e. sleep debt). For this research question we examine sleep debt, as we are interested in whether we find a relationship of accumulated sleep loss with the tendency to increase lightweight activities.

When students are more sleep deprived and using technology, they might seek out activities involving fewer cognitive resources [15]. When working online, they may also be more likely to be distracted from work, and social media is reported as a common form of distraction [47]. A study of Facebook use and student engagement, using the National Survey of Student Engagement (NSSE) showed a negative relationship of Facebook use and engagement in educational activities [21]. It has also been observed in the workplace that when people are engaged in computer work Facebook affords a light break from work [31]. The most common social media site among adults ages 18-29 is Facebook, with 87% reporting using it in 2014 [14]. Others have also reported Facebook as the most popular social media site among college students [21]. We therefore focus on Facebook use and thus expect that when students have higher sleep debt, when online they would be more likely to spend more time doing Facebook as a lightweight activity and also as a distraction.

H4: Students with more sleep debt will engage in more Facebook use.

RQ4. How is sleep debt related to mood? A meta-analysis of laboratory sleep studies found that sleep deprivation significantly negatively impacts mood [42]. However, in contrast, a study of college students who were sleep deprived for 24 hours showed no significant changes in mood, such as negative mood states of anger and anxiety [43]. The authors explain this to the notion that 24 hours of sleep deprivation is long enough to affect fatigue but not long enough to impact mood. A large cross-sectional survey study of college students though did find a relationship between self-reported sleep disturbances and negative mood [28]. Because sleep loss over 24 hours did not affect mood, we expect that longer accumulated sleep could affect mood. Therefore in this research question we examine sleep debt. Based on these studies we expect that the more sleep debt one has, the more it would negatively impact mood. Most studies of the effects of sleep deprivation and mood have been done in the laboratory or with surveys. We are not aware of studies that have examined the relationship of sleep deprivation and mood where people have been tracked in an *in situ* environment. Therefore, we hypothesize:

H5: Students with more sleep debt will experience more negative mood.

METHODOLOGY

We conducted an *in situ* observational study at a large public university on the U.S. west coast in Jan.-May of 2014. We used a mixed-methods approach with automatic computer and phone logging as the primary method of data collection. In order to capture the context of students' life at school, their sleep schedule, and mood, we also used daily surveys and a one-time general survey about attitudes and demographic information. Computer and phone logging and other data collection occurred over seven days.

Participants and Procedure

Participants were recruited from undergraduate courses, student residences, and snowball sampling. In total, we collected data from 76 undergraduates: 34 males and 42 females. Due to the availability of monitoring software and its limitations, the study was restricted to students who used both Windows computers and Android phones. Students' ages ranged from 18 to 23 years (mean=19.3) and the median college year was sophomore.

On Day 1 of the study, participants visited a campus laboratory where the computer and phone logging software were installed on their devices. Students who also had desktop computers were given software installation instructions. Participants were sent a link to an online general survey on Day 1 and instructed to complete it before the end of the study (by Day 7). Two daily surveys were sent each day: one at 7 a.m. (a sleep diary for the night before), asking participants to complete it once awake and another at 9 p.m. (an end-of-day survey), asking them to complete it before going to bed. On Day 7, semi-structured exit interviews (for about 30 minutes) were conducted. Participants were asked about their experiences during the study, their technology habits, and their beliefs about how technology could affect stress, productivity, and mood. Descriptive coding was used to identify key themes that emerged from these interviews [46]. Participants were paid $100 for their participation.

Measures

A total of 71 people were used in the analysis. Five people were excluded due to missing computer data (logging software problems, software getting uninstalled by antivirus software, and one participant uninstalling the software). For these 71 participants, we collected computer and phone logs, sleep duration, social media use and daily surveys, and single general surveys.

Computer and phone logging. Computer activity over seven days was captured with Kidlogger (kidlogger.net). This Windows freeware generated one log record each time a user opened a new window or switched between already open windows. A window was an application or a web browser tab. Each log record included the start time and duration of the active window, the name of the application, a URL if the window was a web browser tab, and idle time. Timestamps were recorded to the second. Only time spent in the current window was measured. For example, if a webpage was open in the background when the user used Word in the foreground, Kidlogger only counted the time spent in Word. Computer idle time was not included. Phone logging over seven days was collected using the AWARE Framework application (www.awareframework.com). A log record was generated each time a user opened an application, web browser tab or switched between apps. The log captured activity to the millisecond. Data from computer and phone logging was partitioned into daily logs and numbered, generating at least seven days of computer/phone use per person. Due to scheduling issues, for some participants more than 7 days of data was collected. The distribution of full days of data collection was as follows: 58 students have 5 full days (7 days in total); 9 students have 6 full days (8 days in total); 1 student has 8 full days (10 days in total); 3 students have 7 full days (9 days in total); and 1 student has 8 full days (10 days in total).

*Facebook (**FB**).* Measures of FB usage from both the computer and phone logs were used to calculate frequency and duration of visits. The duration of time on FB from computer and phone logs were added together to produce a total daily time on Facebook.

Focus duration. Multitasking can be considered from different perspectives: at a broad level examining task switching, or at finer-granularity, examining attention shifts among different activities which could be within the same task. We adopt this fine-granularity perspective to investigate the relationship of sleep and its effects on how people shift their attention when working on the computer. We feel that measuring duration of focus on computer screens is a reasonable proxy for attention duration with computer work, and this has been used as a measure of attention in multitasking, cf [32]. By computing its inverse, average duration of focus can alternatively be converted into a measure of average switching among different computer windows per time unit. Focus duration is measured as the average duration spent on any active window, based on the logging software.

Sleep duration. Daily sleep duration was measured via a self-report sleep diary, modified from [36]. Starting from Day 2 of their study, participants were asked to enter the time they went to bed the previous day (hour and minute) and the time they woke up (hour and minute). Thus, data were collected for at least six nights (sleep on Days 1-6). Five days is considered sufficient to produce reliable measures of sleep [45]. Sleep diaries have been found to be very accurate [7], are commonly used in sleep studies [5, 8, 9, 41] and have been used as a gold standard when testing sleep-monitoring devices, e.g. [34]. Self-reported sleep has also been validated with actigraphs [54]. Sleep diary reports were included in the end-of-day surveys described below.

Sleep debt. People can accumulate sleep debt on days when they work and they generally compensate for loss of sleep on free days. Sleep debt is operationalized as follows. The larger the difference between mid-sleep time on free days compared to mid-sleep time on work days, the larger is considered the sleep debt [44]. The mid-sleep time is calculated as the mid-point between sleep onset and awakening. The analysis by Roenneberg and colleagues [44] shows that most people compensate for sleep loss during the week (work days) by sleeping longer on weekends (free days). Therefore, the ideal mid-sleep time on free days is calculated from observed mid-sleep time on free days, corrected by the weekend and weekday sleep durations, by the following formula recommended by [44]:

$$MS_{FSC} = MS_F - .05*(SD_F-(5*SD_W + 2*SD_F)/7)$$

where MS_F=mid-sleep time on free days, SD_F=sleep duration on free days, and SD_W is sleep duration on work days. $(5*SD_W + 2*SD_F)/7$ is the average weekly sleep need.

Based on students' schedules, we used weekday as a "workday" and weekends were "free days". We took the difference between the mid-sleep time of each workday and the ideal mid-sleep time, as the daily sleep debt. We took the absolute value, since the theory of sleep debt is that it is the absolute departure from the ideal mid-sleep time that is representative of sleep debt. It is the disruption from ideal sleep that matters. As sleep debt has a long tail, we used a log transformation to make the distribution normal.

Mood. Mood was measured using the PANAS scale at the end of every day. The PANAS [53] is a well-validated scale that measures two dimensions of mood: positive and negative affect. Following [27], we created a measure of Affect Balance, which refers to a balance between positive and negative affect, where the negative score is subtracted from the positive score.

Survey measures. Participants filled out daily end-of-day surveys where they answered questions on work pressure and perceived productivity. Other daily measures were also asked but are not covered in this paper. A general survey asked students for demographic information, technology use habits, course load, and class standing.

Measures used

The following are definitions of our measures used.

- *Work Pressure: (End-of-day survey): I feel that I was under work/study pressure today* (using a Likert scale, 1=Strongly disagree; 5=Strongly agree).
- *Perceived Productivity: (End-of-day survey): How productive do you feel you were today?* (using a Likert scale, 1= Not at all; 5=Extremely).
- *Sleep Duration*: *(Sleep diary)* the amount of sleep self-reported daily based on time to sleep the previous night and time one woke up the next morning. Greater values for sleep duration reflect a greater amount of sleep.
- *Sleep Debt:* calculated by the formula above, based on self-reported daily sleep. Greater values represent a greater amount of sleep debt.
- *Total Computer Duration:* the total daily active time on the computer, based on the logging software.
- *Focus Duration:* the average duration spent on any active computer window, based on the logging software. One outlier was removed.
- *FB Duration on Computer/Phone*: the total daily FB use on the computer and phone combined, based on the logging software. One outlier was removed. A square root transformation was done to improve normality.
- *Affect balance:* the positive daily PANAS score minus the negative daily PANAS score (End-of-day survey)
- *Interviews*: participant responses to semi-structured interviews of their technology experiences.

Control variables:

- *Age, gender* (General survey)
- *Workload*: number of course credit units taken at the time of the study (General survey)
- *Deadlines: (From the end-of-day survey): How much did deadlines influence you today?* (using a Likert scale, 1= Not at all; 5=Extremely) (End of day survey).

RESULTS

We collected more than 1,720 hours of computer logs from 71 participants, excluding computer idle time. Most participants reported in exit interviews that the week of the study was representative of a typical school week.

Overview of results

We begin by reporting an overview of the results. Table 1 shows descriptive statistics of the measures of interest. The average sleep duration in our sample was 7.9 hours, with a wide range of 2.6 to 14.0 hours. Students showed a positive sleep debt, meaning that on average they accumulated sleep loss. Focus duration on any computer window averaged 1 minute, 38 seconds. Sleep duration and sleep debt are weakly negatively correlated: r= -.11, p<.05.

Research questions and analyses

For our analyses we used linear mixed-effects models (LMM) using SPSS, with Subjects as random effects, to handle the nested nature of the data (each participant has multiple days of data). We used a random intercept for participants; all other factors in the model were entered as fixed effects. Parameters were estimated using the maximum likelihood method. For LMM, SPSS calculates

Type III F tests and uses the Satterthwaite approximation for calculating denominator degrees of freedom. For our analyses, we used the measure of sleep duration the night before (Sleep Duration) (H1-H3) and the measure of sleep debt (Sleep Debt) (H4-H5) to examine the association with the variables of interest on the current day. We controlled for age, gender, workload (i.e. Credit Units), and deadlines. We only analyzed full days of data collection and days when the computer usage was greater than zero. We removed four cases (i.e. four days of different individuals) when computers were not used, as these did not represent typical computer usage for these four students. Thus, for each person we averaged six days of measures used for sleep duration, for calculating sleep debt, and for the other measures. We used thematic coding of the exit interviews to identify themes on sleep and computer use.

RQ1: Impacts of sleep on perceptions of work pressure and productivity

Our first research question addressed the effects of sleep duration on students' perceived work pressure and reported productivity. At the end of each day, participants reported how much work pressure they felt they were under, and how productive they felt they had been. For Hypothesis 1, using a LMM, controlling for deadlines, workload, age, and gender, we found a strong trend that sleep duration the night before was negatively associated with reported work pressure the next day (Table 2). An R^2 statistic for LMM must account for the variance explained by both the fixed and random effects. As there is no standard method for specifying an R^2 in LMM [16], we can provide an estimate of the R^2 using fixed effects alone. This value will *underestimate* the amount of variance explained, as random effects are not included, but it will provide a reasonable estimate. For this model, the adj. R^2 = .56. (Table 2). Not surprisingly, the control variable of deadlines was positively correlated with work pressure. Control variables of age, gender, and workload were not significant. The results thus weakly support H1: the less sleep people had the night before, the higher their reported work pressure.

Daily measures	Mean (SD)	Median	Min	Max
Sleep Duration (hr)	7.95 (2.03)	8.00	2.58	14.00
Sleep Debt	.89 (.76)	.70	.01	3.90
Total Computer Duration (hr)	3.93 (2.88)	3.51	.001	13.02
Total Phone Duration (hr)	1.54 (2.89)	1.28	0	10.75
Focus: Avg. duration/window (min)	1 min 39 sec (1.15)	1 min, 13 sec	0	6 min 17 sec
Duration of FB on computer [1] (min)	33 min 31 sec (38.8)	19 min 36 sec	0	3 hr 19 min
Duration of FB on phone[1] (min)	16 min 16 sec (23.25)	8 min 54 sec	13 sec	2 hr 6 min
Work pressure (1, low-5, high)	2.94 (1.46)	3.00	1	5
How productive (1, low-5, high)	2.75 (1.03)	3.00	1	5

Table 1. Average daily measures for participants. Measures are based on full days of computer logging, and only on days when the computer was used. [1]Descriptive measures of FB in this table are based on days when FB was used.

H1: Work Pressure	Coeff (SE)	t	p
Intercept	-.59 (1.16)	-.51	.61
Sleep Duration	**-.05 (.03)**	**-1.90**	**.06**
Controls:			
Age	.09 (.05)	1.66	.10
Female (ref. to males)	-.20 (.13)	-1.56	.13
Workload	.01 (.02)	.52	.61
Deadlines	.73 (.04)	19.43	.001

Table 2. RQ1. H1: results of the effect of sleep duration the night before on daily work pressure.

Hypothesis 2 stated that longer sleep duration the night before would be associated with higher ratings of productivity for the current day. Results are in Table 3. Surprisingly, the results showed the opposite effect: the longer the sleep duration, the lower the reported productivity, adj. R^2 = .17. The control variable of deadlines was positively correlated with productivity. None of the other control variables were significant. Thus, we reject H2, as the result was in the opposite direction that we expected.

H2: Productivity	Coeff (SE)	t	p
Intercept	2.64 (1.24)	2.14	.04
Sleep Duration	**-.06 (.03)**	**-2.22**	**.03**
Controls:			
Age	-.03 (.06)	-.44	.66
Female (ref. to males)	.18 (.14)	1.31	.19
Workload	.01 (.02)	.42	.68
Deadlines	.28 (.04)	7.73	.001

Table 3. RQ1. H2: results of the effect of sleep duration the night before on daily productivity.

In interviews, several common ideas emerged around sleep, work, and technology. First, staying up late was associated with increased pressures the next day. The reasons for this pattern of sleep deprivation and work pressure varied. Some students reported staying up late in order to study for tests or complete high stakes assignments, such as P9, who explained: "*I want to sleep but I need to get this done. There's just so much work to do, you know*?" Participants also cited "wasting time" on technology as a reason for staying up late and having to work harder the next day. For example, P57 described the reciprocal relationship between his sleeping and SM use. He noted that his SM use is "*bad because I notice after a while, 'Why am I still on this? I need to do my lab homework or something*.' *And then I was like,* '*Okay, I guess I'm not sleeping until late tonight.*'" A theme among participants was that longer sleep was associated with a more relaxed schedule, thus providing context for rejecting H2 and the finding that longer sleep duration was associated with lower productivity. Lower productivity may also be associated with shorter sleep duration because participants chose to catch up on sleep during times with fewer obligations. Several participants described sleeping in on weekends, such as P56, who reserved "*stress-free days so I don't check my phone as much because I'd rather sleep.*" Similarly P32 had "*an actual routine Monday through Friday…versus weekends where I'll sleep in."*

RQ2. Sleep and computer usage

Our next set of hypotheses examined the relationship of sleep duration on people's computer focus duration the next day, shown in Table 4. Hypothesis 3 stated that sleep duration should be positively related to Focus Duration. As a proxy for focus, we measured the amount of time that a computer window was in active use. We then computed the average duration of focus on all computer windows in active use for that day. The results show a significant effect of sleep duration on Focus Duration: with less sleep the night before, the average focus duration on any computer window the following day correspondingly became significantly shorter, adj. R^2 = .04. The control variable of deadlines was significantly negatively correlated with focus duration: $F(1, 302)=8.23$, p <.004). The more deadlines participants had, the shorter was their focus duration on any computer screen. The other control variables were not significant. Therefore, the results support Hypothesis 3.

H3: Focus Duration	Coeff (SE)	t	p
Intercept	192.28 (117.54	1.64	.11
Sleep Duration	**3.79 (1.59)**	**2.38**	**.02**
Controls:			
Age	-3.82 (5.53)	-.69	.49
Female (ref. to males)	-12.37 (13.51)	-.92	.36
Workload	-1.63 (2.34)	-.70	.49
Deadlines	-6.24 (2.13)	-2.93	.004

Table 4. RQ2. H3: results of the effect of sleep duration the night before on online focus duration. All measures taken on a daily basis.

In the interviews, one theme regarding focus duration recurred throughout: sleep deprivation resulted in distraction the following day, particularly in class. P68, for example, described how switching focus helped her stay awake after staying up late: "*In class I get really sleepy and then I'll go do something on the Internet…then I'll be like okay, I'm awake now*." For one participant, lack of sleep also led him to feeling out of control and distractible: "*When I'm tired I have no control, I get distracted left and right.*" This example highlights a potential feedback loop, with poor sleep causing distractibility, leading to further sleep deprivation.

RQ3. Sleep and Facebook and Other Social Media use

We next examined sleep debt (as opposed to duration) and FB use. H4 stated that the higher the sleep debt, the longer the duration spent on FB. The results show that sleep debt does show a significant positive relationship with FB use on the computer and phone, adj. R^2 = .06 (Table 5). The control variables of Workload and Deadlines showed a significant positive correlation with Facebook use. We thus find support for H4.

The interviews provided some insight on the findings. Participants described a relationship of sleep and social media use. Increased social media use after short sleep duration may in part be a strategy, as mentioned in RQ1, to stay awake. For example, P65 stated that she used it during lectures: "*When I fall asleep I use it to wake myself up and get back to class*." P7 described a similar behavior as part of his waking routine: "*So that I don't go back to sleep, I forcibly open Instagram and I forcibly open Facebook so I don't go back to sleep. I made it a habit to look at something and process stuff so I can wake up*."

Students also discussed use of other social media sites as a lightweight activity that was integral to sleep and wake

H4: FB Duration	Coeff (SE)	t	p
Intercept	-75.12 (45.67)	-1.65	.11
Sleep Debt	**4.17 (1.99)**	**2.10**	**.04**
Controls:			
Age	3.53 (2.15)	1.64	.11
Female (ref. to males)	.19 (5.29)	.04	.97
Workload	2.01 (.91)	2.20	.03
Deadlines	1.45 (.72)	2.02	.04

Table 5. RQ3. H4: results of the effect of sleep debt on Facebook duration on computer and phone.

routines. Social media use was viewed as undemanding: "*it's easy to just scroll through Reddit. Just mindless behavior. Like procrastination time. And it's just easy. Scroll down, open a funny picture, move on to the next thing*" (P76). Twenty students described how social media use was a common practice as part of their before-bed routines. This use was for a variety of purposes, including relaxing and keeping up with information. For example, P9 reported: "*I go on Tumblr every night before I go to sleep to relax or debrief for the day.*" Similarly, P25 described her sleep routine: "*I watch videos until I fall asleep, and that's every single night. I noticed that starting this year in college, I always do that. It helps me fall asleep.*"

The interview results that social media was used as a lightweight activity to relax before sleep makes sense given that out of 71 informants, 51 reported using social media to take breaks during schoolwork. Some illustrative comments included those by P43 who said that she switched to Facebook as a way to escape the stress of schoolwork: "*I feel refreshed because I have a break time to not think about school work.*" P59 said that his social media routine included "*scrolling down through posts over and over again. It's a good way to get my mind off of school work and stress*." Participants also noted that social media use was part of their waking routines: "*I check Reddit a lot…before I go to sleep and also when I wake up….Just to see if there is anything new*" (P66). However, some reported that social media as part of their sleep routine interfered with their ability to get adequate sleep: "*I would be like 'What am I doing? I'm supposed to be sleeping.' But then I use [YouTube] like 10 minutes….I use it a lot before I go to sleep*" (P3).

RQ4. Sleep and Mood

Our last hypothesis examined the relationship of sleep debt and mood. We expected that more sleep debt would be related to more negative affect. Our dependent variable was Affect Balance [27], which is an indicator of positive well-being based on the PANAS scores [53]. Results in Table 6 show that there is a significant negative relationship of sleep debt with Affect Balance: the more sleep debt one has accumulated, the more negative is one's mood, adj. R^2 = .10. Gender was significant: $F(1, 67)=13.13$, $p<.001$: females have significantly more positive mood than males. The other controls were not significant. Therefore, we found support for H5.

H5: Affect Balance	**Coeff (SE)**	**t**	**p**
Intercept	-11.43 (12.62)	-91	.37
Sleep Debt	**-1.83 (94)**	**-1.94**	**.05**
Controls:			
Age	.97 (.60)	1.61	.11
Female (ref. to males)	5.36 (1.45)	3.69	.001
Workload	-.02 (.25)	-.06	.95
Deadlines	-.30 (.33)	-.91	.37

Table 6. RQ4. H5: results of the effect of sleep debt on mood.

DISCUSSION

Although studies have documented the effects IT use can have on sleep patterns, our results point to the converse: sleep duration can impact IT usage. Shorter sleep duration the previous night was related to higher work pressure and perceived productivity the next day. We also found that the shorter the sleep duration the night before, focus duration was shorter on the computer the next day. With more sleep debt, people spend more time on Facebook the next day. Sleep debt negatively impacts mood.

Our findings contribute to the growing body of research that has been examining the interplay of sleep and IT use. To date, studies have examined how IT use impacts sleep, generally finding that more time online leads college students to receive less sleep [1, 39, 50]. Other work has examined measurement of quality and quantity of sleep, e.g. through the use of smart phones, wearable devices, or sensing social behavior [3, 11, 24, 38]. Our work instead sheds light on the converse phenomenon: how sleep patterns can affect people's IT use and mood.

There has been much research interest in HCI on the topic of multitasking. Further, there has also been a body of research documenting that college students experience poor sleep habits, which in turn can lead to reduced cognitive functioning [30] and poor academic performance [44]. Our result that less sleep is associated with shorter duration of focus is related to multitasking behavior; the shorter the duration of focus on a computer screen, the more frequently one switches between screens, i.e. switching attention to different content [32]. Multitasking is also associated with lack of cognitive control and focus [40]. Our finding of shorter attention duration is consistent with other findings that show that when people are more tired, they are more distractible [26]. Thus, our results build on prior work showing that poor sleep affects cognitive functioning: we found that effects of poor sleep can be manifest in computer activity as well, specifically in terms of shorter focus duration while using the computer.

This result has theoretical implications for multitasking in HCI. It suggests that it is not just external interruptions, applications such as email, habitual behavior, or amount of projects that influence duration of focus [19, 32], but that there could be physiological and cognitive reasons for switching computer activities, due to lack of sleep. As we controlled for deadlines and workload, the shorter focus duration result implies that there is a factor beyond a student's work situation that could be affecting their attention duration. The association of amount of sleep with multitasking suggests that people's tendency to multitask can vary not only with task and the environment, but also can potentially change with sleep patterns. Thus, poor sleep patterns may contribute to explaining why online multitasking occurs, which is of theoretical interest for HCI.

Our results of sleep patterns on work pressure and productivity also contribute to the research literature. There is an established pathway of less sleep and lower productivity for adults, e.g. [23]. For college students, sleep patterns have been examined with lab-based performance tests (e.g. math or attention tasks after sleep-deprivation) and GPA [54] but never with *in situ* observation. Thus, our results show that poor sleep patterns can impact perceptions of work pressure and productivity for students. Future research can examine how these perceptions might be mediators of student performance.

The result showing that less sleep is associated with higher reported work pressure and higher productivity suggests that with less sleep, students may be spending more time on work activities. Less sleep can also mean that people are getting more work done, which would explain the result of higher perceived productivity. Fewer hours of sleep enables more time available to spend on work. Combining this idea with the result of higher work pressure suggests that with less sleep people could be experiencing a higher cognitive workload, e.g. due to deadlines, which we found to positively correlate with work pressure. Thus, less sleep can provide benefits, but may have repercussions in terms of higher work pressure and the ability to maintain focus.

Higher work pressure can place more cognitive demands on an individual. Some research has suggested that social media use is associated with less effortful thinking [55]. Combining our results, it is possible then that with less sleep, and with feeling more work pressure, people may turn to lightweight activities such as Facebook.

Shorter focus suggests being more distractible. The combination of shorter attention focus (and possibly more distractibility), and higher Facebook use leads us to posit that less sleep may lead to more self-interruptions. It is plausible that people self-interrupt to view Facebook, as its habitual use has been documented, cf [13, 52]. The qualitative results combined with the quantitative results help us better understand a potential role of Facebook with respect to work. Facebook might provide a mental break or distraction while conducting work on the computer. Consistent with this idea are data from the interviews where most students reported that social media was used as a work break. However, it is important to note that more Facebook use and increased multitasking may reflect, rather than result from, less sleep. This relationship can be tested in a laboratory setting. We also need to be cautious that not all Facebook use is for leisure activity or breaks. Although not a strong theme of Facebook use, four participants did mention that they used Facebook groups for school-related activities such as sharing information for group projects, organizing club activities, or participating in Q&A for class materials. We urge future studies to investigate sleep variables and types of Facebook activities.

College students are the cohort of highest users of social media. We explored social media use other than Facebook use in our sample post facto with sleep debt and found no relationship. One reason could be that social media is very heterogeneous. Social media can be used for a variety of purposes: e.g. information seeking, communication, or keeping up with friend networks. Different social media are also associated with different social norms; thus, we expect that behavior with social media can be quite diverse. It is possible that even with less sleep, people's needs that are satisfied by many types of social media may not change, but with Facebook, perhaps with sleep debt there is increased pressure to keep up with one's social network. Another reason could be that patterns of general social media use for this college student cohort might be highly variable, unlike with Facebook use which most college students use. Some support for this idea is found in the 2014 Pew study which shows that Facebook use is much higher than the next most popular social media site, Instragram, which 53% of young adults use [14]. Thus, it could be that aside from Facebook, the use of social media is fairly diverse in our sample and differences in its use may not be manifest with changing sleep patterns. This suggests further exploration with specific social media sites. As new social media sites gain in popularity, there may arise new relationships with patterns of sleep debt.

Our results that show that sleep debt is associated with negative mood corroborate laboratory studies, which show the same findings [28, 42, 43]. However, our contribution is that we show that these results occur in *in situ* environments in the course of natural day-to-day activities. In addition, the relationship of sleep debt and a more negative mood could be mediated by higher work pressure, as we discovered. We feel that these results lead to an opportunity for further research to test the interaction of sleep patterns, specific social media sites, and mood.

We looked at a one-way directional relationship of sleep duration on behaviors. However, more broadly, our study suggests that the relationship of sleep and IT use can be bidirectional. Identifying a relationship in the opposite direction is important, especially if these variables are reciprocal in nature (in other words, less sleep leads to more Facebook use and in turn more Facebook use could lead to less sleep). While our study of examining the role of sleep duration on IT use is a first step, future research should look at iterative processes. There may in fact be a cyclic relationship of sleep duration and certain behaviors.

Designing for sleep patterns

Our results inform some ideas of how technology could be designed to help remedy the effects of lack of sleep. We present the following suggestions. Our results suggest that sleep patterns should be considered when designing interfaces. People experience "social jet lag" [38], when people's circadian rhythms are mismatched to their work schedules or social lives. Interfaces could be customized to adapt to individuals' practices, as they are affected by their sleep patterns. For example, if an individual's attention focus is markedly decreased (as evidenced by shorter attention duration on computer screens or switching screens), then this could be a signal to trigger an intervention to take a relaxation break. Our results also suggest that people may gear their IT usage depending on their level of mental alertness. For example, lightweight computer activity could be beneficial in the morning to ease into computer work. There is utility to understanding computer usage as students wake or go to sleep that could help in their performance. Lastly, our results suggest that amount of sleep may be a variable of interest when doing user experience studies or *in situ* observations of IT use.

Limitations

Though our primary independent variables were sleep duration the night before, and sleep debt, which occur before the other measures temporally, we cannot state a causal relation. There may be any number of other underlying variables that mediate the relationship between sleep and IT usage. A limitation is that phone Facebook use may be overestimated; the highest durations of phone Facebook use were captured late at night, perhaps after participants had fallen asleep. Some participants stated that they used social media—especially on their phones—to fall asleep. Another limitation is that we did not measure quality of sleep but only focused on sleep duration. However, because we took multiple measures over different days for each individual, we can take into account variations of sleep duration within individuals. Still, it would be important in a future study to consider quality as well as quantity of sleep, including daytime naps. Lastly, sleep was based on self-report, which has been validated in previous studies. Nevertheless, future studies could use unobtrusive observational measures such as actigraphs for more precise estimates.

Our results apply to college students, based on our sample. It is unclear whether our results would generalize to other groups and domains, such as in the workplace. We do however strongly suspect that some relationships we found would generalize more broadly, such as with sleep and duration of computer window focus. Considering the importance of sleep in job performance, this could be an important area for further research.

CONCLUSIONS

As new sensors, biosensors and other innovative tools for measuring behavior continue to be developed, we envision that the results they yield will prove useful to the HCI community in improving the user experience. Our results point to sleep duration as one factor that is associated with IT usage. Although there is growing evidence of social media and computer usage disrupting sleep, this study shows that sleep affects IT usage as well. We hope that our research can spark future research into other techniques to explore more deeply the relationship of sleep and IT use.

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