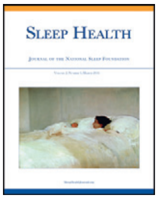
Sleep Health 2 (2016) 49–56

Contents lists available at ScienceDirect

Sleep Health

Journal of the National Sleep Foundation

journal homepage: http://www.elsevier.com/locate/sleh



Sleeping with technology: cognitive, affective, and technology usage predictors of sleep problems among college students

Larry Rosen, PhD *, Louis M. Carrier, PhD, Aimee Miller, MA, Jeffrey Rokkum, MA [1], Abraham Ruiz, BA [2]

Department of Psychology, California State University Dominguez Hills, Carson CA 90747, USA

ARTICLE INFO

Article history:
Received 19 August 2015
Received in revised form 11 November 2015
Accepted 12 November 2015

Keywords:
Sleep
Technology
Executive functioning
Anxiety
College students
Stress
Smartphone usage
Nighttime awakenings
Cognition
Affective factors

ABSTRACT

Objectives: Sleep problems related to technology affect college students through several potential mechanisms including displacement of sleep due to technology use, executive functioning abilities, and the impact of emotional states related to stress and anxiety about technology availability.
Design: In the present study, cognitive and affective factors that influence technology usage were examined for their impact upon sleep problems.
Participants and measurements: More than 700 US college students completed an online questionnaire addressing technology usage, anxiety/dependence, executive functioning, nighttime phone usage, bedtime phone location, and sleep problems.
Results: A path model controlling for background variables was tested using the data. The results showed that executive dysfunction directly predicted sleep problems as well as affected sleep problems through nighttime awakenings. In addition, anxiety/dependence increased daily smartphone usage and also increased nighttime awakenings, which, in turn, affected sleep problems.
Conclusions: Thus, both the affective and cognitive factors that influence technology usage affected sleep problems.

The National Sleep Foundation recommends that young adults of college age get between 7 and 9 hours of sleep per night with a caveat that 6 hours may be appropriate.[1] Studies have shown that college students are falling short of this recommendation.[2–4] A longitudinal study tracking Canadian university students from 2005 to 2009 found that the mean sleep hours ranged from 6.72 to 6.93 hours per night with a strong link between later bedtime and lower grade point averages.[5] According to this study, "A 14-min average delay in bedtime translated into a one letter-grade drop" (p. 20). The current study examines an explanatory model for sleep problems that includes affective and cognitive components as well as daily and nighttime technology use.

Technology use and sleep displacement

Numerous studies have proposed that technology use, particularly before bedtime, serves to displace sleep. Gradisar et al[6] reported that 9 in 10 Americans used a technological device during the last hour before bedtime with two-thirds of young adults using cell phones during that time and that more interactive devices used during the hour before bedtime predicted increased sleep problems. Gradisar et al pointed specifically at the cell phone showing data that of those who reported using their cell phones during the last hour before bed, more than half (57%) left their ringer on, which was, in turn, associated with difficulty returning to sleep after awakening; 20% of young adults reported being awakened at least a few nights a week, most often by an alert or notification from a cell phone. A 2013 study of college students[7] found that 47% reported nighttime awakenings to answer text messages and 40% awoke to answer phone calls, which, in turn, predicted poorer sleep quality.

Other recent studies have also validated and extended these findings among college-aged young adults. Specifically tracking college students, researchers have found that those students who used their mobile phones and texted more on a typical day showed more sleep problems.[8,9] In addition, Long Xu, Zhu, Sharma, and Zhao[10] found that those Chinese college students who used more social media evidenced more sleep problems. Similarly, Fossum, Nordnes, Storemark, Bjorvatn, and Pallesen[11] found that Norwegian college students who used more nighttime media in bed—particularly the computer and mobile phone for playing, surfing, and reading—showed more insomnia.

* Corresponding author. Tel.: +1 310 243 2325.
E-mail address: lrosen@csudh.edu (L. Rosen).
[1] Present address: School of Education, Iowa State University.
[2] Present address: Department of Psychology, University of Maryland, Baltimore County.

http://dx.doi.org/10.1016/j.sleh.2015.11.003

These results have been validated with adolescents and young adults across a variety of countries and settings.[8,12–17]

Impact of anxiety on sleep

Several studies have investigated the impact of emotional states on sleep including the effects of stress and anxiety on sleep. For example, Doane and Thurston[18] found that high daily stress among adolescents was associated with reduced sleep duration. Using similar samples, Short, Gradisar, Lack, Wright, and Dohnt[19] discovered that anxious adolescents evidenced a longer time to fall asleep than nonanxious teens. Honing in on a possible reason for the impact of anxiety, Moore, Slane, Mindell, Burt, and Klump[20] found that the strongest predictor of sleep problems was sociability due to increased time that adolescents spent communicating with peers during the evening. Finally, Bartel, Gradisar, and Williamson[21] performed a meta-analysis of 41 studies including more than 85,000 adolescents and found that presleep worry was related to delayed bedtimes and sleep problems.

Several studies of university students and young adults have found similar impacts of stress and anxiety on sleep. In a longitudinal study of Swedish college students, Thomée et al[22] discovered that those who perceived mobile phone use as stressful showed the greatest risk of sleep problems. Similar impacts of anxiety on sleep problems were found in college students in the United States,[4] Canada,[5] and Hungary.[23] Similar to the impact of sociability on adolescent sleep, Galambos et al[5] found that whereas stress was predictive of all sleep indicators across a 4-year study, social support was a positive predictor of sleep quantity.

Cognitive and physiological correlates of sleep

As suggested by Gradisar et al,[6] the source of sleep difficulties may be due to cognitive or physiological arousal. Ferraro, Holfeld, Frankl, Frye, and Halvorson[24] compared good and poor sleepers and found that, compared with good sleepers, poor sleepers showed more state and trait anxiety as well as poorer executive functioning. Cheever, Rosen, Carrier, and Chavez[25] removed cell phones from 163 college students who were then not allowed to do anything for more than an hour and measured their anxiety 3 times, 20 minutes apart, starting 10 minutes after the students sat down in the classroom. Heavy smartphone users showed increased anxiety within 10 minutes that continued to rise for the remainder of the hour. Moderate users showed only an increase in anxiety halfway through the study, which then stayed constant, whereas light users showed no increase in anxiety. Because heavy smartphone users get anxious when they are not allowed to access their phone, this may suggest that physiological arousal (anxiety) leads them to overuse technology before and during bedtime hours.

As corroboration of the impact of arousal on not being able to access one's smartphone, Clayton, Leshner, and Almond[26] implemented a laboratory study where they did not allow iPhone users to answer their ringing phone and observed concomitant increases in blood pressure, heart rate, and self-reported anxiety as well as a decline in cognitive performance. Przybylski, Murayama, DeHaan, and Gladwell[27] suggested that this anxiety might stem from fear of missing out—FOMO—based on a desire to stay continually connected through email, messaging, and social media.

Using a sample of 17- to - 19-year-old Egyptian students, Morsy and Shalaby[16] found that those who evidenced the lowest attention scores were those who had the least sleep. Two additional studies examined the impact of sleep deprivation on cognitive arousal, with 1 study demonstrating that after total sleep deprivation adults showed changes in the way that prefrontal cortex areas, including working memory, communicated with each other.[28] A second study specifically showed that poor sleep led to decrements in processing in the dorsolateral prefrontal cortex and reduced the linkage between the ventral striatum and the insula during reward processing.[29]

Multitasking and sleep

Research has shown that college students multitask much of the time and with the most tasks.[30,31] Multitasking has been shown, in everyday college life, to add stress and to result in later nights using multiple forms of technology.[32–35] Recent studies have corroborated these multitasking effects with adolescents who are soon to become college students,[14] whereas others have found that adolescents who multitask more consume more caffeinated drinks, which, in turn, promote sleep disturbances.[36]

A model of sleep problems

Several research teams have attempted to model the impact of a variety of variables on sleep problems among adults, college students, and adolescents. Simor et al[23] found that adult sleep problems were a partial mediator between chronotype (when one prefers to sleep) and negative emotionality. Looking at the issue of sleep from a different perspective, Adams and Kisler[7] found that nearly half of their sample of college students evidenced nighttime awakenings to answer texts and phone calls. Their model found that more nighttime awakenings predicted lower sleep quality, which, in turn, mediated the prediction of increased depression and anxiety.

In a study examining life satisfaction among college students, Li, Lepp, and Barkley[37] validated a proposed model with total daily cell phone use predicting nighttime cell phone use and use during classroom lecture and study time, which both, along with locus of control, predicted sleep quality. Similarly, using sleep quality and computer use to predict psychological and somatic symptoms, a cross-cultural study in Finland, Denmark, and France[38] found that sleep duration was a partial mediator between computer use and symptomology. Arora et al[39] found that, for UK adolescents, sleep duration was a mediator between technology use and body mass index. Finally, Chen et al[40] found that a combination of factors including bedtime anxiety, body weight, bedtime excitement, and depression predicted sleep duration.

Based on the available research and previously tested models with adolescents, college students, and adults, the path model depicted in Figure 1 is proposed to account for sleep problems in college students. The model proposes that sleep problems arise through a possible series of paths that emanate from both cognitive (executive functioning) and affective (anxiety about missing out on technology use) factors, each of which may impact technology usage including amount of daily smartphone usage, multitasking, nighttime phone placement, and nighttime awakenings to check the phone.

Method

Participants

A sample of undergraduate university students at an urban Southern California state university completed an online, anonymous questionnaire as part of an extra credit assignment in 2 large, upper-division general education courses. The survey was hosted on SurveyMonkey.com, and participants accessed the survey at a location of their choice. The data set was collected in 2 waves in September 2014 and in February 2015 to obtain a sample size sufficient for performing a path analysis with multiple paths and variables.

Of the 873 students who participated, 734 completed the survey. Overall, the sample included 310 (42%) men and 424 (58%) women with a mean age of 25.87 (SD = 6.61; median [M] = 24), and the ethnic/cultural composition of the sample was 53% Hispanic (n = 390),

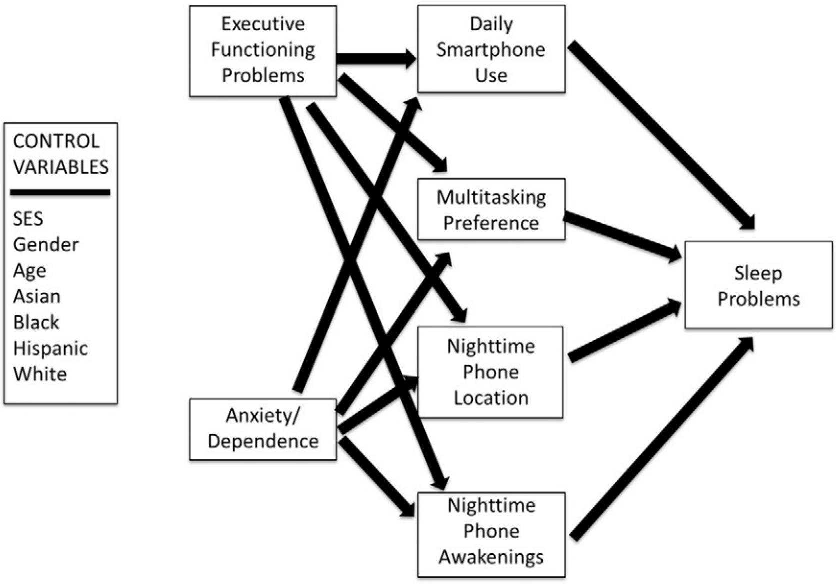


Fig. 1. Proposed path model for sleep problems in college students.

17% black/African American (n = 121), 13% Asian (n = 94), 12% white (n = 86), and 6% "Other" (n = 43). One in 3 (35%) were not employed; 48% were employed part-time, and 15% were employed full-time. The median income (based on ZIP code census data) averaged $51,725 (SD = $19,892).

Instrumentation and materials

Daily smartphone usage

The Daily Smartphone Usage subscale of the Media and Technology Usage and Attitudes Scale[41] was used to assess daily smartphone usage. This self-report scale includes 9 items (eg, "How often do you read e-mail on a mobile phone?"), each on a 10-point frequency-of-use scale ranging from "never" to "all the time." Items are averaged to derive a scale ranging from 1 to 10, with higher scores indicating more daily smartphone use. Rosen et al[41] reported that this scale has a Cronbach alpha coefficient of .93.

Anxiety without technology/dependence on technology

This subscale of the Media and Technology Usage and Attitudes Scale[41] includes 3 items reflecting anxiety/dependence related to being without a phone (eg, "I get anxious when I don't have my cell phone") or the Internet and being dependent on technology (eg, "I am dependent on my technology"). Each item is rated on a 5-point Likert scale from strongly agree to strongly disagree, and the subscale has a reported Cronbach alpha of .83.[41] Items are averaged to provide a score from 1 to 5, with higher scores indicating more anxiety without technology and more reported dependence on technology.

Executive functioning problems

Executive functioning problems were measured using Webexec, a measure developed to assess executive functioning problems over the Internet.[42] Webexec includes 6 items that ask participants to rate the extent to which they have problems in: (1) maintaining focus; (2) concentrating; (3) multitasking; (4) maintaining a train of thought; (5) finishing tasks; and (6) acting on impulse. Each item is rated on a 4-point scale from no problems experienced (scored a 1) to a great many problems experienced (4). The measure provides a single total score ranging from 6 to 24, with higher scores indicating more executive functioning problems. The scale has a reported Cronbach alpha of .76.[42]

Multitasking preference

This scale included 4 items taken from the Multitasking Preference Inventory,[43] each on a 5-point Likert scale from strongly agree to strongly disagree. Items were selected from the original 14-question inventory (alpha = .88) by using those with the top 4 loadings in a factor analysis. Three items were phrased in the same direction indicating a preference for multitasking or task switching (eg, "I prefer to work on several projects in a day rather than completing one project and then switching to another"), and 1 item was phrased in the opposite direction. This latter item was reversed scored, and the 4 items were summed, with higher scores indicating a stronger preference for multitasking or task switching. In a recent study,[41] these 4 items formed a single factor with a Cronbach alpha of .85.

Nighttime phone location

Participants were asked where they typically placed their phone when they went to sleep with possible answers of under my pillow, on my bed, next to my bed, in my bedroom but not close to my bed, in another room, and "other" for which they were required to supply a description of the "other" location. Responses were combined into 2 categories: (1) close to the participant (including under my pillow, on my bed, and next to my bed) and (2) in another room or far away from the participant.

Nighttime awakenings

Participants were also queried about awakening at night to check their phones with the following question: "On a typical night, after you have fallen asleep, how often do you awaken and check your phone for something other than the time (eg, text messages, email, social media, etc.)?" Response choices included never, once, 2 times, 3 times, 4-5 times, 6-8 times, and more than 8 times. Based on the response distribution, those choices were combined into 3 categories: (1) never; (2) once a night; and (3) 2 or more times a night.

Sleep Problem Index I

The Medical Outcomes Study Sleep Measure (RAND MOS Sleep Scale[44–46]) was used to assess sleep problems. The MOS Sleep Scale's

Sleep Problem Index I includes 6 items about the frequency of various sleep problems in the past 4 weeks with 6 possible responses ranging from all the time to none of the time. These items include a range of sleep quality issues including: (1) not getting enough sleep to feel rested upon waking; (2) awakening with shortness of breath or a headache; (3) having trouble falling asleep; (4) awakening during sleep time and having trouble falling asleep again; (5) having trouble staying awake during the day; and (6) not getting the amount of needed sleep. A psychometric study found that Cronbach alpha ranged from .78 to .83 in 2 samples.[44] The MOS Sleep Scale also queried the number of hours the participant slept per night over the past 4 weeks as an open-ended question.

Demographics

Participants were asked their sex, birth year, ethnic/cultural background, and ZIP code. The latter was used to estimate median income from the Census Bureau data.[47]

Results

Preliminary analyses

Before examining the proposed model of sleep problems, independent and dependent variables were examined for distributions and reliability. All variable distributions were within acceptable limits for skewness and kurtosis, and all but one Cronbach alpha coefficient was greater than .82 with only the alpha for the Sleep Problem Index I lower at .68. However, further investigation of this scale suggested that adding or removing items would not improve the reliability and the items did form a single scale. Table 1 displays the descriptive statistics for all interval scale measures.

In terms of the 2 categorical independent variables, half the participants (50%) kept their phone close by when they slept, and 49% checked it for something other than the time at least once a night (32%) or 2 or more times a night (17%). Finally, the MOS Sleep Scale asked about the number of hours of sleep per night that the participant estimated over the past 4 weeks, resulting in a mean of 6.68 hours (M = 7.00, SD = 1.12), with 33.5% of the participants getting less than 7 hours per night, the minimum recommendation from the National Sleep Foundation, and another 32% getting exactly 7 hours per night.

Table 2 provides the first-order correlations between the Sleep Problem Index I and all interval-scale independent variables. As can be seen in Table 2, all independent variables correlated significantly with sleep problems. In addition, a 1-way analysis of variance was performed comparing the Sleep Problem Index I score with Nighttime Awakenings with Tukey *B* post hoc test indicating that those who never awakened to check their phone evidenced significantly fewer sleep problems (M = 34.86, SD = 16.85) than those who awakened once to check their phones (M = 39.01, SD = 16.32), who, in turn, showed fewer sleep problems than those who awakened 2 or more times to check their phones (M = 45.99, SD = 17.58); $F_{2,731} = 21.26$, $P < .001$. Finally, an independent *t* test comparing where the phone was placed during the night found the opposite of what was predicted: those who kept their phone close at hand during the night had significantly *fewer* sleep problems (M = 36.84, SD = 16.00) than those who put their phone away in another room or away from their bed (M = 39.46, SD = 18.36); $t(730) = -2.05$, $P = .041$.

Table 1
Descriptive statistics for all interval scale independent and dependent variables.

Variable	Mean	SD	Skewness	Kurtosis	Alpha
Daily smartphone usage[a]	6.64	1.93	−.49	.34	.89
Anxiety/dependence[b]	2.48	0.98	.41	−.42	.82
Executive functioning problems[c]	11.95	3.66	.77	.78	.86
Multitasking preference[d]	3.32	1.00	−.34	−.65	.86
Sleep Problem Index I[e]	38.11	17.27	.50	−.06	.68

[a] Possible range from 1 to 10, with higher scores indicating more usage.
[b] Possible range from 1 to 5, with higher scores indicating more anxiety without technology and more dependence on technology.
[c] Possible range from 6 to 24, with higher scores indicating more executive functioning problems.
[d] Possible range from 1 to 5, with higher scores indicating a stronger preference for multitasking or task switching.
[e] Possible range is 0 to 100, with higher scores indicating more sleep problems.

Table 2
Zero-order correlations between interval scale independent variables and the dependent variable Sleep Problem Index I.

Independent variable	Zero-order correlation coefficient
Daily smartphone usage	.19***
Anxiety/dependence	.21***
Executive functioning problems	.32***
Multitasking preference	.10**

** $P < .01$.
*** $P < .001$.

Path model testing

Based on the literature, the proposed path model predicted that, after removing control variables (age, sex, SES and ethnic/cultural background), both cognitive and affective components—executive functioning and anxiety/dependence, respectively—would predict sleep problems by acting on 4 behaviors—daily smartphone usage, multitasking preference, nighttime phone location, and nighttime phone awakenings—to predict sleep problems. A series of hierarchical multiple regressions was performed by first factoring out the effects of the control variables on executive functioning and anxiety/dependence. The second step required factoring out the effects of both the control variables and the cognitive and affective variables on each behavioral variable, and the final step examined the significant predictive paths when using all 3 sets of variables hierarchically to predict sleep problems. Figure 2 displays the significant paths including beta weights for all significant predictors; $F_{13,705} = 12.61$, $P < .001$, $R^2 = .189$.

As can be seen in Figure 2, it is clear that predicting sleep problems provides a more parsimonious picture than the predicted path model in Figure 1. From the viewpoint of a cognitive impact on sleep problems, more executive functioning problems predicted more nighttime phone awakenings that, in turn, predicted more sleep problems. However, there was also a direct link between executive functioning problems and sleep problems, with the latter link—the strongest of all links—indicating that the more executive functioning problems someone has maintaining focus and attention and not acting impulsively, the more sleep problems they exhibited.

The affective component of anxiety about missing out on using the phone and the Internet and feeling dependent on technology predicted sleep problems through 2 separate paths. First, being more anxious about and dependent on technology predicted more daily smartphone usage that then predicted more sleep problems. Second, more anxiety/dependence predicted more nighttime phone awakenings, which also predicted more sleep problems.

Two other pathways in Figure 1 are worth mentioning. First, although more anxiety/dependence predicted a stronger multitasking preference, this link did not predict sleep problems. Second, for nighttime phone location, those who placed their phone away from their bed showed more sleep problems rather than fewer sleep problems

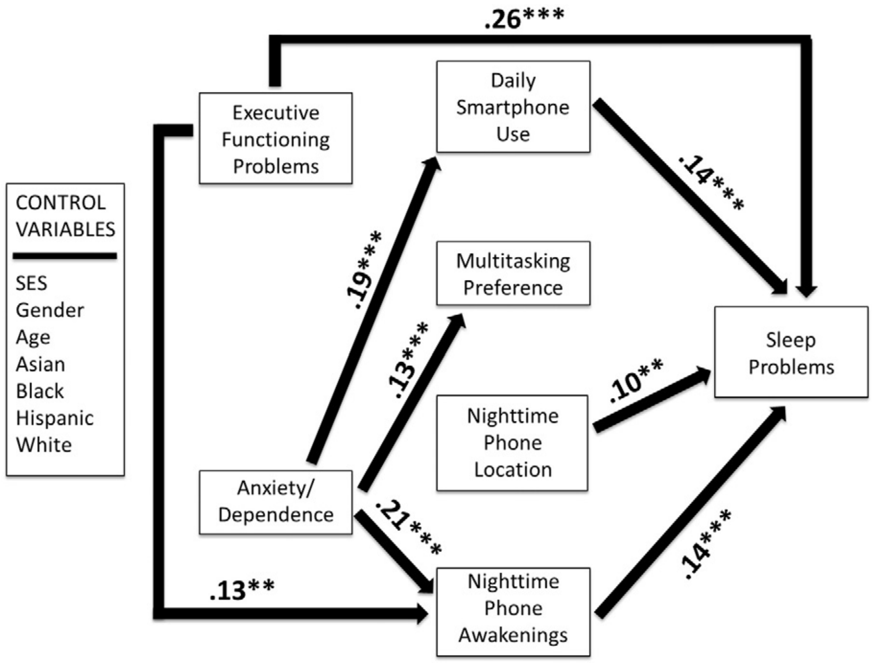


Fig. 2. Path model predicting sleep problems including beta weights for significant paths. ** P < .01. *** P < .001.

as predicted. This link, which was the weakest of all links in the model, bears further study.

Discussion

College students have been shown to be facing a daily sleep debt that negatively impacts their performance and their health. Sleep is a complex process that involves neurotransmitters such as melatonin that place the brain in a state that is conducive to sleep. Light given off by most technological devices—including smartphones, tablets, televisions, and others—works to retard the release of melatonin and has been shown to delay sleep onset. This relationship is so well established that the National Sleep Foundation recommends that no interactive technology be used during the last hour before bedtime[6] and the Mayo Clinic recently released a study concluding that if you are not able to remove your devices from the bedroom during the last hour before bedtime, you should dim your smartphone or tablet brightness setting and position the device at least 14 inches from your face, which reduces the amount of blue wavelength light entering your eyes and impacting melatonin release.[48] Many studies[39,49] have pinpointed smartphones and tablets as the main culprits in college student bedtime behaviors. The behaviors include extensive use directly in front of the face in the last hour before sleep, placing the phone close to the bed during sleep with the ringer or vibration operational, and either answering alerts and notifications or checking for them upon awakening during the night.

This study examined a specific model whereby a cognitive process—executive functioning problems—and an affective process—anxiety/dependence—might be responsible for sleep problems by leading the student to increased daily smartphone use and increased multitasking to support that use, as well as nighttime placement of the phone close by and nighttime awakenings to check for alerts and notifications. The cognitive component of this model was partially supported with executive dysfunction directly predicting sleep problems as well as predicting increased nighttime awakenings that, in turn, predicted more sleep problems. However, contrary to expectations, executive dysfunction did not predict daily smartphone use, nor did it predict nighttime phone location. These issues should be examined in future studies.

On the affective side, 2 paths to sleep problems emanated from anxiety/dependence, one of which predicted increased daily smartphone use leading to sleep problems and the other of which predicted increased nighttime phone awakenings, which also led to sleep problems. The link between anxiety/dependence and multitasking was validated, but this did not lead to sleep problems. Finally, placing a phone away from the room or far from the bed counterintuitively predicted *more* sleep problems, although this path was the weakest and may reflect other processes such as a feeling of being away from one's phone—referred to as *nomophobia*—leading to anxiety and sleep problems.[50] It is possible that having the phone away from the room or far from the bed might have aroused anxiety about not hearing the phone ring in an emergency or not hearing a wake-up alarm. Alternatively, Belk's[51] extended self-concept, whereby we regard our possessions as part of ourselves, may suggest that moving the phone—clearly an important possession—away from our person might reduce our extended-self state and induce anxiety.

The path model tested in this study was derived from research on sleep problems including other tested models, none of which identified both cognitive and affective components as the precursor of daytime and nighttime technology use leading to sleep problems. The majority of models proposed sleep problems as a mediator between or moderator of technology use and psychological issues such as depression, anxiety and other affective symptomology,[7,38] life satisfaction,[37] or body mass index.[39] The one model that attempted to predict sleep duration directly[40] included anxiety but did not include any cognitive factors.

Educational ramifications of daytime and nighttime technology use

Combining the results of this model with the other presented models, it is clear that increased technology use both during the day as well as during the night leads to sleep problems. From the cognitive perspective, these results suggest that it would be important to help college students become more metacognitive about their technology use during the daytime given its predictive path to sleep problems. Research shows college students to be among the heaviest users of technology, with the majority accessing their smartphone dozens if not hundreds of times a day both during class time[35,52–55] and outside of the classroom while studying.[30,31,56] Although some professors opt to eliminate the phone (and other devices) from the classroom, this only serves to increase anxiety[25] and potentially induce nomophobia. Perhaps a better solution might be to provide a "technology break"[56] during the class session that would allow and encourage students to use their phones only at regularly scheduled times while silencing them in between those times.

Phone use at night also negatively impacted sleep with a precursor of anxiety about missing out on technology and a feeling of dependence on technology. This is hardly surprising given that this study and others have shown that at least half of all college students sleep with their phones on alert (ring or vibrate) and a majority of students awaken to check their phone at least once a night. These awakenings most assuredly introduce blue wavelength light, which increases daytime alerting neurotransmitters such as cortisol, and most likely interferes with subsequent sleep. At a minimum, it is likely that these nocturnal interruptions negatively impact sleep cycles, which then may lead to daytime drowsiness and learning difficulties.

Following the National Sleep Foundation and the Mayo Clinic, the clear recommendation for pre-bedtime device use is to either dim the phone and keep it 14 inches from one's eyes or remove it completely during the last hour before bedtime and then remove it completely from the sleep environment prior attempting to fall asleep. There is a small hint in the path model that suggests that some students may have difficulty with this, as having the phone away from their bed predicted more sleep problems. However, if the phone were no longer available, that would ameliorate against the negative impact of checking in when awakened by an alert or notification. For many, this drastic move may prove difficult, but it would break that link between nighttime device use and sleep problems.

Affective and cognitive issues

The path model assessed the impact of executive functioning problems as well as anxiety/dependence on subsequent technology use leading to sleep problems. Strikingly, executive functioning problems led directly to sleep problems as well as predicting increased sleep problems by increasing nighttime awakenings. Given that the measure of executive functioning assessed attention (problems with focus, concentration, and train of thought), task completion (multitasking and difficulties finishing tasks), and impulse control, it may be important to teach college students metacognitive strategies to help maintain focus and attention while avoiding impulsive acts and constant task switching. Several authors have suggested that students lack digital metacognitive awareness about their executive functioning, which then negatively impacts their classroom performance.[31,52,57,58] One research team[59] developed a "sleep hygiene index" composed of issues including nighttime technology use, negative psychological states, including stress and anxiety, and other daily behaviors that might serve as a way of assessing student metacognition concerning many of the issues raised in this model.

The path with the most links to sleep problems was anxiety about missing out on technology use or a feeling of dependence on technology. This is a critical issue that has been referred to in the popular literature as *FOMO*—fear of missing out—or *nomophobia*—fear of being out of mobile phone contact. Both of these issues are defined by the appearance of anxiety, which, as shown in this model, predicts sleep problems by leading to increased daily smartphone use as well as increased nighttime awakenings. This phenomenon has been demonstrated in the laboratory[26] and in the classroom[25] and is a real concern as a driving force toward a constant need to "check in", primarily with technologies and devices that connect us to others.[56] With this in mind, it may be helpful for students to use "technology breaks" both inside the classroom and outside the classroom as a way to slowly wean themselves from feeling a constant anxiety-based need to check in.

Limitations

This study has several limitations. First, the sample included university students at a minority institution that may not represent all university students because the participants were older than the standard university population and, in addition to attending college, more than half were employed part-time with 1 in 7 employed full-time. However, the path model was tested only after factoring out demographic variables including ethnic/cultural background and a median income derived by ZIP code as a proxy for socioeconomic status. Second, the measurement tools that were used were self-reports of technology usage, executive functioning problems, anxiety/dependence, and sleep problems. It is possible that the students were not honest in reporting their behaviors, although prior use of each measure ensured reliability and validity and responses were completely confidential and anonymous. Third, the Sleep Problem Index I had a borderline reliability coefficient, which may mean that it does not adequately represent a unitary construct of sleep problems. However, that measure has been used with a variety of populations and has continually produced solid, repeatable results. Given the solid path analytic links, it is possible that a more reliable sleep problems measure would have shown even stronger results. In addition, to the best of our knowledge, the MOS Sleep Scale has not been used extensively with nonwhite samples and, to the extent that this study includes predominantly minority participants, further research is needed to ensure the tool's cultural validity.[60] Fourth, the present study relies on correlations and, as such, cannot truly establish causality. However, care was taken to test a specific path model, and that model showed several clear paths predicting sleep problems. It is possible, however, that additional variables might impact those paths, and this deserves future study. Fifth, it would be useful to know whether participants silenced their phone or left it on when they went to bed. This was not asked in the first wave of data collection, but a question was added to the second wave, which indicated that: only 5% turned their phone off; 33% silenced their phone, with 53% leaving the ringer on; and 61% left the vibrate function active. In addition, 57% of those who had their phone next to the bed placed it face up, whereas 43% indicated they placed the phone face down. Sixth, the measure of anxiety/dependence was specifically related to anxiety about not being able to check in with technology and feeling dependent on technology. No attempt was made to assess underlying general trait anxiety that may be responsible for the expressed state anxiety. Finally, given the prevalence of depressive symptoms among college students[61], it might be advisable to control for this variable in future studies.

Conclusion

College students are notoriously short on sleep. In this study, the majority of students slept with their smartphones nearby and awakened at night to check for messages. One-third of the sampled students showed fewer hours of sleep than recommended by the National Sleep Foundation, with an additional third self-reporting exactly 7 hours of sleep, the minimum recommended sleep duration. The study examined a possible explanatory path model for sleep problems and uncovered a variety of significant paths stemming from both cognitive and affective factors. Executive functioning problems directly predicted sleep problems as well as predicting increased nighttime awakenings that, in turn, predicted sleep problems. Anxiety about being away from technology and dependence on technology predicted increased daily smartphone use and increased nighttime phone awakenings, both of which predicted increased sleep problems. The results were discussed as a function of increasing metacognition and reducing anxiety to foster appropriate sleep and, hopefully, improve classroom performance.

Conflict of interest statement

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.

References

1. Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation's sleep time duration recommendations: methodology and results summary. *Sleep Health*. 2015;1(1):40–43.
2. Gradisar M, Gardner G, Dohnt H. Recent worldwide sleep patterns and problems during adolescence: a review and meta-analysis of age, region, and sleep. *Sleep Med*. 2011;12(2):110–118.
3. Knowlden AP, Sharma M, Bernard AL. A theory of planned behavior research model for predicting the sleep intentions and behaviors of undergraduate college students. *J Prim Prev*. 2012;33(1):19–31.
4. Lukowski AF, Milojevich HM. Sleep quality and temperament among university students: differential associations with nighttime sleep duration and sleep disruptions. *Behav Sleep Med*. 2015;13(3):217–230.
5. Galambos NL, Vargas Lascano DI, Howard AL, Maggs JL. Who sleeps best? Longitudinal patterns and covariates of change in sleep quantity, quality, and timing across four university years. *Behav Sleep Med*. 2013;11(1):8–22.
6. Gradisar M, Wolfson AR, Harvey AG, Hale L, Rosenberg R, Czeisler CA. The sleep and technology use of Americans: Findings from the National Sleep Foundation's 2011 Sleep in America poll. *J Clin Sleep Med*. 2013;9(12):1291–1299.
7. Adams SK, Kisler TS. Sleep quality as a mediator between technology-related nomophobia, depression, and anxiety. *Cyberpsychol Behav Soc Netw*. 2013;16(1):25–30.
8. Murdock KK. Texting while stressed: implications for students' burnout, sleep, and well-being. *Psychol Pop Media Cult*. 2013;2(4):207–221.
9. White AG, Buboltz W, Igou F. Mobile phone use and sleep quality and length in college students. *Int J Humanit Soc Sci*. 2011;1(18):51–58.
10. Long Xu X, Zhu RZ, Sharma M, Zhao Y. The influence of social media on sleep quality: a study of undergraduate students in Chongqing, China. *J Nurs Care*. 2015;4:253. http://dx.doi.org/10.4172/2167-1168.1000253.
11. Fossum IN, Nordnes LT, Storemark SS, Bjorvatn B, Pallesen S. The association between use of electronic media in bed before going to sleep and insomnia symptoms, daytime sleepiness, morningness, and chronotype. *Behav Sleep Med*. 2014;12(5):343–357.
12. Arora T, Broglia E, Thomas GN, Taheri S. Associations between specific technologies and adolescent sleep quantity, sleep quality, and parasomnias. *Sleep Med*. 2014;15(2):240–247.
13. Custers K, Van den Bulck J. Television viewing, Internet use, and self-reported bedtime and rise time in adults: implications for sleep hygiene recommendations from an exploratory cross-sectional study. *Behav Sleep Med*. 2012;10(2):96–105.
14. Hysing M, Pallesen S, Stormark KM, Jakobsen R, Lundervold AJ, Sivertsen B. Sleep and use of electronic devices in adolescence: results from a large population-based study. *Br Med J Open*. 2015;5(1), e006748.
15. Lin CH, Chen SK, Chang SM, Lin SS. Cross-lagged relationships between problematic Internet use and lifestyle changes. *Comput Hum Behav*. 2013;29(6):2615–2621.
16. Morsy AAK, Shalaby NS. The use of technology by university adolescent students and its relation to attention, sleep, and academic achievement. *J Am Sci*. 2012;8(1):264–270.
17. Thomée S, Härenstam A, Hagberg M. Computer use and stress, sleep disturbances, and symptoms of depression among young adults–a prospective cohort study. *BMC Psychiatry*. 2012;12(1):176.
18. Doane LD, Thurston EC. Associations among sleep, daily experiences, and loneliness in adolescence: evidence of moderating and bidirectional pathways. *J Adolesc*. 2014;37(2):145–154.
19. Short MA, Gradisar M, Lack LC, Wright HR, Dohnt H. The sleep patterns and well-being of Australian adolescents. *J Adolesc*. 2013;36(1):103–110.
20. Moore M, Slane J, Mindell JA, Burt SA, Klump KL. Sleep problems and temperament in adolescents. *Child Care Health Dev*. 2011;37(4):559–562.
21. Bartel KA, Gradisar M, Williamson P. Protective and risk factors for adolescent sleep: a meta-analytic review. *Sleep Med Rev*. 2015;21:72–85.
22. Thomée S, Härenstam A, Hagberg M. Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults-a prospective cohort study. *BMC Public Health*. 2011;11(1):66.
23. Simor P, Zavecz Z, Pálosi V, Török C, Köteles F. The influence of sleep complaints on the association between chronotype and negative emotionality in young adults. *Chronobiol Int*. 2015;32(1):1–10.
24. Ferraro FR, Holfeld B, Frankl S, Frye N, Halvorson N. Texting/iPod dependence, executive function and sleep quality in college students. *Comput Hum Behav*. 2015;49:44–49.
25. Cheever NA, Rosen LD, Carrier LM, Chavez A. Out of sight is not out of mind: the impact of restricting wireless mobile device use on anxiety levels among low, moderate and high users. *Comput Hum Behav*. 2014;37:290–297.
26. Clayton RB, Leshner G, Almond A. The extended iSelf: the impact of iPhone separation on cognition, emotion, and physiology. *J Comput-Mediat Commun*. 2015;20(2):119–135.
27. Przybylski AK, Murayama K, DeHaan CR, Gladwell V. Motivational, emotional, and behavioral correlates of fear of missing out. *Comput Human Behav*. 2013;29(4):1841–1848.
28. Verweij IM, Romeijn N, Smit DJ, Piantoni G, Van Someren EJ, van der Werf YD. Sleep deprivation leads to a loss of functional connectivity in frontal brain regions. *BMC Neurosci*. 2014;15(1):88.
29. Telzer EH, Fuligni AJ, Lieberman MD, Galván A. The effects of poor quality sleep on brain function and risk taking in adolescence. *Neuroimage*. 2013;71:275–283.
30. Carrier LM, Cheever NA, Rosen LD, Benitez S, Chang J. Multitasking across generations: multitasking choices and difficulty ratings in three generations of Americans. *Comput Hum Behav*. 2009;25:483–489.
31. Carrier LM, Rosen LD, Cheever NA, Lim AF. Causes, effects, and practicalities of everyday multitasking. *Dev Rev*. 2015;35:64–78.
32. Bowman LL, Levine LE, Waite BM, Gendron M. Can students really multitask? An experimental study of instant messaging while reading. *Comput Educ*. 2010;54(4):927–931.
33. Levine LE, Waite BM, Bowman LL. Electronic media use, reading, and academic distractibility in college youth. *Cyberpsychol Behav*. 2007;10(4):560–566.
34. Lin L, Bigenho C. Learning in Technology-Immersive Learning Environments. In: Rosen LD, Cheever NA, Carrier LM, editors. The Wiley Blackwell Handbook of Psychology, Technology and Society. Hoboken, NJ: Wiley-Blackwell; 2015. p. 420–425.
35. Wood E, Zivcakova L. Understanding Media Multitasking in Educational Settings. In: Rosen LD, Cheever NA, Carrier LM, editors. The Wiley Blackwell Handbook of Psychology, Technology and Society. Hoboken, NJ: Wiley-Blackwell; 2015. p. 404–419.
36. Calamaro CJ, Mason TB, Ratcliffe SJ. Adolescents living the 24/7 lifestyle: effects of caffeine and technology on sleep duration and daytime functioning. *Pediatrics*. 2009;123(6):e1005–e1010.
37. Li J, Lepp A, Barkley JE. Locus of control and cell phone use: implications for sleep quality, academic performance, and subjective well-being. *Comput Hum Behav*. 2015;52:450–457.
38. Nuutinen T, Roos E, Ray C, et al. Computer use, sleep duration and health symptoms: a cross-sectional study of 15-year olds in three countries. *Int J Public Health*. 2014;59(4):619–628.
39. Arora T, Hussain S, Lam KH, Yao GL, Thomas GN, Taheri S. Exploring the complex pathways among specific types of technology, self-reported sleep duration and body mass index in UK adolescents. *Int J Obes*. 2013;37(9):1254–1260.
40. Chen T, Wu Z, Shen Z, Zhang J, Shen X, Li S. Sleep duration in Chinese adolescents: biological, environmental, and behavioral predictors. *Sleep Med*. 2014;15(11):1345–1353.
41. Rosen LD, Whaling K, Carrier LM, Cheever NA, Rokkum J. The media and technology usage and attitudes scale: an empirical investigation. *Comput Hum Behav*. 2013;29(6):2501–2511.
42. Buchanan T, Heffernan TM, Parrott AC, Ling J, Rodgers J, Scholey AB. A short self-report measure of problems with executive function suitable for administration via the Internet. *Behav Res Methods*. 2010;42(3):709–714.
43. Poposki EM, Oswald FL. The multitasking preference inventory: toward an improved measure of individual differences in polychronicity. *Hum Perform*. 2010;23:247–264.
44. Hays RD, Martin SA, Sesti AM, Spritzer KL. Psychometric properties of the medical outcomes study sleep measure. *Sleep Med*. 2005;6(1):41–44.
45. Hays RD, Stewart AL. Sleep Measures. In: Stewart AL, Ware JE, editors. Measuring Functioning and Well-Being: The Medical Outcomes Study Approach. Durham, NC: Duke University Press; 1992. p. 235–259.
46. Spritzer KL, Hays RD. MOS Sleep Scale: A Manual for Use and Scoring, Version 1.0; 2003[Los Angeles, CA].
47. U.S. Census Bureau. American FactFinder. Retrieved from http://www.census.gov/2010census/data/; 2010.
48. Mayo Clinic. Are smartphones disrupting your sleep? Mayo Clinic examines the question. Retrieved from http://newsnetwork.mayoclinic.org/discussion/are-smartphonesdisrupting-your-sleep-mayo-clinic-study-examines-the-question/?mc_id=youtube; 2013.
49. Chang AM, Aeschbach D, Duffy JF, Czeisler CA. Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. *Proc Natl Acad Sci*. 2015;112(4):1232–1237.

50. Yildirim C, Correia AP. Exploring the dimensions of nomophobia: development and validation of a self-reported questionnaire. *Comput Hum Behav*. 2015;49:130–137.
51. Belk RW. Extended self in a digital world. *J Consum Res*. 2013;40(3):477–500.
52. Bowman LL, Waite BM, Levine LE. Multitasking and Attention: Implications for College Students. In: Rosen LD, Cheever NA, Carrier LM, editors. The Handbook of Psychology, Technology and Society. Hoboken, NJ: Wiley-Blackwell; 2015. p. 388–403.
53. Hammer R, Ronen M, Sharon A, Lankry T, Huberman Y, Zamtsov V. Mobile culture in college lectures: instructors' and students' perspectives. *IJELLO*. 2010;6:293–304.
54. Tindell DR, Bohlander RW. The use and abuse of cell phones and text messaging in the classroom: a survey of college students. *Coll Teach*. 2012;60(1):1–9.
55. Wood E, Zivcakova L, Gentile P, Archer K, De Pasquale D, Nosko A. Examining the impact of off-task multi-tasking with technology on real-time classroom learning. *Comput Educ*. 2012;58(1):365–374.
56. Rosen LD, Carrier LM, Cheever NA. Facebook and texting made me do it: media-induced task switching while studying. *Comput Hum Behav*. 2013;29(3):948–958.
57. Lepp A, Barkley JE, Karpinski AC. The Relationship Between Cell Phone Use and Academic Performance in a Sample of US College Students. *SAGE Open*. 2015;5(1) [2158244015573169].
58. Terry C. Media multitasking, technological dependency, & metacognitive awareness: a correlational study focused on pedagogical implications. Society for Information Technology & Teacher Education International Conference, vol. 2015, no. 1. ; 2015. p. 1304–1311.
59. Knowlden AP, Sharma M, Bernard AL. Sleep hygiene of a sample of undergraduate students at a midwestern university. *Am J Health Stud*. 2012;27(1):23–31.
60. Viala-Danten M, Martin S, Guillemin I, Hays RD. Evaluation of the reliability and validity of the Medical Outcomes Study sleep scale in patients with painful diabetic peripheral neuropathy during an international clinical trial. *Health Qual Life Outcomes*. 2008;6(6):113.
61. American College Health Association. American College Health Association National College Health Assessment II: Reference Group Executive Summary. Hanover, MD: American College Health Association; 2012.