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Although higher levels of cellphone use have been correlated with sleep problems, few studies have investigated specific qualities of cellphone use that may account for this relationship. Recently, significant associations among nighttime cellphone use, compulsive orientation toward cellphone use, and multiple characteristics of compromised sleep were found in a sample of undergraduate students enrolled at a small liberal arts college (Murdock, Horissian, & Crichlow-Ball, 2016). The current study expands upon these findings. Data were collected from 2 samples of undergraduates: 273 students enrolled at a midsized state university and 152 self-identified students recruited through Mechanical Turk. Hierarchical regression analyses were conducted to test the hypotheses that nighttime cellphone notifications and qualities of compulsive cellphone use would predict sleep problems and daytime sleepiness, even after taking into account the overall frequency of cellphone use. Full support for hypotheses was found for both domains of sleep-related functioning in both samples. Findings suggest that contextual aspects of cellphone use, such as its timing and compulsivity, may be more important to emerging adults' sleep than aspects of cellphone use such as the number of texts or time spent on calls. Sleep promotion programs for emerging adults should target specific cellphone use qualities—that is, the when, where, and how of cellphone use—to promote behavior change and improved sleep.

Public Policy Relevance Statement
In two samples of U.S. college students, higher levels of nighttime cellphone use and compulsive orientation toward cellphone use were associated with greater sleep problems and daytime sleepiness. These contextual elements of cellphone use were predictive of sleep-related problems even after rates of overall cellphone use were taken into account. Thus, the timing and compulsive qualities of individuals' cellphone behaviors might be fruitful targets for sleep promotion interventions.

Keywords: emerging adulthood, cellphone, sleep, compulsive

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Cellphones or smartphones are owned by 98% of emerging adults (i.e., 18- to 29-year-olds) in the United States (Anderson, 2015). Texting is the most frequently utilized cellphone function in this age group (Smith, 2015). Emerging adults report that on an average day, they send and receive more than 100 texts (Experion Marketing Services, 2013; Murdock, Horissian, & Crichlow-Ball, 2016) and spend 95 min texting (Roberts, Yaya, & Manolis, 2014). Most in this age group never (35%) or rarely (48%) turn their phones off (Rainie & Zickuhr, 2015), and a vast majority endorses sleeping with the phone within arm's reach (Lenhart, 2010). In a nationwide poll, more than one third of 18- to 24-year-olds reported sending and/or receiving texts at 3 a.m. (Experion Marketing Services, 2013).

College students appear to habitually experience daytime sleepiness (Oginska & Pokorski, 2006), poor sleep quality (Lund, Reider, Whiting, & Prichard, 2010), and feeling that they did not get enough sleep to function well (Gradisar et al., 2013). The recommended sleep duration for emerging adults is 7–9 hr (Hirshkowitz et al., 2015), but at least 8.5 hr are recommended for optimal functioning and well-being (Lund et al., 2010). Poor sleep quality has been linked with higher levels of negative mood, physical symptoms, stress, use of medications, and persistent psychological distress (Glozier et al., 2010; Lund et al., 2010), and a dose-response relationship has been demonstrated between sleep duration and multiple domains of psychological functioning (Kalak, Lemola, Brand, Holsboer-Trachsler, & Grob, 2014). Electronic media use has been identified as a factor contributing to chronic sleep loss in young adults (Owens et al., 2014), but the mechanisms of this association have not been fully investigated.

Cellphone Use and Sleep-Related Functioning

Perhaps not surprisingly, studies of emerging adults have documented significant associations of quantitative measures of their text messages and/or cellphone calls with aspects of sleep-related functioning such as sleep problems (Murdock, 2013), sleep disturbances (Thomee, Harenstam, & Hagberg, 2011), and subjective sleep quality (Murdock et al., 2016). Thomée and colleagues (2007) found longitudinal support for texts and calls as a predictor of difficulties falling asleep one year later among young adult men (but not women).

Some studies have specifically investigated links between emerging adults' cellphone habits at night and sleep. Findings have been mixed across different dimensions of sleep-related functioning. Data from the National Sleep Foundation's (2011) Sleep in America poll revealed a significant association of bedtime cellphone use with difficulty falling asleep, but not with later bedtimes (Gradisar et al., 2013). Fossum, Nordnes, Storemark, Bjorvatn, and Pallesen (2014) reported a significant association of bedtime cellphone use with severity of insomnia symptoms, but not with daytime sleepiness. Adams and Kisler (2013) found that a subset of undergraduates in their university sample endorsed responding to texts and cellphone calls after bedtime, and these students experienced an average of 46 min of sleep disruption per week. However, even in this sample as a whole, students reported an average of 25 min per week of sleep disruptions because of text messages and cellphone calls after bedtime. Despite these notable levels of sleep disruption, in this sample neither the total number of daily texts and phone calls nor the total time awake because of texts and cellphone calls was significantly correlated with self-reported sleep problems. Li, Lepp, and Barkley (2015) recently found statistical support for a path model in which higher levels of college students' overall cellphone use predicted higher levels of nighttime cellphone use, which predicted greater sleep problems, which in turn, predicted lower satisfaction with life. Also, higher levels of overall cellphone use predicted higher levels of cellphone use during class and study time, which predicted lower grade point average, which in turn, predicted lower satisfaction with life.

Taken together, these results reinforce the importance of understanding sleep quality as a foundational aspect of well-being, but leave open the question of exactly how cellphone use may be linked with emerging adults' sleep. Instead of focusing on purely quantitative measures of cellphone use frequency, theoretical models must address multiple layers of habitual cellphone-related behaviors and cognitions that may help to illuminate links with sleep-related functioning.

Compulsive Qualities of Cellphone Use

Within recent years, multiple constructs have been developed concerning problematic psychological tendencies toward cellphone use (Billieux, 2012). Some measures have drawn from the behavioral addiction literature to conceptualize cognitive (e.g., thinking about the phone, wanting to check it, and feeling out of sorts when separated from it) and behavioral (e.g., checking the phone and keeping it within arm's reach) aspects of problematic cellphone use (David, Kim, Brickman, Ran, & Curtis, 2015; Roberts et al., 2014; Walsh, White, & Young, 2010). Several studies have examined personality and mental health correlates of compulsive/addictive cellphone use (Bianchi & Phillips, 2005; Billieux, Van Der Linden, & Rochat, 2008; Harwood, Dooley, Scott, & Joiner, 2014; Roberts, Pullig, & Manolis, 2015). For instance, O'Connor and colleagues (2013) utilized factor analysis to identify four factors of the Cell Phone Overuse Scale (CPOS; Jenaro, Flores, Gómez-Vela, González-Gil, & Caballo, 2007): anticipation, activity interfering, emotional reaction, and problem recognition. They found that subscales were consistently but differentially correlated with outcomes such as impulsivity, problematic alcohol use, and relational attachment style. Perhaps most notably, only the anticipation subscale (i.e., thinking about the phone when it is turned off and thinking about new messages that may be received) was significantly associated with a history of motor vehicle crashes.

It appears that only three studies have examined associations between compulsive qualities of cellphone use and emerging adults' sleep characteristics. Jenaro and colleagues (2007) utilized the Cellphone Overuse Scale, which is based on diagnostic criteria parallel to those for pathological gambling, in a study of Spanish undergraduates. Higher scores on this measure were associated with insomnia symptoms, but not with sleep duration. Ferraro, Holfeld, Frankl, Frye, and Halvorson (2015) examined a construct of texting dependency encompassing excessive use as well as texting-related negative emotional reactions, disruption of relationships, and psychological/behavioral symptoms. Using standard thresholds for scores on the Pittsburgh Sleep Quality Index, they found that college students classified as "poor" sleepers had higher levels of texting dependency when compared with "good" sleepers.

Recently, in a sample of undergraduates enrolled at a small liberal arts college, Murdock and colleagues (2016) utilized hierarchical multiple regression analysis to investigate unique associations of the average number of daily text messages, awareness of nighttime cellphone notifications, and compulsion to respond to nighttime notifications with multiple aspects of sleep-related functioning. A greater average number of daily text messages was significantly associated only with subjective sleep quality, but greater awareness of nighttime cellphone notifications was significantly associated with global sleep problems, sleep disruptions, and subjective sleep quality. After partialing out the variance accounted for by daily texts and nighttime notifications, compulsion to respond to nighttime notifications contributed additional unique variance in predicting subjective sleep quality.

It appears that compulsive or addictive features of cellphone use are common among emerging adults; in a recent nationwide poll of college students in the United States, 10–20% endorsed such psychological experiences (Smetaniuk, 2014). Therefore, compulsive cellphone tendencies may be an important element of risk for emerging adults to experience compromises in sleep-related functioning.

The Current Study

This study builds on the findings of Murdock and colleagues (2016), described previously, in which cellphone use frequency, nighttime use, and compulsivity were associated with college students' sleep-related functioning. The current study expands on these results by assessing a more robust construct of compulsive cellphone use and by investigating these processes in two additional groups of undergraduates. The Compulsive Cellphone Use Questionnaire was developed for this study to assess affective, cognitive, behavioral, and social aspects of excessive and repetitive cellphone use that is at least partially motivated by anxiety reduction.

Two hypotheses were tested in this study. Hypothesis 1 was that after taking into account the variance accounted for by overall cellphone use (i.e., daily texts and calls), greater awareness of nighttime cellphone notifications would

be significantly associated with poorer sleep-related functioning (i.e., global sleep problems and daytime sleepiness). Hypothesis 2 was that after accounting for overall cellphone use and awareness of nighttime cellphone notifications, higher levels of compulsive cellphone use would be associated with poorer sleep-related functioning.

These hypotheses were tested in two separate samples: undergraduate students enrolled at a midsized state university; and self-identified undergraduate students who participated in the study via Amazon's Mechanical Turk (MTurk). MTurk is an online crowdsourcing marketplace in which *workers* (i.e., members of the public) select among thousands of *Human Intelligence Tasks* (HITs) that are submitted by *requesters* (i.e., task creators: researchers, businesses). Workers can earn small amounts of monetary compensation for successfully completing tasks. However, if their work fails to meet quality checks, requesters can reject their work and refuse to pay. Workers' acceptance/rejection ratings can affect their eligibility to participate in future tasks.

MTurk is an increasingly popular tool for academic researchers to collect behavioral science data (Chan & Holosko, 2016). MTurk participants tend to be more ethnically, racially and socioeconomically diverse than participants recruited through more traditional methods (Behrend, Sharek, Meade, & Wiebe, 2011; Buhrmester, Kwang, & Gosling, 2011). There is evidence that psychometric characteristics of measures administered via MTurk are consistent with those generated from in-person and other Internet samples (Buhrmester et al., 2011; Casler, Bickel, & Hackett, 2013), and that MTurk workers exhibit superior attention to instructions when compared with participants in traditional college samples (Hauser & Schwarz, 2016; Ramsey, Thompson, McKenzie, & Rosenbaum, 2016).

Method

Participants and Procedure

Demographic characteristics of Samples 1 and 2 are presented in Table 1. Constructs for the current study were assessed, and target sample sizes were set, as part of a larger study investigating links between cellphone use and college students' psychosocial well-being.

Sample 1.   Sample 1 included 273 undergraduate students (90% female) enrolled at a midsized, northeastern, public university and recruited through classes in the Human Development and Family Studies Department, in which students from a variety of majors were enrolled. Participants completed an online survey at their convenience and were eligible to earn extra credit. A total of 291 students completed the study, but 13 surveys were excluded from the final dataset because respondents' ages fell more than 3 *SD*s above the mean age of the sample, and five surveys were excluded because of missing data.

Sample 2.   Sample 2 included 152 individuals (50% female) who accessed an online survey through Amazon's MTurk. Participants were eligible if they endorsed being at least 18 years of age, living in the United States, and currently enrolled in a 2- or 4-year college. Participants were required to have an MTurk acceptance rating of at least 95%. They were eligible to earn $0.75, a typical rate for a 20-min MTurk survey. Eighteen percent of the sample was enrolled in a 2-year college; 9% was enrolled in a 4-year community college; and 73% was enrolled in a 4-year college or university. A total of 161 individuals completed the study, but eight surveys were rejected for containing incorrect responses to two out of the three validity check items (e.g., Choose your favorite color from the following: red, car, truck, grass.), and one survey was excluded from the final dataset because of missing data.

Measures

Questionnaires were presented in the same order across all participants: (a) estimated daily texts and calls; (b) nighttime cellphone use; (c) global sleep problems; (d) daytime sleepiness; (e) compulsive cellphone use; and (f) demographic information.

Participants reported their sex, age, class year, ethnicity, race, and the educational attainment of up to two parents, ranging from 1 (*did not finish high school*) to 8 (*doctoral degree*). The mean parental education of two parents was calculated.

Estimated daily texts and calls.   Participants were asked to estimate, on an average day, the

Table 1
Demographic Characteristics of Participants

Variable	Sample 1 (N = 273)			Sample 2 (N = 152)		
	M (SD)	Range	% (n)	M (SD)	Range	% (n)
Sex			90 (246) female			50 (76) female
Age	20.7 (1.40)	18–28		21.7 (1.77)	18–26	
Class year	2.72 (.94)	1–4	10 (26) First year	2.96 (1.22)	1–6	12 (18) First year
			33 (91) Sophomore			27 (41) Sophomore
			33 (90) Junior			26 (40) Junior
			24 (66) Senior			25 (38) Senior
						10 (15) 5th–6th year
Ethnicity			9 (25) Hispanic/Latino			15 (22) Hispanic/Latino
Race[a]			86 (235) White			76 (115) White
			8 (23) Black			13 (20) Black
			4 (11) Asian			9 (13) Asian
			1 (3) American Indian/Alaska Native			1 (2) American Indian/Alaska Native
			1 (4) Hawaiian/Pacific Islander			1 (2) Hawaiian/Pacific Islander
Parental education[b]	4.58 (1.82)	1–8	7 (20) < High school	4.35 (1.85)	1–8	6 (10) < High school
			11 (30) GED			15 (22) GED
			13 (35) High school			19 (29) High school
			15 (41) Training			15 (22) Training
			21 (55) Associate's			11 (17) Associate's
			24 (65) Bachelor's			27 (41) Bachelor's
			9 (24) Master's			6 (9) Master's
			<1 (2) Doctoral			1 (2) Doctoral

[a] Participants endorsed all racial identities that applied. [b] Mean for up to two parents. 1 = *Did not finish high school*; 2 = *GED*; 3 = *High school diploma*; 4 = *Specialized training after high school*; 5 =*2-year Associates Degree*; 6 =*4-year Bachelor's degree*; 7 = *Master's degree*; 8 = *Doctoral degree*; GED = Passed a General Educational Development test to earn a Certificate of High School Equivalency.

number of text messages sent and received and the number of minutes spent talking on their cellphone.

Nighttime cellphone notifications. Four items were utilized to assess the frequency of cellphone notifications received at night: (a) During an average week, on how many nights do you hear or see cellphone notifications while you are trying to get to sleep? (b) During an average week, on how many nights do you respond to cellphone notifications while you are trying to get to sleep? (c) During an average week, on how many nights are you awakened by cell phone notifications in the middle of the night, once you have already fallen asleep? (d) During an average night that you are awakened by cell phone notifications after you have fallen asleep, approximately how many times are you awakened? Responses on the first three items could range from zero to seven nights. Responses on Item 4 were made on a 6-point scale ranging from "*zero nights; never awakened*" to

"*five or more times*." Internal consistency of these four items was acceptable in a previous sample drawn from a small liberal arts college ($\alpha = .74$; Murdock et al., 2016) and good in the current Sample 1 ($\alpha = .83$) and Sample 2 ($\alpha = .86$). To standardize response scales, items were z-scored and summed to create a nighttime cellphone notifications variable.

For descriptive purposes, participants were asked to report the typical location of their cellphone at night. Results are presented in Figure 1.

Compulsive cellphone use. The 12-item Compulsive Cellphone Use Questionnaire (CCQ) was developed for this study to assess compulsive qualities of cellphone use, including affective, cognitive, and behavioral aspects of excessive and repetitive cellphone use that is at least partially motivated by anxiety reduction, as well as activity and relationship interference that results from this tendency. The CCQ is presented in Table 2. Participants responded to
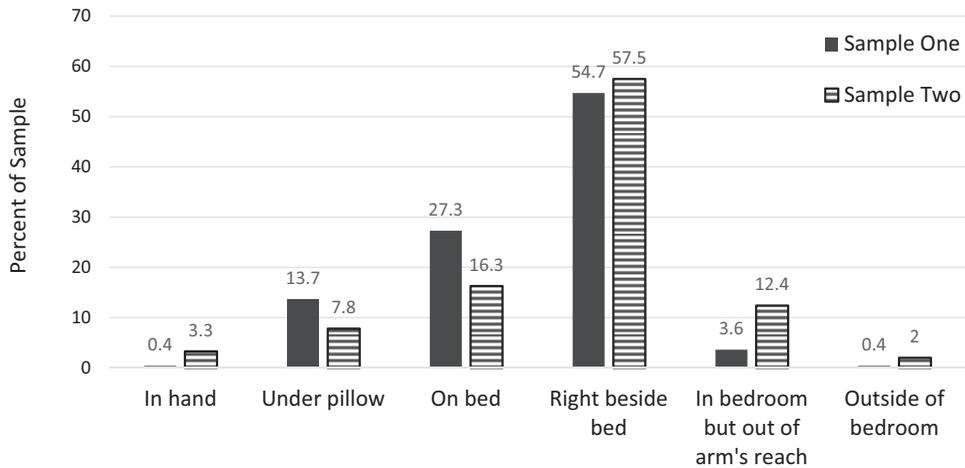
Figure 1. Habitual location of cellphone at night.

items on 5-point scales ranging from 1 ("*not at all*") to 5 ("*very*") or from 1 ("*never*") to 5 ("*almost always*").

Exploratory factor analyses were conducted to examine the structure of the CCQ in Samples 1 and 2. Using Cattell's (1966) scree test one factor was retained, which accounted for 50.9% and 50.1% of the variance in Samples 1 and 2, respectively. Factor loadings of the 12 items ranged from .58 to .81 and from .44 to .81 in

Samples 1 and 2, respectively. Cronbach's alpha was excellent in Sample 1 ($\alpha = .91$) and Sample 2 ($\alpha = .90$), and item analysis revealed no item deletions that would improve the internal consistency of the measure. Responses were summed to form a total score, with higher scores indicating higher levels of compulsive cellphone use.

Global sleep problems. Sleep problems were assessed with the 22-item Pittsburgh Sleep

Table 2
Compulsive Cellphone Use Questionnaire (CCQ)

	Think about the past month when responding to the following items
1[a]	How difficult is it for you to ignore an incoming text message?
2[a]	How hesitant are you to turn off notifications or temporarily disable your phone from incoming calls or messages?
3[a]	How hesitant are you to put physical distance between you and your phone?
4[a]	How much do you feel responsible for being accessible via cell phone at all times?
5[a]	How anxious do you feel when you are not accessible via cellphone?
6[b]	How often do you check repeatedly (e.g., press the phone's "on" button) in anticipation of a text response from someone?
7[b]	When unlocking your phone with the intention of performing a non-text-related activity, how often do you get sidetracked by reading or responding to text messages?
8[b]	If a question comes up and you don't know the answer, how often do you feel the need to look it up immediately on your smartphone?
9[b]	How often do others seem to think that you use your cellphone too much?
10[b]	How often does your cellphone use interfere with other activities that you are trying to do?
11[b]	How often has your cellphone use prompted disagreements or bad feelings between you and someone in your family?
12[b]	How often has your cellphone use prompted disagreements or bad feelings between you and one of your friends?

[a] 1 = *Not at all*; 2 = *A little bit*; 3 = *Somewhat*; 4 = *Quite*; 5 = *Very*.   [b] 1 = *Never*; 2 = *Rarely*; 3 = *Sometimes*; 4 = *Often*; 5 = *Almost always*.

Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The PSQI is a widely used instrument constructed of seven component scores: subjective sleep quality, latency, duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. Raw scores on these components are recoded to a range of 0 to 3. The seven component scores are summed to create a global sleep problems total score with higher scores indicating more troubled sleep.

Daytime sleepiness. A modified version of the Epworth Sleepiness Scale for Children (ESS; Johns, 1991) was utilized to assess daytime sleepiness. Some items were altered to fit a college lifestyle. Participants responded to 12 situations (e.g., "sitting in class" or "as a passenger in a car for more than 15 minutes") by rating their likelihood to feel sleepy on a 4-point scale ranging from 0 ("*would never feel sleepy or doze off*") to 3 ("*high chance of feeling sleepy or dozing off*"). This modified measure is available upon request to the corresponding author. Internal consistency of this measure was good in a previous sample drawn from a small liberal arts college ($\alpha = .85$; Murdock et al., 2016) and excellent in the current Sample 1 ($\alpha = .90$) and Sample 2 ($\alpha = .90$). Items were summed to create a total score with higher scores indicating greater sleepiness.

Results

Preliminary Analyses

As depicted in Figure 1, 96% of Sample 1 and 85% of Sample 2 reported keeping their cellphone within arm's reach at night.

Psychometric properties of primary study variables (i.e., estimated daily texts; estimated daily call minutes; nighttime cellphone notifications; compulsive cellphone use; global sleep problems; and daytime sleepiness) for Samples 1 and 2 are presented in Table 3. Table 4 presents bivariate correlations among primary study variables and subscales of the Pittsburgh Sleep Quality Index.

Among primary study variables, in Sample 2 only, estimated number of daily cellphone call minutes was positively correlated with estimated number of daily texts, $r = .24$, $p = .004$ and with nighttime cellphone notifications, $r = .30$, $p < .001$. The pattern of associations of all other cellphone use variables (daily texts, nighttime cellphone use, and compulsive cellphone use) with primary sleep-related variables (global sleep problems and daytime sleepiness) was similar across the two samples, and statistically significant correlational results are presented below for Samples 2 and 3, respectively. Estimated number of daily texts was significantly correlated with nighttime cellphone notifications ($r = .20$, $p = .001$; $r = .39$, $p < .001$) and compulsive cellphone use ($r = .17$, $p = .006$; $r = .19$, $p = .020$). Nighttime cellphone notifications was significantly associated with compulsive cellphone use ($r = .31$, $p < .001$; $r = .41$, $p < .001$), global sleep problems ($r = .22$, $p < .001$; $r = .35$, $p < .001$), and daytime sleepiness ($r = .26$, $p < .001$; $r = .19$, $p = .017$). Compulsive cellphone use was significantly correlated with global sleep problems ($r = .18$, $p = .003$; $r = .34$, $p < .001$) and daytime sleepiness ($r = .33$, $p < .001$; $r = .51$,

Table 3
Descriptive Statistics for Primary Study Measures

Variable	Sample 1 ($N = 273$)			Sample 2 ($N = 152$)		
	M (SD)	Range	α	M (SD)	Range	α
Estimated number of daily texts	233 (274)	2–1,500[1]		130 (154)	0–669[2]	—
Estimated number of daily cellphone call minutes	29 (33)	0–140[3]		38 (83)	0–204[4]	—
Nighttime cellphone notifications[5]	0 (3.33)	−3.78–9.60	.83	0 (3.43)	−3.35–9.47	.86
Compulsive cellphone use	33.15 (9.55)	12–60	.91	31.40 (9.97)	12–60	.91
Global sleep problems	6.27 (3.12)	1–18	—	5.95 (2.91)	0–14	—
Daytime sleepiness	25.94 (7.32)	12–48	.90	25.11 (7.37)	12–48	.90

[1] 5 outliers were replaced with values at 3 *SD* above the mean. [2] 6 outliers were replaced with values at 3 *SD* above the mean. [3] 7 outliers were replaced with values at 3 *SD* above the mean. [4] 2 outliers were replaced with values at 3 *SD* above the mean. [5] Sum of 4 *z*-scored items.

Table 4

Intercorrelations Among Cellphone Use and Sleep Variables for Sample 1 (N = 273) and Sample 2 (N = 152)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Estimated number of daily texts	—	.24**	.39***	.19*	.14	.06	−.01	.16	.15	.06	.02	.10	.05
2. Estimated number of daily cellphone call minutes	.08	—	.30***	.14	−.02	.03	−.06	.07	.14	.04	.09	−.08	−.24**
3. Nighttime cellphone notifications	.20**	−.09	—	.41***	.35***	.19*	.13	.21*	.25**	.19*	.14	.21**	.24**
4. Compulsive cellphone use	.17**	−.01	.31***	—	.34***	.51***	.15	.17*	.11	.10	.36***	.18*	.31***
5. Global sleep problems	−.03	−.08	.22***	.18**	—	.44***	.55***	.68***	.43***	.54***	.57***	.55***	.62***
6. Daytime sleepiness	.08	−.09	.26***	.33***	.43***	—	.31***	.25***	.09	.04	.50***	.17*	.44***
7. PSQI Subjective sleep quality	−.02	−.06	.11	.11	.71***	.29***	—	.28***	.21*	.23**	.26**	−.01	.36***
8. PSQI Sleep latency	−.06	−.08	.25***	.12*	.69***	.24***	.49***	—	.04	.29***	.31***	.31***	.24**
9. PSQI Sleep duration	.04	−.02	.09	.13*	.56***	.20**	.35***	.20**	—	.53***	.02	−.02	.07
10. PSQI Habitual sleep efficiency	−.05	−.04	.09	.08	.58***	.11	.30***	.23***	.50***	—	.14	.05	.05
11. PSQI Sleep disturbances	.21**	−.04	.33***	.18**	.51***	.39***	.25***	.30***	.10	.13*	—	.26**	.36***
12. PSQI Use of sleeping medication	.01	−.03	.04	.01	.59***	.14*	.30***	.29***	.09	.13*	.27***	—	.34***
13. PSQI Daytime dysfunction	−.16*	−.08	.04	.17**	.53***	.51***	.32***	.20**	.19**	.13*	.24***	.19**	—

Note. PSQI = Pittsburgh Sleep Quality Index. Sample 1 correlations are presented below the diagonal. Sample 2 correlations are presented above the diagonal.
* $p < .05$. ** $p < .01$. *** $p < .001$.

$p < .001$). Global sleep problems was significantly correlated with daytime sleepiness in both samples ($r = .43$, $p < .001$; $r = .44$, $p < .001$).

Sex and age effects for primary study variables were examined in preliminary analyses of both samples. Age was not correlated with any primary study variable in either sample. In Sample 1, independent samples *t* tests revealed significantly higher levels of estimated daily cellphone call minutes for women ($n = 244$, $M = 31.03$, $SD = 33.92$) compared with men ($n = 27$, $M = 16.93$, $SD = 25.04$), $t(37) = 2.67$, $p = .011$. Similarly in Sample 2, significantly higher levels of daily calls were also reported by women ($n = 76$, $M = 39.64$, $SD = 47.29$) compared with men ($n = 75$, $M = 24.53$, $SD = 30.28$), $t(128) = 2.34$, $p = .021$. In Sample 2, women reported significantly higher levels of compulsive cellphone use ($n = 246$, $M = 33.63$, $SD = 9.56$) when compared with

men ($n = 27$, $M = 29.00$, $SD = 8.58$), $t(271) = 2.41$, $p = .016$. However, in Sample 2, levels of compulsive cellphone use were not significantly different between women ($n = 76$, $M = 32.40$, $SD = 10.06$) and men ($n = 75$, $M = 30.47$, $SD = 9.88$), $t(149) = 1.19$, $p = .237$. In Sample 2, levels of global sleep problems were significantly higher among women ($n = 76$, $M = 6.55$, $SD = 3.01$) compared with men ($n = 75$, $M = 5.37$, $SD = 2.68$), $t(149) = 2.54$, $p = .012$. However, in Sample 1, there were no significant differences in global sleep problems between women ($n = 246$, $M = 6.24$, $SD = 3.02$) and men ($n = 27$, $M = 6.48$, $SD = 3.94$), $t(29) = .31$, $p = .755$.

Hypothesis Testing

Hierarchical multiple regression analyses were conducted to test hypotheses. Initially, age, sex, race, ethnicity, and parent education

were entered in Block 1. This block of demographic variables did not account for significant variance in global sleep problems or daytime sleepiness in Sample 1 or Sample 2. However, sex emerged as a significant individual predictor of global sleep problems in Sample 2. Hierarchical regression models were tested with variables entered in the following blocks: (a) participant sex; (b) estimated number of daily texts and estimated number of daily cellphone call minutes; (c) nighttime cellphone notifications; and (d) compulsive cellphone use. Two regression analyses were conducted in each sample to examine the criterion variables of global sleep problems and daytime sleepiness. Cook's distance values were calculated in each regression model and no values over 1 were identified in Sample 1 or Sample 2.

Global sleep problems. Results are presented in Table 5. In Sample 1, Blocks 1 and 2 did not account for significant variance in the outcome. In the third block, nighttime cellphone notifications was a significant predictor (β = .21, t = 3.35, p = .001), accounting for 4% of unique variance. In the fourth block, compulsive cellphone use was a significant predictor (β = .13, t = 2.08, p = .038) and accounted for 2% of unique variance. This model predicted 6% of the variance in global sleep problems.

In Sample 2, sex (males coded as 1, females coded as 2) was a significant predictor of global sleep problems (β = .20, t = 2.54, p = .012), accounting for 4% of unique variance. An additional 4% of variance was accounted for in the second block, with estimated daily texts emerging as a significant predictor (β = .20, t = 2.47, p = .015). In the third block, nighttime cellphone notifications was a significant predictor (β = .41, t = 4.89, p < .001), accounting for 13% of unique variance. In the final block, compulsive cellphone use was a significant predictor (β = .19, t = 2.42, p = .017) and accounted for 3% of unique variance. This model predicted 24% of the variance in global sleep problems.

Daytime sleepiness. Results are presented in Table 6. In Sample 1, Blocks 1 and 2 did not account for significant variance in the outcome. Nighttime cellphone notifications was a significant predictor in the third block (β = .21, t = 3.43, p = .001), accounting for 4% of unique variance. In the fourth block, compulsive cellphone use was a significant predictor (β = .28, t = 4.40, p < .001) and accounted for 7% of unique variance. This model predicted 12% of the variance in daytime sleepiness.

In Sample 2, blocks one and two did not account for significant variance in the outcome.

Table 5
Hierarchical Multiple Regression Analyses Predicting Global Sleep Problems

	Sample 1 (N = 273)					Sample 2 (N = 152)				
Predictors	R^2	ΔR^2	β	t	p	R^2	ΔR^2	β	t	p
Block 1	.00	.00				.04	.04*			
Sex			−.02	.39	.696			.20	2.54	.012
Block 2	.00	.00				.08	.04*			
Sex			−.02	.32	.753			.25	3.06	.003
Estimated daily texts			−.03	.41	.685			.20	2.47	.015
Estimated daily call minutes			−.05	.85	.396			−.11	1.27	.205
Block 3	.04	.04**				.21	.13***			
Sex			−.02	.26	.793			.30	3.84	.000
Estimated daily texts			−.07	1.10	.277			.07	.87	.384
Estimated daily call minutes			−.03	.56	.578			−.21	2.59	.011
Nighttime cellphone notifications			.21	3.35	.001			.41	4.89	.000
Block 4	.06	.02*				.24	.03*			
Sex			−.04	.63	.532			.27	3.48	.001
Estimated daily texts			−.09	1.37	.173			.06	.75	.453
Estimated daily call minutes			−.03	.56	.575			−.20	2.58	.011
Nighttime cellphone notifications			.17	2.63	.009			.33	3.72	.000
Compulsive cellphone use			.13	2.08	.038			.19	2.42	.017

* p < .05.   ** p < .01.   *** p < .001.

Table 6
Hierarchical Multiple Regression Analyses Predicting Daytime Sleepiness

Predictors	Sample 1 ($N = 273$)					Sample 2 ($N = 152$)				
	R^2	ΔR^2	β	t	p	R^2	ΔR^2	β	t	p
Block 1	.00	.00				.01	.01			
Sex			.00	.07	.946			.08	.96	.337
Block 2	.01	.01				.01	.01			
Sex			.02	.35	.723			.09	1.04	.302
Estimated daily texts			.09	1.50	.135			.08	.90	.368
Estimated daily call minutes			−.07	1.20	.232			.00	.04	.965
Block 3	.05	.04**				.05	.03*			
Sex			.03	.42	.674			.11	1.31	.193
Estimated daily texts			.05	.80	.426			.01	.12	.909
Estimated daily call minutes			−.06	.90	.367			−.05	.54	.591
Nighttime cellphone notifications			.21	3.43	.001			.21	2.25	.026
Block 4	.12	.07***				.26	.21***			
Sex			−.02	.34	.733			.03	.45	.654
Estimated daily texts			.01	.23	.822			−.02	.22	.823
Estimated daily call minutes			−.06	.94	.349			−.04	.48	.634
Nighttime cellphone notifications			.13	2.12	.035			.00	.01	.989
Compulsive cellphone use			.28	4.40	.000			.51	6.39	.000

* $p < .05$. ** $p < .01$. *** $p < .001$.

In the third block, nighttime cellphone notifications was a significant predictor (β = .21, t = 2.25, p = .026), accounting for 3% of unique variance. In the third block, compulsive cellphone use was a significant predictor (β = .51, t = 6.39, p < .001) and accounted for 21% of unique variance. This model predicted 26% of the variance in daytime sleepiness.

Additional Analyses

Given the statistically significant sex differences in compulsive cellphone use (Sample 1) and global sleep problems (Sample 2), hierarchical regression analyses were recalculated with the interaction of sex × compulsive cellphone use entered in the fifth block. In Sample 1, the interaction accounted for 2% of unique variance in global sleep problems (β = .95, t = 2.23, p = .027), but accounted for no additional variance in daytime sleepiness (β = .04, t = 0.09, p = .927). In Sample 2, the interaction was not significant for global sleep problems (β = .05, t = 0.20, p = .840) or daytime sleepiness (β = −.28, t = 1.20, p = .231).

To decompose the significant interaction, regression analyses of global sleep problems in Sample 1 were conducted in subsamples of females and males, with variables entered as follows: (a) estimated number of daily texts and

estimated number of daily cellphone call minutes; (b) nighttime cellphone notifications; and (c) compulsive cellphone use. For females (n = 238), nighttime notifications was a significant predictor in the second block (β = .21, t = 3.27, p = .001), accounting for 4% of unique variance, and compulsive cellphone use was a significant predictor in the third block (β = .19, t = 2.78, p = .006), accounting for an additional 3% of variance. This model accounted for 8% of the variance in global sleep problems for females. The model accounted for 10% of the variance for males (n = 26), but there were no statistically significant individual predictor variables.

Discussion

The results of this study build upon evidence from previous research (Murdock et al., 2016) that the timing and compulsivity of cellphone use can explain unique variance in the sleep-related functioning of college students. In comparison to the cursory, one-item measure of compulsion to check nighttime notifications utilized in the previous study, the current study utilized a more comprehensive measure of compulsive cellphone use. Whereas the previous study examined undergraduates at a small

southeastern private liberal arts university, the current study investigated a sample of students at a midsized northeastern public university and students in a nationwide MTurk sample. The study by Murdock et al. (2016) and the current study examined two common dimensions of sleep-related functioning: global sleep problems and daytime sleepiness.

In the current study, both nighttime notifications and compulsive cellphone use were significantly associated with global sleep problems and daytime sleepiness across both samples. Both Hypotheses One and Two were fully supported. Effect sizes for the full hierarchical regression models ranged from small to medium/large (i.e., R^2 of 6%–26%). Very little of this variance was accounted for by overall cellphone use (i.e., estimated daily texts and calls); daily texts emerged as a significant predictor only in the model predicting global sleep problems in Sample 2. In correlational analyses of Pittsburgh Sleep Quality Index subscales, the number of daily texts was significantly positively correlated with sleep disturbance and negatively correlated with daytime dysfunction, only for Sample 1. These findings echo those from the previous study, in which daily texts was significantly negatively correlated with subjective sleep quality but was not significantly associated with most self-reported and actigraphy-measured sleep indicators including sleep problems, daytime sleepiness, sleep disruptions, onset latency, wake after sleep onset, and sleep duration (Murdock et al., 2016). Thus, a direct and consistent association between overall rates of texting and sleep-related functioning is not indicated within these college samples. On the contrary, nighttime cellphone notifications and compulsive cellphone use were significantly correlated with multiple sleep indicators across both samples in the current study.

A majority of college students in this study endorsed keeping their cellphone within arm's reach during sleeping hours. Although most college students are physically close to their cellphones at night, their awareness of nighttime notifications may differ. Greater awareness may reflect a propensity toward compulsive cellphone use; in both current samples these constructs were significantly positively correlated. Even so, in the current study compulsive tendencies accounted for significant unique variance in global sleep problems and daytime sleepiness over and above the variance accounted for by awareness of nighttime notifications. Similarly, in a previous sample of college students, compulsion to check nighttime notifications accounted for significant variance in sleep diary-measured subjective sleep quality over and above the variance accounted for by awareness of nighttime notifications (Murdock et al., 2016). It is possible that some underlying construct, such as anxiety, drives both awareness of nighttime notifications and compulsive cellphone use. For instance, emerging adults who experience anxiety may be more likely to keep their phones in close proximity during the day and/or night as a safety object and/or in order to avoid missing out on information or interactions. Over time, this habit of close proximity may lead to nighttime distractions and/or potentiate the development of compulsive tendencies.

Study Limitations

Several methodological characteristics of the current study should be considered in interpreting its findings. First, the current study did not include objective measures of cellphone usage or sleep-related functioning. Questionnaire measures were utilized to measure all constructs, which increases the likelihood of self-report bias. Questionnaires were administered to participants in a standard order, and thus order effects were not controlled. The cross-sectional nature of the current data precludes drawing firm conclusions about the direction of effects between cellphone use characteristics and sleep-related functioning. That is, the experience of sleep disturbances could make it more likely that someone would engage in nighttime cellphone use and/or would develop a pattern of compulsivity in cellphone use. Indeed, in a recent longitudinal study of Canadian college students, Tavernier and Willoughby (2014) concluded that sleep problems may predispose individuals to engage in higher levels of bedtime technology use in the forms of TV watching and use of social media sites. Additional longitudinal research is necessary to clarify how patterns of cellphone use and sleep characteristics emerge within and across adolescence and emerging adulthood.

Finally, although participants from a variety of sociocultural backgrounds participated in this study, Samples 1 and 2 did not represent the full demographic diversity of college students in the United States.

Future Directions

Although the current study expanded upon Murdock and colleagues' (2016) work by investigating a multifaceted, instead of a narrowly focused, construct of compulsive cellphone use, future research should investigate this construct in even greater depth. For instance, recent studies have identified specific cellphone-related psychological processes associated with problematic health and behavioral outcomes (O'Connor et al., 2013). Furthermore, different mental health implications have been revealed for cellphone use that is motivated by escaping from boredom versus avoiding emotionally activating situations (Panova & Lleras, 2016). It is likely that associations between compulsive cellphone use and sleep-related functioning differ across developmental periods, so future research should examine both younger and older samples. A more nuanced investigation of cognitions, behaviors, and emotions involved in compulsive cellphone use may be fruitful for the creation of empirically based sleep-related interventions.

Sex-specific patterns in cellphone use and sleep were explored on only a superficial basis in the current study. Females were found to have significantly higher levels of compulsive cellphone use than males in Sample 1, and follow-up analyses revealed that nighttime notifications and compulsive cellphone use were significantly positively associated with global sleep problems for females but not for males. Unfortunately, the interpretation of these results is complicated by the extreme overrepresentation of females in Sample 1, and the lack of statistical power to detect significant effects in the male subsample. Although no significant sex differences in compulsive cellphone use were found in Sample 2, or in compulsion to respond to nighttime notifications in a previous college sample (Murdock et al., 2016), some previous studies have found higher levels of attachment to or dependence upon cellphones among female emerging adults when compared

with males (Augner & Hacker, 2012; Geser, 2006; Roberts et al., 2014).

Several factors should be investigated to illuminate possible sex differences in the association of cellphone use and sleep-related functioning. First, there is evidence that males and females experience different motivations for cellphone use (Grellhesl & Punyanunt-Carter, 2012) and cellphone activity choices (Kimbrough, Guadagno, Muscanell, & Dill, 2013; Roberts et al., 2014). These motivations and activities may vary in their propensity to compromise sleep, and might account for inconsistently observed sex-related differences in cellphone-sleep relationships. Also, college-aged females are predisposed to higher levels of anxiety and depression than males, and these disorders significantly impact sleep (Adams & Kisler, 2013). Future studies should assess individual difference variables such as personality characteristics or symptoms of psychopathology, along with measures of cellphone compulsivity. These factors may provide important context for understanding sex-specific trajectories of cellphone use and sleep.

Conclusions

The current study tested a theoretical model linking contextual aspects of cellphone use with sleep-related functioning in two samples of undergraduate students. The results of this study, along with findings from a recent study (Murdock et al., 2016), provided evidence from three samples that nighttime cellphone use and compulsive cellphone use are associated with dimensions of sleep-related functioning, whereas overall cellphone use is not consistently associated with sleep. Thus, it may be more productive for emerging adults' sleep promotion interventions to focus on timing and compulsivity of cellphone use instead of targeting overall reductions in cellphone use. Identifying the underlying cognitive, behavioral, and affective processes that influence compulsive cellphone use may be fruitful in creating behavior change.

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