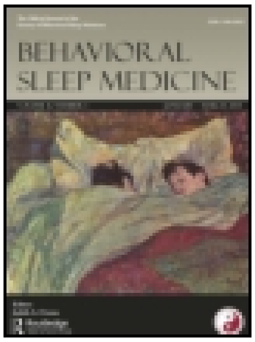

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Emerging Adults' Text Message Use and Sleep Characteristics: A Multimethod, Naturalistic Study

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Emerging adults use text messaging as a principal form of social communication, day and night, and this may compromise their sleep. In this study, a hypothetical model was tested linking daytime and nighttime text message use with multiple sleep characteristics. Subjective and objective measures of texting and sleep were utilized to assess 83 college students over a seven-day period during an academic term. Greater number of daily texts, awareness of nighttime cell phone notifications, and compulsion to check nighttime notifications were significantly associated with poorer subjective sleep quality. Awareness of nighttime notifications was significantly associated with higher self-reported global sleep problems and more sleep disruptions. Results suggest potential benefits of targeting nighttime texting habits in health promotion efforts for emerging adults.

Emerging adulthood, a developmental period extending from approximately ages 18–29 years (Arnett, 2014), is characterized by both ubiquitous cell phone use (Smith, 2015) and suboptimal quantity and quality of sleep (Wolfson, 2010). Text messaging is the most commonly used cell phone feature among young adults (Smith, 2015). College students report using their cell phones for 8–10 hr per day, with more than 90 min per day spent texting (Junco & Cotten, 2012; Roberts, Yaya, & Manolis, 2014). A nationwide poll in the United States found that 18–24-year-old smart phone owners text frequently (an average of 128 texts per day) and throughout the day and night; 37% of respondents endorsed receiving texts at 4 a.m. (Experion Marketing Services, 2013). Although few studies have examined connections between cell phone use and sleep characteristics in emerging adults, initial cross-sectional (Gradisar et al., 2013; Murdock, 2013), and longitudinal (Thomee, Harenstam, & Hagberg, 2011) findings suggest that heavier cell phone use can be associated with sleep disturbances. Sleep is vital to emerging adults' cognitive and emotional well-being as well as their safety (Radek & Kaprelian, 2013). Thus it is imperative for research to illuminate how cell phone use—and specifically, texting habits—may be linked with emerging adults' sleep qualities.

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NIGHTTIME CELL PHONE USE

Recently, the implications of technology use around bedtime have been examined. In several studies of adolescents in Europe and Asia, cell phone use before or after “lights out” has been associated with shorter sleep duration, later bedtime, longer onset latency, more perceived difficulty falling asleep, poorer sleep quality, more insomnia symptoms, higher levels of daytime sleepiness, and lower daytime ratings of feeling rested (Arora, Broglia, Neil, & Taheri, 2014; Cain & Gradisar, 2010; Lemola, Perkinson-Gloor, Brand, Dewald-Kaufmann, & Grob, 2015; Munezawa et al., 2011; Pieters et al., 2014). However, domains of sleep that were measured, as well as sleep characteristics that were found to be significantly associated with bedtime cell phone use, varied across studies (Hale & Guan, 2015).

A recent study found that among college students, greater nighttime cell phone use was significantly associated with more self-reported sleep problems (Li, Lepp, & Barkley, 2015). However, such associations between nighttime cell phone use and sleep rarely have been examined in emerging adults, and results have been inconsistent with respect to affected domains of sleep. In a nationwide sample from the United States, 67% of young adults used their cell phone in the bedroom in the hour before bed, which was associated with greater difficulty falling asleep and with less refreshing sleep, but not with later bedtimes (Gradisar et al., 2013). In a sample of Norwegian college students, cell phone use in bed was positively associated with insomnia symptoms, but was not significantly associated with daytime sleepiness (Fossum, Nordnes, Storemark, Bjorvatn, & Pallesen, 2014).

Several factors may have contributed to these inconsistencies in the literature on nighttime cell phone use. First, studies have been conducted in a variety of cultural settings with participants across a range of developmental periods, and these contextual factors may affect the implications of cell phone use for sleep. Cell phone use variables have been operationalized and measured inconsistently across studies (Hale & Guan, 2015), in part because adolescents’ and emerging adults’ technology habits have changed rapidly during the past decade. Thus, both patterns of cell phone use and their association with sleep problems may not generalize across time. These factors have made it difficult to draw clear conclusions regarding associations between nighttime cell phone use and sleep.

COMPULSIVE TENDENCIES IN CELL PHONE USE

The reinforcing properties of text messaging, such as the perpetual access to social connection that it affords, may make emerging adults prone to developing compulsive or addictive texting habits (Roberts et al., 2014; Sultan, 2014). In a sample of U.S. college students, 10–20% endorsed cell phone use with addictive or compulsive features (Smetaniuk, 2014). These tendencies can be associated with compromises in health and well-being. A recent study found that cell phone involvement, a construct encompassing addictive features of cell phone use such as withdrawal, loss of control, and interpersonal conflict, was associated with higher levels of depression and stress in a predominantly young adult sample, while overall frequency of use was not related to these aspects of well-being (Harwood, Dooley, Scott, & Joiner, 2014). It appears that only one study has examined associations between compulsive qualities of cell phone use and emerging adults’ sleep characteristics. In a sample of Spanish undergraduates, Jenaro, Flores, Gómez-Vela, González-Gil, and Caballo (2007) found that cell phone overuse, a construct designed to parallel pathological gambling, was associated with insomnia symptoms, but not with sleep duration. To date, no studies appear to have investigated compulsive cell phone use symptoms that occur during sleeping hours.

THE CURRENT STUDY

The current study investigated associations among emerging adults' text messaging frequency, awareness of nighttime cell phone notifications, compulsion to check nighttime notifications, and naturally occurring sleep characteristics across a seven-day period during an academic term. The first aim of this study was to explore bivariate correlations between the three indicators of text message use and an array of sleep characteristics measured through multiple methods including self-report questionnaires, a sleep diary, and actigraphy.

The second aim of this study was to test the unique variance in sleep accounted for by each of the three aspects of text message use. A set of hypothetical models was tested with sleep characteristics that were significantly correlated with texting variables in initial analyses. Given previous findings that more frequent texting can set the stage for poor sleep (Murdock, 2013), it was hypothesized that a higher average number of daily text messages would be associated with poorer sleep. It was expected that greater awareness of nighttime notifications would be associated with poorer sleep over and above the variance accounted for by the number of daily texts. Finally, it was hypothesized that beyond the variance explained by daily texts and nighttime notifications, higher levels of compulsion to check nighttime notifications would be associated with poorer sleep.

METHOD

Participants

Participants included 83 undergraduate students (48 female) enrolled at a southeastern liberal arts college. Students' ages ranged from 18 to 22 years (mean age = 20.54, *SD* = 1.22). Two percent of participants was of Hispanic origin, and race was as follows: 87% White, 2% Black or African American, 10% Asian, and 1% Hawaiian or Pacific Islander. The sample was comprised of 24% first year students, 16% sophomores, 19% juniors, and 40% seniors.

Procedure

Data were collected during the 2013–2014 academic year. Participants were recruited through fliers, e-mail notices, word of mouth, and sign-up sheets in university classes. Participants corresponded with research assistants via e-mail to schedule two assessment appointments separated by one week.

Upon arriving at the laboratory for Assessment One, participants were given an informed consent form approved by the university's institutional review board. They completed a 20–30-min online survey during which a research assistant was available to answer questions. Participants were fitted with an Actiwatch-2 wristband (Philips Respironics, Bend, OR) and instructed to wear the wristband continuously for seven days and nights, removing it only for activities that could damage the device (e.g., contact sports, swimming). They were asked to press the event marker button at the point they started trying to get to sleep each night and at the point they awoke each morning. Participants were also provided with a sleep diary and instructed to complete daily morning and nighttime entries for the next week. Reminder e-mail messages were sent for all assessment appointments and periodically during the week to prompt for sleep diary completion.

The Assessment Two appointment was scheduled one week after Assessment One. Participants turned in the Actiwatch 2 wristband and the sleep diary, completed another 20–30-min online survey, and received $25 for completing the study.

Measures

Participants self-reported their gender and age, and for purposes of descriptive analyses, their class rank, ethnicity, and race.

Average Number of Daily Texts

In Assessments One and Two, participants were asked to use the text record on their cell phone to count the number of text messages they had sent and received during the previous 24-hr period. Research assistants were available to instruct and assist with this task. The mean of these objective text counts was calculated to create the average number of daily texts variable.

Nighttime Cell Phone Notifications

Four items were developed for this study to assess the frequency of cell phone notifications received at night: (a) During an average week, on how many nights do you hear or see cell phone notifications while you are trying to get to sleep? (b) During an average week, on how many nights do you respond to cell phone 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 six-point scale ranging from “zero nights; never awakened” to “five or more times.” Internal consistency of these four items was acceptable ($\alpha = .74$). In order to standardize response scales, items were *z*-scored and summed to create a nighttime cell phone notifications variable.

Compulsion to Check Nighttime Notifications

Participants’ sense of psychological pressure regarding nighttime cell phone use was assessed with one item: “How strongly do you feel compelled to check cell phone notifications at night?” Participants responded on a five-point scale ranging from 1 (not at all) to 5 (very).

Questionnaire-Measured Sleep Characteristics

Global sleep problems were assessed with the 22-item Pittsburgh Sleep 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 total score, with higher scores indicating more troubled sleep.

Daytime sleepiness was assessed with a modified version of the Epworth Sleepiness Scale for Children (ESS; Johns, 1991). Some items were modified from the original measure 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 four-point scale ranging from 0 ("would never feel sleepy or doze off") to 3 ("high chance of feeling sleepy or dozing off"). This measure had good internal consistency in the current sample (α = .85).

Sleep Diary-Measured Sleep Characteristics

Participants completed sleep diary entries each night before going to sleep and each morning upon awakening. In each morning entry, participants circled non–cell-phone-related factors that disrupted their previous night's sleep from a checklist of eight common sleep-disrupting factors in college life: roommate/s; noise; too hot or cold; had to go to the bathroom; emotional upset or stress; insomnia; too much caffeine; and too much alcohol. Participants could also circle and describe an "other" factor. The *number of sleep disruptions* was summed for each night. Each morning, participants also rated their *subjective sleep quality* for the previous night by responding to the prompt, "What was the quality of your sleep last night?" on a seven-point scale ranging from 1 (very poor) to 7 (very good). For data analysis, average scores of sleep disruptions and subjective sleep quality were calculated across the seven nights of study participation.

Morning entries also included self-reports of the time the participant started trying to get to sleep and how many minutes it took to fall asleep the night before, and the time of morning awakening. This information was utilized in the coding and verification of actigraphy data.

Actigraphy-Measured Sleep Characteristics

Participants wore Actiwatch-2 wristbands (Philips Respironics, Bend, OR) for a seven-day period. Wristbands contain an accelerometer that provides continuous motion data used to code sleep characteristics. They also contain an ambient light sensor to aid in establishing when lighting sources are turned on or off in reference to a sleep period. The Actiware 6.0 software program was utilized to manage and score actigraphy data. Wristbands were configured to collect data in 60-s epochs. The wake threshold (i.e., activity level below which an epoch is scored as sleep) was set at the default level of 40, or medium sensitivity. This software program uses an algorithm to automatically set sleep intervals based on 10 consecutive min of immobility at sleep start time and wake time.

Once automated intervals were set, each interval for each subject was examined by the first author to confirm convergence of the automatically generated intervals with four points of data: (a) sleep start and wake times entered by participants using the event marker button on the wristband; (b) sleep diary reports of bedtime and wake time; (c) ambient light level; and (d) sleep diary report of sedentary activities in the hour before bed (that may have triggered automated miscoding as the onset of a sleep episode). If an automatically generated interval was not consistent with the majority of these data points, the interval was manually corrected.

Average sleep statistics were automatically generated by the actigraphy software for sleep intervals across the seven nights of the study. *Average sleep duration* reflects the average number of minutes elapsed between the start and end of sleep intervals. *Wake after sleep onset* reflects the average number of minutes scored as being awake during sleep intervals. *Sleep* o*nset latency* reflects the average number of minutes between the start of rest intervals and the start of sleep intervals (i.e., how long it took to fall asleep).

RESULTS

Preliminary Analyses

Psychometric properties of primary study measures are presented in Table 1. Bivariate correlations among primary study measures are presented in Table 2. Age was not significantly correlated with any primary study variable, and was not included in any further analyses.

Examination of bivariate conclusions revealed three sleep variables that were not significantly correlated with any aspect of texting: average sleep duration, wake after sleep onset, and sleep onset latency. Therefore, these actigraphy-measured variables were not tested in regression models.

Independent samples *t*-tests were conducted to examine gender differences in variables utilized in hypothesis testing (i.e., average number of daily texts; nighttime cell phone notifications; compulsion to check nighttime notifications; global sleep problems; number of sleep disruptions; daytime sleepiness; and subjective sleep quality). Two significant gender differences emerged among these variables. Women reported a significantly higher average number of daily texts (n = 48, M = 144.81, SD = 107.85) when compared to men (n = 35, M = 95.59, SD = 96.39), $t(81) = 2.15$, $p = .04$. Women also reported significantly higher levels of nighttime cell phone notifications (n = 48, M = 8.83, SD = 4.88) when compared to men (n = 34, M = 6.56, SD = 2.96), $t(79) = 2.62$, $p = .01$.

TABLE 1
Psychometric Properties of Primary Study Measures

	Measure	*M*	*SD*	*Range*	*α*
Average number of daily texts	Average of two 24-hr counts from cell phone	124.05	105.44	1–482	
Nighttime cell phone notifications	4 self-report items	7.89	4.32	3–22	.74
Compulsion to check nighttime notifications	1 self-report item	2.29	1.02	1–5	
Global sleep problems	18-item questionnaire	5.80	2.39	1–12	
Daytime sleepiness	12-item questionnaire	26.34	6.09	13–42	.83
Average sleep duration[1]	7-day actigraphy	440.97	57.26	270–599	
Wake after sleep onset[1]	7-day actigraphy	48.48	17.11	20–101	
Sleep onset latency[1]	7-day actigraphy	8.43	7.02	0–33	
Number of sleep disruptions	7-day sleep diary	0.90	0.51	0–2.43	
Subjective sleep quality	7-day sleep diary	4.71	0.87	3–7	

Note. [1]Reported in minutes.

TABLE 2
Intercorrelations Among Texting and Sleep Variables[1]

	1.	*2.*	*3.*	*4.*	*5.*	*6.*	*7.*	*8.*	*9.*	*10.*
1. Average number of daily texts	—									
2. Nighttime cell phone notifications	.34**	—								
3. Compulsion to check nighttime notifications	.13	.46***	—							
4. Global sleep problems	.10	.40***	.32**	—						
5. Daytime sleepiness	−.04	.13	.23*	.42***	—					
6. Average sleep duration	−.04	.10	.02	.05	.21	—				
7. Wake after sleep onset	−.06	.02	.01	.02	.03	.41***	—			
8. Onset latency	−.13	.06	.08	.04	.29**	.17	.15	—		
9. Number of sleep disruptions[2]	.05	.41***	.21	.37**	.10	.34**	.23*	.19	—	
10. Subjective sleep quality	−.22*	−.28*	−.47***	−.37**	−.16	−.16	−.19	−.15	−.29**	—

Note. $*p < .05$, $**p < .01$, $***p < .001$. [1]Due to missing data, *n*s for individual correlations range from 81–83. [2]Disruptions exclusive of cell phone notifications.

Hierarchical Regression Models

Hierarchical multiple regression analyses were conducted with variables entered in the following blocks: (a) average number of daily texts; (b) nighttime cell phone notifications; and (c) compulsion to check nighttime notifications. Four regression analyses were conducted to examine criterion variables of global sleep problems, number of sleep disruptions, daytime sleepiness, and subjective sleep quality. Two subjects were missing data for one or more primary study variables, and these cases were excluded from regression analyses. Tests for multicollinearity indicated low levels for average number of daily texts (VIF = 1.27), nighttime cell phone notifications (VIF = 1.02), and compulsion to check notifications (VIF = 1.13).

Regression results are presented in Table 3. In the first model predicting global sleep problems, average number of daily texts was not a significant predictor in the first block, but nighttime cell phone notifications was a significant predictor in the second block ($\beta = .41$, $t = 3.74$, $p < .001$), accounting for 15% of unique variance. In the third block, compulsion to check nighttime notifications accounted for 2% of unique variance but was not a significant predictor. This model predicted 18% of the variance in global sleep problems.

Similar results were found in the second model predicting sleep disruptions. Average number of daily texts was not significant, but nighttime cell phone notifications was a significant predictor ($\beta = .44$, $t = 4.09$, $p < .001$), accounting for 18% of unique variance. Compulsion to check nighttime notifications was not a significant predictor. This model predicted 18% of the variance in sleep disruptions.

In the third model predicting daytime sleepiness, none of the predictor variables was statistically significant. The overall model accounted for 6% of the variance in the daytime sleepiness.

In the fourth model predicting subjective sleep quality, average number of daily texts was a significant predictor in the first block ($\beta = -.24$, $t = 2.20$, $p = .03$), accounting for 6% of the

TABLE 3
Hierarchical Multiple Regression Analyses Predicting Sleep Characteristics (N = 81)

Predictors	R^2	ΔR^2	*ß*	*t*	*p*
Criterion Variable: Global Sleep Problems					
Block 1:	.01	.01			
Average number of daily texts			.10	0.89	.38
Block 2:	.16	.15***			
Average number of daily texts			−.04	0.35	.73
Nighttime cell phone notifications			.41	3.74	.00
Block 3:	.18	.02			
Average number of daily texts			−.03	0.30	.76
Nighttime cell phone notifications			.32	2.70	.01
Compulsion to check nighttime notifications			.18	1.52	.13
Criterion Variable: Sleep Disruptions					
Block 1:	.00	.00			
Average number of daily texts			.06	0.53	.60
Block 2:	.18	.18***			
Average number of daily texts			−.09	0.82	.41
Nighttime cell phone notifications			.44	4.09	.00
Block 3:	.18	.00			
Average number of daily texts			−−.09	0.81	.42
Nighttime cell phone notifications			.43	3.54	.00
Compulsion to check nighttime notifications			.03	0.23	.82
Criterion Variable: Daytime Sleepiness					
Block 1:	.00	.00			
Average number of daily texts			−.04	0.40	.69
Block 2:	.03	.03			
Average number of daily texts			−.10	.84	.40
Nighttime cell phone notifications			.16	1.39	.17
Block 3:	.06	.03			
Average number of daily texts			−.09	.80	.43
Nighttime cell phone notifications			.07	0.50	.62
Compulsion to check nighttime notifications			.21	1.69	.10
Criterion Variable: Subjective Sleep Quality					
Block 1:	.06	.06*			
Average number of daily texts			−.24	2.20	.03
Block 2:	.10	.04*			
Average number of daily texts			−.16	1.45	.15
Nighttime cell phone notifications			−.23	2.00	.05
Block 3:	.25	.15***			
Average number of daily texts			−.18	1.70	.09
Nighttime cell phone notifications			−.02	0.17	.86
Compulsion to check nighttime notifications			−.44	3.99	.00

Note. $^*p \leq .05$. $^{**}p < .01$. $^{***}p < .001$.

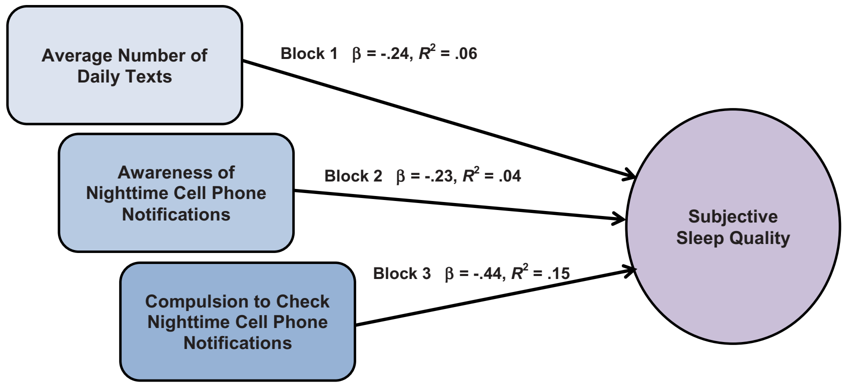

FIGURE 1 Graphic model of hierarchical multiple regression predicting subjective sleep quality

variance. In the second block, nighttime cell phone notifications was significantly associated with subjective sleep quality (β = -.23, t = 2.00, p = .05), accounting for an additional 4% of the variance. In the third block, compulsion to check nighttime notifications was a significant predictor (β = -.44, t = 3.99, p < .001), accounting for a unique 15% of variance. This model predicted a total of 25% of the variance in sleep quality. A graphic model of these results is presented in Figure 1.

Using the Bonferroni correction for multiple comparisons, nighttime cell phone notifications remained a statistically significant predictor of global sleep problems and sleep disruptions, and compulsion to check nighttime notifications remained a statistically significant predictor of subjective sleep quality.

In light of the significant gender differences revealed in average number of daily texts and nighttime cell phone notifications, regression models were tested on an exploratory basis separately for females (n = 47) and males (n = 33). The model predicting global sleep problems accounted for 20% of the variance for women and 24% of the variance for men. Nighttime notifications was the only significant predictor for women (β = .48, t = 3.27, p = .002) and for men (β = .37, t = 2.25, p = .03). The model predicting number of sleep disruptions accounted for 21% of the variance for women and 12% of the variance for men. Nighttime notifications was the only significant predictor, for women only (β = .48, t = 3.24, p = .002). The model predicting daytime sleepiness accounted for 8% of the variance for women and 14% of the variance for men. Nighttime notifications was the only significant predictor, for men only (β = .36, t = 2.15, p = .04). Finally, for women the regression model predicting subjective sleep quality accounted for 37% of the variance with compulsion to check nighttime notifications emerging as a significant predictor (β = -.55, t = 4.10, p < .001). In contrast, for men this model accounted for only 13% of the variance in subjective sleep quality, with no statistically significant individual predictors.

DISCUSSION

The first aim of this study, to explore bivariate correlations among text messaging and sleep variables, yielded findings that may inform the design and methodology of future studies investigating these constructs. Significant correlations in the expected direction emerged between some objective and subjective measures of sleep: actigraphy-measured wake after sleep onset was positively correlated with sleep-diary–measured number of sleep disruptions, and actigraphy-measured sleep onset latency was positively correlated with questionnaire-measured daytime sleepiness. Surprisingly, actigraphy-measured wake after sleep onset was not correlated with the texting variable of nighttime cell phone notifications, which specifically incorporates notifications that disrupt sleep. Inconsistencies in the degree of concordance between actigraphy measures and subjective measures of sleep characteristics have been regularly reported in the literature (Kawada, 2008; O'Donnell et al., 2009; Wilson, Fung, Walker, & Barnes, 2013). Sadeh (2011) has suggested that actigraphy measures tend to have particularly poor correspondence with self-reported aspects of sleep quality such as night wakings, and has raised concerns about the validity of actigraphy methods to sensitively assess wakefulness during periods of sleep across different devices, populations, and conditions. As in previous research, it is unclear whether in the current study, the pattern of correlations among objective and subjective measures of sleep characteristics should signal confidence in, versus concerns about, the validity of measures (Sadeh, 2011). In fact, it is likely that subjective and objective measures provide different and equally useful information about sleep experiences. In comparison to objective measures of sleep characteristics, subjective measures may capture perceptual aspects of sleep that are more sensitively aligned with psychologically salient behaviors and experiences.

Although texting variables were not significantly correlated with actigraphy-measured sleep variables in this study, hypothesis testing revealed consistent associations of texting variables with sleep characteristics reported via self-report questionnaires and daily sleep diary entries. The objective report of average number of daily texts emerged as a significant predictor of one aspect of sleep: subjective sleep quality. Taken together with previous evidence that emerging adults' self-reported average number of daily texts was associated with self-reported sleep problems (Murdock, 2013), this supports the notion that higher levels of overall texting frequency may be both directly and indirectly associated with compromises in emerging adults' sleep. In this study, awareness of nighttime cell phone notifications accounted for significant unique variance in the prediction of global sleep problems, number of sleep disruptions, and subjective sleep quality. This is consistent with several previous studies demonstrating associations of nighttime cell phone use with similar self-reported aspects of sleep among emerging adults (Li et al., 2015) and adolescents (Fossum et al., 2014; Lemola et al., 2015; Munezawa et al., 2011; Pieters et al., 2014). Finally, in what appears to be one of the first investigations of compulsive cell phone use and sleep in emerging adults, compulsion to check nighttime cell phone notifications was significantly associated with subjective sleep quality in this sample, even after texting frequency and nighttime notifications were taken into account. Consistent findings were very recently reported in a study of college students in the United States, in which poor sleepers reported higher levels of texting dependence when compared to good sleepers (Ferraro, Holfeld, Frankl, Frye, & Halvorson, 2015).

The most robust support for the hypotheses in this study—a large effect—was found in the model predicting participants' average daily ratings of sleep quality. The clinical importance of perceived sleep quality is highlighted by evidence linking it with other aspects of health and well-being. For instance, Lemola, Ledermann, and Friedman (2013) found that although actigraphy-measured sleep characteristics were not consistently related to subjective well-being, one significant association of actigraphy-measured sleep duration variability with subjective well-being was partially mediated through poor subjective sleep quality. In other words, perceptions of sleep quality partially bridged the gap between more psychologically distal, objective aspects of sleep and self-appraisals of well-being. Thus, the meaning one makes of sleep experiences may be as or more relevant for health and well-being outcomes than objective qualities of the sleep itself. This may help to explain inconsistent findings in the literature on cell phone use and sleep in which a variety of objective and subjective sleep measures have been utilized. Given Li and colleagues' (2015) evidence that self-reported sleep problems mediated the association between college students' nighttime cell phone use and subjective well-being, it is clear that subjective sleep quality should be investigated further as a potential pathway through which cell phone use may indirectly influence psychological functioning.

Although mechanisms for the association between texting and sleep characteristics were not explored in this study, it could be postulated that awareness of and compulsion to check nighttime notifications involve physiological, cognitive, and affective activation that is salient enough to influence global perceptions of sleep experiences. In future research it would be useful to explore if cell phone–related sleep disruptions are, to a greater degree than other types of sleep-disrupting factors, associated with subjective ratings of sleep quality. Furthermore, subjective sleep quality should be examined as a potential mediator of the associations of cell phone–related (versus non–cell-phone-related) sleep disruptions with indicators of health and well-being.

Strengths and Limitations

This study addresses a timely issue of increasing interest to educators, families, and public health professionals. Methodological strengths of the study include the assessment of naturally occurring sleep patterns across a full week of undergraduate students' academic lives and the use of multiple methods of measurement, including both subjective and objective instruments. Common method variance was minimized in regression models by using a combination of measurement tools (e.g., objective report of number of daily texts; one-time questionnaire self-reports of typical nighttime cell phone notifications and compulsion to check notifications; daily sleep diary reports of subjective sleep quality).

Three important caveats should be considered in the interpretation of these findings. First, although the hypothetical model in this study presumes that texting factors contribute to compromises in sleep, the cross-sectional design does not allow a determination of the direction of effects. It is unclear if compromises in sleep *result* from nighttime texting or *predispose* one to engage in text message use in bed, a question that has been raised with respect to similar cross-sectional results linking cell phone use in bed with insomnia symptoms and late chronotype in a sample of Norwegian young adults (Fossum et al., 2014). In previous prospective studies, cell phone use was associated with subsequent increases in tiredness (Van den Bulck, 2007) and difficulty falling asleep (Thomée, Eklöf, Gustafsson, Nilsson, & Hagberg, 2007). However, recent longitudinal findings have indicated 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 among Canadian college students (Tavernier & Willoughby, 2014). Further research is needed to illuminate longitudinal and bidirectional associations between characteristics of cell phone use and sleep patterns.

In the current study, female students reported significantly higher rates of daily texting and nighttime cell phone notifications than male students, and no significant gender differences were found in compulsion to check nighttime notifications. Previous studies of emerging adults have yielded inconsistent findings regarding gender differences in cell phone use, with some indicating greater use or compulsive use among women compared to men (Augner & Hacker, 2012; Fossum et al., 2014; Murdock, Gorman, & Robbins, 2015; Roberts et al., 2014) and others finding no significant gender differences (Adams & Kisler, 2013; Murdock, 2013). Regression models were tested separately for females and males in the current study, revealing potentially important gender differences in the nature and strength of associations between texting and sleep characteristics. Unfortunately, low statistical power in gender-specific regression analyses limits the confidence with which these findings can be interpreted. Future research should not only compare base rates of cell phone–related behaviors across genders, but also investigate if gender-specific hypothetical models are necessary to clarify associations of cell phone use with sleep and well-being.

Finally, conclusions from the current study are limited by the demographic homogeneity of the sample. Given that socioeconomic status and race have been empirically linked to sleep patterns (Mezick et al., 2008), it is imperative for future studies to examine associations of cell phone use and sleep characteristics within a more diverse sample of emerging adults.

CONCLUSIONS

This study has illuminated links between text message use and compromises in sleep within college students' naturally occurring sleep patterns. It is notable that texting variables were significantly related only to subjective aspects of sleep, but not objective actigraphy-measured characteristics. The predictive model, including average number of daily texts, awareness of nighttime notifications, and compulsion to check nighttime notifications, accounted for significant variance in subjective assessments of sleep problems, disruptions, and quality, with medium to large effect sizes. These findings suggest a potentially clinically significant association between texting and sleep, and this could inform emerging adults' health-promoting sleep hygiene choices. For instance, if cell phones are turned off and kept out of arm's reach, if only during sleeping hours, emerging adults may find that the lack of nighttime notifications and stimuli for compulsive responding minimizes their sleep problems and improves sleep quality.

In studies conducted across the globe, health-related correlates of cell phone use have been identified, including obesity (Chahal, Fung, Kuhle, & Veugelers, 2012), somatic complaints (Al-Klaiwi & Meo, 2004; Jenaro et al., 2007), depression (Harwood et al., 2014), smoking and alcohol use (Leena, Tomi, & Arja, 2005), and risky driving (O'Connor et al., 2013). This study contributes to the increasing evidence that texting use should receive further attention in both research and health promotion programs for emerging adults.

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REFERENCES

Adams, S. K., & Kisler, T. S. (2013). Sleep quality as a mediator between technology-related sleep quality, depression, and anxiety. *Cyberpsychology, Behavior, and Social Networking*, *16*(1), 25–30. http://doi.org/10.1089/cyber.2012.0157

Al-Khlaiwi, T., & Meo, S. (2004). Association of mobile phone radiation with fatigue, headache, dizziness, tension and sleep disturbance in Saudi population. *Saudi Medical Journal*, *25*(6), 732–736.

Arnett, J. J. (2014). Presidential address: The emergence of emerging adulthood: A personal history. *Emerging Adulthood*, *2*(3), 155–162. http://doi.org/10.1177/2167696814541096

Arora, T., Broglia, E., Neil, G., & Taheri, S. (2014). Associations between specific technologies and adolescent sleep quantity, sleep quality, and parasomnias. *Sleep Medicine*, *15*(2), 240–247. http://doi.org/10.1016/j.sleep.2013.08.799

Augner, C., & Hacker, G. W. (2012). Associations between problematic mobile phone use and psychological parameters in young adults. *International Journal of Public Health*, *57*(2), 437–441. http://doi.org/10.1007/s00038-011-0234-z

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R.,…Kupfer, D. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193–213.

Cain, N., & Gradisar, M. (2010). Electronic media use and sleep in school-aged children and adolescents: A review. *Sleep Medicine*, *11*(8), 735–742.

Chahal, H., Fung, C., Kuhle, S., & Veuglelers, P. J. (2012). Availability and night-time use of electronic entertainment and communication devices are associated with short sleep duration and obesity among Canadian children. *Pediatric Obesity*, *8*, 42–51. http://doi.org/10.1111/j2047-6310.2012.00085.x

Experion Marketing Services. (2013). *The 2013 digital marker*. Retrieved from http://www.experian.com/assets/marketing-services/reports/2013-digital-marketer-download.pdf?SP_MID=768&SP_RID=1097370

Ferraro, F. R., Holfeld, B., Frankl, S., Frye, N., & Halvorson, N. (2015). Texting/iPod dependence, executive function and sleep quality in college students. *Computers in Human Behavior*, *49*, 44–49. http://doi.org/10.1016/j.chb.2015.02.043

Fossum, I. N., Nordnes, L. T., Storemark, S. S., Bjorvatn, B., & Pallesen, S. (2014). The association between use of electronic media in bed before going to sleep and insomnia symptoms, daytime sleepiness, morningness, and chronotype. *Behavioral Sleep Medicine*, *12*(5), 343–357. http://doi.org/10.1080/15402002.2013.819468

Gradisar, M., Wolfson, A. R., Harvey, A. G., Hale, L., Rosenberg, R., & Czeisler, C. A. (2013). The sleep and technology use of Americans: Findings from the National Sleep Foundation's 2011 Sleep in America poll. *Journal of Clinical Sleep Medicine*, *9*(12), 1291–1299. http://doi.org/10.5664/jcsm.3272

Hale, L., & Guan, S. (2015). Screen time and sleep among school-aged children and adolescents: A systematic literature review. *Sleep Medicine Reviews*, *21*, 50–58. http://doi.org/10.1016/j.smrv.2014.07.007

Harwood, J., Dooley, J. J., Scott, A. J., & Joiner, R. (2014). Constantly connected: The effects of smart-devices on mental health. *Computers in Human Behavior*, *34*, 267–272. http://doi.org/10.1016/j.chb.2014.02.006

Jenaro, C., Flores, N., Gómez-Vela, M., González-Gil, F., & Caballo, C. (2007). Problematic internet and cell-phone use: Psychological behavioral, and health correlates. *Addiction Research & Theory*, *15*(3), 309–320. http://doi.org/10.1080/16066350701350247

Johns, M. W. (1991). A new method for measuring daytime sleepiness: The Epworth Sleepiness Scale. *Sleep: Journal of Sleep Research & Sleep Medicine*, *14*(6), 540–545.

Junco, R., & Cotten, S. R. (2012). No A 4 U: The relationship between multitasking and academic performance. *Computers & Education*, *59*(2), 505–514. http://doi.org/10.1016/j.compedu.2011.12.023

Kawada, T. (2008). Agreement rates for sleep/wake judgments obtained via accelerometer and sleep diary: A comparison. *Behavior Research Methods*, *40*(4), 1026–1029. http://doi.org/10.3758/BRM.40.4.1026

Leena, K., Tomi, L., & Arja, R. (2005). Intensity of mobile phone use and health compromising behaviours: How is information and communication technology connected to health-related lifestyle in adolescence? *Journal of Adolescence*, *28*(1), 35–47. http://doi.org/10.1016/j.adolescence.2004.05.004

Lemola, S., Ledermann, T., & Friedman, E. M. (2013). Variability of sleep duration is related to subjective sleep quality and subjective well-being: An actigraphy study. *PLoS ONE*, *8*(8).

Lemola, S., Perkinson-Gloor, N., Brand, S., Dewald-Kaufmann, J. F., & Grob, A. (2015). Adolescents' electronic media use at night, sleep disturbance, and depressive symptoms in the smartphone age. *Journal of Youth and Adolescence*, *44*(2), 405–418. http://doi.org/10.1007/s10964-014-0176-x

Li, J., Lepp, A., & Barkley, J. (2015). Locus of control and cell phone use: Implications for sleep quality, academic performance, and subjective well-being. *Computers in Human Behavior*, *52*, 450–457. http://doi.org\10.1016.j.chb.2015.06.021

Mezick, E. J., Matthews, K. A., Hall, M., Strollo Jr., P. J., Buysse, D. J., Kamarck, T. W.,. . . Reis, S. E. (2008). Influence of race and socioeconomic status on sleep: Pittsburgh SleepSCORE Project. *Psychosomatic Medicine*, *70*(4), 410–416. http://doi.org/10.1097/PSY.0b013e31816fdf21

Munezawa, T., Kaneita, Y., Osaki, Y., Kanda, H., Minowa, M., Suzuki, K.,. . . Ohida, T. (2011). The association between use of mobile phones after lights out and sleep disturbances among Japanese adolescents: A nationwide cross-sectional survey. *Sleep: Journal of Sleep and Sleep Disorders Research*, *34*(8), 1013–1020.

Murdock, K. K. (2013). Texting while stressed: Implications for students' burnout, sleep, and well-being. *Psychology of Popular Media Culture*, *2*(4), 207–221. http://doi.org/10.1037/ppm0000012

Murdock, K. K., Gorman, S., & Robbins, M. (2015). Co-rumination via cellphone moderates the association of perceived interpersonal stress and psychosocial well-being in emerging adults. *Journal of Adolescence*, *38*, 27–37. http://doi.org/10.1016/j.adolescence.2014.10.010

O'Connor, S. S., Whitehill, J. M., King, K. M., Kernic, M. A., Boyle, L. N., Bresnahan, B. W.,. . . Ebel, B. E. (2013). Compulsive cell phone use and history of motor vehicle crash. *Journal of Adolescent Health*, *53*(4), 512–519. http://doi.org/10.1016/j.jadohealth.2013.05.015

O'Donnell, D., Silva, E. J., Münch, M., Ronda, J. M., Wang, W., & Duffy, J. F. (2009). Comparison of subjective and objective assessments of sleep in healthy older subjects without sleep complaints. *Journal of Sleep Research*, *18*(2), 254–263. http://doi.org/10.1111/j.1365-2869.2008.00719.x

Pieters, D., De Valck, E., Vandekerckhove, M., Pirrera, S., Wuyts, J., Exadaktylos, V.,. . . Cluydts, R. (2014). Effects of pre-sleep media use on sleep/wake patterns and daytime functioning among adolescents: The moderating role of parental control. *Behavioral Sleep Medicine*, *12*(6), 427–443. http://doi.org/10.1080/15402002.2012.694381

Radek, K. S., & Kaprelian, J. (2013). Emerging adult sleep quality: Health and academic performance factors of assessment. *Sleep Disorders and Therapy*, *2*(2). http://doi.org/10.4172/2167-0277.1000112

Roberts, J. A., Petnji Yaya, L. H., & Manolis, C. (2014). The invisible addiction: Cell-phone activities and addiction among male and female college students. *Journal of Behavioral Addictions*, *3*(4), 254–265. http://doi.org/10.1556/JBA.3.2014.015

Sadeh, A. (2011). The role and validity of actigraphy in sleep medicine: An update. *Sleep Medicine Reviews*, *15*(4), 259–267. http://doi.org/10.1016/j.smrv.2010.10.001

Smetaniuk, P. (2014). A preliminary investigation into the prevalence and prediction of problematic cell phone use. *Journal of Behavioral Addictions*, *3*(1), 41–53. http://doi.org/10.1556/JBA.3.2014.004

Smith, A. (2015, April 1). *U.S. smartphone use in 2015*. Retrieved from http://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015/

Sultan, A. J. (2014). Addiction to mobile text messaging applications is nothing to "lol" about. *Social Science Journal*, *51*(1), 57–69. http://doi.org/10.1016/j.soscij.2013.09.003

Tavernier, R., & Willoughby, T. (2014). Sleep problems: Predictor or outcome of media use among emerging adults at university? *Journal of Sleep Research*, *23*(4), 389–396. http://doi.org/10.1111/jsr.12132

Thomée, S., Eklöf, M., Gustafsson, E., Nilsson, R., & Hagberg, M. (2007). Prevalence of perceived stress, symptoms of depression and sleep disturbances in relation to information and communication technology (ICT) use among young adults: An explorative prospective study. *Computers in Human Behavior*, *23*(3), 1300–1321.

Thomee, S., Harenstam, A., & Hagberg, M. (2011). Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults: A prospective cohort study. *BMC Public Health*, *11*(1), 66.

Van den Bulck, J. (2007). Adolescent use of mobile phones for calling and for sending text messages after lights out: Results from a prospective cohort study with a one-year follow-up. *Sleep*, *30*(9), 1220–1223.

Wilson, D. L., Fung, A., Walker, S. P., & Barnes, M. (2013). Subjective reports versus objective measurement of sleep latency and sleep duration in pregnancy. *Behavioral Sleep Medicine*, *11*(3), 207–221. http://doi.org/10.1080/15402002.2012.670674

Wolfson, A. R. (2010). Adolescents and emerging adults' sleep patterns: New developments. *Journal of Adolescent Health*, *46*(2), 97–99.