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The Sleep and Technology Use of Americans: Findings from the National Sleep Foundation's 2011 Sleep in America Poll

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Study Objectives: To describe the technology use and sleep quality of Americans, and the unique association between technology use and sleep disturbances.

Methods: Interviews were conducted via random digit dialing (N = 750) or the Internet (N = 758). 1,508 Americans (13-64 years old, 50% males) matched to 2009 U.S. Census data provided complete interviews. The sample was further divided into adolescents (13-18 years, N = 171), young adults (19-29 years, N = 293), middle-aged adults (30-45 years, N = 469), and older adults (46-64 years, N = 565) to contrast different generations' technology use. Participants answered a 47-item semi-structured survey, including questions about their sleep habits, and the presence and use of technology in the hour before bed in the past 2 weeks.

Results: Nine of 10 Americans reported using a technological device in the hour before bed (e.g., TVs the most popular; 60%). However, those under 30 years of age were more likely to use cell phones (72% of adolescents, 67% of young adults) than those over 30 years (36% of middle-aged, and 16% of older adults). Young adults' sleep patterns were significantly later than other age groups on both weekdays and weekend nights. Unlike passive technological devices (e.g., TV, mp3 music players), the more interactive technological devices (i.e., computers/laptops, cell phones, video game consoles) used in the hour before bed, the more likely difficulties falling asleep ($\beta = 9.4$, $p < 0.0001$) and unrefreshing sleep ($\beta = 6.4$, $p < 0.04$) were reported.

Conclusions: Technology use near bedtime is extremely prevalent in the United States. Among a range of technologies, interactive technological devices are most strongly associated with sleep complaints.

Keywords: Sleep, sleep disturbances, technology, electronic media, interactive devices

Commentary: A commentary on this article appears in this issue on page 1301.

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SCIENTIFIC INVESTIGATIONS

The emergence of the computer chip and the rapid technological advances that ensued have enhanced industrialized societies' ability to work and play. Indeed, in the 1970s, technology was hoped to promote a 4-day work week by reducing the physical strain of labor, thus providing more time for leisure.[1] Personal computers (PCs) began to enter homes in the early 1980s, and ownership has increased steadily; nearly 8 of 10 Americans now own a PC.[2,3] Video game console ownership paralleled PC ownership in homes in the 1980s, and in 2011 approximately US$17.8 billion was spent on video game hardware.[4] In the mid-1990s, 2 of 10 Americans had personal access to the developing Internet.[3] Now, 7 of 10 Americans have access to the Internet in their homes.[3] However, it is the once-humble cell phone that is now ubiquitous worldwide. In 2011, there were 6 billion cell phone subscriptions worldwide—enough for 87% of the world's population.[5] These technological devices have become smaller and therefore more portable. One exception is that television screen dimensions have grown. However, "watching TV" may now be performed on smaller devices (e.g., cell phones) due to increased multi-functionality.

BRIEF SUMMARY

Current Knowledge/Study Rationale: To date, there has not been a large-scale survey across generations using comprehensive measures of sleep and technology use close to bedtime.

Study Impact: Americans' use of technology near sleep is highly prevalent, and related to sleep difficulties, especially in younger age groups (i.e., < 30 years of age).

For example, in addition to making phone calls, cell phones now allow the user to instant message, listen to music, send emails, play games, and surf the Internet. Furthermore, technological devices have become more affordable, thus allowing more users to access technology as we enter the second decade of the new millennium.

The affordability and portability of technology has seen these devices move into bedrooms. In the 2006 Sleep in America Poll, 97% of US teens had at least one technological device in their bedroom, with mp3 players being the most popular (90%) followed by TVs (57%), video games and cell phones (42%), and computers (28%) with Internet access (21%).[6]

Prevalence rates from other countries sometimes match those found in the USA. (e.g., 60% of Israeli adolescents have a TV in their bedroom; 60% have a computer in their bedroom).[7] More recent US data demonstrate that media presence in the bedroom has increased. For example, 33% of young people (8-18 years) now have Internet access in their bedroom.[8] For adults, 30% of Belgians had a TV in their bedroom and 25% had Internet access in their bedroom,[9] and these figures double for Korean adults.[10] Evening use of these devices in Japan have also ranged from 48% to 60%.[11] In terms of concern about sleep and health, it is not the mere presence of these devices in the bedroom, but more importantly, when, and the extent to which these devices are used. Despite longstanding recommendations that stimulating activities should be avoided when preparing for bed,[12] several studies have shown that technology use still occurs regularly before bed.[6,7,12-16] However, these studies have not comprehensively assessed the range of technological devices used in the bedroom in the hour before bed and their associations with sleep. Accordingly, the first aim of the present study is to describe the technology use of Americans in their bedrooms in the hour before bed using a national poll of adults. A second aim is to describe Americans' self-reported sleep habits and sleep quality. The third aim of the present study is to investigate associations between technology use and sleep.

Several mechanisms have been proposed for how evening technology use may affect sleep.[17,18] One of these mechanisms is that the use of stimulating technological devices may cause hyperarousal that interferes with healthy sleep initiation. Stimulating technological devices may include those devices with which the user is frequently interacting, such as video consoles, cell phones, and computers. Such interactions may impede the natural withdrawal of sympathetic nervous system activity necessary for sleep onset.[19-21] In contrast, other devices may involve "passive observation" and require little input from the user of the device (e.g., watching TV, listening to music). Therefore, we hypothesize that use of stimulating technological devices in the hour before bed will be associated with sleep problems (i.e., difficulty initiating sleep, unrefreshing sleep). Furthermore, difficulty maintaining sleep may occur from devices that wake individuals. Van den Bulck found that 10% to 20% of adolescents use their cell phone or are awakened by incoming calls/text messages after lights out.[22,23] Therefore, the effects of cell phones on maintaining sleep will also be investigated.

METHODS

Participants

The sample consisted of 1,508 participants, ages 13-64 years, who resided in the United States (50% males, 50% females). Of the total sample, 37% resided in the South, 23% in the West, 22% in the Midwest, and 17% in the Northeast. Over the previous month, 64% percent of the total sample was employed, 22% were enrolled as students, and 19% were neither (see footnote 1). Approximately half the sample was married (54%), a third were single (33%), and the remaining participants were either divorced (6%), in a de facto relationship (4%), separated (2%), or widowed (1%). The majority of Americans sampled were white/Caucasian (81%), followed by African American (7%) Asian (6%), Hispanic (4%) or American Indian (1%) (see footnote 2). Since one of the objectives of the study was to compare the sleep habits and technology use of Americans across different age groups, the sample was split into the categories of adolescents (13-18 years, N = 171, 11.3% of the total sample), young adults (19-29 years, N = 293, 19.4% of the sample), middle-aged adults (30-45 years, N = 469, 31.1% of the sample), and older adults (46-64 years, N = 575, 38.2% of the sample).

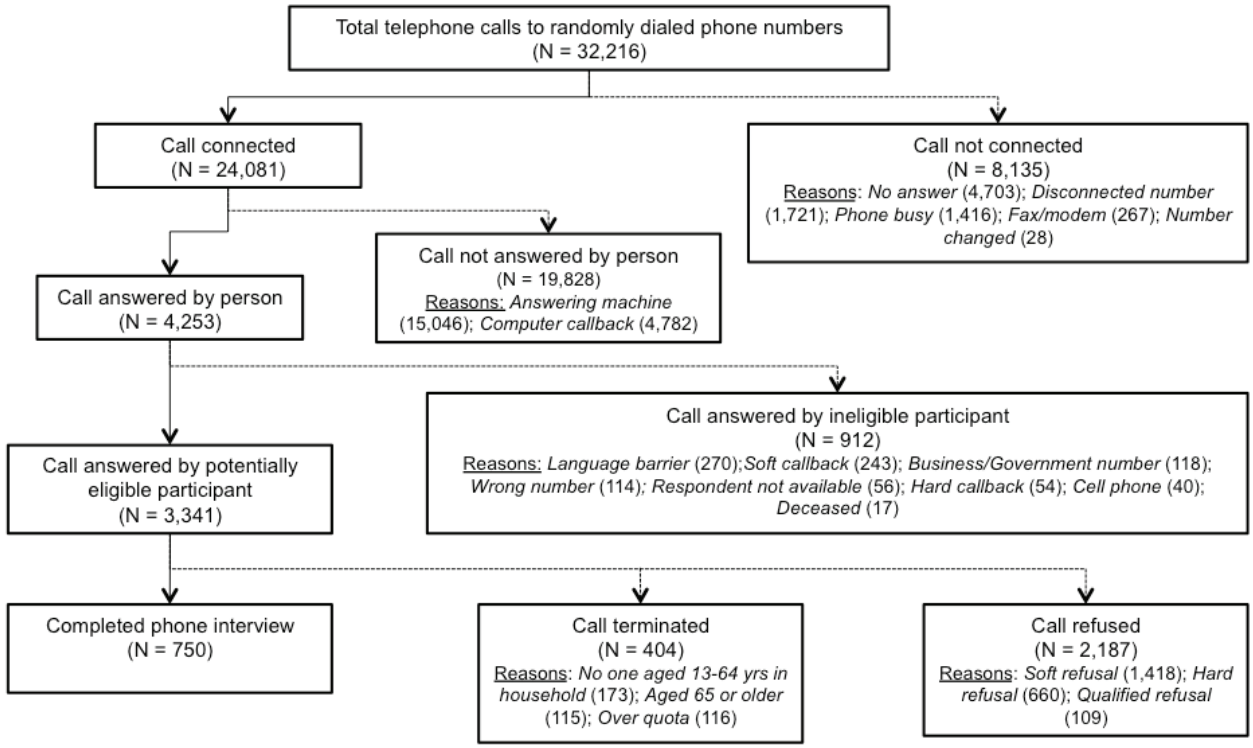
Approximately half the sample completed phone surveys (N = 750), and the remaining participants completed the survey on the web (N = 758). These multiple methods were performed because telephone sampling tends to over-represent older populations, and thus the web-sampling would provide a better representation of younger populations. Consistent with that expectation, younger populations were more likely to complete web surveys than phone surveys (adolescents: N = 50 for phone vs. N = 113 for web; young adults: N = 71 for phone vs. N = 161 for web), yet older populations were more likely to complete phone surveys than web surveys (middle adults: N = 268 for phone vs. N = 201 for web; older adults: N = 353 for phone vs. N = 294 for web). Random digital dialing (RDD) was performed by SDR Consulting, Inc. (Atlanta, USA) to generate a set of phone numbers. **Figure 1** presents a flowchart of participant recruitment via RDD as per STROBE guidelines.[24] The overall phone response rate for the 2011 Poll was 2.3% (see footnote 3), with a cooperation rate of 23.3% (see footnote 4), a refusal rate of 11.9% (see footnote 5), and a contact rate of 17.6% (see footnote 6).[25] The maximum sampling error for the total sample was ± 2.5 percentage points (95% CI). This study was exempt from institutional review board approval as the research conducted by the National Sleep Foundation (a not-for-profit organization) involved observations of public behavior where human subject data were de-identified.[26]

Measures

The survey instrument consisted of 47 structured questions with coded responses. The survey opened with several questions targeting key demographic information (i.e., age, region, employment, gender), followed by questions reporting participants' sleep habits on weekdays and non-working days (including daytime naps) over the past 2 weeks. Further questions assessed sleep quality (e.g., *On how many nights would you say* "*I had a good night's sleep*"?), sleep need (e.g., *On average how many hours of sleep do you need to function at your best the next day*?), and the impact of not getting enough sleep on occupational/vocational performance and relationships with significant others. The survey included the Epworth Sleepiness Scale[27] to assess daytime sleepiness. Participants were also asked about the frequency of drowsy driving, and coping behaviors (e.g., average daily caffeine consumption). The frequency of sleep problems (difficulty falling asleep, difficulty maintaining sleep, unrefreshing sleep) was asked (e.g., "*In the past 2 weeks, would you say you had difficulty falling asleep*?"), with responses measured on a 4-point Likert scale ranging from "*every night or almost every night*" to "*never.*"

Eleven questions asked participants about the presence and use of various technological devices in the bedroom (e.g., TV,

Figure 1—Flowchart of participant recruitment using Random Digit Dialing to arrive at N = 750 quota



cell phones, computer/laptops, video/computer games) in the hour before bed in the past 2 weeks. Questions were also asked about the types of activities performed on these devices in the hour before bed (but not limited to use in the bedroom), the content viewed, and sleep interruptions resulting from technological devices during the night. Presence and use of technological devices was answered in a Yes/No format, and frequency of technology use was typically answered on a Likert scale ranging from "*Never*" to "*Every night or almost every night.*"

Not all questions were asked for all participants. For example, if a participant indicated they did not use a particular device before bed (e.g., cell phone), they then skipped questions related to particular functions and content on such a device. For ethical reasons, adolescents were not asked particular questions that older participants were (e.g., whether not getting enough sleep affected their intimate or sexual relations). The survey instrument appears in full in the Appendix of the 2011 Summary of Findings (http://www.sleepfoundation.org/article/sleep-america-polls/2011-communications-technology-use-and-sleep).

Procedure

In 2010, the National Sleep Foundation assembled an expert panel of sleep researchers, chaired by one of us (RR). Panel members were informed of the 2011 Sleep in America Poll objectives, and together developed the survey instrument over a series of conference calls. WB&A Market Research were contracted to conduct the 2011 Sleep in America Poll. Professional interviewers conducted phone interviews mainly on weekdays (17:00 to 21:00), Saturdays (10:00-14:00), and Sundays (16:00-20:00). Remaining phone surveys were conducted on weekdays (09:00-17:00). A sample of cell phones was included with landline phones to reach the growing trend of cell phone-only households.[28] Phone surveys were completed on average in 18.0 min. No equivalent data were available for surveys completed on the web. Web surveys were conducted via an E-Rewards online panel of registrants. All surveys were conducted with the respondents themselves (i.e., including adolescents). The survey was introduced as "the annual Sleep in America Poll" conducted on behalf of the National Sleep Foundation. Potential respondents were informed of the confidentiality of any information they provided. Data were collected from late October 2010 to late November 2010. To reduce the impact of age on the results, data were weighted based on age so as to be comparable to 2009 U.S. Census data estimates.[29]

Statistical Analyses

Independent z-tests were used to compare outcome variables (reported as percentages) across the 4 age groups.[30] Significant differences between groups occurred when the *z*-statistic exceeded 1.96 (using 95% confidence interval). *Z*-scores > 2.57 were significant using 99% confidence interval. A series of linear regressions were used to assess the unique contributions from various aspects of technology use on sleep while controlling for significant covariates (i.e., age, gender, ambient light, naps, caffeine consumption). The "amount of technology used" was the main predictor variable and is defined as the total number of devices used in the hour before bed, which resulted from the question, "*Thinking about the past 2 weeks, on a typical night which of the following are in your bedroom and you use in the hour before trying to go to sleep*?" This predictor variable was further split into the number of interactive technological devices used (i.e.,

computers/laptops, cell phone, video gaming) and the number of passive technological devices used (i.e., TV, reading, mp3 music players) to test the hypothesis that stimulating devices are more likely to relate to difficulties sleeping. Statistical significance was set at $\alpha = 0.05$. When statistical significant differences were detected, standardized regression coefficients (i.e., standardized beta [β]) were reported. The β represents the change in the dependent variable (sleep difficulty) for every one standard deviation change in the independent variable (number of technology items used). Due to the high variability in the way technology use is measured, standardizing the beta coefficient allows for easier comparisons across studies.

RESULTS

Technology Presence and Use

For the entire sample, 90% of Americans reported using some form of technological device in the bedroom in the hour before trying to sleep. Of those aged under 30 years, technology use was even more prevalent (96% of adults younger than 30 years used some form of technology). For the overall sample, TVs were the most commonly used (60%), then cell phones (39%), followed by computers/laptops (36%), electronic music devices (29%), telephones (21%), video game consoles (8%) and lastly e-book readers (6%). There were, however, notable age differences.

Although 39% of the entire sample used cell phones in their bedroom in the hour before bed, 72% of adolescents and 67% of young adults used cell phones, both significantly more than middle adults (30-45 years: 36%), and older adults (46-64 years: 16%); all zs $\geq$ 8.78. Similar significant patterns emerged for computers/laptops (both adolescents and young adults 60% vs. older adults 22%) and electronic music devices (adolescents = 64% and young adults 43% vs. older adults = 17%; all zs $\geq$ 7.91). Although not as prevalent, video game consoles were used significantly more by under 30s (adolescents = 23%; young adults = 18% vs. older adults = 1%; all zs $\geq$ 6.78).

Several other significant demographic differences were found for devices used in the bedroom in the hour before bed. Females were more likely than males to use the telephone (24% vs. 18%), and read printed books (54% vs. 43%) and e-book readers (7% vs. 4%; all zs $\geq$ 2.56). Conversely, males were more likely to use a video gaming console (12% vs. 3%; z = 6.74). Single Americans were about twice as likely to use a computer/laptop (45% vs. 24%), cell phone (52% vs. 21%), electronic music device (34% vs. 17%), or videogame console (9% vs. 2%) than married Americans (all zs $\geq$ 4.88). African Americans were more likely to watch TV (76%) than white Americans (59%) and Asian Americans (49%), and use a telephone compared to all other Americans (53% vs. $\leq$ 29%; all zs $\geq$ 3.75). Asian Americans were more likely to use a computer/laptop (68%) than all other groups (32% to 49%; all zs $\geq$ 2.79). African Americans and Hispanic Americans (both 61%) used cell phones more than white Americans (34%) and Asian Americans (45%; all zs $\geq$ 2.29). White Americans were less likely to use an electronic music device (24%) than all other groups (40% to 49%) and a video gaming console (6%, vs. 13 and 20% for Asian Americans and Hispanic Americans, respectively; all zs $\geq$ 1.96). These percentages mirror some findings from a previous Sleep in America Poll.[16]

When investigating specific activities performed in the hour before bed (but not necessarily in the bedroom) for the entire sample, watching TV was the most common activity performed at least a few nights a week (79%). This was followed by: doing homework on the computer (68%); surfing the Internet (54%); reading a printed book/magazine (48%); doing work on the computer (40%); personal emailing (39%); social networking (38%); text messaging (38%); talking on the phone (29%); watching a video (21%); work-related e-mailing (19%); video gaming (19%); listening to music (18%); and reading on an e-book (5%). Nearly the entire sample (97%) reported performing at least one of these activities in the hour before bed.

Sleep Habits, Sleep Quality

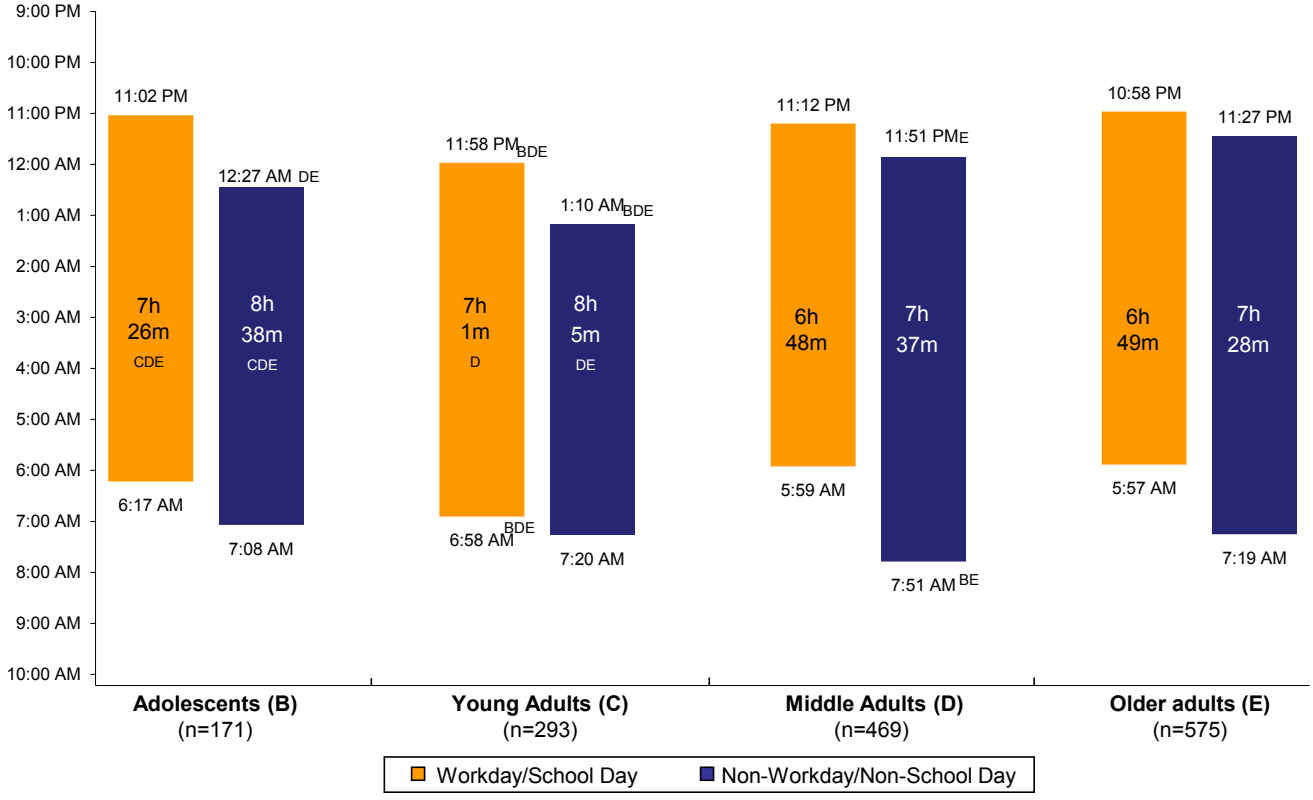
Figure 2 presents the weekday and non-workday sleep habits of the various age groups. Young adults went to bed significantly later than all other age groups on both weekdays and weekends, and adolescents went to bed significantly later on weekends than groups over 30 years of age. Wake times were reasonably consistent across age groups with 2 exceptions. On weekdays, young adults rose significantly later than all other age groups, and on weekends middle adults rose later than adolescents and older adults.

As total sleep time varies as a function of age,[31] whether participants were obtaining enough sleep to meet their needs was also measured. Overall, 35% of the sample reported getting enough sleep on weeknights, whereas roughly 6 in 10 Americans (63%) claimed they were not getting enough sleep to function properly. This was particularly true for adolescents (67%), young adults (67%), and middle adults (65%) compared to older adults (58%). For those Americans reporting insufficient sleep (N = 420), 94% reported at least some impact on at least one of the following: mood, school work, family life or home responsibilities, work, social life or leisure activities, and/or intimate/sexual relations (see **Figure 3**). Of these Americans, 51% reported not obtaining enough sleep had a *major* impact on one of these areas of functioning. Of Americans who drive, 37% reported they had driven drowsy in the past month. One in 2 young adults reported this occurred at least once a month, which was significantly more than every other age group (older adults = 28%; middle adults = 30%; adolescents = 40% [see footnote 7]).

Associations between Technology Use and Sleep Problems

We explored possible associations between technology use and sleep using a series of linear regressions (**Table 1**). The amount of technology use before bed (the greater the number of technological devices used in the bedroom in the hour before bed) did not predict any unique variance in bedtimes on weeknights after controlling for demographic (age and gender) or other sleep hygiene variables (light in the bedroom, naps, and caffeine consumption) known to also affect sleep (t_{1467} = 1.09, p > 0.05). Since we hypothesized that certain technological devices could be more engaging and thus lead to later bedtimes (e.g., cell phone), regression analyses were performed for each device; however, none contributed significant variance to weeknight bedtimes. Of

Figure 2—Self-reported sleep habits on weekdays and weekends between adolescents (B), young adults (C), middle adults (D) and older adults (E)



Values on top of bars represent mean bedtimes; values within bars represent mean total sleep times; values below bars represent mean rise times; alphabetic letters adjacent to means represent significant differences between age groups. For example, CDE adjacent to 7h 26m in adolescents' school day total sleep time means this value is significantly different to young- (C), middle- (D), and older adults (E).

all variables considered, only napping (on weekends) was significantly related to later bedtimes in each analysis (β = 5.7%-6.2%; all $p < 0.05$). Interestingly, frequent nappers (napping > 3 times in past 2 weeks) were more likely to use interactive technological devices before bed ($F_{1,1504} = 6.88$, $p = 0.009$), suggesting significant overlap between napping and using stimulating technological devices when predicting bedtimes.

After controlling for covariates, we found that the amount of media used in the bedroom in the hour before bed was significantly related to difficulty falling asleep ($t_{1460} = 3.07$, $p = 0.002$, $\beta = 8.4$). Thus, the more Americans were poly users of technology before bed, the more severe was their difficulty initiating sleep. As these electronic media consisted of both passive (TV, reading, mp3 music players) and interactive devices (computers/laptops, cell phone, video gaming), separate analyses were performed to assess whether the stimulating devices were more associated with difficulty sleeping. Passive devices did not significantly contribute to difficulty falling asleep ($t_{1460} = 1.73$, $p = 0.08$); however, interactive devices did ($t_{1460} = 3.29$, $p = 0.001$, $\beta = 9.4$). This significance primarily resulted from using video gaming consoles ($\beta = 10.6$, $p < 0.0001$), but also from cell phones ($\beta = 6.4$, $p = 0.03$) and computers/laptops ($\beta = 5.5$, $p = 0.049$).

Of all technological devices to interrupt sleep during the night, cell phones were the only devices targeted in the 2011 Poll.

Figure 3—Significant impacts on areas of functioning from not getting enough sleep

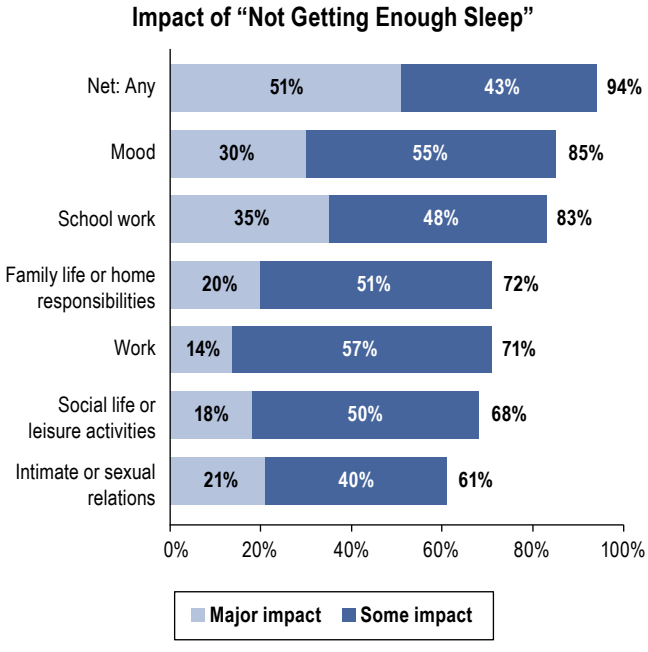


Table 1—Linear regression analyses for technology use predicting bedtimes and sleep difficulties after controlling for covariates

	Bedtimes					Difficulty Falling Asleep					Difficulty Maintaining Sleep					Unrefreshing Sleep				
	B	SE	β	R^2	p	B	SE	β	R^2	p	B	SE	β	R^2	p	B	SE	β	R^2	p
Demographic																				
Age	-1.21	2.13	-0.02	–	0.57	-0.01	0.00	-0.08	–	0.004	0.02	0.00	0.30	–	0.0001	-0.01	-0.01	-0.10	–	0.001
Gender	-89.41	57.04	-0.04	–	0.12	0.23	0.05	0.12	–	0.0001	0.26	0.08	0.13	–	0.002	0.19	0.05	0.11	–	0.0001
Sleep Hygiene																				
Light	-12.03	31.91	-0.01	–	0.71	0.02	0.03	0.02	–	0.40	0.12	0.04	0.11	–	0.006	0.07	0.03	0.07	–	0.01
Caffeine	5.76	5.59	0.03	–	0.30	0.00	0.01	0.01	–	0.85	0.01	0.01	0.04	–	0.35	0.01	0.01	0.04	–	0.16
Naps (weekday)	31.57	35.09	0.03	–	0.37	0.05	0.03	0.04	–	0.14	0.00	0.05	0.00	–	0.96	0.09	0.03	0.09	–	0.003
Naps (weekend)	96.36	45.77	0.06	–	0.04	0.07	0.04	0.05	–	0.09	0.07	0.07	0.05	–	0.30	-0.01	0.04	-0.01	–	0.88
Technology Use																				
Total	-21.54	18.63	-0.03	0.01	0.25	0.05	0.02	0.08	0.04	0.002			na			0.03	0.02	0.05	0.05	0.048
Passive	-42.69	31.51	-0.04	0.01	0.18	0.05	0.03	0.05	0.04	0.08			na			0.03	0.03	0.03	0.05	0.28
Interactive	-17.10	29.93	-0.02	0.01	0.57	0.08	0.03	0.09	0.05	0.001			na			0.05	0.03	0.06	0.05	0.04
Cell Phones#	na					na					0.21	0.05	0.18	0.16	0.0001	na				

Total, the total amount of pre-sleep devices used in the hour before bed; Passive, passive devices used in the hour before bed (i.e., TV, mp3 music players, reading); Interactive, interactive devices used in the hour before bed (i.e., computers/laptops, cell phones, videogame consoles); na, not applicable as the only device measured for interrupting sleep was cell phones; #N = 555, otherwise N = 1,468; gender was coded male = 1, female = 2.

Twenty-two percent of the entire sample reported going to sleep with their cell phone ringers on in their bedroom. Furthermore, 10% were awakened *at least a few nights a week*, with awakenings occurring more in adolescents (18%) and young adults (20%). When investigating the association between leaving cell phones on and Americans' ratings of their difficulty maintaining sleep, a linear regression analysis was performed only for those who kept their cell phone in their bedroom overnight *and* left their ringer on (N = 331). After adjusting for demographic and sleep hygiene variables, being awakened by one's cell phone uniquely contributed towards Americans' perception of their difficulty in maintaining sleep ($\beta = 17.9$, $p < 0.0001$).

The same pattern emerged when assessing various forms of technology use on Americans' reporting unrefreshing sleep. The more media used in the bedroom before bed was related to the frequency of reporting unrefreshing sleep ($t_{1461} = 1.98$, $p = 0.048$, $\beta = 5.4$), which was primarily accounted for by the use of interactive technological devices ($t_{1466} = 2.17$, $p = 0.04$, $\beta = 6.1$) but not passive activities ($t_{1466} = 1.06$, $p > 0.05$).

DISCUSSION

The findings from the 2011 Sleep in America Poll show technology use in the hour before bed is common practice, with 90% of Americans engaging with technology. Furthermore, many Americans are reporting inadequate sleep. Up to two-thirds of adolescents (13-18 years) and adults (19- to 29-year-olds) reported inadequate sleep on weeknights. Between 8.5 to 9.25 hours has been recommended for adolescents and 7-8.2 hours for adults.[32-35] Significant, and even dangerous, daytime consequences (37% of Americans had driven drowsy in the past month) were frequently reported by those experiencing inadequate sleep. The analyses from the present study show evening technology use is associated with sleep, such that more technology use is associated with poorer sleep. While the present study was cross-sectional, precluding conclusions regarding a causal relationship, the findings are consistent with the potential mechanisms by which technology use may affect sleep, including bedtime displacement, cognitive and physiological arousal, light and electromagnetic transmissions from technological devices, and devices interrupting the maintenance of nocturnal sleep.[17,18] The present study was able to assess some of these mechanisms.

Links between Technology Use and Sleep

Although previous studies have found that later bedtimes are related to the use of TVs, computers, videogames, and the Internet,[9,14,36] the present study did not find evidence of any technological devices contributing to later bedtimes. This may have occurred due to the present study accounting for other variables known to affect bedtimes, including caffeine consumption,[37,38] bedroom lighting,[39,40] and napping.[41,42] Of these variables, napping was the only variable to be significantly related to bedtimes. We note previous studies that demonstrated a link between evening technology use and bedtimes did not statistically control for such confounding variables,[14,36] which may account for differences between study findings.

The greater number of technological devices used in the hour before bed was related to higher ratings of difficulties initiating sleep. The strength of this association was greatest for stimulating activities, such as using videogame consoles, cell phones, and computers/laptops. These results suggest that once Americans do decide to go to bed, they have significant difficulty sleeping if they have used stimulating technologies shortly beforehand. The cognitive[43,44] and physiological arousal[45,46] from using such devices may interfere with Americans' preparation for sleep. Similar findings occurred for reports of unrefreshing sleep, with the greater likelihood of reporting such poor sleep quality being related to the use of interactive technological devices before bed. However, we cannot exclude the possible contributions of other factors such as screen light[47] and electromagnetic transmissions[48] from the same devices. Although more research is needed to better understand why such devices are related to sleep initiation difficulties, it is clear that Americans should schedule passive activities in between their use of interactive technological devices and sleep (i.e.,

passive technological devices; TV, electronic music devices, books), as these showed weaker associations with sleep.

One surprising finding from the present study was the extent to which Americans are going to sleep with their cell phone *turned on* in their bedroom. Of those who reported that they use their cell phone before bed (22%), 57% leave their ringer on (10% of the entire sample), which is associated with difficulty returning to sleep after an awakening. One in ten Americans reported being awakened at least a few nights a week, with younger people awakened by their cell phones (adolescents = 18%, young adults = 20%). These figures concur with previous findings.[22,23] The inability to maintain sleep may be due to these Americans performing behaviors during the night (e.g., texting) that are arousing and incompatible with sleep. The problem could be worse than our study suggests, as only cell phones were targeted in this Poll. Many Americans reported using other technological devices when awake during the night (e.g., computers/laptops); however, it was not clear if these devices woke them up with alerting sounds, or whether people woke spontaneously and used these devices until re-initiating sleep. This may have implications for the quality of Americans' sleep.

Implications for Evening Technology Use

Since the 1970s, stimulus control therapy instructions have stated that the bed (and bedroom) should only be used for sleep and sexual activity.[49,50] The findings from the 2011 Sleep in America Poll indicate that 9 of 10 Americans surveyed are not following this basic recommendation. However, the present study's findings offer correlative evidence that some forms of technology confer weak effects on sleep (i.e., passive activities; watching TV, reading). Use of these devices may challenge the notion of using the bed only for sleep. Passive devices may be helpful as they are a pleasurable activity that fills the void while waiting to fall asleep.[51,52] Conversely, a sleep tip considered "common sense"[53] and imbedded within the principles of sleep hygiene is that one should avoid stimulating activities before bedtime.[12,54] The present study demonstrated that the use of stimulating activities with technological devices that involve interactivity (cell phones, laptops, videogame consoles) were associated with difficulty falling asleep and unrefreshing sleep. With the high proportion of Americans who use technology close to bedtime, combined with the significant impact on daily functioning as a result of inadequate sleep, a clear delineation is needed between devices that are acceptable, or not, in the hour before bed.

Limitations of the Present Study

There are several limitations of the present study. Although efforts were made to match participant characteristics to 2009 US Census data,[29] the present Poll nevertheless contains a small proportion of error variance that limits generalizability to the population. Our response rate may be considered low, yet we note most surveys do not conform to STROBE guidelines,[24] and thus report liberal rates akin to cooperation rates (i.e., do not include "calls not connected" and "calls not answered by a person"; see **Figure 1**). The Poll was presented as a "sleep survey," hence introducing a possible self-selection bias.[55,56] It may be likely that those Americans with a vested interest in sleep (e.g., those with sleep problems) may have been more inclined to participate. Although the web survey gained access to participants who may be difficult to recruit via phones, it could be argued that further selection bias may exist in that these participants may be more likely to own and use multiple technological devices. However, using a singular recruitment method could result in sampling biases which would slant findings more so than multiple methods. We therefore believe viewing the multiple methods as a confound needs to be reframed. It is likely that future surveys of technology use will incorporate multiple methods to balance any biases due to over-represented younger or older people. We did report age group differences between web and phone surveys, but any further analysis of differences on technology use between these two methods is likely a function of age (i.e., younger age groups use technology and are more likely to complete web surveys). Data on the number of e-surveys undeliverable, deliverable but not commenced, and not completed were unavailable, thus making it difficult to assess any biases in sampling. Due to informed consent concerns, the Poll did not assess children's use of technology (≤ 12 years). Further insights may be found for younger children's susceptibility to technology-induced sleep problems.[57] Hopefully, many parents are implementing the American Pediatric Association's recommendation of less than two hours of screen time per day,[58] but are not using this screen time in their child's bedtime routine. We note that the wake-up time for the adolescent group is earlier than those reported from recent reviews.[59,60] More data are required to assess whether adolescents who use technology report unique sleep patterns. The Poll used a cross-sectional design; thus the scope for determining cause and effect is limited (e.g., do Americans have difficulties falling asleep due to using interactive technological devices—or—do Americans who have preexisting difficulties falling asleep have an affinity for interactive technological devices?). Our self-reported sleep items are not ideal, and although ambitious, future large surveys of sleep and technology could use more valid time-use diaries. In summary, we recognize that the published summary of findings and media release from the 2009 National Sleep Foundation Poll has received criticism for not adhering to various scientific principles (e.g., extrapolating "sleep problem" to "insomnia"; "Poll-pushed" questions; lack of transparency of sampling biases; lack of statistical analyses controlling for extraneous variables).[61] The present study represents a scientific presentation of the 2011 National Sleep Foundation results, which should be viewed in conjunction with the growing number of field surveys and experimental laboratory studies in this area to understand the weight of evidence for the role of technology use on sleep in modern society.

Concluding Remarks

The technology use of Americans in their bedrooms is prevalent, especially in the hour before attempting sleep. To our surprise, technology use during the sleep period was much higher than expected. Analysis of different age groups demonstrated that those who use technology in the hour before bedtime are younger than 30 years of age. These groups also report the largest amounts of sleep problems. These findings suggest that technology use is emerging as a possible contributing factor to sleep disturbance in the twenty-first century. Future research should investigate whether adolescents (13-18 year olds) and young adults (19-29 year olds) will continue evening technology

use into late adulthood, and what effects their modeling of technology use will have on future generations to come.

FOOTNOTES

1. < 1% refused to answer.
2. < 2% refused to answer.
3. Response rate is total completed interviews of the total calls dialed (750 of 32,216).
4. Cooperation rate is total completed interviews (750) of total calls to potentially eligible participants (3341) plus deceased (17) and language barrier (270) call dispositions, minus calls terminated (-404) (750 of 3224).
5. Refusal rate is the total number refusing the interview (2187) of all potentially eligible participants (3341) plus deceased (17), language barrier (270), answering machines (15046), and not available (56) dispositions, minus calls terminated (-404) (2,187 of 18,326).
6. Contact rate is the percentage of participants reached by interviewers of the total calls connecting, including answering machines and no answers (3,224 of 18,613).
7. These findings are derived from data of only adolescents who drive.

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