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Original Research Article



# Technology Use and Sleep in Adolescents With and Without Attention-Deficit/Hyperactivity Disorder

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## Abstract

**Objectives** This study used a multi-informant approach to examine differences in types and rates of technology used by adolescents with and without attention-deficit/hyperactivity disorder (ADHD), associations between technology use and sleep/daytime sleepiness, and whether technology use was differentially related to sleep/daytime sleepiness in adolescents with and without ADHD. **Methods** Eighth graders with ($n = 162$) and without ($n = 140$) ADHD were recruited. Adolescents completed questionnaires assessing time spent using technology, sleep-wake problems, school-night time in bed, and daytime sleepiness. Parents and teachers reported on adolescents' technology use and daytime sleepiness, respectively. **Results** Adolescents with ADHD had significantly greater total technology, television/movie viewing, video game, and phone/video chatting use than adolescents without ADHD. Adolescents with ADHD engaged in twice as much daily video game use compared to those without ADHD (61 vs. 31 min). Controlling for medication use, ADHD status, pubertal development, sex, and internalizing symptoms, greater parent- and adolescent-reported technology use was associated with more sleep-wake problems and less time in bed. ADHD status did not moderate the relations between technology use and these sleep parameters. In contrast, ADHD status moderated the association between parent-reported technology use and teacher-reported daytime sleepiness, such that this association was significant only for adolescents with ADHD. **Conclusions** Technology use, although more prevalent in adolescents with ADHD, is linked with more sleep problems and reduced school-night sleep duration regardless of ADHD status. Technology use is associated with teacher-rated daytime sleepiness only in adolescents with ADHD. Clinicians should consider technology usage when assessing and treating sleep problems.

**Key words**: attention-deficit/hyperactivity disorder; screen time; sleep; technology.

## Introduction

Technology use is increasing, with the average adolescent engaging in several hours of screen time daily (Rideout, Pai, Saphir, Pritchett, & Rudd, 2015). Excessive technology use in youth is associated with numerous negative outcomes, including attention and internalizing problems (George, Russell, Piontak, & Odgers, 2018; Sarmiento et al., 2018). Additionally, screen time has been linked to poor sleep outcomes in youth, specifically shorter duration and longer onset of sleep (Hale & Guan, 2015; Hysing et al., 2015).

Youth and adults with attention-deficit/hyperactivity disorder (ADHD) are at heightened risk for problematic technology use and sleep problems. Specifically, the presence of an ADHD diagnosis or symptoms is linked to compulsive/addiction-driven Internet use (Anderson, Steen, & Stavropoulos, 2017), greater rates of social media use and addiction (Gul, Yurumez Solmaz, Gul, & Oner, 2018), greater access to video games in the bedroom, and greater preoccupation/lack of control with video game play (Mazurek & Engelhardt, 2013). Additionally, youth with ADHD are at risk for parent-reported sleep problems (e.g., longer sleep onset) and elevated daytime sleepiness (Cortese, Faraone, Konofal, & Lecendreux, 2009).

Most studies examining links between ADHD and technology have been conducted with child or adult samples (Montagni, Guichard, & Kurth, 2016; Seo, Kim, & David, 2015; Yen, Yen, Chen, Tang, & Ko, 2009). It is presently unknown whether there are differences in types and rates of technology use between adolescents with and without ADHD. Further, many pediatric studies to date have assessed technology use using parent-report measures; given that adolescents spend much of their day away from parents, it is important to incorporate youth self-report of technology use (Engelhardt, Mazurek, & Sohl, 2013; Mazurek & Engelhardt, 2013). A recent preliminary study found increased adolescent-reported technology use to be associated with more sleep problems in adolescents with ADHD, though the sample size was modest ($N = 81$) and a comparison group of adolescents without ADHD was not included (Becker & Lienesch, 2018). Additionally, existing research has only examined technology use in relation to self-reported sleepiness; no study has examined whether increased daytime sleepiness is also observed by teachers at school, who are less aware of children's technology use habits (Becker & Lienesch, 2018; Fossum, Nordnes, Storemark, Bjorvatn, & Pallesen, 2014; Nathan & Zeitzer, 2013). Lastly, given the elevated risk for both problematic technology use and sleep difficulties in youth with ADHD, it is crucial to investigate whether the links between technology use and sleep/sleepiness differ in youth with ADHD relative to those without ADHD. The only known study to evaluate this found that the link between media use specifically in the bedroom and sleep quantity did not differ between boys with and without ADHD (Engelhardt et al., 2013). However, this study did not examine different types of technology use or technology use outside of the bedroom and relied solely on parent report of technology and sleep.

The present study evaluated parent- and adolescent-reported technology use and associations of technology use with sleep and daytime sleepiness in a large sample of adolescents with and without ADHD. Based on prior findings (Anderson et al., 2017; Gul et al., 2018; Mazurek & Engelhardt, 2013), we hypothesized that youth with ADHD would engage in greater levels of all assessed technology use according to both adolescents and parents. We also predicted that more parent- and adolescent-reported technology use would be associated with poorer adolescent-rated sleep and greater teacher-rated daytime sleepiness. Lastly, given previous research (Engelhardt et al., 2013), we hypothesized that the link between technology use and sleep outcomes would not differ between adolescents with and without ADHD.

## Methods

### Participants

Participants included 302 adolescents (ages 12–14 years) in eighth grade who were recruited from local public schools across two sites located in the Southeastern and Midwestern United States. The purpose of the larger longitudinal study is to evaluate differences between adolescents with and without ADHD, and so adolescents with ADHD were purposefully oversampled in order to have an approximately 1:1 ratio. Approximately half ($n = 162$) of the sample was diagnosed with ADHD (120 predominantly inattentive presentation; 42 combined presentation), with the remaining participants ($n = 140$) comprising of a comparison sample without ADHD. Further description of the sample can be found in Table I.

### Procedures

Adolescents in eighth grade and their parents were recruited across two consecutive years for a prospective longitudinal study examining sleep in adolescents with and without ADHD. Longitudinal data collection is ongoing; only baseline data were available and used in the present study. The study was approved by the (Virginia Commonwealth University and Cincinnati Children's Medical Hospital Center) Institutional Review Boards, and written informed consent and child assent were obtained from each family. Potential participants were recruited via flyers and letters provided to schools. Given that the study sought to recruit adolescents with and without ADHD, two sets of recruitment materials were used, with one set specifically directed toward youth with attention difficulties and/or ADHD. Schools distributed the recruitment materials to all eighth grade

**Table I.** *Sample Characteristics*

| | Total sample ($N = 302$) | ADHD group ($n = 162$) | Comparison group ($n = 140$) | |
|---|---|---|---|---|
| | *M* ± *SD* | *M* ± *SD* | *M* ± *SD* | Group differences |
| Age (years) | 13.17 ± 0.40 | 13.17± 0.41 | 13.18 ± 0.40 | $t = 0.26, p = .80$ |
| Estimated IQ | 107.03 ± 13.39 | 104.75 ± 13.89 | 109.67 ± 12.31 | $t = 3.23, p = .001$ |
| Pubertal development | 2.67 ± 0.70 | 2.58 ± 0.68 | 2.76 ± 0.71 | $t = 2.19, p = .03$ |
| Females | 3.07 ± 0.62 | 3.11 ± 0.57 | 3.05 ± 0.66 | $t = -0.60, p = .55$ |
| Males | 2.34 ± 0.58 | 2.31 ± 0.57 | 2.40 ± 0.61 | $t = 0.99, p = .33$ |
| | *N* (%) | *N* (%) | *N* (%) | |
| Female | 135 (44.7) | 57 (35.2) | 78 (55.7) | $\chi^2 = 12.80, p < .001$ |
| Race | | | | $\chi^2 = 9.17, p = .06$ |
| White | 247 (81.8) | 129 (79.6) | 118 (84.3) | |
| Black | 16 (5.3) | 12 (7.4) | 4 (2.9) | |
| Asian | 14 (4.6) | 4 (2.5) | 10 (7.1) | |
| American Indian/Alaskan | 1 (0.3) | 1 (0.6) | 0 (0) | |
| Bi/multiracial | 24 (7.9) | 16 (9.9) | 8 (5.7) | |
| Hispanic/Latinx | 14 (4.6) | 7 (4.3) | 7 (5.0) | $\chi^2 = 0.08, p = .78$ |
| Medication use | 120(39.7) | 105 (64.8) | 15(10.7) | $\chi^2 = 91.79, p < .001$ |
| Comorbid mental health diagnosis | 107 (35.4) | 74 (45.7) | 33 (23.6) | $\chi^2 = 16.04, p < .001$ |
| ODD/CD | 41 (13.6) | 35 (21.6) | 6 (4.3) | $\chi^2 = 19.20, p < .001$ |
| Any anxiety | 73 (24.2) | 46 (28.4) | 27 (19.3) | $\chi^2 = 3.40, p = .07$ |
| Any depression | 24 (7.9) | 16 (9.9) | 8 (5.7) | $\chi^2 = 1.78, p = .18$ |

*Note*. Presence of comorbid mental health diagnosis based on parent or adolescent report (only parents were administered ODD and PTSD modules). ADHD = attention-deficit/hyperactivity disorder; ODD/CD = oppositional defiant disorder/conduct disorder. Any anxiety = presence of generalized anxiety disorder, social phobia, obsessive-compulsive disorder, and/or posttraumatic stress disorder (PTSD). Any depression = presence of major depression or dysthymia.

families by e-mail, within an information packet at the beginning of the school year, or at events attended by eighth grade parents. Interested families ($n = 405$) contacted the research team to complete a phone screen to ensure adolescents were in eighth grade, regular education classes, and not diagnosed with an organic sleep condition. Families meeting the phone screen criteria ($n = 360$) were invited to receive a comprehensive assessment, which 313 families attended. At this assessment, participants and their parents completed their respective versions of the *Children's Interview for Psychiatric Syndromes* (ChIPS; Weller, Weller, Fristad, Rooney, & Schecter, 2000) and rating scales, and participants were administered the *Wechsler Abbreviated Scale of Intelligence – Second Edition* (WASI-II; Wechsler, 2011). Families received $75 for completing this assessment and were also provided with written and verbal feedback briefly summarizing the results of the evaluation. Parent, adolescent, and teacher ratings were collected using Research Electronic Data Capture (Harris et al., 2009). Inclusion criteria included: (a) enrolled in eighth grade; (b) estimated Full Scale IQ (FSIQ)≥80 based on the WASI-II; and (c) enrolled in regular education classes. Exclusion criteria were (a) meeting criteria for autism spectrum disorders, bipolar disorder, or a dissociative or psychotic disorder; (b) previous diagnosis of an organic sleep disorder (e.g., obstructive sleep apnea, narcolepsy, restless leg syndrome, and periodic limb movement disorder) according to parent report during the phone screen; and (c) not meeting criteria for either the ADHD or comparison groups as described below.

### ADHD Diagnosis

All potential participants underwent a comprehensive ADHD diagnostic evaluation in accordance with criteria of the Fifth Edition of the *Diagnostic and Statistical Manual for Mental Disorders* (DSM-5; American Psychiatric Association, 2013). Participants met criteria for ADHD on the basis of the parent version of the ChIPS (P-ChIPS; Weller et al., 2000), in line with well-established assessment guidelines for diagnosing ADHD (Pelham, Fabiano, & Massetti, 2005). To be eligible for participation in the ADHD group, adolescents were required to meet all DSM-5 criteria for either the ADHD combined presentation or predominantly inattentive presentation on the P-ChIPS, including: at least six symptoms of inattention at clinically significant levels; presence of ADHD symptoms prior to age 12 years, presence of ADHD symptoms in two or more settings (e.g., home, school), evidence that symptoms contribute to impairment in home, academic, and/or social functioning; and symptoms of ADHD are not better explained by another mental disorder (e.g., anxiety, depression). In line with most studies of adolescents with ADHD, meeting criteria for ADHD, predominantly hyperactive/impulsive presentation was considered an exclusionary criterion.

Extremely low base rates of this presentation in adolescence suggest that hyperactive/impulsive symptoms in the absence of symptoms of inattention are likely attributed to a condition other than ADHD (Willcutt et al., 2012). Only two potential participants were excluded on the basis of this exclusionary criterion. Participants were included in the comparison (i.e., non-ADHD) group if the parent endorsed fewer than four symptoms of ADHD in both domains (i.e., inattention and hyperactivity/impulsivity) on the P-ChIPS. All participants were assessed for common comorbid mental health conditions (i.e., mood and anxiety disorders, disruptive behavior disorders, and obsessive compulsive disorder).

## Measures

### Technology Use

Consistent with recent recommendations made for assessing adolescent technology use (Anderson et al., 2017), parents and adolescents separately answered questions regarding youth's use of technology. Parents indicated in minutes how much time their child spends on the following activities on a typical school night: (a) playing video and/or computer games; (b) watching TV/movies; and (c) using a phone for texting, video messaging, and/or Internet browsing. These items were also summed to create a total time spent using technology variable.

Adolescents were administered four similar items that were rated on a 6-point Likert scale (0 = *never*; 5 = *more than 4 hr*) based on total amount of time the adolescent spends on each technology "on the average day." Technology use assessed includes: (a) watching video content, including video games; (b) emailing/sending messages on social media; (c) texting/instant messaging; and (d) talking on the phone or video chatting. A sum score of these four items was also calculated to estimate total technology use.

### Sleep Habits Survey

The sleep habits survey (SHS; Wolfson & Carskadon, 1998) is a self-report measure of sleep functioning validated for use in youth ages 10–19 years (Wolfson et al., 2003). School-night total sleep and wake times as reported on the SHS do not significantly differ from sleep duration as reported on a daily sleep diary or estimated using actigraphy (Wolfson et al., 2003). For the present study, the 10-item sleep-wake problems subscale was used, which assesses the frequency of a number of sleep-related problems, such as falling asleep in class, staying up late, having a hard time falling asleep, and nightmares. Items for this subscale are rated on a 5-point Likert scale (1 = *never*; 5 = *every day/night*). The subscale demonstrated adequate internal consistency in the present sample, $\alpha = .76$. In addition, school-night time in bed was calculated from two items on the SHS that asked the adolescents what time they usually go to bed and wake up on school days.

### Pediatric Daytime Sleepiness Scale

The Pediatric Daytime Sleepiness Scale (PDSS; Drake et al., 2003) is a well-established self-report measure of daytime sleepiness (Lewandowski, Toliver-Sokol, & Palermo, 2011). The PDSS consists of eight items rated on a 5-point scale (0 = *never*, 4 = *always*). The PDSS was validated specifically as an adolescent self-report measure to examine the relationship between daytime sleepiness and academic functioning (Drake et al., 2003). In the present study, a mean score across items was calculated ($\alpha = .77$).

### Teacher's Daytime Sleepiness Questionnaire

The Teacher's Daytime Sleepiness Questionnaire (TDSQ) is a teacher-report measure of daytime sleepiness (e.g., difficulty staying awake, yawning) and behaviors associated with sleepiness that are observed in the classroom setting, such as irritability (Owens, Spirito, McGuinn, & Nobile, 2000). The TDSQ consists of 10 items rated on a 3-point scale ranging from "usually" (every day) to "never or rarely" (less than once per week). For the present study, the mean of six items pertaining specifically to daytime sleepiness was calculated, with higher mean scores indicating greater daytime sleepiness ($\alpha = .82$).

## Covariates

### Pubertal Development

The Physical Development Scale (Petersen, Crockett, Richards, & Boxer, 1988) is a validated, noninvasive self-report measure assessing pubertal development. There are separate forms for males and females to complete (six items on each); a mean score of five items pertaining specifically to physical indicators of puberty was calculated for analyses ($\alpha$ = .70 and .76 for females and males, respectively).

### Medication Use

The Services for Children and Adolescents Parent Interview (Jensen et al., 2004) is a clinician-administered interview that asks parents whether their children are receiving a variety of pharmacological and nonpharmacological treatments and adapted for this study to include sleep medication. In the present study, current medication use for attention, behavioral, emotional, or sleep problems was included as a binary (yes/no) variable.

### Internalizing Symptoms

The Revised Children's Anxiety and Depression Scale (RCADS; Chorpita, Moffitt, & Gray, 2005) is a 47-item adolescent-report measure that assesses *DSM*-based anxiety and depression symptoms on a 4-point scale (1 = *never*, 4 = *always*). The RCADS has demonstrated excellent reliability and validity in clinical and school-based samples (Ebesutani et al., 2011), including youth with ADHD specifically (Becker, Schindler, et al., 2018). For the present study, the average of all items except three that related to sleep was calculated for a mean internalizing score that was independent of sleep difficulty ($\alpha = .96$).

### Data Analysis Plan

All analyses were conducted in SPSS, Version 25. A series of analyses of covariance (ANCOVAs) were conducted to analyze the difference between participants with and without ADHD on parent- and adolescent-reported technology use, controlling for sex, given known differences in technology use between males and females (Lee, Mcenany, & Weekes, 1999). Partial eta-squared was calculated as a measure of effect size, with .0099, .0588, and .1379 as benchmarks for small, medium, and large effects, respectively (Richardson, 2011). Next, hierarchical regressions were conducted with the full sample to evaluate the link between technology use and sleep. All analyses included sex, pubertal development, ADHD group status, medication status, and RCADS total internalizing problems in the first step as covariates, and technology use in the second step. These covariates were chosen given the known differences in sleep that emerge during pubertal maturation generally and between males and females (Johnson, Roth, Schultz, & Breslau, 2006), as well as to control for any effects of pharmacological treatments and comorbid internalizing symptoms (Becker, Langberg, & Byars, 2015). Lastly, moderation analyses were conducted using the PROCESS macro, Version 3 (Hayes, 2017). Group status (ADHD or comparison) was included as a moderator of the relationship between parent-rated technology variables and adolescent/teacher-rated sleep/sleepiness. All moderation analyses also included the covariates described above.

## Results

Missing data were minimal across all study variables. With the exception of the TDSQ, the percent of data missing for included variables was 0–1.7%. Thirty-six participants (11.9%) were missing TDSQ data. Participants who had missing teacher data did not differ significantly from those who had complete teacher data on ADHD status, race, sex, ethnicity, FSIQ, primary household income, or any technology or sleep variables ($ps > .10$). As a result, pairwise deletion was used for missing data.

Descriptive information on the study variables and results of ANCOVA are presented in Table II. Based on adolescent report, relative to adolescents without ADHD, adolescents with ADHD reported significantly greater video game use, talking/video chatting on the phone, and total technology use, above any effects of sex. There were no significant differences on emailing/messaging on social media or texting/instant messaging.

According to parent report, relative to adolescents without ADHD, parents indicated adolescents with ADHD spend more time playing video or computer games and watching television/movies, as well as more time across technologies, above any effects of sex. On average, parents of youth with ADHD reported that their child spends 3 hr a day using technology, whereas parents of youth without ADHD reported daily technology use of 2 hr, 20 min. Adolescents with ADHD were rated as spending double the amount of time playing video games relative to their peers without ADHD (61 vs. 31 min, respectively), and as spending eight more minutes daily watching television/movies. There were no significant differences on time using a mobile phone.

Separate regression analyses were conducted with adolescent total technology use predicting adolescent-rated sleep outcomes (i.e., sleep-wake problems, total hours slept on school nights, daytime sleepiness), controlling for medication status, ADHD group status, pubertal development, sex, and internalizing symptoms. Results are presented in Table III. Results revealed that greater adolescent-reported technology use was significantly associated with more sleep-wake problems and less school-night time in bed. Specifically, for every one-point increase in adolescent-reported total technology use, the sleep-wake problems subscale increased by 0.31 points ($b = 0.31$). Additionally, for every one-point increase in adolescent-reported technology use, adolescents reported a 0.09 hr (5.4 min) decrease in total time in bed ($b = -0.09$). Adolescent-reported technology use was unassociated with adolescent-reported daytime sleepiness.

Separate regression analyses were also conducted to examine parent-reported technology use in relation to the same adolescent-rated sleep outcomes as well as teacher-rated daytime sleepiness, with the same covariates. Results are presented in Table IV. Over and above the effects of the covariates, more parent-rated technology use was significantly associated with greater adolescent-reported sleep-wake problems and less school-night time in bed. For every minute increase in parent-reported technology use, adolescents reported a 0.01 point increase in sleep-wake problems ($b = 0.01$). Further, for every minute increase in parent-rated technology use, adolescents reported a 0.18 min reduction in total time in bed ($b = -0.003$), meaning that for every hour of additional technology use, school-night time in bed reduced by 11 min. More

**Table II.** *Descriptive Statistics and Comparisons of Technology Variables Between Adolescents With and Without Attention-Deficit/Hyperactivity Disorder*

| | ADHD, *M* (*SD*) | Comparison, *M* (*SD*) | *F*-test significance, $\eta^2$ |
|---|---|---|---|
| Parent report (min) | | | |
| Total technology use | 177.07 (114.35) | 136.16 (72.33) | $p < .001$, $\eta^2 = .04$ |
| Video/computer game | 61.17 (62.82) | 30.89 (45.29) | $p < .001$, $\eta^2 = .04$ |
| TV/movie | 59.38 (48.13) | 51.45 (40.16) | $p = .031$, $\eta^2 = .02$ |
| Text/internet/video message on phone | 56.51 (61.20) | 53.81 (35.58) | $p = .258$, $\eta^2 < .01$ |
| Adolescent-report | | | |
| Total technology use | 7.08 (4.17) | 5.93 (2.69) | $p = .004$, $\eta^2 = .03$ |
| Video content/games | 3.11 (1.42) | 2.35 (1.16) | $p < .001$, $\eta^2 = .06$ |
| Emailing/messages | 1.18 (1.43) | 1.10 (1.01) | $p = .376$, $\eta^2 < .01$ |
| Texting/instant message | 1.62 (1.52) | 1.60 (1.14) | $p = .584$, $\eta^2 < .01$ |
| Phone/video chat | 1.17 (1.26) | 0.88 (0.88) | $p = .011$, $\eta^2 = .02$ |

*Note*. Adolescents reported on their technology use on a 6-point Likert scale (range 0–5), with greater numbers indicating greater amount of technology use. Response anchors for adolescent-reported technology use were: 0 = *never*; 1 = *less than 1 hr*; 2 = *about 1–2 hr*; 3 = *about 2–3 hr*; 4 = *about 3–4 hr*; and 5 = *more than 4 hr*, and adolescent-report total technology use is the sum of the individual items. *F*-test significance includes sex as covariate. ADHD = attention-deficit/hyperactivity disorder.

**Table III.** *Hierarchical Linear Regression Analyses of the Effects of Adolescent-Reported Total Technology Use on Adolescent-Reported Sleep and Daytime Sleepiness*

| Dependent variables | $F$ | $R^2$ | $\Delta F$ | $\Delta R^2$ | $p$ (of $\Delta F$) |
|---|---|---|---|---|---|
| SHS sleep/wake problems | 25.93 | .35 | 15.61 | .04 | <.001 |
| SHS time in bed | 6.73 | .12 | 25.75 | .08 | <.001 |
| PDSS | 21.16 | .31 | 1.77 | <.01 | .185 |

*Note*. First step of all analyses include sex, ADHD group status, medication use status, pubertal status, and adolescent-reported internalizing problems. ADHD = attention-deficit/hyperactivity disorder; PDSS = Pediatric Daytime Sleepiness Scale; SHS = sleep habits survey.

**Table IV.** *Hierarchical Linear Regression Analyses of the Effects of Parent-Reported Total Technology Use on Sleep and Daytime Sleepiness*

| Dependent variables | $F$ | $R^2$ | $\Delta F$ | $\Delta R^2$ | $p$ (of $\Delta F$) |
|---|---|---|---|---|---|
| SHS sleep/wake problems | 24.34 | .34 | 9.08 | .02 | .003 |
| SHS time in bed | 5.23 | .10 | 17.14 | .05 | <.001 |
| PDSS | 21.61 | .31 | 3.67 | .01 | .057 |
| TDSQ | 4.30 | .09 | 16.34 | .06 | <.001 |

*Note*. SHS and PDSS are adolescent-reported; TDSQ is teacher-reported. First step of all analyses include sex, ADHD group status, medication use status, pubertal status, and adolescent-reported internalizing problems. ADHD = attention-deficit/hyperactivity disorder; PDSS = Pediatric Daytime Sleepiness Scale; SHS = Sleep Habits Survey; TDSQ = Teacher's Daytime Sleepiness Questionnaire.

parent-reported technology use was also significantly associated with greater teacher-reported daytime sleepiness but not adolescent-reported daytime sleepiness when controlling for the effects of the covariates. For every additional minute of parent-reported technology use, the TDSQ increased by 0.004 units ($b = 0.004$).

Moderation analyses revealed that ADHD status moderated the relation between parent-reported technology use and teacher-rated daytime sleepiness when controlling for sex, medication status, pubertal development, and total internalizing symptoms ($F[1,254] = 4.46$, $\Delta R^2 = .02$, $p = .036$). Specifically, parent-reported technology use was associated with higher teacher-rated daytime sleepiness in adolescents with ADHD ($b = 0.005$, $SE = 0.001$, 95% CI [0.003, 0.008], $t = 4.58$, $p < .001$) but was unassociated with teacher-reported sleepiness in adolescents without ADHD (95% CI [−0.004, 0.005], $p = .85$). This means that for adolescents with ADHD, a 1-min increase in parent-reported technology use was linked to a 0.005 increase on the TDSQ. All other moderation analyses did not indicate significant effects of ADHD status on the relation between parent- or adolescent-reported technology use and sleep/sleepiness outcomes (all $p$s > .07).

## Discussion

The purpose of the present study was to evaluate rates of technology use in adolescents with and without ADHD and to examine the effects of technology use on sleep and daytime sleepiness. As hypothesized, adolescents with ADHD had significantly higher rates of technology use relative to their peers without ADHD, although this was not consistent across all forms of technology. This was the first study to examine a variety of different types of technology use according to both parents and adolescents in a sample that included youth with and without ADHD. In this sample, parents reported that adolescents with ADHD spend more time playing video/computer games and watching television/movies compared to adolescents without ADHD, whereas adolescents with ADHD also reported greater levels of video content (including video games) and more time spent talking on the phone/video chatting compared to adolescents without ADHD. In all, adolescents with ADHD spent twice as much time playing

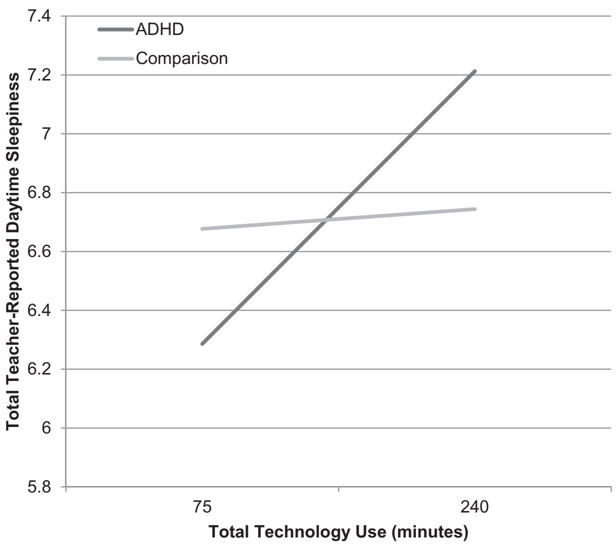


**Figure 1.** Parent-reported technology use is associated with teacher-reported daytime sleepiness for adolescents with ADHD but not adolescents without ADHD. ADHD = attention-deficit/hyperactivity disorder.

video games daily than their peers without ADHD. This extends past research concluding that youth with ADHD are at risk for excessive video game use by confirming this difference using adolescent report (Mazurek & Engelhardt, 2013). However, the lack of differences in either parent- or adolescent-reported mobile phone use between adolescents with and without ADHD is counter to studies in the adult literature linking elevated ADHD symptoms with problematic mobile phone use (Seo et al., 2015). ADHD may not emerge as a risk factor for problematic phone use until after the middle-school period, perhaps because mobile phone use is more ubiquitous among adolescents generally (Rideout et al., 2015).

Both adolescent- and parent-reported technology use was linked to poorer sleep and parent-reported technology was also related to increased daytime sleepiness, even when controlling for a host of other variables linked to sleep/sleepiness including ADHD status, medication use, pubertal development, sex, and internalizing symptoms. Total technology use was associated with more adolescent-reported sleep-wake problems, less school-night time in bed, and more teacher-reported daytime sleepiness. The majority of these relations did not significantly differ between adolescents with and without ADHD, suggesting that technology use is associated with poorer sleep regardless of ADHD status. However, technology use was positively associated with teacher-rated daytime sleepiness only among youth with ADHD. Although previous studies have evaluated the link between technology use and daytime sleepiness in youth, including adolescents with ADHD, this is the first time that increased technology use was found to also be associated with teacher-rated sleepiness, indicating the effects of technology use extend to the classroom setting in youth with ADHD (Becker & Lienesch, 2018; Hale & Guan, 2015). Daytime sleepiness predicts poorer academic performance in middle-school-aged students with ADHD (Drake et al., 2003; Langberg, Dvorsky, Marshall, & Evans, 2013). As such, greater rates of technology use may be indirectly linked to poorer school-related outcomes in this population, perhaps due to problems with sleep/sleepiness. Future research should explore this possibility.

It is important to note that although there were significant associations between technology use and sleep, these associations were relatively small in magnitude (e.g., each additional hour of parent-reported technology use was linked to an 11-min reduction in sleep). This is in line with other recent findings that technology use or screen time has a relatively small but significant effect on sleep in youth (e.g., every hour of screen time use is associated with 3–8 fewer minutes of sleep in children; Przybylski, 2018). This suggests that although global technology use is important to consider when evaluating for and treating sleep problems in adolescents, it is likely that more nuanced examinations of technology use (e.g., types of technology used, purpose of the use, time of day) can more effectively pinpoint specific technology-related intervention targets. In addition, there may be contextual factors related to technology use, including some that may be especially relevant to adolescents with ADHD, that could exacerbate the negative relation of technology use to sleep, such as oppositional behaviors, parenting, or motivations for technology use (e.g., fear of missing out).

The present study had several strengths, including a large sample, well-defined groups, validated sleep measures, and use of multiple informants. However, sleep and technology use were assessed purely via subjective measures; future studies should incorporate objective measures of sleep, such as actigraphy. To date, there has been very little research evaluating the validity of parent- and adolescent-reported technology use, which has been noted as a limitation in this field (Hale & Guan, 2015). Nevertheless, a recent review of the effects of technology on sleep by Hale and Guan (2015) found that 99% of studies completed to date have relied on parent/youth report of both sleep and technology. Technology use could also be examined via daily diaries or a web-based application that objectively monitors use of mobile phones and other devices. It is important to note the timeframe for technology use was not consistently measured between parent and adolescent reporters. Specifically, whereas adolescents were asked about their habits over the course of the day, parents were asked about their adolescents' technology use in the evening; follow-up studies should investigate whether there is a cumulative effect of daily technology use on sleep or if these effects are driven by use immediately before bedtime. In addition, technology use was assessed across domains without considering differential effects of active versus passive types of technology use. There is some evidence to suggest that active technology (e.g., video games) has a greater effect on sleep than passive technology (e.g., television), specifically when used in the hour before bed (Gradisar et al., 2013). An important future direction is to examine whether this type of technology use has a similar effect on sleep in adolescents with ADHD, especially given the greater video game use among this population.

Further, the cross-sectional nature of the study precludes the ability to make causal inferences. Longitudinal and experimental designs should be used to gain further understanding of the effects of technology use on subsequent sleep problems. Lastly, although a number of theoretically linked important variables were controlled for in our analyses, there are additional covariates that could be controlled for or examined in more details in future studies. For instance, although we controlled for sex in our analyses, a more nuanced approach would examine the effects of sex on the association between technology use and sleep, given differences in technology use and sleep between male and female adolescents (Hysing et al., 2015; Lee et al., 1999).

## Conclusions

Adolescents with ADHD engage in greater total video game time according to both parent- and adolescent-report relative to adolescents without ADHD, irrespective of sex. Adolescents with ADHD also reported spending more time talking/video chatting on their phones relative to peers without ADHD, whereas parents reported that adolescents with ADHD spend more time watching television/movies. Further, both adolescent- and parent-reported technology use was linked to a number of adolescent- and teacher-rated sleep outcomes, including sleep-wake problems, school-night time in bed, and daytime sleepiness. These associations were present above the effects of ADHD/sleep medications, sex, pubertal development, and internalizing symptoms. Further, whereas associations between technology use and sleep did not differ between adolescents with and without ADHD, a link between technology use and teacher-reported daytime sleepiness was only present in youth with ADHD, suggesting the effects of technology use may extend to classroom functioning in this population. Future research should evaluate these relations using longitudinal and objective data.

This study extends the current state of the field by confirming that adolescents with ADHD engage in more technology use generally, and particularly video game use, than adolescents without ADHD and by demonstrating within- and cross-rater associations between technology use and poorer sleep and increased daytime sleepiness. Additionally, the associations of technology use with sleep are similar for adolescents with and without ADHD, but only extend to daytime sleepiness in the classroom in youth with ADHD. Health-care providers and clinicians should consider asking parents about their child's technology use to determine whether their patients are at risk for sleep problems, particularly if there is a history of daytime sleepiness in school. This is especially important during adolescence, when youth are more likely to experience difficulty sleeping and increased daytime sleepiness (Gradisar et al., 2011; Millman, 2005). For adolescents who display a reduced sleep duration or have difficulty initiating/maintaining sleep, health-care providers should recommend reducing their technology use throughout the day and provide information on the link between technology use and reduced sleep quality and quantity. It may be especially important to focus on technology use in the hours before bedtime (Gradisar et al., 2013). Even if adolescents are unwilling to completely disengage from technology use a full 1–2 hr before bedtime, they may be willing to disengage 30 min before bedtime and/or to use evening modes/blue light blocking applications.

Further, when working specifically with youth with a diagnosis of ADHD, health-care providers should inquire about the presence of daytime sleepiness at school, ideally by gathering information from the adolescent's teachers directly. For those who display elevated daytime sleepiness, a recommendation to reduce the amount of technology use should be conveyed. It is likely that this information will need to be shared, and reviewed, with both adolescents and their parents. Parents may be especially interested in recent experimental research showing shortened sleep duration to cause poorer daytime functioning (including inattention and oppositionality) in adolescents with ADHD (Becker, Epstein, et al., 2018), as well as prospective research linking technology use to increased ADHD symptoms over time in adolescence (Ra et al., 2018). Importantly, if sleep psychoeducation is insufficient and adolescents continue to experience problematic sleep, perhaps in part due to poor sleep habits including technology use, more intensive interventions may be warranted (e.g., Harvey et al., 2018).

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