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The Prospective Association Between Electronic Device Use Before Bedtime and Academic Attainment in Adolescents

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A B S T R A C T

Purpose: To examine longitudinal associations between five commonly used technology devices prior to bedtime and real-life academic outcomes in adolescents.
Methods: A total of 853 adolescents were recruited to a three-year prospective cohort study, with annual assessments. Academic grades/levels for three core subjects (English, Mathematics, and Science) were extracted from school records, and standardized (z-scores) were derived at the end of each academic year. A validated questionnaire was used to determine the frequency of using five types of technology (television viewing, video gaming, mobile telephone use, listening to music, and social networking) before bedtime.
Results: After adjustment, English attainment was the subject most affected by prebedtime technology use, where three of five technologies assessed were negatively and prospectively associated (social networking [$\beta = -.07$ and $p = .024$], video gaming [$\beta = -.10$ and $p = .008$], and mobile telephone [$\beta = -.07$ and p=.017]). Social networking ($\beta = -.07$and $p = .042$), television viewing ($\beta = -.08$ and $p = .044$), and mobile telephones ($\beta = -.07$ and $p = .031$) were associated with significant impairment in English for girls whereas attainment in boys was most impaired by video gaming ($\beta = -.12$ and $p = .014$).
Conclusions: The use of electronic devices by adolescents before bedtime may reduce their academic attainment, but apart from video gaming for boys, the negative impact of near bedtime technology use on academic performance is small.

IMPLICATIONS AND CONTRIBUTION

Several concerns have been raised regarding the health and performance implications of increasing technology use by adolescents, particularly near bedtime. This prospective study observed that technology use near bedtime (particularly social networking by girls and video gaming by boys) was associated with reduced academic performance, but the effect was small.

Electronic media device availability, accessibility, and utilization have precipitously increased among adolescents [1]. Frequent exposure to different types of electronic media devices has been linked to multiple adverse outcomes including poor sleep [2], higher body mass index (BMI) [3], reduced daytime functioning [4], decreased working memory in video gamers [5], and increased alcohol and tobacco use in adolescents [1]. A birth cohort study found that excessive television viewing during adolescence was the strongest predictor of subjective report of leaving school without academic qualifications [6]. Recent studies have also shown deleterious effects of technology use upon academic performance [7,8]. The majority of studies, however, have not focused on frequency of prebedtime use of technology. In contrast to the many studies that have documented undesirable effects of different types of technology use, beneficial outcomes have also been reported. For example,

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previous studies have documented that video gaming can improve problem-solving abilities [9], visual-spatial skills [9], and reaction times [10]. Another study found a positive association between the duration of home internet use and performance on standardized reading tests as well as grade point average in adolescents from low-income families [11]. More recently, another group demonstrated that Facebook users (≥1 year) scored higher on assessments of verbal ability, spelling, and working memory compared to less frequent users [12]. These more recent studies suggest that device type as well as the content exposure are likely to be important for educational-related outcomes, as reflected in a recent systematic review of prospective studies [13]. Indeed, there is increasing interest in internet-based interventions to enhance knowledge and educational outcomes surrounding health-related behaviors [14] as well as for reducing suicidal ideation and depressive symptoms among adolescents [15].

Little is known about the prospective effects of bedtime use of technologies on academic outcomes in adolescents [16]. Contemporary adolescents now have access to a diverse range of portable devices and engaging in technology-based activities prebedtime is widespread. Sleep, as well as hours spent undertaking homework may be mediators of the relationship between technology use and academic performance. Interestingly, gender differences between technology use by type (girls engage more with mobile phones whereas boys tend to interact with video games) [11,17] as well as performance outcomes in core academic subjects [18] have been documented [19]. However, some have relied on subjective academic outcomes [20,21], while others have investigated the contribution of a combination of lifestyle behaviors to abilities of preadolescents in reading, writing, and mathematics [22] yet none have focused on the effects of prebedtime technology use upon academic attainment in core subjects. Given the documented technology type preference observed by gender this warrants investigation of the potential prospective effects of technology type on academic attainment according to gender.

To date, there are very few studies that have investigated the prospective associations between frequency of bedtime use for a range of specific technologies and objective academic attainment in the three core academic subjects (English, Mathematics, and Science). Furthermore, there are no studies of this type that have examined potential gender differences in relation to academic-related outcomes. Sleep as well as time spent undertaking homework, are potential mediators of the relationship between technology use and academic attainment, but these have scarcely been examined. The objectives of our study were three-fold. First, we sought to examine the potential associations between near bedtime use of five different technology types and real-life academic attainment outcomes in a large adolescent cohort. Second, we assessed potential gender differences in these relationships. Third, we investigated the possibility of sleep and hours spent undertaking homework in a typical week as potential mediators of the relationship between technology use and academic attainment. We hypothesized that: (1) there would be a negative effect of electronic device use before bedtime upon objective academic attainment; (2) gender differences would be observed for these associations; and (3) sleep and/or hours spent completing homework in a typical week would mediate the relationship between technology use and academic performance.

Methods

Nine secondary schools in the Midlands region of England (UK) were approached for participation in the Midlands Adolescent Schools Sleep Education Study. Schools were selected to ensure different school types within different areas were included, which served as a proxy of socio-economic status. Eight schools agreed to participate in the three-year cohort study. Parents/guardians of all students registered in year 7/8 (age 11–13 years) of each participating school were sent a letter outlining the study and requesting consent during the first term of academic year 2011/2012. Parental response rate was 80% and a total of 892 adolescents were eligible to participate. These students were approached for study participation. Other study criteria were that: (1) the student provided assent; (2) they were not taking sleep medication (prescribed/over the counter); (3) they did not have a physician diagnosed sleep disorder; and (4) they had not travelled to a different time zone four weeks prior to providing data at the time points assessed. Baseline data were collected during academic year 2011/2012 where 853 adolescents participated, and data collection for the same measures was repeated during the same term for a further two years (2012/2013 and 2013/2014). The study received ethical approval from the University of Birmingham Research Ethics Committee (ERN_08-437).

Academic attainment

The primary outcome measure, academic attainment, was objectively determined at the end of each academic year from school records for English, Mathematics, and Science for each student. Given that the methods of assessment differ according to school type as well as year group, we generated an academic attainment z-score for each year of study and for each participating school. Science at baseline was assessed in all schools except for one. Complete data on Science attainment were obtained for all schools at the last two time points. Mathematics and English were assessed in all schools at all three time points.

Technology use

Participants were asked to estimate the frequency of multiple types of technology use from a questionnaire [23]. Specifically, participants stated the frequency of using the following technologies on weekdays 2 hours before bedtime: television viewing, video gaming, mobile phones, computer/laptop use for social networking, and listening to music. Response options for each technology were “never,” “sometimes, ” “usually, ” and “always” (coded 0–3) with one response permitted for each technology. Participants completed this questionnaire online in a classroom setting with instructions by a trained researcher. The online questionnaire was completed under exam-like conditions to minimize peer influence on reporting outcomes to reduce potential biases.

Other measures

A number of demographic data were collected: age (years), gender, and school type (independent/public). At each assessment, height (to the nearest .5 cm) and weight (to the nearest .1 kg) were obtained to derive BMI (kg/m^2). Given that our group previously demonstrated a negative linear relationship between obesity and academic outcomes, this was considered to be an important confounder of the relationship under investigation [3]. The online questionnaire also required participants to complete the Cleveland

Adolescent Sleepiness Questionnaire [24] at each assessment and a total score was calculated to estimate daytime sleepiness (higher scores represented higher levels). Given the well documented relationship between daytime sleepiness and academic performance [25], we also included this as a potential confounder. We further obtained objective estimates of total sleep time (TST) from wrist actigraphy (GT3X+, The ActiGraph), worn by participants for seven consecutive days/nights. TST was used in our analysis as a potential mediator of the relationship between technology use and academic attainment, based on previous evidence which suggests that bedtime technology use interferes with several sleep outcomes [2]. The previously validated Schools Sleep Habits Survey also formed a part of the online survey and we extracted data to obtain information on the number of hours spent performing homework across a typical week, which was used to adjust for time–displacement (the more time spent on using technology, the less time spent doing homework). All of the above measures were selected a priori based on scientific knowledge and were used as potential confounders of the associations explored.

Statistical analysis

All statistical analyses were performed using Stata version 13 (Texas). Academic outcomes (Mathematics, English, and Science) were transformed into z-scores due to different schools having different assessment criteria. We explored z-score for student participants for each participating school to ensure sufficient variability. The primary analysis was performed by fitting latent growth models using linear mixed models, which took account of the within-subject variability, using academic results at all three time points. Models were fitted to determine the prospective associations between each of the five types of technology for each of the academic subjects. We present two models for the total sample where model 1 adjusts for age, gender, BMI, school type, and daytime sleepiness, and model 2 further adjusts for the number of weekly hours spent on homework (Table 2). We also repeated our analysis according to gender and present the unadjusted and adjusted (age, BMI, school type, level of daytime sleepiness, and number of weekly hours spent on homework) findings in Figure 1. In the adjusted models; BMI, level of daytime sleepiness and number of hours spent on homework were fitted as time varying covariates. Mediation analysis was performed using Stata's multilevel mediation analysis command (ml_mediation). The output produces include direct, indirect, and total effects from the model equations.

Results

The majority (75%) of the sample attended public schools and 25% attended an independent school. The median age of participants at baseline was 12 years (Inter Quartile Range: 12,13), and 45.1% of the sample was male. The mean BMI at baseline was 19.8 $\pm$ 3.6 kg/m^2 and the mean Cleveland Adolescent Sleepiness Questionnaire score was 29 $\pm$ 8. Both BMI and daytime sleepiness levels, steadily increased at each of the two subsequent assessments. The sample characteristics at all three time points assessed are fully described in Table 1.

Prospective associations between bedtime use of technology type and academic attainment

English (β = −.07 and p = .024) and Science (β = −.06 and p = .017) were negatively affected by social networking (Table 2). TV viewing was negatively and significantly associated with attainment in English and Science in the univariate model, but these associations diminished after full adjustment. Music listening was not significantly associated with attainment in any subject before or after adjustment. Video gaming was negatively and significantly associated with all subjects before adjustment and the relationship remained for English attainment after adjustment (β = −.10 and p = .008). Mobile phone use was negatively associated with attainment in English (β = −.07 and p = .017) and Mathematics (β = −.07 and p = .008), after adjustment (Table 2).

Gender differences in technology types and academic attainment

Figure 1 shows the gender differences for each technology type in relation to the three core academic subjects over time. Adolescent girls who reported use of all technologies showed a significant decrease in attainment for English only after adjustment (β = −.03 and p = .016). Girls who engaged in social networking (β = −.07 and p = .042), TV viewing (β = −.08 and p = .044), and mobile telephone use (β = −.07 and p = .031) had significantly lower English attainment, after adjustment. After adjustment, boys who engaged in video gaming before bedtime had significantly reduced attainment in English (β = −.12 and p = .014) but not the other two subjects. Frequency of use of the five technologies examined at each of the three annual assessments is highlighted in Figure 2.

Mediation analysis

There was no evidence to support sleep as a mediator of technology use for academic performance outcomes. The proportion of total effect mediated by sleep was lower than 5% for English, Science, and Mathematics.

For English, almost 30% of the total effect of the relationship between TV viewing and performance was mediated by time spent doing homework/studying. Other technologies were not mediated as much by the number of hours spent completing homework in a typical week. For Science, the highest proportion of total effect mediated by time spent undertaking homework was on the relationship between video game and academic performance (58%) and the relationship between TV viewing and Science (36%). There was no evidence that time spent completing homework was a mediator between Mathematics performance and any of the technologies assessed in our study.

Discussion

Our prospective analysis of a large cohort of adolescents, shows that social networking negatively impacted Science and English attainment while video gaming affected English only, and mobile phone use was linked to poorer grades in English and Mathematics. There were gender differences with girls being most affected by social networking, television viewing, and mobile phone usage in relation to performance in English while the association in boys was observed to be greatest with video gaming. TST and hours spent completing homework in a typical week did not mediate the relationship between technology use and academic attainment.

One previous study explored the prospective associations between six technology-related activities (time spent on Internet, email, computer games, studying, video gaming, and television viewing) and cognitive achievement using three subsets of a standardized test [19]. There was a marked increase in most technology-related activities over the five-year follow up. Concurrently, a

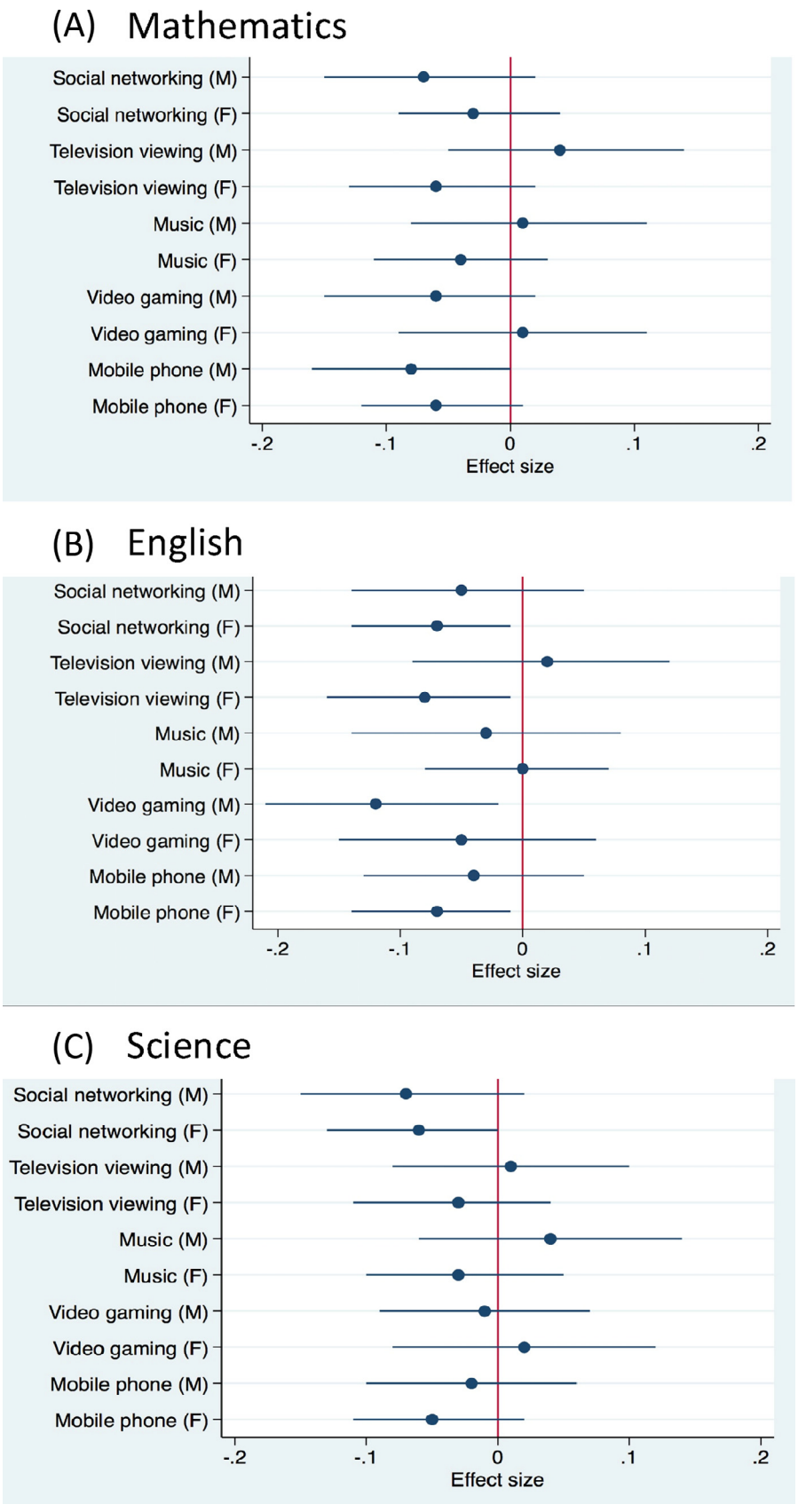

Figure 1. Effect sizes of technology types used before bedtime on the three core academic subjects, reported by gender.

Table 1
Characteristics of the adolescent cohort at each of the annual time points assessed in the Midlands Adolescent Schools Sleep Education Study

Characteristics	
Age at baseline (y), median (IQR)	12 (12,13)
Male, n (%)	385/853 (45.1)
BMI (kg/m^2), mean ± SD	
Baseline (n = 502)	19.8 ± 3.6
Year 1 follow up (n = 466)	20.4 ± 5.2
Year 2 follow up (n = 322)	21.0 ± 3.6
School type (n = 853)	
Public 1, n (%)	112 (13.1)
Independent 1, n (%)	61 (7.2)
Public 2, n (%)	62 (7.3)
Public 3, n (%)	224 (26.3)
Independent 2, n (%)	67 (7.9)
Public 4, n (%)	175 (20.5)
Independent 3, n (%)	87 (10.2)
Public 5, n (%)	65 (7.6)
CASQ score, mean ± SD	
Baseline (n = 594)	29 ± 8
Year 1 follow up (n = 649)	30 ± 8
Year 2 follow up (n = 362)	31 ± 8
English z-score, median (IQR)	
Baseline (n = 563)	.14 (−.52, .65)
Year 1 follow up (n = 533)	.27 (−.48, .69)
Year 2 follow up (n = 523)	−.04 (−.54, .75)
Mathematics z-score, median (IQR)	
Baseline (n = 570)	−.06 (−.65, .68)
Year 1 follow up (n = 533)	.17 (−.66, .75)
Year 2 follow up (n = 523)	.22 (−.58, .72)
Science z-score, median (IQR)	
Baseline (n = 369)[#]	−.03 (−.70, .92)
Year 1 follow up (n = 522)	.12 (−.76, .77)
Year 2 follow up (n = 528)	.12 (−.58, .82)
Homework (hours p/week)	
Baseline (n = 485)	3.53 ± 2.92
Year 1 follow up (n = 494)	3.69 ± 3.64
Year 2 follow up (n = 293)	5.84 ± 4.79

BMI = body mass index; CASQ = Cleveland Adolescent Sleepiness Questionnaire; IQR = Inter Quartile Range; SD = standard deviation;
[#] One school did not assess Science at baseline.

decline in all three cognitive assessments was observed, with passage comprehension yielding the greatest effect, where the mean test score reduced by 7.84 points. The only consistent positive association noted was for computer games, passage comprehension, and applied problems, although these relationships did not remain significant (or positive) for some ethnicities/genders [19]. Unexpectedly, computer use for studying was not positively associated with any cognitive outcome in boys, but was positive and significant in girls for letter-word identification. Previously, it was purported that electronic device use could displace time spent studying [26], although this hypothesis was refuted by another group [19], and was not supported by our findings.

Our study differs from the study discussed above in two key ways. First, while it should be noted that Hofferth & Moon obtained detailed information surrounding technology use including time diaries of activity type, duration, and location, we examined frequency of use (not duration) of specific technology devices specifically prior to bedtime. Second, our academic attainment outcome was derived from real-life performance outcomes rather than standardized cognitive tests. The main issue with these types of assessments relates to factors on the test day, which may falsely affect scores [27]. We suggest that academic performance should be assessed over the entire academic year to overcome these limitations. In our study, we examined the overall average of English, Mathematics, and Science at the end of each academic year to better evaluate academic performance. Better performance in these subjects is a known predictor for university entrance [28] and life satisfaction [29].

In our total sample, the use of each type of technology before bedtime, except for music listening and TV viewing, was associated with poorer English outcomes. Given the notable gender differences in use of specific technologies [11,17] and academic task-specific abilities [18], our large sample permitted scrutiny of these relationships according to gender. We observed that girls were more extensively affected by technology in relation to education attainment compared to boys. Social networking, TV viewing, and mobile phone before bedtime negatively affected English attainment in girls, whereas adolescent boys who engaged in video gaming prior to bedtime had poorer English attainment, even after adjustment for estimated number of hours spent completing homework in a typical week.

Some have argued that the differences in academic outcomes depend on media content, which may mediate the relationships

Table 2
Longitudinal associations among total technology use and individual technologies in relation to subject-specific academic attainment in a large cohort of UK adolescents

Technology type	Subject	*n*	Model 1 Effect size (95% CI) *p* value	*n*	Model 2 Effect size (95% CI) *p* value
Social networking	English	546	−.06 (−.11, −.01) .012	442	−.07 (−.12, −.01) .024
	Mathematics	545	−.06 (−.11, −.02) .004	442	−.05 (−.10, .01) .094
	Science	519	−.09 (−.13, −.04) <.001	408	−.06 (−.12, −.01) .017
Television viewing	English	544	−.07 (−.13, −.02) .007	435	−.06 (−.12, .01) .080
	Mathematics	543	−.04 (−.09, .00) .070	435	−.04 (−.10, .02) .186
	Science	519	−.06 (−.11, −.01) .028	402	−.02 (−.08, .04) .435
Music	English	543	.02 (−.04, .07) .503	438	−.02 (−.08, .04) .545
	Mathematics	542	−.02 (−.07, .03) .445	438	−.04 (−.10, .02) .172
	Science	517	.02 (−.03, .07) .378	405	−.01 (−.07, .05) .827
Video gaming	English	547	−.15 (-.21, −.09) <.001	440	−.10 (−.17, −.03) .008
	Mathematics	546	−.06 (−.11, −.01) .024	440	−.05 (−.11, .01) .131
	Science	521	−.09 (−.14, −.04) .001	407	.00 (−.07, .07) .993
Mobile phone	English	546	−.05 (−.10, .00) .044	443	−.07 (−.12, −.01) .017
	Mathematics	545	−.07 (−.11, −.03) .001	443	−.07 (−.12, −.02) .008
	Science	520	−.05 (−.09, .00) .041	410	−.03 (−.09, .02) .182

Model 1: adjusted for age, gender, school type, body mass index, and daytime sleepiness (derived from the total CASQ score).
Model 2: further adjusted for total number of estimated hours spent on completing homework (weekly).
CI = confidence interval; n = number of participants.

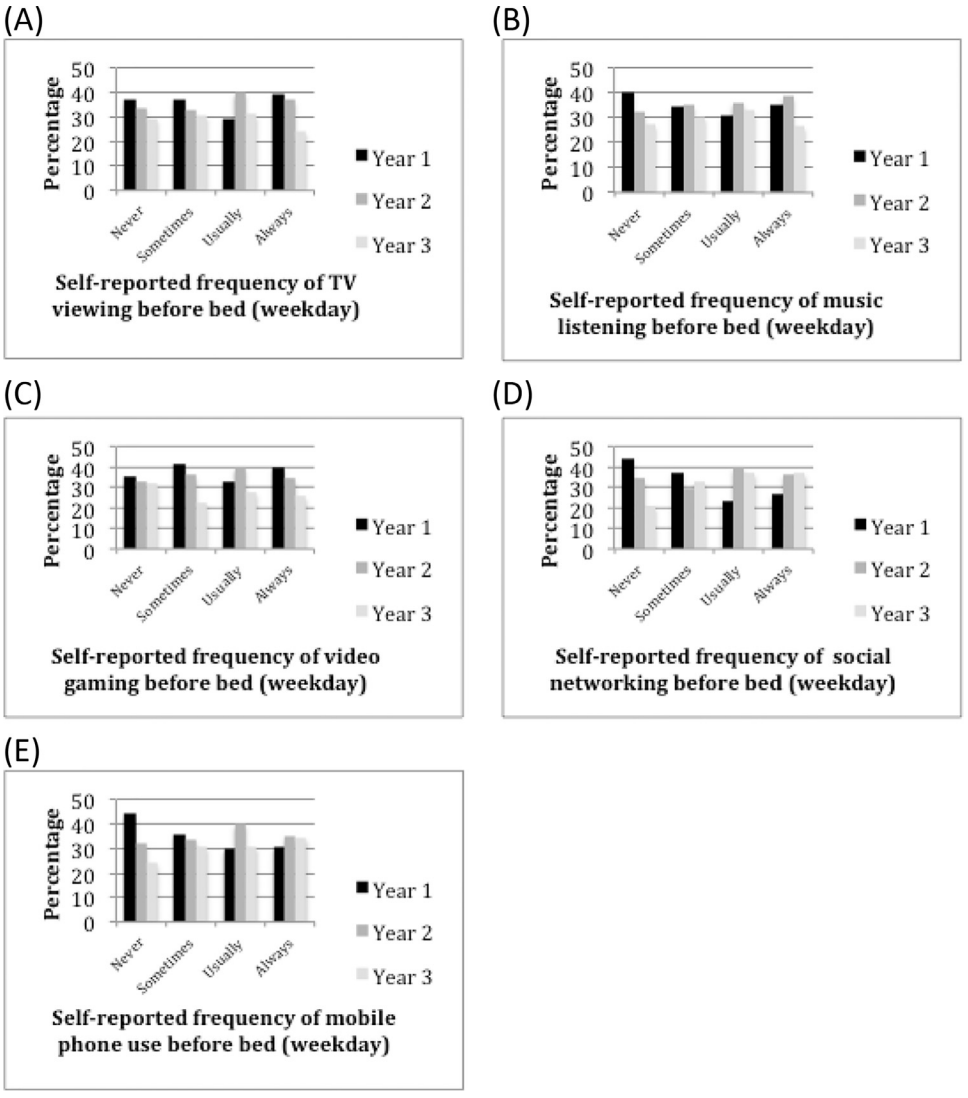

Figure 2. Changes in the frequency of technology use, according to device type and time point. (A) denotes the percentage of participants in each response category for television viewing on weekdays according to each time point assessed; (B) highlights the percentage of participants in each response option for listening to music before bed on weekdays across each annual time point; (C) depicts the percentage of participants for the frequency of video gaming before bed on weekdays across the three annual assessments; (D) denotes the percentage of participants in each response category for social networking on weekdays according to each time point assessed; (E) shows the percentage of participants in each response category for mobile telephone use before bed on weekdays across each of the years assessed.

observed in our study [9]. One early study showed a 13% increase in the odds of poorer academic performance in 4,508 US young adolescents with increasing television viewing (weekdays) and an 11% increased risk in those with access to more television channels [30]. Content was determined according to the frequency of watching R-rated movies (not intended for those <17 years old), and showed that boys who watched this type of content had >60% increased risk of poorer self-reported academic outcomes [30]. Mechanisms surrounding our observations are likely to be related to content exposure in addition to the frequency and duration of use. Indeed, our findings demonstrate that social networking, TV viewing, and video gaming were the activities that most influenced academic outcomes. The content of these two media-related activities are unlikely to incorporate any academic element although it may be argued that social networking requires English language skills and video gaming requires decision-making and spatial abilities. Sleep disruption, as a result of technology use preceding bedtime, may result in daytime sleepiness with downstream effects on academic performance and attainment. However, despite adjusting for levels of daytime sleepiness in our study, the observations remained.

Although our study did not focus on the content of technology use, we accounted for other factors reported to influence academic performance such as age [31], daytime sleepiness [25], BMI [3], and school type [32], as well as number of hours undertaking homework activities in a typical week [26]. Future studies should plan to identify content as well as simultaneous use of multiple technologies in relation to real-life academic outcomes in adolescents to establish a comprehensive understanding of the influence that technology has upon key academic outcomes.

Given the well documented contribution that daytime sleepiness and sleep-disordered breathing has upon academic outcomes [25], the bedroom environment is likely to play an important role. We have previously demonstrated multiple

harmful effects upon sleep parameters with increasing frequency of bedtime technology [2] and similar findings have been reported by others [33]. While neither of these studies sought to examine bedtime technology use in relation to academic outcomes, one possible explanation of the results observed in the present study is that one or more sleep features mediate the relationship. Our analysis, however, found no support for objectively estimated TST as a mediator of the technology-academic attainment association. In the meantime, recommendations to limit the use of prebedtime technology within the bedroom environment could be made as a precautionary measure.

The strength of our study lies within the large sample of students with a range of academic capabilities, and socioeconomic backgrounds. Furthermore, we gathered objective academic data from school records. We were also able to adjust for range of potential important confounding factors and aspects that have been overlooked in previous studies such as number of hours spent performing homework-related activities. We also investigated gender differences in relation to the associations assessed given the large body of evidence, which suggests there are differences between girls and boys for use of specific technologies [11,17] and academic-related tasks [18].

Our study has a number of limitations. First, we did not have complete technology used data for all participants recruited at baseline for the two follow-up assessments due to various reasons including withdrawal, relocation to another school, other academic commitments, absenteeism, or tardiness. Moreover, due to one school having no academic performance outcomes at baseline for Science, this resulted in smaller numbers at baseline for this core subject. Second, frequency of the use of technologies used was assessed using a questionnaire, with potential recall and social desirability biases. Moreover, the tool employed would characterize individuals that check their mobile phone every night before bed as a frequent user but this does not capture duration of use. The tool employed assumes consistent use of technology according to the response options offered. These self-reported estimates may introduce systematic error given that the assumption is that participants who indicated “usually” were consistently heavier users of technology compared to those who reported “sometimes” using the technology. Future studies could consider utilizing mobile technologies to accurately assess frequency as well as multitasking media and duration of time spent using electronic devices prior to bedtime. Third, we did not obtain information about media content or simultaneous technology use. Finally, we specifically asked about technology use before bedtime, and did not capture habits across an entire day, which may partially explain the observed small effect sizes.

Our prospective findings, gathered from a large sample of adolescents, show small adverse effects on core academic attainment when engaging in technology-related activities before bedtime. Key gender differences in the impact of technology use on academic performance were also observed even after adjustment for the number of self-reported hours of homework undertaken in a typical week. Positive effects of technology use were not observed for any academic outcome. The focus of our study was technology use before bedtime, and therefore may not be reflective of overall daily technology use (frequency, duration, and content) and its impact on education. While detailed prospective studies are required, our findings are reassuring giving the pervasive bedtime technology use among adolescents.

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