Journal of Adolescence 83 (2020) 122–130

Contents lists available at ScienceDirect

Journal of Adolescence

journal homepage: www.elsevier.com/locate/adolescence

Social media use predicts later sleep timing and greater sleep variability: An ecological momentary assessment study of youth at high and low familial risk for depression

Jessica L. Hamilton[a], Shannon Chand[a], Lauren Reinhardt[a], Cecile D. Ladouceur[a,b], Jennifer S. Silk[a,b], Megan Moreno[c], Peter L. Franzen[a], Lauren M. Bylsma[a,*]

[a] Department of Psychiatry, University of Pittsburgh, USA
[b] Department of Psychology, University of Pittsburgh, USA
[c] Department of Pediatrics, University of Wisconsin School of Medicine, USA

ARTICLE INFO

Handling editor; Dr. J. Tubman

Keywords:
Social media
Electronic media use
Sleep
Depression risk
Adolescence

ABSTRACT

Introduction: Social media (SM) use has been increasingly recognized as a potential contributor to poor sleep. Few studies have examined SM use and sleep using ecological momentary assessment (EMA), compared different types of media use (SM, television, gaming), or examined whether youth at high and low familial risk for depression are differentially affected by SM use.
Methods: The current study included 76 youth (46% female; Mean age = 11.28 years) who were recruited based on parental history of recurrent depression (N = 35 high risk; N = 41 low risk) in the United States. Youth completed a 9-day EMA protocol, which included current activity at time of prompt and daily sleep onset and offset times. Regression and multilevel models were conducted to examine the effects of media use on sleep.
Results: Results indicated that youth who used more SM (mean and number of days) went to sleep later, but did not have shorter sleep duration. Youth with more SM use also had higher levels of variability of both sleep timing and sleep duration across the 9-day period. There were no effects of gaming or TV on sleep, and youth at high risk for depression did not have differences in SM use or its effects on sleep compared to low-risk youth.
Conclusions: These findings indicate a unique impact of SM use on sleep timing and variability for youth (regardless of risk status), which may suggest a unique and modifiable pathway through which SM use contributes to poor health.

1. Introduction

Sleep is critical for physical and mental health, particularly during the developmental period of adolescence (Dahl & Lewin, 2002). Most adolescents receive less than the recommended 8–10 h of sleep per night (Hirshkowitz et al., 2015). Importantly, sleep duration has decreased among youth in recent years, which coincides with the advent and rapid growth in social media (SM) use (Twenge, Krizan, & Hisler, 2017). Indeed, cross-sectional studies of adolescents indicate that higher levels of SM use are linked with sleep outcomes, including poorer sleep quality (Levenson, Shensa, Sidani, Colditz, & Primack, 2017, 2016; Woods & Scott, 2016), shorter sleep duration (Kelly, Zilanawala, Booker, & Sacker, 2018; Reynolds, Meltzer, Dorrian, Centofanti, & Biggs, 2019), later sleep

* Corresponding author. 3811 O'Hara Street, Pittsburgh, PA, 15213, USA.
E-mail address: bylsmal@pitt.edu (L.M. Bylsma).

https://doi.org/10.1016/j.adolescence.2020.07.009
Received 10 January 2020; Received in revised form 8 July 2020; Accepted 10 July 2020

timing, longer onset latency, and more daytime sleepiness (Scott, Biello, & Woods, 2019b). To date, no known study has investigated the relationship between SM use and sleep variability (e.g., extent of regularity and/or fluctuations in sleep onset timing and duration), which is linked with mood disorders, suicidality (Bernert, Hom, Iwata, & Joiner, 2017; Soehner et al., 2019), and medical health conditions (Slavish, Taylor, & Lichstein, 2019). Importantly, sleep disruption (i.e., disruption in duration, timing, and/or variability) is a risk factor for physical and mental health problems (Roberts, Roberts, & Duong, 2009), and adolescence begins a period of increasing risk for the onset of most mental health problems, including depression and suicide (CDC, 2018). Thus, it is critical to understand whether SM use is uniquely associated with sleep disruption among adolescents, particularly among youth who might be more vulnerable to the effects of SM use.

Although most types of electronic media, including television and videogaming, have been linked to sleep outcomes (for reviews, see Cain & Gradisar, 2010; Carter, Rees, Hale, Bhattacharjee, & Paradkar, 2016; Hale & Guan, 2015), the *social* aspect of SM may be particularly impactful for youth. While the conceptualization of SM has changed over time with the expansion of applications and platforms, social networking sites (which include features of text/direct messaging) possess certain affordances that distinguish this subset of SM [hereafter referred to as SM]. According to affordance-based models of SM (Moreno & Uhls, 2019; Nesi, Choukas-Bradley, & Prinstein, 2018), SM has varying functional affordances, including levels of availability, visualness (i.e., extent of photos/videos), permanence, publicness, cue absence (i.e., degree of physical [facial/tonal] cues), quantifiablility (e.g., countable social metrics), and asynchronicity (i.e., time lapse between communication) (Nesi et al., 2018). These functional affordances and features make this type of SM particularly important to consider for youth outcomes, including sleep (Scott & Woods, 2019). In the context of developmental changes in the importance of peer relationships and status, adolescents have heightened sensitivity to potential social reward or threat (Breiner et al., 2018; Gunther Moor, van Leijenhorst, Rombouts, Crone, & Van der Molen, 2010). This sensitivity may be more pronounced on SM given the social and emotional affordances it provides (Moreno & Uhls, 2019). Compared to other forms of media, SM has rich social content that is readily accessible any time of the day or night, which may heighten the negative effects of SM use on sleep (Crone & Konijn, 2018). Further, adolescents may fear missing out on online interactions that can have offline consequences for peer relationships and status within networks (Scott, Biello, & Woods, 2019a; Scott & Woods, 2018), leading to a feeling of constant threat or worry when not online. Combined with 24/7 expectations of availability, further exacerbated by SM notifications and smartphone accessibility, youth may be able to use SM more easily in bed and have more difficulty disengaging from SM at night, thereby impacting sleep (Scott et al., 2019a; Scott & Woods, 2019).

Little research, however, has empirically examined the associations of different types of media use and sleep, which may shed light on the specificity of these effects to different types of media and potential mechanisms through which media impacts youth sleep. One recent cross-sectional study compared the effects of social messaging (e.g., email, instant messaging, texting, social media sites), television/movie watching, gaming (e.g., playing games on the computer, TV, or a handheld device), and web-surfing on sleep duration and insomnia symptoms (Li et al., 2019). This study demonstrated that all forms of electronic media use were associated with more insomnia symptoms and shorter sleep duration among 15-year-olds (Li et al., 2019). Yet, research is needed that uses prospective designs and assessments at multiple timepoints, rather than relying on questionnaires of SM use and sleep administered at a single timepoint. Identifying differential effects of media use using a more fine-grained approach may shed light on the pathways through which media impacts sleep, and whether SM use has unique effects.

Importantly, there are important individual differences in whether youth are vulnerable to the negative effects of SM use on sleep. Youth with depression or elevated symptoms are more likely to use SM (Shensa, Sidani, Dew, Escobar-Viera, & Primack, 2018) and use it in ways that may be problematic and exacerbate symptoms (Radovic, Gmelin, Stein, & Miller, 2017). Thus, it is possible that youth who are at heightened risk for depression will be more negatively affected by SM. Offspring of parents with a history of depression are often considered to be 'high risk' for depression and other psychopathology (Weissman et al., 2006). Specifically, youth of parents with a depression history are at 3–4 times increased risk for depression (Weissman et al., 2016), sleep disturbance (Hamilton, Ladouceur, Silk, Franzen, & Bylsma, 2020), and emotion dysregulation (Silk, Shaw, Skuban, Oland, & Kovacs, 2006). Despite not currently having depression themselves, offspring of depressed parents may possess certain cognitive-affective vulnerabilities, such as poorer emotion regulation (Silk et al., 2009) or cognitive biases (Joormann, Gilbert, & Gotlib, 2010), that increase their use of SM or intensify affective responses to SM content. It is also possible that parenting and environmental differences among those with and without depression histories (Kopala-Sibley et al., 2017) influence the structure and supervision of youth, including the development and enforcement of rules around technology use or bedtime. As such, these youth could represent a vulnerable group for SM use and its negative consequences. To date, however, no known study has investigated differential patterns or effects of SM use among offspring of parents with depression, which may provide a potential target for selected prevention programs.

1.1. The current study

To advance our understanding of SM use and sleep, the current study uses ecological momentary assessment (EMA) to capture digital media use and compare the effects of different types of electronic media use, including SM, television (TV), and gaming, on domains of sleep. Importantly, the current study also examines multiple sleep characteristics using an ecologically-valid approach of daily sleep diaries to assess sleep duration, timing, and variability across multiple days, and evaluates differential effects of SM use on sleep youth at high- and low-risk for depression (based on having a biological parent with a recurrent history of depression). Overall, we hypothesize that youth with higher levels of all media use (SM, TV, or gaming) will have poorer sleep (shorter duration, later timing, and more variable), but that SM use will have a particularly strong association with sleep domains compared to TV or gaming use. As an exploratory aim, we examined whether youth with parents with a depression history and without any lifetime history of psychopathology (high- and low-risk, respectively) had different patterns of SM use. We further tested whether high risk youth were more vulnerable to the effect of SM use on sleep, expecting that high-risk youth would be more vulnerable to SM's effects. Identifying whether high- and low- risk youth have distinct SM use and its potential impact on sleep may provide preliminary information about the potential pathways through which SM use affects risk for mental health symptoms.

2. Method

2.1. Study recruitment and procedure

Recruitment and Clinical Assessment. Male and female youth aged 9 to 13 were recruited from the community as part of a larger study on neurobehavioral indices of emotional functioning and depression risk (Hamilton et al., 2020). Families were recruited to participate in the study through local advertising (e.g., websites, research registries). Potential participants completed a phone screening about parental and child mental health history, and eligible participants (both child and one of his/her biological parents) completed a semi-structured diagnostic interview with trained interviewers to confirm diagnoses. Youth were recruited on the basis of having at least one biological parent with recurrent depression (2 or more episodes; 88% were mothers), deemed "High Risk". Youth of parents without a lifetime history of psychopathology were considered to be at "Low Risk." Given the larger goal of the study to identify risk factors for future depression among youth, exclusion criteria for all participants included parental history of mania or psychosis, which may differently affect youth outcomes and identified risk factors. For youth to be eligible for the 'Low Risk' group, parents could not have any current or lifetime history of psychopathology. Similarly, youth in the study were excluded if they met diagnostic criteria for a current or lifetime history of a depressive disorder, or any pervasive developmental disorder, intellectual disability, history of substance abuse/dependence, or a serious head injury or neurological condition, which may impact completion of study procedures. Participants who were eligible following the clinical interview completed questionnaires about youth depressive symptoms, pubertal development, and demographic information. Both parent and child provided consent and assent prior to the study procedures and were compensated for their time and participation. The local Institutional Review Board approved all study procedures. Data collection occurred throughout the year from 2015 to 2017. In the current study, each participant had one period of EMA data collection.

EMA Protocol. Following the clinical assessments, eligible youth then completed a 9-day EMA data collection for five weekdays and four weekend days throughout the year (always beginning on a Saturday). EMA included dropdown menu options about current activity at time of the prompt (e.g., media use) and a morning sleep diary for youth to report sleep onset and offset times. The protocol was administered using a custom app (based on the WebDataXpress platform developed locally) installed on Android smartphones, which were provided to all participants for the study duration. Participants were permitted to download child-appropriate external applications on the smartphones and use the phone for their personal use during the study (although voice calls and SMS picture messaging were blocked).

Weekday prompts were delivered three times during specified time frames (between 4:00PM-9:30PM) and once in the morning. Weekend prompts were delivered eight times and occurred at random between 10:00AM–10:00PM (not more than once per 1.5 h). Participants included in the current study had to have completed at least one daily sleep diary and have complete data on independent variables included in analyses, which resulted in 76 people (out of 89 who completed EMA). There were no significant differences on study variables between participants in the present study compared to those not included from the larger sample.

2.2. Baseline measures

Youth Depressive Symptoms. Youth reported their depressive symptoms using the 33-item Mood and Feelings Questionnaire (MFQ)-Long Form (Angold et al., 1995). The sleep items were removed from the total score to avoid confounding in analyzing the association of sleep and depressive symptoms, with scores ranging from 0 to 61 for the MFQ. Internal reliability for the MFQ in the current sample with sleep items removed ($\alpha = 0.96$) was excellent.

Puberty. We assessed pubertal development using the Pubertal Development Scale (Petersen, Crockett, Richards, & Boxer, 1988). The PDS is a well-validated measure of self-reported pubertal development, with higher scores reflecting more pubertal maturation. Scores were calculated using a coding system that parallels the Tanner Stages and converts the PDS to a 5-point scale (Shirtcliff, Dahl, & Pollak, 2009).

2.3. EMA measures

Sleep Duration and Timing. On morning sleep diaries, youth reported the timing of sleep onset ("About what time did you go to sleep last night?"), which was used to assess the onset of sleep, which is one key characteristic of sleep timing. Youth also reported timing of sleep offset ("About what time did you wake up this morning?"). Sleep onset and offset times were used to calculate a proxy of sleep duration (e.g., difference between sleep offset and onset times). Since the sleep diary did not include an item on waking after sleep onset, estimates of sleep duration are likely to be inflated in some individuals. Self-reported sleep has demonstrated modest to strong correlations with actigraphy-derived sleep parameters among youth (Wolfson et al., 2003). Variability of sleep was calculated using each individual's standard deviation for both sleep duration and sleep onset over the 9-day period (Bei et al., 2017).

Media Use Frequency. On the EMA prompt, participants were asked "What were you doing when the phone beeped?" Participants could respond with up to 43 possible activities, which included media use and an 'Other' category with text write-in. The 'Social media use' [SM use] category was defined as "Facebook, Instagram, Twitter, or other social networking" and "Texting a friend or chatting online." The questions did not specify the device on which these activities occurred. Responses were dichotomized at each prompt (0/1) based on participant endorsement of either activity. TV/Video-watching included the item "Watching TV or a movie at home or someone's house." Gaming included items of "Playing video games (on a game console or computer)" or "Online gaming with another person," which was dichotomized (0/1) at each prompt. As noted above, online gaming was not considered a form of SM in the current study. A total of 12 prompts were originally coded by the participant as 'Other' and recoded by three trained coders into the media use categories based on written responses with excellent agreement (K = 0.95). Example items recoded for each category included "playing Minecraft" or "playing games on phone" (recoded Gaming), "posting on Instagram" (recoded SM use), and "watching videos" (recoded TV or Video). Each person's individual mean (or ratio) of the endorsed category relative to the total number of EMA prompts completed that day was uniformly multiplied by 100 to reflect percentage of daily media use as a proxy for frequency. Daily and overall means, as well as the total number of days where participants used each media were calculated. Given the younger sample in this study and frequency of SM endorsed (see below), individuals also were categorized as a "SM User (1)" vs. "Non-SM user (0)" whether they reported any or no SM use over the 9-day EMA period.

2.4. Statistical analyses

First, we examined our data distributions for media use and sleep variables. There were 9 outliers for sleep variables and mean media use across all observations (± 2 SD above or below the mean); thus, analyses were conducted both with and without these values for sensitivity. Given similar study findings, results from the full sample are presented. Descriptive statistics and bivariate correlations for primary variables were examined, and *t*-tests were conducted to examine demographic differences of media use by sex and age. We also examined media use by weekday vs. weekend and timing of study completion (school-break/school year). In all analyses, we covaried youth pubertal development, age, sex, youth current depressive symptoms, and school-break timing.

For analyses examining whether media use was associated with sleep variability of timing and duration, we conducted linear regression analyses in R 3.6 with average levels (or percentage) of media use endorsed as the main predictors. Given the large number of zeros for SM use and gaming, we also examined the number of days for each type of media use over the study period. Supplemental analyses were conducted to determine the effects of whether the individual did or did not use any SM or gaming (dichotomized variable of SM user (1) or non-SM user (0)). For analyses predicting daily sleep timing (i.e., onset) and duration, we conducted multilevel modeling in R with Full Information Maximum Likelihood (FIML). However, due to limited daily endorsement of media use, models included media use at the between-person level only, including mean-levels of use over the 9-day period and number of days of media use predicting average (intercept) of daily sleep timing and sleep duration over the study period. Fixed effects were entered for all covariates, and random effects were included for the intercepts of sleep parameters. Supplemental analyses were conducted for weekdays and weekend days separately for sleep timing and duration. For our exploratory aim to examine whether high and low risk youth had different effects of SM on sleep, we conducted t-tests to assess differences in SM use and moderation analyses with mean-level variables predicting sleep variability and the intercept of sleep duration and timing. When significant, these interactions were probed for high and low risk youth at high and low levels of SM use.

3. Results

A total of 76 youth were included in the present analyses: 35 (51% female) high-risk and 41 (56% female) low-risk youth. Demographic information and means of primary study variables for the full sample and by risk status are included in Table 1. Bivariate correlations are provided in Table 2. On average, youth completed 32 EMA prompts (68%; range from 5 to 46) out of 47 possible diaries. Total number of EMA responses were not correlated with any study variables ($r's < 0.17$). Overall, 61% of youth reported any SM use, 62% reported any videogame use, and 93% reported any TV use at the time of prompt over the 9 days. There were no differences in media use for those who completed the study in the school year versus school break ($t's < 1.4$). Interestingly, there were no differences in sleep duration or timing between youth at high- and low-risk ($t < 1.33$), nor were there differences in SM, TV, or gaming use ($t < 0.75$).

3.1. Media use predicting sleep duration and timing

In our multilevel models, there was significant variance in average sleep duration and sleep timing at both the between- and within-person levels. Overall, our models indicated that there was a significant main effect of mean SM use, but not gaming or television use, on timing (Table 3), such that youth with more SM use had later average sleep timing over the EMA period. Similarly, there was a significant effect of days of SM use, but not gaming or television, on timing, with more SM days associated with later sleep timing during the study period (Est = .17, $SE = 0.06$, $p < .01$). There were no main effects on sleep duration of media use mean (Table 3) or number of days for SM use ($Est = -0.06$, $SE = 0.05$, $p = .23$), gaming ($Est = 0.05$, $SE = 0.06$, $p = .40$), or television ($Est = -0.02$, $SE = 0.05$, $p = .75$). For our supplemental analyses by week and weekend days, results remained largely the same. However, the strength of association between SM use and later timing was larger for weekdays than weekend days (Supplemental Tables 1 and 2).

3.2. Media use predicting variability of sleep duration and timing

For our regression analyses predicting variability of sleep timing and duration over the 9-day period, we found a significant main

Table 1
Demographics of overall sample and by youth high- and low-risk status.

	Overall Sample (N = 76)		High Risk (N = 35)		Low Risk (N = 41)		Statistical Difference
	M (N)	SD (%)	*M (N)*	*SD (%)*	*M (N)*	*SD (%)*	*t* (χ^2)
Demographic							
Sex (% male)	41	54%	18	51%	23	56%	.17
Child Age	11.28	1.45	11.29	1.53	11.26	1.39	.11
Race (% AA)	40	53%	20	57%	20	49%	.53
Puberty	2.88	1.15	3.00	1.15	2.78	1.15	.82
Depressive Symptoms	8.23	10.74	9.60	10.88	7.07	10.62	1.02
Sleep Variables							
Sleep Duration Mean	9.05	0.98	9.12	1.02	8.99	.94	.53
Sleep Duration Variability	1.45	0.98	1.62	1.23	1.31	.69	1.33
Sleep Onset Mean	23.12	1.50	23.30	1.61	22.96	1.40	.97
Sleep Onset Variability	1.07	0.53	1.12	.59	1.02	.49	.78
Media Use							
SM use	9.57	16.80	8.04	13.43	10.88	19.30	.75
TV use	19.00	15.41	18.82	16.63	19.15	14.50	.09
Videogame use	9.09	14.01	8.46	11.28	9.63	16.11	.37
SM days	1.87	2.35	1.63	2.26	2.07	2.43	.82
TV days	1.93	2.35	3.20	2.50	4.02	2.32	.26
Videogame days	3.64	2.31	1.86	2.25	2.00	2.24	1.57

Note: *$p < .05$, **$p < .01$, ***$p < .001$. Youth who did not identify as White or Black/African American identified as biracial (N = 3), Asian American (N = 1), Pacific Islander (N = 2), or Native American (N = 2). Sex is coded as 0 = female; 1 = male. SM = Social Media. Use reflects percentage of EMA prompts endorsed out of total number of EMA prompts over study period. Days reflects total number of days in which media was endorsed for each type.

Table 2
Bivariate correlations of study variables.

Variable	1	2	3	4	5	6	7	8	9	10
1. Child Age	–									
2. Puberty	.55	–								
3. Depressive Symptoms	.15	.17	–							
4. Sleep Onset Mean	.16	.19	.10	–						
5. Sleep Duration Mean	-.03	.04	.12	-.59	–					
6. Sleep Duration Variability	.06	.20	.18	.48	-.15	–				
7. Sleep Onset Variability	-.03	.18	.15	.44	-.18	.70	–			
8. SM use	.06	-.02	-.04	.22	-.13	.24	.28	–		
9. TV use	-.09	.02	-.02	-.16	.06	.05	-.00	.08	–	
10. Videogame use	.03	-.17	-.12	-.03	.02	-.14	-.19	-.02	-.12	–

Note. SM = Social Media. Correlations above 0.22 and above are significant.

Table 3
Multi-level models of media use predicting average sleep timing and sleep duration.

Predictors	Sleep Timing			Sleep Duration		
	Estimates	CI	p	Estimates	CI	p
(Intercept)	21.67	19.34–24.00	< 0.001	9.86	7.99–11.73	< 0.001
Risk Status	0.10	−0.46–0.67	0.72	0.07	−0.38–0.53	0.75
Child age	0.00	−0.24–0.24	0.99	−0.09	−0.28–0.11	0.39
Sex	0.61	−0.06–1.28	0.08	−0.41	−0.95–0.13	0.14
Depressive Symptoms	−0.00	−0.03–0.03	0.90	0.01	−0.01–0.03	0.41
Puberty	0.31	−0.00–0.62	0.06	0.05	−0.20–0.31	0.68
School-break	1.25	0.63–1.86	< 0.001	−0.12	−0.61–0.38	0.64
TV use	−0.02	−0.04–0.00	0.08	0.00	−0.01–0.02	0.57
Videogame use	−0.01	−0.04–0.01	0.28	0.01	−0.01–0.03	0.24
SM use	0.02	0.01–0.04	0.01	−0.01	−0.02–0.01	0.22
Random Effects						
Residual Variance (σ^2)	1.38*			2.56*		
Random intercept variance (τ_{00})	1.28*			0.60*		

Note: CI = Confidence Intervals; SM = Social Media. Media use reflects the percentage of endorsed prompts relative to total study EMA prompts over the entire study period. Risk status coded as 0 = Low Risk; 1 = High Risk. Sex is coded as 0 = Female; 1 = Male. Sleep timing refers to the timing of sleep onset.

Table 4
Effects of media use on variability of sleep timing and sleep duration.

	Sleep Timing SD			Sleep Duration SD		
Predictors	Estimates	CI	p	Estimates	CI	p
(Intercept)	1.51	0.54–2.48	< 0.001	1.25	−0.59–3.10	0.19
Risk Status	0.07	−0.17–0.30	0.58	0.28	−0.16–0.72	0.22
Child Age	−0.09	−0.18–0.01	0.09	−0.06	−0.25–0.13	0.52
Sex	0.22	−0.05–0.50	0.12	0.20	−0.33–0.73	0.47
Depressive Symptoms	0.01	−0.00–0.02	0.18	0.01	−0.01–0.04	0.18
Puberty	0.13	0.01–0.26	0.04	0.18	−0.06–0.42	0.15
School-break	−0.07	−0.33–0.18	0.57	−0.14	−0.63–0.34	0.56
TV Use Mean	−0.00	−0.01–0.00	0.40	−0.00	−0.01–0.01	0.98
Videogame Use Mean	−0.01	−0.02–0.00	0.10	−0.01	−0.03–0.01	0.36
SM Use Mean	0.01	0.00–0.02	< 0.001	0.02	0.00–0.03	0.02
R^2/adjusted R^2	0.219/0.113			0.167/0.053		

Note: CI = Confidence Interval; SD = Standard Deviation (used to reflect variability); SM = Social Media. Media use reflects the percentage of endorsed prompts relative to total study EMA prompts over the entire study period. Risk status coded as 0 = Low Risk; 1 = High Risk. Sex is coded as 0 = Female; 1 = Male. Sleep timing refers to the timing of sleep onset.

effect of average SM use on both variability of sleep timing and duration (Table 4). There were no effects of videogames or television on variability in timing or sleep duration. Our models examining number of days of media use on sleep variability also supported our findings, with more days of SM use associated with more variability of timing (*Est* = .17, CI = 0.10-0.23, $p < .001$) and duration (*Est* = 0.20, CI = 0.06-0.34, $p = .01$). Our supplemental analyses examining youth with and without any SM use also yielded similar results (Supplemental Table 3).

3.3. Differences in SM use and sleep among youth at high and low risk

For our interactive analyses of youth risk status and SM use on sleep, there were no significant effects of risk status and SM use predicting sleep duration (*Est* = .01; SE = 0.01, $p = .42$) or timing (*Est* = 0.02; SE = 0.02, $p = .27$). Similarly, there were no significant interactive effects with youth risk status (high vs low) and SM use predicting timing (Est = 0.001, SE = 0.01, $p = .86$) or variability in sleep timing or duration (Est = 0.01, SE = 0.01; $p = .65$).

4. Discussion

Social media (SM) use has received increasing attention as a potential contributor to poor sleep and mental health problems among adolescents. Despite public concern and speculation about the impact of SM use (Twenge, Joiner, Rogers, & Martin, 2018), less research has examined the specific impact of SM use compared to other forms of digital media, particularly on sleep— which is critical for healthy adolescent development. To address these gaps, the current study used EMA to compare SM use with other prominent forms of media, including gaming and television, and key sleep outcomes (duration, timing, and variability), which are linked to a range of health and academic outcomes. Further, exploratory analyses examined whether youth at high-risk for depression (based on a parental depression history) were more likely to use SM or more vulnerable to the effects of SM use on poor sleep than lower-risk peers.

Overall, our results indicate that SM use has a unique effect on sleep health outcomes, such that higher levels of SM use predict later sleep timing and greater sleep variability (of both sleep duration and timing). However, there was no effect of SM use on sleep duration. Despite higher overall endorsement of TV and comparable gaming levels at EMA prompts as SM, there were no effects of gaming or TV use on sleep outcomes. These findings indicate that SM use has a unique impact on these sleep characteristics (e.g., timing and variability), suggesting that it is not simply the ‘screen time’ of digital media but specific effects of SM that impacts sleep.

It is surprising that SM use was not associated with sleep duration, particularly given that later sleep onset often results in insufficient sleep. It is possible that youth were able to compensate lost sleep by sleeping longer in the morning, or that more fine-grained analyses of individual nights of sleep duration assessed via actigraphy would yield different results. Future research should use these methods to provide more nuanced information and additional characteristics of sleep, including nighttime awakenings, wake after sleep onset, and daytime sleepiness. Regardless, it appears that SM use still contributes to a less regular sleep schedule, as indicated by overall higher levels of variability of timing and duration over a 9-day period. Higher levels of variability may reflect more circadian misalignment among youth, which may contribute to poorer sleep and mood, as well as adverse health outcomes (Bei, Manber, Allen, Trinder, & Wiley, 2017). Importantly, our exploratory findings indicate that youth at high-risk for depression were not more likely to endorse media use, including SM, nor were they more likely to have stronger associations between SM use and sleep. Thus, our findings suggest that certain aspects of sleep, namely timing and variability, may be uniquely impacted by SM use for all youth, regardless of risk status. However, we did not examine other depression vulnerability factors (e.g., rumination, effortful control) (Clifford, Doane, Breitenstein, Grimm, & Lemery-Chalfant, 2020), which may be more pronounced among youth who are high-risk for depression (Loechner et al., 2020), and may exacerbate the effects of SM use on sleep. Such factors should be modeled in larger samples of at-risk youth, particularly using longitudinal and intensive monitoring designs.

Although our study did not explore potential mechanisms through which SM use impacts sleep (Scott & Woods, 2019), there are several theoretical possibilities that warrant attention. First, research on SM use more generally has highlighted the potential for *displacement* effects (i.e., taking time away spent sleeping), 2) *bright and blue light* effects (i.e., bright light, especially blue spectrum wavelength light, suppresses melatonin, thereby delaying sleepiness), and 3) *psychophysiological activation* (i.e., physiologically or psychologically arousing content eliciting positive or negative emotional responses) (Cain & Gradisar, 2010). The unique associations of SM and sleep outcomes, and comparable or higher levels of other media use, may suggest the latter as a potential mechanism through which SM affects youth sleep (Scott & Woods, 2019). First, SM inherently has more *social* content and affordances (Moreno & Uhls, 2019), which is not only designed to keep youth's attention, but it also has more personally-relevant information and quantifiable social feedback (Nesi et al., 2018). Social feedback and one's standing in a peer network are important in adolescence (Nelson, Leibenluft, McClure, & Pine, 2005). Thus, SM may have both more rewarding (e.g., positive comments, likes, new followers) and potentially threatening content (e.g., negative comments, absence of feedback, cyberbullying) (Shapiro & Margolin, 2014). Given that youth are more sensitive to both social reward and threat (Blakemore, 2008) and prone to ruminative processes (Hamilton, Stange, Abramson, & Alloy, 2015), SM may be more difficult to disengage from and also have more affective consequences (Crone & Konijn, 2018; Sherman, Payton, Hernandez, Greenfield, & Dapretto, 2016). This may make it more difficult to wind down and fall asleep, and pre-sleep cognitive arousal may be one way in which SM use affects sleep (Scott & Woods). Thus, it may be that SM confers risk for later sleep timing and more variable sleep schedules through its effects on psychophysiological arousal. However, it would be advantageous for future research to examine neurophysiological processes during SM use, which would provide empirical evidence for this theoretical explanation.

In addition, it would be beneficial to further analyze the different platforms and features within SM (Nesi et al., 2018), given that there are different uses and gratifications that may distinctly impact sleep (Scott & Woods, 2019). Given that SM applications now include features that incorporate aspects of video streaming and gaming, future research is needed to determine whether our findings are replicated when device and behaviors within SM are considered. Although youth may not be using more SM per our EMA prompts, it is possible that SM use may occur on more portable devices than TV or gaming (Twenge, Hisler, & Krizan, 2019), allowing youth to use it in their bed and at night, and potentially out of the purview of parental awareness. Importantly, since we did not capture last timing of use or the device used, our findings cannot necessarily rule out the possibility that SM use is displacing time spent asleep or disrupting it due to blue light emissions. Although this argument has been made by other authors (Boers, Afzali, Newton, & Conrod, 2019), neither study parsed out *when* youth are using SM compared to other forms of digital media and what type of device is being used. This makes it hard to know whether youth with SM use are more likely to be using a smartphone versus other device (e.g., game console), which also was not examined in this study. Future studies should examine the timing of SM use relative to other forms of media, and the specific context in which it is being used (e.g., in bed, at nighttime, on smartphone). Particularly now that nearly all forms of media are now accessible via smartphone, which was less prominent during the years that this study was conducted (2015–2017), it will be important to compare specific types of smartphone use and the times at which youth are accessing it for different purposes. Further, the number of platforms has continued to grow exponentially in recent years, which has also altered how youth are using SM (such as YouTube, group chat). Thus, the findings here may represent only a snapshot into the emerging trends of SM use, which warrant in-depth examination in real time.

Several limitations should be noted, which have implications for study interpretations and future directions. First, although over 90% of youth use SM and 45% report using it “constantly” (Anderson & Jiang, 2018), rates were lower in 2015 (when the current study was launched), particularly among youth under 13. In our study, rates of overall SM use (and gaming use) were relatively low proportionally to the other activities endorsed over the EMA period. Although this time period may not reflect the general trend of SM use in recent years (Anderson & Jiang, 2018), it is important to note that the majority of youth in our study were *not* using SM regularly (or more than 50% of the study period). Consequently, this lower endorsement of SM use limited our ability to test the temporality of SM use and sleep, which makes these findings overall cross-sectional in nature despite the strengths of our assessment approach. It is possible that our study design of providing youth with smartphones altered their engagement with SM and other media. Although youth were permitted to download external applications and use the phone for personal use, it is quite possible that many did not. Given that the age of smartphone ownership and SM use among youth has declined in the US (Anderson & Jiang, 2018), future studies may be able to examine SM use more naturalistically using youth's own smartphones.

It is important to note that youth with SM use during this time period, when SM use lower in this age group, may reflect other ‘third variables’ that explain the relationships found in this study. For instance, more lax parenting practices among parents who allowed SM use for youth under 13 despite media age requirements may account for the observed relationships between SM use and sleep. Parenting styles may similarly explain more variable sleep schedules and later sleep timing, if parents are less involved and/or there are fewer rules set or enforced regarding media use and/or bedtimes (Short et al., 2011). Other individual or environmental factors that were not assessed may also influence sleep timing and regularity, such as exposure to acute or chronic stressors in one's environment and pre-sleep cognitive arousal (Wuyts et al., 2012), which remains important to examine in future studies. The specific characteristics of our sample (e.g., selected on the basis of parental psychopathology) may not generalize across adolescents. However, examining SM use and its effects on sleep in at-risk youth remains an important factor to examine in larger samples, and we hope this study prompts future research in this area, as this may have important clinical implications for prevention and intervention. Although our EMA design provides a unique measure of SM and other media endorsement, it does not capture the full experience of SM, such as duration, timing, and motivations for use, content, or subjective experiences online. There are important differences in *how* youth use SM, and whether SM varies across developmental stages. It will be critical to evaluate the full SM context to better understand the aspects of SM that impact sleep, such as assessing subjective experiences and using novel methods of passive sensing of smartphone-based SM use.

Our study advances the field and our understanding of SM use and sleep in critical ways. Our EMA design provides a distinct measurement of SM and other media use that may be less subject to self-report bias or over-inflated estimates of SM use by youth, which limits the potential for youth with sleep problems simply to perceive more SM use. In addition, our study is the first to examine SM use and sleep outcomes in a sample of youth (ages 9–13) at high- and low risk for depression. Our findings show that SM use impacts sleep timing and variability for youth regardless of depression vulnerability (at least parental depression vulnerability). These findings have important implications for public policy and guidelines involving SM use, including among at-risk youth. Although our findings by no means imply causality on the effects of SM use on sleep outcomes, they do suggest that SM may have a distinct association with sleep health. In particular, SM use impacts later sleep timing and more variable sleep schedules, which are known risk factors for poor physical and mental health outcomes (e.g., depression, suicidality, substance use). Thus, given the body of literature to which our study uniquely adds, it is important for parents, clinicians, and educators to be aware that SM use may be a contributing factor for poor sleep, and that monitoring and regulating SM use is one potential method to improve sleep outcomes during the developmental period of adolescence.

Declaration of competing interest

The authors have no conflicts of interest to declare. This work was supported by NIH grants to Jessica L. Hamilton (T32HL082610) and Lauren M. Bylsma (K01MH104325). Subject recruitment for this project was also supported by an NIH grant to University of Pittsburgh's Clinical and Translational Science Institute (UL1TR001857).

Acknowledgments

We would like to thank Lorraine Scott and Amanda Adams for their contribution to data collection for this study.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.adolescence.2020.07.009.

References

Anderson, M., & Jiang, J. (2018). *Teens, social media, and technology.* (Retrieved from pewresearch.org).

Angold, A., Costello, E. J., Messer, S. C., Pickles, A., Winder, F., & Silver, D. (1995). The development of a short questionnaire for use in epidemiological studies of depression in children and adolescents. *International Journal of Methods in Psychiatric Research, 5*, 237–249.

Bei, B., Manber, R., Allen, N. B., Trinder, J., & Wiley, J. F. (2017). Too long, too short, or too variable? Sleep intraindividual variability and its associations with perceived sleep quality and mood in adolescents during naturalistically unconstrained sleep. *Sleep, 40*(2), https://doi.org/10.1093/sleep/zsw067.

Bernert, R. A., Hom, M. A., Iwata, N. G., & Joiner, T. E. (2017). Objectively assessed sleep variability as an acute warning sign of suicidal ideation in a longitudinal evaluation of young adults at high suicide risk. *Journal of Clinical Psychiatry, 78*(6), e678–e687. https://doi.org/10.4088/JCP.16m11193.

Blakemore, S. J. (2008). The social brain in adolescence. *Nature Reviews Neuroscience, 9*(4), 267–277. https://doi.org/10.1038/nrn2353.

Boers, E., Afzali, M. H., Newton, N., & Conrod, P. (2019). Association of screen time and depression in adolescence. *JAMA Pediatr.*. https://doi.org/10.1001/jamapediatrics.2019.1759.

Breiner, K., Li, A., Cohen, A. O., Steinberg, L., Bonnie, R. J., Scott, E. S., ... Galvan, A. (2018). Combined effects of peer presence, social cues, and rewards on cognitive control in adolescents. *Developmental Psychobiology, 60*(3), 292–302. https://doi.org/10.1002/dev.21599.

Cain, N., & Gradisar, M. (2010). Electronic media use and sleep in school-aged children and adolescents: A review. *Sleep Medicine, 11*(8), 735–742. https://doi.org/10.1016/j.sleep.2010.02.006.

Carter, B., Rees, P., Hale, L., Bhattacharjee, D., & Paradkar, M. S. (2016). Association between portable screen-based media device access or use and sleep outcomes: A systematic review and meta-analysis. *JAMA Pediatrics, 170*(12), 1202–1208. https://doi.org/10.1001/jamapediatrics.2016.2341.

Cdc (2018). Injury prevention and control: WISQARS. Retrieved from https://www.cdc.gov/injury/wisqars/index.html.

Clifford, S., Doane, L. D., Breitenstein, R., Grimm, K. J., & Lemery-Chalfant, K. (2020). Effortful control moderates the relation between electronic-media use and objective sleep indicators in childhood. *Psychological Science, 956797620919432*. https://doi.org/10.1177/0956797620919432.

Crone, E. A., & Konijn, E. A. (2018). Media use and brain development during adolescence. *Nature Communications, 9*(1), https://doi.org/10.1038/s41467-018-03126-x 588.

Dahl, R. E., & Lewin, D. S. (2002). Pathways to adolescent health sleep regulation and behavior. *Journal of Adolescent Health, 31*(6 Suppl), 175–184.

Gunther Moor, B., van Leijenhorst, L., Rombouts, S. A., Crone, E. A., & Van der Molen, M. W. (2010). Do you like me? Neural correlates of social evaluation and developmental trajectories. *Social Neuroscience, 5*, 461–482.

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

Hamilton, J. L., Ladouceur, C. D., Silk, J. S., Franzen, P. L., & Bylsma, L. M. (2020). Higher Rates of Sleep Disturbance Among Offspring of Parents With Recurrent Depression Compared to Offspring of Nondepressed Parents. *Journal of Pediatric Psychology, 45*(1), 1–11. https://doi.org/10.1093/jpepsy/jsz079.

Hamilton, J. L., Stange, J. P., Abramson, L. Y., & Alloy, L. B. (2015). Stress and the development of cognitive vulnerabilities to depression explain sex differences in depressive symptoms during adolescence. *Clincal Psychological Science, 3*(5), 702–714. https://doi.org/10.1177/2167702614545479.

Hirshkowitz, M., Whiton, K., Albert, S. M., Alessi, C., Bruni, O., DonCarlos, L., et al. (2015). National sleep foundation's updated sleep duration recommendations: Final report. *Sleep Health, 1*(4), 233–243. https://doi.org/10.1016/j.sleh.2015.10.004.

Joormann, J., Gilbert, K., & Gotlib, I. H. (2010). Emotion identification in girls at high risk for depression. *Journal of Child Psychology and Psychiatry, 51*(5), 575–582. https://doi.org/10.1111/j.1469-7610.2009.02175.x.

Kelly, Y., Zilanawala, A., Booker, C., & Sacker, A. (2018). Social media use and adolescent mental health: Findings from the UK millennium cohort study. *Eclincal Medicine, 6*, 59–68. https://doi.org/10.1016/j.eclinm.2018.12.005.

Kopala-Sibley, D. C., Jelinek, C., Kessel, E. M., Frost, A., Allmann, A. E. S., & Klein, D. N. (2017). Parental depressive history, parenting styles, and child psychopathology over 6 years: The contribution of each parent's depressive history to the other's parenting styles. *Development and Psychopathology, 29*(4), 1469–1482. https://doi.org/10.1017/S0954579417000396.

Levenson, J. C., Shensa, A., Sidani, J. E., Colditz, J. B., & Primack, B. A. (2016). The association between social media use and sleep disturbance among young adults. *Preventive Medicine, 85*, 36–41. https://doi.org/10.1016/j.ypmed.2016.01.001.

Levenson, J. C., Shensa, A., Sidani, J. E., Colditz, J. B., & Primack, B. A. (2017). Social media use before bed and sleep disturbance among young adults in the United States: A nationally representative study. *Sleep, 40*(9), https://doi.org/10.1093/sleep/zsx113.

Li, X., Buxton, O. M., Lee, S., Chang, A. M., Berger, L. M., & Hale, L. (2019). Sleep mediates the association between adolescent screen time and depressive symptoms. *Sleep Medicine, 57*, 51–60. https://doi.org/10.1016/j.sleep.2019.01.029.

Loechner, J., Sfarlea, A., Starman, K., Oort, F., Thomsen, L. A., Schulte-Korne, G., et al. (2020). Risk of depression in the offspring of parents with depression: The role of emotion regulation, cognitive style, parenting and life events. *Child Psychiatry and Human Development, 51*(2), 294–309. https://doi.org/10.1007/s10578-019-00930-4.

Moreno, M. A., & Uhls, Y. T. (2019). Applying an affordances approach and a developmental lens to approach adolescent social media use. *Digital Health, 5*. https://doi.org/10.1177/2055207619826678 2055207619826678.

Nelson, E. E., Leibenluft, E., McClure, E. B., & Pine, D. S. (2005). The social re-orientation of adolescence: A neuroscience perspective on the process and its relation to psychopathology. *Psychological Medicine, 35*(2), 163–174.

Nesi, J., Choukas-Bradley, S., & Prinstein, M. J. (2018). Transformation of adolescent peer relations in the social media context: Part 1-A theoretical framework and application to dyadic peer relationships. *Clinical Child and Family Psychology Review, 21*(3), 267–294. https://doi.org/10.1007/s10567-018-0261-x.

Petersen, A. C., Crockett, L., Richards, M., & Boxer, A. (1988). A self-report measure of pubertal status: Reliability, validity, and initial norms. *Journal of Youth and Adolescence, 17*, 117–133.

Radovic, A., Gmelin, T., Stein, B. D., & Miller, E. (2017). Depressed adolescents' positive and negative use of social media. *Journal of Adolescence, 55*, 5–15. https://doi.org/10.1016/j.adolescence.2016.12.002.

Reynolds, A. C., Meltzer, L. J., Dorrian, J., Centofanti, S. A., & Biggs, S. N. (2019). Impact of high-frequency email and instant messaging (E/IM) interactions during the hour before bed on self-reported sleep duration and sufficiency in female Australian children and adolescents. *Sleep Health, 5*(1), 64–67. https://doi.org/10.1016/j.sleh.2018.10.008.

Roberts, R. E., Roberts, C. R., & Duong, H. T. (2009). Sleepless in adolescence: Prospective data on sleep deprivation, health and functioning. *Journal of Adolescence, 32*(5), 1045–1057. https://doi.org/10.1016/j.adolescence.2009.03.007.

Scott, H., Biello, S. M., & Woods, H. C. (2019a). Identifying drivers for bedtime social media use despite sleep costs: The adolescent perspective. *Sleep Health*. https://doi.org/10.1016/j.sleh.2019.07.006.

Scott, H., Biello, S. M., & Woods, H. C. (2019b). Social media use and adolescent sleep patterns: Cross-sectional findings from the UK millennium cohort study. *BMJ Open, 9*(9), Article e031161. https://doi.org/10.1136/bmjopen-2019-031161.

Scott, H., & Woods, H. C. (2018). Fear of missing out and sleep: Cognitive behavioural factors in adolescents' nighttime social media use. *Journal of Adolescence, 68*, 61–65. https://doi.org/10.1016/j.adolescence.2018.07.009.

Scott, H., & Woods, H. C. (2019). Understanding links between social media use, sleep and mental health: Recent progress and current challenges. *Current Sleep Medicine Reports, 5*(3), 141–149.

Shapiro, L. A., & Margolin, G. (2014). Growing up wired: Social networking sites and adolescent psychosocial development. *Clinical Child and Family Psychology Review, 17*(1), 1–18.

Shensa, A., Sidani, J. E., Dew, M. A., Escobar-Viera, C. G., & Primack, B. A. (2018). Social media use and depression and anxiety symptoms: A cluster Analysis. *American Journal of Health Behavior, 42*(2), 116–128. https://doi.org/10.5993/AJHB.42.2.11.

Sherman, L. E., Payton, A. A., Hernandez, L. M., Greenfield, P. M., & Dapretto, M. (2016). The power of the like in adolescence: Effects of peer influence on neural and behavioral responses to social media. *Psychological Science, 27*(7), 1027–1035. https://doi.org/10.1177/0956797616645673.

Shirtcliff, E. A., Dahl, R. E., & Pollak, S. D. (2009). Pubertal development: Correspondence between hormonal and physical development. *Child Development, 80*(2), 327–337. https://doi.org/10.1111/j.1467-8624.2009.01263.x.

Short, M. A., Gradisar, M., Wright, H., Lack, L. C., Dohnt, H., & Carskadon, M. A. (2011). Time for bed: Parent-set bedtimes associated with improved sleep and daytime functioning in adolescents. *Sleep, 34*(6), 797–800. https://doi.org/10.5665/SLEEP.1052.

Silk, J. S., Shaw, D. S., Skuban, E. M., Oland, A. A., & Kovacs, M. (2006). Emotion regulation strategies in offspring of childhood-onset depressed mothers. *Journal of Child Psychology and Psychiatry, 47*(1), 69–78. https://doi.org/10.1111/j.1469-7610.2005.01440.x.

Silk, J. S., Ziegler, M. L., Whalen, D. J., Dahl, R. E., Ryan, N. D., Dietz, L. J., ... Williamson, D. E. (2009). Expressed emotion in mothers of currently depressed, remitted, high-risk, and low-risk youth: Links to child depression status and longitudinal course. *Journal of Clinical Child and Adolescent Psychology, 38*(1), 36–47. https://doi.org/10.1080/15374410802575339.

Slavish, D. C., Taylor, D. J., & Lichstein, K. L. (2019). Intraindividual variability in sleep and comorbid medical and mental health conditions. *Sleep, 42*(6), https://doi.org/10.1093/sleep/zsz052.

Soehner, A. M., Bertocci, M. A., Levenson, J. C., Goldstein, T. R., Rooks, B., Merranko, J., ... Birmaher, B. (2019). Longitudinal associations between sleep patterns and psychiatric symptom severity in high-risk and community comparison youth. *Journal of American Acadademy of Child and Adolescent Psychiatry*. https://doi.org/10.1016/j.jaac.2018.09.448.

Twenge, J. M., Hisler, G. C., & Krizan, Z. (2019). Associations between screen time and sleep duration are primarily driven by portable electronic devices: Evidence from a population-based study of U.S. Children ages 0-17. *Sleep Medicine, 56*, 211–218. https://doi.org/10.1016/j.sleep.2018.11.009.

Twenge, J., Joiner, T. E., Rogers, A. E., & Martin, G. N. (2018). Increases in depressive symptoms, suicide-related outcomes, and suicide rates among U.S. Adolescents after 2010 and links to increased new media screen time. *Clinical Psychological Science, 6*(1), 3–17.

Twenge, J. M., Krizan, Z., & Hisler, G. (2017). Decreases in self-reported sleep duration among U.S. adolescents 2009-2015 and association with new media screen time. *Sleep Medicine, 39*, 47–53. https://doi.org/10.1016/j.sleep.2017.08.013.

Weissman, M. M., Berry, O. O., Warner, V., Gameroff, M. J., Skipper, J., Talati, A., et al. (2016). A 30-year study of 3 generations at high risk and low risk for depression. *JAMA Psychiatry, 73*(9), 970–977. https://doi.org/10.1001/jamapsychiatry.2016.1586.

Weissman, M. M., Wickramaratne, P., Nomura, Y., Warner, V., Pilowsky, D., & Verdeli, H. (2006). Offspring of depressed parents: 20 years later. *American Journal of Psychiatry, 163*(6), 1001–1008. https://doi.org/10.1176/ajp.2006.163.6.1001.

Wolfson, A. R., Carskadon, M. A., Acebo, C., Seifer, R., Fallone, G., Labyak, S. E., et al. (2003). Evidence for the validity of a sleep habits survey for adolescents. *Sleep, 26*(2), 213–216.

Woods, H. C., & Scott, H. (2016). #Sleepyteens: Social media use in adolescence is associated with poor sleep quality, anxiety, depression and low self-esteem. *Journal of Adolescence, 51*, 41–49. https://doi.org/10.1016/j.adolescence.2016.05.008.

Wuyts, J., De Valck, E., Vandekerckhove, M., Pattyn, N., Bulckaert, A., Berckmans, D., ... Cluydts, R. (2012). The influence of pre-sleep cognitive arousal on sleep onset processes. *Intternational Journal of Psychophysiology, 83*(1), 8–15. https://doi.org/10.1016/j.ijpsycho.2011.09.016.