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EMPIRICAL RESEARCH

Adolescents' Electronic Media Use at Night, Sleep Disturbance, and Depressive Symptoms in the Smartphone Age

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Abstract Adolescence is a time of increasing vulnerability for poor mental health, including depression. Sleep disturbance is an important risk factor for the development of depression during adolescence. Excessive electronic media use at night is a risk factor for both adolescents' sleep disturbance and depression. To better understand the interplay between sleep, depressive symptoms, and electronic media use at night, this study examined changes in adolescents' electronic media use at night and sleep associated with smartphone ownership. Also examined was whether sleep disturbance mediated the relationship between electronic media use at night and depressive symptoms. 362 adolescents (12–17 year olds, M = 14.8, SD = 1.3; 44.8 % female) were included and completed questionnaires assessing sleep disturbance (short sleep duration and sleep difficulties) and depressive symptoms. Further, participants reported on their electronic media use in bed before sleep such as frequency of watching TV or movies, playing video games, talking or text messaging on the mobile phone, and spending time online. Smartphone ownership was related to more electronic media use in bed before sleep, particularly calling/sending messages and spending time online compared to adolescents with a conventional mobile phone. Smartphone ownership was also related to later bedtimes while it was unrelated to sleep disturbance and symptoms of depression. Sleep disturbance partially mediated the relationship between electronic media use in bed before sleep and symptoms of depression. Electronic media use was negatively related with sleep duration and positively with sleep difficulties, which in turn were related to depressive symptoms. Sleep difficulties were the more important mediator than sleep duration. The results of this study suggest that adolescents might benefit from education regarding sleep hygiene and the risks of electronic media use at night.

Keywords Electronic media use in bed before sleep · Smartphone · Sleep · Sleep duration · Sleep difficulties · Depressive symptoms · Sleep hygiene · Adolescence

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Introduction

The aim of this study is to examine changes in electronic media use in bed and adolescents' sleep associated with smartphone ownership. Moreover, we test whether electronic media use in bed before sleep is associated with

depressive symptoms and whether this relationship is mediated by sleep disturbance including short sleep duration and sleep difficulties. To do so, we follow a theoretical model proposed by Cain and Gradisar (2010) suggesting that increased electronic media use—particularly in the bedroom before sleep—is related to sleep disturbance. Moreover this model suggests that sleep disturbance in turn is associated with impaired daytime functioning. Despite important work in this area, research has not kept pace with changes in technology and the broad use of such electronic devices as smartphones. Therefore, to the authors' best knowledge this study is the first that addresses changes in adolescents' electronic media use at night, sleep, and mental health associated with the use of smartphones.

Electronic Media Use and Adolescents' Sleep

Adolescence is a time of changing sleep patterns with a pronounced shift of bedtimes to later in the evening. For many adolescent students, this results in sleep deprivation during the school week and sleeping in on weekends (Crowley et al. 2007; National Sleep Foundation 2006; Perkinson-Gloor et al. 2013; Lemola et al. 2012). The delay of bedtime during adolescence is considered to be due to both biological maturation and environmental factors (Crowley et al. 2007). Among the environmental factors that may delay bedtimes, electronic media use in the evening has been suggested to play an outstanding role (Cain and Gradisar 2010).

During the last several decades, there has been a particularly pronounced increase in the use of electronic media during leisure time among children and adolescents. Moreover, there is clear increase in media use from childhood to adolescence (Rideout et al. 2010) and many adolescents consider the various kinds of electronic media use as their favorite leisure time activity (Willemse et al. 2012). Nowadays, more than half of adolescents from technologically advanced countries report to consume electronic media on most evenings during the last hour before they go to bed (National Sleep Foundation 2011) and for more than two thirds the last activity of the day was related to electronic media use at least 3 times per week (Kubiszewski et al. 2013).

There is a growing body of evidence that electronic media use during adolescence is related to later bedtimes, shorter sleep duration, and sleep disturbance (Cain and Gradisar 2010, for a systematic review). The greatest attention had been addressed towards the relationship between TV-consumption and sleep; of 20 studies examining this link, which were identified by Cain and Gradisar (2010), 17 have found a significant relationship between the amount of watching TV and poor sleep. With regard to the use of computers, internet, or video game playing, 15 studies have been identified which consistently reported later bed times, shorter sleep duration, and longer sleep latency to be related to greater use of these electronic media. Two out of three studies also reported more daytime sleepiness/tiredness (Van den Bulck 2004; Eggermont and Van den Bulck 2006), while one study could not confirm this relationship (Li et al. 2007). With regard to mobile phone use and sleep, seven studies had been conducted till 2010 (Cain and Gradisar 2010). Two studies found shorter sleep duration being related to greater mobile phone use (Harada et al. 2002; Punamäki et al. 2007), while one study could not confirm this link (Yen et al. 2008); three studies found that greater mobile phone use was associated with increased daytime sleepiness/tiredness (Van den Bulck 2003, 2007; Söderqvist et al. 2008), while no relationship was found with sleep latency (Gaina et al. 2005) or sleep difficulties (Söderqvist et al. 2008; Yen et al. 2008).

More recent studies regarding adolescents' bedtime mobile phone use include two surveys conducted in Japan examining the relation of mobile phone communication after lights out with sleep (Munezawa et al. 2011; Oshima et al. 2012). Munezawa et al. (2011) found both texting and calling after lights were turned off to be related with more sleep disturbance (including short sleep duration, subjective poor sleep quality, excessive daytime sleepiness, and insomnia symptoms) controlling several confounders (including gender, grade-level, alcohol-drinking, smoking, eating breakfast, extracurricular activities, and mental health). Oshima et al. (2012) reported mobile phone use after lights were turned off to be negatively related to sleep duration only in younger adolescents ages 13–15 years, while no such relation was found in 16–18 year olds. Taken together, there is a large body of evidence that electronic media use is related to disturbed sleep. However, the published studies to date have all been conducted before the latest electronic revolution affecting adolescents' lives has taken place.

The Possible Role of Smartphones for Adolescents' Electronic Media Use

The availability of smartphones may change adolescents' patterns of electronic media consumption profoundly. First, when having access to wireless Internet, smartphones allow communication with peers without charge, by using for instance Internet based messenger applications such as WhatsApp. Particularly the cost of calling and sending text messages was a limiting factor of adolescents' mobile phone communication before smartphones became easily available. During that time adolescents applied various tricks to avoid charges related to calling or texting (Prezza et al. 2004). For instance, "ringing" was a procedure involving one adolescent dialing a friend but interrupting

the call before the other person could take the phone. Hence,—and without charge—the other mobile phone displayed who was calling, whereby telling that person "I was thinking of you." Another more elaborate trick was to answer "yes" or "no" questions by the number of phone ring signals (e.g., one signal meant "yes" and two signals meant "no"). The availability of smartphones and wireless Internet access, however, make such practices obsolete. Beyond replying to simple questions, smartphones and the access to wireless Internet offer several new opportunities to communicate free of charge such as, for instance, sharing pictures and short movies with a predefined group of friends. Beside the decrease of costs related to communication, smartphones are also more convenient to use while lying in bed to surf the Internet or to watch videos from Youtube as smartphones have the advantage of being lighter and handier than for instance notebook computers. Their superior handiness compared to other electronic media thus make smartphones particularly practical to use when already lying in bed. While being convenient, these points also bear the risk that adolescents increase their use of the mobile phone in general and when lying in the bed.

The rate of smartphone ownership varies by Nation and age group, and is currently rapidly increasing. In the United States, for instance, the percentage of the population who owned a smartphone increased from 35 % in 2011 to 56 % in 2013 (Smith 2013). In Switzerland, the number of the 12–19 year olds who owned a smartphone increased from 47 % in 2010 to 79 % in 2012 (Willemse et al. 2012); the same representative survey study revealed that the number of adolescents using the mobile phone to surf the Internet increased from 16 % in 2010 to 66 % in 2012. Similar rates have been reported for Germany, where 25 % of the 12–19 year olds owned a smartphone in 2011 while this number has increased to 72 % in 2013 (Medienpädagogischer Forschungsverbund Südwest 2013); 60 % of the adolescents in Germany also reported to subscribe to a flat-rate data plan for their mobile phones. However, scientific knowledge whether smartphone ownership affects adolescents' electronic media use in the bed before sleep, and whether it increases the risk of poor sleep and daytime functioning, is still missing.

Possible Mechanisms Linking Electronic Media Use with Poor Sleep

Cain and Gradisar (2010) propose several mechanisms through which electronic media use in the evening may reduce sleep duration and interfere with sleep quality. As a first mechanism, electronic media use may displace sleep. As an unstructured leisure activity with no fixed starting and stopping point, it involves an increased risk of expanding and taking up more time, and thus displacing other possible activities and sleep (Kubey 1986; Van den Bulck 2004).

As a second mechanism, it has been proposed that electronic media use before sleep may increase mental, emotional, or physiological arousal. This possible mechanism has been examined by six experimental studies that all examined the effects of playing video games. In a first study, Higuchi et al. (2005) studied young male adults who played an exciting video game late at night or performed simple tasks with low mental load in front of a screen as a control condition. Playing video games slightly increased sleep latency and heart rate, and it decreased subjective sleepiness compared to a control condition. In a similar vein, Dworak et al. (2007) found that video game playing resulted in longer sleep latency and poorer memory performance on the following day in adolescent boys. Moreover, an Australian study found that playing video games in the evening as compared to more passive watching of a movie decreased male adolescents' sleepiness and increased sleep latency (although only to a slight degree; Weaver et al. 2010). However, physiological arousal was not affected in this study. A second Australian study also found moderately reduced sleep quality but no effect on heart rate among adolescents with previous video game experience (King et al. 2013). Finally, in two Swedish studies, violent video game playing was compared with non-violent video game playing. The first study, which included male adolescents with rather low experience with violent video games, revealed that violent video game playing induced stronger autonomic responses than non-violent gaming (while not affecting subjective sleep quality or cortisol secretion; Ivarsson et al. 2009a, b). The second experiment found differential effects of experimental exposure to violent versus non-violent video games according to the previous gaming experience such that adolescents with low gaming experience showed more negative effects related to heart rate variability, sleep quality, and mood after the violent game pointing to the importance of the previous experience with video games (Ivarsson et al. 2013). Taken together, experimental studies are in line with a causal role of playing video games for poor sleep. However, physiological arousal (including heart rate variability) and neuroendocrine responses (including cortisol secretion) were not confirmed as the mediators of this effect—at least not in experienced video game players. It is possible that mental and/or emotional arousal which was not assessed in these studies mediated the effects on sleep. With regard to other types of electronic media use, electromagnetic radiation emitted by mobile phones has been reported to delay melatonin production and could therefore be related to later sleep onset (Wood et al. 2006). Moreover, communication via mobile phone when lying in the bed before sleep has also been

suggested to increase emotional and/or cognitive arousal and might therefore affect sleep (Munezawa et al. 2011). However, this latter mechanism has not yet been tested experimentally.

As a third mechanism, Cain and Gradisar (2010) suggested that light emission of the screens of electronic media devices might affect sleep. In line with this notion, there is evidence from an experimental study with young adults that particularly light emission of modern flat screens with LED back light technology may interfere with sleep. LED back light screens emit an increased amount of light in the short wave length spectrum of around 460 nm which suppresses melatonin secretion in the evening and reduces subjective and objective signs of sleepiness (Cajochen et al. 2011). However, one recent study comparing the impact of the three conditions (a) 1 hour of bright tablet screen exposure, (b) 1 h of short-wavelength filtered tablet screen exposure, and (c) 1 h of dim tablet screen exposure on adolescents' pre-bedtime alertness, sleep, and daytime functioning found only minimal differences (Heath et al. 2014). No evidence is yet available indicating whether more than 1 h of exposure to a tablet screen might have a stronger effect on adolescents' sleep.

A fourth mechanism by which particularly mobile phones in the bedroom may disturb sleep is that incoming messages may wake adolescents up at night. Recently, a representative survey of the US population revealed that 18 % of adolescents aged between 13 and 18 years are woken up by text messages after sleep onset at least few times per week compared to only 10 % of individuals aged between 30 and 45 years (National Sleep Foundation 2011). Similar rates of being woken up by incoming text messages and calls after lights out have been reported by adolescents in Belgium (Van den Bulck 2007). In this latter study, the odds of being very tired during the day strongly increased with the frequency of mobile phone use after lights out. Moreover, also a nation-wide study with Japanese adolescents showed that the use of mobile phones after lights out was associated with poor sleep and excessive daytime sleepiness (Munezawa et al. 2011).

The Role of Sleep for Depression in Adolescence

While severe cases of depression are comparably rare before puberty, the prevalence rate drastically increases until the end of adolescence (Hankin et al. 1998; Kessler et al. 2001). Around 20 % of the population has experienced a depressive episode when turning 18 years old, which also involves a highly increased risk for further depressive episodes in adulthood (Lewinsohn et al. 1993). It is therefore of major interest to understand why this rate is increasing during adolescence, to identify possible risk and protective factors, and to develop efficacious treatment and prevention approaches.

The comorbidity of depression with sleep problems is very high with 73 % of adolescents with depressive disorder also suffering from a sleep disorder (Lui et al. 2007). Moreover, most studies examining correlations between sleep disturbance and depressive symptoms in adolescents found significant correlations (e.g., Short et al. 2013, Lemola et al. 2011). Often researchers assumed a bi-directional relationship between the sleep disturbance and mental health (e.g., Cortese et al. 2013). However, in a recent meta-analysis summarizing longitudinal and treatment studies that examined the prospective role of sleep disturbance in the development of depression and vice versa during adolescence, Lovato and Gradisar (2014) concluded that sleep disturbance rather acts as a precursor to the development of depression while little support was found for a predictive role of depressive symptoms in the development of sleep disturbance. These findings point to the importance of sleep disturbance in the etiology of depression during adolescence.

In a related vein, experimental studies have tested the causal role of sleep restriction for vulnerability factors that are known to be related to depression. A recent experimental study showed that restricted sleep to 6.5 h for 5 days—a regimen mimicking common sleep curtailment during a school week—resulted in increased self-reports of tension, anxiety, and fatigue as well as greater parent rated oppositionality/irritability and poorer emotional regulation in adolescents aged 12–17 years (Baum et al. 2014). Likewise, curtailing sleep to 6.5 h on a first night and to <2 h on a second night showed similar effects involving increased negative affect and decreased positive affect in adolescents aged 10–16 years (Dagys et al. 2012; McGlinchey et al. 2011; Talbot et al. 2010). In a computerized analysis of emotional markers in speech, adolescents appeared to be even more vulnerable to the effects of sleep deprivation compared to adults (McGlinchey et al. 2011).

The mechanism through which short sleep has an impact on emotional and behavioral functioning in adolescents may involve an increase in negative mood and a decrease in the ability to regulate emotions (Baum et al. 2014). In adulthood, a neuroimaging study showed increased amygdala activity in sleep deprived individuals as well as decreased connectivity between the prefrontal cortex and the amygdala (Yoo et al. 2007). Amygdala activity is known to reflect processes related to negative affectivity including anxiety. The increase in amygdala activity and decrease in prefrontal control of the amygdala related to sleep deprivation may indicate proneness to negative affect and lower ability to regulate negative feelings (Yoo et al. 2007).

The Role of Sleep Disturbance for the Relationship Between Electronic Media Use and Depression

While it is generally accepted that electronic media use during adolescence has a predictive role in the development of depression (Primack et al. 2009) and that electronic media use is related to sleep disturbance (Cain and Gradisar 2010), studies that explicitly examine the mediating role of sleep disturbance for the relationship between electronic media use and depressive symptoms are rare. Most studies analyzing relationships between electronic media use, sleep disturbance, and depressive symptoms simultaneously in adolescents (Munezawa et al. 2011; Oshima et al. 2012) or in young adults (Brunborg et al. 2011) defined one of these variables as a covariate rather than a mediator. One study treated depressive symptoms as a covariate when studying the relationship between mobile phone use after lights out and sleep disturbance finding that the raw association was attenuated when the covariates (including depressive symptoms) were controlled (Munezawa et al. 2011). A second study treated sleep duration as a covariate when studying the relationship between mobile phone use after lights out and poor mental health, suicidal ideation, and self-injury (Oshima et al. 2012). Similarly as in the former study, the raw associations were attenuated when controlling for covariates. Furthermore, also Brunborg et al. (2011) controlled for depressive symptoms when assessing the relationship between using the mobile phone in the bedroom at night and sleep disturbance in young adults. A formal test of the mediation hypothesis that sleep disturbance may mediate the relationship between electronic media use and depressive symptoms was conducted by two studies (Adams and Kisler 2013; Lemola et al. 2011). Results from Adams and Kisler (2013) support the mediation hypothesis in a sample of college students. In contrast, Lemola et al. (2011) could not find mediation of the relationship between habitual video game playing at night and depressive symptoms by sleep disturbance in a sample of adolescents and young adults who played the online multiplayer role play game World of Warcraft.

Taken together, there is a wealth of evidence that electronic media use before bedtime, sleep disturbance, and depressive symptoms in adolescence are interrelated. However, studies assessing how the availability of smartphones—including the opportunity to cheaply and conveniently communicate with peers when already lying in the bed—changes the use of electronic media in adolescents' bedrooms are missing. Moreover, there is only little research studying the hypothesis that disturbed sleep acts as a mediator of the relationship between electronic media use and depressive symptoms in adolescence.

The Current Study

In the current study, we examine whether adolescents who own a smartphone differ from their peers who do not own a smartphone regarding their electronic media use in bed before sleep. Moreover, we examine whether electronic media use in the bed is related to sleep disturbance (including short sleep duration and sleep difficulties), and whether short sleep duration and sleep difficulties mediate the relationship between electronic media use in bed and depressive symptoms. In particular we test the following hypotheses.

Possession of a smartphone is related to more electronic media use in general and particularly in bed before sleep (Hypothesis 1). We expect that adolescents with a smartphone more often use electronic media as smartphones allow to communicate with peers without charge (e.g., by using smartphone applications such as WhatsApp or the Facebook application for smartphones). Moreover, due to their small size smartphones are more convenient to use than for instance notebook computers when lying in the bed. Due to these reasons, we assume that the advent of smartphones in adolescents' bedrooms profoundly change electronic media use in the bed and thus might also affect sleep.

Electronic media use in bed before sleep is related to higher levels of depressive symptoms (Hypothesis 2). In line with previous research (Brunborg et al. 2011; Lemola et al. 2011; Oshima et al. 2012) we expect that higher levels of depressive symptoms in adolescents who more often use electronic media in bed before sleep.

Electronic media use in bed before sleep is related to shorter sleep on weekday nights and/or sleep difficulties on weekday nights (Hypothesis 3). We expect electronic media use in bed before sleep to be related to shorter sleep and/or sleep difficulties in line with previous research (Cain and Gradisar 2010 for a review; Brunborg et al. 2011; Dworak et al. 2007; Eggermont and Van den Bulck 2006; Fossum et al. 2014; Higuchi et al. 2005; King et al. 2013; Munezawa et al. 2011; Oshima et al. 2012; Van den Bulck 2007). Several factors may lead to less sleep in adolescents who use electronic media in bed before sleep, including that it may replace the time for sleep and it may increase arousal due to the media contents or due to alerting features of the screens including brightness and the specific wave-length of LED-backlight screens (Cain and Gradisar 2010).

The relationship between electronic media use in bed before sleep and depressive symptoms is partly mediated by sleep duration and/or sleep difficulties (Hypothesis 4). We expect that the relationship between electronic media use in bed and depressive symptoms is at least partly due to sleep disturbance. This expectation is based on the theoretical model proposed by Cain and Gradisar (2010) suggesting that electronic media use has an impact on daytime functioning via sleep disturbance. Moreover, there is now a

large body of evidence indicating that sleep disturbance in adolescence predicts the development of depressive symptoms (Lovato and Gradisar 2014).

In further analyses, we explore whether the relations between electronic media use in bed before sleep, sleep duration, sleep difficulties, and depressive symptoms are moderated by age (Additional Research Question 1). Moreover, we explore (Additional Research Question 2) which type of electronic media use is most strongly related with sleep duration, sleep difficulties, and depressive symptoms. We do not propose hypotheses regarding which media device would be most strongly related to sleep disturbance and depressive symptoms.

Method

Procedure

Participants were recruited from public high schools in northwestern Switzerland. Principals of all 42 high schools within the area received a letter with information on the study aims and procedures. Approximately 1 week later, the principals of the 42 high schools were contacted by phone to ask if they were interested in participation. Seven high school principals agreed that school classes of their school participated in the study. In total, the seven participating schools consisted of 82 school classes and teachers of 32 of those agreed to participate. The 32 school classes consisted of 646 students, of which 390 agreed to participate and if underage, had consent from their parents. Trained study personnel visited the school classes and administered questionnaires on sleep, media consumption before going to sleep, and psychological health. Completing the questionnaire took approximately 25 min. After completing the questionnaires students either received an interventional lesson on sleep hygiene or general information on sleep related topics such as dreaming. One month later, students were visited a second time and completed the same questionnaires. The present paper reports data collected at the first school visit and from all participating students. Data for the present study was gathered between October 2012 and February 2013. Students and parents of underage students gave written informed consent to participate in the study. The study was approved by the Ethics Committee of Basel and performed in accordance with the ethical standards laid down in the Declaration of Helsinki.

Participants

In total, 390 adolescents aged 12–20 years completed the questionnaires at the first data assessment time of whom 362 (92.8 %) were underage, i.e. between 12 and 17 years old. Young adults (ages 18–20; n = 28; 7.2 %) were excluded from the analyses of the current study in order to address the research questions within underage adolescents. Among the remaining 362 students, 200 (55.2 %) were male and 162 (44.8 %) were female. A majority indicated to speak only German/Swiss German at home (55.8 %), 21.3 % indicated to speak German/Swiss German and another language at home, and 22.9 % indicated to speak only another language at home.

Measures

Sleep Duration

To assess sleep duration, students were asked to indicate the time they turn off the lights to go to sleep on regular school nights (Monday to Thursday night) and the time they get up in the morning of regular school days (Monday to Friday morning). Sleep duration was defined as the time between the indicated "lights off"-time and rise time.

Sleep Difficulties

Sleep difficulties were assessed with five items from the German translation of the Insomnia Severity Index (ISI; Bastien et al. 2001; translated by the 3rd author of the present article). Reliability and validity of the German version were established in a previous study (Gerber et al. 2010). The items were answered on a 5-point Likert scale (0 = *not at all/very satisfied* and 4 = *very much/very dissatisfied*) and assessed difficulties falling asleep and maintaining sleep, satisfaction with the current sleep pattern and feeling rested after awakening (e.g. "In the last 2 weeks, did you have difficulties falling asleep?"). A higher mean score represents more sleep difficulties (Cronbach's alpha = .71).

Electronic Media Use in Bed Before Sleep

To assess electronic media use in bed before sleep students were asked about their behavior regarding media consumption in bed before going to sleep on a regular school night. Media consumption in bed was assessed with four items assessing how often participants watch TV or movies, play video games, talk on the phone or text, and spend time online on Facebook or in chat rooms or surf the Internet before going to sleep and while already in bed. Answer categories ranged from 1 (*never*) to 5 (*most of the time to always; at 5–7 days per week*). A higher sum score represents more electronic media consumption in bed before going to sleep (Cronbach's alpha = .70).

Daily Duration of Electronic Media Use in General

To assess the duration of electronic media use in general the students indicated on four items how many minutes and hours they (1) watch TV, (2) play video games, (3) spend time online on Facebook, (4) spend time on the Internet in total on an ordinary school day. Moreover, they indicated how many text messages they send per day (including short messages, WhatsApp messages etc.).

Depressive Symptoms

Depressive symptoms were assessed with six items taken from the short version of the "Allgemeine Depressionsskala" (ADS-K; Hautzinger and Bailer 1993), the German version of the Center of Epidemiological Studies Depression Scale (CES-D; Radloff 1977), including "feeling depressed", "feeling everything one does is an effort", "feeling fearful", "feeling sad", "that one could not get going", and "that one enjoyed life" (reverse coded). Thus, no item assessing sleep disturbance was included. The items were answered on a 4-point Likert scale ranging from 0 (*occurred never or rarely*) to 3 (*occurred most of the time or always*) reflecting how often the symptoms were experienced during the preceding week. Higher scale mean scores reflect higher levels of depressive symptoms (Cronbach's alpha = .73).

Statistical Analysis

First, mean value comparisons and frequency comparisons of the study variables between smartphone owners and owners of a conventional mobile phone were conducted by analysis of variance (ANOVA) and χ^2 statistics (test of *Hypothesis 1*). Second, Pearson correlations were calculated. The Pearson correlations represent preliminary analyses to present the zero-order relations between the study variables. Third, regression analyses were conducted as suggested by Baron and Kenny (1986) to test mediation. This included the following steps: (a) Prediction of the dependent variable (depressive symptoms) by the independent variable (electronic media use in bed; test of *Hypothesis 2*). (b) Prediction of the mediators (sleep duration and sleep difficulties) by the independent variable (electronic media use in bed; test of *Hypothesis 3*). (c) Prediction of the dependent variable (depressive symptoms) by both the independent variable (electronic media use in bed) and the mediators (sleep duration and sleep difficulties; test of *Hypothesis 4*; for partial mediation it is required that the direct relation between the independent variable and the dependent variable is reduced by inclusion of the mediator to the model). In order to also formally test the significance of the indirect effects we then additionally employed the SPSS procedure *Indirect* by Preacher and Hayes (2008), assessing the models with both mediators simultaneously via bootstrapping. All regression models controlled adolescents' age and gender. Fourth, we tested whether any of the regression models of the previous steps were moderated by adolescents' age (test of *Additional Research Question 1*) following the procedure suggested by Aiken and West (1991). Finally, further regression models specified simultaneous entry of the four different types of electronic media consumption in bed before sleep and the variable whether the mobile phone was switched off during the night according to the "stepwise" algorithm (probability-of-F-to-enter: 0.05; probability-of-F-to-remove: 0.10; test of *Additional Research Question 2*). Again all regression models controlled adolescents' age and gender.

Results

Table 1 shows descriptive statistics of the study variables and the comparisons of the electronic media use between the group owning a smartphone (n = 299; 82.6 % of the sample) and the group owning a conventional mobile phone (n = 51; 14.4 % of the sample) (test of *Hypothesis 1*). Only a minority of 10 adolescents (2.8 %) indicated not to own a mobile phone and were therefore excluded from this comparison. Adolescents owning a smartphone were somewhat older and more often spoke a different language than German at their homes than their peers who had a conventional mobile phone. With regard to their electronic media consumption in general, they spent more time on the Internet and on Facebook, and they sent several times more text messages per day, while they did not spend more time watching TV or playing video games. Regarding their electronic media use in bed before sleep, they more often watched videos, communicated by phone or text message, more often spent time online, and more often had their phones switched on during the night, while they did not significantly differ regarding video game playing in the bed. Furthermore, smartphone owners switched off the lights later at night than their peers with conventional mobile phones, while they did not differ significantly regarding sleep duration, sleep difficulties, and symptoms of depression.

Table 2 presents Pearson correlations for participants' age, gender, sleep, depressive symptoms, and variables of electronic media use at night. Age was negatively related to sleep duration and it was positively related to depressive symptoms and all types of electronic media use at night except for playing video games. Girls had higher levels of depressive symptoms and reported more calling and/or text messaging in bed before sleep, while they also reported less

Table 1 Description of the study variables and comparisons between adolescents with a smartphone and with a conventional mobile phone

	Total sample ($N = 362$)		Adolescents with a smartphone ($n = 299$)		Adolescents with a conventional mobile phone ($n = 51$)		Statistics[a]
	n/mean	(%/SD)	n/mean	(%/SD)	n/mean	(%/SD)	
Age (years), mean (SD)	14.82	(1.26)	14.9	(1.2)	14.3	(1.3)	$F = 12.57$, $p < 0.001$
Gender (female) *n* (%)	162	(44.8)	136	(45.5)	23	(44.2)	$\chi^2 = 0.03$, $p = 0.87$
Language spoken at home (German only) *n* (%)	202	(55.8)	155	(51.8)	37	(71.2)	$\chi^2 = 6.67$, $p = 0.01$
Sleep on weekdays							
Time of switching lights off, mean (SD)	10:26	(0:55)	10:30	(0:55)	10:10	(0:48)	$F = 5.75$, $p = 0.02$
Time of getting up, mean (SD)	06:30	(0:23)	06:31	(0:24)	06:25	(0:20)	$F = 3.32$, $p = 0.07$
Sleep duration (hours), mean (SD)	8:04	(0:54)	8:01	(0:55)	8:14	(0:52)	$F = 2.54$, $p = 0.11$
Sleep difficulties, mean (SD)	2.20	(0.68)	2.21	(0.68)	2.13	(0.61)	$F = 0.73$, $p = 0.39$
Depressive symptoms, mean (SD)	1.58	(0.48)	1.59	(0.48)	1.53	(0.44)	$F = 0.79$, $p = 0.37$
Amount of media use on weekdays, hours, mean (SD)							
Watching TV	1:41	(1:22)	1:44	(1:23)	1:32	(1:22)	$F = 0.83$, $p = 0.36$
Playing video games	0:53	(1:00)	0:54	(1:01)	0:46	(0:46)	$F = 0.79$, $p = 0.37$
To be on the Internet (total)	1:52	(1:39)	2:00	(1:42)	1:08	(0:59)	$F = 12.36$, $p < 0.001$
To be on Facebook	0:48	(1:07)	0:54	(1:11)	0:17	(0:28)	$F = 13.54$, $p < 0.001$
Number of text messages sent per day, mean (SD)	71.11	(89.53)	84.63	(92.89)	7.06	(10.49)	$F = 36.10$, $p < 0.001$
During the night mobile phone is…[b] *n* (%)							
Switched on and at the bed	204	(57.6)	181	(60.5)	21	(41.2)	$\chi^2 = 24.28$, $p < 0.001$
Switched on but not at the bed	75	(21.2)	68	(22.7)	6	(11.8)	
Switched off or not in bedroom	75	(21.2)	50	(16.7)	24	(47.1)	
Media use in bed before sleep, mean (SD)	9.49	(4.18)	10.10	(4.18)	6.76	(2.76)	F = 30.20, $p < 0.001$
Media use in bed before sleep *n* (%)							
Watching TV/videos							
Never	183	(50.8)	144	(48.3)	34	(66.7)	$U = 6{,}004.5$, $p = 0.01$
Once a week or less	61	(16.9)	49	(16.4)	7	(13.7)	
Twice a week	43	(11.9)	37	(12.4)	5	(9.8)	
3–4 times a week	29	(8.1)	27	(9.1)	2	(3.9)	
5–7 times a week	44	(12.2)	41	(13.8)	3	(5.9)	
Playing video games							
Never	245	(68.1)	200	(67.1)	36	(70.6)	$U = 7{,}225.5$, $p = 0.50$
Once a week or less	47	(13.1)	40	(13.4)	6	(11.8)	
Twice a week	36	(10.0)	27	(9.1)	8	(15.7)	
3–4 times a week	22	(6.1)	21	(7.0)	1	(2.0)	
5–7 times a week	10	(2.8)	10	(3.4)	0	(0.0)	
Communication by phone or text message							
Never	92	(25.6)	57	(19.1)	26	(51.0)	$U = 3{,}743.0$, $p < 0.001$
Once a week or less	48	(13.3)	39	(13.1)	9	(17.6)	
Twice a week	42	(11.7)	31	(10.4)	10	(19.6)	
3–4 times a week	64	(17.8)	60	(20.1)	3	(5.9)	
5–7 times a week	114	(31.7)	111	(37.2)	3	(5.9)	
To be online (on Facebook, Chatroom, etc.)							
Never	146	(40.6)	100	(33.6)	37	(72.5)	$U = 4{,}359.0$ $p < 0.001$
Once a week or less	52	(14.4)	49	(16.4)	3	(5.9)	
Twice a week	41	(11.4)	34	(11.4)	5	(9.8)	
3–4 times a week	55	(15.3)	50	(16.8)	5	(9.8)	
5–7 times a week	66	(18.3)	65	(21.8)	1	(2.0)	

[a] Statistics refer to the comparison between adolescents who own a smartphone versus adolescents who own a conventional mobile phone

[b] The question whether the mobile phone was switched on during the night was also replied by three of the individuals who indicated not to own a mobile phone

Table 2 Pearson correlations between study variables

		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	Age										
2.	Gender	***−.14***									
3.	Sleep duration on weekdays	***−.42***	−.05								
4.	Sleep difficulties	.01	.08	***−.16***							
5.	Depressive symptoms	*.13*	*.12*	***−.22***	***.44***						
6.	Mobile switched on after lights out	***.42***	−.07	***−.39***	***.14***	***.15***					
7.	Media use in bed (scale)	***.31***	−.02	***−.40***	***.20***	***.28***	***.44***				
8.	Watching TV/videos in bed	***.19***	*−.14*	***−.24***	*.12*	***.19***	***.25***	***.70***			
9.	Playing video games in bed	.07	***−.21***	*−.13*	.02	***.16***	***.16***	***.55***	***.38***		
10.	Calling/text messaging in bed	***.34***	*.13*	***−.37***	***.18***	***.19***	***.45***	***.81***	***.33***	***.23***	
11.	To be online (Facebook, Chat etc.) in bed	***.27***	.08	***−.37***	***.22***	***.25***	***.39***	***.81***	***.36***	***.21***	***.68***

Pairwise exclusion of missing values. Gender coding: male = 1, female = 2. Coding of "Mobile switched on after lights out": mobile switched off after lights out (or not in the bedroom) = 1, mobile switched on but not at the bed = 2, mobile switched on and at the bed = 3. Media use in bed (scale) represents the mean score of the four variables watching TV/videos in bed, playing video games in bed, calling/text messaging in bed, and to be online (Facebook, Chat etc.) in bed

Italics $p < 0.05$; *italics and bold* $p < 0.01$; *italics, bold, and underlined* $p < 0.001$

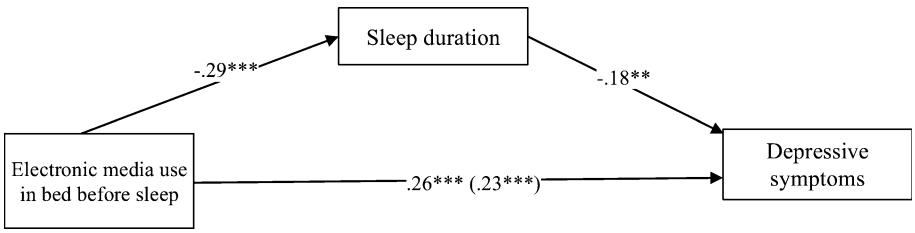

Fig. 1 Mediation of the relationship between electronic media use in bed before sleep and depressive symptoms by sleep duration. Coefficients are standardized regression coefficients that are controlled for age and gender. The coefficient in *brackets* represents the standardized regression coefficient when the mediator (sleep duration) is also in the model. $^{**}p < 0.01$; $^{***}p < 0.001$

watching of TV and videos and less often played video games in bed compared to boys. Sleep duration on weekdays was negatively related to depressive symptoms and all types of electronic media use at night, while sleep difficulties were positively related to these variables (except for a non-significant relation to video game playing in bed). Depressive symptoms were positively related to all types of electronic media use at night.

Figure 1 represents the regression models testing the relations between electronic media use in bed before sleep (independent variable), sleep duration (mediator), and depressive symptoms (dependent variable), while Fig. 2 shows the same model with sleep difficulties as the mediator. The regression models revealed that electronic media use in bed before sleep was related to higher levels of depressive symptoms ($\beta = .26$, $t = 4.84$, $p < 0.001$; test of *Hypothesis 2*). Moreover, regression models revealed that electronic media use in bed before sleep was also related to shorter sleep on weekday nights ($\beta = -.29$, $t = -6.00$, $p < 0.001$) and sleep difficulties ($\beta = .21$, $t = 3.91$, $p < 0.001$; test of *Hypothesis 3*) controlling for age and gender. The direct effect of electronic media use in bed on depressive symptoms remained significant after inclusion of the mediator to the regression model, but was substantially reduced when sleep difficulties as the mediator came to the model (from $\beta = .26$, $t = 4.84$, $\Delta R^2 = 0.060$; $p < 0.001$ to $\beta = .17$, $t = 3.49$, $\Delta R^2 = 0.026$; $p < 0.001$) and somewhat reduced when sleep duration as the mediator came to the model (from $\beta = .26$, $t = 4.84$, $\Delta R^2 = 0.060$; $p < 0.001$ to $\beta = .23$, $t = 4.10$, $\Delta R^2 = 0.043$; $p < 0.001$) indicating partial mediation (test of *Hypothesis 4*). Testing the indirect effect with both mediators in the model revealed only significance of the indirect path via sleep difficulties (B = 0.08, SE = 0.02, bias corrected CI 0.04–0.13 based on 3,000 bootstrap samples) but not sleep duration (B = 0.02, SE = 0.02, bias corrected CI −0.01 to 0.05).

Testing the age-moderation of the associations between electronic media use in bed before sleep, sleep duration, sleep difficulties, and depressive symptoms showed no significant interactions with age (all p values ≥ 0.10; additional *Research Question 1*).

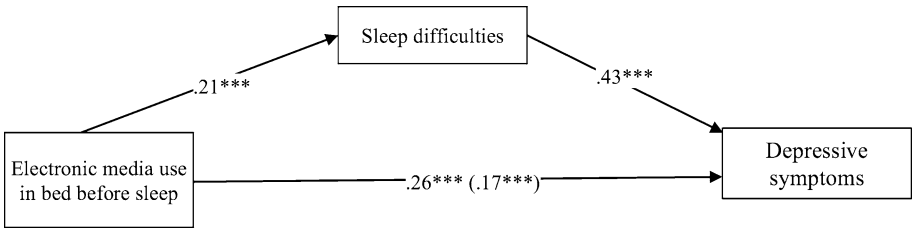

Fig. 2 Mediation of the relationship between electronic media use in bed before sleep and depressive symptoms by sleep difficulties. Coefficients are standardized regression coefficients that are controlled for age and gender. The coefficient in *brackets* represents the standardized regression coefficient when the mediator (sleep difficulties) is also in the model. ***$p < 0.001$

Testing which type of electronic media use in bed was most strongly associated with sleep duration, sleep difficulties, and depressive symptoms stepwise regression was conducted (additional *Research Question 2*). Being online (Facebook, Chat etc.) in bed ($\beta = -.21$, $t = -4.13$, $p < 0.001$) and having the mobile phone switched on at night ($\beta = .20$, $t = 3.71$, $p < 0.001$) (but not watching TV, playing video games, and calling/text messaging in bed) were related with sleep duration on weekdays. Being online (Facebook, Chat etc.) in bed before sleep ($\beta = .22$, $t = 4.10$, $p < 0.001$) (but not watching TV, playing video games, calling/text messaging in bed, and having the mobile switched on at night) was related with sleep difficulties. Moreover, being online (Facebook, Chat etc.) in bed ($\beta = .19$, $t = 3.43$, $p < 0.001$) and playing video games ($\beta = .15$, $t = 2.86$, $p = 0.005$) (but not watching TV, calling/text messaging in bed, and having the mobile switched on at night) were related with depressive symptoms.

Discussion

Adolescence is a time of increasing vulnerability for severe mental health disorders such as depression. Epidemiological studies show that the incidence of new cases of depression drastically increases with puberty (Hankin et al. 1998; Kessler et al. 2001). As the recurrence rate during adulthood is high, prevention of depression with onset during adolescence is of major importance (Lewinsohn et al. 1993). During adolescence, sleep patterns change with a pronounced shift of bedtimes to later in the evening, increasing sleep deprivation during the school week and sleeping in on weekends (Crowley et al. 2007). Importantly, there is growing evidence that sleep disturbance in adolescence may predict the development of depression (Lovato and Gradisar 2014). In order to prevent the burden of depression with onset during adolescence, it appears to be a promising venue to identify and address sleep disturbance (Lovato and Gradisar 2014).

In addition to the increase in the prevalence of depression with the transition from childhood to adolescence, there is also a secular trend of an increasing incidence of depression during adolescence since the 1960s (Kessler et al. 2001). A similar but decreasing secular trend has been reported for adolescents' sleep duration (Dollman et al. 2007; Iglowstein et al. 2003). Although speculative, it is possible that these secular trends have a common cause. One such possible cause is the increasing availability of electronic devices that has changed adolescents' every day lives profoundly since the 1960s. There is now a large body of evidence confirming that electronic media use particularly is related and may cause sleep disturbance (Cain and Gradisar 2010). Moreover, there is also evidence of a predictive role of media use for the development of depression (Primack et al. 2009). A theoretical model proposed by Cain and Gradisar (2010) suggests that electronic media use may cause sleep disturbance, which in turn may cause daytime dysfunction such as increased depressive symptoms. One aim of the current study was to test whether adolescents' sleep disturbance mediates the relationship between electronic media use at night and symptoms of depression. A further aim of the current study was to examine how smartphones have changed adolescents' electronic media use at night as during the latest years the prevalence of smartphones has escalated among adolescents in Switzerland (Willemse et al. 2012). Due to the large functional range of smartphones, their handiness, and the inexpensiveness of accessing the Internet, we hypothesized that owning a smartphone would change electronic media use at night and increase sleep disturbance in adolescents.

Our results show that adolescents who owned a smartphone sent a lot more text messages and spent more time on the Internet and on Facebook per day than their peers with conventional mobile phones, while they did not watch more TV or play video games. At night when lying in the bed, adolescents who owned a smartphone were a lot more likely to communicate by calling or text messaging or to be online (e.g., on Facebook or chat), and somewhat more likely to watch TV or videos (which may also be done on

the smartphone screen), while they were not more likely to play video games. Furthermore, adolescents who owned a smartphone were more likely to go to bed later, although their sleep duration was not shorter on average, and they did not report more sleep difficulties or symptoms of depression than their peers who owned a conventional mobile phone. These findings are in line with our first hypothesis that adolescents with smartphones report more electronic media use when lying in the bed and are consistent with the interpretation that the availability of new electronic devices may strongly change adolescents' habits. However and interestingly, the effect did not generalize to more sleep disturbance or symptoms of depression. This points to the interpretation that it is more important when, how much, and how often adolescents use their electronic devices than whether they use a smartphone or a conventional mobile phone.

Consistent with our second hypothesis, we found that electronic media use in the bed before sleep was related to higher levels of depressive symptoms. This is in line with several studies showing that electronic media use in general (e.g., Primack et al. 2009) and at night are related to depressive symptoms in adolescents (Lemola et al. 2011; Oshima et al. 2012). Moreover, these results are thus also in line with similar reports concerning young adults (Brunborg et al. 2011; Thomée et al. 2011). Consistent with our third hypothesis and in line with a large body of evidence (e.g., Cain and Gradisar 2010), we found that electronic media use in the bed before sleep was related to shorter sleep duration and more sleep difficulties. Moreover, consistent with our fourth hypothesis our findings are in line with the theoretical model involving the mediation of the relationship between electronic media use and depressive symptoms by sleep disturbance (Cain and Gradisar 2010). Particularly sleep difficulties substantially decreased the relationship between electronic media use and depressive symptoms when added to the regression model (the reduction of the criterion variance explained by electronic media use was from 6 to 2.6 % when entering sleep difficulties to the regression model indicating that more than half of the effect was mediated by sleep difficulties). Less strong was the mediating role of sleep duration, which even disappeared when tested in a model simultaneously with sleep difficulties. The relationships between electronic media use, sleep disturbance, and depressive symptoms appeared relatively consistent across the studied age range as no moderation by age was found.

All types of electronic media use in the bed before sleep were moderately to strongly correlated with each other. Moreover, they were correlated with shorter sleep and more symptoms of depression, which is consistent with earlier reports (e.g., Cain and Gradisar 2010). Also consistent with earlier studies watching TV or videos, calling or text messaging, and spending time online were correlated with sleep difficulties. However, no such correlation was found between playing video games in bed before sleep and sleep difficulties. The latter finding is surprising, although there are also other reports that adolescents who are experienced in playing video games may not necessarily have poor sleep when playing before sleep (Lemola et al. 2011). The electronic media use type that was most strongly related with sleep disturbance and depressive symptoms was spending time online (e.g., on Facebook or chatrooms) when lying in the bed before sleep.

Depression during adolescence is a severe condition involving a high recurrence rate during young adulthood (Lewinsohn et al. 1993). As the incidence is drastically increasing during adolescence and prevalence rates have also risen across the last few decades (Kessler et al. 2001) it is of major interest to provide ways of prevention during adolescence. A promising venue for prevention of depression during adolescence is by improving adolescents' sleep quality as there is evidence that disturbed sleep is a vulnerability factor for the development of depressive symptoms during adolescence (Lovato and Gradisar 2014).

Recommendations to prevent sleep disturbance in adolescents might involve the following. First, as electronic media use before sleep is related with sleep disturbance and depressive symptoms many adolescents might benefit from improved sleep hygiene involving a reduction in electronic media use before and at bedtime. In our study, more than 80 % of the adolescents owned a smartphone and more than a third of these adolescents reported to write text messages or were still online most of the nights when they were already in bed before sleep. This reflects the endemic of electronic media use among adolescents nowadays and the decrease of parental control of their children's media consumption. Sleep hygiene education for adolescents might be taught in classrooms and parents could be informed regarding the risk and possible strategies to reduce adolescents' electronic media use at night. Second, and in addition to sleep hygiene education, adolescents' smartphones might feature specific applications supporting adolescents to maintain sleep hygiene. For instance, such applications might track the time when adolescents use their phone (or other electronic media), at what time there is noise in their bedroom, and at what time they go to sleep and when they get up. Such sleep hygiene applications for smartphones might also actively provide reminders when sleep hygiene rules are violated. Finally, adolescents suffering from excessive media use and a sleep disorder should be identified by school psychologists and referred to cognitive behavioral treatment of insomnia in adolescence as there is now evidence that maintaining healthy sleep patterns in adolescents might possibly reduce the incidence of depression in adolescence (Lovato and Gradisar 2014).

Our study also has limitations. First, media use, sleep disturbance, and depressive symptoms were self-reported by adolescents using questionnaires. This may involve bias due to common method (for a discussion of this issue related to the link between subjective sleep disturbance and mental health problems see e.g., Lemola et al. 2013). Moreover, questionnaire measures of behavior may be biased by memory difficulties. While sleep could be assessed objectively with actigraphy in future studies, sleep hygiene and electronic media use could be measured by experience sampling methods in order to achieve higher validity of measurement. Second, the correlational nature of the present study precludes causal conclusions regarding the relationship between electronic media use, sleep disturbance, and depressive symptoms. While experimental work with adolescents has convincingly shown that sleep restriction compromises emotional regulation (e.g., Baum et al. 2014), future studies might also try to experimentally restrict electronic media use at night to test whether adolescents are willing and able to reduce their electronic media use for a certain time for research purposes and whether sleep and psychological adjustment could be positively influenced by such a procedure. Finally, our study cannot advance our knowledge which mechanisms might be involved in possible effects of electronic media use on sleep disturbance.

Conclusion

Our findings suggest that the availability of smartphones is related to increased electronic media use of adolescents at night. Further, our findings confirm earlier reports that electronic media use at night is related to sleep disturbance. Sleep disturbance in turn appears to be a partial mediator of the relationship between electronic media use at night and depressive symptoms. Adolescents might benefit from education regarding sleep hygiene and the risk of electronic media use at night as improving sleep quality may be a key factor in the prevention of depression.

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