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The Relation Between Use of Mobile Electronic Devices and Bedtime Resistance, Sleep Duration, and Daytime Sleepiness Among Preschoolers

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This study investigated the relation between preschoolers' mobile electronic device (MED) use and sleep disturbances. A national sample of 402 predominantly college-educated and Caucasian mothers of 3–5-year-olds completed a survey assessing their preschoolers' MED use, bedtime resistance, sleep duration, and daytime sleepiness. Heavier evening and daily tablet use (and to some extent, smartphone use) were related to sleep disturbances. Other forms of MED use were not consistently related to sleep disturbances. In addition, playing games on MEDs at bedtime was related to compromised sleep duration, although other forms of MED use at bedtime were not related to sleep outcomes. Although the relations between MED use and sleep disturbances were small in size, they were larger than the relations between sleep and other predictors in the models. Continued work should investigate how MED exposure is related to children's cognitive, psychological, emotional, and physiological development, particularly given the popularity and widespread use of these devices.

Children are increasingly consuming media via mobile electronic devices (MEDs), which allow them to watch television programs, read books, or play games in practically any physical space (Common Sense Media, 2013). MEDs are unique compared to traditional toys or television because they offer a combination of features, such as interactivity, reactivity, and portability (Christakis, 2014), which can provide a compelling user experience. But what effects do MEDs have on children? Experts remain cautiously optimistic that MEDs could benefit children because the devices encourage interactivity and personal adaptability compared with television

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viewing (Kirkorian & Pempek, 2013). However, MED exposure may have detrimental effects as well. In particular, MEDs emit short-wavelength blue light that may interfere with young children's sleep (Salti et al., 2006). The purpose of this study was to investigate this possibility and to examine whether MEDs pose a unique risk for disturbed sleep among preschoolers.

MEDs include a number of media devices, such as tablet computers, smartphones, laptop computers, handheld electronic game players, and iPods. Parents appear to find MEDs valuable, as evidenced by recent reports documenting children's access to and use of MEDs. For example, according to a national survey of parents of children ages 8 and younger, 40% of children have access to tablet devices, 63% have access to smartphones, and 75% of children have access to some MED (Common Sense Media, 2013). In addition, children may model their parents' MED use since higher MED use among parents is related to higher MED use among children (Lauricella, Wartella, & Rideout, 2015). According to Common Sense Media's (2013) report, children ages 0 to 8 spent an average of 15 min a day with MEDs, a threefold increase in time since 2011. In their study, although television was the preferred medium for delivering educational content, 38% of children often or sometimes viewed educational content via MEDs. Other popular activities performed on MEDs, as noted by Common Sense Media (2013), included playing games for fun, watching videos, and reading books.

At this time, little research has been conducted on the effects of MEDs on children. Regardless, debates over the benefits and harms of MEDs—especially tablets—for children have emerged in the popular media (e.g., Dobrow, 2014, January 21) and scholarly writings (e.g., Christakis, 2014). Some consider tablet devices to be superior to television because they can be used interactively and adapted to the needs of the user, which could theoretically promote learning (Kirkorian & Pempek, 2013). Some scholars have begun to rethink their position on media use among young children, seriously considering the possible benefits of interactive tablet devices for this population (Christakis, 2014).

Although children enjoy using tablet devices (Couse & Chen, 2010), most research suggests that tablets do not offer a superior learning platform compared with books (Dundar & Akcayir, 2012) and may detract from preschoolers' learning (Krcmar & Cingel, 2014; Parish-Morris et al., 2013). In a study of preschoolers, Krcmar and Cingel (2014) found that electronic versions of books prompted more conversations about electronic features than story content. However, Masataka (2014) showed that preschoolers who received intensive exposure to a digital version of a book learned more than children who received the same amount of exposure to a printed one.

Although the current debate surrounding MEDs' effects on children has centered on its educational potential, MED use may have other consequences for children. In particular, since there is evidence that screen time disrupts children's sleep (Cain & Gradisar, 2010; Hale & Guan, 2015), MEDs may disturb sleep as well. Prior work has found that exposure to televisions, computers, and mobile phones is related to poor sleep quality among both preschool-aged and school-aged children as well as adolescents (Arora, Broglia, Thomas, & Taheri, 2014; Garmy, Nyberg, & Jakobsson, 2012; Garrison, Liekweg, & Christakis, 2011; Hale & Guan, 2015; Polos et al., 2015), especially when exposure occurs in the evening (Garrison et al., 2011). Most of the work on screens and sleep has been conducted among adolescents and adults (Fossum, Nordnes, Storemark, Bjorvatn, & Pallesen, 2014; Kubiszewski, Fontaine, Rusch, & Hazouard, 2014; Nuutinen et al., 2014; Pieters et al., 2014; Van den Bulck, 2004); however, there is evidence that the relation between media exposure and sleep exists among younger children as well (Garmy et al., 2012; Marinelli et al., 2014).

There are several reasons why MED use could affect sleep. Self-luminous, electronic screens, such as televisions, computers, and MEDs, emit short-wavelength, or blue, light that is known to suppress the brain's melatonin secretion among both adults (Wood, Rea, Plitnick, & Figueiro, 2013) and children (Salti et al., 2006). The release of melatonin occurs in the evening, in response to decreased or dim light exposure, and helps prepare the body for sleep (LeBourgeois et al., 2013). Consequently, it is not surprising that Chellappa et al. (2013) found that evening exposure to blue light was related to poorer-quality sleep. Moreover, blocking blue light from a computer screen via special glasses can reduce melatonin secretion suppression and otherwise increase the potential for better sleep among adolescents (van der Lely et al., 2015). Ocular light exposure plays a critical role, as extraocular light exposure (e.g., behind the knees) does not suppress nocturnal melatonin secretion in humans (Hebert, Martin, & Eastman, 1999). As a result, bright-light displays from MEDs are important to consider as potential disruptions to children's sleep quality since light is absorbed through the eyes. Moreover, children may be especially vulnerable to the effects of evening light because of their larger pupil size (Higuchi, Nagafuchi, Lee, & Harada, 2014).

In addition, MEDs provide opportunities to engage in arousing activities, such as playing games and sending and receiving text messages. When these activities occur at bedtime, the increased arousal could harm children's transition to sleep (Cain & Gradisar, 2010; Hale & Guan, 2015). A few studies have found that adolescents who send and receive texts, or engage in media multitasking, at bedtime sleep fewer hours than other adolescents (Munezawa et al., 2011; Van den Bulck, 2007). With a sample of adults, Higuchi, Motohashi, and Maeda (2005) found that playing computer games uniquely interfered with sleep compared with other computer-based activities. As a result, MEDs may provide a variety of arousing activities that, when consumed at bedtime, could delay sleep onset.

Although nonmobile media (i.e., televisions, desktop computers) also emit blue light and can transfer arousing material, MEDs may pose a unique threat to children's sleep. First, their portability means that MEDs may be used in conjunction with bedtime routines in a child's bedroom. Increasingly, parents are using MEDs to read stories to their children (Common Sense Media, 2013). Moreover, parents may try to entice their children into bed by engaging in other activities available via MEDs, such as playing music or games. As a result, children may receive a dose of short-wavelength light immediately before going to bed. Overall, the portability and versatility of MEDs may promote increased use among children, especially during time periods where blue-light exposure may be detrimental to sleep. In this way, evening MED use might be distinctly related to children's sleep disturbances, above and beyond the influence of television viewing.

Second, MEDs are held close to the face, which theoretically could exacerbate the effects of short-wavelength light exposure (Calamaro, Mason, & Ratcliffe, 2009). Televisions are viewed at a distance, thereby allowing blue light intensity from the source to the viewer to decay (Calamaro et al., 2009). However, the opposite situation occurs when children use MEDs. These devices are held just inches from the face, which may allow children to absorb more concentrated levels of blue light. In fact, Figueiro, Wood, Plitnick, and Rea (2013) found that light from television was not strong enough to suppress melatonin among adults. In addition, a recent meta-analysis showed that computer and mobile phone use were related to adolescents' disrupted sleep but television viewing was not (Bartel, Gradisar, & Williamson, 2015). Other research has found that the intensity of light exposure affects the degree of disruption to circadian rhythms (McIntyre, Norman, Burrows, & Armstrong, 1989). From this perspective, MED exposure could bear a stronger relation with children's sleep compared with nonmobile media use.

Our study offers a first look at the relations between MED exposure, television exposure, and sleep disturbances among preschoolers. Understandably, due to MEDs' relatively recent widespread adoption, a very small percentage of the research to date has examined MED use, with no studies examining preschoolers' MED use and sleep. Given the importance of sleep to children's development, and the rapid adoption and use of MEDs among both parents and children, we investigated whether MED use was related to preschoolers' bedtime resistance, sleep duration, and daytime sleepiness. As Hale and Guan (2015) noted, due to rapidly evolving screen media, it is important to consistently monitor whether and how various types of screen technologies affect sleep. Moreover, very little research has examined how screen time is related to sleep among preschoolers.

Although we focused on MEDs due to their novelty, we aimed to understand whether MEDs are uniquely related to sleep, above and beyond television exposure. Given the plethora of MEDs available, we examined multiple forms of MED use, including use of tablets, smartphones, video iPods, game players, and laptop computers. We also used a multidimensional conceptualization of sleep disturbances and focused on indicators of sleep disturbances prior to sleep time (i.e., bedtime resistance), during sleep (i.e., duration of nighttime sleep), and after sleep (i.e., daytime sleepiness). We expected that preschoolers' overall MED use will be related to greater bedtime resistance (H1a), compromised sleep duration (H1b), and more daytime sleepiness (H1c), even after accounting for preschoolers' television exposure time.

In addition to examining overall MED use, we explored how MED use *in the evening* would be related to preschoolers' sleep disturbances. Melatonin is released in the brain at nighttime in order to prepare the body for sleep; as a result, evening MED use may be particularly disruptive to sleep. We predicted that preschoolers' use of MEDs in the evening will be related to more bedtime resistance (H2a), compromised sleep duration (H2b), and more daytime sleepiness (H2c), after controlling for preschoolers' evening television exposure.

Finally, we investigated whether engaging in certain types of activities via MEDs is better or worse for children's sleep. We asked whether game playing, reading, or watching television programs on MEDs at around bedtime was uniquely related to preschoolers' sleep disturbances, above and beyond the influence of preschoolers' evening television exposure (RQ). Figure 1 presents a conceptual diagram of the hypothesized relationships.

METHODS

Participants and Procedures

A national sample of 402 mothers of 3-, 4-, and 5-year old children in the United States was gathered for this research using a national panel company. Respondents were required to meet several eligibility criteria, which included being the mother of a 3–5-year-old child who was not born prematurely, weighed at least 5 pounds at birth, who has not been diagnosed with a serious congenital anomaly or significant birth defect, and who did not experience any major trauma during delivery.

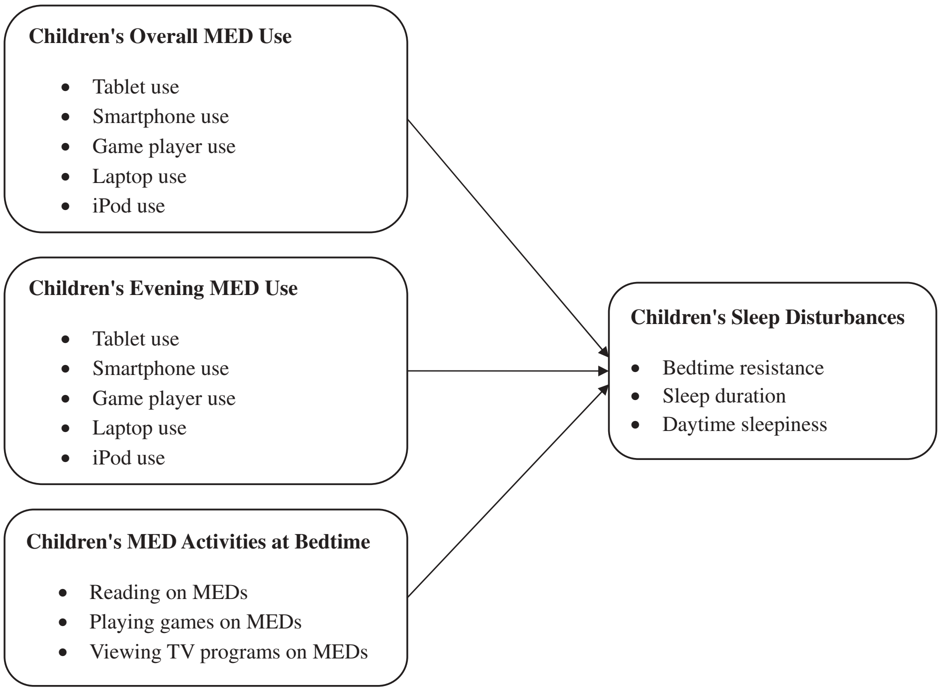

FIGURE 1 Conceptual diagram of the hypothesized relationships.

On average, the participating mothers were 34.5 years old (*SD* = 8.7) and married or cohabitating (80%). Eighty percent reported their ethnicity as Caucasian, followed by African American (7%), Hispanic (6%), Asian or Pacific Islander (4%), multiracial (2%), and Native American (0.5%). Based on a recent report of the population characteristics of families with children under the age of 18 (U.S. Department of Health and Human Services, 2014), this suggests that our sample was overrepresented by Caucasians and underrepresented by African Americans and Hispanics. Slightly more mothers reported on male children (52%) than female children (48%). More information on the demographic characteristics of the sample is reported in the section on covariates.

Participants completed a 20-min online survey. They were instructed to complete the questions with their 3–5-year-old child in mind. If participants had more than one 3–5-year old child, they were instructed to select one of their children and to respond consistently with this child in mind.

Measures

Children's overall MED use

With separate questions for each medium, parents reported how many hours their child uses a tablet, a smartphone, a video iPod, a handheld game player, and a laptop computer on a typical weekday and on a typical weekend day during three time periods: morning (defined as "from the time the child awakens until lunch time"), afternoon (defined as "between lunch and dinner time"), and evening (defined as "between dinner and bedtime"). Participants were provided with a list of twelve 30-min increments of time (e.g., "not at all," "1.5 hours," "3 hours," "more than 5 hours"). Consequently, parents responded to a total of six media use questions for each medium (e.g., average weekday tablet use in the morning, afternoon, and evening and average weekend tablet use in the morning, afternoon, and evening).

For each MED, we translated the responses into minutes (e.g., "not at all" was translated into 0, "1.5 hours" was translated into 90) and summed across the responses from each day part to calculate a total exposure time score, in minutes, for weekdays and weekends. For each MED, we then multiplied the sum for the weekday use by 5 and the sum for the weekend use by 2. These two products were then summed and divided by 7 to produce average daily use, in minutes, for each MED ($M = 84.15$, $SD = 126.69$ for average daily tablet use, $M = 24.56$, $SD = 66.48$ for average daily smartphone use, $M = 35.34$, $SD = 83.61$ for average daily game player use, $M = 30.31$, $SD = 79.70$ for average daily laptop use, $M = 10.45$, $SD = 47.02$ for average daily iPod use). For each MED, average daily use in minutes was converted into average daily use in hours to be included in the regression models. This approach to assessing and calculating children's media use from parent reports has been used in prior work (e.g., Cespedes et al., 2014). Daily exposure estimates were deemed desirable to account for fluctuations that occur during the week and so that average exposure could be compared with average sleep disturbances.

Children's evening MED use

Average evening MED use was calculated in the same manner as overall MED use by relying on respondents' reports of their child's weekday and weekend evening exposure ($M = 23.46$, $SD = 39.78$ for average evening tablet use, $M = 7.10$, $SD = 22.59$ for average evening smartphone use, $M = 8.88$, $SD = 23.43$ for average evening game player use, $M = 7.53$, $SD = 21.92$ for average evening laptop use, $M = 2.74$, $SD = 13.32$ for average evening iPod use). For each MED, average evening use in minutes was converted into average evening use in hours to be included in the regression models.

Children's total television viewing

Parents reported how many hours their child watches television during the morning, afternoon, and evening on a typical weekday and on a typical weekend day. We calculated daily television time in the same manner as overall MED use ($M = 228.15$, $SD = 158.42$). The television viewing estimate, in minutes, was converted into hours to be included in the regression models.

Children's evening television viewing

We calculated measures of average daily evening television viewing in the same manner that we arrived at estimates for evening MED use ($M = 76.77$, $SD = 63.15$). The evening television viewing estimate, in minutes, was converted into hours to be included in the regression models.

Children's MED activities at bedtime

Parents were asked to "think about the time right around your 3–5-year-old child's bedtime" and then to report, for each MED, (a) how often they read stories to their child on a tablet, smartphone, video iPod or laptop computer at around the child's bedtime (4 questions), (b) how often their child plays games on a tablet, smartphone, video iPod, handheld game player or laptop computer at around the child's bedtime (5 questions), and (c) how often their child watches TV shows or movies on a tablet, smartphone, video iPod or laptop computer at around the child's bedtime (4 questions). Response options ranged from *0 days per week* (1) to *7 days per week* (8). We calculated the average number of days per week engaged in these activities by averaging across reports of use on each MED (M = 1.28, SD = .69 for reading on MEDs, M = 1.38, SD = .70 for game playing on MEDs, M = 1.32, SD = .65 for watching television programs on MEDs).

Children's sleep disturbances

The bedtime resistance, sleep duration, and daytime sleepiness subscales of the Children's Sleep Habits Questionnaire (CSHQ; Owens, Spirito, McGuinn, 2000) were used to assess sleep disturbances. Parents rated the frequency of children's sleep behaviors on a 3-point scale including *rarely* (0 to 1 time per week), *sometimes* (2 to 4 times per week), and *usually* (5 to 7 times per week). Responses to the questions for each subscale were summed to create a scale for bedtime resistance (M = 9.21, SD = 3.02, α = .78), sleep duration (M = 4.15, SD = 1.45, α = .74) and daytime sleepiness (M = 11.33, SD = 2.58, α = .68). Higher scores were indicative of greater bedtime resistance, compromised sleep duration, and more daytime sleepiness, respectively.

Covariates

In our analyses, we controlled for the age of the child, the number of days the child attends preschool, the mother's education, the mother's income, and the mother's employment status. Parents indicated the child's age by checking one of three boxes that included "3 years old" (coded as 1), "4 years old" (coded as 2), and "5 years old" (coded as 3). On average, parents indicated that their child was 4 years old, M = 2.00, SD = .80. Parents reported the number of days per week their child attends preschool or goes to a childcare provider by checking one of eight boxes ranging from "0 days per week" (coded as 0) to "7 days per week" (coded as 7). On average, children attended preschool or went to a childcare provider two days per week, M = 2.59, SD = 2.22. Parents also reported how much education they have received by indicating the highest level of education they have completed, ranging from "less than high school" (coded as 1) to "graduate degree" (coded as 6). On average, parents had received some college education, M = 3.50, SD = 1.28. Parents reported whether they were working outside of the home by indicating "yes" (coded as 1, 43.3% of parents) or "no" (coded as 2, 56.7% of parents), indicating that our sample was overrepresented by stay-at-home mothers since about 64% of mothers of children under the age of 6 in the United States work outside of the home (Bureau of Labor Statistics, 2015). Parents also reported their annual household income by checking one of eight boxes ranging from "less than $10,000" (coded as 1) to "$200,000 or more" (coded as 8). Average annual household income ranged between $25,000 and $49,999, $M = 4.26$, $SD = 1.39$.

Data Analysis

We used multiple regression analysis to analyze the data. For each analysis, we entered the child's age, frequency of attending childcare, the mother's education level, the mother's employment status, and household income into the first block of the equation, as these variables are typically related to children's sleep disturbances, media exposure, or both (Magee, Lee, & Vella, 2014; Marinelli et al., 2014).

We conducted separate analyses to test whether overall MED use or MED use in the evening is problematic for sleep, with each analysis controlling for TV viewing either overall or in the evening in the second block of the regression equation, and entering either overall MED use or evening MED use for each MED separately in the third block of the equation. Overall MED use and evening MED use were included in the regression models as average daily use in hours.

Finally, we examined the relation between children's sleep disturbances and evening reading on MEDs, evening game playing on MEDs, and evening television program viewing via MEDs. Evening MED activities were included in the regression models as average weekly use in number of days.

The descriptive statistics of all measures included in the study are displayed in Table 1. No respondents had missing data for the variables included in the model. The absence of missing data could have been because the online survey notified respondents when they skipped questions and asked them whether they wished to continue without answering or not.

RESULTS

Children's Overall MED Use and Sleep Disturbances

We found evidence that, even with television viewing controlled, MED use was related to sleep disturbances among preschoolers (Table 2). First, we found that the block of MED use explained a significant 4% of additional variance in bedtime resistance beyond the block of control variables and the block of television viewing. Individually, tablet use was significantly related to bedtime resistance ($\beta = .17$, $p < .01$), indicating that more tablet use was related to greater bedtime resistance. For each standard deviation increase in tablet use, there was a .17 standard deviation increase in bedtime resistance. Smartphone use was marginally significantly related to bedtime resistance ($\beta = .09$, $p < .10$), indicating that for each standard deviation increase in smartphone use, there was a .09 standard deviation increase in bedtime resistance. Children's game player use, laptop use, and iPod use were not significantly related to bedtime resistance.

Second, we found that children's tablet use was significantly related to sleep duration ($\beta = .13$, $p < .01$), such that more tablet use was related to compromised sleep duration. For each standard deviation increase in tablet use, there was a .13 standard deviation increase in compromised sleep duration. Children's smartphone use, game player use, laptop use, and iPod use were not significantly related to sleep duration.

Third, we found that children's tablet use ($\beta = .09$, $p < .10$) was marginally significantly related to daytime sleepiness, indicating that more tablet use was related to more daytime

TABLE 1
Descriptive Statistics of All Measures

	M	*SD*	*Observed range*	*α*
Mother's education	3.50	1.28	1–6	
Household income	4.26	1.39	1–8	
Child's age	2	.80	1–3	
Childcare attendance (days/week)	2.59	2.22	0–7	
TV viewing (minutes/day)	228.15	158.42	0–990	
Evening TV viewing (minutes/day)	76.77	63.15	0–330	
Tablet use (minutes/day)	84.15	126.69	0–754.29	
Evening tablet use (minutes/day)	23.46	39.78	0–287.14	
Smartphone use (minutes/day)	24.56	66.48	0–805.71	
Evening smartphone use (minutes/day)	7.10	22.59	0–278.57	
Game player use (minutes/day)	35.34	83.61	0–647.14	
Evening game player use (minutes/day)	8.88	23.43	0–180	
Laptop use (minutes/day)	30.31	79.70	0–672.86	
Evening laptop use (minutes/day)	7.53	21.92	0–137.14	
iPod use (minutes/day)	10.45	47.02	0–540	
Evening iPod use (minutes/day)	2.74	13.32	0–158.57	
Reading on MEDs at bedtime (days/week)	1.28	.69	1–8	
Playing games on MEDs at bedtime (days/week)	1.38	.70	1–6.60	
Viewing television programs on MEDs at bedtime (days/week)	1.32	.65	1–8	
Bedtime resistance	9.21	3.02	6–18	.78
Sleep duration	4.15	1.45	3–9	.74
Daytime sleepiness	11.33	2.58	8–23	.68

Note. Categories for mother's education were "less than high school"; "high school or GED"; "some college"; "college degree"; "some graduate school"; and "graduate degree" (coded as 1–6, respectively). Categories of household income were "less than $10,000"; "$10,000 to $14,999"; "$15,000 to $24,999"; "$25,000 to $49,999"; "$50,000 to $99,999"; "$100,000 to $149,999"; "$150,000 to $199,999"; and "$200,000 or more" (coded as 1–8, respectively). Categories for child age were "3 years old"; "4 years old"; and "5 years old" (coded as 1–3, respectively).

sleepiness. For each standard deviation increase in tablet use, there was a .09 standard deviation increase in daytime sleepiness. Children's smartphone use, game player use, laptop use, and iPod use were not significantly related to daytime sleepiness.

For children's tablet use, H1 was supported for bedtime resistance (H1a) and sleep duration (H1b), and weakly supported for daytime sleepiness (H1c). For children's smartphone use, H1 was weakly supported for bedtime resistance (H1a), but not supported for sleep duration (H1b) or daytime sleepiness (H1c). For children's game player use, laptop use, and iPod use, H1 was not supported.

Children's Evening MED Use and Sleep Disturbances

We found evidence that, with evening television viewing controlled, evening MED use was related to sleep disturbances among preschoolers (Table 2). First, we found that the block of evening MED use explained a significant 5% of additional variance in bedtime resistance beyond the block of control variables and the block of evening television viewing.

TABLE 2
Regression Analysis of the Relation Between Children's Overall MED Use and Evening MED Use (Hours per Day) and Bedtime Resistance, Sleep Duration, and Daytime Sleepiness

	Overall MED Use								
	Bedtime resistance			*Sleep duration*			*Daytime sleepiness*		
	B	*SE*	*β*	*B*	*SE*	*β*	*B*	*SE*	*β*
Step 1									
Mother's education	–.09	.13	–.04	.02	.06	.02	-.09	.11	–.04
Mother's employment	.02	.33	.00	.01	.16	.00	–.77	.27	–.15**
Household income	–.08	.12	–.04	–.02	.06	–.02	–.04	.10	–.02
Child's age	–.62	.19	–.16**	–.10	.09	–.06	.17	.16	.05
Childcare attendance	.05	.07	.04	.03	.04	.04	.25	.06	.22***
R^2		.03*			.01			.11***	
Step 2									
TV viewing	.15	.06	.13*	.09	.03	.17**	.18	.05	.18***
Incr. R^2 /R^2		.03***/.06**			.03***/.04*			.05***/.16***	
Step 3									
Tablet use	.24	.07	.17**	.09	.04	.13*	.11	.06	$.09^{+}$
Smartphone use	.25	.14	$.09^{+}$	–.01	.07	–.01	.05	.11	.02
Game player use	.02	.12	.01	–.00	.06	–.00	.14	.10	.08
Laptop use	.18	.13	.08	–.01	.06	–.01	–.04	.11	–.02
iPod use	–.24	.20	–.06	.04	.10	.02	.24	.17	.07
Incr. R^2 /R^2		.04**/.10***			.02/.06*			$.02^{+}$/.18***	
F		4.05***			2.12*			7.67***	

	Evening MED Use								
	Bedtime resistance			*Sleep duration*			*Daytime sleepiness*		
	B	*SE*	*β*	*B*	*SE*	*β*	*B*	*SE*	*β*
Step 1									
Mother's education	–.08	.13	–.04	.02	.06	.02	–.08	.11	–.04
Mother's employment	.00	.33	.00	.01	.16	.00	–.73	.27	–.14**
Household income	–.10	.12	–.05	–.03	.06	–.03	–.05	.10	–.02
Child's age	–.65	.19	–.17**	–.10	.09	–.06	.13	.16	.04
Childcare attendance	.02	.07	.02	.02	.04	.03	.24	.06	.21***
R^2		.03*			.01			.11***	
Step 2									
Evening TV viewing	.43	.15	.15**	.21	.07	.15**	.45	.12	.19***
Incr. R^2 /R^2		.04***/.06***			.03***/.04*			.05***/.16***	
Step 3									
Evening tablet use	.79	.23	.17**	.27	.12	.12*	.26	.19	.07
Evening smartphone use	.91	.40	.11*	–.12	.20	–.03	.09	.33	.01
Evening game player use	–.14	.41	–.02	.20	.20	.06	.30	.34	.05
Evening laptop use	.76	.44	$.09^{+}$	–.01	.22	–.00	.24	.36	.03
Evening iPod use	–.83	.73	–.06	.15	.36	.02	1.12	.60	$.10^{+}$
Incr. R^2 /R^2		.05**/.12***			.02/.06*			.03*/.18***	
F		4.63***			2.24*			7.89***	

Note. $^{+}p < .10$. $*p < .05$. $**p < .01$. $***p < .001$.
Analyses control for demographics, childcare attendance, and TV viewing/evening TV viewing.

Individually, evening tablet use (β = .17, $p < .01$) and evening smartphone use (β = .11, $p < .05$) were significantly related to bedtime resistance, indicating that more evening tablet use and more evening smartphone use were related to greater bedtime resistance. For each standard deviation increase in evening tablet use, there was a .17 standard deviation increase in bedtime resistance; for each standard deviation increase in evening smartphone use, there was a .11 standard deviation increase in bedtime resistance. In addition, evening laptop use (β = .09, $p < .10$) was marginally significantly related to greater bedtime resistance. For each standard deviation increase in evening laptop use, there was a .09 standard deviation increase in bedtime resistance. Children's evening game player use and evening iPod use were not significantly related to bedtime resistance.

Second, we found that evening tablet use (β = .12, $p < .05$) was significantly related to sleep duration, indicating that more evening tablet use was related to compromised sleep duration. For each standard deviation increase in evening tablet use, there was a .12 standard deviation increase in compromised sleep duration. Children's evening smartphone use, evening game player use, evening laptop use, and evening iPod use were not significantly related to sleep duration.

Third, we found that the block of evening MED use explained a significant 3% of additional variance in daytime sleepiness beyond the block of control variables and the block of evening television viewing. Individually, evening iPod use (β = .10, $p < .10$) was marginally significantly related to daytime sleepiness, indicating that more evening iPod use was related to more daytime sleepiness. For each standard deviation increase in evening iPod use, there was a .10 standard deviation increase in daytime sleepiness. Children's evening tablet use, evening smartphone use, evening game player use, and evening laptop use were not significantly related to daytime sleepiness.

Hence, for children's evening tablet use, H2 was supported for bedtime resistance (H2a) and sleep duration (H2b), but not for daytime sleepiness (H2c). For children's evening smartphone use, H2 was supported for bedtime resistance (H2a), but not supported for sleep duration (H2b) or daytime sleepiness (H2c). For children's evening laptop use, H2 was weakly supported for bedtime resistance (H2a), but not supported for sleep duration (H2b) or daytime sleepiness (H2c). For children's evening iPod use, H2 was weakly supported for daytime sleepiness (H2c), but not supported for bedtime resistance (H2a) or sleep duration (H2b). For children's evening game player use, H2 was not supported.

Children's Reading, Game Playing, and Television Viewing on MEDs and Sleep Disturbances

First, we examined whether reading, game playing, and television program viewing via MEDs would predict bedtime resistance (Table 3). We found that reading, game playing, and television viewing on MEDs explained a significant 2% ($p < .05$) of additional variance in bedtime resistance beyond the block of control variables and the block of evening television viewing. However, individually, reading on MEDs, playing games on MEDs, and viewing television programs via MEDs were not significantly related to bedtime resistance.

In the second regression analysis, we found that reading on MEDs, playing games on MEDs, and television viewing on MEDs explained a marginally significant 2% of additional variance in sleep duration beyond the block of control variables and the block of evening television viewing.

TABLE 3
Regression Analysis of the Relation Between Children's Reading on MEDs, Playing Games on MEDs, and Viewing Television Programs on MEDs at Around Bedtime (Days per Week) and Bedtime Resistance, Sleep Duration, and Daytime Sleepiness

	Bedtime resistance			*Sleep duration*			*Daytime sleepiness*		
	B	*SE*	*β*	*B*	*SE*	*β*	*B*	*SE*	*β*
Step 1									
Mother's education	–.07	.13	–.03	.04	.06	.04	–.08	.11	–.04
Mother's employment	.06	.33	.01	.03	.16	.01	–.75	.27	–.14**
Household income	–.11	.12	–.05	–.04	.06	–.04	–.05	.10	–.03
Child's age	–.52	.19	–.14**	–.09	.09	–.05	.17	.15	.05
Childcare attendance	.03	.07	.02	.02	.04	.03	.25	.06	.21***
R^2		.03*			.01			.11***	
Step 2									
Evening TV viewing	.49	.14	.17**	.23	.07	.17**	.50	.12	.21***
Incr. R^2 /R^2		.04***/.06***			.03***/.04*			.05***/.16***	
Step 3									
Reading on MEDs	.03	.27	.01	–.18	.13	–.09	.12	.22	.03
Playing games on MEDs	.29	.29	.07	.12	.14	.06*	.32	.24	.09
Television viewing on MEDs	.42	.33	.09	.27	.16	.12	.14	.27	.04
Incr. R^2 /R^2		.02*/.08***			$.02^+$/.05**			$.02^+$/.17***	
F		4.01***			2.51**			9.14***	

Note. $^+p < .10$. $^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.
Analyses control for demographics, childcare attendance, and evening TV viewing.

Playing games on MEDs was significantly related to sleep duration (β = .06, $p < .05$), indicating that more game playing on MEDs at around bedtime was related to compromised sleep duration. For each standard deviation increase in playing games on MEDs, there was a .06 standard deviation increase in compromised sleep duration. Reading on MEDs and television viewing on MEDs were not significantly related to sleep duration.

In the third regression analysis, we found that reading on MEDs, playing games on MEDs, and viewing television programs via MEDs explained a marginally significant 2% of additional variance in daytime sleepiness beyond the block of control variables and the block of evening television viewing. Individually, reading on MEDs, playing games on MEDs, and television viewing on MEDs were not related to daytime sleepiness.

DISCUSSION

Recently, Christakis (2014) outlined the possible benefits and harms of interactive mobile media, concluding that "there is much work to be done in the laboratory" (p. 400). With research on the educational value of MEDs pending, we explored the implications of children's MED use for another important outcome related to children's development: sleep. We found that some types of MED use —both overall and in the evening—were related to sleep disturbances among preschoolers.

Of all of the devices we examined, tablets were the only platform to show consistent relations with children's sleep disturbances. Preschoolers' use of tablet devices alone, above and beyond the influence of television time and our standard control variables, was related to greater bedtime resistance and problems with sleep duration. Future work should consider why tablets, of all MEDs, may be the most potent disruptors of sleep. One possibility is that, compared to most other MEDs, tablets have larger screen sizes, which may attract more viewer attention (McNiven, Krugman, & Tinkham, 2012) and deliver more light. The influence of screen size may also explain why television viewing was more consistently related to sleep outcomes compared to MEDs. Interestingly, some prior work has shown that the sleep quality of adults and adolescents is more disrupted by MEDs compared with televisions (Bartel et al., 2015; Figueiro et al., 2013). Developmental differences in light sensitivity may help explain some of these discrepancies, since Crowley, Cain, Burns, Acebo, and Carskadon (2015) found that younger adolescents were more affected by evening light exposure compared with older adolescents. Similarly, Higuchi et al. (2014) found that children were more vulnerable to evening light compared with adults. However, to our knowledge, no work has extended this inquiry to investigate young children's relative blue light sensitivity. Integrating our findings from those of prior work, we speculate that perhaps preschoolers are at a greater risk of vulnerability to blue light exposure compared with other age groups, with relatively larger screens exacerbating that risk. Future work is needed to address this possibility.

The relations between MED use and sleep disturbances we observed accounted for the influence of television viewing, either overall or in the evening. It was important to control for the influence of traditional viewing of television on a television set in order to observe whether MEDs should be considered independent contributors to children's sleep disturbances. Without these controls, it would be tempting to conclude that our observed relations merely reflected the influence of overall screen time, which is still dominated by television.

In fact, we did observe that television viewing, both overall and during the evening, was significantly related to each indicator of sleep disturbances. In some cases, television exposure was a stronger contributor to sleep disturbances, compared with MEDs. In other cases, their relations with sleep were quite similar. Given that scholars have long been concerned about the disruptions of sleep caused by television viewing (Cespedes et al., 2014), we should now consider MED use a possible contributor to children's sleep disruption as well.

Perhaps it is the combination of exposure to short-wavelength light, held at short range from the face, that contributes to sleep difficulties. However, it is possible that this potential is offset when interacting with MEDs with particularly small screen sizes. Smaller screen sizes are associated with less viewer attention to content (McNiven et al., 2012), as they are perceived as relatively less emotionally arousing (Detenber & Reeves, 1996; Ivory & Magee, 2009; Kim & Sundar, 2013). As noted above, this may be why tablets, with their relatively large screens, were more consistently related to sleep disturbances compared with other MEDs. Experimental work would be helpful to untangle the relative impact of proximity to blue light and screen size on sleep disturbances.

In addition, it could be that sleep is disrupted because preschoolers engage in arousing forms of play when using MEDs. For example, game playing on MEDs was significantly associated with preschoolers' sleep disturbances, but calmer activities, such as reading and watching television on MEDs, were not. In their review of the literature researching the links between screen time and sleep quality, Hale and Guan (2015) found that more interactive forms of screen time, such as video-game playing and computer use, were more consistently related to compromised sleep compared with more passive television viewing. Nevertheless, the majority of studies examining television viewing and sleep disturbances among children still found that exposure was detrimental to sleep.

At the same time, we acknowledge that using any type of screen can consume a significant amount of time that can displace sleep (Hale & Guan, 2015). Any type of activity can displace sleep time. However, screen time may pose a unique risk for sleep hygiene. Children and adults are susceptible to attentional inertia in which time spent looking at television is related to an increased probability of continuing to look at the television (Anderson, Choi, & Lorch, 1987). To our knowledge, attentional inertia has not been studied with MEDs, yet there is no reason to suspect the same phenomenon would not apply. Regardless, it is sensible to suggest that increased time with MEDs, especially at around bedtime, directly reduces time available for sleep.

Of our three indicators of sleep disturbances, MED use was most strongly related to preschoolers' bedtime resistance. It is understandable that preschoolers who play with MEDs find them enticing and do not wish to stop play in order to prepare for sleep. This problem may be exacerbated when preschoolers play with these devices close to bedtime. Also, children who use MEDs around bedtime might fall asleep in another room or in another bed, for example, when using MEDs in a sibling's bedroom. As a result, the mobility of MEDs may increase struggles at bedtime.

The relations we observed appear relatively small in size. And yet, they were larger than the relations between sleep and other predictors in our models, such as household income, maternal education, and so on. This suggests that, compared with other factors, MED use is an important contributor to children's sleep. Moreover, as MED use becomes further ingrained in family rituals and children's exposure increases, the strength of these associations could grow. Also, as children mature, these relations could strengthen because children's ownership and use of MEDs increases (Lauricella, Cingel, Blackwell, Wartella, & Conway, 2014). By the time they reach adolescence, young people also use MEDs for a wider range of activities. For instance, adolescents are frequent users of smartphones for texting, tablets for social network use, and online communication (Lauricella et al., 2014; Lenhart, 2012). Further, studies have shown that large proportions of adolescents use (smart)phones after lights out (National Sleep Foundation, 2014; Oshima et al., 2012; Van den Bulck, 2007). Research is needed that addresses the cumulative effects of MEDs over time.

It is also possible that sleep disturbances influence children's MED use. Children who resist bedtime, have trouble sleeping through the night, and are drowsy during the day may be challenging to satisfy. Sleep-deprived children may become easily agitated or difficult more generally, leading parents to provide them with MEDs as pacifiers. Parents often observe that their children become quiet and calm when placed in front of media (Rideout & Hamel, 2006). Given that MEDs are widely conceived as educational and beneficial to children (Common Sense Media, 2013), parents might be especially drawn to them as means of occupying challenging children.

Also, parents may turn to MEDs as a sleep aid for their children. While using MEDs to help children transition to bedtime may be effective in the short run, it may also make them accustomed and even addicted to the use of MEDs as a sleep aid. In fact, using MEDs as a sleep aid may produce undesired effects, as it could increase bedtime resistance and decrease children's sleep quality. A vicious circle might develop, in which the use of MEDs as a sleep aid leads to sleep disturbances, which, in turn, may encourage parents to use MEDs. Like the relation between television use, computer use, and sleep (Magee et al., 2014), the relation between children's MED use and sleep disturbances could thus be bidirectional. Because our study was cross-sectional and correlational, we cannot determine whether MED use causes sleep troubles or whether sleep deprivation leads to more MED use.

Our findings suggest that parents may wish to reconsider their children's use of MEDs and possibly limit exposure. Time with MEDs not only increases children's overall screen time, but MED use may be problematic for children's sleep. Sleep is critical to development, as children who are sleep-deprived perform relatively worse on cognitive and academic tests (Bub, Buckhalt, & El-Sheikh, 2011), exhibit less adaptive social behaviors (Simola, Liukkonen, Pitkaranta, Pirinen, & Aronen, 2014), and experience worse health outcomes (Snell, Adam, & Duncan, 2007). Prior work has found that media use indirectly affects children's outcomes by disrupting sleep (Nathanson & Fries, 2014; Nuutinen et al., 2014). Likewise, MEDs could have an indirect effect on cognitive, academic, social, and health behaviors via sleep behaviors.

There are several limitations of this study. First, although we gathered a national sample of mothers, these participants still constitute a convenience sample of mothers who have consented to regularly complete online surveys for compensation. Second, our data are based on mothers' reports of their children rather than on observations. Given that MED use takes many different forms and is likely spread throughout the day, sometimes in small increments, it may be difficult for parents to accurately report the amount of time their children spend with these devices. Moreover, parent reports of children's behaviors (both regarding media use and sleep) can be biased and represent an inferior method (Hale & Guan, 2014), especially compared to other methods like time diaries. This issue may be amplified given that there may have been some variety in how parents interpreted our questions. For example, our measures of preschoolers' MED activities asked parents to report on behaviors "at around the child's bedtime." Some parents may have interpreted this to mean the hour or so preceding lights out, while others could have interpreted this to mean the point at which parents say goodnight to the child and leave the room. Because measurement error would attenuate true relations (Hutcheon, Chiolero, & Hanley, 2010), we should expect to observe stronger relations between MED use and sleep when better measurement is employed. Third, our study did not measure any of the mechanisms we proposed to underlie the relations between MED use and sleep disturbances. Fourth, because of our methodology, we were unable to determine whether the relation between MED use and sleep is causal. And, if we cannot be certain about causal direction, then the interpretation of these relations is inherently ambiguous. As both Hale and Guan (2015) and Cain and Gradisar (2010) discovered in their reviews of the literature on this topic, this is a common problem. They noted that experimental work, in which children are randomly assigned to either an exposure or a no-exposure intervention group, is necessary to ascertain whether reducing or eliminating evening MED time can improve preschoolers' sleep. Finally, the magnitude of the effects we observed was relatively small and based on multiple analyses, thus increasing the likelihood of Type 1 error. Future work is needed to discover whether these results can be replicated.

Our study found that MED use, especially tablet use, was related to indicators of sleep disturbances among preschoolers. These relations held independently of the contributions to sleep disturbances made by traditional television viewing. If scholars are concerned about how television viewing affects children's sleep, then they should consider the implications of MED use on children's sleep as well. Unlike some other risk factors for poor sleep, MED use can be modified and might therefore serve as a pathway for improving children's sleep quality. We encourage future research to continue this line of work to gain a fuller understanding of how MEDs affect young children's development.

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