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Media multitasking and sleep problems: A longitudinal study among adolescents

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ABSTRACT

The increase in media multitasking among adolescents has raised concerns regarding its possible negative impact on sleep. Although cross-sectional studies have found a relationship between media multitasking and sleep problems, knowledge about the causal direction is lacking. In a first step to understand causality, we examined the longitudinal relationship between media multitasking and sleep problems among 1443 adolescents (7th and 8th graders, 11–15 years, 51% boys), who completed a questionnaire three times at three-to-four month intervals. We employed random intercept cross-lagged panel models, which specifically examine cross-lagged correlations within (rather than between) individuals. The findings showed no cross-lagged correlations for the overall sample. However, the results indicated that, for 7th graders and girls, media multitasking was (marginally) related to more subsequent sleep problems. Our findings provide first evidence that media multitasking may affect the sleep of 7th graders and girls.

1. Introduction

Adolescents are growing up in technologically immersive environments. Due to the ongoing development of mobile media devices, young people have access to media 24/7. Consequently, along with the increased amount of time that adolescents spend using media, *how* they use media has changed dramatically (Rideout, Foehr, & Roberts, 2010). More than ever before, young people use multiple media devices simultaneously or switch rapidly between media on a single device – a behavior that is referred to as media multitasking. Over the past twenty years, the proportion of media time that eleven-to eighteen-year-olds spend media multitasking has increased from 16% to 29% (Rideout et al., 2010). In the same period, concerns and research about the possible negative consequences of media multitasking on adolescents' development have rapidly accumulated (van der Schuur, Baumgartner, Sumter, & Valkenburg, 2015).

Adolescence is acknowledged as a unique phase of development characterized by the continuing maturation of cognitive, emotional, and social domains of functioning (e.g., Burnett, Sebastian, Kadosh, & Blakemore, 2011). Growing evidence shows that sleep plays a crucial role in the healthy development of adolescents (Shochat, Cohen-Zion, & Tzischinsky, 2014). Sleep problems have been shown to interfere with adolescents' functioning, such as their psychosocial health and academic performance (e.g., Owens, 2014). Sleep problems are multifaceted and include various aspects of sleep-related disturbances, such as shortness of sleep, night awakenings, and difficulties falling asleep (Cain & Gradisar, 2010). These sleep problems typically manifest themselves in increased feelings of sleepiness during the day, which may hinder adolescents' everyday functioning in multiple ways (Cain & Gradisar, 2010; van Maanen et al., 2014). Although the importance of healthy sleep in adolescence is widely recognized, sleep problems are common in this phase of life (Gradisar, Gardner, & Dohnt, 2011), and have significantly increased in recent decades (e.g., Keyes, Maslowsky, Hamilton, & Schulenberg, 2015). Estimates of the prevalence of sleep problems among adolescents range from approximately 25%–40% (Kilincaslan, Yilmaz, Batmaz Oflaz, & Aydin, 2014; Ohayon, Roberts, Zulley, Smirne, & Priest, 2000).

The simultaneous increase in media use and sleep problems among adolescents has captured the attention of researchers. A

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growing number of studies have found that the use of screen-based media (e.g., the time spent watching television or playing videogames) has a negative impact on adolescents' sleep (e.g., Cain & Gradisar, 2010). Recently, researchers have suggested that media multitasking may also contribute to the high rates of sleep problems among adolescents (Calamaro, Mason, & Ratcliffe, 2009). However, only three studies have examined the relationship between media multitasking and sleep problems. These studies showed that media multitasking was related to shortened sleep (Calamaro et al., 2009; Mark, Wang, Niiya, & Reich, 2016; Pea et al., 2012), more difficulties in falling asleep, and daytime sleepiness (Calamaro et al., 2009).

Although these three studies have provided preliminary evidence for the relationship between media multitasking and sleep problems, two main shortcomings in the current literature on media multitasking warrant our attention. First, due to the cross-sectional nature of the available studies, there is as yet no evidence of the causal direction of the relationship between media multitasking and sleep problems. Second, although contemporary media effects theories (e.g., Slater, 2015; Valkenburg & Peter, 2013) have repeatedly pointed at the importance of examining individual differences in the susceptibility to media effects, most previous media multitasking studies have failed to assess the moderating influence of even the standard demographic factors like age and sex. Therefore, the present study employed a three-wave panel design in a first attempt to understand the causal direction of the relationship between media multitasking and sleep problems, and to examine the moderating role of age and sex.

1.1. The causal direction of the relationship between media multitasking and sleep problems

Although researchers generally assume that media multitasking interferes with adolescents' healthy sleep, the relationship between media multitasking and sleep problems may be more complex than previously assumed. Most contemporary media effect theories posit that media effects are transactional (Bandura, 2001; Knobloch-Westerwick, 2014; Slater, 2015; Valkenburg, Peter, & Walther, 2016). These theories assume reciprocal causal relationships between media use and media outcomes, resulting in predictive paths both from media use to media outcomes and from these outcomes to media use (e.g., Bandura, 2001; Slater, 2015). Based on theories of transactional media effects, we anticipate that a reciprocal causal relationship also holds for the relationship between media multitasking and sleep problems. That is, media multitasking may positively predict sleep problems as most often assumed, while sleep problems may also positively predict media multitasking.

As studies have only examined the cross-sectional relationship between media multitasking and sleep problems (Calamaro et al., 2009; Mark et al., 2016; Pea et al., 2012), empirical evidence for a reciprocal relationship between media multitasking and sleep problems is lacking. However, several longitudinal studies on the relationship between *screen-based media use* and sleep problems have investigated reciprocal relationships, albeit with mixed results (e.g., Becker, Langberg, & Byars, 2015). Some studies found a reciprocal relationship between screen-based media use and sleep problems (Chen & Gau, 2016; Magee, Lee, & Vella, 2014), whereas other studies found that screen-based media use acted as either a predictor (e.g., Johnson, Cohen, Kasen, First, & Brook, 2004; van den Bulck, 2007) or a consequence of sleep problems (Tavernier & Willoughby, 2014). These mixed findings in the field of screen-based media use further emphasize the importance of examining the reciprocal causal direction of the relationship between media multitasking and sleep problems.

Existing studies mainly assume that media multitasking leads to sleep problems. This assumption is primarily based on the reasoning for the effect of screen-based media use on sleep problems (Calamaro et al., 2009; Pea et al., 2012). Three underlying mechanisms of the effect of screen-based media use on sleep problems have been proposed. First, screen-based media use may displace sleep (Cain & Gradisar, 2010). Second, exposure to bright screen light may lead to delayed sleep onset because of the suppressed secretion of melatonin, which is necessary to regulate the circadian timing system (e.g., Crowley, Cain, Burns, Acebo, & Carskadon, 2015). Third, screen-based media use may enhance physiological arousal (i.e., bodily sensations such as accelerated heart rate and breathing; Cain & Gradisar, 2010), which has been associated with sleep problems (Paavonen, Pennonen, Roine, Valkonen, & Lahikainen, 2006; van den Bulck, 2004).

These three explanations for the effects of screen-based media use on sleep problems may also explain the impact of media multitasking on sleep problems. Moreover, the effects of media multitasking on sleep problems may even be stronger than those of general time spent using screen-based media (Calamaro et al., 2009). Specifically, with respect to the displacement of sleep, media multitasking may result in more displacement than exposure to a single screen-based medium. To illustrate, when adolescents simultaneously engage in a video game and a social networking site on a laptop, it may take them longer to finish the video game or get to the next level - than when they would only focus on that video game. As for the exposure to bright screen lights, those adolescents who engage in media multitasking using multiple devices are exposed to more screen lights compared to their peers who use one screen at a time (Calamaro et al., 2009). Finally, because of the constant switching between media, media multitasking may constitute a more arousing activity than the use of a single medium. In fact, switching between media on a computer (e.g., e-mail and Facebook) has been shown to lead to temporarily increased physiological arousal (Yeykelis, Cummings, & Reeves, 2014).

Based on these explanations, we argue that media multitasking enhances sleep problems among adolescents. To better understand the causal relationship between media multitasking and sleep problems, we employ a three wave longitudinal design. We assume that adolescents who show increased levels of media multitasking will experience more sleep problems three-to-four months later, resulting in the following hypothesis:

Hypothesis 1. The frequency of media multitasking will be positively related to subsequent sleep problems among adolescents.

Although the main assumption is that media multitasking leads to sleep problems, there is also reason to hypothesize that sleep problems are related to an increase in subsequent media multitasking. Several studies have found support for the negative effect of sleep problems on adolescents' executive functions (e.g., Ferraro, Holfeld, Frankl, Frye, & Halvorson, 2015; Gruber, Cassoff, Frenette, Wiebe, & Carrier, 2012; Warren, Riggs, & Pentz, 2017; Xanidis & Brignell, 2016). Executive functions are cognitive processes that regulate an individual's attention and behavior, including impulsivity and inhibition (e.g., Miyake et al., 2000). For example, compared to children whose sleep was extended, children whose sleep was restricted engaged in more restless impulsive behaviors after five nights (Gruber et al., 2012). Similarly, a longitudinal study demonstrated that sleep problems were associated with more deficits in subsequent inhibitory control (e.g., doing things without thinking first) among adolescents (Warren et al., 2017).

These studies are particularly relevant as executive functions are known to be key predictors of media multitasking (e.g., Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013; Yang & Zhu, 2015; Zhang, 2015). For example, college students who reported higher levels of impulsivity reported that they engaged more often in media multitasking (Sanbonmatsu et al., 2013). Additionally, delictis in inhibition were associated with more media multitasking among adolescents (Baumgartner, Weeda, van der Heijden, & Huizinga, 2014). Thus, it could be argued that adolescents who experience difficulties in their executive functions, due to sleep problems, find it more difficult to resist incoming streams of information (e.g., an incoming text message and social media alerts) that are not directly related to their main media activity (e.g., watching a television program; Yang & Zhu, 2015). Taken together, we hypothesize:

Hypothesis 2. The level of sleep problems will be positively related to subsequent media multitasking among adolescents.

1.2. *The possible moderating role of age and biological sex*

It has become increasingly clear that media effects are not universal, indicating that some individuals may be more susceptible to such effects than others (Bandura, 2001; Slater, 2015; Valkenburg & Peter, 2013). Therefore, it is likely that the relationship between media multitasking and sleep problems is not the same for all adolescents. To increase our understanding of the relationship between media multitasking and sleep problems, we examined the moderating role of two well-known demographic predictors of media multitasking and sleep problems: age (e.g., Baumgartner et al., 2014; Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010) and sex (e.g., Dewald et al., 2010; Rideout et al., 2010).

The current study focuses on the developmental period of early to middle adolescence. Along with developmental changes (e.g., Steinberg et al., 2008), this phase has been marked by crucial environmental changes, such as changes in adolescents' social network, school context, and family relationships (e.g., Eccles et al., 1993). One of the most important environmental changes at the onset of adolescence is the move from primary to secondary school in the Netherlands. Researchers have linked this transition to an increase in media use (e.g., Catherine & Michael, 2016) as well as to disruptions in adolescents' sleep patterns (e.g., Quach, Hiscock, Canterford, & Wake, 2009). Thus, the transition from early to middle adolescence might be a critical window to study the relationship between adolescents' engagement in media multitasking and sleep problems. For these reasons, we examine the moderating role of age on the relationship between media multitasking and sleep problems, by proposing the following research question:

Research question 1: Does age moderate the relationship between media multitasking and sleep problems?

Besides examining age differences, adolescence is also a crucial period to examine sex differences regarding the relationship between media multitasking and sleep problems. With respect to media multitasking, studies have repeatedly found that adolescent girls more frequently engage in media multitasking than boys (e.g., Rideout et al., 2010). Additionally, studies have found that adolescent girls reported more sleep problems than adolescent boys (e.g., Dewald et al., 2010). However, knowledge on possible sex differences in the longitudinal relationship between media multitasking and sleep problems is missing. Therefore, we propose a second research question:

Research question 2: Does sex moderate the relationship between media multitasking and sleep problems?

1.3. *Understanding causality: the importance of examining within-person effects*

Longitudinal data provide the opportunity to better understand the time ordering of variables, and thus provide initial evidence for the causality of a relationship (Curran & Bauer, 2011). To investigate reciprocal relationships using longitudinal data, researchers have typically used the cross-lagged panel model (CLPM; Adachi & Willoughby, 2015; Hamaker, Kuiper, & Grasman, 2015). The cross-lagged paths of the CLPM are commonly interpreted as causal effects between media use and the outcome variable of interest (Hamaker et al., 2015). Recently, researchers have expressed concerns regarding the use and interpretation of the CLPM (Curran & Bauer, 2011; Hamaker et al., 2015; Keijsers, 2015). One of the main disadvantages of the CLPM is that it does not disentangle between-person variance from within-person variance. Because the CLPM aggregates both sources of variance, it is thus unclear whether the cross-lagged paths reflect a between-person or within-person effect.

Being unable to disentangle within and between person variance is problematic, because from a theoretical standpoint we are particularly interested in effects that occur within individuals (Curran & Bauer, 2011). Specifically, we want to investigate whether a particular adolescent who frequently engages in media multitasking experiences more sleep problems over time. To address these shortcomings of the CLPM, the random intercept CLPM (RI-CLPM) has been recently introduced (for a full description of the model, see Hamaker et al., 2015). The RI-CLPM splits between-person from within-person variance, by taking into account that the repeated measures are nested within individuals. In particular, the RI-CLPM controls for the stable between-person correlation, that is the correlation between the rank order position of an individual in media multitasking and the rank order position of an individual's sleep problems over time. As a result, the RI-CLPM allows us to specifically investigate the within-person cross-lagged correlations between media multitasking and sleep problems. In the present paper, we therefore employed the RI-CLPM instead of the common CLPM.

2. Method

2.1. *Sample*

This study involved a three-wave longitudinal study with three-to-four month intervals, conducted among a non-probability sample of adolescents from seven secondary schools in rural and urban areas throughout the Netherlands. In Wave 1 1262 adolescents filled out the survey, 1254 adolescents participated in Wave 2, and 1174 adolescents participated in Wave 3. Participants were excluded if they reported incorrect identification numbers or had missing values on all main variables ($N_{Wave1} = 27$; $N_{Wave2} = 38$; $N_{Wave3} = 71$). In total, 1441 adolescents ($N_{Wave1} = 1241$; $N_{Wave2} = 1216$; $N_{Wave3} = 1103$) filled out the survey in at least one wave ($M_{age} = 12.61$, $SD_{age} = 0.75$; 51% boys). Of these participants, 904 adolescents (63%) participated in all three waves, 311 adolescents (22%) in two waves, and 226 adolescents (15%) in one wave. The attrition was mainly due to busy school schedules. At some schools it was not possible to schedule data collection for all participating classes in each wave. Fifty-two percent ($n = 414$) were in their first year of secondary school (i.e., grade 7) and 48% ($n = 388$) were in their second year (i.e., grade 8). In the Netherlands, adolescents are typically 12 years old when they go to secondary school.

2.2. Procedure

After the ethical approval was obtained from the ethical committee of the authors' institute, the authors contacted multiple schools across the Netherlands via e-mail. In total, seven schools responded and agreed to participate in this study. In consultation with these schools, the participating classes were selected based on the school class schedules and educational level. Of the participating classes, passive informed consent of the parents as well as informed assent of the adolescents was obtained before the start of the study. We collected the data around early November 2014, early March 2015, and the end of June 2015. The selected time points were all around the end of a school term (i.e., first-term, mid-term, and end-term). During a short introduction by the research team, we informed participants about the content of the questionnaire and assured that their participation was completely confidential and voluntary. Subsequently, the participants filled out an online survey during class under supervision of a member of the research team and/or the teacher. It took participants approximately 30 min to complete the survey. After each wave, the participants received a small present (monetary value around $ 0.50) for their participation.

2.3. Measurements

2.3.1. Media multitasking

We measured media multitasking with the short media multitasking measure for adolescents (MMM-S) (Baumgartner, Lemmens, Weeda, & Huizinga, 2017), which is based on the media multitasking index (MMI) developed by Ophir, Nass, and Wagner (2009). The MMM-S is validated for adolescents and the items of this short scale correlate highly with the full scale (Baumgartner et al., 2017). The MMM-S consists of three main media activities: 1) watching TV, 2) sending messages via phone or computer (e.g., WhatsApp, Snapchat), and 3) using social networking sites (e.g., Facebook, Instagram). For each of the three main media activities, participants indicated how often they typically engage in that media activity simultaneously with each of the other two media activities as a secondary activity. Thus, media could be used on both multiple devices and on a single device. In addition, listening to music was included as a secondary activity for all three main activities. Listening to music is often not a primary media activity, but is included in most media multitasking measures (Ophir et al., 2009).

In total, the scale consists of nine items: (1) three items for watching TV ('While watching TV, how often do you [use social networking sites]/[send messages via phone or computer]/[listen to music] at the same time?'), (2) three items for using social networking sites, and (3) three items for sending messages via phone or computer. Participants indicated their engagement in media multitasking on a five-point scale, with 0 = *never*, 1 = *almost never*, 2 = *sometimes*, 3 = *often*, and 4 = *very often*. The nine items were averaged into one mean index (Wave 1: $M = 1.93$, $SD = 1.01$, Cronbach's alpha = .89; Wave 2: $M = 1.88$, $SD = 1.02$, Cronbach's alpha = .91; Wave 3: $M = 1.85$, $SD = 1.03$, Cronbach's alpha = .92). Higher scores on this scale indicate more frequent media multitasking.

2.3.2. Sleep problems

To measure sleep problems, we employed the Sleep Reduction Screening Questionnaire (SRSQ), which is a validated measure to screen for multifaceted symptoms of sleep problems among Dutch adolescents (van Maanen et al., 2014). When measuring subjective sleep problems among adolescents it is crucial to include a measure of daytime sleepiness, because that is how adolescents experience their sleep problems (Cain & Gradisar, 2010). Self-report measures similar to this scale have shown to correlate highly with objective sleep measures among adolescents (Wolfson et al., 2003). The SRSQ consists of nine items based on three domains: three items on sleepiness (e.g., 'I feel sleepy during the day'), three items on shortness of sleep (e.g., 'I am a person who does not get enough sleep'), and three items on loss of energy (e.g., 'I have enough energy during the day to do everything [reversed]'). The items were rated on a 5-point scale, 0 = *never*, 1 = *almost never*, 2 = *sometimes*, 3 = *often*, and 4 = *very often*. The nine items were averaged into one mean index; A higher score indicates more sleep problems. Cronbach's alpha for the scale with nine items was .79 ($M = 1.44$, $SD = 0.68$) in the first wave, .79 ($M = 1.50$, $SD = 0.69$) in the second wave, and .77 ($M = 1.56$, $SD = 0.67$) in the third wave.

2.4. Data analysis

Structural equation modeling was applied to analyze the longitudinal relationship between media multitasking and sleep problems. The RI-CLPMs were tested using the statistical program Mplus 7 (Muthén & Muthén, 2012). All models were estimated using Full Information Maximum Likelihood, to cope with missing data across waves (Muthén & Muthén, 2012). To increase the parsimony of the models, stability and cross-lagged paths were constrained to be equal in all models. Model fit was evaluated with the chi-square measure of exact fit, the Root Mean Square Error of Approximation (RMSEA) and its 95% confidence interval, and the Comparative Fit Index (CFI). Close fit of the model was indicated by RMSEA values below .05 and CFI values above .95. Finally, RMSEA values between .05 and .08 and CFI values between .90 and .95 indicate satisfactory fit.

The RI-CLPM controls for past levels of the outcome variables, sleep problems, and media multitasking. Although previous studies have shown that both media multitasking (Wang & Tchernev, 2012) and sleep problems (Tavernier & Willoughby, 2014) are stable over time, high stability does not preclude maturation or change at the individual level. Thus, particularly in a transition period such as early to middle adolescence, both media multitasking and sleep problems may change over time at the individual level. Before running the RI-CLPM, we examined the amount of between-person and within-person variance by calculating the intra-class correlations (ICC). For media multitasking, the ICC was .72, indicating that 72% of the variance was explained by between-person variance and that 28% of the variance was explained by within-person variance. For sleep problems, the ICC was .65. This demonstrated that 65% of the variance was explained by between-person variance, whereas 35% of the variance was explained by within-person variance. This implies that a substantial part of the variance was due to within-person changes over time.

In the RI-CLPM (see Fig. 1), the CLPM is extended following the procedures described by Hamaker et al. (2015). First, each observed variable was regressed on its own latent factor, with each loading constrained at 1. This resulted in six within-person latent factors, reflecting the within-person variance. Between these six within-person latent factors stability paths, cross-lagged paths, covariances between media multitasking and sleep problems at Wave 1, and covariances between the disturbances of media multitasking and sleep problems at Wave 2 and Wave 3 were added to the model. In addition, random intercept factors were added for media multitasking and sleep problems to control for the stable between-person variance. The observed scores were the indicators of these random intercept factors, with all factor loadings constrained at 1. Finally, between these two random factors we added a covariance to the model. The moderating role of age and sex was examined by applying multiple group analyses.

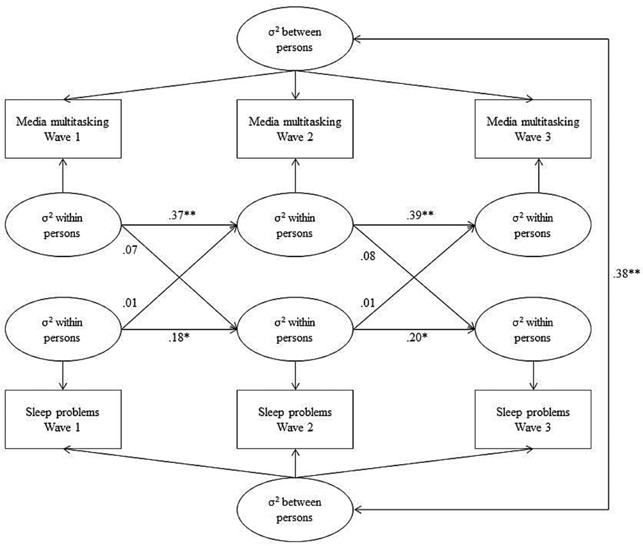

Fig. 1. Simplified RI-CLPM with the standardized maximum likelihood parameter estimates for the within-person relationship between media multitasking and sleep problems. *Note*. $^{*}p < .05$; $^{**}p < .001$.

3. Results

3.1. Descriptive statistics

Table 1 displays the means, standard deviations, and correlations for media multitasking and sleep problems at each assessment point. Although the means of media multitasking were slightly below two (i.e., 'sometimes') (Wave 1: $M = 1.93$, $SD = 1.01$; Wave 2: $M = 1.88$, $SD = 1.02$; Wave 3: $M = 1.85$, $SD = 1.03$), the findings indicate that media multitasking was common among adolescents. In Wave 1, 33% of the participating adolescents reported that they sometimes engage in media multitasking (Wave 2 = 32%; Wave 3 = 32%). In addition, 17% indicated that they engage often or very often in media multitasking (Wave 2 = 16%; Wave 3 = 15%). The means of sleep problems were also below two (i.e., 'sometimes') (Wave 1: $M = 1.44$, $SD = 0.68$; Wave 2: $M = 1.50$, $SD = 0.69$; Wave 3: $M = 1.56$, $SD = 0.67$). In Wave 1, 20% of the participating adolescents indicated that they sometimes experienced sleep problems (Wave 2 = 24%; Wave 3 = 31%), and 2% reported that they often experienced sleep problems (Wave 2 = 3%; Wave 3 = 2%).

As Table 1 shows, all correlation coefficients between media multitasking and sleep problems were significant and positive in each wave. Adolescents engaging in higher levels of media multitasking reported more sleep problems. General media use was positively related to both media multitasking and sleep problems. In addition, girls reported significantly more media multitasking than boys. Eighth graders engaged more often in media multitasking and reported more sleep problems than 7th graders.

3.2. Longitudinal relationships

The RI-CLPM model showed an exact fit, χ^2 (5) = 3.54, $p = .618$, RMSEA = .00 (90% CI [.00, .03]), and CFI = 1.00. There was a moderately strong between-person correlation between the random intercept factors of media multitasking and sleep problems ($b^* = .38$, $p < .001$). This implies that adolescents who engage in media multitasking more frequently, reported more sleep problems across the three waves. In addition, both media multitasking ($b^* = .37$ and .39, both $p < .001$) and sleep problems ($b^* = .18$, $p = .001$ and $b^* = .20$, $p = .004$) displayed a significant within-person stability over time.

As displayed in Fig. 1, the within-person correlation between media multitasking and subsequent sleep problems was not significant from Wave 1 to Wave 2 ($b^* = .07$, $p = .176$) nor from Wave 2 to Wave 3 ($b^* = .08$, $p = .178$). Similarly, there was no significant within-person correlation between sleep problems and subsequent media multitasking from Wave 1 to Wave 2 ($b^* = .01$, $p = .910$) nor from Wave 2 to Wave 3 ($b^* = .01$, $p = .910$). These findings do not support Hypotheses 1 and 2.

3.2.1. The moderating role of age

The model showed an exact fit, χ^2 (10) = 9.71, $p = 466$, RMSEA = .00 (90% CI [.00, .04]), and CFI = 1.00. The model revealed a moderately strong between-person correlation between the random intercept factors of media multitasking and sleep problems for both age groups (grade 7: $b^* = .33$, $p < .001$; grade 8: $b^* = .39$, $p < .001$).

For adolescents in grade 7, the within-person stability paths of media multitasking ($b^* = .43$ and .45, both $p < .001$) and sleep problems ($b^* = .26$ and .30, both $p < .001$) were significant. The within-person correlation between media multitasking and subsequent sleep problems approached significance from Wave 1 to Wave 2 ($b^* = .13$, $p = .055$) and from Wave 2 to Wave 3 ($b^* = .13$, $p = .051$). The within-person correlations between sleep problems and subsequent media multitasking were not significant ($b^* = .03$, $p = .535$ and $b^* = .04$, $p = .536$).

For adolescents in grade 8, the within-person stability paths were significant for media multitasking ($b^* = .33$ and .36, both $p < .001$), but not significant for sleep problems ($b^* = .12$, $p = .144$; $b^* = .13$ $p = .179$). The within-person correlations between media multitasking and subsequent sleep problems (both $b^* = .01$, $p = .906$) and the within-person correlations between sleep problems and subsequent media multitasking ($b^* = .04$, $p = .562$ and $b^* = .05$, $p = .563$) were not significant.

Table 1
Zero-order pearson correlations, means, and standard deviations for media multitasking, sleep problems, age, and sex.

Measure		1	2	3	4	5	6	10
1	MM W1	–						
2	MM W2	$.73^{**}$						
3	MM W3	$.67^{**}$	$.75^{**}$					
4	SP W1	$.24^{**}$	$.23^{**}$	$.24^{**}$				
5	SP W2	$.27^{**}$	$.26^{**}$	$.24^{**}$	$.66^{**}$			
6	SP W3	$.27^{**}$	$.25^{**}$	$.29^{**}$	$.61^{**}$	$.65^{**}$		
7	Age	$.10^{**}$	.06	$.08^{*}$	$.12^{**}$	$.09^{*}$	$.13^{**}$	
8	Sex (0 = boys)	$.24^{**}$	$.27^{**}$	$.32^{**}$	$.07^{*}$	.02	.04	-.01
	Mean	1.93	1.88	1.85	1.44	1.50	1.56	12.61
	SD	1.01	1.02	1.03	0.68	0.69	0.67	0.75

Note. $^{*}p < .05$; $^{**}p < .001$. MM = Media multitasking; SP = Sleep problems; W1 = Wave 1; W2 = Wave 2; W3 = Wave 3.

3.2.2. The moderating role of sex

For sex, the model showed an exact fit, χ^2 (10) = 7.76, p = .652, RMSEA = .00 (90% CI [.00, .03]), and CFI = 1.00. For both girls and boys, there was a moderately strong between-person correlation between the random intercept factors of media multitasking and sleep problems (girls: b^* = .43, p < .001; boys: b^* = .32, p = .001).

For girls, the within-person stability paths were significant for media multitasking (b^* = .30 and .36, both p < .001), but not significant for sleep problems (b^* = .12, p = .142; b^* = .13, p = .184). The within-person correlation between media multitasking and subsequent sleep problems was (marginally) significant from Wave 1 to Wave 2 (b^* = .14, p = .053) and from Wave 2 to Wave 3 (b^* = .16, p = .049). In contrast, the reverse within-person correlations between sleep problems and subsequent media multitasking were not significant (both b^* = .07, p = .292 and p = .296).

For boys, the within-person stability paths were significant for media multitasking (b^* = .45 and .42, both p < .001) and sleep problems (b^* = .22, p = .003 and b^* = .24, p = .005). However, both the within-person correlations between media multitasking and subsequent sleep problems (both b^* = .06, p = .444 and p = .446) and the within-person correlations between sleep problems and subsequent media multitasking were not significant for boys (both b^* = −.03, p = .659 and p = .658).

4. Discussion

The considerable increase in media multitasking in recent decades has raised concerns regarding the possible negative impact of media multitasking on sleep problems. Although cross-sectional studies demonstrated that media multitasking is related to sleep problems (e.g., Calamaro et al., 2009; Mark et al., 2016), evidence for the direction of this relationship has been lacking. Such evidence is pivotal because media multitasking could be conceptualized as both a cause and a consequence of sleep problems. To take a first step in understanding the causal relationship between media multitasking and sleep problems, we conducted a three wave longitudinal study among adolescents.

Consistent with previous cross-sectional studies that demonstrated that media multitasking was associated with sleep problems (e.g., Calamaro et al., 2009; Mark et al., 2016), our findings showed a near to medium positive relationship between media multitasking and sleep problems in each of the three waves. Adolescents who engaged in higher levels of media multitasking reported more sleep problems. Moreover, in line with these cross-sectional findings, the RI-CLPM demonstrated a stable moderate between-person relationship between media multitasking and sleep problems. Thus, as expected media multitasking and sleep problems are positively related among adolescents.

To explore the longitudinal relationship between media multitasking and sleep problems, we were especially interested in within-person processes over time. More specifically, we examined whether an increase in an adolescent's media multitasking behavior was linked to an increase in sleep problems three-to-four months later. In contrast to our expectations (see Hypothesis 1 and Hypothesis 2), media multitasking was not related to an increase in subsequent sleep problems, nor were sleep problems positively related to subsequent media multitasking for the overall sample. This suggests that media multitasking and sleep problems do not influence each other. However, our findings indicated that there might be a small relationship between media multitasking and subsequent sleep problems among 7th graders and girls. For 7th graders and girls, media multitasking was (marginally) associated with more subsequent sleep problems.

Although the relationship between media multitasking and subsequent sleep problems was small among 7th graders and girls, these findings should not be interpreted as trivial (Adachi & Willoughby, 2015). To understand why 7th graders and girls are especially susceptible to the negative effects of media multitasking on sleep, it might be important to consider the role of psychological stress (i.e., the perceived inability to cope with the demands of everyday life) that results from media multitasking. Several studies have shown that individuals who experience daily stressors are more likely to report sleep problems (Doane & Thurston, 2014; Galambos, Howard, & Maggs, 2011). As young people perceive the current media multitasking environment as stressful (Bardhi, Rohm, & Sultan, 2010; Mark, Wang, & Niiya, 2014), it is expected that the elevated levels of psychological stress resulting from daily media multitasking might be disrupting adolescents' sleep.

In the current study, the 7th graders just transitioned from elementary to secondary school, which means that they experience multiple environmental changes (e.g., Eccles et al., 1993). For example, they have to get used to a new school and new teachers, build new friendships, and become more independent from their parents (e.g., Eccles et al., 1993). Along with these changes, adolescents experience changes in their media environment. For example, after transitioning schools, adolescents watch television more frequently (e.g., Gebremariam et al., 2012), and use more social media (Catherine & Michael, 2016). As media use increases, adolescents are also more likely to engage in media multitasking (Rideout et al., 2010). It might thus be assumed that adolescents experience a multitude of stressors during this period. The cumulative stress theory (Simmons, Burgeson, Carlton-Ford, & Blyth, 1987) posits that when changes occur simultaneously, adolescents may find it difficult to cope with these changes. Because 7th graders experience several transition-related changes during this period, they may find it difficult to also cope with the changes in their media environment and thus perceive media multitasking as particularly stressful.

With respect to the sex differences, girls are known to be particularly vulnerable to stress (e.g., Gunnar, Wewerka, Frenn, Long, & Griggs, 2009) and often deal insufficiently with stress (e.g., Nolen-Hoeksema, 2001). It has been shown that girls perceive higher levels of stress than boys when exposed to similar situations (e.g., Beyens, Frison, & Eggermont, 2016; Gunnar et al., 2009; Thomée, Eklöf, Gustafsson, Nilsson, & Hagberg, 2007; Östberg et al., 2015). For example, girls were more stressed about not being popular on Facebook than boys (Beyens et al., 2016). In addition, compared to boys, girls more often cope with stress by ruminating (i.e., focusing on their own concerns), instead of searching for solutions that decrease levels of stress (Nolen-Hoeksema, 2001). In sum, because girls may be more likely to experience psychological stress and insufficiently cope with stress resulting from media multitasking than boys, girls may be particularly susceptible to the possible negative effects of media multitasking on sleep.

Inconsistent with our second hypothesis, we found no support for the impact of sleep problems on subsequent media multitasking frequency. However, sleep problems may still affect media multitasking if shorter time intervals are considered. When adolescents experience sleep problems this may lead to deficits in executive functions shortly after (Gruber et al., 2012). Subsequently, these deficits in executive functions may lead to an increase in media multitasking (e.g., Baumgartner et al., 2014; Yang & Zhu, 2015). In line with this, Mark et al. (2016) found that adolescents who experienced more sleep problems reported more media multitasking the next day. These findings suggest that sleep problems have a proximal effect on media multitasking, but that this effect may not be visible anymore three-to-four months later.

Because our findings indicate that media multitasking may result in more sleep problems among 7th graders and girls, it could be important to inform adolescents about the possible negative consequences of media multitasking on their sleep. As the present study shows, media multitasking is common and rather stable over time, suggesting that it has become a habit for many adolescents. This may be problematic because habits, once formed, are difficult to change. To prevent habituation to media multitasking, adolescents may need to learn to inhibit their responses to internal (e.g., boredom) and external triggers (e.g., incoming text messages) that may result in media multitasking. An effective way in which parents and teachers can prevent habitual media multitasking is by setting clear and consistent rules about media and smartphone use (Valkenburg, Piotrowski, Hermanns, & Leeuw, 2013).

4.1. Shortcomings and future research

Our study should be regarded as a first step in providing knowledge on the long-term effects of media multitasking on sleep problems. However, we acknowledge that our study has shortcomings that should be addressed in future research. First, although the RI-CLPM automatically controls for all stable differences among individuals (Hamaker et al., 2015), it is still possible that other factors play a confounding role in the relationship between media multitasking and sleep problems. Therefore, both longitudinal and experimental studies are needed to confirm our findings.

Second, future studies are needed to understand when and for whom media multitasking is particularly disruptive. Future studies that examine the impact of media multitasking on sleep should further distinguish between *which* media adolescents use (i.e., device, content), *how* they use media (i.e., single-tasking, multitasking using a single device, multitasking using multiple devices), and *when* they use media (i.e., day, evening, night). Furthermore, this study suggests that the relationship between media multitasking and sleep problems may not be universal. Although examining the moderating role of age and sex was an important first step, this should be extended by examining wider age ranges, and by considering the cultural background with respect to the moderating role of gender. For example, the cultural background has been shown to be important for explaining differences in media multitasking (Kononova, Zasorina, Diveeva, Kokoeva, & Chelokyan, 2014; Voorveld, Segijn, Ketelaar, & Smit, 2014).

Third, longitudinal and experimental studies are needed to examine possible processes underlying both directions of the relationship between media multitasking and sleep problems. For the influence of media multitasking on sleep problems, we have discussed several possible underlying mechanisms that may explain this relationship, such as exposure to bright screens, heightened levels of arousal, and elevated levels of psychological stress. Examining these underlying mechanisms will help us to understand why media multitasking and sleep problems are related.

Fourth, findings in the current study may have been affected by the length of the time intervals used in this study (three-to-four month intervals). Therefore, future studies should include varying time intervals to fully understand how the longitudinal relationship between media multitasking and sleep problems develops over time. For example, time series data consisting of multiple time sample points within shorter time intervals might provide crucial information on the immediate effects of media multitasking on sleep problems and vice versa (e.g., Wang & Tchernev, 2012).

Finally, although the media multitasking and sleep problem instruments that we used have both been validated among adolescents, this study included only subjective self-reports. Future studies are advised to measure media multitasking and sleep problems in multiple ways to compare the reliability and validity of the different measures used. Ultimately, such studies should combine subjective measures (e.g., self-report, teacher reports, parent reports) and objective measures (e.g., automated tracking devices to measure media multitasking and sleep).

4.2. Conclusion

The findings of the present study suggest that current concerns about the possible negative impact of media multitasking on sleep problems are only partly justified. Although we found no support for a longitudinal relationship between media multitasking and sleep problems for the overall sample, our findings do indicate that media multitasking was (marginally) related to increased sleep problems three-to-four months later among 7th graders and girls. While more research is needed, media multitasking among 7th graders and girls may warrant attention because sleep is essential for adolescents' healthy development. If media multitasking interferes with adolescents' sleep, other aspects of their development that are related to sleep problems (Becker et al., 2015; Shochat et al., 2014), such as their socioemotional functioning (Owens, 2014) and academic performance (Dewald et al., 2010), may be affected.

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