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ABSTRACT

There are concerns that social media (SM) use and SM stress may disrupt sleep. However, evidence on both the cross-sectional and longitudinal relationships is limited. Therefore, the main aim of this study is to address this gap in the literature by examining the cross-sectional and longitudinal relationships between SM use, SM stress, and sleep (i.e., sleep latency and daytime sleepiness) in adolescents. In total, 1,441 adolescents 11–15 years, 51% boys) filled out a survey in at least one of three waves that were three to four months apart (N_{Wave1} = 1,241; N_{Wave2} = 1,216; N_{Wave3} = 1,103). Cross-sectionally, we found that SM use and SM stress were positively related to sleep latency and daytime sleepiness. However, when examined together, SM use was not a significant predictor of sleep latency and daytime sleepiness above the effects of SM stress. The longitudinal findings showed that SM stress was positively related to subsequent sleep latency and daytime sleepiness, but only among girls. Our findings stress that it is important to focus on how adolescents perceive and cope with their SM use, instead of focusing on the mere frequency of SM use.

Concerns have been raised regarding the negative influence of social media (SM) use on young people's sleep (Zimmerman, 2008). The possible relationship between SM use and sleep has been attributed to three well-known underlying mechanisms for the adverse impact of electronic media use on sleep (Cain & Gradisar, 2010). First, the time young people spend on SM may actually encroach on the time that is available to sleep, this is the time displacement hypothesis (Cain & Gradisar, 2010). Second, SM use is known to increase arousal (Cain & Gradisar, 2010; Mauri, Cipresso, Balgera, Villamira, & Riva, 2011). For example, Mauri and colleagues (2011) found that during Facebook use participants showed high physiological arousal. These increased levels of physiological arousal may make it more difficult for adolescents to fall asleep (e.g., van den Bulck, 2004). Third, when adolescents engage in SM use they are exposed to bright screen lights, which can disrupt the secretion of the sleep hormone melatonin (e.g., Crowley, Cain, Burns, Acebo, & Carskadon, 2015). In line with this reasoning, it has been shown that people who use devices that emanate bright screen lights before bedtime actually take longer to fall asleep, their circadian rhythms are disrupted, and they experience an increase in daytime sleepiness (Chang, Aeschbach, Duffy, & Czeisler, 2015).

Up to now, studies that directly examined the relationship between SM use and sleep have yielded mixed results (e.g., Garett, Liu, & Young, 2016; Levenson, Shensa, Sidani, Colditz, & Primack, 2016; Xu et al., 2016). Whereas one study showed that SM frequency was related to more sleep disturbances, including more difficulty falling asleep and lower sleep quality (Levenson

et al., 2016), other studies showed limited or no support for a negative relationship between SM use and sleep (Garett et al., 2016; Tavernier & Willoughby, 2014; Xu et al., 2016).

One explanation for these mixed results might be that it is not the *frequency* of SM use per se that disrupts sleep and sleep-related parameters, but that the way adolescents *experience* their SM use influences the relationship between SM and sleep (Lee, Ho, & Lwin, 2016). More specifically, it has been argued that some adolescents experience high levels of stress from using SM (Beyens, Frison, & Eggermont, 2016). To date, only few studies have specifically focused on the relationship between SM stress and adolescent sleep (e.g., Garett et al., 2016; Xanidis & Brignell, 2016), and no studies have aimed to disentangle the effect of SM use from SM stress. Studies on SM stress focused either on SM dependency or SM-related anxiety. For example, three studies among emerging adults showed that SM dependency was related to lower sleep quality (Wolnicza et al., 2013; Xanidis & Brignell, 2016) and delayed bed and rising times (Andreassen, Torsheim, Brunborg, & Pallesen, 2012). In addition, Garett et al. (2016) demonstrated that sending tweets that evoked fear (i.e., SM-related anxiety) was associated with lower sleep quality. Overall, these studies indicate that SM stress is adversely associated with multiple sleep variables.

The relationship between SM stress and sleep mirrors earlier research that showed that experiencing stress in general is negatively related to several aspects of sleep (e.g., Doane & Thurston, 2014; Galambos, Howard, & Maggs, 2011; Lund, Reider, Whiting, & Prichard, 2010). For example, adolescents

reported that stress resulted in lying awake at night and day-time sleepiness (American Psychological Association, 2014). The negative impact of stress on sleep has been explained by the activation of multiple neurotransmitters and the release of stress hormones (Sanford, Suchecki, & Meerlo, 2014). For example, increased cortisol levels have been associated with a subsequent decrease in sleep episode duration (Zeiders, Doane, & Adam, 2011). Moreover, rumination, which is a maladaptive but common technique to cope with stress, has been linked to an increase in sleep latency (i.e., the time between bedtime and sleep onset, Pillai, Steenburg, Ciesla, Roth, & Drake, 2014) and daytime sleepiness (Matthews, Hall, Cousins, & Lee, 2016). It may thus be assumed that adolescents who ruminate about SM interactions when lying in bed may experience stress, which in turn may adversely affect their sleep.

In short, although there is initial evidence for the negative relationship between SM use and sleep as well as the negative relationship between SM stress and sleep among emerging adults, there are still important gaps in the literature that need to be addressed. First, because existing studies focused on emerging adults when studying the impact of SM on sleep, our knowledge about this relationship among adolescents is limited. Adolescence might be a particularly relevant developmental stage to study, as adolescents are avid users of SM (Lenhart, Purcell, Smith, & Zickhur, 2010). Second, existing studies have not examined SM use and SM stress together. Therefore, the unique effects of SM use and SM stress on sleep have not yet been untangled. Third, most studies solely investigated the relationship between SM use and sleep cross-sectionally. Thus, although causality is assumed, evidence on a potential detrimental effect of SM use and SM stress on sleep is still missing.

The current study will address these three gaps in the current literature by investigating the unique relationship between both SM use and SM stress and two sleep parameters cross-sectionally as well as longitudinally among adolescents. In this study we focused on sleep latency and daytime sleepiness. Based on previous studies, we expect that both SM use (H1a) and SM stress (H1b) are cross-sectionally related to longer sleep latency and more daytime sleepiness. Moreover, we expect that both SM use (H2a) and SM stress (H2b) will lead to an increase in sleep latency and daytime sleepiness *over time*.

A final gap in the literature is that moderating factors, such as gender, have not been considered. There are, however, some crucial differences between boys and girls with respect to SM use and SM stress. Girls are more likely than boys to use SM (Antheunis, Schouten, & Krahmer, 2016; Müller et al., 2016), and are also more likely to report SM stress (Beyens et al., 2016; Thomée, Harenstam, & Hagberg, 2011). These differences between boys and girls may also result in differences in the relationship between SM use and sleep as well as SM stress and sleep. Specifically, girls may be particularly susceptible for the negative impact of SM use and SM stress on sleep. First, it may be more likely that SM use displaces or disrupts sleep among girls because they more frequently use SM than boys (Punamäki, Wallenius, Nygård, Saarni, & Rimpelä, 2007). Second, compared to boys, girls more often insufficiently cope with stress by ruminating (Nolen-Hoeksema, 2001), which has been shown to increase sleep

latency (Pillai, Steenberg, et al., 2014) and daytime sleepiness (Matthews et al., 2016).

Overall, we expect that the relationship between SM use and subsequent sleep latency (H3a), and between SM use and subsequent daytime sleepiness (H3b) will be stronger for girls than boys. Similarly, we expect that the relationship between SM stress and subsequent sleep latency (H4a), and between SM stress and subsequent daytime sleepiness (H4b) will be stronger for girls than for boys.

Method

Participants

This study was part of a three-wave longitudinal study among adolescents of seven secondary schools throughout Netherlands. We collected data of 1,262 adolescents in Wave 1, 1,254 adolescents in Wave 2, and 1,174 adolescents in Wave 3. If the participants reported incorrect identification numbers or had missing data on all main variables ($N_{\text{Wave1}} = 27$; $N_{\text{Wave2}} = 38$; $N_{\text{Wave3}} = 71$), they were excluded from the analyses. With respect to the cross-sectional analyses we included the participants that had available data within the specific wave ($N_{\text{Wave1}} = 1{,}241$; $N_{\text{Wave2}} = 1{,}216$; $N_{\text{Wave3}} = 1{,}103$).

As for the longitudinal data analyses, we included all participants that participated in at least one wave of data collection. This resulted in a total of 1,441 adolescents ($M_{\text{age}} = 12.61$, $SD_{\text{age}} = 0.75$; 51% boys). Of these adolescents, 904 adolescents (63%) participated in all three waves, 311 adolescents (22%) in two waves, and 226 adolescents (15%) in one wave. The main reason for attrition was that not all classes were available for data collection in each wave due to busy school schedules. We examined whether adolescents who participated in all three waves differed from adolescents who participated in only one or two waves. For SM use we found no significant differences between the three groups (Wave 1: $F(2,1241) = 1.23$, $p = .294$; Wave 2: $F(2,1216) = 1.09$, $p = .338$; Wave 3: $F(2,1108) = 2.66$, $p = .070$). For SM stress we found no differences between the three groups in Wave 1 and Wave 2 (Wave 1: $F(2,1184) = 1.05$, $p = .350$; Wave 2: $F(2,1165) = 1.24$, $p = .290$), but there were group differences in Wave 3 (Wave 3: $F(2,1083) = 3.05$, $p = .048$). However, when comparing participants who participated in all three waves ($M = 1.05$) with the participants who participated in only one wave ($M = 1.38$) using post-hoc analyses (Bonferroni) we found no significant difference between these groups.

As for the dependent variables, we found significant differences between the three groups for sleep latency (Wave 1: $F(2,1168) = 3.78$, $p = .023$; Wave 2: $F(2,1155) = 6.82$, $p = .001$; Wave 3: $F(2,1078) = 4.49$, $p = .011$), and daytime sleepiness in Wave 2 and Wave 3, but not in Wave 1 (Wave 1: $F(2,1155) = 1.97$, $p = .140$; Wave 2: $F(2,1147) = 4.91$, $p = .008$; Wave 3: $F(2,1076) = 3.85$, $p = .022$). Overall, adolescents who participated in only one or two waves reported a longer sleep latency and more daytime sleepiness, compared to adolescents who participated in all three waves. However, the post-hoc analyses (Bonferroni) showed that the differences between participants who participated in all three waves ($M_{sleeplatency} = 35.71$; $M_{daytimesleepiness} = 1.37$) and

the participants who participated in only one wave ($M_{sleeplatency}$ = 49.40; $M_{daytimesleepiness}$ = 1.61) was only significant in Wave 2. In Wave 1 and Wave 3, the post-hoc analyses showed no significant differences in sleep latency and daytime sleepiness between participants who participated in all three waves (Wave 1: $M_{sleeplatency}$ = 36.48; $M_{daytimesleepiness}$ = 1.31; Wave 3: $M_{sleeplatency}$ = 39.49; $M_{daytimesleepiness}$ = 1.44), and respondents who participated in one wave (Wave 1: $M_{sleeplatency}$ = 40.96; $M_{daytimesleepiness}$ = 1.42; Wave 3: $M_{sleeplatency}$ = 54.00; $M_{daytimesleepiness}$ = 1.70). Thus, although we found some differences in the dependent variables, only in Wave 2 these differences were significant between participants who participated in all three waves and those who participated in only one Wave. Therefore, we decided to include all cases in the analyses.

Procedure

This study was approved by the ethical committee of the authors' institute before the start of the study. To recruit adolescents, schools across Netherlands were contacted via e-mail. Seven schools responded that they were willing to participate. Of the participating classes, we obtained passive informed consent of the parents. These data collection moments were scheduled around the end of the main school terms (November 2014, March 2015, and June 2015) resulting in three-to-four month intervals. The participants received information on the survey and were guaranteed that their answers were fully confidential. After we obtained informed assent of the participants, they filled out the online survey, which took 30 min. To express our gratitude to the participants, they all received a small present after completing the survey.

Measures

Social media use

SM use was measured using 12 items, including the most popular types of SM use (van den Eijnden, Lemmens, & Valkenburg, 2016): (1) Facebook, (2) Facebook Messenger, (3) Instagram, (4) WhatsApp, (5) Snapchat, (6) Pinterest, (7) Twitter, (8) Vine, (9) Tumblr, (10) Telegram, (11) Google+, and (12) You Tube. We used a 4-point scale, 0 = *never*, 1 = *sometimes*, 2 = *often*, and 3 = *always*. Similar to other media use measures (e.g., Gil de Zúñiga, Jung, & Valenzuela, 2012; Slater, 2003), this measure of SM use can best be seen as an index of how often someone uses SM rather than a reflective scale. The items in this scale are more likely to be compensatory rather than exchangeable. For example, someone with a high SM use may either use one of these SM extensively, or engage in a variety of different types of SM for shorter periods of time. Engaging in one specific type of SM thereby is not necessarily related with engaging in other types of SM. Therefore, all items were averaged into one mean index, Wave 1: M = 0.85, SD = 0.40, Cronbach's alpha = .74; Wave 2: M = 0.86, SD = 0.38, Cronbach's alpha = .73; Wave 3: M = 0.88, SD = 0.39, Cronbach's alpha = .73. A higher score implies more SM use. As expected, girls more often used SM than boys, Wave 1: M = 0.94, SD = 0.39, than boys, Wave 1: M = 0.76, SD = 0.40; $F(1, 1242)$ = 60.96, $p < .001$.

Social media stress

To measure SM stress, we developed 10 items: five items on emotional responses to SM use and five items which may indicate SM dependency. The five items on emotional responses were: have you (1) 'felt tensed or restless when you could not use social media?', (2) 'felt disappointed when you did not get an immediate response if you posted something on social media?', (3) 'continuously pondered about something that happened on social media?', (4) 'felt tense or restless when you knew you received a social media message but could not look at it immediately', and (5) 'felt disappointed when you had not received a message on social media'. The items that may indicate excessive social media use were: have you (1) 'neglected other activities to use social media?', (2) 'had the need to use social media more often or for a longer time?', (3) 'spent little time with friends/family because you were using social media?', (4) 'frequently checked social media to see if you had received a new message?', and (5) 'unsuccessfully tried to limit your social media use?'. All items were rated on a 5-point scale, 0 = *completely not true*, 1 = *not true*, 2 = *a little bit true*, 3 = *true*, and 4 = *completely true*. The ten items loaded on one factor (all factor loadings above .65). We composed a mean score of these items (Wave 1: M = 0.98, SD = 0.75, Cronbach's alpha = .89; Wave 2: M = 0.95, SD = 0.78, Cronbach's alpha = .92; Wave 3: M = 1.06, SD = 0.86, Cronbach's alpha = .94). A higher score indicated more SM stress. Girls reported more SM stress, Wave 1: M = 1.06, SD = 0.72, than boys, Wave 1: M = 0.91, SD = 0.76; $F(1,1185)$ = 11.41, $p = .001$.

Sleep latency

Sleep latency was measured with the question: 'On average, how long does it take before you fall asleep?'. We used a continuous scale ranging from 0 to 180 minutes (Wave 1: M = 38.19, SD = 36.21; Wave 2: M = 37.94, SD = 37.83, Wave 3: M = 41.17, SD = 41.39).

Daytime sleepiness

To measure daytime sleepiness, we used the Sleep Reduction Screening Questionnaire (SRSQ; van Maanen et al., 2014).This measure has been a validated measure to screen for sleep reduction in adolescents and particularly examines the consequence of sleep reduction during daytime (van Maanen et al., 2014). The SRSQ includes nine items (e.g., 'I feel sleepy during the day', 'I am a person who does not get enough sleep', and 'I have enough energy during the day to do everything [reversed]'). A 5-point scale was used ranging from, 0 = *never* to 4 = *very often*. One item ('I am immediately awake when I wake up') was excluded due to a low factor loading. The remaining eight items showed good reliability in each of the three waves (Cronbach's alpha for Wave 1: .78; Wave 2: .80; and Wave 3: .79). We calculated one mean score (Wave 1: M = 1.33, SD = 0.71; Wave 2: M = 1.40, SD = 0.71; Wave 3: M = 1.48, SD = 0.71) with higher scores reflecting more daytime sleepiness.

Analyses

Cross-sectional relationships

We examined the cross-sectional relationships between SM use, SM stress, sleep latency, and daytime sleepiness based on the Pearson's correlations in all three waves (H1). In addition, we conducted two hierarchical regression models to examine the unique predictive contribution of SM use and SM stress to both sleep variables.

Longitudinal relationships

We applied a random intercept cross-lagged panel model (RI-CLPM) to examine H2, H3, and H4 (for a full description of the model see Hamaker, Kuiper, & Grasman, 2015). By controlling for the between-person correlation across the waves, the RI-CLPM informs us about the within-person processes over time (Hamaker et al., 2015). However, to examine the within-person processes, within-person variations over time are essential. Therefore, before testing the RI-CLPM, we investigated the within-person variance by calculating the intra-class correlations (ICC) of each variable. All variables showed sufficient within-person variance (SM use = 37%; SM stress = 58%; sleep latency = 53%; daytime sleepiness = 42%). See Figure 1 for a representation of the RI-CLPM. We constrained the stability and the cross-lagged paths to be equal from Wave 1 to Wave 2 and from Wave 2 to Wave 3. With respect to H3 and H4, we examined the moderating role of gender using multiple group analyses in the RI-CLPM.

We tested the models using the statistical program Mplus 7. To cope with missing data across waves, we used Full Information Maximum Likelihood (Muthén & Muthén, 2012). The fit of the models were assessed based on three fit measures (e.g., Kline, 2004), 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). The chi-square measure shows the exact fit of the model, with p-values above .05 implying exact fit. RMSEA values below .05 and CFI values above .95 indicate good fit.

Results

Cross-sectional relationships

The correlations between all variables are presented in Table 1. SM use demonstrated moderate positive correlations with daytime sleepiness in all three waves. In contrast, SM use was not related to sleep latency in Wave 1, and only small correlations were observed in Wave 2 and 3. Thus, H1a was only partly supported by our findings. Supporting H1b, SM stress was positively related to sleep latency and daytime sleepiness in each of the three waves.

To investigate whether SM stress has a unique contribution to sleep above the effect of SM use, we conducted two hierarchical regression models at Wave 1. Each baseline model included age and gender as control variables. Thereafter, we included SM use and SM stress stepwise. While SM use was
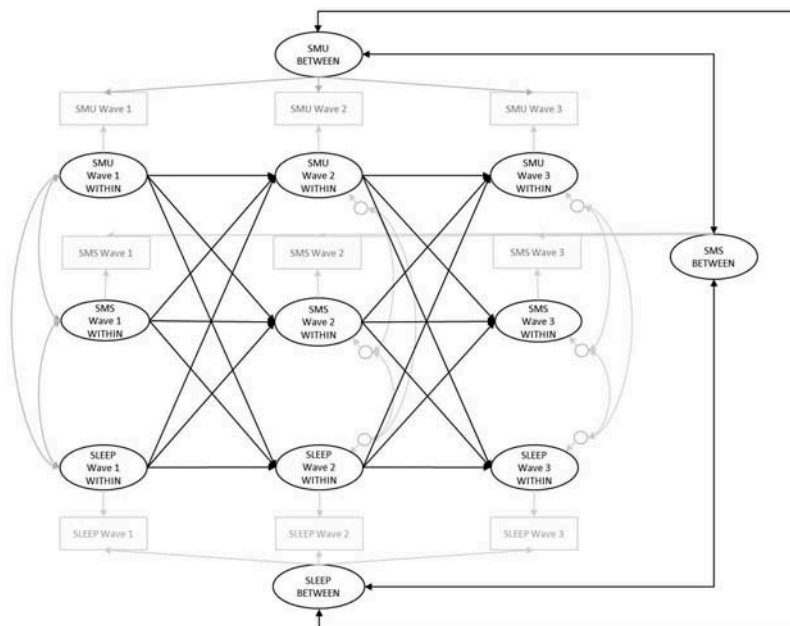

Figure 1. A depiction of the random intercept cross-lagged panel model including the relationships between social media use (SMU), social media stress (SMS), and sleep (SLEEP) across the three waves. The observed variables are represented in the squares. Of these observed variables, latent variables at both the between and within level were constructed. These latent variables are displayed as ovals. The three random intercepts (SMU BETWEEN, SMS BETWEEN, and SLEEP BETWEEN) reflect the between-person variances. The nine latent within-person variables (SMU WITHIN Wave1–Wave 3, SMS WITHIN Wave1–Wave 3, SLEEP WITHIN Wave 1–Wave 3) reflect the within-person variances. The within-person paths are illustrated by the modeling structure between the nine latent within-person variables: two autoregressive paths between the latent factors of SMU WITHIN, two autoregressive paths between the latent factors of SMS WITHIN, and two autoregressive paths between the latent factors of SLEEP WITHIN; two cross-lagged paths from the latent factors of SMU WITHIN to SMS WITHIN and two cross-lagged paths from the latent factors of SMS WITHIN to SMU WITHIN; two cross-lagged paths from the latent factors of SMU WITHIN to SLEEP WITHIN and two cross-lagged paths from the latent factors of SLEEP WITHIN to SMU WITHIN; two cross-lagged paths from the latent factors of SMS WITHIN to SLEEP WITHIN and two cross-lagged paths from the latent factors of SLEEP WITHIN to SMS WITHIN; correlations between SMU WITHIN, SMS WITHIN, and SLEEP WITHIN at Wave 1, and between the residual correlations of SMU WITHIN, SMS WITHIN, and SLEEP WITHIN at Waves 2 and 3.

Table 1. Zero-order Pearson correlations for social media use, social media stress, sleep latency, and daytime sleepiness across the three waves.

	SMU W1	SMU W2	SMU W3	SMS W1	SMS W2	SMS W3	TFA W1	TFA W2	TFA W3	DS W1	DS W2
SMU W1											
SMU W2	.74**										
SMU W3	.70**	.76**									
SMS W1	.39**	.39**	.37**								
SMS W2	.30**	.35**	.32**	.53**							
SMS W3	.29**	.29**	.33**	.46**	.54**						
SL W1	.05	.05	.06	.17**	.09*	.06					
SL W2	.03	.08*	.08*	.14**	.13**	.09*	.64**				
SL W3	.05	.07*	.08*	.09*	.11**	.14**	.54**	.61**			
DS W1	.22**	.22**	.21**	.43**	.36**	.31**	.20**	.18**	.15**		
DS W2	.20**	.24**	.20**	.34**	.48**	.33**	.16**	.24**	.17**	.65**	
DS W3	.22**	.21**	.26**	.33**	.37**	.51**	.12**	.19**	.23**	.59**	.64**

** $p \leq .001$;* $p < .05$. SMU = social media use; SMS = social media stress; SL = sleep latency; DS = daytime sleepiness.

not related to sleep latency in the first ($b^\star = .06$, $p = .057$) nor in the second step ($b^\star = -.01$, $p = .655$), SM stress positively predicted sleep latency ($b^\star = .18$, $p < .001$). With respect to daytime sleepiness, SM use was significantly associated with more daytime sleepiness ($b^\star = .20$, $p < .001$). However, after including SM stress to the model, the relationship between SM use and daytime sleepiness was not significant anymore ($b^\star = .06$, $p = .234$), while SM stress positively predicted daytime sleepiness ($b^\star = .42$, $p < .001$). These findings suggest that the experience of SM stress may be more problematic for adolescents' sleep than the frequency of SM use.

Longitudinal relationships

We examined two RI-CLPMs for the overall sample, one model for sleep latency and one model for daytime sleepiness. With regard to sleep latency, the RI-CLPM showed a good fit, χ^2 (13) = 15.03, $p = .306$, RMSEA = .01 (90% CI [.00, .03]), and CFI = .999. At the between-person level, we found no significant correlations between the random intercept factors of SM use and sleep latency ($b^\star = .07$, $p = .137$), while the relationships between SM use and SM stress ($b^\star = .61$, $p < .001$), and SM stress and sleep latency ($b^\star = .19$, $p = .003$) were significant. This implies that adolescents who reported higher levels of SM stress also reported higher levels of SM use, and that adolescents who experienced more SM stress reported longer sleep latency across the three waves. At the within-person level over time, we found no significant cross-lagged paths of SM use and SM stress on subsequent sleep latency (see Table 2). This means that SM use and SM stress did not further increase sleep latency among adolescents over time. These findings are in contrast to H2a and H2b.

For daytime sleepiness, the model fit was good, χ^2 (13) = 10.07, $p = .689$, RMSEA = .00 (90% CI [.00, .02]), and CFI = 1.000. The between person-correlations were significant between the random intercept factors of SM use and SM stress ($b^\star = .61$, $p < .001$), SM use and daytime sleepiness ($b^\star = .35$, $p < .001$), and SM stress and daytime sleepiness ($b^\star = .61$, $p < .001$). This indicates that adolescents who more frequently engaged in SM use more often experienced SM stress and daytime sleepiness, and that adolescents who reported higher SM stress showed more daytime sleepiness. In contrast to our hypotheses, we found no significant within-person cross-lagged paths of SM use (H2a) and SM stress (H2b) on subsequent sleep latency, as displayed in Table 2. Thus, SM use and SM stress did not further increase daytime sleepiness among adolescents.

Differences between boys and girls

Because we argued that the relationships may differ for boys and girls, we run multigroup analyses. The model on sleep latency showed satisfactory fit, χ^2 (26) = 32.44, $p = .179$, RMSEA = .02 (90% CI [.00, .04]), and CFI = .998. For boys, the between-person relationships between SM use, SM stress, and sleep latency were all positive and significant (SM use and SM stress: $b^\star = .61$, $p < .001$; SM use and sleep latency: $b^\star = .13$, $p = .038$; SM stress and sleep latency: $b^\star = .31$, $p = .001$), whereas for girls we only found a significant positive between-person correlation between SM use and SM stress ($b^\star = .59$, $p < .001$).

Table 2. The standardized within-person correlations between social media use, social media stress, and sleep (Sleep Latency and Daytime Sleepiness) for the overall sample, boys, and girls.

	Sleep latency						Daytime sleepiness					
	Overall		Boys		Girls		Overall		Boys		Girls	
	W1–W2	W2–W3	W1–W2	W2–W3	W1–W2	W2–W3	W1–W2	W2–W3	W1–W2	W2–W3	W1–W2	W2–W3
Stability paths												
SMU	.14	.10	.08	.06	.23*	.17	.15	.11	.11	.08	.23*	.16
SMS	.21**	.21**	.14	.13	.29**	.30**	.19**	.18*	.12	.11	.29**	.31**
SLEEP	.24**	.24**	.22*	.18*	.27**	.31*	.19**	.21*	.24**	.25*	.09	.09
Cross-lagged paths												
SMU → SLEEP	−.00	.00	−.00	−.00	.10	.09	−.05	−.04	−.17*	−.13*	.10	.08
SMS → SLEEP	.05	.05	−.04	−.04	.20*	.22*	.04	.05	−.01	−.01	.14*	.17*
SLEEP → SMU	.04	.04	−.04	−.05	.21*	.21*	−.04	−.04	−.20*	−.20*	.11	.10
SLEEP → SMS	.02	.02	−.11	−.10	.19*	.20*	.06	.05	.06	.05	.03	.03

** $p \leq .001$;* $p < .05$; SMU = social media use; SMS = social media stress; SLEEP = refers to the corresponding sleep outcome: sleep latency or daytime sleepiness.

We also found differences between boys and girls at the within-person level (see Table 2). For boys, we found no significant cross-lagged paths of SM use and SM stress on subsequent sleep latency. For girls, we also found that SM use was not significantly related to subsequent sleep latency, but the findings showed that SM stress was positively related to subsequent sleep latency (Wave 1 tot Wave 2: $b^* = .20$, $p = .005$; Wave 2 to Wave 3: $b^* = .22$, $p = .002$). This implies that for girls, SM stress further increased sleep latency three-to-four months later. In line with H4a, the findings suggested that girls were more susceptible for the long-term effects of SM stress on sleep latency, than boys. H3a was not supported.

For daytime sleepiness, the models showed good fit, χ^2 (26) = 20.51, $p = .767$, RMSEA = .00 (90% CI [.00, .02]), and CFI = 1.00. The findings at the between-person level were similar for boys and girls. The between-person relationships between SM use, SM stress, and daytime sleepiness were all positive and significant for boys (SM use and SM stress: $b^* = .62$, $p < .001$; SM use and daytime sleepiness: $b^* = .43$, $p < .001$; SM stress and daytime sleepiness: $b^* = .62$, $p < .001$), and for girls (SM use and SM stress: $b^* = .59$, $p < .001$; SM use and daytime sleepiness: $b^* = .31$, $p < .001$; SM stress and daytime sleepiness: $b^* = .59$, $p < .001$).

At the within-person level, we did find different patterns for boys and girls (see Table 2 for an overview of the findings). For boys, we found that SM use was negatively related to subsequent daytime sleepiness (Wave 1 to Wave 2: $b^* = -.17$, $p = .017$; Wave 2 to Wave 3: $b^* = -.13$, $p = .018$). In contrast to our expectations, this implies that boys who often use SM reported less daytime sleepiness. For girls, we found that SM stress was significantly related to more subsequent daytime sleepiness (Wave 1 to Wave 2: $b^* = .14$, $p = .039$; Wave 2 to Wave 3: $b^* = .17$, $p = .041$). This means that girls who experienced higher SM stress reported more daytime sleepiness three-to-four months later. Thus, while these findings showed no support for H3b, we found that girls are susceptible for the longitudinal relationship between SM stress and daytime sleepiness, while boys are not. This is in line with H4b.

Discussion

Previous research has found support for an adverse relationship between SM use and sleep (Levenson et al., 2016), as well as between SM stress and sleep (e.g., Garett et al., 2016; Xanidis & Brignell, 2016). Surprisingly, these studies specifically focused on emerging adults, while adolescents are the main users of SM (Lenhart et al., 2010). The current study was the first to examine the cross-sectional and longitudinal relationships between SM use, SM stress, and sleep (i.e., sleep latency and daytime sleepiness) among adolescents.

In line with existing cross-sectional studies among emerging adults, both sleep latency and daytime sleepiness were related to SM use as well as to SM stress. Although support for the relationship between SM use and sleep latency was limited, we consistently found positive relationships between SM use and daytime sleepiness, SM stress and sleep latency, and SM stress and daytime sleepiness. In addition, the cross-sectional findings suggested that SM stress was a stronger predictor of the sleep variables than SM use. This indicates

that it may not be the *frequency* of SM use per se that hinders adolescents' sleep but the stress that is associated with the usage of SM. As SM stress was more strongly related to these aspects of sleep than SM use, it may be important to look at specific explanations for the role of SM stress.

To date, the explanation for the relationship between SM stress and sleep has leaned heavily on the theoretical understanding of the relationship between SM use and sleep, such as displacement of sleep, elevated levels of arousal, and exposure to bright screen lights (e.g., Cain & Gradisar, 2010; Xanidis & Brignell, 2016). Although it could be argued that those explanations still play a role in explaining the negative relationship between SM stress and sleep, it is important to further develop our theoretical understanding of why SM stress negatively affects sleep. One important underlying mechanism that may be specifically relevant for the relationship between SM stress and sleep might be biological reactions to stress. More specifically, SM stress may result in a general stress response characterized by the activation of stress hormones (e.g., cortisol; Sanford et al., 2014), which has been shown to hinder sleep (e.g., Zeiders et al., 2011).

Another explanation may be that those adolescents who experience stress related to their SM use have maladaptive coping strategies, which have also been negatively related to sleep variables. As a response to stress, young people may ruminate about stress-related problems (Morin, Rodrigue, & Ivers, 2003; Sadeh, Keinan, & Daon, 2004) or disengage from their stress-related thoughts and feelings (Pillai, Roth, Mullins, & Drake, 2014). Both rumination and disengagement have been shown to interfere with sleep (e.g., Matthews et al., 2016; Pillai et al., 2014). For example, one study found that pre-sleep rumination negatively predicted sleep latency among emerging adults (Pillai et al., 2014). Moreover, adolescents may disengage from their stress-related problems by seeking distractions (e.g., watching television, listening to music), which hinders sleep (Matthews et al., 2016).

With respect to the longitudinal relationship, we found that, for the overall sample, evidence for a long-term relationship was less pronounced than expected. We found no evidence for a prospective relationship between SM and the selected sleep parameters; an increase in SM use or SM stress did not further impair sleep latency and daytime sleepiness for the sample as a whole. However, we did find a small positive relationship between SM stress and subsequent sleep latency, as well as between SM stress and subsequent daytime sleepiness among girls. This indicates that for girls the experience of SM stress may negatively affect sleep over time. SM stress may not only have an impact on their current sleep but may also predict future sleep. Thus, girls may be more susceptible to the long-term negative effect of SM stress on sleep than boys.

There are at least two explanations for why girls are particularly susceptible to these effects. A first explanation may be that girls tend to cope insufficiently with stress. While boys are more likely to approach their problems in a more active manner, girls may cope with stress by ruminating (Nolen-Hoeksema, 2001). As discussed above, rumination may disrupt several aspects of adolescents' sleep, such as sleep latency (Pillai et al., 2014) and sleep quality (Thomsen, Mehlsen, Christensen, Zachariae, 2003). These findings indicate that rumination as a result of SM stress, may strengthen the

relationship between SM stress and at least some aspects of sleep over time. In line with this assumption, one study found that rumination moderated the relationship between stressful life events and insomnia (Pillai et al., 2014). A second potential explanation for these gender differences is that a certain amount of SM stress is needed to be detrimental for adolescents sleep. As girls more frequently perceived their SM use as being stressful than boys (e.g., Beyens et al., 2016; Thomée et al., 2011), more girls may have surpassed the threshold for SM stress to interfere with sleep than boys.

In contrast to the common assumption that SM use and SM stress have a negative impact on sleep, we found that SM use was related to less subsequent daytime sleepiness for boys. However, at the between-person level we found a positive relationship between SM use and daytime sleepiness. Together, these findings may reflect a Simpson's Paradox (i.e., findings at the within-person level are the opposite of findings at the between-person level; Kievit, Frankenhuis, Waldorp, & Borsboom, 2013). While boys who more frequently use SM reported a longer sleep latency and daytime sleepiness than their peers (between-person level), boys reported less daytime sleepiness in periods when they more frequently use SM compared to periods when they less frequently use SM (within-person level). This unexpected finding for boys emphasizes the importance of disentangling between-person from within-person relationships and individual differences. Future studies are needed to further understand the relationship between SM use and sleep among adolescent boys.

Our study adds to a growing field of research that investigates the role that SM plays in the lives of young people today. Although replications are needed to confirm our finding of gender differences in particular, this study highlights the importance of a more nuanced view on the impact of SM use and related experiences on sleep, and provides important insights for future research. Most importantly, the findings suggest that researchers should particularly focus on how adolescents perceive their SM use instead of solely examining the frequency of SM use. In addition, we should further examine which adolescents are particularly vulnerable for the long-term effects of SM stress on sleep, for example adolescents who frequently ruminate due to stress may be more susceptible for this long-term effect. Finally, to better understand both the cross-sectional and longitudinal relationship between SM stress and sleep, future studies are advised to identify possible underlying mechanisms, such as the activation of biological stress hormones and maladaptive coping strategies.

Acknowledgments

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