

13 The Effects of Digital Media and Media Multitasking on Attention Problems and Sleep

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With the rise of social and mobile media, not only has the amount of media use changed but also how and when adolescents use media. Almost half of US American adolescents claim that they are almost always online (Anderson & Jiang, 2018). Being constantly online also leads to new forms of media use, such as media multitasking. Media multitasking is commonly defined as using two types of media simultaneously, or using media while engaging in other non-media activities, such as using media while doing homework, during dinner, or during face-to-face conversations (Jeong & Hwang, 2012; van der Schuur et al., 2015). Media multitasking is highly prevalent, particularly among young people (Carrier et al., 2015).

The rise of digital media and media multitasking has led to concerns whether these forms of media use deteriorate adolescents' attention. The main assumption is that if adolescents get used to using media wherever they are and whenever they want, they might have difficulties sustaining their attention, for example when doing their homework or when attending school (Ralph et al., 2015). Moreover, the constant use of digital media has been linked to sleep problems among adolescents (Hale et al., 2019). Since sleep is crucial for the healthy development of adolescents, including their attention and level of sleepiness in school, it is important to understand the ways in which digital media affects sleep. This chapter provides an overview of the current state of the field on the effects of digital media and media multitasking on attention and sleep.

Digital Media and Attention Problems: What Do We Know?

There is a long tradition in media effects research studying the effects of media on attention problems and ADHD-related behaviors. The focus was long on the effects of watching television or playing video games that have been the most popular forms of media use among adolescents in the past. For example, a meta-analysis from 2014 shows that there is indeed a small but significant association between the time children and adolescents spent watching TV and video games and ADHD-related behaviors (Nikkelen et al., 2014). This is further supported in a more recent review of the literature

(Beyens et al., 2018). The effects of TV and video games on attention problems have been typically attributed to two main characteristics of these media types: their fast-paced and potentially violent content. It has been assumed that both of these characteristics might lead to higher arousal states to which adolescents potentially habituate (e.g., see Beyens et al., 2018). In the past decade, however, the media landscape and the types of media that are popular among adolescents have changed dramatically. This has resulted in a research shift away from the effects of traditional types of media (i.e., TV and video games) toward understanding the potential effects of social media and media multitasking on attention.

Media Multitasking and Attention

In 2009, Ophir, Nass, and Wagner published a seminal paper on differences in cognitive processing styles between heavy and light media multitaskers. Specifically, heavy media multitaskers were more easily distracted than light media multitaskers during a cognitive task they performed in the laboratory. It was the first study explicitly investigating the potential effects of media multitasking on cognitive processes. The authors interpreted their findings as an indication that people who multitask with media frequently have a completely different processing style than people who do this less frequently. Following this study, a plethora of studies have been conducted to understand the relationship between media multitasking and various aspects of attention (for reviews, see Uncapher & Wagner, 2018; van der Schuur et al., 2015). The literature can be differentiated into studies using self-report-based measures of attention in everyday life, and studies using cognitive tasks to measure the level of sustained attention in laboratory settings. It is, however, important to note that most of these studies focused on young adults (i.e., university students), and very few studies focused specifically on adolescents.

Studies using self-reports for attention problems in everyday life have consistently shown that adolescents who media multitask more frequently have more problems focusing their attention (for a review see van der Schuur et al., 2015). For example, media multitasking is positively related to increased attentional failures and mind wandering in young adults (i.e., undergraduate students; Ralph et al., 2013). Moreover, adolescents who media multitask more frequently have more attention problems and higher levels of impulsivity (Baumgartner et al., 2014, 2018). A recent meta-analysis supported these findings by showing that media multitasking and attention problems in everyday life are significantly positively related, with small to moderate effect sizes (Wiradhany & Koerts, 2019).

In contrast to the studies on everyday functioning, studies that tested differences in sustained attention with cognitive tasks in the laboratory show

more mixed results. Whereas some find no differences between heavy and light media multitaskers on various tasks related to sustained attention or distractibility (e.g., Baumgartner et al., 2014; Ralph et al., 2015; Wiradhany et al., 2019), others find small effects (e.g., Cain & Mitroff, 2010; Madore et al., 2020; Moissala et al., 2016). Overall, the findings based on cognitive tasks are less consistent than those based on self-reports, and are more difficult to compare as different cognitive tasks are used across studies. Although the existing findings are rather mixed, a recent review of the literature concludes that for tasks measuring sustained attention, evidence points toward performance detriments for heavy media multitaskers in comparison to light media multitaskers (Uncapher & Wagner, 2018).

Despite rather mixed findings for performance differences in cognitive tasks, overall, the existing studies support the idea that adolescents who media multitask more frequently show more attention problems in their everyday lives. However, almost all of these studies are cross-sectional and therefore conclusions about the direction of the effect cannot be drawn. Notably, it is also possible that media multitasking does not lead to attention problems, but that adolescents who are more easily distracted in their everyday lives are more likely to engage in media multitasking. To date, only a few longitudinal studies exist that tried to establish the causal direction of these effects. One longitudinal study found that adolescents who used media more often during academic activities (such as while doing homework) reported increased difficulties in focusing their attention during academic activities over time (van der Schuur et al., 2015). Another study found effects of media multitasking on attention problems only among early adolescents (12–13 years old) but not among middle adolescents (Baumgartner et al., 2018). Thus, there is some but limited evidence for long-term effects of media multitasking on attention. In line with media effects theories, such as reinforcing spiral models (Slater, 2007), it has been proposed that the effects of media multitasking on attention problems might be reciprocal, with adolescents suffering from attention problems being more drawn to media multitasking, and media multitasking in the long run further exacerbating their attention problems (Baumgartner et al., 2018). However, more longitudinal research is needed to empirically test this proposition.

Social Media Use and Attention

Evidence for a relationship between social media use and attention is even more scarce. Only a few studies to date have specifically examined the relationship between the frequency of social media use and attention problems. These studies tentatively point toward a relationship between the use of social media and inattentiveness with adolescents using social media more frequently showing more signs of attention problems (Barry et al.,

2017; Boer et al., 2020). The evidence for a relationship between attention problems and *problematic* or *addictive* social media use is more compelling. Several studies showed that adolescents who use social media in obsessive or problematic ways, also report more attention problems (e.g., Boer et al., 2020; Mérelle et al., 2017; Settanni et al., 2018; Yen et al., 2007). For example, one study found associations between problematic social media use and hyperactivity among a large sample of more than 20,000 Dutch adolescents (Mérelle et al., 2017), and another study found cross-sectional correlations between problematic social media use and attention deficits, impulsivity, and hyperactivity (Boer et al., 2020).

The question of causality across these studies is key. Does the use of social media deteriorate adolescents' attention capacities or are those adolescents who have difficulties sustaining their attention more drawn to social media? Due to the scarcity of longitudinal studies in this realm this question cannot yet be conclusively answered. One longitudinal study investigating the reciprocal relationships between ADHD and social media use found no evidence for an effect of social media use frequency on ADHD over time but an effect of *addictive* social media use on ADHD (Boer et al., 2020). This indicates that not the frequency of use per se but more problematic usage patterns (such as uncontrollability of usage or displacement of social activities) might be detrimental to adolescents' attention. Although this study found no evidence for attention problems being a predictor of developing problematic social media use patterns, another study found that ADHD symptoms in adolescents were the strongest predictor for developing internet addiction two years later (Ko et al., 2009).

Taken together, it seems likely that adolescents with attention problems are more drawn to social media in general, and that they are also more likely to show problematic usage patterns. The stimulating and arousing nature of digital media is particularly appealing to individuals showing symptoms of ADHD as they have a higher need for stimulation (Weiss et al., 2011). Digital media might provide the optimal level of stimulation to them. However, it is still unknown how far the (problematic) use of digital media further increases attention problems. The existing studies indicate that there is indeed a possibility that problematic usage patterns further deteriorate attention. However, due to the small amount of longitudinal studies, it is difficult to draw definite conclusions.

How Do Social Media and Media Multitasking Affect Attention?

To understand how social media and media multitasking affect attention problems among adolescents, it is important to identify theoretical explanations for such effects. Three potential explanations have been put

forward to explain the potential effects of media multitasking on attention: 1) habituation to high arousal levels, 2) becoming increasingly sensitive to irrelevant information, and 3) deterioration of attentional control processes (see Baumgartner et al., 2018).

Similarly to the mechanism that was proposed for the effects of violent and fast-paced TV on attention, habituation to high arousal levels might also play a role in the effects of media multitasking and social media use on attention. Media multitasking is considered an arousing activity, and it has been shown that switching between media activities increases arousal levels (Yeykelis et al., 2014). Thus, it can be assumed that when adolescents engage frequently in media multitasking, they habituate to these rather high arousal levels. This in turn makes them favor stimulating and arousing activities in the future. That individuals can habituate to media stimuli has been previously shown for video games with gamers physiologically habituating to arousal levels after repeated video game play (Grizzard et al., 2015). In the context of media multitasking this could mean that adolescents habituate to the arousing nature of multitasking, and as a consequence find less stimulating single-task environments less appealing (e.g., sitting in class or listening to a lecture).

The second potential explanation is that media multitasking affects basic cognitive processes. Ever since Ophir et al. (2009) showed differences in cognitive processing among heavy and light media multitaskers, it has been suspected that engaging in media multitasking may cause these different processing patterns. Engaging in media multitasking requires individuals to attend to multiple streams of information. It has thus been argued that this type of information processing may train the brain to become more sensitive to irrelevant information (Ophir et al., 2009). If individuals get used to continuously attending to several streams of information, they might be more easily distracted by irrelevant external (and potentially internal) distractions (Adler & Benbunan-Fich, 2012).

The third mechanism that has been suggested is that by engaging in media multitasking, adolescents deteriorate their basic attentional control processes. This has been called the “deficit-producing hypothesis” (Ralph et al., 2013). The main assumption is that media multitasking might deteriorate adolescents’ ability to regulate their attention internally as they get used to external stimulations. A similar mechanism has previously been assumed for the effects of fast-paced TV content for which it was suggested that fast-paced content captures attention in a bottom-up fashion and does not train adolescents’ volitional attention processes (e.g., Lillard & Peterson, 2011). Thus, by engaging in media multitasking frequently, adolescents might not train their ability to guide their attention. This may lead to deficits in these attentional control processes over time (Rothbart & Posner, 2015).

Next to these three cognitive mechanisms, others have argued that digital media use may increase symptoms of ADHD among adolescents by replacing

time spent with more developmentally beneficial activities (Weiss et al., 2011). Thus, even if digital media use has no direct effect on cognitive processes, it may still interfere with the healthy development of these skills because it replaces developmentally important activities, such as playing or having conversations with friends and family (Pea et al., 2012).

Importantly, although all of these mechanisms are theoretically plausible, empirical research assessing the mediating role of these mechanisms is still missing. Understanding the underlying mechanisms, however, is crucial as this will help to develop intervention studies that target the problematic aspects of digital media use rather than restricting digital media use in general.

Are There Any Positive Effects of Digital Media on Attention?

If digital media has the potential to affect attentional processes, the question is warranted whether digital media use may not also have positive effects on cognition and attention. Indeed, it has been argued that engagement in media multitasking may also train attentional processes (i.e., trained attention hypothesis: Kobayashi et al., 2020; van der Schuur et al., 2015). It has been assumed that people who engage frequently in media multitasking may improve their task switching skills and lower their switching costs by training these skills. Evidence for this trained attention hypothesis for media multitasking is scarce. However, one brain imaging study found some evidence for improved attentional brain activity among heavy media multitaskers (Kobayashi et al., 2020), and another study found better task switching performance among heavy media multitaskers (Alzahabi et al., 2013). Interestingly, it has been recently suggested that there are curvilinear relationships in that intermediate media multitaskers have better attentional control than low or heavy media multitaskers (Cardoso-Leite et al., 2016). More research is needed to establish whether such positive or curvilinear effects do indeed occur.

In contrast to the rather mixed findings on potential beneficial effects of media multitasking, research on the positive effects of playing action video games are more consistent. These studies show positive effects of playing action video games on several attentional skills, such as focused attention, selected attention, and sustained attention (for a recent meta-analysis, see Bediou et al., 2018, and for a review focusing specifically on attention, see C. S. Green & Bavelier, 2012). These effects were shown for cross-sectional studies but also for intervention studies that showed improvements in these cognitive skills after playing games for 20–40 hours. Most of these studies focused on young adults; however, a few also corroborated these effects for children and adolescents (Dye et al., 2009). Action video games pose a high demand on divided attention, information filtering, and

motor control. It is therefore assumed that engaging in these games trains these attentional processes and can therefore benefit attentional control (e.g., Bediou et al., 2018).

In sum, there is some evidence that digital media has positive effects on attention skills. However, this highly depends on the content and type of media used. Particularly, first-person action video games seem to be beneficial. Moreover, effects are dependent on the amount of time spent with particular media. Extant literature suggests possible curvilinear relationships with moderate amounts of exposure being more beneficial than no exposure or too much exposure (Cardoso-Leite et al., 2016; Schmidt & Vandewater, 2008).

Future Research Directions for the Effects of Digital Media on Attention

Overall, research so far has found supporting evidence for a relationship between the amount of media multitasking and social media on the one hand and attention problems on the other hand. Adolescents who engage more frequently in media multitasking and who show more problematic social media use patterns, are also more likely to have attention problems in their everyday lives. The key endeavor for future research is to establish the causality of this relationship. It is yet unclear whether adolescents with attention problems are more drawn to engage in media multitasking, or whether media multitasking affects attention over time. Tentative evidence suggests a reciprocal relationship in that adolescents with attention problems are more drawn to specific types of media and media use patterns, and that spending too much time with these digital media further increases their attention problems (Baumgartner et al., 2018).

Next to the fundamental question of causality, it is crucial to understand the characteristics and affordances of digital media that lead to potential effects on attention. Which characteristics of social media and media multitasking impair attention, and how do these differ from other types of media? Understanding these characteristics is important for several reasons. First, this may help our understanding of the underlying mechanisms through which they are at work. Despite several theoretical assumptions about these mechanisms, empirical evidence is clearly lacking. Understanding these mechanisms might help adolescents to find more beneficial ways to use digital media without banning these completely from their lives. Moreover, a theoretical understanding of which characteristics are problematic would have crucial advantages in the current fast-changing media landscape. Currently, research lags behind new technological developments, and the same questions emerge with every new type of media. To create a more sustainable research agenda it would be helpful to understand the key characteristics of media that drive these effects, and compare and differentiate these among different media types (Orben, 2020).

Digital Media Use and Sleep: What Do We Know?

Sleep plays a critical role in the development of adolescents. Insufficient sleep has been linked to decreased cognitive functioning, increased risk of obesity, and diminished well-being, such as depressive symptoms and perceived stress (e.g., Shochat et al., 2014; Short et al., 2013). From late childhood to early adolescence sleep-related problems increase (Mitchell et al., 2020), with approximately 75% of students in their last year of high school getting insufficient sleep in comparison to only 16% of 6th graders (i.e., fewer than eight hours per night; National Sleep Foundation, 2006). Due to the importance of sleep for healthy psychological and physical development, it is concerning that so many adolescents today get insufficient sleep. Digital media are often seen as one of the main culprits for insufficient sleep and sleep problems, especially among adolescents (e.g., Bhat et al., 2018; Mireku et al., 2019). Particularly smartphones and social media are used extensively by adolescents, and frequently when already in bed or even during the night (e.g., Scott & Woods, 2019; van den Bulck, 2003, 2007).

There is consensus in the field that digital media use is linked to insufficient sleep in adolescents. Several reviews and meta-analyses support this notion (see, e.g., Carter et al., 2016; Hale et al., 2019; LeBourgeois et al., 2017). For example, a meta-analysis on the effects of mobile media devices on sleep, concluded – based on 20 studies with a total of more than 125,000 children and adolescents – that the use of media devices was consistently linked to insufficient sleep quantity, lower sleep quality, and increased daytime sleepiness (Carter et al., 2016). Similarly, in a more recent review of the literature, digital media use was related to adolescents going to bed later, needing more time to fall asleep, waking up during the night, showing signs of sleep problems, and daytime sleepiness (Hale et al., 2019). These effects have been shown for the general time that adolescents spent with media, but particularly for bedtime media use (Hale et al., 2019) and are consistent across various countries and cultural backgrounds (Hale et al., 2019).

Despite this strong evidence for cross-sectional relationships between digital media use and sleep, there are only a few longitudinal and experimental studies, and evidence from these studies is rather mixed. Some longitudinal studies found that digital media use was related to less sleep one or two years later (Johnson et al., 2004; Mazzer et al., 2018; Poulain et al., 2019). In contrast, others did not find longitudinal effects of media use on sleep (Tavernier & Willoughby, 2014), or only for specific subgroups (van der Schuur et al., 2018). For example, media multitasking was over time only related to increased sleep problems among girls but not among adolescent boys (van der Schuur et al., 2018).

To further establish the causality of the relationship, a few intervention studies exist that encouraged adolescents or young adults to reduce the use of specific media before bedtime to examine whether this improves sleep length

and quality. These studies typically show improvements in sleep quality during intervention. For example, engaging in a smartphone app-based slow-breathing exercise improved subsequent sleep in comparison to using social media before going to bed (Laborde et al., 2019). Similarly, reducing adolescents' screen time after 9pm on school nights was related to increased sleep duration and improved daytime vigilance (Perrault et al., 2019). A recent meta-analysis on 11 intervention studies concluded that interventions can be successful in reducing screen time and improving sleep time (on average by 11 minutes per day) among children and adolescents (Martin et al., 2020). These studies are promising as they show that reducing screen time can have beneficial effects on sleep. Longer intervention studies, however, are needed to further test the long-term effectiveness and willingness to comply among adolescent samples.

Why and How Do Digital Media Affect Sleep?

Three underlying mechanisms are typically put forward in the literature to explain the effects of digital media use on sleep (e.g., Bartel & Gradisar, 2017). First, the use of digital media before bedtime or when already in bed might displace sleep time. Second, the blue light emitted from digital devices might interfere with the secretion of the sleep hormone, melatonin. Third, the arousing content of digital media might make it difficult for adolescents to fall asleep after media use.

Sleep displacement may occur in two stages: it may lead adolescents to go to bed later and, once in bed, media use may delay the time when adolescents close their eyes and try to fall asleep (Exelmans & van den Bulck, 2017a). Evidence for sleep displacement is consistent for adolescent samples, and has been shown to occur for various types of digital media, such as smartphone, social media, video games, and TV (e.g., Hysing et al., 2015; Kubiszewski et al., 2013). Overall, the literature clearly points toward later bedtimes for adolescents who use digital devices in the evening. Delayed bedtimes and sleep times might be particularly problematic for adolescents who have strict school starting times and cannot easily sleep in. For adult samples, it has been shown that digital media use might lead to later bedtimes but in turn also to later rise times (Custers & van den Bulck, 2012).

Particularly for the use of smartphones, sleep displacement might also occur after sleep onset during the night, when incoming messages interrupt sleep. Several studies reported that smartphones lead to nighttime awakenings (Fobian et al., 2016; van den Bulck, 2003), and these nighttime awakenings might negatively influence sleeping patterns in the long run (Foerster et al., 2019). Therefore, adolescents who take their devices to bed might not only fall asleep later but might also be awakened by these devices during the night. Based on the existing literature, it is very likely that sleep displacement is

a contributing factor for the detrimental impact of digital media on sleep. However, it is likely not the only factor because sleep displacement can only account for effects on sleep quantity but to a lesser account for the effects on sleep quality.

The bright screen light emitted by electronic devices has also been considered one of the main culprits for the effects of digital media on sleep. It has been argued that the artificial light emitted by electronic devices may lead to a disruption of the circadian rhythm, leading to increased alertness, and deteriorating sleep quality (Cho et al., 2015). When considering the effects of artificial light on sleep at least three factors need to be considered: the intensity of the emitted light, the duration of light exposure, and the type of light (Cho et al., 2015). Bright light is more disruptive for sleep, as well as short-wave and blue light. Electronic devices, such as smartphones, emit short-wave blue light that is said to suppress the production of the hormone melatonin, which plays an important role in making people sleepy and supporting healthy sleep.

Several studies found negative effects of screen light on subsequent sleepiness and sleep quality (Cajochen et al., 2011; Chang et al., 2015; A. Green et al., 2017). For example, exposure to a very bright LED-backlit computer screen affected melatonin levels and sleepiness of male adults (Cajochen et al., 2011). Similarly, negative effects of reading an e-reader before going to sleep were found (Chang et al., 2015). Importantly, the effects of screen light might be stronger for adolescents than for adults, as adolescents seem to be more affected by short-wave light than adults (Nagare et al., 2019).

Despite several studies finding effects of screen light on sleep quality, it is still highly debated in the field whether the light emitted from tablets, e-readers, TVs, and smartphones is bright enough to interfere with melatonin secretion and sleep. In a recent study, no or only very small and clinically insignificant effects of a bright tablet screen were found (Heath et al., 2014). Moreover, in those studies that found effects on melatonin secretion and/or sleep, sample sizes were rather small, and participants were exposed to rather extreme artificial light conditions, such as five hours of an extremely bright screen (Cajochen et al., 2011), or four hours of a bright e-reader screen (Chang et al., 2015). The clinical relevance of these findings is therefore still debatable. Overall, it is rather unlikely that the light emitted from digital devices is the only or even the most influential mechanism in explaining the effects of digital media on sleep.

The final mechanism that has been put forward is arousal. It is assumed that specific media content might lead to increased physiological arousal, which in turn makes it difficult for people to fall asleep after media use. This mechanism has received the least research attention, and a comprehensive theoretical conceptualization is missing. More specifically, we lack a clear conceptualization of which content characteristics lead to which effects on which mediator (e.g., physiological arousal, cognitive alertness). Bedtime media

use might differ widely among adolescents, and from a media psychological perspective it is likely to assume that not all content is equally detrimental to all adolescents' sleep. Although adolescents might use media for the same amount of time before going to bed, their usage patterns might differ tremendously, and their sleep might be differentially affected by their use. For example, one teenager might be listening to relaxing music on their smartphone when in bed, while another teen is actively posting and reacting on their social media accounts. It is likely that these different types of media use lead to very different effects on arousal and sleep.

Moreover, not only the type of content that adolescents consume might have an effect on sleep but also *how* these media are used. For example, interactive media (i.e., video games) seem to have a stronger negative impact on sleep than the passive use of media (i.e., watching a DVD; McManus et al., 2020; Weaver et al., 2010). Similarly, engaging in media multitasking is also related to sleep problems among adolescents (van der Schuur et al., 2018). These studies stress the importance of investigating not only screen time but examining more specifically the types of digital media use and the ways digital media are used.

There is limited understanding about the mechanisms that link varying content types and usage behaviors to sleep quantity and quality. So far, it has been frequently suggested that digital media use leads to heightened physiological arousal (Exelmans & van den Bulck, 2017b). However, specific types of media content may not necessarily increase physiological arousal but might lead to increased cognitive alertness that prohibits sleep (Weaver et al., 2010; Wuyts et al., 2012). Empirical investigations of these mechanisms for digital media are largely missing. One study showed small effects of video game play on alertness but not on arousal, stressing the importance of differentiating between these two processes (Weaver et al., 2010).

In sum, our current understanding of which digital media content factors are related to sleep, and through which mechanisms, is very limited. We know very little about whether specific content and usage patterns affect the varying sleep indicators differently and through which underlying mechanisms content affects sleep (see also Hale & Guan, 2015).

Future Research Directions for Digital Media and Sleep

Although concerns that media negatively affect the sleep of adolescents have a long tradition, these worries are exacerbated with the rise of smartphones and social media as these media types are used more than any other type of media by youth, and are often carried with them to bed. To avoid negative effects of digital media on sleep, the standard advice to adolescents is not to use any types of digital media in the two hours before going to bed (LeBourgeois et al., 2017). This is also reflected in current intervention studies that solely focus on removing digital media from the

bedroom altogether (Martin et al., 2020). Although this advice is common and accepted by many, there are at least two problems related to this advice.

First, this strategy is in stark contrast to adolescents' lived experience and developmental needs, and consequently it is unlikely that adolescents will agree to completely ban these devices from their bedrooms. Second, this advice is based on a rather simplistic view on the effects of digital media on sleep that considers the use of the device as universally detrimental. However, how exactly adolescents use digital media before bedtime can vary tremendously, plausibly resulting in differential effects on their sleep quantity and quality. Despite years of research into the effects of digital media on sleep, there are still important shortcomings in the literature that make it difficult to draw final conclusions about the effects of digital media on sleep. Solving these issues in future research is critical to being able to provide adolescents with effective advice on how to use digital media in healthy ways.

Causality

Although there is consistent evidence in the literature for a negative relationship between digital media use and sleep, the direction of this relationship is less than clear. The vast majority of the existing studies are based on cross-sectional designs, making it impossible to draw conclusions about the direction of the relationship (Exelmans & van den Bulck, 2019). Although it is generally assumed that the use of digital media deteriorates sleep, it could also be that the relationship is reversed in that adolescents who sleep less tend to use more digital media. For example, adolescents who do not sleep well might use digital media as a means to cope with stress and insomnia, or because they are depleted and do not have the capacities for regulating their media use efficiently. For example, university students used more social media on days they had slept less during the previous night (Mark et al., 2016). Similarly, sleep-deprived children watched more TV during the day in an experimental study (Hart et al., 2017).

Findings like this cast doubt on the idea that there is a simple cause-and-effect relationship between digital media and sleep. Recent advancement in media effects theories conceptualize media use and effects as reciprocal, evolving dynamically over time (Slater, 2007). In the case of media use and sleep this could mean that adolescents suffering from sleep problems are more likely to use more media that in turn may further deteriorate their sleep. This dynamic and reciprocal nature for smartphone use and sleep is understudied as it demands assessing use and effects over longer time periods in the natural environment of adolescents. One two-wave study found some evidence by showing that media use and sleep times were reciprocally related in adolescents over a one-year period (Poulain et al., 2019). Understanding the nature of the relationship between digital media use and sleep is of key importance for our understanding of the effects of digital media and for intervention and prevention programs.

Individual Responses and Potential Facilitating Effects

Recent theoretical advances in media effects research stress the importance of individual susceptibilities to media effects (Beyens et al., 2020; Valkenburg & Peter, 2013). Also, for the relationship between sleep and digital media, individual differences are likely to be of importance. First, individuals differ in how they use digital media before sleep. For example, Scott and Woods (2018) showed that adolescents with higher levels of fear of missing out tended to use social media longer before sleep time and were more cognitively aroused before falling asleep. Thus individualized usage patterns might lead to varying effects. This is also important because not all evening media diets might be problematic. Some adolescents might use their smartphones in a way that benefits their sleep by actually decreasing their aroused state. This assumption builds on established media effects paradigms that argue that media are used to regulate arousal levels and to establish physiological homeostasis (Zillmann, 1988). For example, people can use apps to seek out social support, relax, and regulate sensory stimulation (Harrison et al., 2019). Research has shown that some people report that they use media in bed to wind down from the day (Eggermont & van den Bulck, 2006). However, little research has investigated whether digital media can be used in ways that benefit adolescents' sleep. Understanding such effects could help to educate adolescents to use their smartphones in more beneficial ways.

A second reason why it is important to study individual differences is that, while uniform effects of some content are possible, adolescents likely differ in their individual responses to digital media content. For example, one study found that adolescents who used social media more frequently slept less well than those who used social media less frequently. However, this effect disappeared when social media stress was taken into account, showing that only those respondents who experienced high levels of stress from their social media use suffered from sleep problems (van der Schuur et al., 2019). Moreover, this study showed that social media use was more problematic for the sleep of girls and early adolescents. Similarly, others found that only those who were more emotionally invested in their social media use slept less well (Woods & Scott, 2016), and that physiological reactions to violent game play differed depending on previous game experience (Ivarsson et al., 2013). Investigating these individual responses to smartphone use is crucial to understand why specific content is problematic for some adolescents but not for others.

Improved Measurement

The vast majority of existing studies relied on self-reports of media use and/or sleep. Self-reports for media use and sleep have been shown to be unreliable and it is thus likely that existing studies suffer from substantial measurement errors. Luckily recent developments in digital media and sleep tracking make it easier to assess digital media use as well as sleep unobtrusively and

objectively. For example, there is a multitude of commercially available sleep trackers available with some studies showing promising results using them. We therefore hope that future research will try to combine self-reports with more objective measures for both digital media use and sleep. Assessing the complexity of digital media use objectively will be a crucial step to move beyond investigating screen time toward understanding differential effects of specific content (Carter et al., 2016; Hale et al., 2019; Scott & Woods, 2019).

Overall Conclusion

Parents, educators, and researchers alike are interested in the effects that our digitalized society has on adolescents. Whether digital media impairs attention and sleep has been investigated in a large amount of studies. Yet, the conclusions that we can draw are still limited. Overall, there is compelling evidence that adolescents who use social media more frequently and who are engaging in media multitasking more frequently are more likely to show attention problems in their everyday lives. Moreover, using digital media before bedtime is related to less sleep and more sleep problems. However, the key question of whether digital media causally impairs attention and sleep cannot yet be conclusively answered. To answer this question, it is crucial for the field to advance the theoretical as well as methodological approaches that we currently employ.

Concerning theory development, it is of key importance to identify content characteristics and affordances of digital media that drive such effects. Extracting these factors is crucial to understand not only the effects of today's digital media landscape but also the effects of future media technologies that will emerge (see also Orben, 2020). Moreover, identifying content characteristics will allow us to differentiate potential detrimental from facilitating digital media use. For some adolescents, specific types of media use might have beneficial effects, for example, when they use relaxing smartphone content before they go to bed. Such beneficial effects are oftentimes neglected in current research.

Once we have a clearer theoretical understanding of the content characteristics that drive effects, we need to employ methodological techniques that are able to empirically test those effects in more precise ways. For this, it is important to move beyond cross-sectional studies relying on self-reports of general "screen time" toward assessing digital media in its complexity. Current technological developments facilitate the tracking of digital media use and sleep unobtrusively, objectively, and continuously. Moreover, current advancements in computational methods allow us to integrate, extract and analyze these types of complex data in more efficient ways. This will pave the way toward more advanced studies that examine the dynamic nature of digital media use, sleep and attention in unprecedented ways, and that will accelerate our knowledge of the effects of digital media on youth.

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