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38
DIGITAL MEDIA AND SLEEP IN CHILDREN

Alicia Allan and Simon Smith

Introduction

Digital media are a ubiquitous part of modern childhood. The integration of digital devices into all aspects of daily life means that the potential benefits and opportunities of digital media are accompanied by, and tempered against, concerns regarding the impact on children’s social, emotional, and cognitive development. Healthy sleep is a fundamental component of well-being in childhood, and children have a high need for sleep. Current recommendations suggest that healthy sleep durations gradually reduce from 12–16 hours (per 24 hours) in children aged 4–12 months, to 10–13 hours for children aged 3–5, and 8–10 hours for teenagers (Paruthi et al., 2016). Sleep gradually consolidates across the early childhood years as children reduce their daytime napping and achieve the majority of their sleep at night (Galland, Taylor, Elder, & Herbison, 2012).

Sleep is integral to many social, emotional, and cognitive dimensions of growth and development, and poor or disrupted sleep has been associated with poorer health, well-being, and educational outcomes (Chaput et al., 2016). Sleep quality, duration, timing, and regularity can each affect a child’s developmental trajectory, with immediate and long-term consequences for everyday behaviour, learning, and health (Miller, Kruisbrink, Wallace, Ji, & Cappuccio, 2018; Quach, Hiscock, Canterford, & Wake, 2009; Sadeh, Gruber, & Raviv, 2002; Vriend et al., 2013). New learning, in particular, strongly depends on processes of memory consolidation and generalisation that occur during sleep (Gómez & Edgin, 2015). For these reasons, good sleep in childhood needs to be protected and promoted.

Available evidence suggests a relationship between increased digital media use and poor sleep in children. Two systematic reviews (Cain & Gradisar, 2010; Hale & Guan, 2015) and subsequent meta-analyses (Bartel, Gradisar, & Williamson, 2015; Carter, Rees, Hale, Bhattacharjee, & Paradkar, 2016) have found that children with greater exposure to screen media in the evening hours show significantly shorter night-time sleep duration, poorer sleep quality, and increased daytime sleepiness when compared with those with no, or little, evening screen exposure. Further, preliminary intervention evidence suggests that reducing evening screen use can improve sleep in adolescents (Perrault et al., 2019). A number of potential mechanisms have been proposed to explain this relationship, however the causal evidence base for these mechanisms is still developing (LeBourgeois et al., 2017). This chapter describes pathways via which digital media may impact sleep in children, summarises available evidence regarding each of these mechanisms,
and outlines limitations in order to inform future research. Although this chapter focuses on children up to early adolescence, findings in adolescent and adult populations are discussed when they illustrate plausible pathways and where data is scarce for younger groups.

**Possible Mechanisms**

Experiences across the entire waking day can influence children’s night-time sleep, but the period just before sleep is particularly important (Mindell & Williamson, 2018). Digital media exposure in the evening could negatively impact children’s sleep via three potential mechanisms (Hale et al., 2018; LeBourgeois et al., 2017). These are a) increased evening light exposure; b) pre-sleep arousal; and c) sleep displacement. Currently, none have a strong causal evidence base in children, however many of the underlying processes are supported by considerable experimental and observational evidence. Figure 38.1 shows these predicted processes, each of which could work independently or together to affect sleep quantity, quality, timing, and regularity.

*Figure 38.1 Possible mechanisms for disruption to sleep onset from digital media.*
Light Exposure

Light from digital media may directly interfere with sleep onset and indirectly affect circadian (body clock) timing in children. The human physiological system has evolved to synchronise with a natural light–dark cycle that is very bright during the day and very dark at night (Smolensky, Sackett-Lundeen, & Portaluppi, 2015). In contrast, the light environment experienced by many children in their homes and bedrooms bears little resemblance to that natural state. Daytime has been effectively extended by the use of ambient artificial lighting, by at least several hours in the wintertime (Stothard et al., 2017), and this extension has likely been exacerbated by the proliferation of light-emitting electronic devices (Gringras, Middleton, Skene, & Revell, 2015). People’s non-visual circadian system is particularly sensitive to the type of light emitted from these devices, which is rich in short (blue) wavelengths (Cajochen et al., 2011; Lucas et al., 2014; Zeitzer, Dijk, Kronauer, Brown, & Czeisler, 2000). Children also use devices close to their eyes (and therefore light receptors) relative to other ambient sources such as ceiling lights, increasing the relative ‘dose’ of biologically meaningful light that is received (Gringras et al., 2015).

The effect of evening light exposure from digital devices is twofold. First, bright light is directly alerting and, second, light acts to delay the body’s internal clock. The immediate effects of light on alertness and cognitive performance are well-demonstrated in adults (Lok, Smolders, Beersma, & de Kort, 2018; Souman, Tinga, te Pas, van Ee, & Vlaskamp, 2018) and a smaller, but sound, body of evidence demonstrates these same effects in children (e.g., Hartstein, LeBourgeois, & Berthier, 2018). Acute alerting effects can be desirable during the day, however in the evening they directly conflict with sleep initiation which ordinarily requires darkness.

Indirectly, light can influence sleep by delaying the timing of children’s internal body clock. The circadian rhythm is a fundamental physiological rhythm that drives daily patterns of rest and activity, as well as many other biological and metabolic processes (Roenneberg, Kantermann, Vetter, & Allebrandt, 2013). Light is the primary input to this body clock and can directly shift the circadian rhythm in and out of synchrony with the outside world (Duffy & Wright, 2005). In both children and adults, the hormone melatonin starts to rise in the hours before bedtime, marking the onset of pre-sleep processes (Benloucif et al., 2005). The release of melatonin also acts to synchronise the central clock with other ‘clocks’ distributed throughout the body (LeBourgeois et al., 2013). Exposure to light suppresses the normal evening release of melatonin and can delay the timing of the internal clock (Zeitzer et al., 2000). This delay means that children may only feel sleepy later in the evening, resulting in later sleep onset and morning wake-up times. Because wake-up times are often fixed by regular daily commitments such as carer work routines and attendance at childcare or school, delayed sleep onset can result in shorter overall sleep duration (see the second bar in Figure 38.1).

Experimental studies have shown that bright evening light does suppress melatonin production in pre-school-age children (delaying the internal clock and associated sleepiness; Akacem, Wright, & LeBourgeois, 2018), and that a delayed internal clock is associated with later bedtimes in children (Akacem, Wright, & LeBourgeois, 2016). Therefore, light from devices could be similarly disruptive. In adults, reading on a device before bed reduces sleepiness and delays deep sleep onset when compared with reading a physical book (Grohn et al., 2016). Consistent with this, light from a tablet device is sufficient to suppress evening melatonin release in adolescents following an hour of use in the evening, with longer duration linked to increased suppression (Figueiro & Overington, 2016). Duration of screen time after 9 p.m. has also been associated with later melatonin onset in adolescents (Perrault et al., 2019). Available evidence suggests that children and adolescents are more sensitive to the effects of light than are adults (Crowley, Cain,
Burns, Acebo, &Carskadon, 2015; Higuchi, Lee, Kozaki, &Harada, 2016), such that light from digital devices may have an even greater effect on their sleep.

This underlying mechanism for sleep disruption has a strong causal evidence base, particularly in adults and adolescents. However, emitted light varies considerably based on device type, brightness settings, and the content on the screen (Gringras et al., 2015). As yet, the meaningful impact of light from habitual device use on children’s sleep outcomes is unknown. The effect of light before sleep can be reduced by minimising its intensity (by reducing brightness settings), reducing the amount of short/blue wavelengths emitted, and changing its timing (reducing both overall exposure duration and exposure close to bedtime) (Figueiro &Overington, 2016; Gringras et al., 2015; Nagare, Plitnick, &Figueiro, 2018).

**Pre-Sleep Arousal**

While light emission from digital devices raises concerns regarding hardware, there are equally plausible effects from device content. Sleep initiation occurs following a complex set of inter-related psychological and physiological transitions that involve a gradual decrease in arousal, and eventually sleep (Ogilvie, 2001). Recommendations around bedtime routines and ‘sleep hygiene’ (principles of good sleep habits) generally target the pre-bed period, in which children should be withdrawing from the emotional and cognitive attachments and demands of the outside world (Mindell & Williamson, 2018). Sleep hygiene practices aim to block out or limit external and internal stimuli (both physical and psychological). In contrast, some device-mediated activities may induce pre-sleep arousal, a psychologically or physiologically stimulated state that makes it difficult to subsequently initiate sleep (Booztin &Epstein, 2011). In this case, even if bedtime is not delayed, children may take longer to fall asleep once in bed, reducing overall sleep time (see bar three in Figure 38.1). Higher levels of reported pre-sleep arousal (particularly cognitive arousal) have been associated with sleep disturbance in children aged 8–10 years (Gregory et al., 2008). Changing media content type without altering overall screen time has been shown to affect sleep (Garrison &Christakis, 2012). Activities that induce a high level of anxiety or psychological arousal, regardless of their format, are very likely to interfere with a child’s ability to fall asleep (Garrison, Liekweg, &Christakis, 2011).

A number of studies have demonstrated connections between social media use and pre-sleep arousal. In a study assessing pre-bed behaviours in adolescents, pre-sleep arousal partially mediated the relationship between social media use and time taken to fall asleep (Harbard, Allen, Trinder, &Bei, 2016). Scott and Woods (2018) reported an association between social media use and increased pre-sleep cognitive arousal, however how this compares with the psychological stimulation provided by other pre-bed activities is unclear. Finally, Reynolds, Meltzer, Dorrian, Centofanti, and Biggs (2019) demonstrated an association between high-frequency online social interactions (email and instant messaging) and perceived insufficient sleep duration, but not reduced time in bed, in children aged 8–16 years. There are also demonstrated relationships between playing violent video games and physiological arousal in adolescent boys, with potential subsequent effects on sleep (Ivarsson, Anderson, Åkerstedt, &Lindblad, 2013). However, children may respond differently to the same content or activity, depending on their temperament or previous exposure (Ivarsson et al., 2013).

Even if pre-sleep activities are not themselves stimulating, the presence of devices in the bedroom provides a reminder of connection to an infinitely large social group and stream of information. Experimental evidence in adults demonstrates that the simple presence of one’s smartphone can reduce available cognitive resources (Ward, Duke, Gneezy, &Bos, 2017). Lessons from behavioural psychology and the potency of classical conditioning mean that even if device use is restricted to calming or relaxing activities closer to bedtime, it could still induce psychological
arousal associated with previous use. These principles underpin the practice of stimulus control therapy, a fundamental component of interventions to address insomnia disorders (Bootzin & Perlis, 2011).

There are other possible pathways via which pre-sleep arousal might affect sleep in children. In addition to interfering with sleep onset, psychologically stimulating activities prior to bed may also reduce sleep maintenance and consolidation (Beyens & Nathanson, 2019). It is also possible that stressful parent–child interactions around limiting or stopping device use could increase physiological arousal prior to the sleep period. Frequent use of media devices throughout the day could also minimise children’s ability to self-soothe, such that when there is ‘quiet time’ prior to bed, they struggle to relax. Although plausible, these possibilities remain to be explored in empirical research.

### Sleep Displacement

Finally, undertaking particularly engaging activities in the pre-sleep period may delay children’s bedtime. Digital device use may displace sleep, such that children spend time that they would otherwise be sleeping using digital technology (see the final row of Figure 38.1). Pre-sleep arousal and sleep displacement may work together to delay sleep onset and therefore reduce sleep duration (Exelmans & Van den Bulck, 2017). Any pre-bed activity has the potential to displace sleep in children. However, there is early evidence that screen-based activities may reduce children’s sleep to a greater extent than reading a book prior to bed, although this should be interpreted cautiously due to the observational nature of the research (Hale et al., 2018).

Digital media are most likely to displace sleep when use becomes excessive or unregulated. Children who use digital devices excessively may meet criteria for digital addiction (an emerging but contentious definition of problematic digital media use). Digital addiction has demonstrated relationships with poor sleep in children, although these are better established in adolescents (Chen & Gau, 2016). Even moderate levels of screen time are consistently associated with shorter sleep duration (Cain & Gradisar, 2010; Carter et al., 2016; Harbard et al., 2016; Scott & Woods, 2018), suggesting that it is not only extremely high device use that has the potential to delay sleep onset and displace sleep. While there has been considerable research addressing the personal characteristics of individuals susceptible to online addiction, there is limited empirical scrutiny of the design decisions made by online service providers to drive use and engagement. Design of the online environments in which content is presented and strategies that are used to engage users may be equally as important as the content itself. The next section explores characteristics of digital activity environments that may increase the risk of sleep displacement in children, however these possibilities are speculative and have not been empirically tested.

Online activities rewarding constant connection may result in sleep displacement, and social rewards or punishments can be particularly powerful. Providing likes on social media activates brain circuitry involved in reward processing in teenagers and young adults (Sherman, Hernandez, Greenfield, & Dapretto, 2018), suggesting high potency of online services. Some social networking platforms incorporate reward-based strategies that can induce fear of missing out (FOMO; Scott & Woods, 2018) and pressure to stay connected. Examples of this are messaging applications that quantify ‘streaks’ of communication between friends, that make content expire after a set time period, require attention at specified times of the day, or require constant ‘check-ins’ from users for rewards such as points or badges. Massively multiplayer online games (MMOs) have been specifically identified as leading to excessive screen time and interference with sleep (Lam, 2014). These games can also have strong social expectations, where the feeling of ‘letting down’ team-mates might limit children’s willingness to stop play at their usual bedtime, and children may game with older players (who have later bedtimes) or those in different time zones.
These effects are true for both children and adults, but children may have more difficulty self-regulating their engagement, as the executive functions that underpin self-regulation are still developing during childhood (Rothbart, Posner, & Kieras, 2006).

Activities that encourage children to lose track of time or lack clear exit points may also delay bedtime and displace sleep. Games and services can induce a sense of ‘flow’, where a user feels fully immersed and has a distorted perception of time (Rau, Peng, & Yang, 2006). Children may have less control over stopping an activity if they have reduced awareness of time passing. A number of design features can minimise clear exit points from digital activities. These include auto-play features, which are present in many online video streaming services, games that lack clear save points, and the ‘infinite scroll’ of many social media feeds, where information is not presented in discrete pages, but instead as a never-ending stream of content. There is large variation in the extent to which digital applications, services, and games utilise compelling reward and control strategies. It is almost certainly the case that some types of digital media activities are more prone to displacing sleep than are others; however, there is scarce evidence examining what specific digital media characteristics are more likely to delay children’s sleep.

**Potential Benefits of Digital Media**

Digital media also has considerable potential to provide information, deliver activities, or promote ambient conditions that encourage and facilitate healthy sleep in children. There are many learning applications used by children that are delivered via digital media and have important benefits for children. There is also great potential for digitally supported relaxation and passive digitally automated strategies to promote sleep, such as programmable lighting, music, storytelling, or relaxation sounds. Further, there are many existing apps and devices to track and support sleep in children, and this increased availability presents opportunities for greater awareness of children’s sleep behaviour and needs in families. However, there is no current evidence base for these strategies in children, despite the current proliferation of health management apps (Byambasuren, Sanders, Beller, & Glasziou, 2018). Indeed, there is evidence that the information provided by commercially available sleep apps and devices can be misleading (Meltzer, Hiruma, Avis, Montgomery-Downs, & Valentin, 2015), if not counterproductive. Even if individual applications are beneficial for creating a sleep-supportive environment, the fact that they are embedded in a device that is also highly connected and can still deliver other cognitively arousing content means that they should be used with some care.

**Limitations of Existing Research**

The existing research base is almost exclusively observational in nature and should be interpreted with some caution. It is not possible to determine with much certainty whether technology use contributes to sleep difficulties or whether children with sleep difficulties turn to digital media as a coping or mitigation strategy for their sleep difficulties. Children’s health, social, and environmental context are also confounding factors associated with both sleep difficulties and increased screen use. For example, overall screen time seems to be higher in lower-income families with less educated caregivers (Przybylski, 2019; Tandon et al., 2012). Families that allow their children more screen time report both increased sleep latency (time to fall asleep) and a more negative family environment (Bartel et al., 2015). These family and home-life factors may explain both the increased screen use and poor sleep observed in current studies. Digital media could also impact sleep indirectly via other aspects of well-being. Sleep duration is related to other health outcomes such as dietary habits and obesity (Tambalis, Panagiotakos, Psarra, & Sidossis, 2018). Increased screen time could displace daytime physical activity, quality social time and
relationships, and increase obesity, all of which have their own associations with sleep. These relationships are not yet sufficiently examined, and this limits the ability to attribute changes in sleep to digital media use.

Most studies have relied on parental report or self-report of both digital media use and sleep in children, which is likely to introduce considerable error, particularly where all data come from a single observer (e.g., the problem of common method variance and other sources of bias; Exelmans & Van den Bulck, 2019; Hale et al., 2018). Studies that incorporate objective sleep measurement techniques are needed. There is also immense variation in the measurement of ‘digital media use’, which is often operationalised poorly or simplistically (e.g., high versus low screen time) (Hale & Guan, 2015). ‘Screen time’ today runs the full gamut of the human cognitive and emotional experience, and it is increasingly difficult to disentangle digital activities from one another. Children can task-switch frequently, both between and within devices, encouraged by notifications and application cross-integration. Devices can provide both calming and alerting experiences, sometimes closely juxtaposed. This introduces challenges for researchers and, thus far, the field has not effectively characterised screen-based activities to establish what types may be problematic for children’s well-being, and for sleep in particular (Exelmans & Van den Bulck, 2019).

There has been broader analysis of multiple large-scale cross-sectional social datasets to examine the relationship between digital technology use and psychological well-being in adolescents, in a way that accounts for the pitfalls inherent in analysing data from large observational studies. These analyses show that even if a causal relationship between digital technology and well-being does exist, current data suggest that the size of this relationship is likely very small, with minimal meaningful impact on day-to-day well-being (Orben & Przybylski, 2019). Most of the available research reported here rates poorly on schema designed to rate the certainty of an evidence base (Carter et al., 2016). Together, this means that a causative relationship cannot be currently established. In order to improve the quality of evidence, strongly controlled trials in the field are needed. Existing reviews have already called for future research that adopts experimental designs to supplement the predominantly observational research base (Carter et al., 2016; Hale et al., 2018). A clearer and more nuanced description of the causal mechanisms involved will allow better identification of what specific digital media features may be problematic (or beneficial) for sleep.

**Practice Points**

The American Academy of Pediatrics (AAP) has guidelines regarding screen use in children, suggesting that screens should not be used for one hour prior to bedtime, and that bedrooms remain screen-free, particularly before bed (AAP, 2016). Because there is limited evidence about the types of activities that cause sleep problems, the blanket advice (i.e., no screen time) is likely reasonable, but would ideally be refined to be more activity-specific in the future as the evidence base evolves. Existing research and knowledge of the pre-sleep processes outlined in this chapter suggest a number of practice points. These recommendations relate specifically to sleep, and sit within broader advice regarding healthy management of digital media use in children (see Hill et al., 2016). The following considerations and practical strategies may be of use to parents and carers for managing devices in the hours prior to bedtime:

- Light from devices should be minimised in the hours before bed, as longer periods of exposure have larger effects on the body clock. Melatonin onset occurs several hours before habitual sleep onset, so the potential for suppression of melatonin by light from light-emitting devices extends over at least that period;
• Brightness of screens should be dimmed as much as possible when used near to bedtime;
• The use of ‘Night-mode’ on many devices to change the colour and brightness of screens may help to reduce the proportion of blue light emitted;
• The effect of light upon sleep–wake regulation is time-specific, so there is no reason to be concerned about the effects of increased morning or daytime light exposure on children’s sleep. In fact, bright light may be beneficial during the day;
• To minimise the potential for dysfunctional associations and pre-sleep arousal, avoid allowing children to use devices in the bedroom, and do not allow use of devices in the bed itself at any point during the day;
• Consider the potential emotional and arousal content of activities completed on devices in the lead up to bedtime. Avoid content that has the potential to increase psychological and physiological arousal;
• Establish clear expectations with social networks regarding ‘off-time’ that starts well prior to the sleep period;
• Limit activities that have reward structures designed to encourage persistent and ongoing use (e.g., ‘streaks’) in the hours prior to bedtime, and substitute for activities that have clear time limits or clear ‘break points’;
• Disable auto-play features where possible, to limit children losing track of time and delaying sleep preparation.

Summary

Sleep is critical for children, and current evidence suggests that increased digital media use is associated with a range of negative sleep outcomes, particularly later bedtimes and reduced sleep duration. There are multiple plausible pathways underpinning this relationship, with some support but limited rigorous evidence to support these mechanisms as causal, particularly in children. The rate of technological change means that evaluation of the impact of digital media lags well behind adoption. Given the embeddedness of digital devices in modern childhood, there is a great need for high-quality field research around this issue. Well-controlled field trials will be required to establish whether digital media use has a meaningful impact on children’s sleep. Future research also needs to be re-framed around activity characteristics and online environments such as reward structures and sense of connection to broader networks rather than differences in device type, which is becoming an increasingly immaterial distinction as portable devices mediate all aspects of life.

References

Digital Media and Sleep in Children


411

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