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Adverse physiological and psychological effects of screen time on children and adolescents: Literature review and case study[☆]

Gadi Lissak

Meuhedet Health Services, Jerusalem, Israel

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ABSTRACT

A growing body of literature is associating excessive and addictive use of digital media with physical, psychological, social and neurological adverse consequences. Research is focusing more on mobile devices use, and studies suggest that duration, content, after-dark-use, media type and the number of devices are key components determining screen time effects. Physical health effects: excessive screen time is associated with poor sleep and risk factors for cardiovascular diseases such as high blood pressure, obesity, low HDL cholesterol, poor stress regulation (high sympathetic arousal and cortisol dysregulation), and Insulin Resistance. Other physical health consequences include impaired vision and reduced bone density. Psychological effects: internalizing and externalizing behavior is related to poor sleep. Depressive symptoms and suicidal are associated to screen time induced poor sleep, digital device night use, and mobile phone dependency. ADHD-related behavior was linked to sleep problems, overall screen time, and violent and fast-paced content which activates dopamine and the reward pathways. Early and prolonged exposure to violent content is also linked to risk for antisocial behavior and decreased prosocial behavior. Psychoneurological effects: addictive screen time use decreases social coping and involves craving behavior which resembles substance dependence behavior. Brain structural changes related to cognitive control and emotional regulation are associated with digital media addictive behavior. A case study of a treatment of an ADHD diagnosed 9-year-old boy suggests screen time induced ADHD-related behavior could be inaccurately diagnosed as ADHD. Screen time reduction is effective in decreasing ADHD-related behavior.

Conclusions: Components crucial for psychophysiological resilience are none-wandering mind (typical of ADHD-related behavior), good social coping and attachment, and good physical health. Excessive digital media use by children and adolescents appears as a major factor which may hamper the formation of sound psychophysiological resilience.

1. Introduction

Current young generation experiences electronic media as a central part of their lives. Children and adolescents use for leisure an increasingly growing variety of digital media devices. Rapid technological improvements allow condensing into the users' experience a growing variety and faster-paced stimuli which is accessible almost any time and place through mobile devices, consequently, drawing youth to an excessive screen time use over the recommended 2 h per day limit (Henderson et al., 2016). In many of western and some far-east countries appear a continuous rise in youth's digital media consumption. In 2011, 52% of 0 to 8-year-old children had access to a mobile device. This access had increased, by 2013, to 75% (Chassiakos et al., 2016). In 1999, the average screen time of 8–18 year-olds was 6.21 h per day and had increased by 2009 to 7:38 h, (Magee et al., 2014). Additionally, a shift in the youth's device of choice appears to be occurring. With more than 75% of families owning some mobile device, use of smartphones and other Internet-enabled small devices is rising (Lauricella et al., 2015). Consequently, adolescents owning a smartphone are likely to have higher screen time compared to adolescents with a conventional mobile phone because they have higher online and calling/sending messages time (Lemola et al., 2015). Thus, the use of mobile devices which allows access to most types of content, and encourages multi-screening (Cain and Gradisar, 2010; Cajochen et al., 2011), is creating a growing concern (Falbe et al., 2015) and is drawing research attention.

Along with advantages associated with access to information and fast communication, in recent years many studies associated screen exposure to health and psychological problems among infants, children, and adolescents. This article reviews screen time effects on sleep, the cardiovascular system, orthopedics, and vision and screen time psycho-

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E-mail address: gadilk@gmail.com.

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neurological and social outcomes. A case study of an ADHD diagnosed nine-year-old boy presents an example of screen time in-the-field-effects and will assist to conclude the role of screen time in the formation of the psychophysiological resilience of the young generation.

2. Screen time effects on sleep

Children in 2011 were estimated to sleep, on average, one hour less per night when compared with children of the early 20th century (Magee et al., 2014). In Britain, 20–30% of young children experience sleep problems (Cheung et al., 2017). Sleep is highly important for neurodevelopment of infants and toddlers. Accumulating evidence indicates that inadequate sleep, both in duration and quality may compromise youth's physical and mental health and psychosocial functioning. Additionally, risk-taking behavior and school performance are likely to be negatively affected by inadequate sleep (Falbe et al., 2015). Sleep may also critically affect the regulation of circadian rhythms by affecting the pineal hormone melatonin, which is involved in enhancement of immune function and inhibition of development of cancer (Figueiro and Overington, 2015; Blask, 2009).

The association between digital media and sleep duration and quality relates to infancy through adolescence (Parent et al., 2016). Novel findings suggest an inverse association between sleep duration and subsequent screen time. A longitudinal study of 4–8-year-olds found that short sleep time can promote a following-day fatigue, thus leading to more screen viewing sedentary behavior. Researchers, therefore, suggested a bidirectional association between children's length of sleep and screen time (Magee et al., 2014). An examination of all developmental stages found that sleep disturbances, when they are a result of excessive screen time, are linked to internalizing, externalizing, and peer problems (Parent et al.). Another study related to the effects of sleep on executive functioning and theory of mind (ToM) (i.e., the capacity to understand mental states, motives, and feelings of others). This study examined preschoolers and found that extensive exposure to background TV or nighttime TV viewing was associated with decreased sleep duration, consequently resulting with decreased ToM (Nathanson and Fries, 2014).

Digital media time is considered to affect sleep through the following means:

(a) Displacing other activities: screen time can displace physical activity time known to be beneficiary for sleep. Additionally, screen time can come at the expense of sleep time (Cheung et al., 2017; Chahal et al., 2013), thus shortening sleep duration and quality (Cheung et al., 2017; Cain and Gradisar, 2010; Magee et al., 2014). Children of lower-income families are reported to have increased TV viewing and reduced sleep quality. However, a large number of digital devices in higher socioeconomic status families could be assigned for contributing to increased screen exposure and shorter sleep time (Magee et al., 2014)

(b) Time of use: Evening and nighttime exposure to bright light and blue light emitted by self-luminous devices may suppress melatonin production, affect the timing of melatonin production and, consequently, cause circadian disruption (Cheung et al., 2017; Figueiro and Overington, 2015; Falbe et al., 2015; Cajochen et al., 2011). Bedtime access to media devices is associated with compromised sleep components of various age ranges (Carter et al., 2016). Sleep problems correspond to toddlers' evening media exposure (Garrison et al., 2011) and to night-time access to digital devices, which according to another study seemed to have caused to fifth graders a decrease in sleep length (Chahal et al., 2013). Falbe et al. reported that use of mobile phones after bedtime by seven graders was associated with a year later report of feeling significantly more tired. Pre-adolescents and adolescents are reported to experience sleep problems particularly if they use digital media after 9:00 p.m. Additionally, extended messaging post-bedtime is likely to decrease sleep duration of high school students and to cause them daytime sleepiness and poorer academic achievements (Grover et al., 2016). Other findings on cohorts aged 16–19 reported that over four hours of digital media use is associated with extended sleep onset latency (Hysing et al., 2017).

(c) Media type – television vs. small touch-screens: the number of TV viewing hours of infants and toddlers was found related to irregularities in day naptime and bedtime onset (Thompson and Christakis, 2005). Passive TV viewing by five and six-year-olds, in particular, who were viewing adult-targeted TV programs, was found to be associated with sleep disturbances. Both active and passive viewings were found associated with sleep-wake transition disorder among 5–6-year-old children (Paavonen et al., 2006). A more recent study added that increased passive exposure to TV was independently related with reduced daytime sleep (Cheung et al., 2017).
In contrast to TVs, small touch-screens can emit audible notifications (e.g., text messages) during sleep time, thus delaying falling asleep or causing an inadequate sleep. Thus, it was found that 18% of adolescents were reported to be awakened by mobile phones at least a few times a night (Falbe et al., 2015). Touch-screen devices were also found to affect toddlers aged 6–36 months as reported in a study which found a significant association between frequency of touch-screen device use (mostly tablets) which increased daytime sleepiness (average of 10.8 min) and decreased night sleep (15.6 min in average). Also, overall night and day sleep duration increased and night sleep onset (falling-asleep time) became longer for this population (Cheung et al., 2017).

(d) Media content: exposure, primarily to video games, may increase children's psychophysiological arousal, therefore affecting sympathetic regulation (Cheung et al., 2017; Falbe et al., 2015; King et al., 2014). Consequently, arousal may disturb pre-bedtime relaxation and is likely to cause delayed sleep onset and shortened sleep time (Cheung et al.; Magee et al., 2014). Garrison et al. (2013) further elaborated on the effect of violent media content on 3–5 year-olds and reported that 12 min of violent daytime content or 15 min of evening media increases the risk of inadequate sleep. Use of social media is another type of content found to affect sleep. Wood and Scott (2016) reported that adolescents' use of social media at night time predicts inadequate sleep, especially when emotional investment is involved. Moreover, the combined effect of looking at a bright mobile phone display while involved in an excitement provoking task (e.g., fast paced/violent game or worrying messaging) may increase psychophysiological arousal, thus disrupting sleep (Oshima et al., 2012).

(e) Location: media devices located in children's bedroom are likely to increase overall screen exposure especially at evenings. Small sized touch-screen devices enable them to flexibly be used in children's rooms, both by the children and by parents who increasingly use such devices for interacting with their children (Northwestern University - School of Communication - Center on Media and Human Development, 2014). Findings by Brambilla et al. (2017) suggested that children's use of electronic media devices in the bedroom is related to decrease in sleep duration. The number of media devices owned by adolescents, particularly when located in the bedroom, was related to delayed bedtimes, shorter sleep duration, increased bedtime resistance, and a higher level of sleep disturbance (Bruni et al., 2015; Hysing et al., 2017).

(f) Electromagnetic radiation is sensed as light: The pineal gland, producing melatonin, may sense electromagnetic radiation as light. Therefore exposure to electromagnetic radiation from wireless devices may delay melatonin production, thus affecting sleep (Halgamuge, 2013).

3. Cardiovascular system

For more than three decades evidence has been accumulating regarding negative health outcomes of TV viewing as 'sitting' time. Along with technological advancement, this field of interest expanded to examine also a computer and video game time (Biddle et al., 2017). Screen time sedentary behavior is claimed to increase the risk for obesity, HDL dysfunction, and high blood pressure which are major risk factors for cardiovascular morbidity (Merghani et al., 2015; Goldfield et al., 2011; Martinez-Gomez et al., 2009).

3.1. Obesity

The relation between screen time and obesity can be explained by reduced sleep and physical inactivity and by exposure to advertising which negatively affects youth's dietary choices (Mihrshahi et al., 2017; Biddle et al., 2017; Chahal et al., 2013). An increase in passive food consumption is another suggested factor for linking computer-related activities to obesity (Pérez-Farinós et al., 2017). Magee et al. (2014) argued that it is possible that obesity influences both sleep duration and screen time (TV viewing) because sedentary lifestyle may more common for obese children. Thus, the study suggested an interactional relationship between sleep and obesity.

A survey among children aged 9–10 associated three hours screen time or more to obesity (Nightingale et al., 2017). Among types of digital media, bedroom TV viewing was more associated with obese children and adolescents (Pérez-Farinós et al., 2017; Mihrshahi et al., 2017) and with forming a cardiometabolic risk (Staiano et al., 2013). A single video game session was associated with higher food consumption which was unrelated to hunger sensations. Moreover, in the study, after the video game playing time, food intake was not compensated for during the rest of the day. In normal conditions, an increase in plasma glucose follows a rise in satiety sensations, however, in the study, an increase in plasma glucose preceded food intake and reached a higher level than in resting conditions. Thus, results suggested the presence of acute stress (fight-or-flight response) associated with video game playing time. The stress response seemed related to a glucose release into the bloodstream (Chaput et al., 2011).

3.2. Blood pressure

Evidence exists in favor of tracking hypertension from childhood into adulthood (Gopinath et al., 2014). Sedentary behavior and its outcome physical inactivity have an inverse, and direct association with children's blood pressure in all age ranges, when associated with more than two daily hours of Internet use, watching TV and playing video games. Higher odds of elevated blood pressure were found when examining 2–9-year-old children with a two-year follow-up (De Moraes et al., 2014) or among 14–17-year-old adolescents (Cassidy-Bushrow et al., 2014). A marked rise in diastolic blood pressure was linked to each daily screen time hour among 6-year-old examined within a seven-year period (Gopinath et al.), and among pre-adolescents' (mean age 12.7 years). Interestingly every hour of non-screen reading was linked with a decrease in systolic and diastolic blood pressure (Gopinath et al., 2012).

Retinal arteriolar narrowing is considered a potential marker of future adverse cardiovascular events. A study which examined six-year-olds, associated each hour of TV viewing with increased arteriolar narrowing and a 10-mm Hg increase in children's systolic blood pressure. Findings indicated that high outdoor activity correlates with wider retinal arterioles than with children with low outdoor activity time (Gopinath et al., 2011).

3.3. Cholesterol

Van Ekris et al. (2016) reviewed cross-sectional studies which measured overall sedentary behavior including screen time (TV viewing, computer use/video games). The authors found a moderate-to-strong evidence for an association of overall sedentary behavior and HDL-cholesterol level. Among obese adolescents (ages 14–18), video game playing was the only type of sedentary behavior associated with a reduction of HDL cholesterol (Goldfield et al., 2011). The same age range was examined by Martinez-Gomez et al. (2010) who concluded that screen time, over three hours, is associated with significant decrease in HDL cholesterol.

4. Stress regulation

4.1. Sympathetic arousal

Chronic sympathetic arousal can act as a risk for cardiovascular diseases (Curtis and O'Keefe, 2002). Higher levels of sympathetic arousal were found in young adults (Hsieh and Hsiao, 2016) and among school-aged children with Internet addictive behavior. The authors hypothesized that high arousal might be a partial cause for disrupted sleep (Lin et al., 2014).

4.2. Cortisol

Cortisol is a hormone produced by the hypothalamic-pituitary-adrenal (HPA) axis and is considered a stress biomarker for pediatric studies. Both low and high levels of cortisol are associated with poorer performance. Under normal conditions, cortisol levels are low at night. Levels rise toward waking hours and increase steeply after wake-up time. School-aged children who had used media three hours per day demonstrated a reduced cortisol rise one hour after wake-up time. In comparison, children with less than three hours or no daily digital media time displayed a normal rise of morning cortisol (Wallenius et al., 2010). Another study examined cortisol levels in two groups of infants (mean age 10.6 months). One group consisted of infants watching a DVD, and in the other group, infants were playing with blocks. The study found that the infants in the DVD group had a significantly lower cortisol level (30 and 45 min into the activity), implying a cortisol dysregulation (Christakis et al., 2013). Cortisol dysregulation was found also related to social screen time. A study of 12–17 years-olds provided data regarding Facebook use pattern (frequency use, network size, self-presentation, and peer-interaction). Findings suggested that network size is associated with increased diurnal cortisol concentrations (Morin-Major et al., 2016).

4.3. Insulin and diabetes

Insulin is a hormone produced by the pancreatic islets and has a major role in metabolism regulation and fat storage. A state when cells fail to use insulin effectively is called Insulin Resistance which contributes to the pathophysiology of diabetes and is a risk factor for cardiovascular diseases. Recent studies examined various age groups between 8-years-old to late adolescence. Some finding associated screen time as low as two screen time hours per day to abnormal insulin levels (Hardy et al., 2010). Henderson et al. (2016) suggested that every added hour of TV, video game, or computer use is associated with a 5% decrease in insulin sensitivity. In a two years follow-up of this study, high screen time predicted worse insulin sensitivity, although obesity partially mediated these results

5. Vision

Considerable computer screen viewing can lead to eye fatigue, blurred vision, eye dryness, headaches, and discomfort. Such symptoms can be a result of glare, poor lighting or improper viewing setting (Akinbinu and Mashalla, 2014). The Multi-Ethnic Pediatric Eye disease Study (MEPEDS) examined the causes of ocular disease. Finding confirmed that prevalence of childhood myopia in the U.S. has more than doubled over the last fifty years (Varma et al., 2006).

Recent studies have associated vision impairments to lack of outdoor time and prolonged indoor screen time, specifically video game playing. Findings suggest that outdoor activity involves the light-stimulated release of dopamine from the retina which inhibits the development of myopia. Thus, children who spend less time outdoors are at a greater risk of becoming myopic. Furthermore, the effect of time outdoors can reduce, and largely negate, the causes of myopia development, such as in extensive near-work, i.e., screen viewing (French et al., 2013).

Studies have associated close screen viewing (in video games) to development of myopia in ages 1–13-year-old (Jinhua et al., 2015). A study of 3–10 year-olds elaborated on the effects of video games on vision. The participating children who were playing video games more than 30 min almost every day experienced headaches and dizziness and eye strain. Transient diplopia and refractive errors (e.g., short-sightedness) appeared mostly in the dominant eye, eventually resulting in loss of fusion. The absence of stereopsis was observed related only to video game time and not to other digital media devices. Additionally, the presence of eyelid tics was explained as a direct result of the high level of brain stimulation occurring during video game playing (Rechichi et al., 2017).

6. Orthopedics

Sedentary behaviors, or non-exercising seated activities, may result in significant orthopedics effects. Screen time, primarily of small-screen handheld devices is argued to affect posture and creating musculoskeletal load and discomfort symptoms. Such symptoms may be a result of the intensive repetitive wrist and arm movement, and head inclination found mostly during video game playing (Lui et al., 2011). Another significant orthopedic effect relates to youth's bone density. Boys' video game time was found to be adversely associated with bone mineral density (Winther et al., 2015; Shao et al., 2015). Chastin et al. (2014) reported that girls' screen time was negatively associated with femoral and spinal bone mineral content.

7. Depression and suicidal behavior

Depression represents a growing public health concern and is a prevalent disease among adolescents. Findings have linked overall screen time to depression and suicidal behavior among adolescents (Wood and Scott, 2016; Maras et al., 2015). Liu et al. (2015) found a nonlinear dose-response relation between depressive symptoms and overall screen time among children in the age range of 5–18 who were using digital media for over two hours per day.

Symptoms of sleep disturbances are known to precede the development of depressive symptoms and suicidal behavior (Dombrovski et al., 2007). Therefore, inadequate sleep was suggested as a mediating factor linking nighttime screen use to depressive symptoms and suicidal feelings among junior high students (Oshima et al., 2012; Lemola et al., 2015). Oshima et al. stressed the relationship between sleep disturbances and completed suicide. The authors also pointed out that negative mood, suicidal tendencies, and self-injury are likely to be related to mobile phones dependency, frequent message sending and prolonged worry about not receiving messages, especially before bedtime.

8. Attention deficit/hyperactivity disorder (ADHD)

Attention deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by symptoms of inattention and hyperactivity/impulsivity with an early onset in childhood and adolescence. Children in the general population may display various ADHD symptoms (attention problems, hyperactivity, and impulsivity) on a continuous basis. Such behavior is referred to as ADHD-related behavior and is associated with screen time (TV and video games) (Nikkelen and Valkenburg, 2014).

Screen time may be related to ADHD and ADHD-related behavior through various factors. Screen time may hinder the availability for activities that are considered to better stimulate cognitive abilities and long attention span (Nikkelen and Valkenburg, 2014). Zimmerman and Christakis (2007) emphasize that for the developing brain of infants and toddlers appropriate media attention-capturing stimulation displaces learning opportunities with low developmental value.

Children and adolescents aged 6–17 either diagnosed with ADD/ADHD or rated as having attention problems/impulsiveness were found to have a greater rate of screen time (Charmaine et al., 2015; Gentile et al., 2012). Moreover, The severity of attentional symptoms appears to correspond to overall children's the Internet and video game time. ADHD was also shown to be the primary predictor for the development of the Internet addictive behavior (Weiss et al., 2011). Concurrently, data indicates that video games content adds uniquely in predicting attention problems (Gentile et al., 2012). Swing et al. (2010) sampled two group ages: 3–5 graders and late adolescent/early adult students (mean age: 19.8 years) and found that TV viewing and video game playing are linked to increased attention problems in early adulthood and late adolescence/early adulthood. Hence, overall findings indicate a bi-directional causality between video game playing and attention problems/impulsiveness (Weiss et al.; Swing et al.).

8.1. Arousal, violent, fast-paced content, and attention problems

In a normal sleep state, arousal, the outcome of the sympathetic activity, is decreased by the activity of the parasympathetic system. Thus, sympathetic arousal level can act as a biomarker for sleep quality (Ononogbu et al., 2014). Children with poor sleep tend to display hyperactivity and sensation seeking. Therefore, it appears that overtiredness is likely to trigger or exacerbate ADHD symptoms (Geissler et al., 2014).

Violent media content is characterized by antisocial and poor inhibited behavior, both which may induce poor self-control. Particularly for infants and toddlers under age three, media violence may also elevate the arousal level, consequently impeding self-regulation and resulting in attention problems (Zimmerman and Christakis, 2007). Repeated exposure may cause children to desensitize to media violence. Consequently, a certain level of violence will induce less arousal, possibly resulting in demand for more extreme violence level that will re-induce the same or higher arousal level (Nikkelen and Valkenburg, 2014).

Exposure to fast-paced content, i.e., brief edited segments, such as in video games, is not attention demanding (Weiss et al., 2011). Thus, the attention of the exposed user may shift into a scanning-and-shifting mode which, in turn, is likely to trigger increased arousal. Repeated exposure may condition the user into frequently seeking higher arousal levels, thus hampering performing activities demanding prolonged attention, such as schoolwork or class activities (Nikkelen and Valkenburg, 2014).

8.2. Neurological aspect of screen time-related ADHD behavior

Among digital media elements, fast-paced gaming, in particular, offer immediate rewards with an array of strong incentives for further reward obtainment (e.g., through a change of game environment and achievement of the next level). Gaming related rewards were found to increase striatal dopamine release (Weiss et al., 2011), resulting in an induced feeling of pleasure. As a result, the user is inclined to adopt a craving behavior aimed at experiencing repeating short-term pleasures (Christensen, 2017). Engagement in continuous rewarding further exacerbates disinhibition, quick responsiveness and consolidates inattention (Weiss et al.), eventually amplifying ADHD symptoms.

9. Addictive screen time behavior

Literature relating to digital media addictive behavior has focused mostly on Internet use and video games, yet the growing use of applications and texting (mostly used on mobile devices) may also lead to addictive behavior (Love et al., 2015). While males appear to demonstrate video game addiction, the addictive behavior of females is found to be focused primarily on social networking (Andreassen et al., 2016).

9.1. Neuropsychological effects

Studies have utilized brain imaging techniques to determine the involvement of neural circuits in executive functions and craving behavior in individuals who experience a lack of control over their Internet and games time (Brand et al., 2014). Findings concluded that craving behavior in online gaming resembles the addictive behavior in substance dependence (Love et al., 2015). Numerous studies concluded that Internet addictive behavior results in brain frontal lobe structural stated. Such structural changes are related to the ability to filter out irrelevant information and less coping with complicated task demands. The frontal lobe is also related to empathy, suppressing prepotent but incorrect responses, and adapting to change in the environments (Brand et al., 2014; Yuan et al., 2011; Dong et al., 2012; Hou et al., 2017). Other findings revealed impaired white matter associated with emotional processing, dysfunctional decision making and compulsive-repetitive behaviors (Lin et al., 2012).

As divided attention between media devices becomes the "real world" behavior, studies have focused on the effect of screen multitasking. Pea et al. (2012) found that among college students, heavy multitasking scores correspond to decreased gray matter in the anterior cingulate cortex associated with cognitive control performance and socio-emotional regulation. These college students displayed poor results in cognitive functioning factors like task switching, working memory and filtering. The same population presented, in another study, an association between decreased gray matter and poor conflict detection, increased neuroticism and impulsivity, poor control over goal-directed behavior and increased sensation-seeking behavior (Loh and Kanai, 2014).

9.2. Behavioral and social aspects of addictive digital media behavior

Consistent with the finding of decrease of gray matter among heavy media multi-taskers young adults, this population is characterized with more lapses of attention and self-reported everyday non-deliberate mind-wandering (Schutten et al., 2017). Non-deliberate mind-wandering is central to ADHD-related symptoms found among college students (Seli et al., 2015) and is associated with lower trait levels of mindfulness and a higher rate of non-adaptive/negative thinking styles (Jonkman et al., 2017). Non-adaptive/negative thinking styles are found in adolescents who are behaviorally addicted to the Internet and who are reported to have more depression, hostility and ADHD-related symptoms (Yen et al., 2007). Thus, it appears that greater mind-wandering corresponds to media addictive behavior, and if it is not apparent during adolescence it is found in young adulthood.

Heavy multitasking and screen-addicted adolescents were also found to have less social support and attachment with family and peers (Wu et al., 2016; Pea et al., 2012; Richards et al., 2006). Consequently, their life satisfaction level is negatively affected (Boniel-Nissim et al., 2015; Mentzoni et al., 2011). While face-to-face communication is strongly related to positive social well-being (Pea et al., 2012), adolescents are shifting away from this form of communication hindering offline social support. Then, to revive social support while in times of social difficulty, adolescents are inclined to immerse themselves in a vicious cycle of further use of Internet/social networks. However, the social support that they may find online serves to further maintain addictive Internet behavior. On the other hand, non-screen related social support may decrease the Internet addictive behavior (Wu et al., 2016). A low level of social support, together with higher levels of mind wandering are likely to decrease social coping, increase the risk for further depression, isolation, and loneliness, a process which may further maintain addictive behavior (Andreassen et al., 2016). Furthermore, social and psychological factors, which are negatively affected by addictive screen usage, i.e., social support, attachment, mindfulness and level of life satisfaction, were also noted as crucial to the individual's resilience necessary to face life stressors (Pop, 2014; Sahin-Baltaci and Karatas, 2015; Nemati and Farnaz, 2016).

Finally, social aspects of addictive Internet behavior seem to converge around cyberbullying behavior. A study of 14–18-year-old students linked addictive Internet use to cyberbullying. Results demonstrated that Internet use time of more than six daily hours together with high Internet addiction score predicted cyberbullying behavior (Nartgün and Cicioğlu, 2015). Excessive screen use such as six daily hours is reported to result in neuroanatomical changes which are related to decreased empathy, poor impulse control and emotional processing, and dysfunctional decision-making; all components which seem to lay the grounds for cyberbullying behavior.

10. Predictive behavior

Violent behavior is rarely an outcome of a single distinct cause and is likely be a result of often prolonged, effect of multiple factors. More than other risk factors, exposure to aggressive behavior during childhood is the best predictor of violent behavior in older adolescent and adulthood. Decades of studies suggest that exposure to violent content in TV and video games increases the risk for future violent behavior in the same manner as growing up surrounded by real violence. (Huesmann and Taylor, 2006).

10.1. Effects of television viewing

Studies have found a causal relationship between TV violent content to increased risk for antisocial behavior in young children (Christakis and Zimmerman, 2007). Longitudinal studies sampling various age groups between 5 and 11-year old support this claim and argue that time spent on TV viewing (during ages 6–10) is associated with violent behavior 15 years later (Huesmann et al., 2003). Robertson et al. (2013) showed that childhood TV viewing is associated with a diagnosis of antisocial personality disorder and with criminal/violent convictions by early adulthood. Another longitudinal study of 2 year-olds stated that only one hour of daily TV exposure is related to aggression expression, social difficulties, and increased peer victimization at age 13 (Pagani et al., 2016).

10.2. Effects of video game playing

Studies have found a causal relationship between violent content in video games and short-term increased violence and aggressive behavior (Huesmann et al., 2003; Lemmens et al., 2011). Viewing violent content was also linked to decreased prosocial behavior and empathy (Anderson et al., 2010) and reduced inhibition (Palaus et al., 2017). Examining the effect of video game playing of eleven graders over one year revealed that this type of screen time could predict increased violent behavior (Willoughby et al., 2012).

11. Radiation

Concerns about the potential vulnerability of children to radio-frequency electromagnetic radiation (RF-EMR) fields is increasing as children's exposure to wireless devices is on the rise. Children are considered potentially more vulnerable to RF-EMR fields because of the susceptibility of their developing nervous system. Additionally, their brain tissue is more conductive, consequently allowing more RF-EMR penetration relative to the size of their head. Moreover, they will be exposed to RF fields for more years than adults (Kheifets et al., 2005).

For years researchers believed that non-heating RF-EMR radiation could not cause harm. Evidence which links RF radiation to cancer were published by the National Toxicology Program (NTP) of the U.S. National Institute of Health, which released partial findings from its cell phone study on rats. The study found low incidences of tumors in the brains and hearts of male rats exposed to RF radiation. Additionally, the study found evidence of DNA damage caused by RF radiation (Wyde et al., 2016).

Infertility is a prevalent disorder that affects, in the US about 7% of men and 11% of women (National Institute of Health, 2017). Experimental animal and humans studies explored the effects of RF-EMR on the male reproductive function. RF-EMR was found to affect various organs, including the testes, directly or through a thermal effect, e.g., when a cell phone is carried in the trouser pocket near the testes (Yildirim et al., 2015). With emerging data of a decline in male semen quality, mobile phones were examined as a possible contributing factor. Results of these studies show that exposure to RF-EMR through cellular phone use or through use of laptops or tablets is related to carcinogenic risk and reproductive damage (Adams et al., 2014; Yildirim et al.; Sepehrimanesh et al., 2017; La Vignera et al., 2012).

12. Case study

12.1. Background information

Mark is a nine-year-old Caucasian male who was referred for behavioral intervention treatment of ADHD. Mark was living with his parents and his sixteen-year-old sister and thirteen-year-old brother. At intake, Mark's parents reported that he exhibits restlessness and hyperactivity. He also was described as easily distracted, having difficulties listening and following instructions and had difficulties playing quietly. His parents said that he was always "jumpy."

Mark was attending third grade. Two years ago he was diagnosed with ADHD. According to his teacher, Mark showed no involvement in class assignments; he regularly disturbed class activities and behaved aggressively. This behavior has increased during the last year. School asked the parents to refer Mark to ADHD treatment in which he was prescribed with Ritalin. The drug apparently caused Mark to reach a state of under-weight. At that point, Mark's parents searched for an alternative for Ritalin treatment consequently arriving at a behavioral intervention program in which Mark's parents were asked about his screen time habits. The parents reported that he had in his bedroom a PlayStation unit and a computer which he also used to play video games and watch TV. Along using these devices, Mark also multi-screened with his smartphone, occasionally using it for playing video games. Not very often, he also used virtual reality glasses. His parents reported that screens 'quiet' down Mark.

Mark was not interested in participating in any after-school activities. Thus, most of his after-school time was devoted to digital media use, which was estimated to be seven hours in weekday and more on weekends. Once, he played video games with his brother from 9 a.m. until 6 a.m. Mark's weekday's bedtime was usually around 11 p.m., and he was reportedly viewing screen close to bedtime.

12.2. Screen time reduction plan

Mark was seen by the author eleven times as part of the public health treatment program. At the first session, his parents were offered to implement a screen time reduction plan in which every session consisted of reviewing progress and offering treatment modification as needed. The main focus of the treatment plan was to reduce fast paced/violent video game time. At first, Marks parents were directed to remove all media from Mark's bedroom, preferably beginning with the PlayStation. More steps took place aimed at further reducing interactive/video game time, encouraging viewing slow paced content and prohibiting any screen time for at least one hour before sleep hour.

Mark began to show a significant improvement during the first two weeks of the program. His bedtime moved down one hour to 10 p.m. and soon, his parents also reported an improved behavior at home. Mark also began initiating more non-screen activities, such as dog walking and table tennis play.

It was not known until the fourth week of the program that Mark had a signal booster in his room. Mark's father was asked to remove it, not only to reduce radiation exposure but to eliminate the possibility that hypersensitivity to RF radiation may affect Mark. However, home WI-FI remained installed.

During the fourth week, Mark's teacher was already reporting an improved behavior in class. At home, Mark was even more engaged in non-screen activities, and his parent also told that, occasionally, he was just "doing nothing." His parents reported that he was also less tired after waking up and that he was preparing himself for school much faster than before the program began. Through the fifth week, Mark began preparing homework without help. At that time, his father said that he also seemed more "mature" mostly expressed by being abler in delaying gratification. Mark also seemed less easily distracted at home and less hyperactive in class, but he was still aggressive there. By the tenth week, the parents were strongly encouraged to decrease exposure to violent video game content significantly, especially first-person games. Soon on, Mark also seemed to increase family social interactions and was able to prepare for school exams. By the eleventh week, Mark's did not present any aggressive behavior in school. Since the beginning of the program, he also regained 6 kg, consequently returning to normal weight. All behavioral improvements remained stable in a one-year follow-up.

12.3. Case formulation

The screen time reduction plan was aimed at reducing Mark's ADHD symptoms. The plan was constructed based on evaluating his screen time habits. Mark's excessive screen time mostly consisted of violent and fast-paced gaming, which is considered to encourage attention to function in short segments. The major assumption underlying the plan was that Mark might have been caught in a cycle which consisted of attention problems leading to reward craving and arousing seeking behavior. Such behavior, in its turn further exacerbates attentional and aggression symptoms (Weiss et al., 2011). The screen reduction plan was aimed at altering this cycle.

Mark displayed a significant improvement already within the first 2–4 weeks of the program, and within 11 weeks Mark was brought to the point that the diagnosis of ADHD may not have been appropriate for him anymore. No other intervention was implemented during this period; therefore, the change in screen time viewing habits appeared as the only factor associated with Mark's symptom reduction. It is suggested that Mark may have been overdiagnosed; and that before the treatment, he displayed a tendency for ADHD-related behavior which apparently was exacerbated by screen time effects up to a state he appeared an ADHD child. However, along with the elimination of the exacerbating factors the expressions of ADHD-related behavior have been practically diminished.

13. Discussion

The variety of digital media devices is increasingly growing and advancing digital media offer users an increasingly more vivid and faster paced digital environment. Children and adolescents appear to adjust to new technologies seamlessly. However, a growing body of literature associates excessive screen time with physical, psychological, social and neurological adverse health consequence. Additional screen time effects include developmental effects, the effects of exposure to pornography and effects on learning; all who need a more extensive review and were beyond the scope of this article.

Until recently, literature regarding children and adolescent's digital media use has related mostly to TV and computer use. However, as children and adolescents shift more toward the use of mobile devices; research is adjusting its focus accordingly. The effect of growing access to mobile devices and social networks is not well enough understood, apparently, because it is a new and a continuously changing environment, both in pace and content, consequently, drawing youth away from face-to-face communication. Hence, parents seem to need to regain an appreciation of such form of communication because non-screen related social support may decrease the screen time addictive behavior. For young children, non-digital play-oriented experiences best promote executive functions and higher order thinking skills such as impulse control, emotion regulation and task persistence (American Academy of Pediatrics, Media and Young Minds, 2016).

Excessive screen time appears to exacerbate ADHD-related behavior and may also be a countering factor for a successful progress of interventions. As apparent from the presented case study, reducing and changing screen time habits appear to significantly, decrease ADHD-related behavior. Hence, it seems that an intervention for reduction of ADHD symptoms should relate, at an early stage of the intervention, to excessive screen time consumption. Moreover, use of psychotropic medications to treat ADHD is rising in the last decade (Partridge et al., 2014). Thus, research should address the question whether children may be inaccurately diagnosed with ADHD when alternatively; their ADHD-related behavior could diminish in a relatively short time by relating to their screen time habits, also to reduce the loss of time and money for inappropriate diagnosis and ineffective treatment.

The emerging profile of excessive screen users pictures a young individual with inadequate sleep and higher physiological stress inclined to mind wandering or even ADHD-related behavior. Further features may include non-adaptive/negative thinking styles, decreased life satisfaction and a potential for health risks also in adulthood. The conclusion of the overall presented findings pictures that lack of face-to-face communication, multi-tasking, excessive social network use and addictive interactive screen time, mostly of video games; all play a critical role in determining physiological and psychological effects on children and adolescents. Excessive screen time during childhood and adolescence is likely to habituate the mind to relate more easily to external stimuli, i.e., to lack mindfulness. Hence, internal stimuli such as non-adaptive/negative thinking and feelings of decreased life satisfaction, potentially accompanied by health issues expected in adulthood (e.g., cardiovascular diseases and infertility) may induce a stress hard to cope. Consequently, such coping difficulties, in adulthood, may cause a higher occurrence of depression and anxiety. A sound individual resilience allows a person to face stressful life challenges successfully. Resilience is a dynamic psychophysiological construct which some of its crucial components (physical health, social support, attachment, mindfulness and the level of life satisfaction) are compromised by excessive screen use (Pop, 2014; Sahin-Baltaci and Karatas, 2015; Nemati and Farnaz, 2016). Thus, excessive and addictive use of digital media by children and adolescents appears to compromise a development of a sense of positive psychophysiological backbone which is foundational for the formation of a sound resilience in the next generation.

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References

Adams, J.A., Galloway, T.S., Mondal, D., Esteves, S.C., Mathews, F., 2014. Effect of mobile telephones on sperm quality: a systematic review and meta-analysis. Environ. Int. 70, 106–112. http://dx.doi.org/10.1016/j.envint.2014.04.015.

Akinbinu, T.R., Mashalla, Y.J., 2014. Impact of computer technology on health: computer vision syndrome (CVS). Med. Pract. Rev. 5 (3), 20–30. http://dx.doi.org/10.5897/MPR.2014.0121.

American Academy of Pediatrics – Media and Young Minds, 2016. Retrieved on 10.9.17 from 〈http://pediatrics.aappublications.org/content/early/2016/10/19/peds.2016-2591#ref-24〉.

Anderson, C.A., Shibuya, A., Ihori, N., Swing, E.L., Bushman, B.J., Sakamoto, A., Saleem, M., 2010. Violent video game effects on aggression, empathy, behavior in eastern and western countries: a meta-analytic review. Psychol. Bull. 136 (2), 151–173. http://dx.doi.org/10.1037/a0018251.

Andreassen, C.S., Billieux, J., Griffiths, M.D., Kuss, D.J., Demetrovics, Z., Mazzoni, E., Pallesen, S., 2016. The relationship between addictive use of social media and video games and symptoms of psychiatric disorders: a large-scale cross-sectional study. Psychol. Addict. Behav. 30 (2), 252–262. http://dx.doi.org/10.1037/adb0000160.

Biddle, S.J.H., Bengoechea, E.G., Wiesner, G., 2017. Sedentary behaviour and adiposity in youth: a systematic review of reviews and analysis of causality. Int. J. Behav. Nutr. Phys. Act. 14 (1). http://dx.doi.org/10.1186/s12966-017-0497-8.

Blask, D.E., 2009. Melatonin, sleep disturbance and cancer risk. Sleep. Med. Rev. 13 (4), 257–264. http://dx.doi.org/10.1016/j.smrv.2008.07.007.

Brambilla, P., Giussani, M., Pasinato, A., Venturelli, L., Privitera, F., del Giudice, E.M., Chiappini, E., 2017. Sleep habits and pattern in 1-14 years old children and relationship with video devices use and evening and night child activities. Ital. J. Pediatr. 43 (7). http://dx.doi.org/10.1186/s13052-016-0324-x.

Brand, M., Young, K.S., Laier, C., 2014. Prefrontal control and Internet addiction: a theoretical model and review of neuropsychological and neuroimaging findings. Front. Hum. Sci. 8 (375), 1–13. http://dx.doi.org/10.3389/fnhum.2014.00375.

Bruni, O., Sette, S., Fontanesi, L., Baiocco, R., Laghi, F., Baumgartner, E., 2015. Technology use and sleep quality in preadolescence and adolescence. J. Clin. Sleep. Med. 11 (12), 1433–1441. http://dx.doi.org/10.5664/jcsm.5282.

Boniel-Nissim, M., Tabak, I., Mazur, J., Borraccino, A., Brooks, F., Gommans, R., Finne, E., 2015. Supportive communication with parents moderates the negative effects of electronic media use on life satisfaction during adolescence. Int. J. Pub. Health 60 (2), 189–198. http://dx.doi.org/10.1007/s00038-014-0636-9.

Cain, N., Gradisar, M., 2010. Electronic media use and sleep in school-aged children and adolescents: a review. Sleep. Med. 11 (8), 732–745. http://dx.doi.org/10.1016/j.sleep.2010.02.006.

Cajochen, C., Frey, S., Anders, D., Späti, J., Bues, M., Pross, A., Stefani, O., 2011. Evening exposure to a light-emitting diodes (LED)-backlit computer screen affects circadian physiology and cognitive performance. J. Appl. Physiol. 110 (5), 1432–1438. http://dx.doi.org/10.1152/japplphysiol.00165.2011.

Chahal, H., Fung, C., Kuhle, S., Veugelers, P.J., 2013. Availability and night-time use of electronic entertainment and communication devices are associated with short sleep duration and obesity among Canadian children. Pediatr. Obes. 8 (1), 42–51. http://dx.doi.org/10.1111/j.2047-6310.2012.00085.x.

Chaput, J.P., Visby, T., Nyby, S., Klingenberg, L., Gregersen, N.T., Tremblay, A., Sjödin, A., 2011. Video game playing increases food intake in adolescents: a randomized crossover study. Am. J. Clin. Nutr. 93 (6), 1196–1203. http://dx.doi.org/10.3945/ajcn.110.008680.

Charmaine, B., Waring, M.E., Pagotod, S.H., Lemon, S.C., 2015. A television in the bedroom is associated with higher weekday screen time among youth with attention deficit hyperactivity disorder (ADD/ADHD). Prev. Med. Rep. 2, 1–3. http://dx.doi.org/10.1016/j.pmedr.2014.11.001.

Carter, B., Rees, P., Hale, L., Bhattacharjee, D., Paradkar, S., 2016. Association between portable screen-based media device access or use and sleep outcomes. JAMA Pediatr. 170 (12), 1202–1208. http://dx.doi.org/10.1001/jamapediatrics.2016.2341.

Chassiakos, Y.R., Radesky, J., Christakis, D., Moreno, M.A., Cross, C., 2016. Children and adolescents and digital media. Pediatrics 138 (5), e201625936. http://dx.doi.org/10.1542/peds.2016-2593.

Cassidy-Bushrow, A., Johnson, D., Peters, M., Burmeister, C., Joseph, C., 2014. Time spent on the internet and adolescent blood pressure. J. Sch. Nurs. 31 (5), 374–384. http://dx.doi.org/10.1177/1059840514556772.

Chastin, S.F.M., Mandrichenko, O., Skelton, D.A., 2014. The frequency of osteogenic activities and the pattern of intermittence between periods of physical activity and sedentary behaviour affects bone mineral content: the cross-sectional NHANES study. BMC Public Health 14 (1), 1–12. http://dx.doi.org/10.1186/1471-2458-14-4.

Cheung, C.H.M., Bedford, R., Saez De Urabain, I.R., Karmiloff-Smith, A., Smith, T.J., 2017. Daily touchscreen use in infants and toddlers is associated with reduced sleep and delayed sleep onset. Sci. Rep. 7 (46104), 1–7. http://dx.doi.org/10.1038/srep46104.

Christakis, D.A., Zimmerman, F.J., 2007. Violent television viewing during preschool is associated with antisocial behavior during school age. Pediatrics 120 (5), 993–999. http://dx.doi.org/10.1542/peds.2006-3244.

Christakis, D.A., Liekweg, K., Garrison, M.M., Wright, J.A., 2013. Infant video viewing and salivary cortisol responses: a randomized experiment. J. Pediatr. 162 (5), 1035–1040. http://dx.doi.org/10.1016/j.jpeds.2012.10.032.

Christensen, J.F., 2017. Pleasure junkies all around! Why it matters and why 'the arts' might be the answer: a biopsychological perspective. Proc. Biol. Sci. 17 (284), 1854. http://dx.doi.org/10.1098/rspb.2016.2837.

Curtis, B.M., O'Keefe, J.H., 2002. Autonomic tone as a cardiovascular risk factor: the dangers of chronic fight or flight. Mayo Clin. Proc. 77, 45–54. http://dx.doi.org/10.4065/77.1.45.

De Moraes, A.C.F., Siani, A., Barba, G., Veidebaum, T., Tornaritis, M., Molnar, D., 2014. Incidence of high blood pressure in children—effects of physical activity and sedentary behaviors: the IDEFICS study. Int. J. Cardiol. 180, 165–170. http://dx.doi.org/10.1016/j.ijcard.2014.11.175.

Dombrovski, A.Y., Mulsant, B.H., Houck, P.R., Mazumdar, S., Lenze, E.J., Andreescu, C., Reynolds, C.F., 2007. Residual symptoms and recurrence during maintenance treatment of late-life depression. J. Affect. Dis. 103 (1–3), 77–82. http://dx.doi.org/10.1016/j.jad.2007.01.020.

Dong, G., DeVito, E.E., Du, X., Cui, Z., 2012. Impaired inhibitory control in 'Internet addiction disorder': a functional magnetic resonance Imaging study. Psychiatry Res. 203 (2–3), 153–158. http://dx.doi.org/10.1016/j.pscychresns.2012.02.001.

Falbe, J., Davison, K.K., Franckle, R.L., Ganter, C., Gortmaker, S.L., Smith, L., Taveras, E.M., 2015. Sleep duration, restfulness, and screens in the sleep environment. Pediatrics 135 (2), 368–375. http://dx.doi.org/10.1542/peds.2014-2306.

Figueiro, M., Overington, D., 2015. Self-luminous devices and melatonin suppression in adolescents. Light Res. Technol. 48 (8), 966–975. http://dx.doi.org/10.1177/1477153515584979.

French, A.N., Ashby, R.S., Morgan, I.G., Rose, K.A., 2013. Time outdoors and the prevention of myopia. Exp. Eye Res. 114, 58–68. http://dx.doi.org/10.1016/j.exer.2013.04.018.

Garrison, M.M., Liekweg, K., Christakis, D.A., 2011. Media use and child sleep: the impact of content, timing, and environment. Pediatrics 128 (1), 29–35. http://dx.doi.org/10.1542/peds.2010-3304.

Geissler, J., Romanos, M., Hegerl, U., Hensch, T., 2014. Hyperactivity and sensation seeking as autoregulatory attempts to stabilize brain arousal in ADHD and mania? Atten. Deficit Hyperact. Dis. 6 (3), 159–173. http://dx.doi.org/10.1007/s12402-014-0144-z.

Gentile, D.A., Swing, E.L., Lim, C.G., 2012. Video game playing, attention problems, and impulsiveness – evidence of bidirectional causality. Psychol. Pop. Media Cult. 1 (1), 62–70. http://dx.doi.org/10.1037/a0026969.

Goldfield, G.S., Kenny, G.P., Hadjiyannakis, S., Phillips, P., Alberga, A.S., Saunders, T.J., Sigal, J., 2011. Video game playing is independently associated with blood pressure and lipids in overweight and obese adolescents. PLoS One 6 (11), e26643. http://dx.doi.org/10.1371/journal.pone.0026643.

Gopinath, B., Hardy, L.L., Kifley, A., Baur, L.A., Mitchell, P., 2014. Activity behaviors in schoolchildren and subsequent 5-yr change in blood pressure. Med. Sci. Sports Exerc. 46 (4), 724–729. http://dx.doi.org/10.1249/MSS.0000000000000166.

Gopinath, B., Baur, L.A., Hardy, L.L., Kifley, A., Rose, K.A., Wong, T.Y., Mitchell, P., 2012. Relationship between a range of sedentary behaviors and blood pressure during early adolescence. J. Hum. Hypertens. 26 (6), 350–356. http://dx.doi.org/10.1038/jhh.2011.40.

Gopinath, B., Baur, L.A., Wang, J.J., Hardy, L.L., Teber, E., Kifley, A., Mitchell, P., 2011. Influence of physical activity and screen time on the retinal microvasculature in young children. Arterioscler. Thromb. Vasc. Biol. 31 (5), 1233–1239. http://dx.doi.org/10.1161/ATVBAHA.110.219451.

Grover, K., Pecor, K., Malkowski, M., Ming, X., 2016. Effects of instant messaging on school performance in adolescents. J. Child Neurol. 31 (7), 850–857. http://dx.doi.org/10.1177/0883073815624758.

Halgamuge, M.N., 2013. Pineal melatonin level disruption in humans due to electromagnetic fields and ICNIRP limits. Radiat. Prot. Dosim. 154 (4), 405–416. http://dx.doi.org/10.1093/rpd/ncs255.

Hardy, L.L., Denney-Wilson, E., Thrift, A.P., Okely, A.D., Baur, L.A., 2010. Screen time and metabolic risk factors among adolescents. Arch. Pediatr. Adolesc. Med. 164, 643–649. http://dx.doi.org/10.1001/archpediatrics.2010.88.

Henderson, M., Benedetti, A., Barnett, T.A., Mathieu, M.E., Deladoey, J., Gray-Donald, K., 2016. Influence of adiposity, physical activity, fitness, and screen time on insulin dynamics over 2 years in children. JAMA Pediatr. 170 (3), 227–235. http://dx.doi.org/10.1001/jamapediatrics.2015.3909.

Hou, X., Allen, T.A., Wei, D., Huang, H., Wang, K., DeYoung, C.G., Qiu, J., 2017. Trait compassion is associated with the neural substrate of empathy. Cogn. Affect. Behav. Neurosci. http://dx.doi.org/10.3758/s13415-017-0529-5.

Hsieh, D.L., Hsiao, T.C., 2016. Respiratory sinus arrhythmia reactivity of internet addiction abusers in negative and positive emotional states using film clips stimulation. Biomed. Eng. Online 15 (1), 69. http://dx.doi.org/10.1186/s12938-016-0201-2.

Huesmann, R., Moise-Titus, J., Podolski, C., Eron, L.D., 2003. Longitudinal relations between children's exposure to TV violence and their aggressive and violent Behavior in young adulthood: 1977–1992. Dev. Psychol. 39 (2), 201–221. http://dx.doi.org/10.1037/0012-1649.39.2.201.

Huesmann, R.L., Taylor, L.D., 2006. The role of media violence in violent behavior. Annu Rev. Public Health 27, 393–415. http://dx.doi.org/10.1146/annurev.publhealth.26.021304.144640.

Hysing, M., Pallesen, S., Stormark, K.M., Jakobsen, R., Lundervold, A.J., Sivertsen, B., 2017. Sleep and use of electronic devices in adolescence: results from a large population-based study. BMJ Open 5, e006748. http://dx.doi.org/10.1136/bmjopen-2014-006748.

Jinhua, B., Drobe, B., Wang, Y., Chen, K., Seow, E.J., Lu, F., 2015. Influence of near tasks on posture in myopic Chinese schoolchildren. Optom. Vis. Sci. 92 (8), 908–915. http://dx.doi.org/10.1097/OPX.0000000000000658.

Jonkman, L.M., Markus, C.R., Franklin, M.S., van Dalfsen, J.H., 2017. Mind wandering during attention performance: effects of ADHD-inattention symptomatology, negative mood, ruminative response style and working memory capacity. PLoS One 12 (7), e0181213. http://dx.doi.org/10.1371/journal.pone.0181213.

Kheifets, L., Repacholi, M., Saunders, R., Deventer, E., 2005. The sensitivity of children to electromagnetic fields. Pediatrics 116 (2), e303–e313. http://dx.doi.org/10.1542/peds.2004-2541.

King, D.L., Delfabbro, P.H., Zwaans, T., Kaptsis, D., 2014. Sleep interference effects of pathological electronic media use during adolescence. Int. J. Ment. Health Addict. 12, 21–35. http://dx.doi.org/10.1007/s11469-013-9461-2.

Lauricella, A.R., Wartella, E., Rideout, V.J., 2015. Young children's screen time: the complex role of parent and child factors. J. Appl. Dev. Psychol. 36, 11–17. http://dx.doi.org/10.1016/j.appdev.2014.12.001.

La Vignera, S., Condorelli, R.A., Vicari, E., D'Agata, R., Calogero, A.E., 2012. Effects of the exposure to mobile phones on male reproduction: a review of the literature. J. Androl. 33 (3), 350–356. http://dx.doi.org/10.2164/jandrol.111.014373.

Lemmens, J.S., Valkenburg, P.M., Peter, J., 2011. The effects of pathological gaming on aggressive behavior. J. Youth Adolesc. 40, 38–47. http://dx.doi.org/10.1007/s10964-010-9558-x.

Lemola, S., Perkinson-Gloor, N., Brand, S., Dewald-Kaufmann, J.F., Grob, A., 2015. Adolescents' electronic media use at night, sleep disturbance, and depressive symptoms in the smartphone age. J. Youth Adolesc. 44 (2), 405–418. http://dx.doi.org/10.1007/s10964-014-0176-x.

Lin, F., Zhou, Y., Du, Y., Qin, L., Zhao, Z., Xu, J., Lei, H., 2012. Abnormal white matter integrity in adolescents with internet addiction disorder: a tract-based spatial statistics study. PLoS One 7 (1), e30253. http://dx.doi.org/10.1371/journal.pone.0030253.

Lin, P.C., Kuo, S.Y., Lee, P.H., Sheen, T.C., Chen, S.R., 2014. Effects of internet addiction on heart rate variability in school-aged children. J. Cardiovasc. Nurs. 29 (6), 493–498. http://dx.doi.org/10.1097/JCN.0b013e3182a477d5.

Liu, M., Wu, L., Yao, S., 2015. Dose-response association of screen time-based sedentary behaviour in children and adolescents and depression: a meta-analysis of observational studies. Br. J. Sports Med. 50 (20), 1252–1258. http://dx.doi.org/10.1136/bjsports-2015-095084.

Loh, K.K., Kanai, R., 2014. Higher media multi-tasking activity is associated with smaller gray-matter density in the anterior cingulate cortex. PLoS One 9 (9), e106698. http://dx.doi.org/10.1371/journal.pone.0106698.

Love, T., Laier, C., Brand, M., Hatch, L., Hajela, R., 2015. Neuroscience of Internet pornography addiction: a review and update. Behav. Sci. 5, 388–433. http://dx.doi.org/10.3390/bs5030388.

Lui, D., Szeto, G., Jones, A., 2011. The pattern of electronic game use and related bodily discomfort in Hong Kong primary school children. Comput. Educ. 57, 1665–1674. http://dx.doi.org/10.1016/j.compedu.2011.03.008.

Magee, C.A., Lee, J.K., Vella, S.A., 2014. Bidirectional relationships between sleep duration and screen time in early childhood. JAMA Pediatr. 168 (5), 465–470. http://dx.doi.org/10.1001/jamapediatrics.2013.4183.

Maras, D., Flament, M.F., Murray, M., Buchholz, A., Henderson, K.A., Obeid, N., Goldfield, G.S., 2015. Screen time is associated with depression and anxiety in Canadian youth. Prev. Med. 73, 133–138. http://dx.doi.org/10.1016/j.ypmed.2015.01.029.

Martinez-Gomez, D., Tucker, J., Heelan, K.A., Welk, G.J., Eisenmann, J.C., 2009. Associations between sedentary behavior and blood pressure in young children. Arch. Pediatr. Adolesc. Med. 163 (8), 724–730. http://dx.doi.org/10.1001/archpediatrics.2009.90.

Martinez-Gomez, D., Rey-López, J.P., Chillón, P., Gomez-Martinez, S., Vicente-Rodriguez, G., Martín-Matillas, M., Marcos, A., 2010. Excessive TV viewing and cardiovascular disease risk factors in adolescents. The AVENA cross-sectional study. BMC Public Health 10, 274. http://dx.doi.org/10.1186/1471-2458-10-274.

Mentzoni, R.A., Brunborg, G.S., Molde, H., Myrseth, H., Skouverøe, K.J.M., Hetland, J., Pallesen, S., 2011. Problematic video game use: estimated prevalence and associations with mental and physical health. Cyber. Behav. Soc. Netw. 14 (10), 591–596. http://dx.doi.org/10.1089/cyber.2010.0260.

Merghani, A., Malhotra, A., Sharman, S., 2015. The U-shaped relationship between exercise and cardiac morbidity. Trends Cardiovasc. Med. 26 (3), 232–240. http://dx.doi.org/10.1016/j.tcm.2015.06.005.

Mihrshahi, S., Drayton, B.A., Bauman, A.E., Hardy, L.L., 2017. Associations between childhood overweight, obesity, abdominal obesity and obesogenic behaviors and practices in Australian homes. BMC Public Health 18 (44), 1–10. http://dx.doi.org/10.1186/s12889-017-4595-y.

Morin-Major, J.K., Marin, M.F., Durand, N., Wan, N., Juster, R.P., Lupien, S.J., 2016. Facebook behaviors associated with diurnal cortisol in adolescents: is befriending stressful? Psychoneuroendocrinology 63, 238–246. http://dx.doi.org/10.1016/j.psyneuen.2015.10.005.

Nartgün, S.S., Cicioğlu, M., 2015. Problematic Internet use and cyber bullying in vocational school students. Int. Online J. Educ. Sci. 7 (3), 10–26. http://dx.doi.org/10.15345/iojes.2015.03.018.

Nathanson, A.I., Fries, P.T., 2014. Television exposure, sleep time, and neuropsychological function among preschoolers. Media Psychol. 17 (3), 237–261. http://dx.doi.org/10.1080/15213269.2014.915197.

National Institute of Health, 2017. Retrieved on 10.9.17 from 〈https://www.nichd.nih.gov/health/topics/infertility/conditioninfo/Pages/common.aspx〉.

Nemati, S., Farnaz, M.M., 2016. The Relationship between life satisfaction and happiness: the mediating role of resiliency. Int. J. Psychol. Stud. 8 (3), 194–201. http://dx.doi.org/10.5539/ijps.v8n3p194.

Nightingale, C.M., Rudnicka, A.R., Donin, A.S., Sattar, N., Cook, D.G., Whincup, P.H., Owen, C.G., 2017. Screen time is associated with adiposity and insulin resistance in children. Arch. Dis. Child 102 (7), 612–616. http://dx.doi.org/10.1136/archdischild-2016-312016.

Nikkelen, S.W.C., Valkenburg, P.M., 2014. Media use and ADHD-related behaviors in children and adolescents: a meta-analysis. Dev. Psychol. 50 (9), 2228–2241. http://dx.doi.org/10.1037/a0037318.

Northwestern University - School of Communication - Center on Media and Human Development, 2014. Parenting in the age of digital technology – revised. A national survey. Retrieved on 2.9.17 from 〈http://cmhd.northwestern.edu/wp-content/uploads/2015/06/ParentingAgeDigitalTechnology.REVISED.FINAL_.2014.pdf〉.

Ononogbu, S., Wallenius, M., Punamäki, R., Saarni, L., Lindholm, H., Nygård, C., 2014. Association between information and communication technology usage and the quality of sleep among school-aged children during a school week. Sleep. Disord. 2014 (315808). http://dx.doi.org/10.1155/2014/315808.

Oshima, N., Mishida, A., Shimodera, S., Todhigi, M., Ando, S., Yamaski, S., 2012. The

suicidal feelings, self-injury, and mobile phone use after lights out in adolescents. J. Pediatr. Psychol. 37 (9), 1023–1030. http://dx.doi.org/10.1093/jpepsy/jss072.
Paavonen, E.J., Pennonen, M., Roine, M., Valkonen, S., Lahikainen, A., 2006. TV exposure associated with sleep disturbances in 5-to 6-year-old children. J. Sleep. Res 15 (2), 154–161. http://dx.doi.org/10.1111/j.1365-2869.2006.00525.x.
Pagani, L.S., Lévesque-Seck, F., Fitzpatrick, C., 2016. Prospective associations between televiewing at toddlerhood and later self-reported social impairment at middle school in a Canadian longitudinal cohort born in 1997/1998. Psychiatr. Med 46 (16), 3329–3337. http://dx.doi.org/10.1017/S0033291716001689.
Palaus, M., Marron, E.M., Viejo-Sobera, R., Redolar-Ripoll, D., 2017. Neural basis of video gaming: a systematic review. Front. Hum. Neurosci. 11 (248). http://dx.doi.org/10.3389/fnhum.2017.00248.
Parent, B.A., Weasley-Sanders, M.A., Forehand, R., 2016. Youth screen time and behavioral health problems: the role of sleep duration and disturbances. J. Dev. Behav. Pediatr. 37 (4), 277–284. http://dx.doi.org/10.1097/DBP.0000000000000272.
Partridge, B., Lucke, J., Hall, W., 2014. Over-diagnosed and over-treated: a survey of Australian public attitudes towards the acceptability of drug treatment for depression and ADHD. BMC Psychiatry 14 (74). http://dx.doi.org/10.1186/1471-244X-14-74.
Pea, R., Nass, C., Meheula, L., Rance, M., Kumar, A., Bamford, H., Zhou, M., 2012. Media use, face-to-face communication, media multitasking, and social well-being among 8-to 12-year-old girls. Dev. Psychol. 48 (2), 327–336. http://dx.doi.org/10.1037/a0027030.
Pérez-Farinós, N., Villar-Villalba, C., López Sobaler, A.M., Dal Re Saavedra, A.M., Aparicio, A., Santos-Sanz, S., Ortega Anta, R.M., 2017. The relationship between hours of sleep, screen time and frequency of food and drink consumption in Spain in the 2011 and 2013 ALADINO: a cross-sectional study. BMC Public Health 17 (3), 1–12. http://dx.doi.org/10.1186/s12889-016-3962-4.
Pop, B., 2014. Research facts about resilience. J. Depress. Anxiety 3 (4), 1000e107. http://dx.doi.org/10.4172/2167-1044.1000e107.
Rechichi, C., De Mojà, G., Aragona, P., 2017. Video game vision syndrome: a new clinical picture in children? J. Pediatr. Ophthalmol. Strabismus 29, 1–10. http://dx.doi.org/10.3928/01913913-20170510-01.
Richards, R., McGee, R., Williams, S.M., Welch, D., Hancox, R.J., 2006. Adolescent screen time and attachment to parents and peers. Arch. Pediatr. Adolesc. Med 164 (3), 258–262. http://dx.doi.org/10.1001/archpediatrics.2009.280.
Robertson, L.A., McAnally, H.M., Hancox, R.J., 2013. Childhood and adolescent television viewing and antisocial behavior in early adulthood. Pediatrics 131 (3), 439–446. http://dx.doi.org/10.1542/peds.2012-1582.
Sahin-Baltaci, H., Karatas, Z., 2015. Perceived social support, depression and life satisfaction as the predictor of the resilience of secondary school students: the case of Burdur. Eurasia. J. Educ. Res 60, 111–130. http://dx.doi.org/10.14689/ejer.2015.60.7.
Schutten, D., Stokes, K.A., Arnell, K.M., 2017. I want to media multitask and I want to do it now: individual differences in media multitasking predict delay of gratification and system-1 thinking. Cogn. Res. 2 (1), 8. http://dx.doi.org/10.1186/s41235-016-0048-x.
Seli, P., Smallwood, J., Cheyne, J.A., Smilek, D., 2015. On the relation of mind wandering and ADHD symptomatology. Psychon. Bull. Rev. 22, 629–636. http://dx.doi.org/10.3758/s13423-014-0793-0.
Sepehrimanesh, M., Kazemipour, N., Saeb, M., Nazifi, Davis, D.L., 2017. Proteomic analysis of continuous 900-MHz radiofrequency electromagnetic field exposure in testicular tissue: a rat model of human cell phone exposure. Environ. Sci. Pollut. Res. 24 (15), 13666–13673. http://dx.doi.org/10.1007/s11356-017-8882-z.
Shao, H., Xu, S., Zheng, J., Zheng, J., Zheng, J., Chen, J., Huang, Y., 2015. Association between duration of playing video games and bone mineral density in Chinese adolescents. J. Med. Densitom. 18 (2), 198–202. http://dx.doi.org/10.1016/j.jocd.2015.02.007.
Staiano, A.E., Harrington, D.M., Broyles, S.T., Gupta, A., Katzmarzyk, P.T., 2013. Television, adiposity, and cardiometabolic risk in children and adolescents. Am. J. Prev. Med. 44 (1), 40–47. http://dx.doi.org/10.1016/j.amepre.2012.09.049.
Swing, E.L., Gentile, D.A., Anderson, C.A., Walsh, D.A., 2010. Television and video game exposure and the development of attention problems. Pediatrics 126, 214–221. http://dx.doi.org/10.1542/peds.2009-1508.
Thompson, D.A., Christakis, D.A., 2005. The Association between television viewing and irregular sleep schedules among children less than 3 years of age. Pediatrics 116 (4), 851–856. http://dx.doi.org/10.1542/peds.2004-2788.
Van Ekris, E., Altenburg, T.M., Singh, A.S., Proper, K.I., Heymans, M.W., Chinapaw, M.J., 2016. An evidence-update on the prospective relationship between childhood sedentary behaviour and biomedical health indicators: a systematic review and meta-analysis. Obes. Rev. 17 (9), 833–849. http://dx.doi.org/10.1111/obr.12426.
Varma, V., Deneen, J., Cotter, S., Paz, S.H., Azen, S.P., Tarczy-Hornoch, K., Zhao, P., 2006. The multi-ethnic pediatric eye disease study: design and methods. Ophthalmic Epidemiol. 13 (4), 253–264. http://dx.doi.org/10.1080/09286580600719055.
Wallenius, M., Hirvonen, A., Lindholm, H., Rimpelä, A., Nygård, C., Saarni, L., Punamäki, R., 2010. Salivary cortisol in relation to the use of information and communication technology (ICT) in school-aged children. Psychology 1, 88–95. http://dx.doi.org/10.4236/psych.2010.12012.
Weiss, M.D., Baer, S., Allan, B.A., Saran, K., Schibuk, H., 2011. The screens culture: impact on ADHD. Atten. Defic. Hyperact Disord. 3, 327–334. http://dx.doi.org/10.1007/s12402-011-0065-z.
Willoughby, T., Adachi, P.J.C., Good, M., 2012. A Longitudinal study of the association between violent video game play and aggression among adolescents. Dev. Psychol. 48 (4), 1044–1057. http://dx.doi.org/10.1037/a0026046.
Winther, A., Ahmed, L.A., Furberg, A., Grimnes, G., Jordi, R., Nilsen, O.A., Emau, E., 2015. Leisure time computer use and adolescent bone health—findings from the Tromsø Study, Fit Futures: a cross-sectional study. BMJ Open 5 (6), 2–9. http://dx.doi.org/10.1136/bmjopen-2014-006665.
Wood, H.C., Scott, H., 2016. Sleepyteens: social media use in adolescence is associated with poor sleep quality, anxiety, depression and low self-esteem. J. Adolesc. 51, 41–49. http://dx.doi.org/10.1016/j.adolescence.2016.05.008.
Wu, X.-S., Zhang, Z.-H., Zhao, F., Wang, W.-J., Li, Y.-F., Bi, L., Sun, Y.-H., 2016. Prevalence of Internet addiction and its association with social support and other related factors among adolescents in China. J. Adolesc. 52, 103e111. http://dx.doi.org/10.1016/j.adolescence.2016.07.012.
Wyde, M., Cesta, M., Blystone, C., Elmore, S., Foster, P., Hooth, M., … Bucher, J., 2016. Report of partial findings from the National Toxicology Program carcinogenesis studies of cell phone radiofrequency radiation in Hsd: Sprague Dawley® SD rats (whole body exposure). Retrieved on 10.9.17 from 〈http://www.biorxiv.org/content/early/2016/06/23/055699.article-info〉. doi:10.1101/055699.
Yen, J.-Y., Ko, C.-H., Yen, C.-F., Wu, H.-Y., Yang, M.-J., 2007. The comorbid psychiatric symptoms of Internet addiction: attention deficit and hyperactivity disorder (ADHD), depression, social phobia, and hostility. J. Adolesc. Health 41, 93–98. http://dx.doi.org/10.1016/j.jadohealth.2007.02.002.
Yildirim, M.E., Kaynar, M., Badem, H., Cavis, M., Karatas, O.F., Cimentepe, E., 2015. What is harmful for male fertility: cell phone or the wireless internet? Kaohsiung J. Med. Sci. 31, 480–484. http://dx.doi.org/10.1016/j.kjms.2015.06.006.
Yuan, K., Qin, W., Wang, G., Zeng, F., Zhao, L., Yang, X., Tian, J., 2011. Microstructure abnormalities in adolescents with Internet addiction disorder (1-8). PLoS One 6 (6), e20708. http://dx.doi.org/10.1371/journal.pone.0020708.
Zimmerman, F.J., Christakis, D.A., 2007. Associations between content types of early media exposure and subsequent attentional problems. Pediatrics 120 (5), 986–992. http://dx.doi.org/10.1542/peds.2006-3322.