**Max Stern Yezreel Valley College**

**Sleep, Screen Exposure, and Executive Functioning in Adolescents with ADHD**

Executive Functioning in Adolescents with ADHD

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**Abstract**

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder usually diagnosed in childhood, with 30-50% of adolescents displaying symptoms. This disorder severely affects a number of different life domains, including academic achievement, interpersonal relationships, and mental symptomatology. Recently, the link between ADHD and sleep has gained considerable attention, suggesting an association between ADHD and sleep disturbances. ADHD is also thought to be related to a higher exposure to screens. Adolescents in Western society have high exposure to screens, and the impact of this on adolescents with ADHD is as yet unknown. To the best of our knowledge, the combined effect of ADHD and screen exposure on sleep quality has not yet been tested. Poor performance in executive functions (EFs) is also a significant feature of ADHD. The present study aims to investigate the adverse influence of screen exposure on sleep and EFs in adolescents with ADHD. The results will shed light on the patterns of influence between these factors, and may lead to scientific as well as practical conclusions that will help in the design of intervention programs aimed at adolescents with ADHD.

**Lay summary**

The accelerated development of mobile media such as smartphones and tablets together with the fact that this technology is found in almost every household in Western society has increased adolescents’ exposure to screens. Studies have shown that increased exposure to screens harms sleep quality and that low sleep quality affects various cognitive functions that are important for daily functioning. However, there is still a lack of research on specific groups that may be at greater risk of intensive screen exposure and the impact this may have on them.

This study focuses on adolescents with ADHD and examines whether exposure to screens in the sleeping environment affects their sleep quality and cognitive functioning. The findings of this study could serve as a basis for building a research-based intervention program aimed at improving the sleep quality of adolescents with ADHD.

**Theoretical and scientific rationale**

Attention Deficit Hyperactivity Disorder (ADHD) is a neurodevelopmental disorder defined as a constant and persistent pattern of inattention and/or hyperactivity and impulsivity (APA, 2013). This disorder is usually diagnosed in childhood, but between 30% and 50% of adolescents with ADHD will retain the symptoms of the disorder throughout their adult lives (Barkley, 2015). ADHD involves the impairment of cognitive functions such as cognitive flexibility, working memory, and persistent attention functions (Klein et al., 2006; Raz, Bar Haim, Sadeh, & Dan, 2012; Rommelse et al., 2007).  The disorder’s symptoms severely affect the lives of those who suffer from it. In addition to dysfunctional school performance and low academic achievement, people with ADHD often experience behavioral difficulties, aggression, difficulties in interpersonal relationships with family and society, and are more likely to suffer from anxiety, depression, and alcohol, drug, and internet addiction (Barkley, 2015; Ko, Yen, Yen, Chen, & Chen, 2010).

Recently, considerable attention has been given to the possible links between ADHD and sleep disorders and sleep-related cycles (e.g. Hysing et al., 2016; Ito et al., 2017). Studies have shown that sleep disorders, such as difficulty in falling asleep, delay in bed entry, difficulty in meeting sleep requirements and the tendency to stay up late, and sleeping continuity, are more common in children diagnosed with ADHD than in children without this disorder (Gregory & Sadeh, 2012). Corkum et al. (1998) evaluated that about 25-50% of children and adolescents with ADHD presented sleep disturbances, including difficulties in initiating and maintaining sleep, nocturnal waking, delay of sleep phase, increase in nocturnal activity and insomnia (Gruber et al., 2009; Van Der Heijden et al., 2007). Recent studies have indicated a relationship between children with ADHD and poorer sleep quality compared with children without this disorder (Sung et al., 2008; Yoon et al., 2012). The findings in these studies are based on both subjective (questionnaire completed by parents or by children with ADHD) and objective (polysomnography and actigraphy) data (1,3). The mechanism underlying sleep disturbances in individuals with ADHD is unclear and seems to be multifactorial, comprising biological as well as environmental factors (Owens, 2005).

Among the environmental factors, increased exposure to screens including television viewing, video game playing, computer and internet use, and use of cellular phones at night (Adam et al., 2007; [Dorofaeff &](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=Search&Term=%2522Dorofaeff%2520TF%2522%255BAuthor%255D&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_DiscoveryPanel.Pubmed_RVAbstractPlus) [Denny, 2006;](http://www.ncbi.nlm.nih.gov/sites/entrez?Db=pubmed&Cmd=Search&Term=%2522Denny%2520S%2522%255BAuthor%255D&itool=EntrezSystem2.PEntrez.Pubmed.Pubmed_ResultsPanel.Pubmed_DiscoveryPanel.Pubmed_RVAbstractPlus)  Van den Bulck, 2004; 2007; Schweizer et al., 2017) have been proposed as playing a significant role in sleep disturbance among adolescents. The use of mobile information and communication technologies such as smartphones and tablets has increased rapidly in recent years (Papaconstantinou, Bartfay, & Bartfay, 2017). Emerging technologies are now embedded in the daily lives of young children born into a digital ecosystem that is enhanced by mobile media (Reid Chassiakos, Radesky, Christakis, Moreno, & Cross, 2016). A number of adverse health outcomes associated with higher use have been identified, including obesity, decreased physical activity, reduced user well-being, which are reflected in increased anxiety and depression.

There is a growing body of evidence that suggests that media use negatively affects sleep (Bruni et al., 2015). Increased duration of media exposure and the presence of a television, computer, or mobile device in the bedroom in early childhood have been associated with fewer minutes of sleep per night (Cespedes et al., 2014). Other factors contributing to reduced sleep may also include later bedtimes after evening media use and violent content in the media (Garrison & Christakis, 2012), as well as the suppression of endogenous melatonin by blue light emitted from screens (Salti et al., 2006). Studies of teenagers have found that participants who use more social media or who sleep with mobile devices in their room were at greater risk of sleep disturbances (Buxton et al., 2015). For example, Bruni and colleagues (2015) studied the impact of technology use on sleep quality in adolescents. Adolescents’ poor sleep quality was consistently associated with greater mobile phone use and the number of devices in the bedroom. However, it is not yet clear whether the negative impact of screen exposure on sleep quality affects all users in the same way, or whether there are groups at greater risk (for example children with ADHD). Adolescents with ADHD are characterized by longer exposure to screens and media use. The present study will attempt to examine whether the pattern of the relationship between exposure to screens (smartphone and tablet) and sleep quality differs between adolescents with ADHD and adolescents without ADHD.

Alongside the links between ADHD and sleep disturbances, neuropsychological studies have demonstrated deficits in executive functioning in ADHD. Executive functions (EFs) are a set of higher cortical abilities that enable the individual to direct behaviors to goals (Welsh & Pennington, 1989), and include components of attention, planning, reasoning, inhibition, interference control, set-shifting, cognitive flexibility, and working memory (Pennington & Ozonoff, 1996). Three subcortical frontal circuits have been suggested as being linked to EFs: the dorsolateral circuit, the orbitofrontal circuit, and the anterior cingulate circuit. The dorsolateral circuit is related to cognitive processing of planning, problem solving, verbal fluency, and cognitive flexibility. The orbitofrontal circuit is related to social behaviors including self-monitoring, empathy, and inhibitory control. The anterior cingulate circuit is associated with motivation, behavioral monitoring, and control of attention (Cosenza & Guerra, 2011; Spencer, Biederman, & Mick, 2007).

A number of studies have investigated EFs in ADHD, however the pattern of results is equivocal and the components relating to ADHD have yet to be established (Amorim & Marques, 2018). Compared with their counterparts, children and adolescents with ADHD have been found to perform poorly in tests of working memory (Krieger & Amador-Campos, 2018; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005; Sowerby, Seal, & Tripp, 2011), planning (Chiang, Huang, Gau, & Shang, 2013; Dolan & Lennox, 2013; Krieger & Amador-Campos, 2018), flexibility (Mullane & Corkum, 2007; Roberts, Martel, & Nigg, 2017), and inhibition (Hart, Radua, Nakao, Mataix-Cols, & Rubia, 2013; Krieger & Amador-Campos, 2018; Rauch, Gold, & Schmitt, 2012). However, results from other studies did not show significant differences between ADHD and non-ADHD groups in EF tests (e.g. Amorim & Marques, 2018; Romelse et al., 2007; Shallice et al., 2002). With this inconsistency in findings, researchers have suggested that other factors, such as disrupted sleep, may be implicated in the relationship between ADHD and EFs.

Previous findings propose that children with ADHD with concurrent sleep problems have more neuropsychological deficits compared with children without ADHD (Bartholomew & Owens, 2006; Bullock & Schall, 2005; Owens, 2005; Schneider, Lam, & Mahone, 2016; Spruyt, & Gozal, 2011; van der Heijden, Smits, & Gunning, 2005). For example, Gruber and colleagues (2007) found that sleep efficiency (SE) moderated the effect of psychostimulant on attention among children with ADHD. This study also showed a positive influence of medication treatment on the Continuous Performance Test (CPT) only in children with ADHD who were defined as poor sleepers. Moreau, Rouleau, and Morin (2013) found an association between lower SE (actigraphy-defined) and increased variability in reaction time on the CPT in children with ADHD, and demonstrated that shorter sleep duration was related to poorer executive functioning as reported by the parents. Bar, Efron, Gothelf, & Kushnir (2016) showed that children with ADHD with concurrent sleep problems present a more severe clinical presentation across various areas of functioning, including EFs, compared with children with ADHD without sleep problems. However, another study failed to demonstrate an association between sleep measures and attention in children with ADHD (Gruber & Sadeh, 2004).

In summary, previous studies have yielded equivocal evidence regarding the impact of sleep problems on executive functioning in children and adolescents with ADHD. The inconsistencies in the findings may be due to study characteristics such as the study’s measures (self-report vs. objective tests), and the existence of potential intervening factors such as exposure to screens.

The current study aims to investigate the relationship between exposure to screens, sleep quality, and executive functioning in adolescents with ADHD. To the best of our knowledge, this is the first study to examine this relationship using objective measures alongside self-report measures. Exposure to screens has become a part of adolescents' daytime routine, so it is important to deepen our understanding of the wide range consequences this exposure may have, for example on sleep quality and cognitive functioning. The present study will focus on ADHD, a high prevalence neurodevelopmental disorder, in order to examine the unique profile of adolescents with ADHD with regard to the adverse impact of screen exposure on sleep and EFs.

Practical impact of the project: who will benefit and the likely timescale of benefit.

**Research Design**

**Participants**

196 adolescents age 14-16 years will be recruited to the study, using the snow-bold method to form 2 groups: 98 adolescents diagnosed with ADHD 2 and 98 age and sex matched healthy control adolescents.

A sample size of 196 would be needed in order to perform a multiple regression analysis of the performance measures using 8 predictors given a small-medium effect size (0.08), 80% power and 95% confidence (Soper, 2019).

Exclusion criteria: other (other than ADHD) active chronic disease affecting daily functioning, regular use of medication that affects level of daily alertness.

**Measures**

**Demographic and Sleep Measures**

1. **Demographic questionnaire:** including data on: age, sex, grade, diagnosis of ADHD (if yes, age at onset), height, weight.
2. **The modified School Sleep Habits Survey (**Wolfson & Carskadon, 1998; Hebrew translation:  Shochat, Flint-Bretler, Tzischinsky, 2010) includes demographic data, subjective sleep pattern and sleep problem behavior.
3. **Activity monitoring:** Objective sleep patterns will be measured by an activity monitoring device (Actiwatch Spectrum Plus, Philips Respironics). This small wrist-worn device continuously measures objective sleep patterns in the natural environment and provides objective data for sleep patterns. Actiwatch output includes 6 averaged variables for sleep episodes (night and nap): sleep onset, wake-up time, sleep latency, time in bed, total sleep time and sleep efficiency.
4. **Karolinska Sleepiness Scale** (KSS) (Åkerstedt & Gillberg, 1990) Participants will rank their level of sleepiness twice a day (after awakening and before sleep onset) from 1 to 9: 1 = very alert; 9 = very sleepy, great effort required to stay awake.

**Screen Measures:**

1. ***Sleep-Smartphone Hygiene Questionnaire (SSHQ)****:* This questionnaire was developed for the current study and contains 10 Likert-type scale items, ranging from 1 (*neve*r) to 5 (*always*). The items examine habits associated with the smartphone in the sleeping environment (e.g. "I sleep with my smartphone in the bedroom", "I scroll my smartphone while I'm in bed before I fall asleep", "I check my smartphone during the night"). Scores across these items are averaged to create a sleep-smartphone hygiene score for each participant.

***2. Social Media Engagement Questionnaire* (SMEQ**; Przybylski et al., 2013): Social media engagement will be measured with five items assessing the extent to which participants used social media in their daily lives. Participants will be instructed to "Please reflect on how you used social media (e.g., Facebook, WhatsApp, Twitter, Instagram, and email) in the past week". Items are presented on an eight-point Likert-type scale, ranging from 1 (*never*) to 7 (*every day*). Participants will be asked to rate five statements relating to times of use: “within 15 min of waking up,” “when eating breakfast,” “when eating lunch,” “when eating dinner,” and “within 15 minutes of going to sleep’’. Scores across these items will be added together to create a social media engagement score for each participant.

**Cognitive EFs:**

1. A computerized version of **The Wisconsin Classification Card Test (WCST**; Heaton, 1981) evaluates the individual’s ability to reason abstractly and modify their cognitive strategies corresponding to changes in environmental contingencies. It includes a set of 128 cards with three different characteristics: color, figures, and numbers of figures. The WCST assesses components of EFs such as: categorization, impulse control, attention, and cognitive flexibility.
2. A computerized version of **The Corsi Block-Tapping Task** (Schellig, 1997) evaluates visuospatial short-term memory. The test consists of nine black cubes (30×30×30 mm) mounted on a black-colored board. On each slide a sequence of taps is presented, and participant has to repeat these subsequently in the correct sequential order.
3. ***Psychomotor Vigilance Task*** (PVT; Dinges and Powell, 1985; Basner et al., 2011) is a sustained attention reaction time task performed on the iPad. Participants fixate on the display and are required to press a button when the stimulus appears. Interstimulus intervals range from 2 to 10 seconds. Each test bout lasts 3 minutes, from which PVT lapses (reaction times > 500 ms) are obtained. Sustained attention was chosen as the primary outcome measure, as it is sensitive to sleep loss, responsive to multiple tests, and subserves a variety of higher order cognitive functions.

**Procedure**

Before the beginning of the study, the Ethics Committee at Emek Yezreel College will approve this study. Each participant and one of the parents will sign an informed consent.

The RA will take the actigraph, the iPad and the questionnaires to the participant, and will also explain the study procedure. After 5 days, the RA will collect all the materials. During the week participants will wear the actigraph for 4 nights, and the subject will perform the PVT task

In the morning after night sleep and at night before sleep, and on day three, the participant will perform the **WCST** task at night before sleep and the **Corsi Block-Tapping Task** the following morning. Half of the participants will perform the **WCST** at night **and** the **Corsi Block-Tapping Task** in the morning, and half will perform the tests in the opposite order.