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MOBILE PHONES IN THE BEDROOM: IMPACT ON ADOLESCENT SLEEP

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Cynthia Kay Snyder

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The dissertation of Cynthia K. Snyder was reviewed and approved by the following:

Susan J. Loeb
Professor, College of Nursing
College of Medicine
Dissertation Co-Advisor
Co-Chair of Committee

Anne-Marie Chang
Associate Professor, College of Health and Human Development,
College of Nursing
Dissertation Co-Advisor
Co-Chair of Committee

Deepa Sekhar
Associate Professor of Pediatrics, College of Medicine

Julio Fernandez-Mendoza
Associate Professor of Psychiatry, College of Medicine

Judith Hupcey
Professor, College of Nursing
College of Medicine

Lisa A. Kitko
Associate Professor, College of Nursing
Associate Dean for Graduate Education

ABSTRACT

Adolescent mobile phone use is ubiquitous, including after lights out and during the night. Insufficient sleep in adolescents is a public health concern, with nearly 75% of high school students obtaining less than the optimal nightly sleep duration. Poor sleep is associated with negative health consequences, such as weight gain, hypertension, depression, poorer academic performance, increased injury and risk-taking. Normal biopsychosocial adolescent development includes puberty-related sleep changes, prefrontal cortex maturational changes affecting decision-making ability, and increasing reliance on peer relationships with the need for constant connectivity to the social network. Electronic device use impacts normal sleep by time displacement, disruption to circadian timing by blue light exposure, and psychological stimulation related to media content. Although normal adolescent sleep patterns are described in the literature, information is lacking on the psychosocial factors associated with adolescents' mobile phone use after lights out and the effects on sleep. The purpose of this study is to explore the attitudes, behaviors, and sleep patterns of adolescents who use mobile phones in the bedroom setting after lights out.

Guided by the Theory of Planned Behavior, a descriptive, correlational study with prospective micro-longitudinal data collection was conducted to address the study aims: to determine which mobile phone functions adolescents are using after lights out; to identify what factors contribute to adolescents' mobile phone use after lights out; and to describe adolescents' sleep patterns when using mobile phones after lights out. A convenience sample of adolescents, 13-17 years of age, was recruited for a 1-week study, with repeated self-report measures of mobile phone use and wrist actigraphy to measure sleep outcomes. Study participants completed a series of surveys as baseline measures including demographics survey, Mobile Phone Problem Use Scale (MPPUS), Mobile Phone Problem Use Scale-10 (MPPUS-10), Morningness/Eveningness Questionnaire for Children (M/E Scale), and Sleep Practices and Attitudes Questionnaire (SPAQ). The SPAQ has not previously been used in adolescents. Participants wore a wrist actigraphy device for 7 days, with daily self-report diary entries of sleep habits and mobile phone use after lights out. Data were analyzed by descriptive methods, chi square, independent t-test, correlation, and binary logistic regression.

A total of 34 adolescents were recruited from Penn State Health ambulatory specialty clinics, via Penn State StudyFinder, and via a social media link to StudyFinder placed by a parent of a potential participant. The sample was primarily female (61.8%), Caucasian (94.1%), non-Hispanic (94.1%), and 14.5 (SD = 1.28) years of age. Social media was the most commonly used mobile phone function by study participants after lights out. No significant differences were observed for gender or caffeine use and mobile phone use after lights out. Adolescents who engaged in higher average nightly mobile phone use had a significantly lower value of the importance of sleep. No significant differences were observed between sleep patterns, including sleep duration, wake after sleep onset, sleep maintenance efficiency, and sleep quality and average nightly minutes of mobile phone use after lights out.

The study was conducted during the COVID-19 pandemic which required modifications in research procedures. In addition, the usual adolescent lifestyle was disrupted with closure of school and social events with altered sleep and mobile phone usage patterns. Effects of the importance of the peer group were evident among study participants with the influence of the social network as a recruitment tool, a frequently used mobile phone function, and a source of beliefs which lends support to the theoretical framework for decision-making behavior, and a basis for future research.

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Chapter 1

Introduction

Background

Mobile phone use is ubiquitous among adolescents. Media consumption in adolescents is estimated at nearly eight hours per day, exclusive of text messaging and talking on the phone. Aggregation of multiple simultaneous device use approaches 11 hours per day (Rideout, Foehr, & Roberts, 2010). Teens interact with mobile phones at any time throughout the day, with the inability to separate from their phones, and more than 90% of adolescents access mobile phones from the bedroom setting both before and after “lights out” (Calamaro, Mason, & Ratcliffe, 2009). According to the American Academy of Sleep Medicine (AASM) consensus statement (Paruthi et al., 2016), the recommended amounts of sleep needed for optimal health are 9-12 hours daily for children ages 6-12 years, and 8-10 hours daily for teenagers 13-18 years. More than two thirds of U.S. high school students, grades 9 through 12, obtain less than the minimum recommended amount of sleep on school nights (Centers for Disease Control and Prevention [CDC], 2017a). Approximately 69% of high school students reported obtaining less than 8 hours of sleep per day in the biennial Youth Risk Behavior Survey, which was conducted from 2007 to 2013. In the most recent 2017 survey, the prevalence of high school students who obtained less than 8 hours of sleep has increased to 74.6% (CDC, 2018). Among middle school students, approximately 60% obtain less than 9 hours of sleep per night (Becker, Langberg & Byars, 2015).

“Sleep is a vital biopsychosocial state, a naturally occurring process necessary for brain activity and body functions, psychological health and behavior, and individual, family and sociocultural norms. In addition to body processes, sleep is necessary for mental health, such as internalizing and externalizing behaviors ” (Snyder & Chang, 2019, p. 160). Sleep is instrumental in environmental functions such as family and peer relationships, social interactions, and academic performance (Becker, Langberg, & Byars, 2015). Sleep regulation is comprised of a dual process mechanism: a sleep-wake homeostatic mechanism (process S) and a circadian rhythm clock (process C). Process S is the homeostatic process of accruing sleep pressure with length of time awake, with dissipating sleep pressure occurring during sleep; process C is the daily circadian cycle of sleep and wake patterns (Borbely, 1982). Psychosocial factors affecting the sleep state involve family relationships, peer influences, and mental health factors (Becker et al., 2007).

Adolescent Period of Changing Sleep Patterns

Adolescence, defined by the World Health Organization (WHO) as those individuals from 10 to 19 years of age (WHO, 2017), is a transition time from childhood to adulthood with developmental changes in physical, emotional, and decision-making realms. This transitional period is a vulnerable time for changing body functions and patterns, such as sleep. Changes in the biological processes regulating sleep are a normal part of adolescent development. The adolescent undergoes a circadian time shift and phase delay during this period with altered sleep and wake times (Crowley, Acebo & Carskadon, 2007). This shift to an evening chronotype (i.e., a state commonly described as *night owl*) results in delayed bedtimes and later wake times during adolescence. Melatonin hormone release from the pineal gland, which is suppressed by natural, room or artificial light, is necessary for sleep promotion, and is delayed in adolescence, reinforcing the later bedtime and wake times with difficulty to fall asleep (Crowley et al., 2007). A typical sleep schedule for adolescents on a free day (i.e., a day without restrictions of school or other responsibilities) is 3 a.m. to 12 noon (Dahl & Lewin, 2002); however, early school start times dictate early rise times that often lead to sleep insufficiency and excessive daytime sleepiness on weekdays and extra sleeping on weekends to make up for lost sleep (Wolfson & Carskadon, 1998).

Emergence of Mobile Technology and Small Screen Devices

Although smart phones emerged in the early 1990s with the IBM Simon device, it was not until the advent of the iPhone in 2007 that smart phones became readily available to general consumers (Reed, 2010). The Simon device had features of a mobile phone, personal data assistant, and fax capabilities with a touchscreen, but was large, heavy, and costly (Reed, 2010). Nearly two decades later the iPhone was introduced and combined an interactive touch screen and the ability to browse the world wide web with a mobile device (Reed, 2010). Ready availability of wireless communication within homes and communities enhanced the utility of smartphone devices. Tablet computing emerged in 2010 with release of the iPad (Arthur, 2012). Smartphones and tablets combine many features of other electronic devices into the convenience of a compact, handheld portable device. These devices may be used for viewing screen media content, such as television, browsing the internet, accessing social media sites, taking photographs, accessing applications such as gaming, banking, shopping, and others, in addition to phone and short message service (SMS or texting). Other functions of portable media devices include applications such as alarms, computing, and tracking daily activities.

Portable gaming devices emerged in the 1980s and have evolved in a similar fashion like other mobile media devices into a compact handheld device (Gamble, 2017). The most recently-released personal gaming device, Nintendo Switch®, was released in early 2017 and has features of individual or group play as a handheld portable device or on a television screen (Nintendo, n.d.). Electronic book readers emerged in the late 1990s and evolved from a basic device to a compact touchscreen, self-luminous device, with enhanced color graphics and features (Bartram, 2014). These small compact portable devices are collectively termed *small screen media devices* or *mobile media devices.* Although multiple small screen electronic devices are available, smartphones can access similar features as stand-alone personal game devices and electronic book readers. Small screen media devices are readily available to adolescents and can be easily accessed prior to bedtime, while in bed, and during the night after lights out.

Statement of the Problem

Optimal Sleep Recommendations for Adolescents and Typical Sleep Obtained

In developing the sleep duration recommendations for children and adolescents, the AASM consensus panel of clinical and sleep research experts evaluated empirical studies, which examined relationships between sleep duration and health outcomes (Paruthi et al., 2016). Results from the CDC's 2007 Youth Risk Behavior Survey (YRBS) of U.S. high school students in public and private schools revealed that 68.9% of high school students (grades 9-12) obtained less than 8 hours of sleep nightly, with higher prevalence of insufficient sleep in female students and in black students of both genders (Eaton et al., 2010). These statistics pre-date the release of the iPhone® in 2007 and general availability of wireless communication and small screen media devices (Reed, 2010). The most recent statistics from the 2015 YRBS (Wheaton, Jones, Cooper, & Croft, 2018) reveal a higher prevalence of sleep insufficiency among high school students than was found in the 2007 survey. High school students obtaining less than 8 hours of sleep per night increased to 72.7%, with higher prevalence among females, black students, and Asian students. The state of West Virginia had the highest prevalence of sleep insufficiency in the United States, with 82.5% of high school students obtaining less than 8 hours of sleep per night (Wheaton et al., 2018).

Adolescent Vulnerability to Sleep Insufficiency

Adolescents are particularly vulnerable to sleep insufficiency due to physiologic changes in sleep patterns associated with adolescence, early school start times, and availability of and exposure to mobile technology around the clock. Normal physiologic changes in sleep architecture are associated with the progression of pubertal development and include a phase shift in circadian timing to a later chronotype, delayed melatonin release, and longer time to fall asleep. Taken together these factors result in delayed bedtimes (Carskadon, Vieira, & Acebo, 1993; Jenni, Achermann, & Carskadon, 2005). This physiologic circadian shift does not lend itself well to early school start times for adolescents, and automatically predisposes adolescents to sleep insufficiency. A literature review (Wheaton, Chapman, & Croft, 2016) demonstrated that even modest changes to delay school start times improved sleep quantity and was associated with fewer problems with attendance and less sleepiness during the school day. Exposure to electronic media in the pre-bedtime period and during the night further exposes the adolescent to sleep insufficiency.

Technology Use in Adolescents

Technology use is an integral part of the adolescent lifestyle, for academics, entertainment, and socialization. These *digital natives*, who are unaccustomed to life without technology, are commonly seen roaming school halls, neighborhood streets, and shopping malls actively engaged with smart phone devices. According to the Pew Research Center (Lenhart, 2015), about 73% of teens reported having access to a smart phone device, 15% own a basic phone, and 12% do not have cellular phone access. Survey data collected during 2014-2015 by Pew Research Center (Lenhart, 2015) determined nearly 24% of adolescents report almost constant online access via their smartphones. A more recent survey from Pew Research Center in

2018, reported 95% of adolescents have access to a smartphone device, and 45% report nearly constant online use of technology (Anderson & Jiang, 2018).

Use of a social media platform is common among adolescents, and many adolescents use multiple social media platforms (Associated Press-NORC Center for Public Affairs Research [AP-NORC], 2017; Lenhart, 2015). Among 13-17-year-old adolescents, Facebook was the predominant social media platform in the 2015 Pew Research Center analysis (Lenhart, 2015); however, social media trends have demonstrated a shift in preferred platforms as of 2018. Findings from the AP-NORC (2017) survey indicate that the four most commonly used social media platforms among 13-17-year old adolescents were Instagram (76%), Snapchat (75%), Facebook (66%), and Twitter (47%). Pew Research Center reported teens use multiple social media platforms: YouTube (85%), Instagram (72%), and Snapchat (69%) (Anderson & Jiang, 2018); however, the online platforms most frequently used by teens include: Snapchat (35%), YouTube (32%), and Instagram (15%) (Anderson & Jiang, 2018).

Within a 24-hour period, adolescents participate in numerous activities such as academics, socialization, extra-curricular activities, personal care and hygiene, and sleep. Time spent on electronic media displaces time spent on other activities. Development of unhealthy media usage patterns early in life can negatively affect well-being and community trends. Adolescent health is a precursor to adult health, and habits developed prior to and during adolescence are likely to continue into the adult period. Use of electronic media in the bedroom among adolescents is associated with negative health consequences such as obesity, hypertension and cardiovascular disease, type 2 diabetes, depression, and altered cognitive performance (Hale & Guan, 2015; Lemola, Perkinson-Gloor, Brand, Dewald-Kaufmann, & Grob, 2015; Owens & Adolescent Sleep Working Group, 2014).

Concept of Connectedness

It is common to see adolescents actively engaged with a mobile phone device, oblivious to their surroundings, and totally focused on the mobile phone. This phenomenon is termed *connectedness*. The term connectedness is not listed in the dictionary; however, a related term *connected* is defined as: "united, joined, or linked; having a connection; joined together in sequence; having social or professional relationships, especially with influential or powerful persons" (Merriam-Webster, 2018). The concept of connectedness is not identified within the nursing literature; therefore, concept analysis was conducted to identify connectedness within the scientific literature, and to develop a theoretical definition of connectedness. A literature search across a wide array of databases was conducted: nursing-related databases (PubMed, CINAHL, Web of Science), psychology-related databases (PsycINFO), and communication-related databases (Inspec, Compendex, Communications and Mass Media Complete). The keywords mobile phone, technology, smartphone, adolescent, connect* were used for the search. Data were analyzed by thematic analysis to identify and describe connectedness within the adolescent population.

Emergent themes of connectedness describe a type of attachment to a mobile phone device. Adolescents perceive a physical attachment to a mobile phone. Mobile phones are viewed as an extension of themselves, similar to an appendage or a prosthesis (Caronia & Caron, 2004; Caronia, 2005; Vanden Abeele, Antheunis, & Schouten, 2014; Walsh, White, & Young, 2008; Yildirim & Correia, 2015). Adolescents describe feeling naked without being attached to the mobile phone (Yildirim & Correia, 2015). There is a need to be constantly touching the phone, and it is perceived as a form of security object (Walsh et al., 2008). Adolescents need their mobile phones to be constantly on display (Caronia & Caron, 2004) or to be viewed as a fashion article (Vanden Abeele et al., 2014). Some adolescents leave their mobile phones turned on at school, despite school rules prohibiting this practice (Caronia, 2005), or at night (Adachi-Mejia, Edwards, Gilbert-Diamond, Greenolugh, & Olson, 2014; Fobian, Avis, & Schwebel, 2016; Vernon, Barber, & Modecki, 2015).

A second emergent theme is a psychological or emotional attachment to a mobile phone. Adolescents’ fear of missing out on the social connections produced anxiety and worries of being out of touch with the social network (Chotpitayasunondh & Douglas, 2016). The mobile phone is used as a self- or online identity among adolescents (Barth, 2015; Caronia, 2005; Michikyan & Suarez-Orozco, 2016; Walsh & White, 2007; Walsh et al., 2008). Mobile phones establish a private environment separate from parental control, and other people (Barth, 2015; Caronia, 2005). The mobile phone is a salient object, with adolescents constantly thinking about (Ylidirim & Correia, 2015) or checking the phone (Kormendi, Brutoczki, Vegh, & Szekely, 2016; Walsh et al., 2008). There is a need to have constant contact with other people, despite other surrounding circumstances, such as during a therapy session (Barth, 2015) or while driving (McDonald & Sommers, 2015). There is a need to answer mobile phone communications immediately, for fear of losing friendships or contacts with others (Walsh et al., 2008). Feeling value or being loved is associated with mobile phone use; lack of phone calls or messaging is viewed as rejection or being unloved, while phone communications bring a sense of euphoria (Walsh et al., 2008). Being disconnected from the mobile phone brings feelings of being cut off from others (Walsh et al., 2008).

A third emergent theme is a social attachment to a mobile phone. Adolescents view the phone as a cultural norm, with constant connectivity being viewed as a normal adolescent behavior (McDonald & Sommers, 2015), or a social encounter or performance (Caronia & Caron, 2004). The mobile phone is viewed as a way to maintain family and friend relationships (Caronia, 2005; Leena & Arja, 2005; Vanden Abeele, 2014; Walsh et al., 2008). Adolescents describe mobile phones as a way to be available for family and friends (Vanden Abeele, 2016), or a way to seek social engagement (Caronia, 2005). Some adolescents describe not wanting to associate with peers who lack a mobile phone (Leena & Arja, 2005), and lacking a mobile phone is associated with feeling isolation from peers and missing out of activities (Leena & Arja, 2005). In addition, some adolescents view mobile phone ownership as a social status symbol (Walsh, White, & Ross, 2009). Based on this concept analysis, connectedness is theoretically defined as *a physical, emotional, and social attachment to a mobile phone and the services it provides to maintain constant communication.*

Mechanisms for Impact of Electronic Media on Sleep

Proposed mechanisms for the impact of electronic media devices on sleep in childhood and adolescence include: time displacement of sleep by electronic media use, psychological stimulation related to media content, and altered circadian timing related to light emissions from the electronic device (Hale & Guan, 2015; LeBourgeois et al., 2017). The compactness of small screen media allows the device to be used close to the face and eyes, and it is easily used while in bed. Additional information on the impact of electronic media on sleep will be presented in Chapter 2.

Purpose of the Study

The purpose of this study was to explore the attitudes, behaviors, and sleep patterns of adolescents who use mobile phones within the bedroom setting after lights out. The research in this area includes primarily cross-sectional studies, describing correlations of sleep outcomes with mobile media device use at bedtime without causality. Mobile phones are portable devices, which can easily be taken to bed or stored under the pillow at night and accessed freely before and after bedtime for text messaging, phone calls, social media, and internet. Many adolescents feel the need to have constant connectivity with others and the world around them.

Research questions

The following research questions and hypotheses were proposed:

1. Which mobile phone functions are adolescents accessing after lights out?
2. What factors contribute to adolescents' mobile phone use after lights out?
3. What are the sleep patterns of adolescents who use mobile phones after lights out?

The following hypotheses are proposed:

H1. Based on prior research on adolescent mobile phone use, it is hypothesized that:

a. Females use mobile phones after lights out for communication more frequently than males.

b. Males use mobile phones after lights out for entertainment more frequently than females.

H2. Based on prior research on use of electronic media prior to and after lights out, it is hypothesized that:

a. Females have more frequent mobile phone use after lights out than males.

b. Adolescents who consume caffeine prior to bedtime have greater mobile phone use after lights out that adolescents who do not consume caffeine prior to bedtime.

c. Adolescents with increased mobile phone use after lights out place less value on the importance of sleep.

H3. Based on prior research on use of electronic media prior to and after bedtime and sleep duration, sleep quality, and daytime sleepiness, it is hypothesized that use of mobile phones after lights out results in:

a. Shorter sleep duration, as evidenced by actigraphically-measured total sleep time.
b. Reduced sleep quality, as evidenced by increased sleep onset latency, increase in WASO, lowered sleep maintenance efficiency, and decreased perception of sleep quality.

c. Increased next day sleepiness, as evidenced by self-reported daytime sleepiness, and incidence of napping.

Conceptual Framework

The Theory of Planned Behavior (TPB) is a commonly used expectancy value model of attitude formation borrowed from the field of social psychology. It was developed by Icek Ajzen and Martin Fishbein in the 1960s and 1970s, to study attitudes and intentions upon behavior in order to predict and explain human behavior (Madden, Ellen & Ajzen, 1992). The first iteration of the model was called the Theory of Reasoned Action (TRA), with behavioral intentions as the primary tenet of the model (Ajzen & Madden, 1986; Madden et al., 1992). Ajzen and Fishbein postulate that behavioral intentions are influenced by motivational factors, such as effort, in performance of a behavior, and strength of intentions is reflective of the likelihood of behavior change (Ajzen, 1991). The TRA describes the relationship of the constructs of beliefs, attitudes, and intentions, and their influential effect upon behavior to explain voluntary actions (Fishbein & Ajzen, 1975). The TRA has the following constructs: behavioral beliefs, attitude toward behavior, normative beliefs, subjective norms, behavioral intention, and behavior (Fishbein & Ajzen, 1975). However, some behaviors require additional resources for behavioral intentions to be acted upon, posing a barrier to actual or volitional control over the behavior (Ajzen, 1991). Thus, the TRA lacked the ability to address behaviors not under complete or voluntary control of the individual. This limitation posed a barrier to the success of the TRA to predict and explain behavior, and was the impetus for modification of the TRA (Ajzen, 1991). The TPB is an extension of the TRA, with the addition of constructs relating to perceived behavioral control to explain those behaviors that are not under volitional control (Ajzen, 1991; Madden et al., 1992). Perceived behavioral control has both direct and indirect effects on behavior (Madden et al., 1992). The constructs of the TPB are defined in Table 1-1. Ajzen and Fishbein recognized that additional factors affected the beliefs and attitudes antecedent to behavioral intentions, and ultimately, behavior. These factors are termed background factors, and encompass individual, social, and information factors (Ajzen, 1991). Specific background variables include personality, mood, intelligence, values, demographics, and knowledge (Ajzen, 1991).

Table 1-1

Definitions of Theory of Planned Behavior Constructs

Behavioral beliefs	Beliefs which influence the attitude toward a behavior (Ajzen & Madden, 1986)
Attitude toward behavior	The degree to which a person has a favorable or unfavorable evaluation of the behavior in question (Ajzen & Madden, 1986, p. 454)
Normative beliefs	Beliefs that underlie determinants of subjective norms (Ajzen & Madden, 1986)
Subjective norms	The perception of social pressure to perform or not to perform a behavior (Ajzen & Madden, 1986)
Control beliefs	Beliefs about resources or opportunities needed to perform a behavior (Ajzen & Madden, 1986)
Perceived control	Belief in the ease or difficulty in performing a behavior (Ajzen & Madden, 1986)
Behavioral intention	Motivational factors influencing a behavior (Ajzen, 1991)

The TPB was initially tested among a group of college students to evaluate the impact of perceived behavioral control on behaviors both under volitional control and those not under volitional control (Ajzen & Madden 1986). The first experiment involved undergraduate college students in a social psychology class, and the decision to attend class lectures to evaluate why students would attend or not attend class lectures. The study questionnaire was designed to evaluate the TPB constructs. The study confirmed that beliefs were antecedent to attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991; Ajzen & Madden, 1986; Madden et al., 1992). The study results revealed that behavioral intentions exerted the primary effect on behavioral control, and was not mediated by subjective norms, attitude, or prior experiences (Ajzen & Madden, 1986; Madden et al., 1992). The second test of the TPB involved a survey of undergraduate college students in a business administration course and their expectations of achieving an “A” grade in the class (Ajzen & Madden, 1986; Madden et al., 1992). The students were surveyed at two timepoints: the beginning of the semester, and near the end of the semester. The constructs of attitudes, subjective norms, and perceived behavioral control were evaluated, and study results demonstrated support for the constructs of the TPB. There was a significant correlation between beliefs and attitudes, subjective norms, and perceived behavioral control (Ajzen & Madden, 1986). Addition of perceived behavioral control had more predictive capacity in both studies of the TPB than was demonstrated in the earlier version, the TRA (Ajzen & Madden, 1986; Madden et al., 1992).

The TPB has been used as a framework in the following areas of relevant research: adolescent health (Frater, Kuijer, & Kingham, 2017; Gulley & Boggs, 2014; Hassandra, Vlachopoulos, Losmidou, Hatzigeorgiadis, Goudas, & Theodorakis, 2011; Rowe, Andrews, Harris, Armitage, McKenna, & Norman, 2016), sleep health (Knowlden, Sharma, & Bernard, 2012; Strong, Lin, Jalilolghadr, Updegraff, Brostrom, & Pakpour, 2018), and technology-related research (Barkoukis, Lazuras, Ourda, & Tsorbatzoudis, 2016; Gauld, Lewis, White, Fleiter, & Watson, 2017; Heirman & Walrave, 2012; Koh & Machert, 2016; Saeri, Ogilvie, Macchia, Smith, & Louis, 2014). Some examples of the TPB as a theoretical framework for adolescent health include: prediction of physical activity (Frater, Kuijer, & Kingham, 2017; Gulley & Boggs, 2014), intention to smoke (Hassandra, Vlachopoulos, Losmidou, Hatzigeorgiadis, Goudas, & Theodorakis, 2011), and risk-taking while driving (Rowe, Andrews, Harris, Armitage, McKenna, & Norman, 2016). The TPB was used as a theoretical framework in sleep health to predict intentions to sleep in undergraduate students (Knowlden, Sharma, & Bernard, 2012), and to evaluate sleep hygiene behaviors among Iranian high school students (Strong, Lin, Jalilolghadr, Updegraff, Brostrom, & Pakpour, 2018). In the area of technology-related research, the TPB was used to predict behavior related to cyberbullying (Barkoukis, Lazuras, Ourda, & Tsorbatzoudis, 2016; Heirman & Walrave, 2012), smartphone use while walking (Koh & Machert, 2016), and driving (Gauld, Lewis, White, Fleiter, & Watson, 2017), and online social media privacy (Saeri, Ogilvie, Macchia, Smith, & Louis, 2014). Additional information on the TPB is presented in Chapter 2.

Definitions of Key Terms

Table 1-2

Definitions of Key Terms

Adolescent	Individuals from 10-19 year of age (WHO, 2017)
Adolescence	A transitional period during the second decade of life, including puberty (physiologic and behavioral changes associated with activation of the hypothalamic-pituitary-gonadal axis) to develop reproductive maturity, and non-reproductive traits such as social, emotional, and cognitive development (Walker et al., 2017)
Actigraphy	A wristwatch-sized non-invasive device used to monitor rest and activity cycles by measuring gross motor activity*
After lights out	The period of time between getting into bed and turning lights off until getting out of bed following the main sleep period
Chronotype	A natural tendency for an individual to sleep during a particular time in the 24-hour period*
Circadian timing	A biological process occurring in animals, humans and plants with a 24-hour rhythm driven by an internal clock mechanism*
Eveningness	A natural tendency for peak performance later in the day, i.e., evening (Horne & Ostberg, 1977)

Table 1-2

Definitions of Key Terms

Excessive daytime sleepiness	Symptoms of drowsiness or sluggishness during the day which interfere with work, school, activities or relationships*
Insomnia	Habitual sleeplessness or inability to sleep*
Melatonin	A hormone secreted from the pineal gland to aid in controlling sleep and wake cycles*
Morningness	A natural tendency for peak performance earlier in the day, i.e. morning (Horne & Ostberg, 1977)
Polysomnography	A sleep test to record brain waves, oxygenation, heart and respiratory rates, and eye and leg movements*
Sleep architecture	The basic structural organization of normal sleep patterns, including non-rapid eye movement (NREM) sleep with its associated sleep stages, and rapid eye movement sleep (REM) (Altevogt & Colten, 2006)
Sleep diary	A tracking mechanism to record sleep timing and sleep-related behaviors*
Sleep deficiency	A condition occurring by insufficient quantity of sleep, sleeping at the wrong time of the day, and/or poor quality of sleep*
Sleep duration	The hours of sleep obtained in one consolidated sleep episode*
Sleep efficiency	The total sleep time divided by the time in bed, expressed as percent*
Sleep habits	Daily routines surrounding sleep practices*
Sleep onset latency	The duration of time from “lights out” or bedtime to the onset of sleep*
Sleep patterns	A person’s clock-hour schedule of bedtime and arise time along with nap behavior*
Sleep quality	One’s satisfaction with the sleep experience, including sleep initiation, sleep maintenance, sleep quantity, and refreshment upon awakening*
Small screen media device	Small handheld portable electronic media devices which can be held close to the face, such as mobile phones, tablets, and portable gaming devices

Table 1-2

Definitions of Key Terms

Social jetlag	A discrepancy between weekday and weekend sleep phase (Wittman, Dinich, Merrow, & Roenneberg, 2006)
Time in bed	The time from "lights out" to "lights on"*
Total sleep time	The amount of actual sleep time in a sleep episode; the total of all REM and non-REM sleep in a sleep episode*
Wake after sleep onset	Amount of time awake after falling asleep*

Note. *(National Sleep Foundation, 2017). Adapted from Sleeptionary-Definitions of common sleep terms, 2017. *National Sleep Foundation.* Retrieved from https://sleepfoundation.org/sleeptionary

Assumptions

1. Mobile phones have the ability to provide access to a wide variety of services and are the preferred media device among adolescents.
2. Adolescents use mobile phones at bedtime and during the night.
3. Adolescents obtain less than the recommended sleep duration in a 24-hour period.
4. Engagement with mobile phones in the bedroom setting negatively impacts healthy sleep.

Significance of Study

Sleep insufficiency in adolescents is a public health issue with potential negative health consequences (Gradisar et al., 2011). Use of electronic media devices within the bedroom setting, particularly small screen devices held close to the face, negatively impact healthy sleep (Carter, Rees, Hale, Bhattacharjee, & Paradkar, 2016; Hale & Guan, 2015), disrupting the biopsychosocial sleep state. The combination of chronic sleep insufficiency, ready availability of mobile phone devices within the bedroom setting, and adolescent decision-making abilities form the basis for this emerging research.

Negative Health Outcomes Associated with Sleep Insufficiency

Biological health outcomes associated with sleep insufficiency include hypertension, obesity, and diabetes. A meta-analysis of children and adolescents and the relationship between sleep and obesity demonstrated an increase in obesity in the context of sleep insufficiency (Felso, Lohner, Hollody, Erhardt, & Molnar, 2017). Lim (2018) analyzed data on 12-18-year old participants from the Korean National Health and Nutrition Examination Survey 2007-2012 and observed metabolically unhealthy overweight participants were more likely to have short sleep duration (7 hours or less per night) than participants who were normal weight. The shortest sleep duration, less than or equal to 5 hours per night, was associated with participants who were metabolically unhealthy, and overweight. Conversely, sleeping greater than 11 hours per night was associated with being metabolically unhealthy, and normal weight. Hypertension is a risk factor for cardiovascular disease. Bal et al. (2018) evaluated adolescents 11-17 years of age for association between sleep duration and hypertension. Sleeping less than the recommended 8 hours per night was associated with an increased risk of pre-hypertension and hypertension in both adolescent males and females.

Short sleep duration is associated with decreased school performance among adolescents (DeWald, Meijer, Oort, Kerhof, & Bogels, 2010; Fredriksen, Rhodes, Reddy, & Way, 2004; Roberts, Roberts, & Duong, 2009; Wolfson & Carskadon, 1998; Wolfson & Carskadon, 2003). DeWald (et al. 2010) conducted a meta-analytic review of 26 studies of children and adolescents and the relationship between sleep and academic performance. Sleep duration, sleep quality, and daytime sleepiness were analyzed. Self-reported data were collected from the participants or their parents. The strongest effect was between sleep duration and academic performance (DeWald et al., 2010). Among over 2000 middle school students (11-14 years of age), shorter sleep duration was associated with poorer academic performance (Fredriksen et al., 2004). A literature review of studies of middle school, high school, and first year college students observed an association between longer sleep duration and higher grade performance (Wolfson & Carskadon, 2003). In a study of more than 3000 public high school students, 13 to 19 years of age, those students who slept less than 9 hours, had later bedtimes, or had irregular sleep patterns had poorer academic performance (Wolfson & Carskadon, 1998).

Sleep insufficiency is associated with psychological outcomes of daytime sleepiness, and depressive symptoms among adolescents (Fredriksen et al., 2004; Short, Gradisar, Lack, & Wright, 2013). Middle school students who had shorter sleep duration had poorer self-esteem and an increase in depressive symptoms (Fredriksen et al., 2004). A sample of nearly 400 Australian adolescents, 13 to 18 years of age, reported poorer sleep duration and sleep quality, increased daytime sleepiness, increased incidence of depressed mood, and worse grades (Short et al., 2013). Sleep difficulty is associated with suicidal ideation and self-harm behaviors among adolescents (Liu, 2004; Liu & Buysse, 2005; Wong, Brower, & Zucker, 2011). Liu (2004) studied the relationship between sleep patterns and suicidal behaviors in adolescents in China. Sleep duration of less than 8 hours was associated with an increase in suicidal attempts. Wong et al. (2011) observed an association between difficulty sleeping in early adolescence and suicidal thoughts or self-harm behaviors later in adolescence among 280 participants from high-risk alcoholic families.

Social health outcomes associated with sleep insufficiency are related to increased risk of injury (Danner & Phillips, 2008; Pack et al., 1995), and increase in adolescent risk-taking behaviors (McKnight-Eily et al., 2011; Shochat, Cohen-Zion, & Tzischinsky, 2014). Analysis of highway collision records demonstrated an increased incidence of traffic crashes related to falling asleep at the wheel among those drivers 25 years of age and younger (Pack et al., 1995). Sleep deprivation is associated with excessive sleepiness, altered reaction time, and reduced vigilance leading to falling asleep while driving (Pack et al., 1995). Early school start times for high school students contribute to short sleep duration and increased daytime sleepiness, predisposing teen drivers to motor vehicle crashes (Danner & Phillips, 2008). Later school start times for high school students reduced the number of motor vehicle crashes among adolescent drivers (Danner & Phillips, 2008). Shorter sleep duration was associated with an increase in smoking, marijuana use, and drunk driving in a meta-analytic review (Shochat et al., 2014). In addition, increased participation in sexual activity, physical fighting, and serious suicide attempts was associated with sleep insufficiency in the 2007 Youth Risk Behavior Survey (McKnight-Eily et al., 2011).

Negative Sleep Consequences Associated with Bedtime Electronic Media Exposure

Small screen media devices used within the bedroom setting, both before and after lights out, provide a different type of media access than older stationary media devices, such as televisions or computers. These newer devices permit nearly constant access to internet, social media, and real time access to others, which has the potential for nearly continuous electronic media stimulation (Carter et al., 2016). Exposure to electronic media devices within the bedroom setting has negative sleep consequences of short sleep duration, delayed sleep timing, and next day sleepiness (Buxton et al., 2015; Carter et al., 2016; Gradisar et al., 2013; Hale & Guan, 2015; LeBourgeois et al., 2017; Owens, 2014). Sleep deficiency is associated with use of electronic media within the bedroom setting, even when devices are not actively being used (Buxton et al., 2015). A literature review of 67 studies found an association between electronic media use in the bedroom and shorter sleep duration, poorer sleep quality, and an increase in daytime sleepiness (Hale & Guan, 2015). A systematic review and meta-analysis of 20 studies on the use of small screen electronic media devices and sleep outcomes in children and adolescents observed increased odds of shorter sleep duration, poorer sleep quality, and more daytime sleepiness with bedtime use of small screen media devices, as well as the presence of the devices in the bedroom without being used (Carter et al., 2016).

Chapter Summary

Mobile phone use is ubiquitous among adolescents. Mobile phone use has become an embedded tenet in current adolescent culture. The need for adolescents to maintain constant connectivity to their social and information networks sparks concern regarding access to mobile phone devices prior to and after lights out. Adolescents use mobile phones as an all-inclusive electronic media device with the capability of multiple electronic functionality. Electronic media access during the pre-sleep and sleep periods is associated with sleep problems, including short sleep duration, poorer sleep quality, and increased daytime tiredness, and predisposes to negative health outcomes. The changing physiologic sleep patterns of adolescence, early school start times, and exposure to mobile phones in the bedroom can severely affect sleep health. The proposed mechanisms for impact of electronic media exposure include time displacement, light exposure, and psychological disturbance. Much of the current research on bedroom exposure to electronic media is correlational. A descriptive correlational study design, with prospective micro-longitudinal data collection was conducted to evaluate the attitudes, behaviors, and sleep patterns of adolescents who use mobile phones after lights out.

Chapter 2

Review of the Literature

Introduction

The purpose of this literature review is to describe the state of the science and to identify gaps in the literature related to bedtime use of small screen electronic media devices in the adolescent population. The major foci of the conceptual review of the research literature are adolescent development, adolescent sleep patterns, electronic media use in adolescence, and the mechanisms through which electronic media impact sleep using a biopsychosocial approach. In addition, a review of behavioral change theories relevant to this area of inquiry is provided. Attention is devoted to the Theory of Planned Behavior selected to guide this study and the rationale for selecting it. The chapter will close with a summary of both the conceptual and theoretical literature reviews.

Method

A broad literature review was conducted on adolescent development and adolescent sleep using the electronic databases PubMed, PsycINFO, and CINAHL. Articles were limited to the English language; date restrictions were not applied as seminal work in adolescent development and adolescent sleep was done during the second half of the 20th century. Topics and search terms are detailed in Table 2.1. A more focused literature review on electronic media use by adolescents and sleep was conducted using the electronic databases PubMed, PsycINFO, Compendex and Inspec, and Web of Science to search for primary studies and theoretical literature in the English language published from 2007 to the present. Database selection was aimed at identifying a base of literature in the medical, nursing, psychological, and technical fields related to bedtime small screen electronic media use in adolescents. The year 2007 coincided with release of the first iPhone®, making smartphone use readily available to the general public, including adolescents. Limiting to this time frame is logical with rapid changes in the technology field.

Additional search strategies included examination of reference lists of included literature, forward search of included literature for articles citing literature selected for inclusion, and author networking with a field expert. Key words in the search strategy included: mobile phone, cell* phone, smart phone, screen-based media, small screen, electronic media, digital media, screen media, sleep, insomnia, wakefulness, adoles*, child* (Table 2-1). Search terms related to technology were used to retrieve literature relating to small screen device use. Multiple descriptions may be present necessitating use of several technology search terms. Search terms related to sleep (sleep, insomnia, wakefulness) were used to retrieve articles with sleep outcomes; the terms insomnia and wakefulness were used as these sleep disorders may be observed with technology use. Although adolescents were the subject of this literature review, the adolescent population may be indexed under the terms children or adolescents. Search terms were combined within databases to retrieve articles specific to this review. The search strategy used each string independently (technology terms, sleep terms, adolescent and child terms), followed by combining those searches into a final search to include all key words.

This review included peer-reviewed primary studies involving bedtime use of small screen electronic devices in the adolescent population. Studies involving adolescents between the ages of 10 and 19 years were included in the review. The age criteria were based on the WHO (2017) definition of adolescent, which includes both adolescent and preadolescent children. Additionally, use of the term adolescent within the literature does not have a consistent meaning across all studies. For example, the term adolescent may be used to describe the teenage years or to describe any child who has begun puberty or reached pubertal age. In addition, teenagers may be collectively classified as children. Therefore, children and adolescents were used to capture the age range of 10-19 years. Studies that included children and adolescents outside of the age range were included if the mean age was within the stated 10-19 years, and age was stratified. Studies involving bedtime exposure to small screen media with sleep outcomes were included. Studies that included multiple types of screen media were included if there was separate analysis of small screen devices. Articles were excluded if they were: published prior to 2007; non-English language; included infant, toddler, preschool or early school-age range; referred to a specific disease state (such as autism or chronic health conditions); use of mobile phone applications for treating health conditions or use of a mobile phone as an intervention; those that referred to electromagnetic field exposure; or articles that aggregated electronic media use of multiple devices without separate analysis of small screen media devices.

Table 2-1

Literature Search Strings and Key Words for Database Searches

Topic	Search Strings and Key Words
Adolescent development	Adolesc*, child, pubert*, growth and development
Adolescent brain development	Adolescent, brain development, decision making, prefrontal cortex, risk-taking
Adolescent sleep	Adolesc*, devel*, sleep, melatonin, circadian rhythm, homeostatic sleep regulation, social jetlag
Sleep insufficiency	Adolescent, sleep duration, sleep recommendations, sleep guidelines
Policy considerations	Adolescent, school start time, policy
Small screen electronic media in adolescents	Search 1: mobile phone OR cell* phone OR smart phone OR screen-based media OR small screen OR electronic media OR digital media
	Search 2: sleep OR insomnia OR wakefulness
	Search 3: adolesc* OR child*
	Search 4: Combine search 1, 2, 3
Psychological stimulation	Adolescent, video gaming, sleep, social media, psychological arousal, cognitive arousal

Topic	Search Strings and Key Words
Sleep measures	Sleep, subjective, measure, adolescen*, polysomnography, PSG, actigraphy, actigraph, sleep diary, chronotype, melatonin, cortisol, body temperature, questionnaire

Theoretical Model

Theory of Planned Behavior

The Theory of Planned Behavior is an expectancy value model developed by a group of social psychologists studying the relationship of attitudes and intentions on health behavior, as a way to explain and predict health behavior (Ajzen, 1991; Ajzen & Madden, 1986; Madden et al., 1992). The study of health behavior, attitudes, and motivation has its roots in the Health Belief Model (HMB), to study individual readiness for health behavior change (Ajzen & Timko, 1986). The goal of the model was to deal with complex human behavior, and the model incorporates attitudes, subjective norms, and perceived behavioral control, with underlying foundational beliefs leading to behavioral intentions (Ajzen 1991). The original model was termed the Theory of Reasoned Action (TRA); however, the TRA was limited by a lack of predictive ability for behavior not under volitional control (Madden et al., 1992). The TPB and the TRA share common constructs: *behavioral beliefs, attitude toward the behavior, normative beliefs, subjective norm,* and *behavioral intention*, with the addition of the constructs, *perceived behavioral control,* and *control beliefs* for the TPB (Madden et al., 1992).

History of Development and Implementation of the TPB

During the 1960s and 1970s, social psychologists focused on ways to explain and predict human behaviors, with research on attitudes and motivational determinants, as well as a focus on beliefs, such as vulnerability and susceptibility to disease, and effectiveness in coping with the potential for disease (Ajzen & Timko, 1986). However, these efforts were less effective in predicting health behavior than anticipated. Ajzen and Fishbein recognized that attitudes were integrally linked to health behavior when those attitudes were specific to the target action. For example, following orders of a health care provider was specific to attitudes related to health care provider advice, rather than general attitudes regarding health care (Ajzen & Timko, 1986). A set of underlying beliefs was determined to be foundational to behavior (Ajzen, 1991). Those beliefs included behavioral beliefs related to likely consequences of the behavior, normative beliefs related to perceptions and expectations of others, and control beliefs related to factors that enhance or detract from the ability to perform a behavior (Ajzen, n.d.). Ajzen and Fishbein noted that there were also elements of internal and external control over a behavior (Ajzen & Timko, 1986).

Preliminary studies of attitudes and intentions were conducted as a basis for the TRA and TPB (Ajzen & Timko). A pilot study was conducted with undergraduate students to evaluate health beliefs and attitudes toward health and illness, and health-related activities (Ajzen & Timko, 1986). The 53-item survey used a 6-point semantic differential scale. Bipolar adjectives from *never* to *always* were used to understand beliefs and attitudes regarding health behavior. From the pilot study, a questionnaire was developed, which focused on 24 health-related behaviors with corresponding attitudes and perceptions of control, using a 7-point semantic differential-type scale with responses such as *good-bad*, *easy-difficult*, or *always-never*. This survey also incorporated global questions on health, and health-related behavior. Attitudes with specificity to a certain behavior, and perceived control over a behavior demonstrated significant correlations; however, specific behaviors did not reach statistical significance with general health-related attitudes (Ajzen & Timko, 1986).

The TRA was developed from this study of attitudes and intentions; however, it was deemed insufficient to address behaviors that were not completely under the control of the individual. Behaviors not under volitional control are those behaviors with barriers to behavior, such as lack of appropriate resources and opportunities, including time, finances, skills, or dependence upon others (Ajzen, 1991). Addition of constructs to provide for a perception of control, in the absence of actual control, advanced the TRA into the TPB (Ajzen, 1991; Ajzen & Madden, 1986; Madden et al., 1992). Initial testing of the TPB has been discussed in Chapter 1. Support for the addition of the construct of *perceived behavioral control*, with the antecedent *control beliefs*, was achieved to make the theory more predictive of behaviors not under volitional control (Ajzen, 1991; Ajzen & Madden, 1986; Madden et al., 1992). The TBP describes a set of beliefs that are antecedent to attitudes, which are antecedent to behavioral intentions to perform a behavior. The TPB further "distinguishes between three types of beliefs-behavioral, normative, and control-and between the related constructs of attitude, subjective norm, and perceived behavioral control" (Azjen, 1991, p. 198).

Descriptions of TPB Variables

The current version of the TPB is depicted in Figure 2-1. The TPB variables are described below.

Behavioral beliefs

Beliefs which influence the attitude toward a behavior are called *behavioral beliefs* (Ajzen & Madden, 1986). Behavioral beliefs are antecedent to attitudes toward the behavior. Behavioral beliefs are linked to a certain outcome of the behavior. Strong beliefs with positive outcomes influence a positive attitude toward a behavior. The sum of the products of belief strengths and the outcome estimates the attitude (Ajzen & Madden, 1991).

Attitude toward behavior

"The degree to which a person has a favorable or unfavorable evaluation of the behavior in question" (Ajzen & Madden, 1986, p. 454) is termed *attitude toward behavior*. This is a personal factor, and one's attitude toward the behavior can be either positive or negative. Attitudes are antecedent to intentions (Ajzen & Madden, 1991).

Normative beliefs

Beliefs that underlie determinants of subjective norms are called *normative beliefs* (Ajzen & Madden, 1986). Normative beliefs are antecedent to subjective norms. The strength of the normative beliefs is determined by adding the products of the individual's motivation to comply with the key referents' (significant other persons) approval or disapproval of the behavior to estimate the subjective norm (Ajzen & Madden, 1986).

Subjective norms

The perception of social pressure to perform or not to perform a behavior is termed *subjective norms* (Ajzen & Madden, 1986). Key referents influence the decision to perform a behavior by positive or negative beliefs about the behavior. The individual's motivation to comply with the referents' beliefs exerts an effect on the likelihood of performing (or not performing) a behavior.

Control beliefs

Beliefs about resources or opportunities that are needed to perform a behavior are called *control beliefs* (Ajzen & Madden, 1986). Beliefs in sufficiency of resources to perform a specified action result in greater control over the behavior. These resources are non-motivational factors, and may include time, money, skills, or cooperation of others (Ajzen, 1991).

Perceived behavioral control

The belief in the ease or difficulty of performing a behavior is termed *perceived behavioral control* (Ajzen & Madden, 1986). Perceived behavioral control can exert direct or indirect effects upon behavioral intentions, dependent upon the volitional control of the behavior. Behaviors without volitional control or those with a low perception of volitional control exert influence indirectly through intentions (Madden et al., 1992).

Behavioral intention

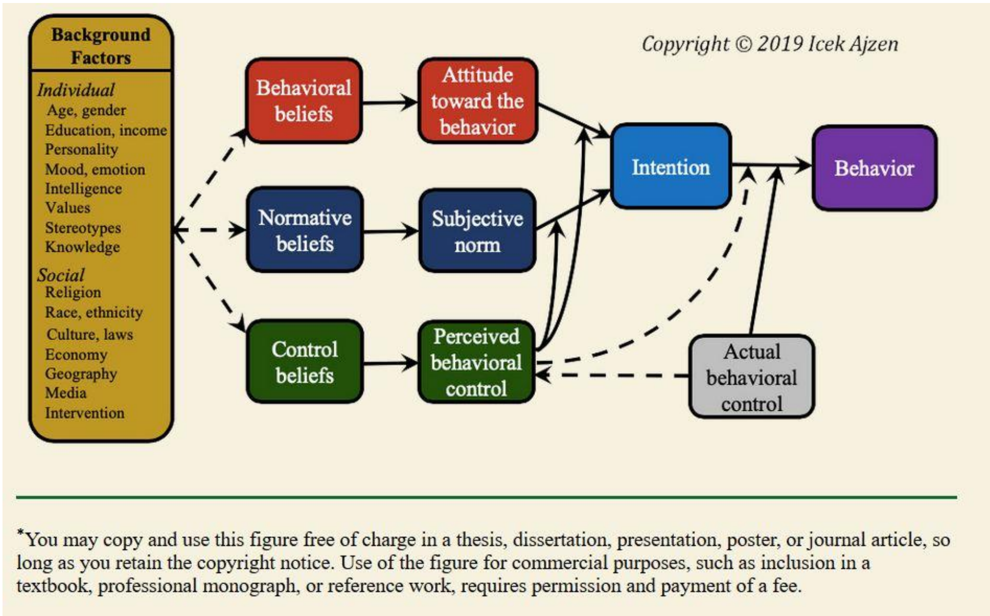
Motivational factors influencing a behavior are called *behavioral intention* (Ajzen, 1991). Intentions are reflective of the amount of effort that one is willing to expend toward the behavior. The strength of intentions affects the likelihood of performing a behavior (Ajzen, 1991).

Background factors

Background factors are external factors that influence health behavior. These factors include individual, social, and information factors (Ajzen, 2017). Individual factors may include personality, mood and emotion, intelligence, values, stereotypes, and experience (Ajzen, 2017). Social factors include demographic factors, such as education, age, gender, religion, race, ethnicity, culture, and laws (Ajzen, 2017). Information factors include knowledge, media, and intervention (Ajzen, 2017).

Figure 2.1

Visual Representation of the Theory of Planned Behavior with Background Factors



Note. The central tenet of the theory is behavioral intentions. Attitudes and beliefs are antecedent to behavioral intentions. Perceived control is determined by motivation and ability. Additional background factors affect attitudes and intentions.

Ajzen, I. (2019). *Theory of Planned Behavior with background factors.* https://people.umass.edu/aizen/tpb.background.html

Use of TPB in Research

The TPB has been used as the theoretical foundation for research. Use of the TPB for relevance to this dissertation include adolescent research, sleep research, and technology research.

Use of TPB in adolescent research

The TPB was used as a theoretical framework for adolescent health in prediction of physical activity (Frater, Kuijer, & Kingham, 2017; Gulley & Boggs, 2014), intentions to smoke

(Hassandra, Vlachopoulos, Losmidou, Hatzigeorgiadis, Goudas, & Theodorakis, 2011), and risk-taking while driving (Rowe, Andrews, Harris, Armitage, McKenna, & Norman, 2016). Frater et al. (2017) determined that societal attitudes and social norms affected the decision to ride a bicycle to school among a group of 331 secondary students. In a study of 193 Appalachian high school students, the TPB was used as a framework to predict and understand exercise frequency (Gulley & Boggs, 2014). Attitudes about physical activity, parental and friend norms, and behavioral intentions predicted uptake of exercise. Hassandra and colleagues (2012) evaluated the TPB constructs in a sample of 763 Greek students, ages 10-18, to determine intentions to smoke. Across the adolescent lifespan, the effects of the TPB constructs changed with student age in prediction of smoking behaviors. A study of 16-18 year old adolescents used the TPB as a framework to predict intentions to take risks while driving (driving over the speed limit, driving while talking on a mobile phone, driving while tired, and driving while under the influence of alcohol) (Rowe et al., 2016). Attitudes toward risk-taking behavior was the most significant predictor of risk-taking behavior.

Use of TPB in sleep research

The TPB was used as a theoretical framework in sleep research (Knowlden, Sharma, & Bernard, 2012; Strong, Lin, Jalilolghadr, Updegraff, Brostrom, & Pakpour, 2018). Knowlden and colleagues (2012) used the TPB to predict intentions to sleep in a 3-phase study of single undergraduate college students not living with parents. The initial phase used the constructs of the TPB in semi-structured qualitative interviews conducted with 11 students to develop survey items regarding beliefs regarding sleeping 7 to 8 hours per night. The second phase evaluated test-retest reliability of the 29-item survey with 37 students. In the final phase, the questionnaire was administered to 211 students, with 197 students meeting eligibility criteria and providing complete data. The findings indicated students perceived that behavioral control was the strongest predictor of sleep intentions, with a low level of volitional control over sleep intentions. Subjective norms and attitudes did not have a direct effect on sleep intentions. The transition from high school to university studies affected the students' sleep intentions, i.e., maladaptation to the time rigor of the university academic course work, lack of appropriate time management, and the expendability of sleep for academic activities (Knowlden et al., 2012). A study of 1822 Iranian high school students used the TPB, coping planning, and action planning to evaluate sleep hygiene behaviors (Strong et al., 2018). Sleep hygiene behaviors evaluated in this study included: incidence of regular sleep schedule, reduction of caffeine intake at night, provision of a restful environment, elimination of hunger and thirst prior to bedtime, and reduction of stressful or anxiety-producing pre-bedtime activities. The study determined that after 6 months, sleep hygiene behaviors were predicted by the TPB constructs, as well as coping and action planning. Those students who used either coping planning and/or action planning regarding sleep hygiene behaviors achieved more success in performing effective sleep hygiene activities (Strong et al., 2018).

Use of TPB in technology research

The TPB was used as a framework in technology-related research to predict behavior related to cyberbullying (Barkoukis, Lazuras, Ourda, & Tsorbatzoudis, 2016; Heirman & Walrave, 2012), smartphone use while walking (Koh & Machert, 2016) and driving (Gauld, Lewis, White, Fleiter, & Watson, 2017), as well as online social media privacy (Saeri, Ogilvie, Macchia, Smith, & Louis, 2014). Barkoukis et al. (2017) used the TPB as the basis for a school-based intervention targeted at reduction of cyberbullying in a sample of 355 students, who were between 16-18 years old. Heirman and Walrave (2012) used the TPB to predict perpetration of cyberbullying among 12-18 year old students. The strongest correlation was observed between attitudes and behavioral intention in predicting cyberbullying. In a study of college students at a large university, which focused on students' decisions to text on their smartphones while walking, Koh and Machert (2016) determined subjective norms was the most significant predictor of texting while walking. This study to evaluate intentions, attitudes, and behavior involved two surveys about using text messaging while walking: one for sending messages, and one for receiving messages. Gauld et al. (2017) used the TPB as a theoretical framework to understand and predict smartphone use for social messaging while driving in a sample of 114 young drivers, who were college students, ages 17-25 years. The TPB constructs of attitudes, social norms, and behavioral intentions were all predictive of smartphone behavior while driving. Saeri and colleagues (2014) used the TPB in a study of 119 first year college students to predict student intentions to protect online privacy among Facebook® users. This 2-week longitudinal study used an online survey, with findings only partially supporting the TPB in predicting behavior. The construct *subjective norms* was the only significant construct in prediction of behavior to protect online privacy. Study participants perceived key referents' opinions regarding online privacy or their examples of modeling online privacy protection as influential in their decision toward increased online privacy protection (Saeri et al., 2014).

Application of the TPB to Adolescents with Bedtime Exposure to Smartphone Devices

Exposure to mobile phones in the bedroom setting before and after lights out can negatively impact sleep health, including sleep loss, poor sleep quality and quantity, and excessive daytime sleepiness (Carter et al., 2016; Hale & Guan, 2015). The TPB can be applied in this context within the constructs of the model to understand and predict behavior related to mobile phone use after lights out in the adolescent population.

Behavioral beliefs

Adolescents' beliefs regarding use of mobile phones in the bedroom are antecedent to decisions whether or not to use a mobile phone after lights out. Additionally, adolescent beliefs about the importance of sleep impact behavioral beliefs regarding use of mobile phones after lights out. Strong beliefs in sleep benefits impact decision-making toward modification of mobile phone use at night. However, many adolescents believe in the need to be connected to their peers at all times of the day or night, which may affect behavioral beliefs.

Attitude toward behavior

Attitudes specific to mobile phone use after lights out and sleep outcomes can be favorable or unfavorable. The strength of these attitudes regarding mobile phone use after lights out is anticipated to affect behavioral intentions.

Normative beliefs

These beliefs are related to motivation to comply with key referents' approval or disapproval of use of nighttime mobile phone. There may be a potential conflict between referents, such as parents and peers in their acceptability of the behavior of using mobile phones after lights out. This conflict in beliefs may affect motivation to comply with referents' opinions.

Subjective norms

Perceptions of social pressure from key referents in adolescents' lives will play a role in decision-making regarding mobile phone use at night. The most significant influences in adolescent life are the peer group, based on the developmental tasks of adolescence in the quest for adulthood. The peer network is a critical part of adolescent life and is perhaps the most influential group. Lesser influences may be exerted by parents and family, educators, healthcare providers, religious leaders, or other adults. The expectation from the peer group of being connected with the social network may be the most significant factor in mobile phone use after lights out.

Control beliefs

Adolescent beliefs about the sufficiency of resources that are needed to perform the associated behavior describe control beliefs. One resource may be cooperation of others. If adolescents believe they need cooperation of others regarding decision-making on mobile phone use after lights out, the peer network may be influential in this resource, either negatively or positively.

Perceived control

The perception of the ease or difficulty to perform the behavior of use or non-use of mobile phones after lights out is dependent upon volitional control of the behavior. Adolescents' use of mobile phones at night may not be a behavior with a high amount of control. Adolescents' need for constant connectivity to the social or peer network may preclude volitional control.

Behavioral intention

These motivational factors of attitudes and intentions play a role in the decision to use mobile phones after lights out. All the previous constructs inform behavioral intentions, by beliefs and attitudes. The need to have constant connectivity with the peer network, as well as the tasks of adolescence appear to have a significant role in development of behavioral intentions.

Background factors

Individual factors of moods and emotion may play an active role in attitudes related to use of mobile phones after lights out in the adolescent. These factors may include prior experiences and intelligence. Social factors are anticipated to play a role in understanding adolescents' use of mobile phones within the bedroom setting. Demographic variables are discussed later in this chapter. Increasing adolescent age, female gender, and black race are discussed as factors in technology use and sleep health. Information factors of individual knowledge may be a factor in decision-making regarding mobile phone use after lights out.

Other Models Considered

Other models that were considered as a theoretical framework for this study include the Theory of Reasoned Action (TRA), and the Health Belief Model (HBM). Both theories are borrowed from the field of social psychology, and are behavioral models used to understand and predict human behavior. The TRA and TPB share common roots, and the TPB is a modification or an enhancement of the TRA (Madden, Ellen, & Ajzen, 1992).

Theory of Reasoned Action

The TRA was developed by social scientists Martin Ajzen and Icek Fishbein in the 1970s, pursuant to a study of attitudes and their relationship to behavior. The TRA is the earliest form of the TPB, and describes the relationship of the constructs of beliefs, attitudes, and intentions, and their influential effect upon behavior to explain voluntary actions (Fishbein & Ajzen, 1975). The TRA has the following constructs: behavioral beliefs, attitude toward behavior, normative beliefs, subjective norms, behavioral intention, and behavior (Fishbein & Ajzen, 1975). Similar to the TPB, the central construct of the TRA, and the best predictor of behavior, is behavioral intention (Ajzen, 1991). Fishbein and Ajzen postulated that behavioral intention was antecedent to behavior change, and behavioral intention was dependent upon personal or social determinants of intention (Ajzen & Madden, 1986; Ajzen & Timko, 1986; Fishbein & Ajzen, 1975). The personal determinant is one's attitude toward the behavior. (Ajzen & Timko, 1986). Attitude is described as "a person's feelings toward and evaluation of some object, person, issue, or event" (Fishbein & Ajzen, 1975, p. 12). Attitudes can be either positive or negative, and the strength of the attitude is related to the success of achieving the behavior (Ajzen, n.d.). The social determinant is subjective norms, or a social pressure toward or against a particular behavior (Ajzen & Timko, 1986). Antecedent to the personal and social determinants of intention are a set of beliefs: behavioral beliefs and normative beliefs (Ajzen, 1991). In addition, external variables (including demographics, attitudes toward targets, personality traits, and other individual variables) affect the behavioral and normative beliefs (Montano & Kasprzyk, 2015).

Ajzen and Fishbein postulated that three conditions needed to be met for successful behavior change with the TRA. The behavior needed to be based on attitudes and intentions. Second, the individual's beliefs in a certain behavior led to some outcome or behavior. And third, the strength of the intentions was related to the likelihood of performing the behavior (Ajzen, 1991). The model developers recognized that behaviors that were outside of volitional control posed a barrier to the success of the model, identifying a limitation of the TRA. This limitation was the impetus for a modification of the TRA, which was named the TPB (Ajzen, 1991).

The TRA has been used as a framework to understand adolescents' intentions regarding alcohol use (Lorenzo-Blanco et al., 2016), teen pregnancy among American Indian girls (Dippel, Hanson, McMahon, Griese, & Kenyon, 2017), ethical behavior (Lehmann & Gorsuch, 2017), cyberbullying (Doane, Kelley, & Pearson, 2016), and communications regarding texting behavior while driving (Wang, 2016). The TRA has been used as a theoretical framework to predict the intention to use alcohol among 8th to 12th grade Latino/a adolescents who recently immigrated to the United States (Lorenzo-Blanco et al., 2016). Adolescents' intention to use alcohol was affected by perceived social norms against alcohol consumption. Dippel and colleagues (2017) used the TRA as a framework to identify attitudes among American Indian youth and intent to engage in risky sexual behavior resulting in pregnancy. Those adolescents who were teen parents demonstrated more negative attitudes regarding teen pregnancy than their peers who were not teen parents, affecting social norms within the community. In a study of adolescents attending a religious-based summer camp, attitudes regarding ethical behavior was the best predictor of behavior and was strongly correlated with religious beliefs (Lehmann & Gorsuch, 2017). The TRA was used as a framework for development of an online educational program to reduce cyberbullying behavior among a population of college students (Doane et al., 2016). A modified version of the TRA was used to predict automobile passengers' intentions to communicate with the driver to stop using text messaging while driving among a population of college students (Wang, 2016). This study demonstrated that passengers' attitudes regarding safety, self-efficacy, and social norms affected the decision to ask the driver, who was a friend, to stop texting.

Health Belief Model

The Health Belief Model (HBM) is a commonly used behavioral health theory borrowed from the discipline of social psychology. The HBM was developed and tested in the 1950s and 1960s by a group of social psychologists (Hochbaum, Kegeles, and Rosenstock) from the U.S. Public Health Service, who were trained in the phenomenological tradition, to explain and predict preventive health behavior (Rosenstock, 1974a). The central tenet of the HBM was that people held a set of beliefs about a disease, and the potential impact to their lives in order to avoid disease, with these beliefs resulting in action (or inaction) regarding a health behavior (Hochbaum et al., 1952; Rosenstock, 1974a).

During the 1950s, the climate of the Public Health Service was one of disease prevention rather than disease treatment. Hochbaum observed that few people took advantage of routine chest x-ray surveillance in the absence of overt symptoms for early detection of tuberculosis (TB) despite ready availability of the itinerant x-ray mobile within the community, and with little or no cost to the consumer (Hochbaum, 1956). The scientists posited that to avoid disease people needed to have a perception of susceptibility to disease, perception of the impact of the severity of the disease upon one's life, and perception of the benefits of action versus the barriers of inaction for health behavior change to occur (Hochbaum, 1956; Rosenstock, 1974a).

The earliest form of the HBM, based on the independent work of the model developers in the 1950s, included three constructs: perceived susceptibility, perceived seriousness, and perceived benefits of and barriers to taking action (Rosenstock, 1974a). In this early version, model developers identified the force to action with the combined levels of perceived susceptibility and perceived severity, and the preference of an action path with the perceived benefits minus the perceived barriers. However, the model was deemed incomplete, and the developers believed an additional variable of a trigger or cue was needed to spur action toward health behavior change (Rosenstock, 1974a). Therefore, the concept *cues to action* was added to the model. The concept of *self-efficacy*, borrowed from Bandura's social cognitive theory, was added in 1988 to capture the perception of one's ability to successfully change health behavior (Skinner, Tiro, & Champion, 2015). The constructs of the HBM are defined in Table 2-2.

Table 2-2

Definitions of Health Belief Model Constructs

Construct	Definition
Perceived susceptibility	The belief that a person may be vulnerable to a health condition (Hochbaum, 1956), or "the subjective risks of contracting the condition" (Rosenstock, 1974a, p. 330)

Perceived severity	The belief in the degree of seriousness contracting a health condition may cause within the individual (Rosenstock, 1974a)
Perceived benefits	The belief in positive consequences or advantages of a health behavior change (Skinner et al., 2015)
Perceived barriers	The belief in obstacles to or negative consequences of adopting a health behavior (Skinner et al., 2015)
Perceived threat	The combination of the perceived susceptibility multiplied by the perceived severity (Rosenstock, 1974a)
Cues to action	Internal or external triggers to provide an impetus for health behavior change (Rosenstock, 1974a)
Perceived self-efficacy	The perception of one's ability or confidence to be successful in adopting a health behavior change (Skinner, Tiro, & Champion, 2015)

The model developers recognized that other factors also played a role in the likelihood of taking action toward a preventive health measure. Modifying factors included demographic variables, such as age, sex, race, and ethnicity. Sociopsychological variables encompassed personality, social class, peer and reference group pressures, and structural variables, such as knowledge, and prior contact with the disease or health condition. Taken together, the modifying factors and sociopsychological variables may affect relationships among the other health beliefs (Rosenstock, 1974a). The health beliefs were organized into categories: modifying factors, individual beliefs, and likelihood of action.

The HBM researchers worked on solving pragmatic issues within the Public Health Service, and this served to test the model. Hochbaum studied TB prevention in adults in three cities to develop public health programming toward prevention and early detection of TB by routine chest x-ray surveillance (Hochbaum, 1956; Rosenstock, 1974b). Model testing expanded to cervical cancer and dental disease prevention, followed by prevention of communicable diseases, such as rheumatic fever, polio, and influenza (Rosenstock, 1974a). The HBM has been used as a theoretical framework across the life spectrum. Relevant to the proposed field of study for this dissertation, the HBM has been used to explain and predict behavior in adolescent research (Adeola, Omorogbe, & Johnson, 2016; Cao, Chen, & Wang, 2014; Chernick et al., 2015; Grandahl et al., 2016; Onyeabor, Martin, Orish, Sanyaolu, & Iriemanam, 2015; Schnall, Rojas, & Travers, 2015; Shakibnia, Timmons, Gold, & Garbers, 2017; Timmons, Shakibnia, Gold, & Garbers, 2017), sleep research (Olsen, Smith, & Oei, 2008; Shahrabani, Tzischinsky, Givati, & Dagan, 2014; Tyrrell, Poulet, Pepin, Veale, 2006), and technology-related research (Khoury et al., 2017; Lau, Wu, Gross, Cheng, & Lau, 2017; Wang, Wu, & Lau, 2016).

The HBM has been applied in adolescent research in contraception and sexual health among females (Chernick et al., 2015; Rahmati-Najarkolaei, Rahnama, Fesharaki, & Behnood, 2016; Shakibnia, Timmons, Gold, & Garbers, 2017; Timmons, Shakibnia, Gold, & Garbers, 2017), in prevention of sexually transmitted infections among males and females through human papillomavirus (HPV) awareness (Onyeabor, Martin, Orish, Sanyaolu, & Iriemanam, 2015) and HPV prevention (Grandahl et al., 2016), and human immunodeficiency virus (HIV) testing among minority adolescents (Schnall, Rojas, & Travers, 2015). The HBM has been applied to adolescent oral and dental health research to promote behavior change for tooth brushing behaviors to prevent dental disease (Rahmati-Najarkolaei, Rahnama, Fesharaki, & Behnood, 2016). Additional areas of adolescent research using the HBM as a theoretical framework include injury prevention for driving and road safety among high school students (Adeola, Omorogbe, & Johnson, 2016; Cao, Chen, & Wang, 2014).

A thorough literature review did not reveal use of the HBM in sleep research in the adolescent population; however, the HBM has been used in adult sleep research aiming to improve adherence to continuous positive airway pressure (CPAP) treatment for sleep apnea (Olsen, Smith, & Oei, 2008; Shahrabani, Tzischinsky, Givati, & Dagan, 2014; Tyrrell, Poulet, Pepin, Veale, 2006). Research involving technology used the HBM as a theoretical basis in screening for smartphone addiction among Brazilian undergraduate students (Khoury et al., 2017), and internet addiction among Chinese secondary school students (Lau et al., 2017; Wang, Wu, & Lau, 2017).

Theoretical Model Analysis and Critique

The TBP, TRA, and HBM have been evaluated as potential theoretical frameworks for this dissertation, and the TPB is selected as the guiding framework. This section will discuss the rationale for selection of this model. The TPB, the TRA, and the HBM are health behavior theories from the field of social psychology, with interest in how individuals make decisions regarding health behavior. The TRA is an earlier version of the TPB, and does not include the constructs *control beliefs, perceived behavioral control,* and *actual behavioral control,* to account for behavior not under volitional control. Adolescent behavior related to use of mobile phones within the bedroom setting may be a behavior not under volitional control, based on the need to maintain a state of constant connectedness with the peer group. In addition, although the TRA has been used in adolescent health research, and technology research, it has not been used in sleep research. While the TRA could be used as a theoretical framework for this work, perceived control is an important aspect of this research.

Both the TPB and the TRA employ a set of beliefs regarding health behavior, affecting a decision on behavior. The beliefs in the HBM are focused around a perception of risk regarding a disease or health condition, and the impact of that risk to the individual (Rosenstock, 1974a); whereas, the beliefs of the TPB are antecedent to attitudes and expectations regarding health behavior (Ajzen, 1991). Both theories use constructs related to benefits and barriers regarding health behavior. It can be inferred that the HBM constructs of *perceived benefits* and *perceived barriers* identify one's preconceived beliefs, or possibly attitudes, about the acceptability of behavior change, and may parallel the TPB construct of *attitudes toward the behavior.* In addition, it can be inferred that benefits and barriers in the TPB are embedded in the construct *control beliefs* by subscribing to the idea that the way in which control over a behavior is perceived is influenced by these benefits and/or barriers. Both theories have an aspect of strength of one or more constructs as being influential in behavior decisions. The HBM identifies that the strength of belief in health risk to the individual, with the constructs *perceived susceptibility* and *perceived severity,* is influential in the ultimate behavior decision (Rosenstock, 1974a); whereas, the TPB asserts that the strength of the attitude toward or against the behavior plays a pivotal role in behavioral intentions (Madden et al., 1992). While both models use a study of beliefs regarding health behavior, the purpose of this dissertation is not to evaluate health risk, but rather to evaluate the role of attitudes in mobile phone use within the bedroom setting among adolescents. In addition, adolescents are less mindful of risk, related to immaturity of the pre-frontal cortex, and risky decision-making ability (Casey, Jones, & Hare, 2008; Casey, Tottenham, Liston, & Durston, 2005; McCormick, Qu, & Telzer, 2016).

Both the HBM and the TPB have a construct that includes an influence affecting health behavior decision-making external to the individual. The HBM construct *cues to action* describes an external force or a salient cue that can prompt the individual toward or against a behavior (Rosenstock, 1974a). This cue may be manifested in the form of advertising, health care provider advice, or other cues. Similarly, the TPB construct *subjective norms* refers to the approval or disapproval, and influence of the social network, including family, friends, and other entities that contribute to the individual's belief system in making a behavior decision (Ajzen, 1991). The influence of the peer network is an integral part of adolescent development, as adolescents face the developmental task of identity versus role confusion, based on Erikson's stages of development (Erikson, 1994). During this developmental phase, the adolescent begins to develop his or her own identity, expands reliance on the peer network, and learns how to fit into society. The HBM constructs lack the influence of the peer network.

Both the TPB and the HBM have a measure, or a proxy measure, of self-efficacy as a construct. The HBP defines this construct as *self-efficacy,* borrowed from Bandura's Social Cognitive Theory (Bandura, 1986), and is defined as the belief in one's ability to make and sustain a behavior change (Rosenstock, 1974a). The TPB uses a proxy measure for self-efficacy, *perceived behavioral control* over the behavior, defined as the perception that one has either direct or indirect control over the behavior (Ajzen, 1991). The HBM assumes one has the ability to make a behavior change, while the TPB recognizes that some behaviors are not under volitional control. This may be a subtle difference in how self-efficacy is interpreted. Adolescent use of mobile phones within the bedroom setting may not be a behavior with high volitional control. Through the study of the concept of connectedness, discussed in Chapter 1, a need for constant connectivity with the social network is imperative among adolescents. This perception of the need to be connected is in line with the TPB construct *perceived behavioral control.*

Additionally, both theories recognize the effect of other variables in the model. The HBM construct *modifying factors* encompasses demographic variables, personality, and knowledge as factors that influence an individual's decision-making process (Rosenstock, 1974a). The TPB identifies similar influences in the form of *background factors,* which incorporate individual, social, and information variables (Ajzen 2017). The HBM is used extensively in general health behavior research among adolescents; however, it has not been used in sleep research in adolescents, and there are few studies in technology research incorporating the HBM as a theoretical framework. Conversely, the TPB has been used as a conceptual framework in adolescent health, sleep, and technology research.

The TPB is selected as the guiding framework for this dissertation. The TRA is an earlier version of the TPB, and lacks the construct *perceived behavioral control* to explain and predict behavior not under volitional control. The behavior of the bedtime mobile phone use by adolescents may be a behavior not under volitional control, limiting the usefulness of the TRA. The HBM focuses on reduction of risk with health behavior, while the TPB is focused on attitudes and intentions toward the behavior. The purpose of this dissertation is not related to risk reduction, rendering the HBM less relevant as a theoretical framework. The external influences of the adolescent peer group are a key component of behavior. The HBM external influence of *cues to action* does not incorporate the peer group as an influence. The construct *self-efficacy* in the HBM is an internal motivator; whereas, the TPB construct of *perceived behavioral control* is an external motivation for behavior, and is an important variable in this dissertation, based on the need for constant connectivity to the peer network via a mobile phone. Although the HBM is used extensively in health behavior research, it has not been used in sleep research in adolescents. The TPB has been more widely used in areas of research specific to adolescents, sleep, and technology. For these reasons, the TPB is the most appropriate theoretical framework for this dissertation.

Adolescent Development

The second decade of life, termed adolescence by the World Health Organization (WHO, 2017), is a period of rapid human development, including biological, psychosocial, and cognitive/intellectual maturity in the transition from child to adult. Although pubertal development resulting in reproductive maturity is typically the defining milestone of adolescence, non-reproductive traits such as social, emotional, and cognitive developmental changes also occur (Walker et al., 2017). The age range of 10-19 years spans a wide breadth of youngsters, with varying levels of physical, social, and emotional development. This age range captures the period from onset of puberty to completion of puberty and into the post-pubertal period, as well as related physical, psychosocial, and emotional development.

Biological Development

Adolescent development is a complex biological phenomenon with physical and neuroendocrine (hormonal) changes to the body, mediated by the neuroendocrine system (Chulani & Gordon, 2014). Puberty is the hallmark of adolescent development, described as "the morphological and physiological changes that occur in the growing boy or girl as the gonads change from the infantile to the adult state" (Marshall & Tanner, 1986, p. 171). As a frame of reference, Tanner (1962) described a continuum of five stages of puberty for penis and testicular size, and pubic hair development in males, and breast and pubic hair development in females, ranging from infantile/prepubertal development (stage 1) through full adult development with reproductive maturity and fertility (stage 5). Stages 2-4 describe intermediate developmental stages.

Physical developmental changes begin with activation of the hypothalamic-pituitary-gonadal (HPG) axis, which has been in a dormant state since early infancy. The HPG axis stimulates production of gonadotropin releasing hormone (GnRH) from the hypothalamus in a pulsatile manner, which exerts a stimulatory effect on the anterior pituitary gland to produce luteinizing hormone (LH) and follicle-stimulating hormone (FSH). LH and FSH provide additional stimulation of the sex steroids, estrogen and testosterone, from the ovaries and testes respectively. The sex steroids, combined with activation of the hypothalamic-pituitary-adrenal (HPA) axis stimulate development of secondary sexual development characteristics of puberty (Chulani & Gordon, 2014; Rogol, Roemmich, & Clark, 2002).

An adolescent growth spurt accompanies pubertal progression, with rapid growth rates second to neonatal growth. The sex steroids, testosterone and estrogen, mediate accelerated growth rates during adolescence with females typically achieving peak growth velocity during stage 2 and 3 of pubertal development, and males achieving peak growth velocity during stages 4 and 5. Height gains during puberty may be up to 9 cm per year in females and 10.3 cm per year in males (Rogol et al., 2002).

Psychosocial Development

Brain development

Changes to the brain during adolescence are reflective of maturational changes in development and are independent of pubertal stimulation (Walker et al., 2017). Neuroimaging studies (functional MRI [fMRI]) demonstrate immaturity and delayed development in the adolescent pre-frontal cortex area of the brain, responsible for decision-making skills. Immaturity in decision-making often leads to increased risk-taking and impulsivity among adolescents (Casey, Jones, & Hare, 2008; Casey, Tottenham, Liston, & Durston, 2005; McCormick, Qu, & Telzer, 2016; Tamnes et al., 2017). Changes in cognitive thought patterns during adolescence transition from concrete thought processes to reasoning, logical, moral, and abstract thought processes. Maturity of the prefrontal cortex is not fully complete until young adulthood (Tamnes et al., 2017; Walker et al., 2017).

Interpersonal relationships

Adolescence is a period of increased independence and autonomy as preparation for transition from parental to autonomous control. Adolescents' acquisition of social skills is facilitated by spending more time interacting with peers than parents. This shift in social context may cause real or perceived adolescent/parent conflict (McCormick, Qu, & Telzer, 2016; Spear, 2000).

Adolescent Sleep

An integral part of adolescent development includes biological and psychosocial changes in sleep patterns, such as altered sleep timing, altered hormonal influences, and social aspects of sleep. Early research into adolescent sleep patterns began in the 1970s with the work of Mary Carskadon, a neuro- and biobehavioral scientist, who became a pioneer in the field of adolescent sleep research (Brown University, 2017).

Sleep Recommendations for Adolescents

A basic question arises when considering optimal sleep recommendations for adolescents. Do adolescents require less sleep as they move through the second decade of life? Or are the sleep needs constant and is the reality of the amount of sleep obtained a function of lifestyle, such as academics, social network, and leisure time use? Early work in the sleep needs of adolescents identified pubertal changes in sleep architecture, but not a change in the amount of sleep need across adolescence (Carskadon et al., 1980). Carskadon and colleagues (1980) evaluated a group of adolescents in a longitudinal manner over several years as they progressed through puberty. Adolescents were evaluated in the sleep laboratory setting for 3-day periods of time during the summer break from school over several years. Without the constraints of a school schedule, adolescents' sleep need remained constant throughout puberty at approximately 9.2 hours nightly (Carskadon et al., 1980). A recent study evaluated sleep need in 15-17-year old adolescents to be approximately 9 hours of sleep needed nightly (Short, Weber, Reynolds, Coussens, & Carskadon, 2018). Both the National Sleep Foundation (NSF) (Hirshkowitz et al., 2015) and the American Academy of Sleep Medicine (AACM) (Paruthi et al., 2016) have issued recommendations of optimal sleep needs for adolescents, based on a multidisciplinary expert panel evaluation of empirical evidence in the literature. Both the NSF and AASM panels issued optimal sleep durations as follows: 9-11 hours per day for school aged children (6-12 years of age), and 8-10 hours per day for adolescents (13-18 years of age) (Hirshkowitz et al., 2015; Paruthi et al., 2016). Based on these sources of evidence evaluation, the CDC has issued the same recommendations (CDC, 2017b).

Biological Influences of Adolescent Sleep

Sleep is regulated by dual interactive but independent processes (models) within the brain. The sleep-wake homeostasis (Process S) regulates sleep amount and intensity of sleep, while the internal clock or circadian rhythm (Process C) regulates the sleep and wake patterns in a cyclical manner (Carskadon & Tarokh, 2013). Prior to adolescence, bedtime and rise times are relatively stable, with younger children demonstrating consistency in sleep patterns. However, sleep and wake patterns change significantly during the second decade of life in tandem with pubertal changes of adolescence (Wolfson & Carskadon, 1998).

Sleep-wake homeostasis

The sleep-wake homeostasis system is a compensatory system, responsible for regulation of sleep pressure or sleep need during periods of wakefulness. The pressure to sleep builds after an extended period of wakefulness, followed by dissipation of the pressure after a period of recovery sleep (Jenni et al., 2005). The longer period of time one remains awake the more sleep pressure increases, signaling the need for sleep. Conversely, as one sleeps the sleep pressure is eased, promoting wakefulness.

Circadian timing

The body's circadian timing is controlled by a pair of suprachiasmatic nuclei (SCN), a pacemaker system located within the hypothalamus of the brain. Light is a powerful stimulus for circadian timing. External light enters the retina of the eyes, where it is transferred through intrinsically photosensitive retinal ganglion cells (ipRGC). The ipRGC are especially sensitive to short wavelength blue light. These impulses are transmitted via a nonvisual pathway through the retinal hypothalamic tract to the SCN in the hypothalamus. The SCN serves as a pacemaker for regulation of circadian function of multiple body activities: activity/rest, sleep/wake, hormonal release, and metabolic processes (Carskadon & Tarokh, 2013). The SCN maintains circadian timing of the sleep/wake cycle to approximately a 24-hour day.

Melatonin, a hormone secreted from the pineal gland, is under control of the circadian cycle from the SCN and is sensitive to light and dark cues. Melatonin levels are extremely low during the day. The release of melatonin is inhibited by light (Crowley et al., 2007). Melatonin is naturally timed to be released during darkness, and light from natural or artificial sources within the environment inhibit melatonin (Carskadon & Tarokh, 2013; Tarokh, Saletin, & Carskadon, 2016). Exposure to bright light at the wrong time can disrupt melatonin secretion, making it difficult to fall asleep (Carskadon et al., 1998).

Changes in sleep during adolescence

Several changes to sleep patterns occur during adolescence: changes in sleep pressure, circadian rhythm, melatonin release, and daytime sleepiness. Changes in sleep patterns are associated with the sex steroids, which rise during puberty (Manber & Armitage, 1999). Although adolescents typically obtain insufficient quantities of sleep, the sleep need does not change during the adolescent period (Carskadon, Harvey, Duke, Anders, & Dement, 1980; Tarokh, Saletin, & Carskadon, 2016; Wolfson & Carskadon, 1998).

Change in the sleep/wake homeostasis system occur as physical maturity during adolescence progresses. Sleep pressure is slower to build up among more physically mature adolescents (i.e., those in Tanner 5 stage of puberty compared with Tanner 1-2 stage of puberty).

This phenomenon causes the more mature adolescent to take longer to fall asleep, and to stay up later in the evening without feeling sleep pressure and the need to go to sleep (Jenni et al., 2005).

Changes in the circadian timing system during adolescence demonstrate a shift to a later sleep and wake-up schedule, associated with the advanced stage of puberty (Carskadon, Vieira, & Acebo, 1993). Weekday sleep patterns differed from weekend sleep patterns, with a shift to later bedtimes and significantly later rise times on weekends, which are not constrained by weekday schedules (Carskadon, Vieira, & Acebo, 1993). This phase shift of the circadian regulator system impacts timing of sleep and secretion of melatonin from light cues. Adolescents at early to mid-pubertal stages demonstrated less response to evening light exposure and had greater suppression of melatonin secretion than adolescents at later stages of puberty (Crowley, Cain, Burns, Acebo, & Carskadon, 2015; Crowley & Eastman, 2017). Japanese junior high school students were exposed to various levels of light to assess melatonin secretion (Harada, 2004), with lower melatonin secretion when exposed to bright light before sleep. Weekly adolescent sleep patterns typically include later bedtimes on school days, with fixed rise times and sleep insufficiency, followed by later bedtimes and rise times on weekends (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). This phenomenon of different sleep patterns between weekdays and weekends, with sleep loss during the week and an attempt at sleep recovery on weekends is termed social jetlag (Wittman, Dinich, Merrow, & Roenneberg, 2006).

Changes in daytime alertness/sleepiness are observed with pubertal changes in sleep patterns. Reduction in nighttime sleep quantity, as well as inconsistent weekday and weekend sleep schedules may contribute to daytime sleepiness. Carskadon et al. (1980) assessed daytime sleepiness in a longitudinal study during summer break from school in a sample of adolescents. Daytime sleepiness increased with Tanner stage of puberty, with subjects with Tanner sexual development stage 3 and 4 exhibiting greater daytime sleepiness than those with Tanner stage 1 or 2. Daytime sleepiness was more marked in the afternoon than at any other times during the day (Carskadon et al., 1980).

Changes in the internal time clock associated with puberty are not unique among human adolescents. Homeostatic and circadian patterns of other mammals during the pubertal transition from child to adult have been studied for comparison of sleep regulatory patterns. Pubertal sleep patterns were compared among adolescent human, rhesus monkey, degu (a rat-like rodent), laboratory rat, laboratory mouse, and fat sand rat species (Hagenauer, Perryman, Lee, & Carskadon, 2009; Hummer & Lee, 2016). Although the pubertal period varies widely among these species, similar changes in the sleep regulatory mechanisms are observed. Among mammalian species, there is a shift to a later timing of sleep and changes in sleep homeostasis, with adolescent mammals displaying a likelihood to develop sleep pressure more slowly and the propensity to stay awake later in the evening (Hagenauer et al., 2009; Hummer & Lee, 2016). This suggests a physiologic basis for altered sleep patterns rather than environmental stimuli.

Psychosocial Influences of Sleep

In addition to biological factors, lifestyle, family, school, community, cultural, and environmental factors during adolescence may affect sleep. The current adolescent lifestyle is brimming with academic, social, sports, and other activities competing for time. Additionally, many adolescents seek after-school or weekend employment to earn money. These activities may extend into the evening hours, limiting the opportunity for sleep. Caffeine and energy drinks may be consumed by adolescents as an aid to stay awake at night or during the school day (Calamaro et al., 2009).

Within modern society, school start times for adolescents typically begin early in the morning, sometimes as early as 7:15 a.m., which is incongruent with adolescent sleep patterns (Carskadon et al., 1998; Martin, Gaudreault, Perron, & Laberge, 2016). Ready availability of multiple technology devices within the home or contained within small handheld portable devices provide the opportunity for unlimited exposure to entertainment (Carskadon, 2011), and communication with peers via social media or mobile phones on a 24/7 schedule (Carskadon, 2011; Hale & Guan, 2015). Technology use provides exposure to artificial light emissions disrupting melatonin release at the optimal time (Chang, Aeschbach, Duffy, & Czeisler, 2015; Touitou, Touitou, & Reinberg, 2016). As teens develop increasing levels of independence, they may self-select bedtime rather than a parent-set bedtime (Carskadon, 2011). Social stressors, such as fears, anxieties, and distressing thoughts may make falling asleep difficult (Dahl & Lewin, 2002).

Environmental factors that may impact sleep include external conditions such as noise and safety (Halperin, 2014), light (Bartel, Gradisar, & Williamson, 2015; Roenneberg & Merrow, 2007), temperature (Okamoto-Mizuno & Mizuno, 2012), and family environment (Bartel et al., 2015). Environmental noise pollution is associated with sleep disturbances, daytime sleepiness, and decreased cognitive performance (Halperin, 2014). Room temperatures that are too warm or too cool affect ability to fall asleep or stay asleep (Okamoto-Mizuno & Mizuno, 2012). Ingestion of stimulants, such as caffeine (Calamaro et al., 2009), alcohol, and nicotine are associated with reduced sleep quantity, and poorer sleep quality (Dimitriou, Knight, & Milton, 2015; Johnson, Roth, & Breslau, 2006). A home environment can influence the ability to sleep. Homes with a negative environment were associated with later bedtimes, short sleep duration, and poorer sleep quality in a meta-analysis; conversely, a positive home environment was protective of healthy sleep behaviors (Bartel et al., 2015).

Sleep Insufficiency in Adolescence

Sleep insufficiency among adolescents is a worldwide public health concern (Gradisar et al., 2011). Worldwide trends in sleep patterns demonstrated similar patterns among Asian, European, and American adolescents in a meta-analysis of 41 surveys of sleep patterns and sleep problems, with delayed bedtimes, less sleep obtained on school nights, and later wake up times on weekends (Gradisar et al., 2011). Insomnia and daytime sleepiness were the most frequently reported sleep problems in adolescents (Gradisar et al., 2011). In the United States, sleeping less than 8 hours per night is prevalent in high school students, with 25.4% of students sleeping 8 or more hours in the 2017 Youth Risk Behavior Survey (CDC, 2018). Among 9th grade high school students, 34.8% of students reported obtaining 8 or more hours of sleep per night, whereas only 17.6% of students in 12th grade reported obtaining 8 or more hours of sleep each night (CDC, 2018). In participating Pennsylvania high schools, 19.4-21.5% of students reported obtaining 8 or more hours of sleep nightly (CDC, 2018).

Biopsychosocial factors contribute to sleep insufficiency in adolescents (Owens, 2014). Biological factors include changing adolescent sleep patterns and sleep timing related to pubertal development (Carskadon et al., 1993), and greater sleep variability between weekdays and weekends (Gradisar et al., 2011). Psychological factors are related to caffeine intake (American Academy of Pediatrics [AAP], 2014; Calamaro et al., 2009), and the need for constant connectedness with the social network. Social factors include early school start times (Bowers & Moyer, 2017; Minges & Redeker, 2016), and the presence and use of technology within the bedroom (Bartel et al., 2015; Cain & Gradisar, 2010; Calamaro et al., 2009; Carter et al., 2016; Hale & Guan, 2015).

Physiological changes to sleep patterns mediated by puberty result in delayed sleep timing, delay in melatonin secretion, and a circadian phase shift to a later chronotype (Wolfson & Carskadon, 2003). Biological changes in sleep patterns related to pubertal development have been discussed above. Insufficient sleep quantity or sleep quality during weekdays contributes to sleeping longer on weekend or non-school days, resulting in higher sleep variability and social jetlag (Komada et al., 2016; Whittmann et al., 2006).

A study of 100 middle and high school students to evaluate nighttime technology use, caffeine intake, and sleep patterns determined that 85% of the sample consumed caffeinated beverages, including coffee products, tea, energy drinks, and soft drinks (Calamaro et al., 2009). Those study participants who used multiple forms of electronic media after 9 p.m. were more likely to consume higher amounts of caffeine, sleep fewer hours at night, fall asleep in school, and take daytime naps. Being connected with the adolescent social network for fear of being out of touch with peers, or to answer phone calls, text messages, or social media communications immediately contributes to sleep insufficiency (Walsh et al., 2008).

Early school start times for adolescents contribute to short sleep duration, increased daytime sleepiness, falling asleep in class, and tardiness (Bowers & Moyer, 2017; Minges & Redeker, 2016). High school students who transitioned from a later school start time to an earlier time demonstrated earlier rise times, but no change in bedtime, resulting in less sleep duration, and more daytime sleepiness (Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). Similarly, comparison of school start times within two public high schools demonstrated shorter sleep duration and more daytime sleepiness in the school with the earlier start time (Dexter, Bijwadia, Schilling, & Applebaugh, 2003). A study comparing a 25-minute delay in school start time at an independent boarding school resulted in increased sleep duration, less daytime sleepiness, and less caffeine consumption with the later start time; however, reverting to the earlier start time negated these results (Boergers, Gable, & Owens, 2014). Technology use within the bedroom setting and the impact on sleep insufficiency will be discussed in detail in a subsequent section of this dissertation.

Consequences of sleep insufficiency and daytime sleepiness among adolescents include poorer academic performance (Short et al., 2013; Wolfson & Carskadon, 2003), increased risk of motor vehicle crashes in adolescent drivers (Danner & Phillips, 2008), and an increase in risk-taking (Shochat et al., 2014). A systematic review of articles on the impact of sleep insufficiency on school performance demonstrated poorer grade performance and falling asleep in class in those students who obtained insufficient or irregular sleep (Wolfson & Carskadon, 2003). Sleep duration, sleep quality, and chronotype were evaluated for the effects on alertness, depression, and academic performance in a study of 385 high school students (Short et al., 2013). Those students with worse sleep quality or an evening chronotype reported poorer academic performance and depression; however, sleep duration did not have an effect on academic performance (Short et al., 2013).

An increase in risk-taking behaviors is associated with sleep insufficiency. Adolescent drivers who obtained insufficient sleep and drove while sleepy were more likely to experience motor vehicle crashes than those who obtain ample sleep. Assessment of the prevalence of motor vehicle crashes among adolescent drivers following a 1-hour delay in school start times resulted in fewer crashes (Danner & Phillips, 2008). Soleimanloo, White, Garcia-Hansen, and Smith (2017) conducted a systematic review of 16 studies to evaluate the performance of young drivers who were suffering from sleep deprivation. Sleep loss was associated with an increase in line crossing, speed-related events, and crash events, although the quality of evidence in the review was low. Male adolescents who obtained inadequate sleep were more likely to engage in risky behaviors, such as fighting, theft, substance use (alcohol, smoking, and drugs), and females were more likely to contemplate or attempt suicide in a systematic review (Shochat et al., 2014).

Policy Considerations Related to Sleep Insufficiency

Policy considerations related to sleep insufficiency encompass school start times and bedtime technology use. Early school start time for adolescents is not conducive to the biological changes occurring during adolescence, reinforcing sleep insufficiency (AAP, 2014; Carskadon & Roth, 2000; Hafner, Stepanek, & Troxel, 2017; Nahmod, Lee, Buxton, Chang, & Hale, 2017; Wheaton, Ferro, & Croft, 2015). Advocacy for changing school start times in middle and high schools has been ongoing for several decades (Carskadon et al., 1998) with little improvement in numbers of schools in the United States who modified start times to meet the adolescent biological state for sleep sufficiency (Hafner et al., 2017; Wheaton et al., 2015). Approximately 80% of U.S. high schools begin classes prior to 8:30 a.m., with a mean start time of 8:03 a.m. (Hafner et al., 2017; Wheaton et al., 2015). The *ZZZ's to A's Act* was introduced in the U.S. Congress to bring attention to school start times in American high schools, by directing the Secretary of Education to study school start times and the impact on high school students' health and academic performance (House of Representatives Bill H. R. 5678, 2014). Policy statements have been issued by both the CDC and the AAP for later school start times for both middle and high school students, both advocating for no earlier than 8:30 a.m. (AAP, 2014; CDC, 2017c; Wheaton et al., 2015). Start School Later is an independent group of health care and sleep professionals, educators, parents, and others, who promote education and advocacy regarding school start times to facilitate improved adolescent health and sleep adequacy (Start School Later, 2019).

The impact of later school times on adolescent sleep health is evident within the literature (Bowers & Moyer, 2017; Carskadon et al., 1998; Hafner et al., 2017; Martin, Gaudreault, Perron, & Laberge, 2016; Minges & Redeker, 2016; Owens, Dearth-Wesley, Herman, Oakes, & Whitaker, 2017). Comparison of the transition from a later school start time to an earlier time revealed an earlier arise time with less total sleep, longer time to fall asleep, and increased daytime sleepiness (Carskadon et al., 1998). Transition to a later school start time for adolescents demonstrated longer sleep times, and less daytime sleepiness in Canadian (Martin et al., 2016) and American high school students (Owens et al., 2017). Meta-analyses of studies evaluating school start time and sleep outcomes among adolescents found later school start times correlated with longer sleep duration, and less daytime sleepiness (Bowers & Moyer, 2017; Minges & Redeker, 2016). A study by the Rand Corporation (Hafner et al., 2017) evaluated adolescent health outcomes and economic considerations of later school start times. Moving high school start times to 8:30 a.m. predicted economic gains, in addition to improved adolescent sleep health.

The AAP has issued a policy statement regarding technology use by children and adolescents from 5 through 18 years of age (AAP, 2016). Recommendations include establishment of a media plan within families to monitor technology use, promote healthy and safe technology use, and education on the benefits and risks related to technology use. Hale (et al., 2018) advocates for establishing limitations on electronic media within the bedroom setting to promote healthy sleep habits, education on the dangers of unchecked media usage, and additional research on the effects of media use as well as child and adolescent sleep and general health.

Electronic Media and Adolescents

Technology Use in Adolescents

Use of electronic media devices is a mainstay for adolescents and is an essential part of adolescent life. Widespread availability of smart phone devices enables adolescents to easily access a wide variety of electronic media. More than 90% of adolescents access the internet daily via use of a mobile device (U.S. Department of Health and Human Services, 2016). Over 70% of adolescents use social media frequently (Lenhart, 2015), with Instagram, Snapchat, Facebook, and Twitter used most frequently among adolescents, according to an AP-NORC poll of 790 adolescents (AP-NORC, 2018). Mobile phones were typically used for multiple purposes in a sample of Hong Kong adolescents (Kwok, Lee, & Lee, 2017). These adolescents reported using mobile phones for studying, leisure activities, text messaging, browsing the internet, social media, gaming, and watching movies. Sending and receiving text messages in the bedroom from a mobile phone is a common media habit (Troxel, Hunter, & Scharf, 2015; Vernon, Modecki, & Barber, 2018). Collection of outbound text messaging prevalence via a mobile phone app observed that nearly all adolescents in the study sent text messages after 8 p.m., and 70% sent outgoing text messages after 10 p.m. and throughout the night (Troxel, et al., 2015).

Bedtime Electronic Media Use in Adolescents

Use of electronic media in the bedroom is pervasive among adolescents (Calamaro et al., 2009). The mobile phone is the most commonly used media device within the bedroom setting (Hysing et al., 2015). The most frequently used mobile phone device features are text messaging and phone calling (Bruni et al., 2015). Use of mobile media devices are reported in the pre-bedtime period, after lights out, and during the nighttime (Bruni et al., 2015; Fobian, Avis, & Schwebel, 2016; Gamble et al., 2014; Gradisar et al., 2013; Johannson, Petrisko, & Chasens, 2016; Munezawa et al., 2011; Pieters et al., 2014; Van den Bulck, 2007).

In a study assessing the effects of media use in the hour prior to bedtime among Belgian youth, 86% of study participants reported having a mobile phone in the bedroom, and 48% reported using their phones in the pre-bedtime period (Pieters et al., 2014). Similarly, about 80% of Australian adolescents reported taking the phone to bed or having the phone in the bedroom overnight in a large study to evaluate sleep habits (Gamble et al., 2014). Among 1656 Belgian adolescents surveyed, 55% reported taking a mobile phone to bed, and 18% of those used their phone for calls or text messaging during the night (Van den Bulck, 2007). In a cross-sectional study of 850 Italian adolescents, after 9 p.m. nearly half send or receive text messages, and roughly a quarter of adolescents talk on the phone (Bruni et al., 2015). Among Japanese high school students in a nationwide survey of 94,777 adolescents, 8.3% make phone calls and 17% send or receive text messages after lights out at least once weekly (Munezawa et al., 2011). American adolescents (n=171) reported use of mobile phones in bed among 72% (Gradisar et al., 2013) and 76% (Johannson et al., 2016) of participants in the 2011 Sleep in America polls. Fobian et al. (2016) studied a group of 55 adolescents (mean age 14.86 years) to evaluate sleep efficiency and use of bedtime media. The study observed 84% of adolescents used electronic media after bedtime. Sleep efficiency was negatively correlated with the amount of time spent on mobile phone access after bedtime, and the number of times being awakened for a mobile phone (Fobian et al., 2016). Adolescents report being awakened by a mobile phone at least a few times per week, with night awakenings caused more frequently by text messages than by phone calling (Adachi-Mejia et al., 2014; Gradisar et al., 2013; Munezawa et al., 2011).

Adolescent Demographic Differences

Subgroups of adolescents were examined for differences in age, gender, geographic region, and to a lesser extent, race/ethnicity, to determine whether there are unique differences among individual adolescents or whether adolescents' bedtime small screen media habits are universal. These demographic differences are assessed to evaluate whether adolescents in most cultures have the same usage patterns regarding mobile technology.

Age

Based on the WHO definition of adolescence, the age group spans a 10-year time frame. Approximately 72% of adolescents use their cell phones pre-bedtime (Gradisar et al., 2013). Older adolescents (typically those in later adolescence or high school age) used mobile phones pre-bedtime or after lights out more frequently than younger adolescents (typically those in early adolescence or middle or junior high school age) (Bruni et al., 2015; Falbe et al., 2015; King, Delfabbro, Zwaans, & Laptsis, 2014; Kubiszewski, Fontaine, Rusch, & Hazouard, 2014; Munezawa et al., 2011). In contrast, one study (Oshima et al., 2012) reported younger adolescents were more likely to use mobile phones after lights out than older adolescents. Unique foci for this study were the outcomes of suicidal ideation and self-injury. Sleep was measured as a covariate. Self-reported data regarding suicidal ideation and self-injury within the previous year, and concurrent mobile phone use were collected (Oshima et al., 2012). Older adolescents were more likely to take their phones to bed (Adachi-Mejia et al., 2014), more likely to own a smart phone, rather than a conventional mobile phone (Lemola et al., 2015), and more likely to spend time on the internet, social media and sending text messages than younger adolescents (Adachi-Mejia et al., 2014; Lemola et al., 2015; Munezawa et al., 2011).

Gender

Gender representations were reported in multiple studies, with approximately evenly balanced male and female gender distributions. Females were more likely than males to use mobile phones in the pre-bedtime period and after "lights out" (Bruni et al., 2015; Fobian et al., 2016; Gradisar et al., 2013; Grover et al., 2016; Hysing et al., 2015; Lange et al., 2017; Munezawa et al., 2011; Nathan et al., 2013; Oshima et al., 2012; Pieters et al., 2014). Females also were more likely than males to take their mobile phone to bed, to use the phone as a wake-up alarm (Adachi-Mejia et al., 2014), and to be awakened by media (Adachi-Mejia et al., 2014; Fobian et al., 2016; Munezawa et al. 2011; Nathan & Zeitzer, 2013). Males spent more time using the phone for video gaming than talking, texting, or social media (Hysing et al., 2015; King et al., 2014), and spent more time using media on both weekdays and weekends than females (King et al., 2014; Lange et al., 2017). Negative sleep outcomes were reported more commonly in females than males among those adolescents who used electronic media at bedtime and after "lights out", including increased daytime sleepiness (Grover et al., 2016; Munezawa et al., 2011; Nathan & Zeitzer, 2013), insomnia complaints (Lange et al., 2017), longer sleep onset latency (King et al., 2014), night awakenings (Nathan & Zeitzer, 2013), and inadequate sleep quantity (Johannson et al., 2016; Munezawa et al., 2011).

Country of origin and race/ethnicity

Studies in this review originated from sixteen countries in five regions worldwide. Europe and North America had the most representation of studies (N=15 and N=10, respectively), followed by Asia (N=8), Australia (N=5), and Middle East (N=1). Articles included in the review spanned a wide geographic area, with most world regions, except South America and Africa, included in the review. Use of small screen media devices was universal; however, there were no differences between country of origin or geographic area with respect to sleep outcomes. Although few studies reported ethnic and/or racial distributions, Hispanic and non-Hispanic Black adolescents were more likely than Caucasian adolescents to sleep near a small screen and obtain fewer minutes of sleep (Falbe et al., 2015), more likely to send text messages during the night, be awakened by media, and have later sleep onset (Fobian et al., 2014). Gradisar (2013) described greater use of mobile phones among Black and Hispanic adolescents than Caucasians in an analysis of the National Sleep Foundation's 2011 Sleep in America poll; however, the racial distribution was predominantly Caucasian (80%).

Effects and Influences of Bedtime Electronic Media Use on Sleep Outcomes

Use of mobile devices within the bedroom setting impacts sleep in adolescents by association with reduced sleep quantity, poorer sleep quality and increased next-day sleepiness. Mobile devices left powered on in the bedroom but not used were disruptive of sleep just as actively as was using a mobile device (Buxton et al., 2015; Carter et al., 2016; Falbe et al., 2014). Sleep duration with use of mobile devices may be negatively affected by delays in bedtime (Adachi-Mejia et al., 2014; Bartel et al., 2015; Garmy & Ward, 2017; Gamble et al., 2014; King et al., 2014; Kubiszewski et al., 2014; Nose et al., 2017), sending or receiving text messages or phone calls after lights out (Chahal, Kuhle, & Veugelers, 2013; Lemola et al., 2015; Schoeni et al., 2015), and continued access to mobile devices throughout the night (Amra et al., 2017).

Poorer sleep quality is associated with the presence of mobile devices in the bedroom left on at night (Buxton et al., 2015; Carter et al., 2016), as well as with active use of mobile devices before and after bedtime (Amra et al., 2017; Carter et al., 2016; Woods & Scott, 2016). Extended duration of mobile technology devices at night resulted in poorer sleep quality, longer time to fall asleep, and earlier wake time (Mak et al., 2014; Oshima et al., 2012). Adolescents who engaged in mobile phone use prior to bedtime and during the night (Grover et al., 2016; Nathan & Zeitzer, 2013; Van den Bulck, 2007) or combined mobile technology use with caffeine at bedtime (Calamaro et al., 2009; Jun, Lee, & Baik, 2017) reported increased daytime sleepiness. Nighttime awakenings for text messages or phone calls resulted in poorer sleep quality and increased daytime sleepiness (Gradisar et al., 2013; Adachi-Mejia et al., 2014; Johannson et al., 2016).

Sleep Measurement Tools

Sleep measurement tools are used to assess biopsychosocial aspects of sleep, including sleep architecture, sleep duration, sleep quality, and daytime sleepiness. Measurement tools include objective tools, such as polysomnography (PSG) and actigraphy, and subjective tools, such as questionnaires and interviews. Each type of measurement tool is useful, and each tool has its strengths and application for sleep measurements. Although sleep duration is commonly measured and provides some useful information, assessment of healthy sleep in adolescents requires more than documentation of sleep duration (Erwin & Bashore, 2017). Furthermore, different types of measurement tools can assess various aspects of sleep, such as sleep architecture or sleep quality, and measurement tools are specific to certain sleep constructs. An objective measurement tool to evaluate activity as a proxy for sleep is not able to measure a subjective assessment of sleep quality. Conversely, a self-report measurement tool designed to evaluate sleep quality is not able to measure a biophysiological assessment of sleep architecture.

Objective and subjective measurement tools are discussed in the following section, with applicability to measure specific sleep constructs.

Objective sleep measures

Objective sleep measurement tools measure sleep and wake patterns directly. Polysomnography and actigraphy are objective sleep measurement modalities. These tools involve use of specialized equipment to measure the biophysiological aspects of sleep.

Polysomnography

PSG originated in the late 1950s with the evolution of sleep medicine, based on previous observations of rapid eye movement (REM) sleep by Kleitman (Chesson et al., 1997), and the ability to measure physiologic brain activity (Deak & Epstein, 2009). PSG provides an analysis of sleep architecture, specific stages of REM and non-REM sleep, with measurements of multiple biophysiological parameters. The parts of the PSG include: electroencephalogram (EEG) to measure brain waves and stages of sleep, electrooculograms (EOG) to measure eye movements, electromyogram (EMG) to measure muscle movements, electrocardiogram (ECG) to measure heart rate, chest and abdominal respiratory monitors, and capnography to measure respiratory rate and nasal air flow, pulse oximetry to measure oxygen saturation, microphone to measure snoring, and video recording for direct observation of body position and sleep habits (Chesson et al., 1997; Ibanez, Silva, & Cauli, 2018; Lewandowski, Toliver-Sokol, & Palermo, 2011). PSG provides multiple body system analyses of sleep-related biophysiological responses involved in sleep, such as neurophysiologic, cardiorespiratory, and other parameters, over an extended period of several hours (Chesson et al., 1997; Jafari & Mohsenin, 2010). PSG can be used in diagnosis of sleep-related health conditions, such as obstructive sleep apnea, narcolepsy, limb movement disorders, or insomnia (Deak & Epstein, 2009).

PSG is typically performed in a specialized sleep laboratory setting, with advanced equipment to measure the multiple physiological parameters related to sleep described above. Sleep laboratories initially collected PSG data by ink markings on paper, which consumed excessive amounts of paper and ink. PSG data are currently collected and stored electronically, providing improvement in data collection, and a more practical way to store voluminous amounts of data (Jafari & Mohsenin, 2010). Certified sleep technologists are in attendance during the laboratory PSG (Deak & Epstein, 2009). These technologists are allied health professionals who have received formal training and certification to perform PSG under the supervision of a licensed physician. Their responsibilities include education, evaluation, treatment, and follow-up of sleep disorder patients (American Association of Sleep Technology, n.d.). The role of the sleep technologist includes placement of various electrodes to monitor biophysiological parameters, setting up the recordings, and direct observation of study participants. Correct placement of electrodes is a critical step to obtaining quality data collection (Jafari & Mohsenin, 2009). Portable PSG, also termed Out of Center Sleep Testing (OCST), can be performed within the home setting in children and adolescents (Brockmann, Perez, & Moya, 2013; Certal, Camacho, Winck, Capasso, Azevedo, Costa-Pereira, 2013), as well as adults (Bruyneel & Ninane, 2014; Iber et al., 2004; Jafari & Mohsenin, 2010; Kapoor & Greenough, 2015).

Multiple levels of PSG are able to be performed, with variability in the physiologic parameters obtained (Jafari & Mohsenin, 2010). Level 1 PSG is conducted within the laboratory setting with constant attendance of a sleep technologist and includes a minimum of seven physiologic parameters: EEG, EOG, chin EMG, airflow, respiratory effort, oximetry, EMG, and video monitoring (Ferber et al., 1994; Jafari & Mohsenin, 2010). Portable PSG (OCST) can be performed within the home setting with specialized equipment and trained staff to apply electrodes, and set up the recording of data, but is not attended by staff during overnight sleep measurement. The level 2 PSG may be performed outside of the laboratory setting, without the presence of a sleep technician. It incorporates a minimum of seven physiologic parameters, similar to the fully-attended in-laboratory study (Ferber et al., 1994; Jafari & Mohsenin, 2010). The level 3 PSG is a portable study with a minimum of four parameters: two measures of ventilation, ECG or heart rate, and oximetry (Ferber et al., 1994; Jafari & Mohsenin, 2010). The level 4 PSG incorporates a minimum of one parameter, usually oximetry (Ferber et al. 1994). Level 3 and 4 PSG have fewer components than the laboratory PSG, with ventilation parameters to measure respiratory rate and airflow, oxygen saturation, and heart rate, providing a cardiopulmonary study of sleep (Jafari & Mohsenin, 2010).

Strengths of PSG

PSG is considered the gold standard of measurement tools for sleep outcomes and comprehensive sleep data (Chesson et al., 1997; Ibanez et al., 2018; Ji & Liu, 2016; Lewandowski, Toliver-Sokol, & Palermo, 2011; Marcus, 2001; Zinkhan et al., 2014). PSG provides a description of sleep stages, cardio-respiratory events, sleep onset latency, wake after sleep onset, and body movements during the sleep period. Although home PSG may not provide the full array of sleep parameters compared to the laboratory PSG, the home PSG provides similar information as the laboratory study for some sleep parameters for diagnosis of conditions such as sleep apnea (Ferber et al., 1994; Iber et al., 2004). Home PSG is less costly than the in-lab PSG (Kim et al., 2015). PSG combined with subjective measurement tools can provide information regarding the psychosocial aspects of sleep in addition to the biophysiological portion. These subjective tools may include questionnaires or interviews and are described under subjective measurement tools.

Limitations of PSG

While the laboratory PSG provides comprehensive information on biophysiological parameters, it is costly, time and labor intensive, and may not be feasible within the research setting for large studies (Ji & Liu, 2016). Both the laboratory and the home PSG lack the psychosocial evaluation of sleep, such as sleep quality, daytime sleepiness or tiredness. In addition, lab-based PSG does not capture the habitual sleep patterns within the natural setting (Lewandowski et al., 2011).

Actigraphy

Actigraphy emerged as a sleep measurement tool in the 1970s (Ancoli-Israel et al., 2003). The actigraph is a computerized device that uses an accelerometer to measure activity counts as a proxy for sleep and wake periods (Ancoli-Israel et al., 2003; Ibanez et al., 2018; Sadeh, 2011; Sadeh & Acebo, 2002). The accelerometer may use piezo-electric microcrystals or capacitive elements to detect movement with dual or triple axes microelectromechanical systems (MEMS) with front-back, up-down, and side-to-side movements (Kolla, Mansukhani, & Mansukhani, 2016), which are translated into digital counts at *a priori* established epoch intervals (Sadeh & Acebo, 2002). Data are collected over a period of time, such as days or weeks (Sadeh & Acebo, 2002). This stored data is then downloaded to a computer and scored by an algorithm to generate a graphic of sleep and wake patterns (Sadeh & Acebo, 2002). The actigraph can be worn on the wrist (Sadeh, 2011), around the neck (https://advancedbrainmonitoring.com), or on the finger like a ring (de Zambotti, Rosas, Colrain, & Baker, 2017; https://mymotiv.com). Research quality actigraphs, and commercially available sleep tracker devices are available from a number of manufacturers. Some examples of these devices are depicted in Table 2-3.

Table 2-3

Research-Grade Actigraphy Devices and Commercial Sleep Trackers

Product	Manufacturer
	Research-Grade Actigraphy Devices
ActiGraph Link	Actigraph (https://www.actigraphcorp.com/actigraph-link)
Night Shift	Advanced Brain Monitoring, Inc. (https://www.advancedbrainmonitoring.com/sleep-medicine/)
Micro Motionlogger Watch	Ambulatory Monitoring Inc. (http://www.ambulatory-monitoring.com/index.html)
MotionWatch 8	CamNtech (https://www.camntech.com/products/motionwatch/motionwatch-8-overview)
ActTrust	Condor Instruments (http://www.condorinst.com.br/en/acttrust/)
Actiwatch Spectrum Plus	Phillips Respironics (http://www.actigraphy.com/solutions/actiwatch/actiwatch-plus-specifications.html)
SOMNOwatch	SOMNOmedics America Inc. (https://somnomedics.com)
	Commercial Sleep Tracker Devices
Fitbit; Fitbit Ultra	Fitbit, Inc. (https://fitbit.com)
Jawbone UP	Jawbone
Apple Watch	Apple (https://apple.com/watch/)
Garmin Connect	Garmin (https://connect.garmin.com)
Motiv	Motiv (https://mymotiv.com)
OURA ring	OURA (https://ouraring.com)

Table 2-3

Research-Grade Actigraphy Devices and Commercial Sleep Trackers

Product	Manufacturer

Note. Night Shift is worn around the neck. Motiv and OURA are ring devices. Jawbone UP product discontinued in 2018 (Hern, 2018). Apple Watch device requires use of an application to provide sleep tracking functionality.

Adapted from Actigraphy side-by-side comparison guide. (2016). Sleep Review. Retrieved from http://www.sleepreviewmag.com/2016/06/actigraphy-side-side-comparison-guide-june-2016/

The OURA® ring (https://ouraring.com) and Motiv (https://mymotiv.com) actigraphy devices, available commercially, measure activity and pulse rate as a proxy for sleep. In addition, the OURA® ring claims to measure sleep stages, based on physiologic measurements of activity, pulse, and body temperature. An actigraph can also be worn on the waist to measure physical activity; however, the physical activity counts are not a validated proxy for sleep. The accelerometer built into a smartphone can be used as a sleep tracker, with the use of iOS or Android applications (Ong & Gillespie, 2016). The smartphone is placed on the sleeping surface or under the pillow to measure activity counts as a proxy for sleep (Choi et al., 2018). All applications record sleep duration, and some report the ability to measure sleep stages (Choi et al., 2018; Ong & Gillespie, 2016). An additional use of the smartphone to record sleep parameters involves placement of a thin pad under the sheets, with connectivity to the smartphone, to record activity, heart rate, breathing, and snoring. Some examples of these devices are Beddit® (https://beddit.com/), and Emfit QS® (https://emfit.com/).

Actigraphy is performed within the home setting and reflects the habitual sleep patterns of the individual. The actigraph records activity in *a priori* segments (epochs), such as 30-second, 1-minute, or other measurement interval, and is analyzed by a computerized scoring algorithm (Sadeh, Hauri, Kripke, & Lavie, 1995). Actigraphy measures only activity counts as a measure of sleep or wake state, and the scoring algorithm is able to calculate sleep duration, sleep onset, sleep offset, wake after sleep onset (WASO), sleep efficiency, and sleep mid-point (Ancoli-Israel et al., 2003; Meltzer, Walsh, Traylor, & Westin, 2012).

Correlation with sleep/wake patterns of PSG demonstrated high levels of agreement between wrist actigraphy and PSG, making it a useful measurement tool for sleep patterns (Ancoli-Israel et al., 2003; Marino et al., 2013; Meltzer, Walsh et al., 2012; Sadeh et al., 1995; Zinkhan et al., 2014). The data obtained from the OURA® ring was not significantly different than data from the PSG for sleep onset latency, total sleep time, and WASO in a sample of adolescents and young adults; however, estimation of specific stages of *light sleep*, *deep sleep*, and *REM sleep* was less robust when obtained from OURA®, than when obtained from PSG (de Zambotti et al., 2017). A study comparing sleep estimation with both a research grade actigraph (ActiGraph Link [ActiGraph]) and several commercially-available sleep trackers (SenseWear Mini armband [Jawbone], Basis Peak [Intel], Fitbit Charge HR [Fitbit, Inc.], Jawbone UP3 [Jawbone], and Garmin Vivosmart [Garmin International, Inc.]) with the Consensus Sleep Diary-Expanded was conducted among a sample of healthy adult participants (Lee, Byun, Keill, Dinkel, & Seo, 2018). The study showed similarities in the ability of the Sensewear Mini, Fitbit Charge HR, Jawbone UP3, and Garmin Vivosmart to approximate the sleep outcomes of total sleep time and time in bed, when compared with the sleep diary, and the research-grade device (Lee et al., 2018). This study was limited by a duration of 3 nights of actigraphy, use of a self-report measure for comparison, and public unavailability of variables used in the scoring algorithms of the commercially-available sleep tracker devices. Validity and reliability testing were unable to be evaluated due to the proprietary nature of the commercial devices' algorithms and inability to obtain the raw data.

Strengths of actigraphy

Similar to home PSG, actigraphy provides the ability to measure sleep objectively within the natural environment. Unlike PSG, there is no equipment to be set up by trained staff within the home setting. In contrast to either laboratory or home-based PSG, actigraphy provides the ability to record sleep data without the constraints of multiple electrodes and monitoring devices that may impede the individual's ability to sleep normally (Ancoli-Israel et al., 2003). Use of actigraphy provides the ability to collect sleep data over a period of days, weeks, or longer in an efficient and less costly manner, compared to PSG (Meltzer, Walsh et al., 2012). Subjective measurement of sleep serves to supplement the biophysiological measurements of actigraphy. Use of a sleep diary concurrently with actigraphy serves to provide additional information on sleep and activity patterns, such as bed time, wake time, and validation of sleep/awake periods during the night, as well as the ability to evaluate sleep onset latency (Ji & Liu, 2016; Short, Gradisar, Lack, Wright, & Carskadon, 2012; Tomita et al., 2013).

Limitations of actigraphy

Measurement of sleep parameters with actigraphy provides less biophysiological information, such as vital signs and sleep architecture (Ibanez et al., 2018; Ji & Liu, 2016), and does not provide a psychosocial assessment of sleep, such as sleep quality, daytime sleepiness, or tiredness, unless it is combined with subjective sleep measures. Unlike PSG, which provides multiple data collection parameters, actigraphy provides one dimension of data collection (Ancoli-Israel et al., 2003). The sleep period may be over- or underestimated with use of actigraphy, as sleep is measured as the lack of activity (Marino et al., 2013). Since actigraphy relies on activity counts, it may provide less accurate information in individuals who have insomnia and lie quietly while awake, or in those who are active sleepers and may not be awake (Sadeh & Acebo, 2002). Actigraphy is less accurate for measurement of WASO than PSG as activity counts during sleep may overestimate WASO, when the individual is indeed asleep, and merely moving during the sleep period (Meltzer, Walsh et al., 2012). Disadvantages of smartphone applications and sleep trackers are the use of a proprietary algorithm for sleep analysis, which may be revised at any time, and the lack of validation research to support assertions (Choi et al., 2018; Mansukhani & Kolla, 2017; Meltzer, Hiruma, Avis, Montgomery-Downs, & Valentin, 2015; Ong & Gillespie, 2016). In addition, the use of commercially available sleep trackers often lacks accuracy in measuring wakefulness and sleep efficiency (Mansukhani & Kolla, 2017; Meltzer et al., 2015).

Subjective sleep measures

Subjective sleep measurement tools can be used to measure sleep quantity, sleep quality, sleep disturbances, and the individual's perceptions of sleep (Ji & Liu, 2016). Subjective sleep measurement tools are typically questionnaires that capture the psychosocial aspects of sleep, such as perceptions of the sleep experience, and daytime symptoms (Erwin & Bashore, 2017; Ji & Liu, 2016; Lewandowski et al., 2011; Spruyt & Gozal, 2011). Subjective measurement tools do not measure sleep architecture, nor the biophysiological parameters of sleep. Systematic reviews of subjective sleep measurement tools classified them in the following categories: general sleep measures; sleep initiation and maintenance measures; daytime sleepiness measures; behavioral assessment of sleep measures; cognitive beliefs about sleep measures; and multidimensional measures (Erwin & Bashore, 2017; Ji & Liu, 2016; Lewandowski et al., 2011; Spruyt & Gozal, 2011). Subjective measurement tools specific to adolescents include either self-reports, parent-reports, or combined self- and parent-reports. Numerous subjective tools are available for general use; however, many tools lack validation in adolescents (Spruyt & Gozal, 2011). Adolescent-specific measurement tools should be used rather than child-specific or adult-specific tools because of the unique nature of adolescent sleep related to pubertal development (Ji & Liu, 2016; Lewandowski et al., 2011). Examples of subjective measurement tools used in adolescents are detailed in Table 2-4.

Strengths of subjective sleep measures

Subjective measurement tools are inexpensive, and reliable measures that can augment objective measures (PSG and actigraphy). This is accomplished by providing an assessment of both quantitative aspects of sleep, as well as perceptions of sleep within the clinical and research settings to provide a more complete picture of the biopsychosocial sleep state (Ji & Liu, 2016).

Limitations of subjective sleep measures

Subjective measurement tools may be subject to reporting bias, such as the time period of recall for specific sleep parameters, which may vary from the previous night to six months (Ji & Liu, 2016). Shorter recall periods may be more easily remembered than longer periods, and daily reporting may be more robust than reports from weekly or monthly sleep behavior (Spruyt & Gozal, 2011). The information obtained in a questionnaire may be subject to reliability issues dependent upon the source of information, such as self-report or parent-report information (Lewandowski et al., 2011).

Self-report questionnaires

Self-report sleep questionnaires are completed independently by the adolescent. These tools may be general measurement tools about sleep habits and perceptions, or may be specific to a sleep condition, such as insomnia. Other types of self-report questionnaires include those measuring sleep quantity, sleep quality, and daytime sleepiness (Erwin & Bashore, 2017; Ji & Liu, 2016; Lewandowski et al., 2011; Spruyt & Gozal, 2011). Although adolescents may be more knowledgeable about their own sleep habits, they may not be aware of sleep behavior such as snoring.

Parent-report questionnaires

Parent-report sleep questionnaires are completed by the parent regarding their child/adolescent's sleep patterns. As adolescents become increasingly independent with age, parents may not have an accurate awareness of adolescents' usual sleep habits, and therefore, may not have the same accuracy as self-reported information (Ji & Liu, 2016; Meltzer et al., 2013). The use of parent-report questionnaires may provide information not obtained from the adolescent (e.g., snoring), and are focused on sleep disturbances and sleep disorders.

Self- and parent-report questionnaires

Self- and parent-reported questionnaires are completed by the adolescent and the parent respectively to provide a broader evaluation of a specific behavior. For example, the Epworth Sleepiness Scale-Revised for Children (validated in adolescents 13-16 years of age) measures both parent and adolescent perspectives on daytime sleepiness (Melendres, Lutz, Rubin, & Marcus, 2004).

Table 2-4

Subjective Sleep Measurement Scales Used Among Adolescents

Questionnaire	Focus of Questionnaire	Population	Respondent
Adolescent Sleep Hygiene Scale	Sleep habits and sleep hygiene on weekdays and weekends	12-18 years	Self

Table 2-4

Subjective Sleep Measurement Scales Used Among Adolescents

Questionnaire	Focus of Questionnaire	Population	Respondent
(Lebourgeois, Giannotti, Cortesi, Wolfson, & Harsh, 2005)			
Adolescent Sleep Wake Scale (Lebourgeois, Giannotti, Cortesi, Wolfson, & Harsh, 2005)	Going to bed; falling asleep; maintaining sleep; reinitiating sleep; returning to wakefulness	12-18 years	Self
Athens Insomnia Scale (Chung, Kan, & Yeung, 2011)	Difficulty with sleep initiation; awakening during the night; early awakening; total sleep time; sleep quality	12-19 years	Self
Children's Report of Sleep Patterns (Meltzer, Avis, Biggs, Reynolds, Crabtree, & Bevans, 2013)	Sleep patterns; sleep hygiene; sleep disturbance	8-18 years	Self
Chronic Sleep Reduction Questionnaire (Dewald, Short, Gradisar, Oort, & Meijer, 2012)	Shortness of sleep; irritation; loss of energy; sleepiness	12.2-16.5 years	Self
Cleveland Adolescent Sleepiness Questionnaire (Spilsbury, Drotar, Rosen, & Redline, 2007)	Daytime sleepiness; sleep in school; alertness in school; sleep in the evening; sleep during transport	11-17 years	Self
Epworth Sleepiness Scale-Revised for Children (Melendres, Lutz, Rubin, & Marcus, 2004)	Daytime sleepiness	13-16 years	Parent/Self
Insomnia Severity Index (Chung, Kan, & Yeung, 2011)	Perceived severity of insomnia symptoms; degree of sleep satisfaction; interference with daytime function; noticeability of impairment; concern for sleep problem	12-19 years	Self

Table 2-4

Subjective Sleep Measurement Scales Used Among Adolescents

Questionnaire	Focus of Questionnaire	Population	Respondent
Pediatric Daytime Sleepiness Scale (Drake, Nickel, Burduvali, Roth, Jefferson, & Badia, 2003)	Sleep patterns, school achievement, mood, sleepiness, quality of life, extracurricular activities	11-15 years	Self
Pediatric Sleep Questionnaire (Chervin, Hedger, Dillon, & Putuch, 2000)	Sleep-related breathing disorders; daytime sleepiness	2-18 years	Parent
Pittsburgh Sleep Quality Index (PSQI) (Zhou et al., 2012)	Subjective sleep quality; sleep latency; sleep duration; sleep efficiency; sleep disturbances; use of sleeping medication; daytime sleepiness	12-18 years (Chinese)	Self
School Sleep Habits Survey (Carskadon, Seifer, & Acebo, 1991)	Sleep schedule regularity; school performance; daytime sleepiness; sleep/wake behavior problems; depressive mood; habitual sleep schedule	13-19 years	Self
Sleep Behavior Questionnaire (Cortesi, Giannotti, & Ottaviano, 1999)	Sleep quantity and quality; sleep habits; sleep latency; parental involvement at sleep onset; night wakings; co-sleeping; naps; nighttime events; daytime drowsiness	6-14 years	Parent
Sleep Disorders Inventory for Student-Adolescent Form (Luginbuehl, Bradley-Klug, Ferron, Anderson, & Benbadis, 2008)	Obstructive sleep apnea syndrome; periodic limb movement disorder; delayed phase sleep disorder; narcolepsy	11-18 years	Parent
Sleep Disturbance Scale for Children (Bruni et al., 1996)	Sleep initiation and maintenance; daytime sleepiness; sleep disordered breathing; sleep arousal	6-18 years	Parent
Sleep Habits Survey	Sleep and wake on school and weekend nights; daytime	10-19 years	Self

Table 2-4

Subjective Sleep Measurement Scales Used Among Adolescents

Questionnaire	Focus of Questionnaire	Population	Respondent
(Wolfson & Carskadon, 1998)	sleepiness; sleep/wake behavior problems		

Sleep diary

The sleep diary is an easy-to-use, no-cost measurement tool to assess sleep and wake patterns. It is comprised of a daily log of sleep, activity, and lifestyle patterns, which are repeated over a specified period of time (Rogers, Caruso, & Aldrich, 1993; Short, Arora, Gradisar, Taheri, & Carskadon, 2017). A Consensus Sleep Diary (CSD) was developed by a panel of sleep experts to standardize the format for the sleep diary, with consistency in measurements of sleep habits (Carney et al., 2012). In addition, lexical analysis was conducted on the CSD for reading level. The CSD is written on a 3rd grade reading level for the sleep diary, and a 6th grade reading level for the sleep diary instructions. Usual sleep habits and daytime routines are recorded in a daily repeated fashion over a period of time to obtain a depiction of habitual patterns. Information recorded in the sleep diary includes bedtime and wake times, night awakenings, subjective perception of sleep, and daytime habits include napping, caffeine intake, and medications (National Sleep Foundation, n.d.). Pencil and paper or electronic formats are available for the sleep diary. The electronic diary has the advantage of a date and time stamp to verify time of sleep diary completion (Blake & Kerr, 2010), and is comparable in performance to the paper and pencil sleep diary (Tonetti, Mingozzi, & Natale, 2016).

The sleep diary is frequently used in tandem with other sleep measurement tools, such as actigraphy to augment, and verify sleep and activity periods (NSF, n.d; Short et al., 2012; Tomita et al., 2013). Assessment of habitual sleep patterns with the sleep diary differs from sleep assessment by subjective questionnaires by providing a more complete picture of the habitual patterns with the repeated measurement of sleep variables. The sleep diary is a basic measurement tool for evaluation of insomnia (Carney et al., 2012) and narcolepsy (Rogers et al., 1993).

Strengths of the sleep diary

The sleep diary is considered a gold standard among subjective sleep measurement tools (Carney et al., 2012; Short et al., 2017). A standardized sleep diary for researchers and clinicians enables comparison of the same items across studies (Carney et al., 2012). The sleep diary is consistent with sleep patterns obtained with PSG in patients with narcolepsy and control subjects (Rogers et al., 1993), and demonstrates agreement with actigraphy among adolescents (Arora, Broglia, Pushpakumar, Lodhi, & Taheri, 2013; Tremaine, Dorrian, & Blunden, 2010). Sleep patterns in adolescents have more variability than other age groups related to pubertal changes affecting sleep patterns (Short et al., 2017). The sleep diary is a reliable method to measure sleep duration, bedtime, wake time, and sleep onset latency in adolescents (Arora et al., 2013; Short et al., 2017), and repeated measurements with the sleep diary over a period of days or weeks can capture the intraindividual variability of adolescents' sleep patterns. Additional strengths include ease of use, portability, and easy accessibility of the measurement tool (Rogers et al., 1993).

Limitations of the sleep diary

Sleep diary limitations include potential recall bias if the diary is not completed in a timely manner, or if it is completed at one time for the entire evaluation period (Short et al., 2017). A study of 1766 adolescents from four countries determined that a minimum of five weekday nights of sleep diary entries are needed to obtain an accurate portrayal of habitual sleep patterns. Assessment of weekend sleep variability requires more than two nights of sleep diary data (Short et al., 2017).

Circadian Timing Measurement Tools

The circadian pacemaker controls hormones, sleep, alertness, and other physiological functions (Klerman, Gershengorn, Duffy, & Kronauer, 2002). Although the circadian pacemaker is not able to be measured directly, markers can be used to estimate circadian timing in response to environmental stimulation, such as external light cues (Klerman et al., 2002; Lewy, Cutler, & Sack, 1999). Circadian timing can be measured by both objective methods, such as biomarkers and actigraphy, and by subjective methods, such as questionnaires.

Objective Circadian Measures

Objective measures of circadian timing include biomarkers such as core body temperature, cortisol levels, melatonin levels (Klerman et al., 2002), and actigraphy (Ancoli-Israel et al., 2003). The parts of the circadian rhythm are circadian period, circadian phase, circadian phase angle, and amplitude. The circadian period is defined as the duration of one complete cycle (e.g. approximately 24 hours). The circadian phase is the clock time at which an event occurs (e.g. melatonin secretion). The circadian phase angle is described as the time interval between a circadian phase measure (clock time) and another circadian phase measure or an external time cue (e.g. light). The amplitude is defined as half of the difference between the peak and nadir levels of a rhythm (Emens et al., 2009; Wirz-Justice, 2007).

Core body temperature

The circadian rhythm of core body temperature (CBT) is controlled by the suprachiasmatic nucleus and thermoregulatory feedback and can be used as a marker of circadian phase (Dijk & Czeisler, 1995; Klerman et al., 2002; Waterhouse et al., 2005). The CBT has a cyclical pattern with the peak level near the habitual bedtime and the nadir level near the habitual wake time (Dijk & Czeisler, 1995; Togo et al., 2007). The circadian timing of the nadir level is the most commonly selected component of the circadian rhythm of CBT as a measure of circadian phase. CBT is measured by a rectal thermistor probe and is considered to be the gold standard marker of circadian rhythm (Togo et al., 2007). More recently, CBT has been measured via an ingestible telemetric temperature-sensitive capsule, which passes through the gastrointestinal tract, and transmits temperature readings over a 24-hour period (Bongers, Daanen, Bogerd, Hopman, & Eijsvogels, 2017; Darwent, Zhou, van den Heuvel, Sargent, & Roach, 2011). However, collection of CBT may not be practical in all settings related to the need for specialized equipment and frequent measurements.

Cortisol level

Cortisol is a glucocorticoid hormone secreted from the adrenal gland, and is regulated in a feedback loop indirectly by the hypothalamus with corticotropin-releasing hormone (CRH) and directly by the pituitary gland with adrenocorticotrophic hormone (ACTH) (Elder, Wetterell, Barclay, & Ellis, 2014; Gatti, Antonelli, Prearo, Spinella, Cappellin, & DePalo, 2009). This hypothalamic-pituitary-adrenal (HPA) axis has a diurnal pattern, coordinated by the suprachiasmatic pacemaker of circadian rhythm (Elder et al., 2014). Cortisol levels are high in the morning, peaking within the first hour after awakening, called the cortisol awakening response (CAR), followed by a decline over the remainder of the day and part of the night, reaching the nadir level during the first half of the sleep period or near midnight (Gatti et al., 2009; Elder et al., 2014; Voderholzer et al., 2012; Zeiders, Sampey, & Adam, 2011). The diurnal cortisol rhythm is dependent upon the sleep cycle, and varies with sleep timing (Elder et al., 2014; Voderholzer et al., 2012; Zeiders, Doane, & Adam, 2011).

Cortisol can be measured in the plasma, urine, saliva (Gatti et al., 2009), or hair (Gray, Dhana, Van Der Vyver, Van Wyk, Khumalo, & Stein, 2018). Urinary cortisol is typically collected over a 24-hour period of time and measures the total cortisol production over this period, making it less useful in determining circadian phase (Gatti et al., 2009). Plasma cortisol levels may be collected at varying times during the day, evening, and night; however, cortisol levels may be adversely affected by a stress response to needle sticks for specimen procurement, causing a rise in cortisol (Gatti et al., 2009). Salivary cortisol levels are a non-invasive alternative to measure cortisol, eliminating the stress of a needle stick for the plasma cortisol level. Salivary cortisol levels correlate well with the plasma levels, providing a reasonable measurement of circadian phase with repeated measurements (Gatti et al., 2009). A more recent cortisol measurement technique is hair cortisol measurement, whereby cortisol is analyzed from the proximal 3 centimeters of hair samples (Gray et al., 2018). Hair cortisol levels may be influenced by developmental stage of the adolescent, and trauma or stress, as well as the use of hair care products which may alter the hair shaft (Gray et al., 2018).

Melatonin level

Melatonin is a hormone secreted from the pineal gland in a cyclic, circadian rhythm (Crowley, Suh, Molina, Fogg, Sharkey, & Carskadon, 2016; McIntyre, Norman, Burrows, & Armstrong, 1987). Melatonin is secreted primarily during nighttime, in response to light/dark patterns (Lewy, 2010). Melatonin levels are normally low during the day, rise prior to bedtime, remain elevated during the night, and then decrease prior to awakening (Crowley et al., 2016). Melatonin is inhibited by light exposure and is a marker of the circadian phase (Benloucif, Guico, Reid, Wolfe, & Hermite-Baleriaux, 2005; Crowley et al., 2016; Lewy et al., 1999). Melatonin is present in blood, urine, cerebrospinal fluid, amniotic fluid, and saliva (McIntyre et al., 1987). Melatonin can be sampled at various points in the circadian rhythm. The most commonly used sampling points include: onset (also called dim light melatonin onset [DLMO]), offset (dim light melatonin offset [DLMOff]), or midpoint (peak) (Crowley et al., 2016). Salivary melatonin is a non-invasive, and efficient method of melatonin measurement. Collection of melatonin samples needs to be performed in dim light to avoid melatonin suppression by environmental light (Benloucif et al., 2008; Crowley et al., 2016; Lewy et al., 1999). Melatonin does not measure sleep architecture or psychosocial aspects of sleep but measures the circadian timing or circadian phase. Measurement of salivary melatonin in dim light at the habitual bedtime is a good estimate of DLMO in adolescents (Crowley et al., 2016).

Actigraphy

Actigraphy can be used to measure the habitual sleep/wake relationships within the home setting, including sleep timing, and activity. Actigraphy as an objective measure of sleep has been described above; however, actigraphy can also be used as an objective measure of circadian timing (Ancoli-Israel et al., 2003). Actigraphy can measure sleep onset, sleep offset, and midpoint of sleep, by identifying sleep/wake rhythms to predict the circadian rhythm, similar to PSG: phase markers of sleep onset or sleep offset times, time of peak activity, amplitude, and mean (Ancoli-Israel et al., 2003). When measured over days or weeks, actigraphy can detect intra-daily variability (Ancoli-Israel et al., 2003). Actigraphy is a less stable circadian marker than core body temperature or melatonin (Carskadon, Acebo, & Richardson, Tate, & Seifer, 1997). Measurement of circadian rhythm by actigraphy requires 7 or more days of data collection for adolescents including 2 weekend days due to sleep variability among adolescents (Acebo et al., 1999; Ancoli-Israel et al., 2003; Carskadon et al., 1997).

Subjective Circadian Measures

Circadian preferences can be measured subjectively by self-report questionnaires, sleep diaries, and interviews. All of these measurement tools provide the individual’s perception of optimal timing for daily activities, such as sleep and activity.

Chronotype questionnaires

Chronotype questionnaire are subjective measures of circadian phase. It is a measure of the body's internal clock mechanism, independent of the solar clock or the social clock (Roenneberg, Wirz-Justice, & Merrow, 2003). Chronotype is a measurement of the individual's perception of when s/he feels best, the preferred time of day for sleep and activity, and behavioral timing (Kantermann, Sung, & Burgess, 2015; Roenneberg et al., 2003). These questionnaires classify individuals into morning types (larks), evening types (owls), or neither type (mixed type) based on their individual time preferences. The Morningness-Eveningness Questionnaire (MEQ) measures the individual's circadian phase preference (Horne & Ostberg, 1976). The Composite Scale of Morningness (CSM) is based on the MEQ, and evaluates morning affect, preferred sleep and wake times, and peak cognitive performance (Randler & Jankowski, 2014; Smith, Reilly, & Midkiff, 1989). The Munich ChronoType Questionnaire (MCTQ) measures preferences for sleep and activity on work or school and free days. Respondents rate themselves into one of seven chronotypes from extreme early to extreme late (Roenneberg et al., 2003). Chronotype questionnaires are easy to use, and inexpensive measurement tools. Chronotype questionnaires can provide value in assessing adolescent sleep preferences. Adolescents have delayed sleep timing and altered sleep patterns related to pubertal changes, including delay in melatonin secretion, and shift to later chronotype (Crowley, Wolfson, Tarokh, & Carskadon, 2018; Wolfson & Carskadon, 2003).

Sleep diary

A sleep diary can be used to provide an estimate of circadian phase and a marker for chronotype (Burgess, 2003; de Souza & Hidalgo, 2014; Martin & Eastman, 2002). The circadian sleep midpoint is calculated from bedtime and wake time when participants self-select sleep schedules. Sleep midpoint is an easily obtained estimate of circadian phase. Sleep midpoint is calculated as the midpoint between sleep onset and offset times and serves as a single reference point for chronotype (Roenneberg et al., 2003).

Individual interviews

Individual interviews can provide a subjective assessment of circadian preferences by asking guided questions related to biological rhythms. One example of a structured interview guide is the Biological Rhythms Interview of Assessment in Neuropsychiatry (BRIAN), designed to evaluate daily patterns of sleep and social rhythms, activity rhythms, and eating patterns (Giglio et al., 2009). This interview guide was tested in adults with bipolar disorder and demonstrated validity with the Pittsburgh Sleep Quality Index (Giglio et al., 2009). Interviews provide a subjective assessment of circadian preference but lack biological markers of circadian rhythm.

Technology Use Measurement Tools

Measurement tools can be used to assess mobile phone and technology use, including problematic mobile phone use, technology devices used within the bedroom setting, and relationships to sleep outcomes. This section describes some of these tools that are available for use in adolescent research regarding technology or mobile phone use.

Mobile Phone Problem Use Scale (MPPUS)

The MPPUS is a measurement tool, developed by Bianchi and Phillips (2005), in response to the observation that overuse of technology was associated with negative health outcomes. Bianchi and Phillips sought to predict mobile phone use, particularly compulsive phone behavior, by measuring symptoms of behavioral addiction. These measures of addiction include tolerance (also termed loss of control), escape from other problems, withdrawal, craving, and negative life consequences (Bianchi & Phillips, 2005). The MPPUS is a 27-item measure using a 10-point Likert-type scale, with responses from 1 (*not true at all*) to 10 (*extremely true*), with 27-270 possible points. The MPPUS has been tested in a sample of 195 adults, ages 18-85 years (mean age 36.07 years), which demonstrated high internal consistency, with Cronbach's alpha 0.93. The validity of the MPPUS was evaluated by strong correlation with self-report mobile phone usage ($r = 0.45$, $p < 0.01$), and moderate correlation with the Addiction Potential Scale ($r = -0.34$, $p < 0.01$), a validated measure of behavior associated with addiction (Bianchi & Phillips, 2005). Limitations of the MPPUS with adolescents include the length of the tool, and redundancy of the questions (Foerster, Rose, Schoeni, & Roosli 2015).

Mobile Phone Problem Use Scale for Adolescents (MPPUSA)

The Mobile Phone Problem Use Scale for Adolescents (MPPUSA) was adapted from the MPPUS for use in British adolescents by Lopez-Fernandez and colleagues (Lopez-Fernandez et al., 2014). The MPPUSA is specific to the adolescent population and uses a 10-point Likert-type scale, with participant responses ranging from 1 (*totally false*) to 10 (*completely true*). The MPPUSA was tested in a sample of 1,024 adolescents, ages 11-18 years of age. Exploratory factor analysis was used to determine the most appropriate items to be included in the questionnaire. The factors included in the MPPUSA include: tolerance (loss of control) (3 items), escape from problems (3 items), withdrawal (3 items), craving (3 items), negative consequences (12 items), and social motivations (2 items). This measure does not include the item, *All of my friends own a mobile phone*, from the MPPUS as it was frequently unanswered in the earlier version of the questionnaire. Ten other questions were adapted to either be more appropriate for adolescents (4 items), or to incorporate British English (6 items) (Lopez-Fernandez et al., 2014). Internal consistency was excellent with Cronbach's alpha 0.97. The MPPUSA is scored from a possible 26 to 260 points, with higher scores indicative of problematic mobile phone use. Scoring for the MPPUSA was consistent with gambling addiction behavior scoring from the addiction literature (Lopez-Fernandez et al., 2014). Scoring for the MPPUSA categorizes the participants into groups based on MPPUSA score of addictive behaviors. Adolescents in this study (89.9%) were able to identify problematic mobile phone use among their peers, but frequently rated themselves lower in problematic mobile phone use. The reliability of the MPPSUA was greater than with the MPPUS in adolescents, and consistent with the previously validated Spanish version of the MPPUSA (Lopez-Fernandez et al., 2014).

Mobile Phone Problem Use Scale-10 (MPPUS-10)

The Mobile Phone Problem Use Scale-10 (MPPUS-10) is a shortened version of the MPPUS, which has been adapted for use in adolescents (Foerster et al., 2015). The MPPUS-10 was developed by Foerster and colleagues to address the limitations of the MPPUS in adolescents regarding mobile phone use, in a short, easily comprehended, non-duplicative measure (Foerster et al., 2015). Principal component analysis was conducted to derive the MPPUS-10 from the MPPUS for questionnaire items that are most appropriate for evaluating adolescent mobile phone use. The factors in the MPPUS-10 included: 3 items relating each to withdrawal (12.5% of total variance), and loss of control, termed tolerance in MPPUS (15.9% of total variance), 2 items relating to negative life consequences (11.8% of total variance), and 1 item each relating to craving (8.8% of total variance), and peer dependence (7.1% of total variance) (Foerster et al., 2015). The MPPUS-10 retains the 10-point Likert-type scale, with 10-100 possible points. A higher score is indicative of increased problematic mobile phone use. The MPPUS-10 was validated in a sample of 412 adolescents, ages 12-17 years, with assessments both at baseline, and follow-up at 1 year. These assessments demonstrated consistency among the factors. Internal consistency of MPPUS-10 was good, with Cronbach’s alpha 0.85, and is similar to the MPPUS in reliability in adults. The MPPUS-10 was significantly correlated with both subjective mobile phone use by self-report, and objective data of mobile phone use obtained from telephone operator-derived data, for phone call frequency, number of outgoing messages, and mobile internet use duration (Foerster et al., 2015).

Mobile Phone Involvement Questionnaire (MPIQ)

The MPIQ was developed by Walsh and colleagues (Walsh, White, & Young, 2010), to evaluate relationships between mobile phone use frequency and involvement with a mobile phone, and the associated psychological factors in 15-24-year old Australian adolescents and young adults (mean age 18 years). Mobile phone involvement was viewed from the perspective of behavioral addiction in the development of the MPIQ. The MPIQ was initially developed as a 25-item questionnaire, then reduced to 8 items, and is scored with a 7-point Likert-type scale from 1 (*strongly disagree*) to 7 (*strongly agree*) (Walsh et al., 2010). The factors of the MPIQ are clustered into the psychological behaviors of *self-identity* and *validation from others* and include: cognitive salience, behavioral salience, interpersonal conflict, conflict with other activities, euphoria, loss of control, withdrawal, and relapse and reinstatement (Walsh et al., 2010). Reliability of the MPIQ was moderate with Cronbach's 0.78 for *self-identity* and 0.81 for *validation from others* (Walsh et al., 2010).

Adolescent Sleep, Caffeine Intake, and Technology Use

The Adolescent Sleep, Caffeine Intake, and Technology Use instrument was developed to evaluate associations between nighttime use of technology and caffeine intake, with the effects on sleep duration and daytime functioning in a population of 100 adolescents, 12-18 year old (Calamaro et al., 2009). The Adolescent Sleep, Caffeine Intake, and Technology instrument is a 36-item questionnaire, which is self-administered by the adolescent. Sleep was assessed by sleep habits, sleep/wake characteristics, and daytime sleepiness, including napping or falling asleep in school. Caffeine use was measured by the specific brand, as well as the quantity of caffeinated beverages which the participants consumed. Assessment of the use of technology between the hours of 9 pm and 6 am included: watching television, text messaging, talking on the phone, using the computer online, playing computer games, watching DVDs or videos, listening to MP3 player, completing homework, and other unspecified activities (Calamaro et al., 2009). Technology use was portrayed as a multitasking index, which was calculated by the total number of hours spent in all technology activities divided by 9 hours (Calamaro et al., 2009). This study revealed that adolescents who spent the most amount of time in multitasking with technology devices consumed more caffeine than those who had a lower multitasking score on the questionnaire. In addition, these study participants demonstrated a higher incidence of falling asleep during school hours and difficulty falling asleep at night (Calamaro et al., 2009). Reliability and validity data are not presented in the study.

Smartphone Addiction Scale-Short Version (SAS-SV)

The SAS-SV was developed by Korean researchers as a shortened and revised version of the Smartphone Addiction Scale (SAS), with smartphone use targeted toward adolescents (Kwon, Kim, Cho, & Yang, 2013). The SAS is a 33-item self-report tool, using a 6-point Likert-type scale (from 1 *strongly disagree* to 6 *strongly agree*) to evaluate six factors of smartphone addiction (Kwon, Lee et al., 2013). These factors include: daily-life disturbance, positive anticipation, withdrawal, cyberspace-oriented relationship, overuse, and tolerance (Kwon, Kim et al., 2013). Deficiencies of the SAS for use in adolescents included validation in young adult college students and adults, an imbalance in the ratio of male and female participants, and vagueness of cut-off points for measurement of smartphone addiction (Kwon, Kim et al., 2013). The SAS-SV was reduced to a 10-item scale, retaining the 6-point Likert-type scale, and revising the cut-off measurement parameters to identify those adolescents who are at risk for smartphone addiction. Internal consistency was evaluated with Cronbach's α of 0.966. The SAS-SV was validated against the Smartphone Addiction Proneness Scale (SAPS) and the Korean self-reporting internet addiction scale (KS-scale), with Cronbach's α of 0.861 and 0.836 respectively (Kwon, Kim et al., 2013). The SAS-SV does not include questions specific to use of mobile phone and sleep in adolescents. Additional information on sleep measurement tools and technology use measurement tools specific to this dissertation are presented in Chapter 3.

Mechanisms of Impact of Electronic Media on Sleep

Several mechanisms have been proposed related to the impact of electronic media use on sleep (Cain & Gradisar, 2010; Carter et al., 2016; LeBourgeois et al., 2017). Time displacement of sleep by electronic media, circadian rhythm delay related to bright light exposure, and psychophysical arousal related to media content are proposed. Although current studies lend support to these mechanisms of action, most studies are cross-sectional, or observational, and rely on self-reported data (LeBourgeois et al., 2017).

Time Displacement

Each day is composed of a finite number of hours, minutes, and seconds. Time spent on one activity comes at the expense of time spent on something else. Certain activities are essential for adolescent life, including academics, personal hygiene, leisure activities, and sleep. Time spent excessively on one activity may interfere with time spent sleeping. Use of mobile media devices within the bedroom is associated with delayed bedtime and short sleep duration (Adachi-Mejia et al., 2014; Arora et al., 2013; Arora, Broglia, Thomas, & Taheri, 2014; Brunetti et al., 2016; Bruni et al., 2015; Carter et al., 2016; Fobian et al., 2016; Harbard, Allen, Trinder, & Bei, 2016; Lemola et al., 2015; Polos et al., 2015; Van den Bulck, 2007).

Adolescents engaging with mobile media devices in the bedroom spend time on media activities in place of sleeping. Adolescents who take a mobile phone to bed and send or receive text messages after lights out had an increase in night awakenings (Adachi-Mejia et al., 2014; Fobian et al., 2016; Garmy & Ward, 2017; Johannson et al., 2016; Schoeni, Roser, & Roosli, 2015), or awakening too early (Fobian et al., 2016; Johannson et al., 2016. Adolescents who own a smart phone device spent more time engaging in text messaging, internet time, and social media consumption at night than those with a conventional mobile phone (Lemola et al., 2015).

Altered Circadian Timing Related to Artificial Light Emissions

Light exposure is a powerful stimulus for alertness (Cajochen, 2007; Souman et al., 2018). Bright light, as well as short wavelength blue light, has a stronger effect on circadian timing, melatonin release, and alertness than longer wavelength light (Cajochen, 2007; Chang et al., 2015; Souman et al., 2018; Touitou, Reinberg, & Touitou, 2017). Small screen devices are equipped with a blue light-enriched light-emitting diode (LED) screen. Effects of artificial light exposure and melatonin release have been studied for the impact on circadian timing and alertness (Figueiro & Overington, 2016; Heath et al., 2014; van der Lely et al., 2015; Wood, Rea, Plitnick, & Figueiro, 2012).

Comparison of effects of light exposure in adolescents with and without wearing blue-blocker glasses to filter short wavelength light (Figueiro & Overington, 2016; van der Lely et al., 2015; Wood et al., 2012) and with differing light conditions (Heath et al., 2014) have been conducted to evaluate the effect on melatonin release and alertness. Figueiro and Overington (2016) studied a group of adolescents and light exposure from self-luminous mobile media devices in the pre-bedtime period. Each participant received a 3-hour exposure to a self-luminous electronic media device prior to bedtime in a 2-night cross-over study. The study compared one night of screen light exposure wearing orange-tinted blue-light blocker glasses and a second night without wearing the glasses. Melatonin suppression was greater on the night without the blue-blocker glasses (Figueiro & Overington, 2016). van der Lely and colleagues (2015) compared use of blue-blocker glasses in the pre-bedtime period with clear glasses in adolescent males in a cross-over study of exposure to LED screens. Greater melatonin suppression was observed with the clear glasses after 5 nights of exposure to each condition (van der Lely et al., 2015).

Wood and colleagues (2012) compared lighting conditions (maximum brightness) and exposure time of self-luminous electronic devices among a population of older adolescents and young adults. Participants were compared with a tablet at maximum brightness, use of goggles with blue-enhanced diodes, and use of orange-tinted goggles, with 1 hour and 2 hours exposure. Exposure to 2 hours of tablet light at maximum brightness resulted in suppression of melatonin levels (Wood et al., 2012). Exposure to blue light conditions for 1 hour and 2 hours suppressed melatonin levels (Wood et al., 2012). Comparison of 1-hour exposure to three different screen light conditions was studied for effects on alertness, sleep timing, and morning sleepiness (Heath et al., 2014). Participants were exposed to bright tablet screen light, dim screen light, and short wavelength filtered light with a screen application, *f.lux.* Although a small non-statistically different effect was observed on effects of pre-bedtime alertness between the bright screen light group and the dim light group, no effects on sleep timing or morning sleepiness were observed (Heath et al., 2014). These findings suggest there may be a dose-response to screen light exposure in the pre-bedtime period, as minimal effects were observed with 1-hour exposure, and significant differences were observed with greater exposure to pre-bedtime screen light (Heath et al., 2014).

Psychological Stimulation by Media Content

Use of mobile technology before and during the sleep period may provide psychological stimulation, with interference in sleep (Cain & Gradisar, 2010). This may include engagement in activities such as video gaming, social media and social networking, and disturbing or violent content of movies or other internet sites. Effects of video gaming near bedtime and the impact on sleep has been studied in adolescents (Ivarsson, Anderson, Akerstedt, & Lindbaugh, 2013; King et al., 2013; Weaver, Gradisar, Dohnt, Lovato, & Douglas, 2010; Wolfe et al., 2014). Comparison of pre-bedtime violent video gaming compared with viewing a documentary film in a counterbalanced design of adolescent males observed cognitive alertness with video gaming but not with film viewing (Weaver el al., 2010). Physiologic alertness was not observed during the study. Some participants in the film-viewing arm fell asleep during the film; however, no participants fell asleep during video game play. Violent video game play prior to bedtime was associated with longer time to fall asleep and increased alertness (Weaver et al., 2010).

Observation of extended video game play prior to sleep was studied for the impact on sleep outcomes, alertness, and next-day outcomes (Wolfe et al., 2014). Adolescent males self-selected video game time for a maximum of five hours prior to bedtime for one night in the sleep laboratory. Participants had shorter sleep duration, next day lowered attention, and poorer verbal memory with video game play (Wolfe et al., 2014). Although participants played on a game console (Wolfe et al., 2014), adolescents frequently access video games from mobile media devices. King et al. (2013) evaluated violent video game play for either 50 or 150 minutes of play prior to bedtime among male adolescents in a crossover design. Each group of participants played either violent or non-violent video games for two hours prior to bedtime. Participants playing for 50 minutes were unsatisfied with game time, desiring additional gaming time. Participants gaming for 150 minutes had shorter sleep duration, less sleep efficiency, and slightly longer sleep onset. A non-significant increase in resting heart rate was observed between the groups (King, Delfabbro, Zwaans, & Kaptsis, 2013).

Ivarsson and colleagues (2013) studied physiologic and psychologic arousal with playing violent or non-violent video games in the pre-bedtime period. Participants were selected with video gaming experience with violent gaming for three or more hours or less than one hour daily. Participants played either violent or non-violent video games for two hours prior to bedtime in a crossover study. Those video gamers with history of less daily video game play had increased heart rate and increased heart rate variability, poorer sleep quality, and poorer alertness while playing violent games compared with those who normally played three or more hours daily (Ivarsson et al., 2013).

Addictive use of mobile phones (Liu, et al., 2017), and engagement with social media prior to and after bedtime may invoke psychological stimulation among adolescents (Arora et al., 2014; Woods & Scott, 2016). Difficulty with being able to turn off the social media or video gaming was associated with increased cognitive difficulty (Arora et al., 2014). Those adolescents who were actively engaged in excessive mobile phone use, video gaming on a mobile phone, or interacting with social media had difficulty falling asleep with a one-hour delay in bedtime (Arora et al., 2014). Social media use during the night was associated with poorer sleep quality, as well as anxiety and depression (Wood & Scott, 2016). Adolescents' fear of missing out on social media communications promoted access of social media during the sleep period. Adolescents who use social media at night and were emotionally invested in social media had lower self-esteem (Woods & Scott, 2016). Addictive use of mobile phones is described as inability to control craving to use mobile phones, anxiety, withdrawal, and depression (Liu et al., 2017). This addictive behavior may lead to rumination and increased engagement with mobile phone use during the nighttime period resulting in poorer sleep quality (Liu et al., 2017).

Chapter Summary

A comprehensive literature review was conducted on the state of the science regarding adolescent use of mobile phones within the bedroom setting. Biopsychosocial development and adolescent sleep patterns, effects of technology use at night, and adolescent decision-making were explored. The combination of need for constant connectivity within the social network, changing biophysiological sleep patterns related to pubertal development, and early school start times, contributes to an alarming preponderance of sleep insufficiency in adolescents. Studies have identified mechanisms related to the impact of mobile phones on sleep outcomes, including time displacement, exposure to blue light, and psychologically disturbing or stimulating content. Combining the biopsychological influences with the use of mobile phones within the bedroom setting increases sleep disruption, promotes poorer sleep quality, and reduces sleep quantity.

This literature review exposed a gap in the psychosocial decision-making process regarding adolescents' mobile phone use at night. Studies have described the psychosocial need for being connected to the social network but have not addressed decision-making on mobile phone use prior to, and after bedtime. The TPB, a health behavior model, is the guiding theoretical framework for this dissertation. Beliefs and attitudes are foundational to behavioral intentions, and ultimately, behavior. The influences of the peer group, as well as the need to be accepted by the peer group, are an important part of adolescent life. Although sleep patterns of adolescents are well described in the literature, this study explored influences of social factors, such as adolescents' attitudes and beliefs regarding mobile phone use after lights out and sleep outcomes. This study explored the beliefs, attitudes and sleep patterns regarding sleep and mobile phone use after lights out.

Chapter 3

Research Design and Methods

Introduction

The purpose of this study was to explore the attitudes, behaviors, and sleep patterns of adolescents who use mobile phones within the bedroom setting after lights out. The terms *after lights out* and *nighttime* are used interchangeably throughout, and encompass the period from the time the adolescent gets into bed and turns off the light until the following morning when he/she gets out of bed. Chapter 1 has provided an introduction to the topic of adolescents' use of mobile phones within the bedroom setting. Chapter 2 synthesized research and theoretical literature relevant to this topic. This chapter describes the study design, sample and setting, measures, data collection, and analysis. The research questions and hypotheses specific to this dissertation are:

1. Which mobile phone functions are adolescents accessing after lights out?

   H1. Based on prior research on use of electronic media prior to and after lights out, it was hypothesized that:

   a. Females used mobile phones after lights out for communication more frequently than males.

   b. Males used mobile phones after lights out for entertainment more frequently than females.

2. What factors contribute to adolescents' mobile phone use after lights out?

   H2. Based on prior research on use of electronic media prior to and after lights out, it was hypothesized that:

   a. Females had more frequent nighttime mobile phone use than males.

   b. Adolescents who consumed caffeine prior to bedtime had greater mobile phone use after lights out than adolescents who do not consume caffeine prior to bedtime.

c. Adolescents with increased mobile phone use after lights out place less value on the importance of sleep.

3. What are the sleep patterns of adolescents who use mobile phones after lights out?

H3. Based on prior research on use of electronic media prior to and after bedtime and sleep duration, sleep quality, and daytime sleepiness, it was hypothesized that use of mobile phones after lights out results in:

a. Shorter sleep duration, as evidenced by actigraphically-measured total sleep time.

b. Reduced sleep quality, as evidenced by increased sleep onset latency, increase in WASO, lowered sleep maintenance efficiency, and decreased perception of sleep quality.

c. Increased next day sleepiness, as evidenced by self-reported daytime sleepiness, and incidence of napping.

Design of the Study

This study employed a descriptive, correlational design in a convenience sample of adolescents. A descriptive correlational study design is a nonexperimental study that provides the ability to describe or establish relationships, associations, or correlations among the study variables or phenomena within the natural environment (Polit & Beck, 2012; Shadish, Cook, & Campbell, 2002). This study design does not manipulate variables and is unable to provide causal explanation(s) (Polit & Beck, 2012; Shadish et al., 2002). The present study aimed to observe and describe adolescents' nighttime mobile phone use, contributing factors to nighttime mobile phone use, sleep attitudes and beliefs, and sleep patterns. Strengths of the study approach include the ability to study a phenomenon that may not be amenable to an experimental design, provision of an efficient way to collect data regarding a phenomenon, and a focus on observation, rather than causation (Polit & Beck, 2012; Shadish et al., 2002). Limitations of this approach include lack of randomization or group comparisons, inability to determine causality, and potential selection bias with non-random sampling. In addition, there is a complexity of interpretation of correlations between attitudes and beliefs, and study phenomena (Polit & Beck, 2012).

One study component was prospective micro-longitudinal data collection for a 1-week period to observe adolescents' sleep patterns and their mobile phone use. This approach used repeated measures to examine multiple variables in a longitudinal manner over a short period of time. Micro-longitudinal data collection affords the ability to determine the temporal relationship between factors (e.g., time spent using a mobile device after lights out and reported next day sleepiness) within the structure of an observational correlational study. Prospective collection of repeated measures of sleep patterns and mobile phone use allowed determination of intra-individual relationships between study factors.

A descriptive correlational design was used in adolescent research to study relationships between sleep quality and depressive symptoms (Dag & Kutlu, 2017), periodic leg movements of sleep and sleep disruption in individuals with narcolepsy (Jambhekar et al., 2011), and sleep duration and glucose metabolism in obese adolescents (Koren et al., 2011). Additionally, a micro-longitudinal approach was used to examine daily activities with intraindividual variability, and effects on sleep outcomes between young adults and older adults (Dautovich, Shoji, & McCrae, 2013), and the impact of loneliness on cortisol and sleep outcomes in first year college students (Sladek & Doane, 2015). Therefore, the aforementioned studies lend support for applying a descriptive correlational design, with micro-longitudinal data collection in this study of adolescents' mobile phone use and sleep.

A second component of the study incorporated data collection in the form of surveys. Survey research collects self-report data to determine interrelationships regarding a phenomenon to evaluate the study sample characteristics, behavior, or intentions (Polit & Beck, 2012). Survey research can also be used to obtain data to study clinical practice, attitudes, and knowledge (Story & Tait, 2019). Survey data may be collected by in-person or telephone interview or self-administered online or paper questionnaires (Polit & Beck, 2012; Story & Tait, 2019). Strengths of survey research include the ability to obtain data in an efficient and economical manner, as well as flexibility, and broad applicability to a variety of study populations (Polit & Beck, 2012). Online surveys incur less cost than a mailed survey (Story & Tait, 2019). Survey research may be foundational for more extensive future research. Possible limitations of survey research are superficiality in the survey questions, brief responses to questions, and the potential of recruiting a sample that is not representative of the population (Polit & Beck, 2012). The online survey may incur technical issues and potential loss of confidentiality (Story & Tait, 2019).

For the current study, repeated measurement surveys were used to augment objectively-derived data, i.e., sleep diary data with actigraphy, as well as to assess daily technology use after lights out. Self-report surveys and questionnaires are commonly used tools to assess sleep outcomes in adolescents, as described in Chapter 2 (Erwin & Bashore, 2017; Ji & Liu, 2016; Lewandowski et al., 2011; Spruyt & Gozal, 2011). In addition, surveys were used to assess attitudes, chronotype, and technology use. Only a few studies (Harbard et al., 2016; Tavernier, Heissel, Sladek, Grant, & Adam, 2017) have used both survey methods to evaluate technology use and actigraphy together to assess sleep outcomes. This study evaluated sleep via actigraphy, with technology use through day-to-day micro-longitudinal diary measurements. Additionally, assessment of adolescents' attitudes toward sleep have not been studied in this context. The combination of these study attributes provides a unique perspective to the phenomenon of technology use after lights out and sleep impact. The research questions, variables of interest to this study, and method of measurement are depicted in Table 3-1. Additional discussion of specific measures is provided below.

Table 3-1

Research Questions, Study Variables, and Method of Measurement

Research question	Study variable	Measurement Method
1. Which mobile phone functions are adolescents accessing after lights out?	Making/Answering a phone call Sending/Receiving a text message Playing a game Viewing social media Viewing entertainment Listening to music/podcasts Browsing the internet for other reasons	Daily diary
2.What factors contribute to adolescents' mobile phone use after lights out?	Attitudes regarding mobile phone use and sleep: Negative life consequences Loss of control Withdrawal Craving Peer dependence	Mobile Phone Problem Use Scale-10 (MPPUS-10) Mobile Phone Problem Use Scale (MPPUS)
	Importance of sleep Sleep health Self-efficacy	Sleep Practices and Attitudes Questionnaire (SPAQ)
	Mobile phone use	Daily diary
	Caffeine intake	Daily diary
	Chronotype	Morningness/Eveningness Scale for Children (M/E scale for children)
3. What are the sleep patterns of adolescents who use mobile phones after lights out?	Sleep duration Bedtime on weekdays Wake time on weekdays Sleep midpoint on weekdays Bedtime on weekends Wake time on weekends Sleep midpoint on weekends Social jetlag Sleep maintenance efficiency Sleep onset latency Wake after sleep onset	Actigraphy-Actiwatch Spectrum Plus (Phillips Respironics)

Table 3-1

Research Questions, Study Variables, and Method of Measurement

Research question	Study variable	Measurement Method
	Number of awakenings Sleep quality Daytime sleepiness	Daily diary

Sample and Setting

A convenience sample of adolescents, ages 13-17 years was recruited for this study. The setting was Penn State Health, Hershey Medical Center pediatric and adolescent ambulatory care clinics and via remote access due to in-person restrictions on research activities as a result of the COVID-19 pandemic. The principal investigator's (PI) is employment within a pediatric specialty clinic afforded leveraging of professional relationships within pediatric and adolescent ambulatory care clinics to serve as study sites.

Inclusion and Exclusion Criteria

Inclusion criteria for the study included ages 13-17 years; either own or have regular access to a smart phone device; have the ability to read and write English; and willingness to participate in the study during the 1-week data collection period. There were no exclusion criteria.

Sampling and Setting

The original plan was to recruit a convenience sample of 30 adolescents from Penn State Health Hershey Medical Center pediatric and adolescent primary care ambulatory clinics. However, space and time constraints within the primary care clinic presented a barrier to recruitment and enrollment. Recruitment from the adolescent medicine ambulatory clinic was approved by the division chief; however, access was denied by nursing practice site leadership.

Recruitment from the pediatric endocrinology ambulatory clinic was approved by the division chief and practice site leadership. In addition, a link was placed on Penn State StudyFinder, a searchable data base of studies seeking participants. An unplanned method of recruitment emerged when the parent of a potential participant posted the StudyFinder link on both her personal social media page and on several local online parent group social media pages.

An additional change occurred during study recruitment and enrollment with the advent of the COVID-19 pandemic in the United States. For safety of research participants, restrictions were placed on in-person contact with research participants to minimize spread of the viral infection and to maintain social distancing requirements. As a result, some participants were enrolled virtually via video conference. Twenty-seven participants were enrolled in person, and eight were enrolled remotely.

There were no data available to suggest the sample size needed to exert an effect on the primary outcome measures. Accordingly, a formal sample size calculation was not done as the goals of this study are to: 1) assess the feasibility of the study design, 2) generate data needed for a formal power calculation, and 3) collect and analyze pilot data for larger-scale grant submission. Based on these facts it was believed that a total sample size of about 30 participants would be sufficient to achieve these aims (J. Zhu, personal communication, April 1, 2019). Thirty participants were anticipated to be enrolled in the study; however, an increase in enrollment to 40 participants was requested due to under-enrollment of male participants, and missing data on some of the initial participants. A sample of 34 adolescents was enrolled in the study.

Measures

The participation period for this study was one week and required one study visit. Potential participants were evaluated for eligibility to participate in the study with a pre-screening eligibility questionnaire, which was completed either via phone or in person prior to initiation of visit 1 procedures. This screening procedure took less than 5 minutes. During visit 1, participants provided informed consent with signature lines for parental permission for the minor child to participate in the study and minor assent to participate, completed a battery of questionnaires (refer to Table 3.2), and received the wrist actigraphy device with oral and written instructions for use over the subsequent 7 days. Participants were given the option of returning the wrist actigraphy device in person, or via pre-paid mailer following the study collection period. Following the 7-day study period, participants returned the actigraphy device by the pre-arranged method.

For those study participants who were enrolled virtually via video conference, a slightly different procedure was followed. Verbal consent and minor assent were obtained verbally in accordance with established Institutional Review Board (IRB) requirements. Each parent and participant then signed the appropriate consent minor assent signature lines on the consent form and scanned and forwarded the complete document to the PI via electronic mail. The PI signed the consent form and returned a copy of the final document to the participant for his/her records. These study participants completed the initial battery of questionnaires at this virtual visit, which took 30-40 minutes of time. Following the virtual visit, the wrist actigraphy device was mailed to their home address, along with a pre-paid return mailer. The 1-week data collection period began when the participant received the wrist actigraphy device. The study protocol is provided in Table 3-2.

Table 3-2

Study Protocol

Study Procedure	Pre-screening (in-person or telephone prior to or at visit 1)	Visit 1	7-day period	Post-data collection
Eligibility questionnaire	X			

Table 3-2

Study Protocol

Study Procedure	Pre-screening (in-person or telephone prior to or at visit 1)	Visit 1	7-day period	Post-data collection
Demographics questionnaire		X		
Mobile Phone Problem Use Scale-10 (MPPUS-10) (Foerster, Roser, Schoeni, & Roosli, 2015) 10 items		X		
Mobile Phone Problem Use Scale (MPPUS) (Bianchi & Phillips, 2005) 1 item		X		
Morningness/Eveningness Scale for Children (M/E for children) (Carskadon, Vieira, & Acebo, 1993) 10 items		X		
Sleep Practices and Attitudes Questionnaire (SPAQ) (Grandner, Jackson, Gooneratne, & Patel, 2014) 3 subscales, 16 items		X		
Instruction for use and distribution of Actigraphy (Actiwatch Spectrum Plus [Phillips Respironics])		X		
7-day Actigraphy			X	
Daily Diary • Consensus Sleep Diary (morning and evening) (Carney, Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2014), 8 items (morning) and 5 items (evening) • Self-report of Nighttime Technology Use (morning), 3 items			X	
Return actigraphy device in person or via pre-paid mailer				X
Participant compensation		X		X

Eligibility Questionnaire

The Eligibility Questionnaire (Appendix A) was designed as a pre-screening tool to determine whether a potential participant was eligible to take part in the study. This questionnaire reviewed the inclusion criteria. Any answers of *no* to inclusion criteria rendered the individual ineligible to participate in the study.

Demographics Questionnaire

The demographics questionnaire (Appendix B) was designed by the PI to measure sample characteristics. This questionnaire collected descriptive parameters, including age, gender, race, and ethnicity.

Mobile Phone Problem Use Scale (MPPUS)

The MPPUS is a measurement tool that has been discussed in Chapter 2. The MPPUS was developed by Bianchi and Phillips as a method to predict potentially addictive or compulsive behavior related to mobile phone use (Bianchi & Phillips, 2005). This 27-item measure uses a 10-point Likert-type scale, with responses from 1 (*not true at all*) to 10 (*extremely true*), with 27-270 possible points. The factors of the MPPUS are measures of addiction and include *tolerance* (also termed *loss of control*), *escape from other problems, withdrawal, craving, and negative life consequences* (Bianchi & Phillips, 2005). High internal consistency was demonstrated with Cronbach's α of 0.93, in a sample of 195 adults, ages 18-85 years (mean age 36.07 years). The validity of the MPPUS was evaluated in a study of self-reported mobile phone usage. A strong correlation was found between the MPPUS and measures of mobile phone use, including time spent using the mobile phone ($r = 0.45$, $p < 0.01$), number of regular calls to the same persons ($r = 0.42$, $p < 0.01$), and cost of mobile phone ($r = 0.43$, $p < 0.01$) (Bianchi & Phillips, 2005). In addition, the MPPUS was moderately correlated with the Addiction Potential Scale ($r = 0.34$, $p <$

0.01), a validated measure of behavior associated with addiction (Bianchi & Phillips, 2005). One item from the MPPUS, which is not present in a shortened version adapted for adolescents (MPPUS-10), was used in the current study: *I lose sleep due to the time I spend on the mobile phone* (Bianchi & Phillips, 2005). This item is selected as it is specific to use of mobile phones and sleep. Together with items from MPPUS-10, this item will be used to evaluate the factor *negative life consequences*.

Mobile Phone Problem Use Scale-10 (MPPUS-10)

The Mobile Phone Problem Use Scale-10 (MPPUS-10) (Appendix C), developed by Foerster and colleagues (2015), is a shorter version of the MPPUS, and has been discussed in Chapter 2. This measurement tool addresses the limitations of the MPPUS in adolescents, with a shorter item count, and questions that are more appropriate for teens (Foerster et al, 2015). This 10-item scale incorporates a 10-point Likert-type scale with the following factors: *withdrawal*, *loss of control*, *negative life consequences*, *craving*, and *peer dependence* (Foerster et al., 2015). A score of 10-100 points is possible, and a higher score is indicative of more problematic mobile phone use. The MPPUS-10 was validated in a sample of 412 adolescents, ages 12-17 years, via assessments both at baseline, and follow-up at 1 year, which demonstrated consistency among the factors. Internal consistency of MPPUS-10 was good, with Cronbach's alpha of 0.85, which is similar to the MPPUS's reliability in adults. Overall scores on the MPPUS-10 were significantly correlated with both subjective mobile phone use by self-report, and objective data of mobile phone use obtained from telephone operator-derived data, for phone call frequency, number of outgoing messages, and mobile internet use duration (Foerster et al., 2015).

The factors in the MPPUS-10 are consistent with the factors in the MPPUS. The factor, *peer dependence*, is a prominent part of adolescent life, and has been discussed in Chapter 2. *Peer dependence* is consistent with the theoretical framework for this study, the Theory of Planned

Behavior, and corresponds with the constructs *normative beliefs* and *subjective norms*. Mobile phones are used as a social device by adolescents, a group who often exhibits poor impulse control. Although the MPPUS-10 is a validated measurement tool for adolescent research, it does not incorporate questionnaire items specifically related to the relationship between mobile phone use and sleep. The MPPUS has one item related to this phenomenon (*I lose sleep due to the time I spend on the mobile phone*) which is not included in the shorter version of the measurement tool. Consequently, one item related to sleep and mobile phone use is selected from the MPPUS, as discussed above, in addition to the MPPUS-10.

Sleep Practices and Attitudes Questionnaire (SPAQ)

The SPAQ (Appendix D) is a theoretically-derived questionnaire regarding habitual sleep behavior, as well as attitudes and beliefs regarding sleep (Grandner, Jackson, Gooneratne, & Patel, 2014). The theoretical frameworks that informed the development of the SPAQ include the following health behavior theories: Health Belief Model (HMB), Theory of Reasoned Action (TRA), and Transtheoretical Model (TTM) (Grandner et al., 2014). Both the HBM and the TRA are discussed in Chapter 2. The HBM posits that health behavior change is attributed to a set of beliefs in negative health consequences which are related to health behaviors, the perceptions of the impact of a certain behavior on the individual's health, and the ability or self-efficacy to affect a behavior change. The TRA, an earlier version of the Theory of Planned Behavior, subscribes to the belief of attitudes and subjective norms as the basis for health behavior change. The TTM capitalizes on the individual's readiness for health behavior change (Grandner et al., 2014). The SPAQ is a 151 item questionnaire, with yes/no or 5-point Likert-type scale items, comprised of 16 subscales to assess 16 domains. These domains include: sleep duration, sleep debt, sleep quality, sleepiness/tiredness, coping with sleepiness, coping with acute insomnia, coping with chronic insomnia, activities in bed, sleep environment, knowledge, importance, impact on sleep, impact of sleep, sleep self-efficacy, sleep and health, and social norms (Grandner et al., 2014). Although the questionnaire is designed to be descriptive, there are subscales or items that can be removed in total or in part if they are determined irrelevant to the research (M. A. Grandner, personal communication, January 9, 2019). Three subscales with selected items were used in this dissertation: *Importance of sleep, Sleep self-efficacy,* and *Sleep and health*. A total of 14 items were included collectively in these subscales. In addition, the SPAQ was modified to include the following additional items to reflect differences between family and friends in adolescent life: *My family thinks that sleep is important,* and *My friends think that sleep is important.*

Scoring

A total of 16 items were included in the SPAQ. Responses were collected on a 5-point Likert-type scale, from strongly agree to strongly disagree. Higher scores (agreement) on the *Importance of Sleep* subscale reflect an increased perception of the sleep importance to the individual. A higher score (agreement) on the *Sleep self-efficacy* subscale indicates higher self-efficacy. Higher scores (agreement) on the *Sleep and health* subscale indicates increased perception of the importance of sleep for health outcomes for the individual (Grandner et al., 2014).

Psychometrics

The SPAQ was developed by a group of sleep experts, with community feedback, testing, and refining through community-based focus groups, and field testing in a sample of 124 adults, 18 to 80 years of age (Grandner et al., 2014). The SPAQ has not been reported as being used in previously published research focusing on adolescent sleep.

Validity

Face validity of the SPAQ was established through the use of community members, focus groups, and research participants to review the content of the tool (Grandner et al., 2014). Content validity was evaluated via expert sleep panel review (two physicians and one psychologist certified in sleep medicine) and through the use of theoretical frameworks in the question formation (Grandner et al., 2014). Criterion validity was assessed for some subscales which had comparable validated measurement questionnaires (Grandner et al., 2014). Questions related to general sleep disorders were compared to Pittsburgh Sleep Quality Index (PSQI). The Sleep Hygiene Index (SHI) was used to compare questions related to sleep hygiene measures. Daytime sleepiness questions were compared to the Epworth Sleepiness Scale (ESS). No scales are currently available to measure sleep-related attitudes and beliefs; however, the SPAQ as a whole was compared to the Dysfunctional Beliefs and Attitudes about Sleep (DBAS), a validated tool specific to beliefs relative to insomnia (Grandner et al., 2014).

Reliability

Reliability of the individual subscales was assessed for internal validity, with the exception of single-item subscales *Sleep duration*, *Sleep debt*, and *Self-efficacy*. Cronbach's α scores ranged from 0.25 for the subscale *Coping with sleepiness* to 0.86 for *Social norms*, with median 0.63. Reliability of subscales specific to this project include *Importance of sleep* (0.64), and *Sleep and health* (0.80). Reliability for the third subscale specific to this dissertation, *Sleep self-efficacy*, is not calculated as this is a single-item scale (Grandner et al., 2014).

Although the SPAQ has not been validated in individuals less than 18 years of age, its developer shared that the tool is adaptable and researchers may select subscales and/or individual items that are relevant for use in their research (M. A. Grandner, personal communication, January 9, 2019). However, due to the lack of empirical data to support use of SPAQ in adolescents, the individual subscales are largely retained intact with the exception of removal of individual items that relate to sexual behavior. In addition, the SPAQ has a theoretical foundation in health behavior theory, one of which is the TRA, a precursor of the TPB. Three subscales are selected from the SPAQ to assess adolescents' attitudes and beliefs regarding sleep.

Morningness/Eveningness Scale for Children (M/E Scale for Children)

The M/E Scale for Children (Appendix E) was developed as a modification of the Composite Scale of Morningness (CSM), a subjective measurement scale of chronotype (Carskadon, Vieiro, & Acebo, 1992). The CSM has been validated and is reliable for use in adults (Smith et al., 1989). The M/E Scale for Children is derived from similar CSM questions regarding preferred timing of common children's activities, such as recess/physical activity, test-taking, bedtime, and wake time in a 10-item scale, which is more consistent with children's and adolescents' daily patterns. The scale was tested among a sample of 183 male and 275 female sixth grade students who were part of a larger study of puberty and circadian phase preference (Carskadon et al., 1993). Sixth grade students were selected for their variability among stages of puberty within the same age group. The M/E composite score was consistent between males and females, i.e., 28 (SD 5.6) and 28. 7 (SD 5.3) respectively (Carskadon et al., 1993).

Scoring

The M/E Scale for Children is rated on a 4- or 5-point scale of phase preference for morningness. Items are scored on a scale from a. = 1 through e. = 5 points, except certain items that are reverse coded, i.e., a. = 5 through e. = 1 points. The points from each question are added to achieve a single score of morningness, from a possible 10, indicative of minimal morning preference, to 42, indicative of maximal morning preference (Carskadon et al., 1993).

Psychometrics

The M/E Scale for Children was compared to the MEQ, and to self-reported sleep bedtime and wake time among sixth grade boys and girls to establish validity and reliability of the tool (Carkadon & Acebo, 1992; Carskadon et al., 1993). Study participants were grouped into morning type (M/E score of >32) and evening type (M/E score of <26) for psychometric testing (Carskadon & Acebo, 1992). Self-reported stage of puberty was correlated with M/E score, with more advanced pubertal stage associated with more evening preference (Carskadon et al., 1993).

Validity

The M/E Scale for Children was compared with the CSM, and with self-reported bedtimes and wake times in 11 and 12 year old male and female participants of the larger study (Carskadon & Acebo, 1992; Carskadon et al., 1993). Spearman rank order correlations demonstrated high correlation between M/E score and bedtime on both weekdays and weekends in boys and girls. A smaller but significant correlation was observed between M/E score and weekend wake time (Carskadon et al., 1993).

Reliability

Reliability of the M/E Scale for Children was assessed for internal consistency, with Cronbach's α 0.82 (Carskadon & Acebo, 1992). Additionally, reliability was assessed by comparison of self-reported bedtimes and wake times among study participants. The M/E Scale for Children demonstrated consistency of sleep timing of both morning and evening groups of participants. The morning group had earlier bedtime and wake times on both weekdays and weekend days. This group was more likely to awaken spontaneously without use of an alarm clock or parent prompt (Carskadon & Acebo, 1992). In addition, consistency among the evening group revealed an increased likelihood of bedtime later than 3 a.m., and wake time later than 12 noon at least once weekly, and an increased incidence of daytime sleepiness compared to the morning group (Carskadon & Acebo, 1992).

Wrist Actigraphy

Wrist actigraphy is an objective measurement tool, which is performed in the natural environment, with an accelerometer device to measure activity counts as a proxy for sleep and wake patterns (Meltzer, Montgomery-Downs, Insana, & Walsh, 2012). The Actiwatch Spectrum Plus® (Phillips Respironics, Murrysville, PA), a rechargeable, waterproof device, was used for wrist actigraphy in this study. The Actiwatch Spectrum Plus® has a micro electromechanical system (MEMS) type accelerometer, with the ability to measure continuous activity counts at 30-second epochs for about 91 days. Additionally, the actigraphy device has the ability to detect when the device is off the wrist, which can correctly identify when the watch has been removed from the wrist, instead of erroneously including this time as sleep (Phillips Respironics, 2013). The Actiwatch was worn on the non-dominant wrist for a 1-week period of data collection. A minimum of 5 days of data collection (including weekday and/or weekend) by actigraphy was needed for completeness of data collection. Participants received written instructions for use and care of the Actiwatch (Appendix F).

Scoring

Actigraphy scoring is done by validated computer scoring algorithms (Johnson et al., 2007; Sadeh, Sharkey, & Carskadon, 1994). Scoring for this study was performed with a validated SAS-based algorithm (SAS v. 9.4, SAS Institute, 2008). The Time Above Threshold (TAT) data mode for scoring calculates the time per epoch that the signal is above a set threshold (Johnson et al., 2007). The Actiware and SAS computer scoring uses the TAT mode of scoring, whereby, if the number of activity counts exceeds the threshold, the epoch is scored as wake, and if the number of activity counts is below the threshold, the epoch is scored as sleep. Time off wrist of four or more hours per day was regarded as an invalid day and sleep intervals were not scored for these days. The computer scoring was followed by two independent scorers who manually reviewed the actigraphy data and revised the scoring as appropriate. Any discrepancies of greater than 15 minutes between scorers were adjudicated by a third scorer. The PI served as the first scorer. Biomarker and Actigraphy Data Coordinating Center research staff served as additional scorers.

Psychometrics

Actigraphy has been demonstrated to be a valid sleep measurement tool for adolescent research by comparison with PSG (Sadeh et al., 1994). Validity, i.e., sensitivity and specificity (Meltzer, Montgomery-Downs et al., 2012), and reliability have been assessed in adolescents (Acebo et al., 1991).

Validity

Sensitivity in sleep measurements involves testing the ability of the tool to accurately measure sleep; whereas, specificity is testing the tool's ability to accurately measure wake after sleep onset. Sensitivity is measured by comparison of the proportion of actigraphically-measured epochs correctly identified as sleep when compared to PSG recordings (Meltzer, Montgomery-Downs et al., 2012). Specificity identifies the proportion of epochs correctly identified as WASO on actigraphy compared to PSG recordings (Meltzer, Montgomery-Downs et al., 2012). High sensitivity of 82.2-95.0 was demonstrated in a review which included 208 pediatric and adolescent studies using actigraphy (Meltzer, Montgomery-Downs et al., 2012). The specificity in this review, 50.9-74.5, was less robust (Meltzer, Montgomery-Downs et al., 2012).

Reliability

Reliability includes an assessment of the number of nights of actigraphy data that are needed to provide measurement consistency within the adolescent population. Intraindividual variability of adolescent sleep patterns in relationship to pubertal changes, and later circadian timing has been discussed in Chapter 2. Acebo and colleagues (1999) studied the number of nights of actigraphy data required to provide reliable estimates of sleep parameters in two studies of adolescents, which compared 7 nights of wrist actigraphy data with sleep diary data and daily phone calls of sleep and wake times. Reliability of ≥ 0.70 was considered adequate, which was achieved with greater or equal to 5 nights of actigraphy data in both studies (Acebo et al., 1999). As much as 28% of actigraphy data were unable to be used due to illness, technical problems with the actigraph, or poor compliance with either wearing the actigraph or completing the sleep diary. Assessment of adolescent sleep variability demonstrated adequate reliability for the sleep onset (0.77-0.88 for 5 week nights; 0.35-0.87 for 3 week nights plus 2 weekend nights), wake after sleep onset (0.87-0.89 for 5 week nights; 0.84-0.89 for 3 week nights plus 2 weekend nights), and sleep efficiency (0.87-0.89 for 5 week nights; 0.87-0.91 for 3 week nights plus 2 weekend nights). However, less reliable estimates were observed with sleep minutes (0.65-0.74 for 5 weeknights; 0.65-0.80 for 3 weeknights plus 2 weekend nights), and sleep period (0.49-0.72 for 5 weeknights; 0.34-0.54 for 3 weeknights plus 2 weekend nights) (Acebo et al., 1999).

A minimum of five nights of scorable actigraphy data, regardless of weekday or weekend, will be needed to be included in the study. The nights of scorable data do not need to be consecutive but need to be the same nights as the sleep diary data.

Daily diary

The Daily Diary includes two parts: Sleep Diary, and Nighttime Mobile Phone Use Diary. Both of these measures are self-report measurement tools and were completed on a daily basis during the 7-day actigraphy portion of the study. Study participants received morning and evening email prompts to complete diary data. Study participants who did not complete the daily diaries received an additional text message or email prompt from the PI to complete the measures.

Sleep Diary

The Consensus Sleep Diary (CSD) (Appendix G) was the result of collaboration by a panel of insomnia experts, along with findings from a focus group study comprised of people with and without sleep conditions (Carney et al., 2012). While the sleep diary provides a range of self-report variables, it is ideally used in combination with an objective sleep measure, such as actigraphy or PSG (Carney et al., 2012). The psychometrics for the CSD are difficult to evaluate, due to the intra-individual characteristics of sleep, sleep instability, and sleep variability. No formal reliability or validity analyses have been reported for the Consensus Sleep Diary; however, construct validity has been established by the expert panel and the focus groups in development of this measure. The sleep diary measures multiple constructs, and individual items on the sleep diary do not necessarily correlate with one another (Carney et al., 2012).

The modified CSD was incorporated into an electronic format for completion both in the morning and in the evening. Questions related to alcohol use were omitted in the CSD for this research study. Participants were given oral and written instructions on how to complete the sleep diary and received twice daily electronic reminders to complete the sleep diary. The sleep diary was used in this study to augment the information obtained from wrist actigraphy, such as validation of sleep and wake times, in addition to displaying habitual sleep habits. A minimum of 5 days/nights of sleep diary data (same nights as actigraphy data) were needed to be included in the data analysis.

Nighttime Mobile Phone Use Diary

The Nighttime Mobile Phone Use Diary (Appendix H) is a brief measure to assess the nighttime use of electronic technology, including which mobile phone functions participants are using on the mobile phone, and the number of times and/or amount of time these functions are used. Participants were prompted to complete the diary in the morning. The diary has 4 questions. Question one asks whether the mobile phone was used between bedtime and wake time. If the mobile phone was not used during this time no further questions were prompted. If affirmation of mobile phone use was indicated, question two asked which mobile phone functions were used, how many times, and the period of time (in hours and minutes) the service was used. The third question was a nested question inquiring about other nighttime technology use; if answered in the affirmative, the participant was asked to specify the device used. The fourth question asked during which portion of the sleep period the participant used the mobile phone. A summary of measurement tools with psychometric properties is summarized in Table 3-3.

Table 3-3

Measurement Tools and Psychometrics

Measurement tool	Tool description	Validity	Reliability	Time to Complete*
Eligibility Questionnaire	• A pre-screening questionnaire to evaluate inclusion and exclusion criteria • 4 items	N/A	N/A	< 5 minutes
Demographics Questionnaire	• Measurement of sample characteristics • 4 items	N/A	N/A	< 5 minutes
Mobile Phone Problem Use Scale-10 (MPPUS-10)[a]	• Prediction of mobile phone use, and compulsive phone behavior in adolescents • 10 items • 10-point Likert-type scale	Compare with MPPUS (27 items) r = 0.95, p <0.001 Compare with MPPUS (17 items not in MPPUS-10) r =0.86, p < 0.001	Cronbach's α 0.85	< 5 minutes
Mobile Phone Problem Use Scale (MPPUS)[b]	• Prediction of mobile phone use and compulsive behavior	Self-report time using mobile phone r = 0.45, p <0.01	Cronbach's α 0.93 in adults Cronbach's α 0.92 in adolescents	< 5 minutes

Table 3-3

Measurement Tools and Psychometrics

Measurement tool	Tool description	Validity	Reliability	Time to Complete*
	• 1 item relating to phone behavior and sleep • 10-point Likert-type scale	Number of people called on regular basis $r = 0.42$, $p < 0.01$ Average monthly phone cost $r = 0.43$, $p < 0.01$		
Sleep Practices and Attitudes Questionnaire (SPAQ)[c]	• Assess attitudes regarding sleep • 3 subscales: Sleep Self-Efficacy, Importance of Sleep, and Sleep and Health • 16 items • 5-point Likert-type scale	Compare with validated measures: Pittsburgh Sleep Quality Index (PSQI)-general sleep disturbance; Epworth Sleepiness Scale (ESS)-daytime sleepiness; Sleep Hygiene Index (SHI)-sleep hygiene measures; Dysfunctional Beliefs and Attitudes Scale-insomnia attitudes and beliefs	Cronbach's α for individual subscales 0.25-0.86 (median 0.63) Importance of sleep: 0.64 Sleep self-efficacy: unable to be calculated (single item scale) Sleep and health: 0.80	10 minutes for 16 subscales (151 items) 5 minutes for 3 subscales (16 items)
Morningness/Eveningness (M/E) Scale for Children[d,e]	• Evaluate the morning or evening	Compare with validated Composite	Cronbach's α 0.82[d]	5 minutes

Table 3-3

Measurement Tools and Psychometrics

Measurement tool	Tool description	Validity	Reliability	Time to Complete*
	preference as an estimate of phase	Scale of Morningness in adults	Compare to self-reported bedtime and wake time	
	preference for timing of sleep and activity by self-report • 10 items	Compare to self-reported bedtime and wake time data		
Wrist Actigraphy[f, g]	• Measurement of sleep and wake patterns by activity counts	Sensitivity 82.2-95.0 % Specificity 50.9-74.5 %[d]	5-7 nights in adolescents: Sleep period, 0.36-0.64 Sleep minutes, 0.62-0.81 Wake minutes, 0.85-0.91 Sleep efficiency, 0.88-0.92[e]	7 days
Consensus Sleep Diary[h]	• Display habitual sleep habits and augment actigraphy data • Morning Diary • Evening Diary	Unable to be calculated due to intra-individual sleep differences	X	< 5 minutes each for morning and evening diaries

Table 3-3

Measurement Tools and Psychometrics

Measurement tool	Tool description	Validity	Reliability	Time to Complete*
	• 8 items in morning • 5 items in evening			
Nighttime Mobile Phone Use Diary	• Assess nighttime mobile phone use • Assess specific mobile phone functions used during the night • 4 items	X	X	< 5 minutes

Note: N/A = not applicable; X = not calculated; *all questionnaire measures were pre-tested for completion time by 1 adolescent male, age 13, who is not part of the study. [a]Foerster, Roser, Schoeni, & Roosli, 2015; [b]Bianchi & Phillips, 2005; [c]Grandner, Jackson, Gooneratne, & Patel, 2014; [d]Carskadon & Acebo, 1992; [e]Carskadon, Vieira, & Acebo, 1993; [f]Meltzer, Montgomery-Downs, Insana & Walsh, 2012; [g]Acebo et al., 1999; [h]Carney, Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2014

Data Collection

The protocol for this study is detailed in Figure 3.1. One study visit with the PI and 7 additional days of data collection, were required for the 1-week study period. All questionnaires and diary data were collected directly within the Research Electronic Data Capture (REDCap) data management and storage system. REDCap is a metadata method which provides a secure electronic system with research tools for data collection, storage, and the ability to export to a statistical software package (Harris, Thielke, Taylor, Payne, Gonzalez, & Conde, 2009).

Distribution of instruments/measures

All potential study participants were screened for eligibility using the Eligibility questionnaire prior to any study procedures. This prescreening occurred either in person, via telephone or videoconference to establish eligibility to participate in the study. Establishment of eligibility occurred prior to signing informed consent or data collection. Visit 1 was comprised of obtaining informed consent, instruction on data collection, and completion of questionnaires. Potential participants and parent(s) were provided with an explanation of the study, with time to ask questions, and signed informed consent and minor assent. Participants completed a battery of questionnaires (demographics questionnaire, MPPUS [1 item], MPPUS-10, SPAQ, and M/E Scale for Children). Study participants were instructed in daily completion of diary data, and how to contact the PI in the event of a problem. Study participants were provided with instructions for using the wrist actigraphy device (Appendix G), and the daily diary (Appendix H). Participants departed from visit 1 wearing a wrist actigraphy device and received a pre-paid mailer to return the wrist actigraphy device to the PI at the completion of the 7-day data collection period. Conversely, some participants opted to return the wrist actigraphy device in person by prior arrangement with the PI. For those study participants who were enrolled via remote videoconference, an alternate process was implemented. Participants and their parent(s) were provided with a consent form via electronic mail and a virtual appointment time was arranged via a videoconference platform. The procedure for review of the consent form was the same as the face-to-face visits. Parents and participants provided verbal informed consent and minor assent, respectively. Verbal consent was documented by the PI, and parent and participants signed the consent form and scanned and returned the consent form to the PI via electronic mail in accordance with IRB protocol. The remainder of the process was the same as face-to-face participants used. The wrist actigraphy device was mailed to the participant, along with a prepaid return mailer. Study participants received daily electronic mail prompts for diary completion at 10 a.m. and 8 p.m. daily.

Participants completed morning and evening daily diary surveys within the REDCap data collection system. Visit 1 took approximately 30-40 minutes of time. Following completion of the 7-day wrist actigraphy, participants either mailed the wrist actigraphy device to the PI in a pre-paid mailer or returned the device in person. Actigraphy data were downloaded following receipt of the device and assessed for completeness of data. Participants received tiered incentives up to $100 for participation in this study. All participants received an initial incentive of $25 following completion of all study procedures at visit one. The incentive was paid via online Amazon gift card which was sent to the participants' email address. Study participants received up to $75 following completion of data collection. Incentives after data collection were pro-rated dependent upon completeness of data. All participants received $25 following return of the wrist actigraphy device. Additional incentives for provision of actigraphy and diary data were provided as follows: $10 for those providing five days of data, $25 for those providing 6 days of data, and $50 for those providing the full 7 days of data.

Plans for data management

All participants were assigned a unique study identification (ID) number. All study-related documentation was identified by study ID number. A master list of study participants' names with a link to the study ID number was maintained by the PI and stored within the password-protected REDCap system. The list of study participants will be destroyed after completion of the study. Access to study data was restricted to the PI and the IRB approved study team, referred to as the *study team* (i.e., the dissertation co-chairs) throughout.

Protection of human subjects

IRB approval (Appendix J) was obtained for this study. Study procedures were reviewed with potential participants and their parent(s) as part of the consent process. Parental permission and minor assent (Appendix K) were obtained prior to any study-related procedures. Additional IRB approvals were obtained to add recruitment sites, to increase study enrollment, and to enroll participants virtually due to COVID-19-related research restrictions. All study-related documentation was coded with a unique study ID number. A master list of participants' names and ID numbers was maintained by the PI and stored in a password-protected computer file (REDCap). Survey data were collected and managed within the REDCap system. Actigraphy data were stored within the actigraphy scoring system by a unique ID number, without personal identifying information. Access to data is restricted to the PI and the study team.

Data Analysis

To investigate the study aims, IBM SPSS Statistics, version 26 was used for data analysis. Significance level was set at 0.05 for all hypotheses testing.

Descriptive Analysis

Participants' demographic characteristics, and their baseline measurements (including MPPUS-10, MPPUS, SPAQ, and M/E Scale for Children) were summarized using descriptive statistics such as mean and standard deviations for continuous variables, and frequency and relative frequency for categorical variables. Due to the small sample size, this study had the potential for insufficient power for analyses of all mobile phone functions used after lights out. Therefore, categories of mobile phone functions that adolescents used after lights out were collapsed into fewer categories of mobile phone use, i.e., communication (phone calls and text messages), entertainment (watching movies/TV, listening to music or podcast, playing games), and use of social media. Additional categories of mobile phone use were collected, but not included in this analysis. The categories of mobile phone usage were further collapsed into binary categories for analysis, i.e., nighttime mobile phone use versus no use and high usage versus low usage.

Hypotheses/Research questions and data analysis

RQ.1. Which mobile phone functions are adolescents accessing after lights out?

H1. Based on prior research on use of electronic media prior to and after lights out, it was hypothesized that:

a. Females used mobile phones after lights out for communication more frequently than males.

b. Males used mobile phones after lights out for entertainment more frequently than females.

Descriptive statistics were generated to summarize the frequency of mobile phone functions accessed after lights out for each category of mobile phone use. Mobile phone functions were further aggregated into three groups (communication, entertainment, and social media use) as described above. Since participants may have selected more than one category of mobile phone use in a single day based on individual mobile phone usage, each category was analyzed individually. Phone use over the 7-day period was averaged to mean nighttime use, and users were grouped into low versus high users based on time spent using the mobile phone, and mobile phone non-users versus users. Chi square was used to analyze the percentage of adolescents who engaged in mobile phone use after lights out. T-test was used for time measurements of media use. Chi square test was used to assess gender versus low/high average nighttime mobile phone use for communication and entertainment purposes. T-test was used to evaluate gender versus total time use of mobile phone use after lights out for communication and entertainment.

RQ.2. What factors contributed to adolescents' mobile phone use after lights out?

H2. Based on prior research on use of electronic media prior to and after lights out, it was hypothesized that:

a. Females have more frequent nighttime mobile phone use than males.

Chi square test was used to assess gender versus low/high average nighttime mobile phone use after lights out. T-test was used to evaluate gender versus total time nighttime use of mobile phones after lights out.

b. Adolescents who consumed caffeine prior to bedtime have greater mobile phone use after lights out than adolescents who do not consume caffeine prior to bedtime. Caffeine use was grouped into non-users versus users, and low users versus high users, and compared with average nighttime mobile phone use after lights out. Chi square test was used to assess the percentage of participants with caffeine use and average nighttime mobile phone use, and T-test to analyze caffeine use and minutes of average nighttime mobile phone usage after lights out.

c. Adolescents with increased mobile phone use after lights out place less value on the importance of sleep. Adolescents' attitudes and beliefs on the importance of sleep was measured at Visit 1, using a Likert scale. Mobile phone use after lights out was averaged into nighttime use comparing low versus high mobile phone use after lights out. The SPAQ subscale scores and the MPPUS-10 and MPPUS variables were analyzed with T-test to assess group comparisons. Correlations between continuous variables were assessed.

RQ.3. What are the sleep patterns of adolescents who use mobile phones after lights out?

H3. Based on prior research on use of electronic media prior to and after bedtime and sleep duration, sleep quality, and daytime sleepiness, it was hypothesized that use of mobile phones after lights out results in:

a. Shorter sleep duration, as evidenced by actigraphically-measured total sleep time. Sleep duration was categorized into two groups, adequate sleep duration (minimum 8 hours) versus inadequate sleep duration.

b. Reduced sleep quality, as evidenced by increased sleep onset latency, increase in WASO, lowered sleep maintenance efficiency, and decreased perception of sleep quality. Sleep quality is a self-report repeated daily measure on a Likert-type scale, and was dichotomized into a binary outcome (low versus high).

c. Increased next day sleepiness, as evidenced by self-reported daytime sleepiness, and incidence of napping. Daytime sleepiness and napping was assessed by no napping versus napping. Chi square test was used to assess napping versus average nighttime mobile phone use. T-test was used to compare napping with time usage of mobile phone functions after lights out. Correlations between sleep variables and mobile phone usage were evaluated. An overall regression model was used with mobile phone time usage as the independent variable. Dependent variables added to the model included napping, sleep duration, and WASO. Covariates included gender, type of function used on the mobile phone, and chronotype.

Psychometrics of Study Measures

Psychometrics of study measures are depicted in Table 3.3 and discussed above, with the exception of the Eligibility, and Demographics questionnaires, where this analysis was not applicable. Psychometrics for the Consensus Sleep Diary were not calculated due to intra-individuality of sleep parameters, which were evaluated by this instrument (Carney et al., 2014). The Nighttime Technology Use Diary was developed by the investigator and does not have psychometric data; however, it was developed under the guidance of a dissertation committee co-chair with extensive research experience in sleep science.

Missing data

Actigraphy and daily diary data needed to be collected for a minimum of 5 days to be included in this research study. Both actigraphy and diary data needed to be collected on the same days, but not necessarily continuous days. This requirement was necessary for accurate scoring of sleep and mobile phone use. The plans to reduce the potential for missing actigraphy and daily diary data included the following: careful verbal and written explanations of study procedures and rationale for completeness of data collection, daily electronic reminders to complete the diary data entries, additional reminders to complete surveys if needed, and pro-rated participant reimbursement for wearing the actigraphy device during the 7-day data collection period and completing daily diary data. Use of text message reminders on the participants' mobile phone for data collection have been successful in reducing study attrition in adolescents (Davis, Demby, Jenner, Gregory, & Broussard, 2016). There was the potential for loss of data in the event of malfunction of the actigraphy device with failure to collect data, which would be unable to be detected until the data download period. All participants returned the actigraphy device, and there were no device malfunctions or error messages.

Validity and Reliability

Following completion of data collection, study measures were assessed for internal consistency using Cronbach's alpha, and compared with study measures which have published data for internal consistency. The SPAQ has not been validated in individuals under the age of 18. Although the sample size was not large enough to conduct validity testing in adolescents, the study results were compared with published validity data for the SPAQ.

Chapter Summary

A cross-sectional descriptive, correlational design was conducted to evaluate the relationships between attitudes, behaviors, and sleep patterns of adolescents who use mobile phones within the bedroom setting after lights out. This chapter describes the methodology used to conduct this dissertation research. Study participants included a sample of adolescents, who completed a battery of questionnaires regarding beliefs and attitudes, mobile phone use, and sleep behavior. Participants wore a wrist actigraphy device to evaluate sleep patterns. Data were collected in a micro-longitudinal fashion over seven days to assess sleep behaviors, sleep patterns, and mobile phone use after lights out. Data analysis included descriptive correlational methods, chi square, t-tests, correlations, and regression.

Chapter 4

Results

The purpose of this study was to explore the attitudes, behaviors, and sleep patterns of adolescents who use mobile phones in the bedroom setting after lights out. This study used a descriptive correlational study design with micro-longitudinal data collection. Study participants completed preliminary questionnaires of attitudes and beliefs, followed by a 1-week period of actigraphy and twice daily sleep and technology use diaries. The following research questions were addressed in this study:

RQ.1. Which mobile phone functions are adolescents accessing after lights out?

RQ.2. What factors contribute to adolescents' mobile phone use after lights out?

RQ.3. What are the sleep patterns of adolescents who use mobile phones after lights out?

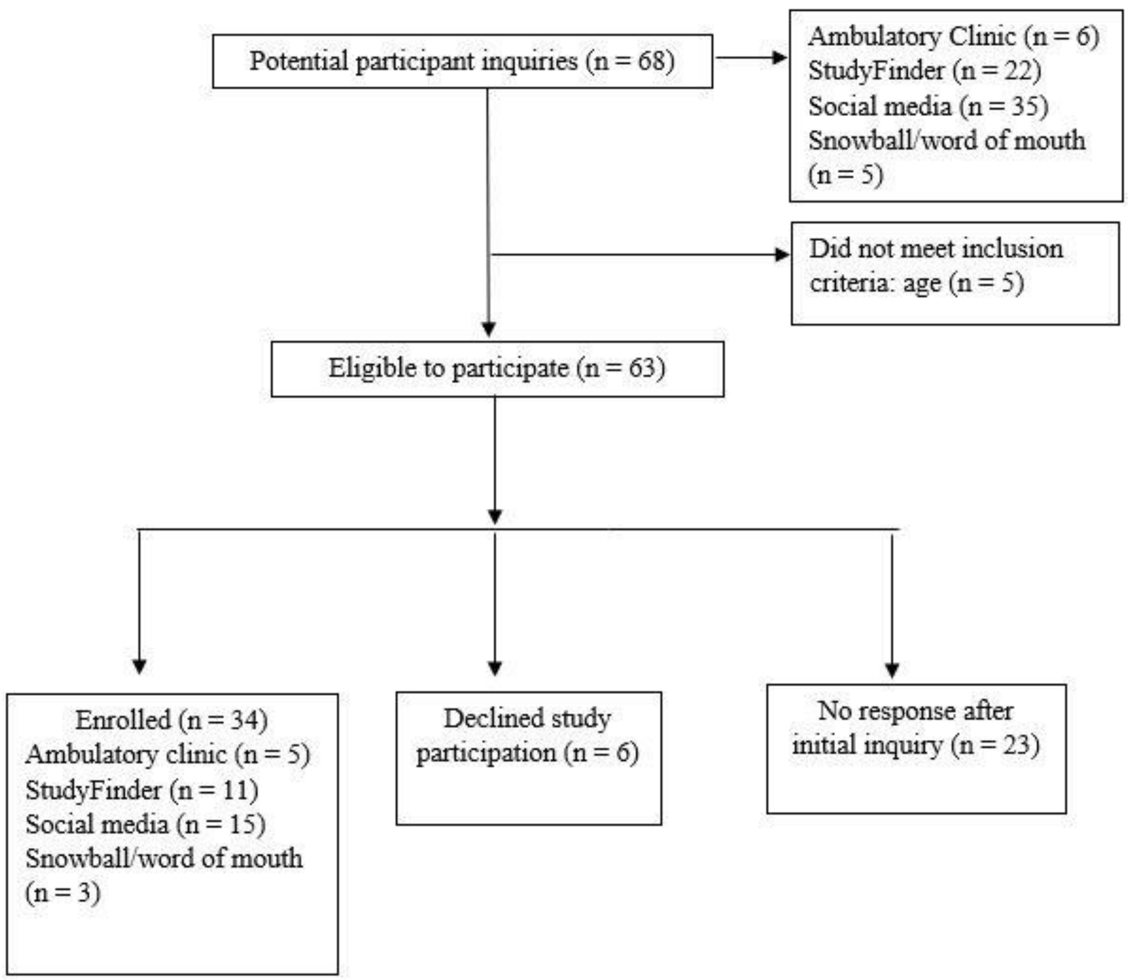
Data were collected from December 2019 through March 2020. Study results are organized by research question. Data were collected during the historic COVID-19 pandemic. Mandatory school closures occurred in the midst of data collection. Although not part of the research questions, exploratory descriptive statistics were performed on study measures pre- and post-school closure.

Study Recruitment and Enrollment

Study participants were recruited from the Penn State Health pediatric endocrinology ambulatory clinic and via Penn State StudyFinder. Participants were either approached in the clinic to inquire about interest or contacted the PI via StudyFinder, phone, or electronic mail. In addition, this study had an unplanned benefit of recruitment via social media with a snowball effect. A parent of a potential participant independently posted a link to the StudyFinder page on her personal social media page and on the social media pages of two local parent groups, which prompted inquiries from parents and potential participants. In addition, some participants talked with peers about their potential enrollment, with subsequent inquiry made to the PI about study participation. Study recruitment and enrollment is detailed in Figure 4-1.

Figure 4-1

Study Recruitment and Enrollment



A total of 68 inquiries were made regarding the study. After review of the study synopsis, evaluation of inclusion criteria, and provision of consent form for review, a total of 34 participants signed informed consent and completed the study. Five potential participants expressed interest in the study, but all were 12 years old and therefore excluded on the basis of age. Six participants originally indicated interest to take part in the study, but declined participation due to involvement in school sports activities, or unwillingness to wear the actigraphy device for a minimum of 20 hours per day. One of the 34 participants did not complete the minimum number of micro-longitudinal measures, i.e., actigraphy, and was excluded from analyses related to sleep measurements.

Sample Description

Thirty-four participants, ages 13-17 years, participated in the study. The sample demographics data are presented in Table 4-1. The sample was 62% female and predominantly Caucasian and non-Hispanic, with mean age 14.56 (SD = 1.28) years. Descriptive statistics were performed on the measures of attitudes and beliefs: MPPUS, MPPUS-10, and SPAQ. Higher scores on the MPPUS and MPPUS-10 signify agreement with the beliefs and mobile phone practices and are indicative of more problematic mobile phone. Higher scores on the SPAQ reflect less concern with sleep practices and attitudes, such as the importance of sleep for health, control over sleep, and the perception of the value of sleep for health outcomes (Table 4-2). The M/E Scale for Children is a measure of chronotype with possible scores ranging from 10 to 42 (refer to Table 4-7). Higher scores are indicative of morning type, whereas lower scores are indicative of evening type. Those not falling into the extremes are classified as intermediate type. Descriptive statistics for individual items are detailed in Table 4-3 for MPPUS and MPPUS-10, and Table 4-4 for SPAQ, respectively.

Table 4-1

Sample Demographics

Characteristics	Frequency (N=34)	Percent*
Age		
13 years	10	29.4
14 years	5	14.7
15 years	12	35.3
16 years	4	11.8
17 years	3	8.8
Gender		
Female	21	61.8
Male	11	32.4
Prefer not to say	1	2.9
Did not answer	1	2.9
Race (may include more than one race)[a]		
White/Caucasian	32	94.1
Black/African American	0	0
Asian	1	2.9
American Indian/Alaska Native	0	0
Native Hawaiian or Other Pacific Islander	0	0
Other	1	2.9
Did not answer	1	2.9
Ethnicity		
Hispanic	1	2.9
Non-Hispanic	32	94.1
Did not answer	1	2.9

Note. *Percent may not add to 100 based on rounding. [a]Choice of multiple options increases percent to more than 100.

Table 4-2

Mean Scores of Measures of Attitudes and Beliefs on Mobile Phone Use and Sleep

Measure	Minimum	Maximum	M	SD
Mobile Phone Problem Use Scale	1	10	5.26	2.30
Mobile Phone Problem Use Scale-10	20	72	43.68	13.31
Sleep Practices and Attitudes Questionnaire	26	49	37.88	6.76

Note. N = 34. MPPUS: single item scale; MPPUS-10: minimum possible score = 10, maximum possible score = 100; SPAQ: minimum score = 16, maximum score = 80.

Table 4-3

Item Scores for Mobile Phone Problem Use Scale and Mobile Phone Problem Use Scale-10

Item	M	SD
I lose sleep due to the time I spend on my mobile phone*	5.26	2.30
I have used my mobile phone to make myself feel better when I was feeling down	6.09	2.93
When out of range for some time, I become preoccupied with the thought of missing a call	2.97	2.05
If I don't have a mobile phone, my friends would find it hard to get in touch with me	7.53	2.52
I feel anxious if I have not checked for messages or switched on my mobile phone for some time	4.41	2.45
My friends and family complain about my use of the mobile phone	4.38	2.68
I find myself engaged on the mobile phone for longer periods of time than intended	6.24	2.33
I am often late for appointments because I'm engaged on the mobile phone when I shouldn't be	1.50	0.92
I find it difficult to switch off my mobile phone	3.94	2.23
I have been told I spend too much time on my mobile phone	5.41	2.64
I have received mobile phone bills I could not afford to pay	1.21	1.03

Note. N = 34. *Single item question for MPPUS. All items are scored on a 10-point Likert scale (1 = not true at all to extremely true). Higher scores are indicative of more problematic mobile phone use.

Table 4-4

Item Scores for Sleep Practices and Attitudes Questionnaire

Item	Mean	SD
1. How much do you agree/disagree with the following statements?		
a. I have control over when and how much I sleep	2.42	0.83
b. As you were growing up, did you parents emphasize the importance of sleep?	1.82	0.72
c. How important is getting healthy sleep for children growing up?	1.42	0.61
d. I care about making sure that I have enough time to sleep	2.27	0.91
e. Getting to bed at a good time is important to me	2.67	1.02
f. I think my sleep is important	1.85	0.66
g. My family thinks that sleep is important	1.55	0.56
h. My friends think that sleep is important	3.09	1.10
2. How important is it to you that by not sleep enough you will:		
a. Feel sleepy during the day	2.15	0.93
b. Fall asleep while driving	3.41	1.58
c. Be more moody	2.52	0.93
d. Have less energy	2.12	0.73
e. Miss more days of work or school	3.94	1.08
f. Perform worse at work or school	2.36	1.05
g. Have problems remembering things or concentrating	2.76	1.17
h. Feel tired	1.64	0.74

Note. N=34. All items are scored on a 5-point Likert scale (1 = strongly agree, 2 = agree, 3 = unsure, 4 = disagree, 5 = strongly disagree). Higher scores are indicative of poorer self-efficacy, lower agreement with beliefs about healthy sleep, and less concern about health effects of insufficient sleep.

Table 4-5

Average Nightly Minutes of Mobile Phone Usage of Mobile Phone Function

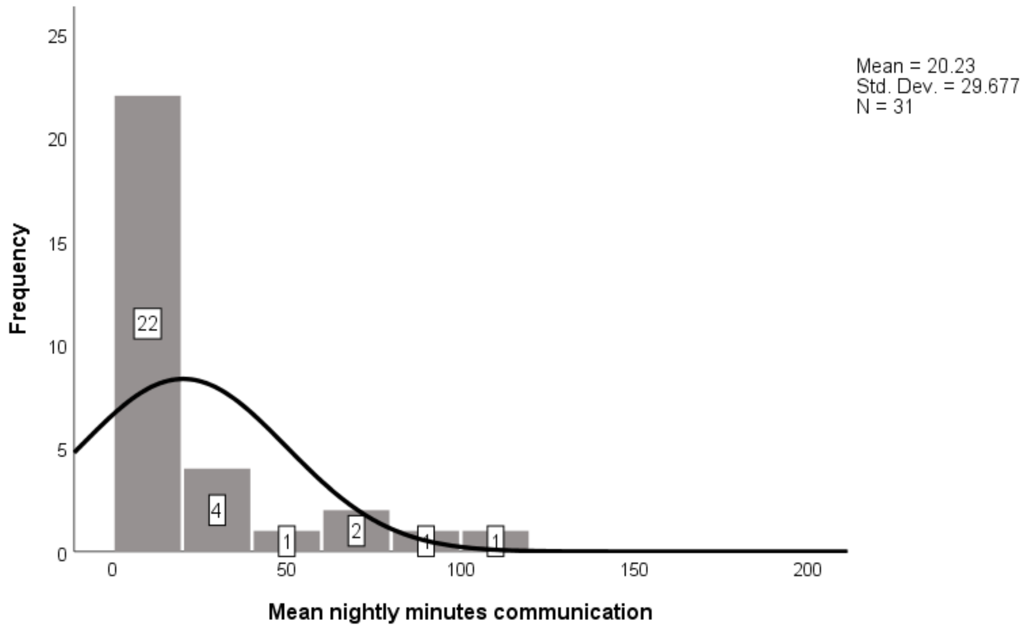
Mobile phone function	N	Min	Max	Mean	SD	Median
Phone call	31	0	115.16	11.74	23.59	2.57
Pre-school closure	19	0	115.16	10.85	26.10	
Post-school closure	12	0	62.85	13.45	19.97	
Text messaging	31	0	80.70	8.48	19.22	0.71
Pre-school closure	19	0	80.70	10.49	23.82	
Post-school closure	12	0	25.71	5.29	7.84	
Social media	31	0	277.71	39.72	59.14	15
Pre-school closure	19	0	141.00	28.95	36.83	15
Post-school closure	12	0	277.71	56.77	82.47	14.99
Music/Podcast	31	0	62.14	5.02	14.18	0
Pre-school closure	19	0	62.14	5.18	15.05	
Post-school closure	12	0	46.57	4.77	13.31	
Gaming	31	0	60.57	5.59	12.57	0
Pre-school closure	19	0	26.14	3.65	7.84	
Post-school closure	12	0	60.57	8.67	17.70	
Movie/TV	31	0	74.28	9.70	16.34	0
Pre-school closure	19	0	34.282	7.22	11.77	
Post-school closure	12	0	74.28	13.62	21.77	
Internet	31	0	77.28	2.90	13.90	0

Pre-school closure	19	0	77.28	4.51	17.72	
Post-school closure	12	0	4.28	0.35	1.23	
Other MP function	31	0	77.14	2.76	13.88	0
Communication	31	0	115.16	20.22	29.67	8.57
Pre-school closure	19	0	115.16	21.35	33.96	9.28
Post-school closure	12	0	67.85	18.44	22.55	7.49
Entertainment	31	0	141.27	20.32	34.48	8.57
Pre-school closure	19	0	113.99	16.06	30.33	0
Post-school closure	12	0	141.27	27.07	40.68	10.71
Overall MP use	31	0	255.71	60.02	62.32	45.00
Pre-school closure	19	0	117.85	47.9	40.87	50.00
Post-school closure	12	0	255.71	79.23	84.87	42.00

Note. COVID-19 pandemic resulted in school closures during recruitment and data collection. Descriptive analyses performed on entire sample, and pre- and post-school closure. MP = mobile phone. Communication = phone calling and text messaging. Entertainment = watching movies/TV, listening to music/podcast, and gaming. Overall MP usage = all mobile phone functions combined. Usage of mobile phone functions is recorded in average minutes after lights out. Participants selected as many mobile phone functions that were used for each day.

Figure 4-2

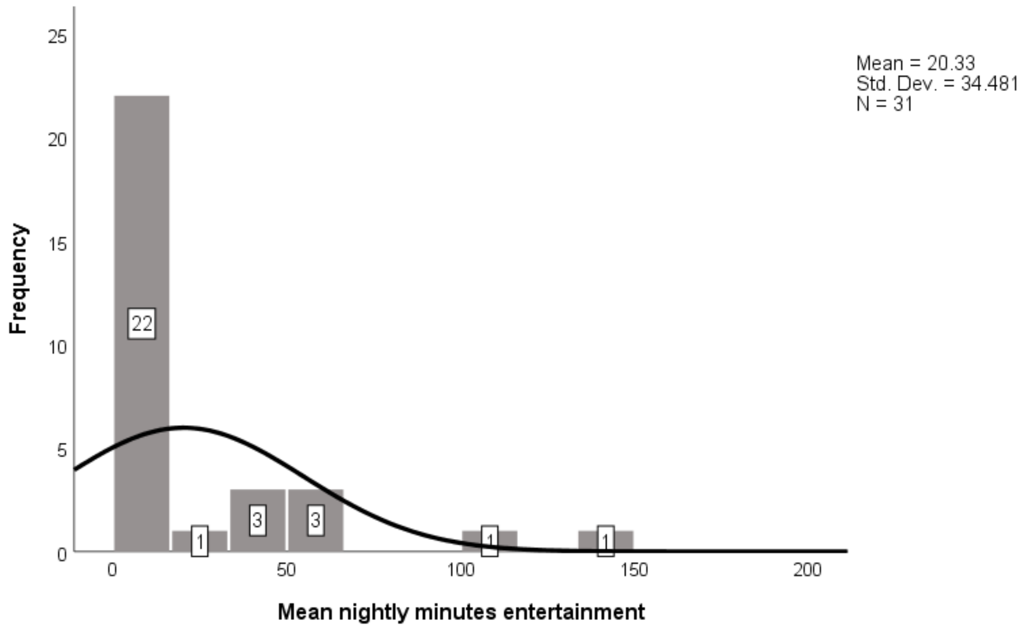
Distribution of Mean Nightly Minutes of Mobile Phone Use for Communication



Note. Communication = mean nightly minutes of phone calling and text messaging.

Figure 4-3

Distribution of Mean Nightly Minutes of Mobile Phone Use for Entertainment



Note. Entertainment = mean nightly minutes of watching movies, playing games, and listening to music or podcast.

Figure 4-4

Distribution of Mean Nightly Minutes of Mobile Phone Use for Social Media

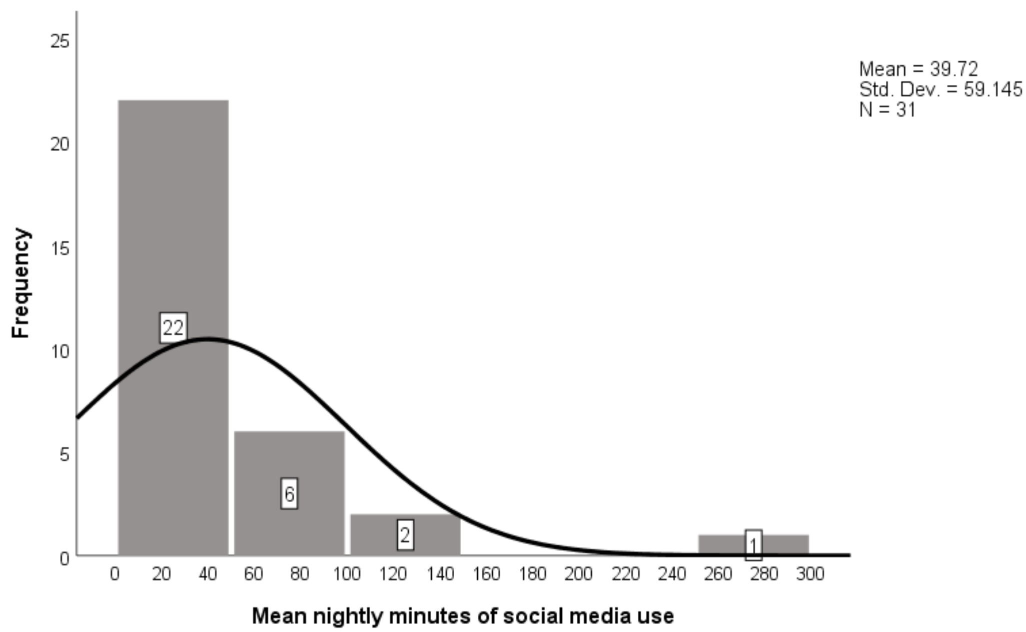


Figure 4-5

Distribution of Mean Nightly Minutes of Mobile Phone Use for all Mobile Phone Functions

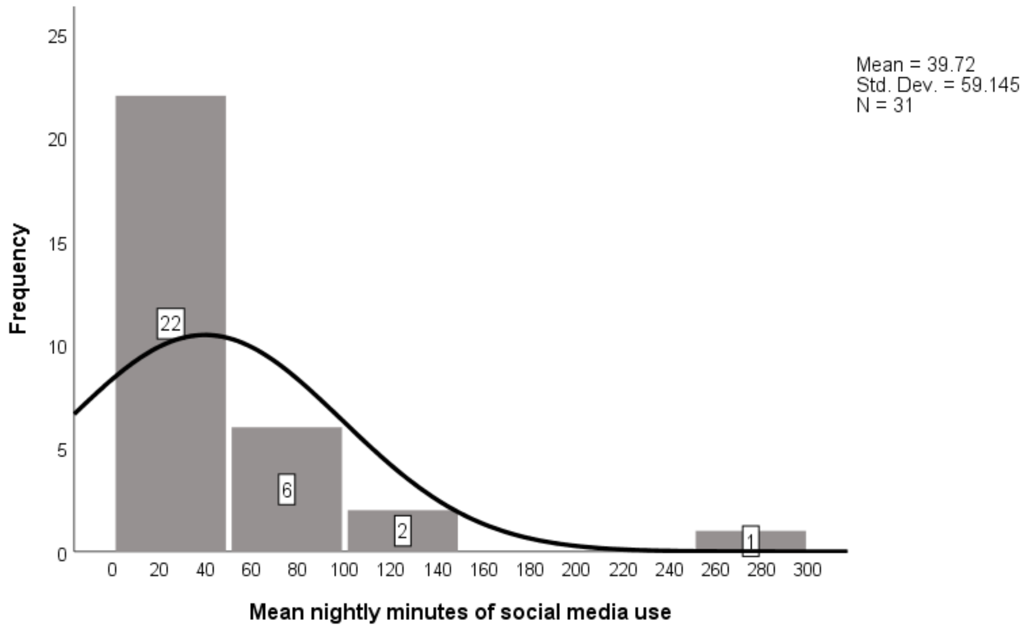


Table 4-6

Average Frequency of Daily Caffeine Use

Sample	N	Frequency	Percent
Full sample	34	26	79.5
Pre-school closure	22	18	81.8
Post-school closure	12	8	66.7

Table 4-7

Characteristics of Sleep Variables

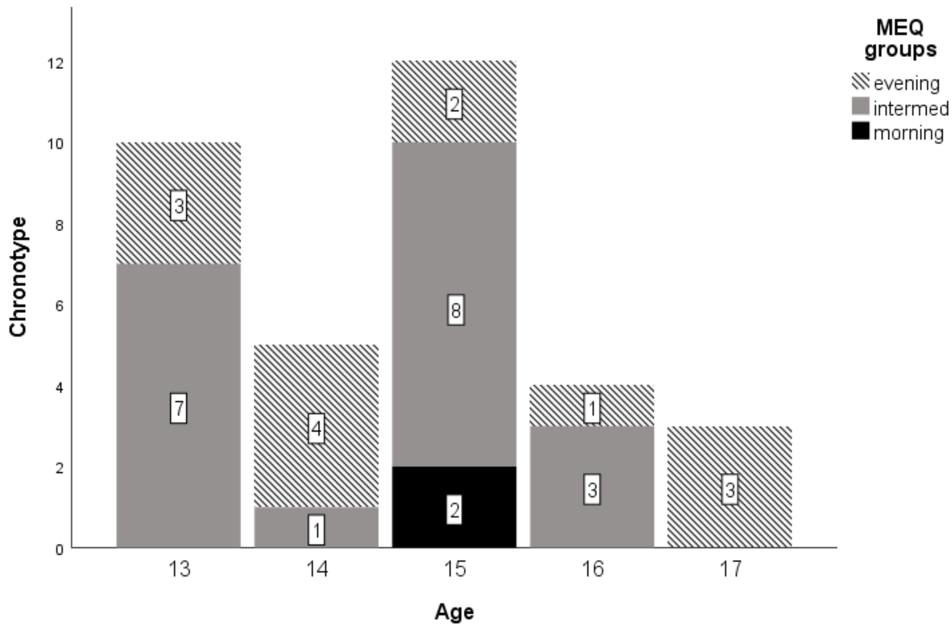
Sleep variable	N	Min.	Max.	Mean	SD
Morningness/Eveningness Scale for Children	34	21	35	26.74	3.40
E = 13 (38.23%); I = 19 (55.8%); M = 2 (5.88%)					
Valid days of actigraphy	33	5	9	6.97	0.52
Pre-school closure	21	6	8	7.05	0.08
Post-school closure	12	5	8	6.83	0.20
Mean nighttime sleep time (mins)	33	377.64	655.50	503.76	61.46
Pre-school closure	21	377.64	655.50	491.01	71.69
Post-school closure	12	462.57	582.42	526.08	28.08
Mean 24-hour sleep time (mins)	33	377.64	688.57	510.21	61.90
Pre-school closure	21	377.64	688.57	500.81	73.67
Post-school closure	12	462.57	582.42	526.67	28.08
Mean wake after sleep onset (mins)	33	13.57	68.62	37.87	13.95
Pre-school closure	21	13.57	68.62	35.99	13.48
Post-school closure	12	18.42	64.37	41.16	14.75
Mean sleep maintenance efficiency %	33	87.22	95.61	91.83	2.34
Pre-school closure	21	87.22	95.29	91.90	2.09
Post-school closure	12	87.29	95.61	91.71	2.84
Mean minutes napping	33	0.00	48.92	6.45	13.01
Pre-school closure	21	0.00	48.92	9.79	15.36
Post-school closure	12	0.00	7.14	0.59	2.01
Mean mins. napping (nappers only)	10	5.35	91.66	30.45	25.64

Mean sleep onset time	33	9:09 pm	3:08 am	11:35	79.2 mins.
Pre-school closure	21	9:09 pm	12:57 am	11:03 pm	70.8 mins.
Post-school closure	12	10:03 pm	3:08 am	12:08 am	81 mins.
Mean sleep offset time	33	6:01 am	12:53 pm	7:58 am	91.2 mins.
Pre-school closure	21	6:01 am	12:53 am	7:22 am	85.8 mins.
Post-school closure	12	6:54 am	11:46 pm	8:54 am	71.4 mins.
Mean sleep midpoint time	33	12:52 am	7:27 am	3:42 am	84 mins.
Pre-school closure	21	12:52 am	7:25 am	3:07 am	73.8 mins.
Post-school closure	12	2:28 am	7:27 am	4:31 am	75 mins.

Note. COVID-19 pandemic resulted in school closures during recruitment and data collection. Descriptive analyses performed on entire sample, and pre- and post-school closure. M/E Scale for Children: minimum possible score = 10, maximum possible score = 42; E = evening type (10-25), I = intermediate type (26-32), M = morning type (33-42

Figure 4-6

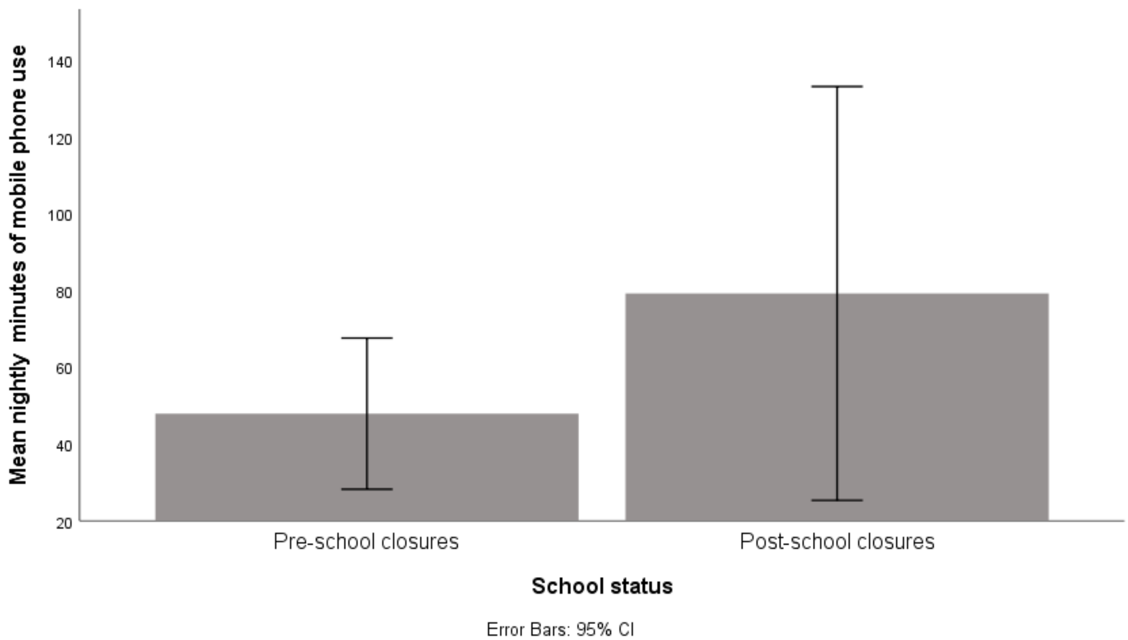
Distribution of Chronotype by Age



Note. N = 34. Chronotype measured by Morningness/Eveningness Scale for Children. MEQ groups: evening type (score 10-25), intermediate type (score 26-32), morning type (score 33-42).

Figure 4-7

Comparison of Mean Nightly Minutes of Mobile Phone Use Among Participants in the Pre- and Post-School Closure Situations



Mobile Phone Functions Accessed after Lights Out

Research question 1: Which mobile phone functions are adolescents accessing after lights out? Mobile phone functions accessed after lights out were analyzed by descriptive statistics. Participants selected all mobile phone functions used after lights out and an average usage (also referred to as nightly average) for each mobile phone function was computed based on the number of days of diary data from the 7-day data collection period. For the full sample, use of social media was the most prevalent mobile phone function used, followed by phone calling, watching movies or TV, text messaging, and playing games. Fewer participants listened to music or podcasts, browsed the internet, or other used mobile phone functions (Table. 4.5).

Average nightly minutes of mobile phone functions used was combined into predetermined groups: phone calling and text messaging were clustered into communication; social media remained its own group; and listening to music or podcast, playing a game, and viewing movies or TV were clustered into entertainment. Additional mobile phone functions were not included in this analysis beyond descriptive analyses. Mobile phone use after lights out was further grouped by non-users versus users, and low versus high users. Average nightly minutes of all mobile phone functions used was a highly skewed variable (Figures 4-2, 4-3, 4-4, 4-5), with a mean 60.02 (SD = 62.32) minutes and median of 45 minutes. Low and high users were determined by the mean value of 60 minutes, with mobile phone use of $\leq$ 60 minutes as low users (including non-users) and > 60 minutes as high users. In addition, three participants were excluded from analyses, because despite answering the question of whether or not they used the mobile phone after lights out, they did not quantify the nightly use, due to a REDCap limitation of not providing the quantifying questions on mobile phone use.

Data were collected on a portion of the sample during the COVID-19 pandemic. Mandatory school closures were in effect during this period. Data were analyzed descriptively for those who provided data prior to school closures and for those who provided data during the school closures. The most frequently used mobile phone function prior to school closures was social media, followed by phone calling and text messaging. Those participants who provided data after schools were closed used social media, watching movies, and phone calling most frequently. The average nightly minutes of social media use, entertainment, and overall phone use were increased after school closures. Average nightly minutes of communication functions decreased after school closures (Table 4-5).

Chi Square Analysis of Mobile Phone Function and Gender

It was hypothesized that females would use mobile phones after lights out for communication purposes more frequently that males, and that males would use mobile phones for entertainment purposes more frequently than females. Analysis of social media was not included in the *a priori* plan; however, since social media was the most commonly used mobile phone function, it was added to the analysis. A chi square test of independence was performed to assess differences in the percentages of adolescents who used mobile phone functions after lights out (communication, entertainment, and social media) and gender (male and female) among mobile phone non-users and users, and among low and high mobile phone users. Two participants were excluded from the gender analyses, as they did not identify as either male or female. One of these excluded participants was also excluded as described above for lack of quantification of mobile phone use. No significant differences were observed between percentages of males and females in regard to their engagement in categories of mobile phone functions used after lights out, i.e., mobile phone use for communication purposes, mobile phone use for entertainment, and mobile phone use for social media, between users and non-users and a separate analysis between low and high mobile phone users. These results do not lend support for the research hypothesis of gender differences related to mobile phone use after lights out (Table 4-8).

Table 4-8

Chi Square Analysis of Mobile Phone Function Used After Lights Out and Gender

Mobile phone function used	% (non-user, user)	*p*	Cramer's V
Communication	Female (19.0, 81.0)	$p = 1.00$	.03
	Male (22.2, 77.8)		$p = .84$
Entertainment	Female (47.6, 52.4)	$p = .69$	.03
	Male (33.3, 66.7)		$p = .46$
Social media	Female (19.0, 81.0)	$p = .64$	.15

	Male (33.3, 66.7)		p = .39
	(low user, high user)		
Communication	Female (71.4, 28.6) Male (66.7, 33.3)	p = 1.00	.04 p = .79
Entertainment	Female (66.7, 33.9) Male (77.8, 22.2)	p = .68	.11 p = .54
Social media	Female (71.4, 28.6) Male (66.7, 33.3)	p = 1.00	.04 p = .79

Note. N = 30 and df = 1 for all analyses. *Minimum cell count violated. Fisher's exact test performed in lieu of χ^2.

Independent Samples T-test of Mobile Phone Function and Gender

Independent samples t-test was performed to test the hypothesis of statistically different average nighttime minutes of mobile phone use between genders. Gender was dichotomized into male and female, and the same participants were excluded as described above. Levene's test for Equality of Variances assumptions was violated as noted in the analyses. Results indicated no significant differences between average nightly minutes of mobile phone use for communication, for entertainment or for social media and gender. Based on these results, the research hypothesis was not supported for gender differences of minutes of mobile phone use after lights out (Table 4-9).

Table 4-9

Independent Samples T-test for Average Nightly Minutes of Mobile Phone Function Used and Gender

Mobile phone function	Gender (M, SD)	t-test (N = 30, df 28)	Cohen's *d*
Communication	Males (21.50, 30.03) Females (20.64, 30.64)	0.71, p = .94	d = .02

Entertainment	Males (12.01, 15.52) Females (24.85, 40.16)	-1.26, *p* = .21* (df = 27.89)	*d* = -.38
Social media	Males (59.61, 96.51) Females (33.09, 34.90)	0.80, *p* = .44* (df = 8.91)	*d* = .44

Note. *Assumption of equality of variance violated.

Factors Contributing to Adolescents' Mobile Phone Use after Lights Out

Research question 2: Which factors contributed to adolescents' mobile phone use after lights out? RQ2.a. It was hypothesized that females had more frequent mobile phone use after lights out compared with males. The average nightly mobile phone use was categorized into mobile phone non-users and users, as described above. A chi square test of independence was performed to assess differences in the percentages of average nightly mobile phone use after lights out and gender. The minimum cell count was violated and Fisher's exact test was performed. No significant differences in average nightly mobile phone use between females and males for mobile phone use were observed (Table 4-10).

Table 4-10

Chi Square Analysis of Average Nightly Mobile Phone Use and Gender

Mobile phone use	%	χ^2	Cramer's V
Non-users and users	Female (9.5, 90.5) Male (22.2, 77.8)	*p* = .56	.17 *p* = .34
Low mobile phone use and high use	Female (47.6, 52.4) Male (66.7, 33.3)	*p* = .44	.17 *P* = .33

Independent samples t-test was performed to assess the relationship between average nightly mobile phone use and gender. There was no significant differences in the minutes of average nightly minutes of mobile phone use between males and females. These analyses fail to support the research hypothesis of gender differences with average nighttime mobile phone use after lights out (Table 4-11).

Table 4-11

Independent t-test Analysis of Average Minutes of Nightly Mobile Phone Use and Gender

MP use	Gender (M, SD)	t-test (N = 30, df = 26)	Cohen's d
Average nightly minutes of MP use	Male (43.21, 49.17) Female (69.65, 70.06)	-1.01 *p* = .32	*d* = -.42

Note. MP = mobile phone.

RQ2.b. It was hypothesized that adolescents who consumed caffeine prior to bedtime have greater mobile phone use after lights out than adolescents who do not consume caffeine prior to bedtime. Caffeine use was collected as a daily total of the number of caffeine drinks and participants were asked the time of the last caffeine drink. Missing data for time of last caffeine drink did not permit analysis of caffeine use based on time prior to bedtime. Data were analyzed based on average daily caffeine (Table 4-6). Among participants, 76.5% of the sample consumed caffeine drinks and 23.5% did not consume any caffeinated beverages. The average daily caffeine use was low, with 80% of the sample consuming one or less caffeine drinks. Mobile phone use after lights out was classified by non-users versus users. Chi square test of independence was used to assess differences in the percentage of average nightly mobile phone use and caffeine use. The cell counts were insufficient to assess with chi square, and Fisher's exact test was performed (Table 4-12). The proportion of adolescents using mobile phones after lights out did not differ by use of caffeine.

Table 4-12

Chi Square Analysis of Mobile Phone Use and Caffeine Use

Mobile phone use	% (N = 31)	χ^2	Cramer's V
Non-users and users	No caffeine use (25, 75)	p = 1.00	.007
	Caffeine use (25.9, 74.1)		p = .96

Independent samples t-test was performed to evaluate the relationship between caffeine use and average nightly minutes of mobile phone use after lights out. The equality of variances assumption was violated in the analysis of mobile phone use after lights out among caffeine non-users and users, with no statistical difference observed between average nightly minutes of mobile phone use after lights out in caffeine non-users compared with users (Table 4-13). These results do not support the hypothesis of differences in mobile phone use after lights out and caffeine use.

Table 4-13

Independent Samples t-test for Average Nightly Minutes of Mobile Phone Use and Caffeine Use

Dependent variable	Group Variable	(M, SD)	T-test	Cohen's *d*
Average nighttime	Caffeine non-users	(82.76, 86.68)	t (29) = 1.20,	d = .67
MP use (minutes)	Caffeine users	(52.12, 51.50)	p = .23	

Note. N = 31. MP = mobile phone.

Data were analyzed descriptively for participants collecting data prior to school closures and after school closures (Table 4-6). More participants used caffeine beverages in the pre-school closures group than in the post-school closures group.

RQ2.c. It was hypothesized that adolescents with increased mobile phone use after lights out place less value on the importance of sleep. This research question was evaluated by assessment of attitudes and beliefs regarding sleep and mobile phone use after lights out. Independent samples t-test was performed to compare the attitudes and beliefs of the MPPUS, MPPUS-10, and SPAQ with average nighttime mobile phone use in non-users versus users and low versus high mobile phone users. High use was classified as greater than 60 minutes, as previously described. The equality of variances assumption was met in all analyses, except as noted. A significant difference in the scores for the SPAQ Importance of Sleep subscale for low and high mean nightly mobile phone use after lights out was observed, but not for mobile phone non-users and users. There were no significant differences in the scores of the attitudes and beliefs for the remaining subscales and factors (Table 4-14). Participants who had high average nightly mobile phone use placed less value on the importance of sleep; therefore, the hypothesis is supported.

Table 4-14

Independent Samples T-test to Compare Attitudes and Beliefs from MPPUS, MPPUS-10, and SPAQ Measurements and Average Nightly Minutes of Mobile Phone Use

Attitudes and Beliefs	Grouping Variable (M, SD)	T-test (N = 31, df = 29)	Cohen's d
Loss of control	Low MP users (14.69, 6.86) High MP users (18.07, 6.23)	-1.22, *p* = .23	*d* = -.43
	MP non-user (12.75, 8.53) MP user (16.85, 6.39)	-1.15, *p* = .25	*d* = -.61
Withdrawal	Low MP users (11.06, 5.57) High MP users (11.73, 5.67)	-0.48, *p* = .63	*d* = -.17
	MP non-user (11.75, 7.63) MP user (11.33, 5.35)	0.13, *p* = .89	*d* = .07
Negative life consequences	Low MP users (2.88, 1.58) High MP users (2.67, 1.23)	0.46, *p* = .64	*d* = .17
	MP non-user (4.25, 2.87) MP user (2.56, 0.97)	1.17, *p* = .32* (df = 3.10)	*d* = 1.2

Craving#	Low MP users (4.88, 3.34) High MP users (7.33, 2.19)	-1.66, *p* = .09	*d* = -.59
	MP non-user (5.50, 3.87) MP user (6.15, 3.87)	-0.39, *p* = .70	*d* = -.21
Peer dependence#	Low MP users (7.06, 2.56) High MP users (7.73, 2.65)	-1.71, *p* = .09* (df = 24.24)	*d* = -.58
	MP non-user (8.00, 2.82) MP user (7.30, 2.59)	0.50, *p* = .62	*d* = .27
Sleep self-efficacy#	Low MP users (2.38, 0.88) High MP users (2.67, 0.90)	-0.71, *p* = .48	*d* = -.25
	MP non-user (2.25, .097) MP user (2.56, 0.89)	-0.63, *p* = .53	*d* = -.34
Sleep importance	Low MP users (13.25, 3.06) High MP users (16.07, 3.47)	**-2.76, *p* = .01**	***d* = -.90**
	MP non-user (13.50, 1.00) MP user (14.78, 3.73)	-0.67, *p* = .50	*d* = -.36
Sleep and health	Low MP users (20.12, 4.89) High MP users (19.71, 5.55)	0.21, *p* = .83	*d* = .07
	MP non-user (17.00, 6.58) MP user (20.37, 4.86)	-1.24, *p* = .22	*d* = -.65

Note. #Denotes single item factor/scale. *Equality of variances assumption violated. Loss of control = MPPUS-10 items 5, 6, 9; Withdrawal = MPPUS-10 items 2, 4, 8; Negative life consequences = MPPUS single item + MPPUS-10 items 7, 10; Craving = MPPUS-10 item 1; Peer dependence = MPPUS-10 item 3; Sleep self-efficacy = SPAQ item 1; Sleep importance = SPAQ items 2-8; Sleep and health = SPAQ items 9-16. MP = mobile phone; MPPUS = Mobile Phone Problem Use Survey; MPPUS-10 = Mobile Phone Problem Use Survey-10; SPAQ = Sleep Practices and Attitudes Questionnaire.

Correlations between the factors and sub-scales of the MPPUS, MPPUS-10, and SPAQ were performed, as all scales measured attitudes and beliefs; however, the MPPUS-10 measured attitudes and beliefs regarding mobile phone use and the SPAQ measured attitudes and beliefs regarding sleep. The factors of the MPPUS-10 are positively correlated with the full MPPUS-10 instrument. The SPAQ sub-scale self-efficacy is positively correlated with the factors loss of control and withdrawal, as well as the MPPUS-10 instrument as a whole; however, the self-efficacy sub-scale is a single item scale. The SPAQ sub-scale importance of sleep is positively correlated with the MPPUS-10 factors negative life consequences and loss of control. The SPAQ sub-scales importance of sleep and sleep and health are positively correlated with the full scale. Correlations among the factors and sub-scales are presented in Table 4-15.

Table 4-15

Correlation Table of Measures of Attitudes and Beliefs

Variables	1	2	3	4	5	6	7	8	9	10	11
1. MPPUS	-										
2. MPPUS-10, craving	.15 (.38)	-									
3. MPPUS-10, peer dependence	.20 (.24)	.30 (.08)	-								
4. MPPUS-10, loss of control	.08 (.62)	**.44* (.009)**	.31 (.07)	-							
5. MPPUS-10, negative life consequences	-.10 (.57)	-.19 (.28)	-.18 (.30)	.09 (.61)	-						
6. MPPUS-10, withdrawal	**.45* (.007)**	.24 (.15)	**.34* (.04)**	**.50* (.002)**	.15 (.38)	-					
7. MPPUS-10, total score	.28 (.10)	**.58* (<.001)**	**.53* (.001)**	**.87* (<.001)**	.13 (.45)	**.79* (<.001)**	-				
8. SPAQ, self-efficacy	.07 (.68)	.30 (.07)	.20 (.25)	**.61* (<.001)**	.22 (.20)	**.38* (.02)**	**.59* (<.001)**	-			
9. SPAQ, importance of sleep	.29 (.08)	.009 (.96)	-.01 (.93)	**.35* (.04)**	**.36* (.03)**	.25 (.14)	.31 (.07)	.05 (.76)	-		
10. SPAQ, sleep & health	.09 (.58)	.14 (.41)	-.30 (.07)	-.06 (.71)	.11 (.50)	-.08 (.64)	-.08 (.65)	-.15 (.39)	.16 (.34)	-	
11. SPAQ, total score	.23 (.17)	.15 (.37)	-.22 (.20)	.20 (.23)	.30 (.07)	.11 (.52)	.17 (.32)	.03 (.83)	**.65* (<.001)**	**.84* (<.001)**	-

Note. N = 34. MPPUS = Mobile Phone Problem Use Scale; MPPUS-10 = Mobile Phone Problem Use Scale-10; SPAQ = Sleep Practices and Attitudes Questionnaire.

Sleep Patterns of Adolescents who use Mobile Phones After Lights Out

Research Question 3: What are the sleep patterns of adolescents who use mobile phones after lights out? Descriptive statistics were performed to understand the characteristics of sleep variables (Table 4-7). Data were analyzed on the sample as a whole and in an exploratory analysis by those participants who provided data prior to and after school closure for COVID-19 precautions. Data were averaged over the 7-day collection period. Participants self-reported chronotype: 38% evening type, 55.8% intermediate type, and 3.8% morning type. The average nighttime sleep duration was 503 minutes (approximately 8.3 hours), with average sleep onset time 11:35 p.m., sleep offset time 7:58 a.m., and circadian midpoint 3:42 a.m.

Participants had greater sleep variability in the pre-school closure period than the post-school closure period. They slept an average of 8.18 hours, with a range from 6.29 to 10.9 hours nightly in the pre-school closure period and slept an average of 8.76 hours with a range from 7.1 to 9.7 hours nightly in the post-school closure period. Participants had greater WASO in the post-school closure period (35.99 versus 41.16 minutes). Napping occurred primarily in the pre-school closure period, with only one participant reporting napping in the post-school closure period. Average sleep onset and offset times were later in the post-school closure period (11:03 p.m. versus 12:08 a.m. and 6:24 a.m. versus 7:42 a.m., respectively). The circadian midpoint of sleep was later in the post-school closure period (3:07 a.m. versus 4:31 a.m.).

RQ3.a. It was hypothesized that use of mobile phones after lights out resulted in shorter sleep duration. Sleep duration for the sample was categorized into adequate sleep duration (71 %) and inadequate sleep duration (29 %), using the recommended minimum sleep requirement for adolescents of 480 minutes (8 hours) as the measure of adequacy, with inadequate sleep defined as ≤ 480 minutes and adequate sleep duration of > 480 minutes. Chi square test of independence was performed to evaluate the relationship between sleep duration and mean nightly mobile phone use. Separate analyses were performed using total nighttime sleep duration and 24-hour total sleep duration (includes nighttime sleep duration plus naps) between low versus high mobile phone users and mobile phone non-users versus users. Chi square test of independence was performed; however, the assumption of cells with adequate count was violated, and Fisher's exact test was performed. No significant differences were observed in the proportion of average nightly mobile phone use after lights out and mean 24-hour sleep duration between those with inadequate and adequate total sleep duration. Similarly, chi square test of independence was performed to evaluate the mean 24-hour sleep duration, with violation of cell counts. No significant differences were observed between mobile phone use after lights out and total sleep duration (Table 4-16).

Table 4-16

Chi Square Analysis of Total Sleep Duration and Mean Nightly Mobile Phone Use

Mobile phone use	Sleep duration (%)	χ^2	Cramer's V
	Total nighttime sleep duration		
*MP non-users and users	Inadequate sleepers (0, 100) Adequate sleepers (38.5, 61.5)	$p = .27$	.28 $p = .11$
MP low users and high users	Inadequate sleepers (29.4, 70.6) Adequate sleepers (38.5, 61.5)	$p = .47$	.14 $p = .43$
	24-hr total sleep duration		
*MP non-users and users	Inadequate sleepers (0, 100) Adequate sleepers (34.6, 65.4)	$p = .28$	.26 $p = .13$
MP low users and high users	Inadequate sleepers (23.5, 76.5) Adequate sleepers (38.5, 61.5)	$p = .44$	.20 $p = .25$

Note. N = 30. MP = mobile phone. *Cell count assumptions violated. Fisher's exact test performed.

Independent t-test was performed to evaluate the relationship between the average nightly mobile phone use after lights out in minutes and sleep duration. Both nighttime total sleep duration and 24-hr total sleep duration were evaluated separately. No significant differences were observed with any of the analyses. Assumptions of equal variances were met in all conditions (Table 4-17). The hypothesis is not supported by these analyses.

Table 4-17

Independent Samples T-Test Comparing Average Total Sleep Duration and Average Nightly Mobile Phone Use

Average nightly MP use (minutes)	Grouping Variable (M, SD)	T-test (N = 30, df = 28)	Cohen's *d*
Average nightly MP use	Total nighttime sleep duration Short sleep duration (58.66, 49.92) Adequate sleep duration (58.96, 69.90)	0.36, *p* = .72	*d* = .14
Average nightly MP use	24-hr total sleep duration Short sleep duration (63.52, 50.38) Adequate sleep duration (56.86, 68.80)	0.40, *p* = .69	*d* = .50

Note. N = 30, df = 28. MP = mobile phone.

RQ3.b. hypothesized that use of mobile phones after lights out was associated with reduced sleep quality, including increase in sleep onset latency (SOL), increase in wake after sleep onset (WASO), lowered sleep maintenance efficiency (SME), and decreased subjective perception of sleep quality. SOL was unable to be evaluated based on insufficient usable data for this variable. Participants reported on the time they tried to go to sleep on the morning sleep diary. SOL is calculated by the sleep onset time on actigraphy minus the survey reported sleep time. Some participants reported sleep initiation times that were significantly after they were documented as asleep by actigraphy. For some participants, this discrepancy was several hours. In addition, there was missing data on some days. Therefore, it was not feasible to calculate this variable.

Independent samples t-test was performed to compare the average nightly minutes of WASO, the average nightly percentage of SME, and the average nightly sleep quality with average nighttime mobile phone use after lights out between mobile phone non-users and users, and between low and high mobile phone users. No significant differences were observed in the average nightly minutes of WASO, the average nightly percentage of SEM, or average nightly measure of sleep quality between mobile phone non-users and users after lights out, or between average daily mobile phone low and high users after lights out (Table 4-18). These analyses do not support the research hypothesis.

Table 4-18

Independent Samples T-test of Average Nightly Minutes of Mobile Phone Use and Measures of Sleep Quality

Sleep variable	Average nighttime MP use (M, SD)	T-test (N = 30, df = 28)	Cohen's *d*
WASO (average nightly minutes)	MP non-user (44.84, 17.63) MP user (35.16, 12.48)	t = 1.37, p = .08	*d = .71*
WASO (average nightly minutes)	Low MP user (37.28, 14.17) High MP user (35.36, 12.623)	t = 0.38, p = .70	*d = .10*
SME (mean daily %)	MP non-user (90.64, 3.47) MP user (92.27, 2.05)	t = -0.91, p = .42* (df = 3.32)	*d = -.58*
SME (mean daily %)	Low MP user (91.95, 2.57) High MP user (92.19, 1.92)	t = -0.27, p = .78	*d = .06*
Sleep quality (average nightly)	MP non-user (3.83 (0.57) MP user (3.72, .064)	t = 0.30, p = .76	*d = .14*
Sleep quality (average nightly)	Low MP user (3.77, 0.67) High MP user (3.69, 0.59)	t = 0.34, p = .73	*d = .09*

Note. MP = mobile phone; WASO = wake after sleep onset; SEM = sleep maintenance efficiency. Sleep quality measured on 5-point scale from 1 = very poor to 5 = very good. *Equality of variance assumption violated.

RQ3.c. hypothesized that mobile phone use after lights out was associated with increased next day sleepiness. Daytime sleepiness is a subjective self-report variable; however, there were no variables to evaluate daytime sleepiness in this study. Napping is a related variable to daytime sleepiness, although not interchangeable. Napping was evaluated by actigraphy and self-report on evening sleep diary. Descriptive statistics were performed to evaluate the percentage of those participants who napped during the 7-day data collection period. Seventy-one percent of participants did not report napping, while 29 percent (N = 10) napped. Among those who took naps, the mean number of napping minutes was 30.45 (SD = 25.64) minutes. Chi square was performed to evaluate the relationship between napping and average nighttime mobile phone use after lights out. No significant differences were observed with the percentage of participants napping and average nightly mobile phone use between those who did not nap and those who napped. Cell counts were violated and Fisher's exact test was performed. Chi square was performed for comparison of napping with low and high mobile phone use after lights out. There were no significant differences observed with the percentage of participants napping and average nightly mobile phone use. The cell counts were violated and Fisher's exact test was performed (Table 4-1).

Table 4-19

Chi Square Analysis of Napping and Average Nightly Mobile Phone Use

Mobile phone use	Napping (%)	χ^2
*MP non-users and users	No napping (17.4, 82.6) Napping (0, 100)	p = .54

*MP low users and high users	No napping (29.4, 70.6) Napping (38.5, 61.5)	*p* = .19

Note. N = 30. *Cell counts violated; Fisher's exact test performed.

Independent t-test was performed to compare napping and minutes of average nighttime mobile phone usage. There was a significant difference in the amount of minutes of napping for those participants who did not use mobile phones after lights out and those who used mobile phones after lights out, but no difference in napping among low and high users of mobile phones after lights out (Table 4-20).

Table 4-20

Independent Samples T-test Comparing Napping with Average Nightly Minutes of Mobile Phone Use

Napping	Grouping variable (M, SD) Average nighttime MP use	Independent t-test (N = 30)
Average daily napping minutes	MP non-user (0.00, 0.00) MP user (5.81, 11.58)	***t* = -2.56, *p* = .01*** (df = 25)
Average daily napping minutes	Low MP user (2.34, 8.37) High MP user (8.56, 13.11)	*t* = -1.49, *p* = .15 (df = 19.24)

Independent t-test was performed to evaluate the average daily minutes of napping in those who took naps between mobile phone non-users and users and between low and high mobile phone use. No differences were observed between groups (Table 4-21). The hypothesis is not supported by this analysis.

Table 4-21

Independent Samples T-test Comparing Napping with Average Nightly Mobile Phone Use Among Nappers

Napping	MP phone use (M, SD)	T-test (N = 10)
Average daily napping minutes	MP non-user (30.87, 25.53) MP user (30.51, 27.42)	t = 0.02, p = .98 (df = 1.64)
Average daily napping minutes	Low MP user (25.38, 19.96) High MP user (33.83, 30.16)	t = -.48, p = .63 (df = 8)

Correlations between mobile phone usage and sleep variables were evaluated. The following correlations were observed among sleep variables. Mean nightly minutes of WASO was positively correlated with both the total 24 hour sleep time and the mean nightly sleep time. SME was negatively correlated with mean nightly minutes of WASO. Sleep onset time was positively correlated with both 24 hour sleep time and mean nightly sleep time. Sleep midpoint was negatively correlated with sleep onset time and positively correlated with sleep offset time. Among the mobile phone usage variables, all mobile phone usage variables were positively correlated. There were no significant correlations among the sleep and mobile phone usage variables (Table 4-22). Binary logistic regression was performed to predict adequate sleep duration with mobile phone use after lights out. Predictor variables in the model included: age, gender, chronotype, and mobile phone function (communication, entertainment, social media). No predictors reached statistical significance, and the model overall was not statistically significant; therefore, adequacy of sleep duration was not able to be predicted.

Table 4-22

Correlation Table of Sleep Variables and Average Nightly Mobile Phone Use

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13
1. ACT TST (24 hrs) mins mean	-												
2. ACT night sleep time mins mean	**.98* (<.001)**	-											
3. ACT WASO mins mean	**.61* (<.001)**	**.60* (<.001)**	-										
4. ACT SME mean	-.32 (.07)	-.29 (.10)	**-.91* (<.001)**	-									
5. ACT nap mins mean	.11 (.54)	-.05 (.77)	.07 (.67)	-.18 (.33)	-								
6. ACT sleep onset time	.01 (.92)	.05 (.75)	.14 (.454)	-.16 (.38)	-.22 (.22)	-							
7. ACT sleep offset time	**.52* (.003)**	**.50* (.004)**	.30 (.10)	-.13 (.47)	.14 (.44)	**-.68 (<.001)**	-						
8. ACT sleep midpoint	.36 (.05)	.32 (.08)	.22 (.24)	-.13 (.46)	.21 (.26)	**-.82 (<.001)**	**.90 (<.001)**	-					
9. SQ mean daily	.009 (.96)	.03 (.86)	.02 (.89)	-.01 (.95)	-.13 (.46)	.09 (.60)	.07 (.68)	-.008 (.96)	-				
10. Avg nightly MP use mins	-.01 (.93)	-.01 (.93)	-.10 (.56)	.16 (.39)	.004 (.98)	-.32 (.08)	.31 (.09)	.29 (.10)	-.12 (.50)	-			
11. Avg nightly SM mins	.05 (.79)	.03 (.86)	.14 (.45)	-.13 (.46)	.10 (.59)	-.01 (.93)	.14 (.44)	.16 (.38)	-.04 (.81)	**.56* (.001)**	-		
12. Avg nightly ENT mins	.18 (.32)	.19 (.30)	.10 (.59)	.02 (.89)	-.059 .79)	-.10 (.59)	.30 (.09)	.19 (.31)	-.07 (.69)	**.59* (.001)**	**.42* (.02)**	-	
13. Avg nightly COMM mins	.02 (.90)	-.008 (.96)	-.06 (.73)	.06 (.73)	.18 (.33)	-.08 (.64)	.13 (.47)	.14 (.44)	-.01 (.93)	**.60* (<.001)**	**.57* (.001)**	**.66* (<.001)**	-

Note. ACT = actigraphy; TST = total sleep time; SEM = sleep maintenance efficiency; WASO = wake after sleep onset; SQ = sleep quality; COMM = communication (includes texting and phone calling); ENT = entertainment (includes listening to music, watching movies, playing games); SM = social media; MP = mobile phone

Chapter 5

Discussion

The purpose of this study was to evaluate the attitudes, behaviors and, sleep patterns of adolescents who use mobile phones in the bedroom setting after lights out. Near-constant use of mobile phones among adolescents is common, with many adolescents using mobile phones at all times of the day, including prior to and after lights out (Anderson & Jiang, 2018; Calamaro et al., 2009). Adolescents' attachments to their mobile phones make this compact device an important part of their daily lives. In addition, sleep insufficiency is rampant among adolescents (CDC, 2017a). The combination of ubiquitous mobile phone use, mobile phone attachment, and chronic sleep insufficiency presents a situation worthy of investigation. This descriptive correlational study used a novel study design with a 1-week micro-longitudinal data collection period consisting of repeated measures of mobile phone use and wrist actigraphy to measure sleep outcomes. This study was guided by the Theory of Planned Behavior to understand adolescents' decision-making in using mobile phones after lights out.

Summary of Findings

- Social media was the most commonly used mobile phone function among adolescents using mobile phones after lights out
- No significant gender differences were observed regarding average nightly use of mobile phone functions or general mobile phone use after lights out

- No significant differences were observed in average nightly mobile phone use after lights out between with adolescents who consumed caffeine beverages and those who did not
- Adolescents with higher average nightly use of mobile phones after lights out placed significantly less value on the importance of sleep than those with lower mobile phone use
- No significant differences were observed with sleep duration, sleep quality, or napping and average nightly mobile phone use after lights out
- There were no significant correlations between degree of mobile phone use and sleep outcomes
- This research was unable to predict sleep sufficiency based on mobile phone use

Recruitment, Enrollment, and Retention of Study Participants

Adolescent recruitment, enrollment, and retention of study participants can be a challenge for researchers (Moreno et al., 2017). Successful recruitment and enrollment strategies for this study included methods beyond just direct face-to-face recruitment and participation was promoted by offering a meaningful tiered participant incentive. Slow initial recruitment, combined with time and space barriers within the ambulatory clinic setting that reduced access to potential participants supported alternate methods of recruitment. Although Penn State StudyFinder proved to be a successful strategy, the influence of social media in recruitment was the largest boon to recruitment. The effect of a parent-initiated placement of the StudyFinder link on several social media pages resulted in rapid recruitment and enrollment. In addition, the snowball effect among adolescents who shared information about the study with their peer group reinforced the importance of the peer network in this age group.

Although the use of social media as a recruitment strategy was unplanned and was initiated independently by parents, it was used by both parents and adolescents to find out about the study, and lends support for the study findings of the use of social media as a popular mobile phone function among adolescents. A systematic review of studies using Facebook© as a recruitment strategy concluded this practice was most successful in the adolescent and young adult age demographics, and a larger audience was able to be reached than with recruitment by conventional means (Whitaker, Stevelink, & Fear, 2017); however, while recruitment may be robust with use of social media, costs for advertisement may exceed those of other forms of recruitment (Moreno et al., 2017; Whitaker, Stevelink, & Fear, 2017). Considering the importance of social media to adolescent study participants and to their parents, it may be worthwhile to consider this platform as a targeted strategy for future recruitment and enrollment activities dependent upon the study requirements. Conversely, targeted recruitment to a specific social media group may result in a homogeneous sample with reduction of variability in a small sample size. Current Pennsylvania population demographics indicate the primary racial composition as approximately 82% Caucasian, 12% Black/African American, 4% Asian (U.S. Census Bureau, 2019). The study demographics show oversampling of Caucasian participants and under-sampling of Black/African American and Asian participants based on the current population demographics, although the geographic region for this study is predominantly Caucasian.

Study completion rates among adolescent sleep research study participants are frequently low, with reasons for lack of completion related to forgetting to complete self-report measures, not desiring to wear the actigraphy device, and lack of motivation to complete the study (Acebo et al., 1999). Participants in this study were motivated to receive the tiered incentive for study completion. All study participants in the current study completed the study; however, one participant did not wear the actigraphy device for the requisite number of days (minimum of five days), and some participants had some missing actigraphy and/or daily diary data. The high study completion rate minimized the potential for missing data for lack of study completion.

While direct data entry into REDCap by participants was convenient for them, a systematic error in the REDCap system on day 5 contributed to missing daily diary data for the morning Consensus Sleep Diary for some participants. For some participants, the REDCap system triggered the day 6 CSD on day 5, rather than the day 5 survey which omitted the day 5 survey from data collection. In other participants, the day 5 CSD response was erroneously entered on day 6. These errors resulted in missing data for day 5, and/or misplaced data on days 6 and 7. In addition, some participants reported not receiving a study survey link for some of the daily surveys. Follow-up by the PI with an additional manual study link and text message reminders for participants who did not complete diary data resulted in improvement in completed survey data collection rates. Approximately one-third of the sample required extra reminders to complete daily diary data and minimized missing data for uncompleted survey measures.

Mobile Phone Functions Accessed After Lights Out

The most frequently used mobile phone function after lights out was social media. This finding is consistent with national polling trends on technology platforms used among adolescents (AP-NORC, 2017; Lenhart, 2015). The specific social media platform used was not queried among the participants in this study. Other mobile phone functions were used as well, including phone calling and entertainment, i.e., watching movies, listening to music, and playing games. The diverse types of social media can provide opportunities for social interactions, blogging, and sharing photos or videos. Data on simultaneous use of multiple functions, such as sending or receiving text messages while listening to music or watching a movie, were not collected. Adolescents report watching movies while in their individual homes and communicating via text or instant messaging during the movie with others who are also watching the same movie.

Additionally, individual social media platforms may incorporate other mobile phone functions within the application, such as the ability to send messages, take and share photographs, as well as other functions. It is unknown how study participants may have used social media with respect to these other features.

Data collection for this study was conducted within the historic COVID-19 pandemic. Usual adolescent routines changed with mandatory school closures during this time. More than half of the study sample collected data prior to school closures and the remainder collected part or all of their data following school closures. Exploratory descriptive analyses of the pre- and post-school closure groups for mobile phone functions had some differences in usage. Social media was universally the most frequently used mobile phone function. However, the pre-school closure group used communication (phone calling and text messaging) more frequently than entertainment, whereas the post-school closure group used entertainment more frequently than communication modalities. It can be surmised that those who provided data during school time may have had more need to communicate with peers on school assignments or activities and had less time available to engage in entertainment features of their mobile phones. Conversely, following school closures adolescents may have had more free time available with the need to fill that time with activities which may have included watching movies or gaming contributing to the differences in mobile phone function used. In addition, adolescents spent more time using mobile phone devices in the post-school closure period and nearly doubled the time spent using social media. With the uncertainty of information about the pandemic and the abrupt closure of the school systems, there may have been an emotional need to remain connected with the peer network. Adolescents who are accustomed to seeing friends during the school day most likely desired to maintain those relationships or they may have experienced boredom with lack of the usual structure during the school week. Engagement with peers via phone calling and text messaging may provide a more personal way to communicate; however, many adolescents are very transparent and engagement with social media is a way to reinforce their online persona and engage with multiple peers simultaneously. These findings lend support for the importance of the social network during this developmental phase.

Some studies report use of preferred mobile phone functions by gender, such as more use of communication functions by females (Bruni et al., 2015; Fobian et al., 2016; Gradisar et al., 2013; Grover et al., 2016; Hysing et al., 2015; Lange et al., 2017; Munezawa et al., 2011; Nathan et al., 2013; Oshima et al., 2012; Pieters et al., 2014), and more engagement with entertainment modalities by males (Hysing et al., 2015; King et al., 2014). Although, some minor gender differences were observed, they did not rise to a significant level to lend support for these study hypotheses of gender differences among mobile phone functions. Overall, males used their mobile phones after lights out more frequently than females for communication (phone calling and texting) and social media, and females used entertainment modalities more frequently than males, which is contrary to the hypothesis.

Evaluation of mobile phone use after lights out averaged to a nightly mean may present a different usage pattern than observing usage over individual days. In addition, it was a bit problematic to combine use of text messaging and phone calling into one communication variable, as they are not typically measured by the same method. Text messaging is best measured by the number of messages sent and received, whereas, phone calling is best measured by time spent using the device. Combining these data into one category may shortchange phone calling by limiting the number of calls made or received to a tally rather than the amount of time engaged in the call(s), and text messaging may be underreported by placing a time variable, rather than a numeric accounting of messages sent and received. Differences in usage patterns related to the school situation may have played a role in the study findings. It can be speculated that females are typically more verbal and social than males; however, current societal mores for adolescent electronic communications have deflected many of these interactions through the use of a virtual persona on social media, with differing styles of preferred communication rather than phone calls or text messaging, or incorporation of these functions within the social media platform.

Factors Contributing to Adolescents' Mobile Phone Use After Lights Out

Contributing factors for adolescents' mobile phone use after lights out included gender, caffeine use, and attitudes and beliefs regarding the value of sleep. Multiple studies lend support to gender differences in mobile phone use, with females more likely to use mobile phones during the sleep period than males (Bruni et al., 2015; Fobian et al., 2016; Gradisar et al., 2013; Grover et al., 2016; Hysing et al., 2015; Lange et al., 2017; Munezawa et al., 2011; Nathan et al., 2013; Oshima et al., 2012; Pieters et al., 2014). There were no significant differences between genders and mobile phone use after lights out. It is possible that evaluation of mobile phone usage after lights out on a daily basis rather than a nightly average may present an alternate picture of intraindividual variability when evaluating gender differences related to mobile phone. Alternatively, mobile phones have enhanced abilities to access many more features than was available during the period of the research cited above (i.e., 2011-2016) and many adolescents have unlimited use of their mobile phone devices throughout the day and night, which may lend support for the lack of gender differences. In addition, the small sample size may pose the greatest factor in the lack of gender differences observed in this study. Males were less represented than females in the study and three male participants did not provide complete mobile phone usage data, further limiting the sample size. Finally, the altered routines related to school closing demonstrated different trends in mobile phone usage among study participants. This factor may have provided additional factors to consider in potential gender differences in nighttime mobile phone use.

A second potential factor in adolescents' use of mobile phones after lights out was use of caffeine beverages. Caffeine use has been implicated in adolescents' attempts to remain alert during the day and later into the evening, in light of poor sleep sufficiency (Calamaro et al., 2009). It was hypothesized that caffeine users would be more likely to have higher mobile phone use after lights out. Although 75% of the sample reported use of caffeine beverages, the overall use of caffeine beverages was lower than anticipated in this study. The prevalence of study participants using caffeine is consistent with population norms for caffeine use (Mitchell et al., 2014); however, the mean daily number of caffeine beverages consumed was less than one per day, although some study participants consumed multiple caffeine beverages daily. In addition, caffeine intake was reported for the whole day, and not analyzed specifically in the pre-bedtime period. These study results demonstrated no differences between those who consumed caffeine beverages and average nightly mobile phone use. Calamaro (et al., 2009) evaluated daily caffeine use, which was quantified by milligrams of daily caffeine use rather than a count of the number of caffeine beverages, and observed an increase in use of technology devices with increased caffeine use. These conflicting results are difficult to explain and are not supported in the literature. Those participants who consume caffeine may be participating in other activities after lights out, such as game consoles, TV, computer, or other unspecified activities rather than solely using mobile phones. Perhaps the greatest factor in study results was the school closures related to the public health pandemic. Adolescents had the flexibility to select sleep patterns that may be more in alignment with their physiologic circadian preference with less need to consume caffeine beverages to maintain alertness during the day and into the early evening period to complete homework assignments. Fewer participants (66.7% versus 81.8%) consumed caffeine beverages post-school closures than while school was still in session. Assessment of the caffeine intake effect and mobile phone use after lights out on the daily level may demonstrate intraindividual differences which were not observed with a mean daily analysis from the week-long study period.

A third factor was the value adolescents place on the importance of sleep in everyday life. It was hypothesized that those participants who used mobile phones after lights out placed less value on the importance of sleep. The MPPUS and MPPUS-10 evaluated attitudes and beliefs specific to mobile phone use, and the SPAQ evaluated sleep practices and attitudes related to sleep in a survey format. This study was the first research study to use the SPAQ in individuals under the age of 18 years of age. The SPAQ was modified from the complete measure to include only individual items and subscales relevant for this research, measured attitudes and beliefs regarding sleep.

This study used three SPAQ subscales, with significant findings observed on one subscale, Importance of Sleep. Those study participants who had higher average nightly mobile phone use placed less value on sleep importance. The influential role of the peer group was highlighted as participants perceived that peers placed less importance on sleep. Although the Sleep and Health subscale did not rise to statistical significance, participants beliefs indicated little value placed on missing school or work related to not obtaining enough sleep. In accordance with the theoretical framework for this study, the TPB (Madden et al., 1992), the adolescent decision-making regarding use of mobile phones is based on a set of underlying attitudes and beliefs regarding sleep and mobile phone use. The belief of less importance of sleep may have influenced the attitudes toward sleep, with resultant increase in mobile phone usage after lights out among those placing less value on the importance of sleep. This initial use of the SPAQ, with careful selection of items and subscales of relevance to the sample and the research question demonstrated value for further use of this instrument. Despite use of several SPAQ subscales rather than the full instrument and a small sample size, the SPAQ was analyzed for internal consistency and exceeded that of the published data, i.e., Cronbach's α of 0.71 (Appendix J), compared to the full-scale SPAQ of 0.63 (Grandner et al., 2014).

Consistent with the normative beliefs and subjective norms constructs of the TPB, the importance of the peer group was evident among individual item responses in the instruments evaluating attitudes and beliefs. Although the factors of the MPPUS and MPPUS-10 did not reach statistical significance, all factors except withdrawal had higher scores of problematic mobile phone use when adolescents had higher average nightly use of mobile phones after lights out. Adolescents had a higher level of concern about using the mobile phone when feeling down, the ability of friends being unable to reach them without a mobile phone, and being engaged on their mobile phone longer than was intended. Moderate concern was placed on others' perceptions of spending excessive time on the mobile phone and losing sleep over phone use.

Sleep Patterns of Adolescents Using Mobile Phones After Lights Out

Normal adolescent sleep patterns are well documented in the literature, with the resultant effects of puberty and hormonal influences (Carskadon et al., 1993). Negative sleep outcomes, such as short sleep duration, reduced sleep quality and increased next day sleepiness are associated with use of electronic media (Bartel et al., Cain & Gradisar, 2010; Calamaro et al., 2009; Carter et al., 2016; Hale & Guan, 2015). Electronic technology devices, including mobile phones, negatively impact sleep by time displacement with device activities, exposure to blue light emissions, and emotionally-disturbing content (LeBourgeois et al., 2017). This study sought to describe adolescent sleep patterns in relation to use of mobile phones within the bedroom setting after lights out. Wrist actigraphy and self-report sleep diary were used to measure sleep outcomes.

Collectively, the participants slept rather well with 75% of the study sample observed to have an average sleep duration of least 8 hours of sleep, and sleep maintenance efficiency of 91%. These findings are somewhat atypical for adolescent sleep patterns as described in the literature review. Self-reported chronotype on Morningness/Eveningness Scale for Children demonstrated that more than half of the sample had an intermediate type (refer to Table 4-7 and Figure 4-5), neither morning nor evening type. It may be expected to see the youngest participants (13 and 14 years old), particularly males, may report a morning chronotype based on typical early pubertal stage for 13 year old males. However, exploratory descriptive analysis of the sample as two sub-samples of participants with pre- and post-school closure groups presents a different picture of the sample which is more in line with published descriptions of adolescent sleep patterns. Participants in the pre-school closure group had earlier sleep onset and offset times, earlier sleep midpoint, greater sleep duration variability, and shorter sleep duration than the post-school closure participants. The sleep patterns of the pre-school closure group reflect the sleep constraints of early school start times and an attempt to obtain an adequate amount of sleep for daytime function and alertness but physiologically not ready to sleep. The post-school closure group sleep patterns are more typical of adolescents who sleep at their preferred circadian timing. Observation of mean nightly sleep patterns did not demonstrate significant differences between the mobile phone use after lights out and 24-hour total sleep time or the nighttime total sleep time.

Sleep quality was analyzed by WASO, SME, and subjective report of sleep quality. WASO was not excessive in this study sample, with mean daily WASO of 37 minutes. It is curious that WASO was increased among those participants who were non-users of mobile phones after lights out and in those who had low mobile phone use after lights out, although this increase was not statistically significant. The pre-school closure group had more minutes of WASO than the post-school closure group. It would be anticipated that those who used mobile phones after lights out or those with higher mobile phone use could be disturbed during the sleep period by mobile phone activity, such as phone calls, text messages, or other audible alerts, leading to an increase in night awakenings and WASO. It is also possible that those participants in the pre-school closure group went to bed earlier in anticipation of an early sleep offset need for school and may not have been physiologically ready to sleep which may have increased night awakenings. The small sample size may have had an influential role in the study results. The sample had a high level of sleep maintenance efficiency which was unaffected by mobile phone use after lights out. Subjectively reported sleep quality was not affected by mobile phone use after lights out.

Without a variable to measure daytime sleepiness, the related variable of napping was evaluated. Napping does not directly evaluate daytime sleepiness, but rather is a behavioral response that may occur as a result of nighttime sleep insufficiency (Gradisar et al., 2008) combined with the opportunity to nap. Overall, napping was relatively uncommon among participants, with 27.3% taking naps and participants who napped slept an average of about 30 minutes daily. Napping was observed in those participants who provided data prior to school closure with the exception of one participant who napped after school closures. The fact that the preponderance of study participants obtained at least the minimum recommended 8 hours of sleep per day and some participants were not constrained by school hours may have minimized the need for napping in this study. However, among those participants who napped there may have been greater night to night sleep variability with some nights of insufficient sleep while other nights had greater than the minimum 8 hours of sleep, with the need for additional sleep time during the day. The observation of minimal to no napping in the post-school closure participants combined with sleep patterns congruent with their physiologic circadian rhythm, i.e., later sleep onset and offset times and later circadian midpoint of sleep, most likely had a significant effect upon the need for napping.

The lack of consistency with previously published studies on sleep outcomes with media use is interesting. More analyses beyond exploratory descriptive analyses of each sub-sample based on the school closure situation may yield differing results. In addition, data analysis on a nightly basis rather than a mean nightly basis may provide additional insights that may provide support or refute previously published studies. Large variability among the variables, with a high degree of skewness may have contributed to the current findings. Conversion of the micro-longitudinal data into a nightly average may demonstrated different results than would analysis of data on a daily level with analysis via multilevel modeling. Small sample size may have contributed to the lack of significant findings, although some findings trended towards those of published literature. Since there were no studies available to base the sample size calculation, the sample size was an estimate, and perhaps that estimate was underpowered. The combination of two sub-samples within the sample further reduces the sample size and sub-sample results may have the effect of moderating results that may have been seen by individual sub-sample analyses. In addition, the mean age of the sample was young, 14.5 years. Individual pubertal and developmental differences among the sample may be reflected based on this stage of typical pubertal development.

The data collection period for this study was situated within the historic COVID-19 public health pandemic where altered life patterns were apparent. Mandatory school and activity closures provided different sleep opportunities for the study participants. The lack of structured hours for school permitted the participants to self-select sleeping hours which may have been different from what may normally be experienced during the regular school week and on weekends consistent with individual circadian timing and chronotype. Participants may have had the opportunity to sleep longer or at different hours than they would have if they were in school. This may be similar to sleep patterns on days off from school or school vacation times, although emotional considerations related to a pandemic crisis could also play a role in sleep patterns. About half the study participants provided data during the period of mandatory school closures.

Although sleep variables correlated appropriately with each other, and mobile phone variables correlated appropriately with each other, as would be expected with measurement of similar items, there were no significant correlations between sleep and mobile phone use after lights out variables on an average nightly level. An attempt to predict adequacy of sleep duration with binary logistic regression was non-significant.

Strengths and Limitations

Assessment of strengths and limitations for the study provide insights into future directions for this line of inquiry. Strengths are related to study design, recruitment, data collection, instrumentation, and the data set. Limitations are related to electronic data capture, changes in recruitment and enrollment, study instrumentation, and sample size with lack of generalizability.

Strengths of the Study

Strengths of this study include a novel study design, an unintended recruitment strategy, use of direct electronic data entry by study participants, initial use of SPAQ in a new population, and a robust data set with the potential for expanded data analysis on the daily level to obtain more insights into relationships between adolescents' mobile phone use after lights out and sleep outcomes. The micro-longitudinal study design permitted collection of a generous set of variables over the study period, with baseline measures of attitudes and beliefs, and micro-longitudinal measures of sleep and mobile phone use after lights out. This data set will provide additional opportunities for within and between person analyses on mobile phone use after lights out and sleep. In addition, the data set is comprised of two sub-samples which will provide additional data analysis potential.

Success in study recruitment evolved from a usual recruitment plan in an ambulatory care clinic to an unintended notice on a social media page, which resulted in a rapid boost in recruitment and enrollment. Consideration of the use of social media to advertise a research study targeting adolescents and/or their parents may serve to facilitate study recruitment. REDCap was used for direct data entry by study participants, which eliminated the need for manual data entry or paper data collection forms, and the resultant data entry verification for accuracy. Anecdotally, the participants shared that the electronic format was preferable over paper forms for their convenience as they completed study measures using their mobile phones.

This study employed the initial use of the SPAQ in individuals under the age of 18 years. Minor modifications were made to one sub-scale item on the instrument to reflect the differing roles of family and friends based on adolescent development, and the subscales were abbreviated to fit the research questions. Use of the SPAQ shows beginning utility in research on attitudes and behaviors in adolescents specific to sleep. Lastly, this study has a robust data set with the potential for additional and more extensive analyses of micro-longitudinal measures to assess daily variables with multi-level modeling.

Limitations of the Study

Study limitations are related to use of REDCap, research changes necessitated by COVID-19 pandemic, instrumentation using self-report measures, and lack of generalizability. Study participants entered data directly into REDCap from twice daily electronic mail notifications with a link to the study measures to be completed. Although testing was done with the REDCap data entry system, there were some barriers with REDCap use for data capture. The initial three participants did not receive a link to some study measures, resulting in missing data for those individuals. The initial battery of questionnaires (Demographics questionnaire, MPPUS, MPPUS-10, M/E Scale for Children, and SPAQ) were all linked within a single electronic mail message to participants, reducing the potential for missing a survey due to lack of study link; whereas, the daily morning survey links for sleep diary and nighttime phone use diary were sent as two separate links, causing both confusion for some participants and lack of completion, despite prior instruction in the study procedures. Study notifications were generated by REDCap at 10 a.m. and 8 p.m. The 10 a.m. time was selected to provide notification at a time when participants would likely not be disturbed by an audible phone alert; however, this was not a good time on school days, as participants did not have the link prior to going to school and needed to remember to complete the survey after 10 am during a school break. In addition, participants indicated a preference for text message notifications, rather than electronic mail notifications, as they use electronic mail infrequently. Use of text message notifications requires additional security permissions through REDCap. Recommendations for REDCap data collection for future studies include more extensive testing, direct link for all surveys due at a particular time point, and use of text messaging for study link notifications for adolescent participants.

A second limitation was related to mandatory restrictions from Penn State University, Penn State Health, and the IRB on in-person research visits related to the COVID-19 pandemic and protections for public safety and health and protection for research participants. Although this unprecedented public health emergency was unanticipated, it required modifications in study enrollment procedures; specifically, the need to move to a virtual visit for enrollment. For this study, 26 participants were enrolled in person prior to the research restrictions, and eight were enrolled remotely. Although remote enrollment presented its own unique challenges in obtaining informed consent, it afforded the opportunity to enroll participants at times other than normal ambulatory clinic operating hours, such as evenings and weekends.

An additional limitation was observed with the Nighttime Mobile Technology Use Diary. This PI-developed measure was useful in collecting mobile phone usage data after lights out among the study participants; however, the measurement survey needs revision to bring greater clarity prior to future use. For example, study participants were asked to provide time usage of various mobile phone functions in either minutes or hours. Some study participants seemed to record the same length of time in both hours and minutes, i.e., 120 minutes and 2 hours for the same mobile phone function on the same day. Future use of this measure would eliminate use of hours and record minutes only. Streamlining the questions on this measure will eliminate redundancy and provide greater precision on the information sought by the measure. Use of self-report measures, such as the CSD, carries the risk of recall bias particularly based on the evaluation period (Short et al., 2007). However, despite the short recall period, inconsistencies in recall were noted with the morning CSD, with respect to the time participants went to bed and when they attempted to initiate sleep. For some participants, their self-reported sleep initiation time was before or significantly after the actigraphically-measured sleep time. Some participants indicated a discrepancy of several hours in some cases. As described above, the timing of the morning study measures for some participants may not have been the most optimal timing for study survey completion.

Lastly, the study participants presented a small homogeneous sample of individuals from one geographic area in rural southcentral Pennsylvania. The sample was primarily Caucasian, female, and on the younger end of the age range (14.56 years). Based on the participant demographics described, these study results may not be generalizable to other geographic areas, racial or ethnic minorities, or to older adolescents.

Future Research

On an average daily level, this study did not demonstrate significant relationships between mobile phone use after lights out and sleep patterns among adolescents; however, the data set affords the opportunity for additional analyses on the daily level. More detailed analyses may provide additional information about these potential relationships. Daily level analysis may expose intra-individual differences among study participants to provide additional insights on use of mobile phones after lights out. Additional analysis on the two sub-samples within the main sample may provide on differences between mobile phone usage and sleep between groups. This could be accomplished by exploratory analysis of the current data set with the potential for replication of the study in adolescents providing data during school time compared with provision of data during summertime off from school. The data collected in this study were from a healthy population of adolescents. Future research could include replication of the study among a group of adolescents within a pre-defined medical condition, such as type 1 diabetes or childhood cancer survivors, for examples, or with a broader age range of adolescents, such as 12 through 19 years of age.

The most significant study finding was related to attitudes and beliefs regarding mobile phone use and sleep. Those adolescents with higher mobile phone use after lights out provided lower ratings indicating less value on sleep importance, as evidenced by the Importance of Sleep subscale in the SPAQ. The influence of social media was apparent as the most widely used mobile phone function among adolescents when considering mobile phone use after lights out. The influences of the peer group through social media in relationship to mobile phone use and sleep is an interesting concept to ponder. Future research into this phenomenon may bring greater insights to mobile phone use in the bedroom setting after lights out. Lastly, the SPAQ was used in a new population of individuals in this study. Additional research on the use of the SPAQ in adolescents is warranted, with a larger sample needed to test this instrument for utility in adolescents.

Study Implications

This study did not demonstrate significant adverse sleep outcomes with mobile phone use after lights out. The question then remains on advocacy for appropriate use of mobile phones among adolescents within the nighttime setting. While it may seem ideal to ban use of mobile phones after lights out, this research does not support sleep disruption with use of mobile phones during the nighttime period, prompting one to consider whether interaction with mobile phones in the bedroom should be permissible. From a historical perspective, adolescents have been taking part in activities after lights out for decades or longer. For example, past generations read comic books or other print materials by flashlight under the blankets. It is encouraging that participants who engaged in greater mobile phone use after lights out were not significantly more likely to have poor sleep outcomes, as it is highly unlikely that adolescents will part with their phones for sleep. The American Academy of Pediatrics (2016) advocates for parents to develop a family media use plan that permits promotion of adequate social experiences with social and emotional development, protection of privacy, prevention of cyberbullying, and minimization of disruptions to sleep. Nurses can be part of the plan to promote healthy media usage within the biopsychosocial context of sleep health in adolescents.

Considering that over the course of the week participation period adolescents demonstrated sleep sufficiency with obtaining at least the minimum amount of 8 hours averaged over the course of the week, it may seem prudent to set some guidelines on mobile phone usage during the lights out period with adolescents. In light of the importance of the social and peer network among adolescents and the need for increasing independence during adolescence, it may seem practical to allow use of mobile phones in the pre-bedtime period and in the morning prior to getting out of bed, and minimize sleep disruptions during the actual sleeping period. Minimization of disruptions to the biophysiological context may include reduction of light emissions by lowering the screen illumination to minimal levels and engaging a blue light filter, and setting sounds to silent. To address the psychosocial aspects related to sleep, recognition of the physiologic pre-frontal cortex development and the relationship to decision-making, it would be worthwhile to establish rules for use of mobile phones after lights out. Discussion about sleep attitudes and the importance of sleep with parents and adolescents may be beneficial in understanding appropriate timing for use of mobile phones after lights out. These strategies would permit adolescents to keep their phones within the bedroom setting while allowing them to make decisions on phone use and have the phone available as an alarm for wake up. Nurses can be instrumental in encouraging parents to develop healthy mobile phone usage plans together with their adolescent children for a mutually agreeable plan and healthy sleep outcomes.

Perhaps the greater impact in this research is the different sleep patterns of those participants who provided data during school time versus those who provided data after school closures. Early school start times have long been implicated as counterproductive to adolescent circadian timing for optimal daily and academic functioning. Although analysis between the sub-groups within the sample was exploratory and descriptive only, the later sleep onset, offset, and midpoint times are reflective of those typically encountered during adolescence. Nurses can be instrumental in advocating for later school start times for high school students in light of preservation of sleep and adolescent health.

Conclusions

This study launched an initial exploration of the attitudes, behaviors, and sleep patterns of adolescents who used mobile phones within the bedroom setting after lights out, using a descriptive micro-longitudinal study design. This study was complicated by the experience of research conducted in the historic time of COVID-19, with subsequent modifications to typical research procedures. The study lacked significant findings on the relationships between mobile phone use after lights out and sleep outcomes, i.e., sleep duration and sleep quality, among study participants who used mobile phones after lights out. However, the study illuminated the stark differences in sleep timing between the participants who provided data prior to and after mandatory school closures during the COVID-19 pandemic in line with physiologic adolescent circadian timing. The influence of social media was noticeable in both recruitment and use of mobile phones after lights out, highlighting the importance of the social network within the adolescent age group supporting the constructs of the TPB in decision-making about behavior. These social influences combined with the diminished beliefs in sleep importance, provide a backdrop for future directions for research.

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Appendix A

Eligibility Questionnaire

Is your age between 13 years and 17 years?	______ yes	_____ no
Do you own or regularly use a smartphone device?	______ yes	_____ no
Do you read and write English?	______ yes	_____ no

Appendix B

Demographics Questionnaire

1. What is your age? _____

2. What is your gender?

☐ Male

☐ Female

☐ Other

☐ Prefer not to say

3. What is your race? Please mark all that apply.

☐ White/Caucasian

☐ Black/African American

☐ Asian

☐ American Indian/Alaska Native

☐ Native Hawaiian/Pacific Islander

☐ Other: (specify) ______________

4. What is your ethnicity?

☐ Hispanic ☐ Non-Hispanic

Appendix C

Mobile Phone Problem Use Scale-10

Table 5 The Mobile Phone Problem Use Scale-10 (MPPUS-10) items with the original item number of the original scale, the number of observations (*N*), factor loadings after rotation, means and standard deviations (SD)

Item	Original item	*N*	Factor loading	Mean	SD
For each item, please mark the box which fits best for you from 1 "Not true at all" to 10 "Extremely true"					
I have used my mobile phone to make myself feel better when I was feeling down. (*Craving*)	2	410	0.49	3.84	2.89
When out of range for some time, I become preoccupied with the thought of missing a call. (*Withdrawal*)	8	410	0.45	2.20	2.07
If I don't have a mobile phone, my friends would find it hard to get in touch with me. (*Peer Dependence*)	17	407	0.57	4.94	3.13
I feel anxious if I have not checked for messages or switched on my mobile phone for some time. (*Withdrawal*)	14	412	0.32	2.74	2.47
My friends and family complain about my use of the mobile phone. (*Loss of Control*)	16	412	0.48	2.98	2.62
I find myself engaged on the mobile phone for longer periods of time than intended. (*Loss of Control*)	20	409	0.38	3.30	2.53
I am often late for appointments because I'm engaged on the mobile phone when I shouldn't be. (*Negative Life Consequences*)	22	410	0.46	1.45	1.14
I find it difficult to switch off my mobile phone. (*Withdrawal*)	13	411	0.36	2.56	2.58
I have been told that I spend too much time on my mobile phone. (*Loss of Control*)	24	410	0.47	2.86	2.68
I have received mobile phone bills I could not afford to pay. (*Negative Life Consequences*)	7	411	0.33	1.37	1.40

Respective factor classification can be found in italic brackets after each item

Written permission to use MPPUS-10 from developer:

martin.roosli@swisstph.ch
Wed 6/10/2020 9:54 AM
Subject: Request for Permission to Use Mobile Phone Problem Use Scale-10

Dear Cynthia
Find attached all papers with relevant descriptions. Scoring is pretty simple, just adding up the scores. Of course you can use it for your research.
Best wishes,
Martin

- - -
Martin Röösli, PhD, Professor of Environmental Epidemiology
Head of the Environmental Exposures and Health Unit
Swiss Tropical and Public Health Institute
Associated Institute of the University of Basel
Mailing: Postfach, 4002 Basel
Office: Socinstrasse 57, CH-4051 Basel, Switzerland
Phone: +41 61 284 8383
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Appendix D

Sleep Practices and Attitudes Questionnaire

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Sub-scales: Sleep self-efficacy

Importance of Sleep

Sleep and Health

Michael Grandner <grandner@gmail.com>
Wed 1/9/2019 12:19 AM

Hello,

Thank you for your interest in the Sleep Practices and Attitudes Questionnaire (SPAQ).

Regarding your questions:

1. It isn't explicitly designed for adolescents but it may still prove useful -- take a look at the items and see what you think.

2. The subscales are not really that important -- I care a lot more about the individual items in most cases. It's made to be more qualitative and descriptive anyway.

The scale is free for any non-commercial research purposes. With that in mind, I would be happy to send you a copy.

With that in mind, I wanted to give you some pointers on using the scale. First of all, even though subscales exist, the scale was designed to be more descriptive and you should be able to feel free to eliminate items and scales that are not useful. The scale is very long and may be shortened to fit a specific study. It was designed to be modular that way.

Thank you again, and let me know if you have any questions!

Take care,

mg

Michael A. Grandner, PhD, MTR, CBSM

--

Assistant Professor of Psychiatry, Psychology, and Medicine

Director, Sleep & Health Research Program

University of Arizona College of Medicine

1501 N Campbell Avenue
BUMC Suite 7326
PO Box 245002
Tucson, AZ 85724-5002

(520) 626-6346

sleephealth@psychiatry.arizona.edu
http://www.sleephealthresearch.com
@uasleephealth

Appendix E

Morningness/Eveningness (M/E) Scale for Children

1*. Imagine: School is canceled! You can get up whenever you want to. When would you get out of bed? Between…

a. 5:00 and 6:30 am
b. 6:30 and 7:45 am
c. 7:45 and 9:45 am
d. 9:45 and 11:00 am
e. 11:00 am and noon

2. Is it easy for you to get up in the morning?

a. No way!
b. Sort of
c. Pretty easy
d. It's a cinch

3*. Gym class is set for 7:00 in the morning. How do you think you'll do?

a. My best!
b. Okay
c. Worse than usual
d. Awful

4*. The bad news: You have to take a two-hour test. The good news: You can take it when you think you'll do your best. What time is that?

a. 8:00 to 10:00 am
b. 11:00 am to 1:00 pm
c. 3:00 to 5:00 pm
d. 7:00 to 9:00 pm

5*. When do you have the most energy to do your favorite things?

a. Morning! I'm tired in the evening
b. Morning more than evening
c. Evening more than morning
d. Evening! I'm tired in the morning

6*. Guess what? Your parents have decided to let you set your own bedtime. What time would you pick? Between…

a. 8:00 and 9:00 pm
b. 9:00 and 10:15 pm
c. 10:15 pm and 12:30 am
d. 12:30 and 1:45 am
e. 1:45 and 3:00 am

7. How alert are you in the first half hour you're up?

a. Out of it
b. A little dazed
c. Okay
d. Ready to take on the world

8*. When does your body start to tell you it's time for bed (even if you ignore it)? Between…

a. 8:00 and 9:00 pm
b. 9:00 and 10:15 pm
c. 10:15 pm and 12:30 am
d. 12:30 and 1:45 am
e. 1:45 and 3:00 am

9. Say you had to get up at 6:00 am every morning: What would it be like?

a. Awful!
b. Not so great
c. Okay (if I have to)
d. Fine, no problem

10*. When you wake up in the morning how long does it take for you to be totally "with it?"

a. 0 to 10 minutes
b. 11 to 20 minutes
c. 21 to 40 minutes
d. More than 40 minutes

FIG. 1. Morningness/eveningness scale for children. A score is derived by adding points for each answer: a = 1, b = 2, c = 3, d = 4, e = 5, except as indicated by *, where point values are reversed. The maximum score is 42 (maximal morning preference) and the minimum is 10 (minimal morning preference).

Carskadon, M. A., & Acebo, C. (1992). Relationship of a morningness/eveningness scale to sleep patterns in preadolescents. *Sleep Research, 21,* 367, by permission of Oxford University Press.

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Appendix F

Instructions for Wearing the Actiwatch

Call or text with any problems/questions

(717) 572-5771

DO:

Wear the Actiwatch on your non-dominant wrist (wrist opposite the hand you write with)

Wear the Actiwatch night and day except when it may become damaged

Take off the Actiwatch when bathing, showering, or swimming

You may wear a wrist/sweatband under the Actiwatch if it's more comfortable

Treat the Actiwatch as you would an expensive watch

DO NOT:

Subject the Actiwatch to excessive impact

Try to take the Actiwatch apart

Expose the Actiwatch to temperature extremes

Appendix G

Consensus Sleep Diary

General Instructions

What is a Sleep Diary? A sleep diary is designed to gather information about your daily sleep pattern.

How often and when do I fill out the sleep diary? It is necessary for you to complete your sleep diary every day. If possible, the sleep diary should be completed within one hour of getting out of bed in the morning. The Nighttime Sleep Diary questions can be completed before you go to bed at night.

What should I do if I miss a day? If you forget to fill in the diary or are unable to finish it, leave the diary blank for that day.

What if something unusual affects my sleep or how I feel in the daytime? If your sleep or daytime functioning is affected by some unusual event (such as an illness, or an emergency) you may make brief notes on your diary.

What do the words "bed" and "day" mean on the diary? This diary can be used for people who are awake or asleep at unusual times. In the sleep diary, the word "day" is the time when you choose or are required to be awake. The term "bed" means the place where you usually sleep.

Will answering these questions about my sleep keep me awake? This is not usually a problem. You should not worry about giving exact times, and you should not watch the clock. Just give your best estimate.

Morning Sleep Diary Item Instructions

Use the guide below to clarify what is being asked for each item of the Sleep Diary.

Date: Write the date of the morning you are filling out the diary.

1\. *What time did you get into bed?* Write the time that you got into bed. This may not be the time you began "trying" to fall asleep.

2\. *What time did you try to go to sleep?* Record the time that you began "trying" to fall asleep.

3\. *How long did it take you to fall asleep?* Beginning at the time you wrote in question 2, how long did it take you to fall asleep.

4\. *How many times did you wake up, not counting your final awakening?* How many times did you wake up between the time you first fell asleep and your final awakening?

5\. *In total, how long did these awakenings last?* What was the total time you were awake between the time you first fell asleep and your final awakening. For example, if you woke 3 times for 20 minutes, 35 minutes, and 15 minutes, add them all up (20+35+15= 70 min or 1 hr and 10 min).

6a. What time was your final awakening? Record the last time you woke up in the morning.

6b. After your final awakening, how long did you spend in bed trying to sleep? After the last time you woke-up (Item #6a), how many minutes did you spend in bed trying to sleep? For example, if you woke up at 8 am but continued to try and sleep until 9 am, record 1 hour.

6c. Did you wake up earlier than you planned? If you woke up or were awakened earlier than you planned, check yes. If you woke up at your planned time, check no.

6d. If yes, how much earlier? If you answered "yes" to question 6c, write the number of minutes you woke up earlier than you had planned on waking up. For example, if you woke up 15 minutes before the alarm went off, record 15 minutes here.

7. *What time did you get out of bed for the day?* What time did you get out of bed with no further attempt at sleeping? This may be different from your final awakening time (e.g. you may have woken up at 6:35 a.m. but did not get out of bed to start your day until 7:20 a.m.)

8. *In total, how long did you sleep?* This should just be your best estimate, based on when you went to bed and woke up, how long it took you to fall asleep, and how long you were awake. You do not need to calculate this by adding and subtracting; just give your best estimate.

9. *How would you rate the quality of your sleep?* “Sleep Quality” is your sense of whether your sleep was good or poor.

10. *How restful or refreshed did you feel when you woke up for the day?* This refers to how you felt after you were done sleeping for the night, during the first few minutes that you were awake.

Nighttime Sleep Diary Item Instructions

Please complete the following items before you go to bed.

Date: Write the date of the evening you are filling out the diary.

11a. How many times did you nap or doze? A nap is a time you decided to sleep during the day, whether in bed or not in bed. “Dozing” is a time you may have nodded off for a few minutes, without meaning to, such as while watching TV. Count all the times you napped or dozed at any time from when you first got out of bed in the morning until you got into bed again at night.

11b. In total, how long did you nap or doze? Estimate the total amount of time you spent napping or dozing, in hours and minutes. For instance, if you napped twice, once for 30 minutes and once for 60 minutes, and dozed for 10 minutes, you would answer “1 hour 40 minutes.” If you did not nap or doze, write “N/A” (not applicable).

12a. How many drinks containing alcohol did you have? Enter the number of alcoholic drinks you had where 1 drink is defined as one 12 oz beer (can), 5 oz wine, or 1.5 oz liquor (one shot).

12b. What time was your last drink? If you had an alcoholic drink yesterday, enter the time of day in hours and minutes of your last drink. If you did not have a drink, write “N/A” (not applicable).

13a. How many caffeinated drinks (coffee, tea, soda, energy drinks) did you have? Enter the number of caffeinated drinks (coffee, tea, soda, energy drinks) you had where for coffee and tea, one drink = 6-8 oz; while for caffeinated soda one drink = 12 oz.

13b. What time was your last drink? If you had a caffeinated drink, enter the time of day in hours and minutes of your last drink. If you did not have a caffeinated drink, write “N/A” (not applicable).

14. Did you take any over-the-counter or prescription medication(s) to help you sleep? If so, list medication(s), dose, and time taken: List the medication name, how much and when you took EACH different medication you took tonight to help you sleep. Include medication available over the counter, prescription medications, and herbals (example: "Sleepwell 50 mg 11 pm"). If every night is the same, write “same” after the first day

15. Comments If you have anything that you would like to say that is relevant to your sleep feel free to write it here.

Consensus Sleep Diary - E (Please Complete Upon Awakening) **ID/NAME: ____________________**

Sample

Today's Date	4/5/11							
1. What time did you get into bed?	10:15 p.m.							
2. What time did you try to go to sleep?	11:30 p.m.							
3. How long did it take you to fall asleep?	55 min.							
4. How many times did you wake up, not counting your final awakening?	6 times							
5. In total, how long did these awakenings last?	2 hours 5 min.							
6a. What time was your final awakening?	6:35 a.m.							
6b. After your final awakening, how long did you spend in bed trying to sleep?	45 min.							
6c. Did you wake up earlier than you planned?	☒ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
6d. If yes, how much earlier?	1 hour							
7. What time did you get out of bed for the day?	7:20 a.m.							
8. In total, how long did you sleep?	4 hours 10 min.							
9. How would you rate the quality of your sleep?	☐ Very poor ☒ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good
10. How rested or refreshed did you feel when you woke-up for the day?	☐ Not at all rested ☒ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested

Consensus Sleep Diary - E (Please Complete Before Bed) **ID/NAME: ________________________**

	Sample							
Today's Date	4/4/11							
11a. How many times did you nap or doze? 11b. In total, how long did you nap or doze?	2 times 1 hour 10 min.							
12a. How many drinks containing alcohol did you have? 12b. What time was your last drink?	3 drinks 9 :20 p.m.							
13a. How many caffeinated drinks (coffee, tea, soda, energy drinks) did you have? 13b. What time was your last drink?	2 drinks 3 :00 p.m.							
14. Did you take any over-the-counter or prescription medication(s) to help you sleep? If so, list medication(s), dose, and time taken	☑ Yes □ No Medication(s): Relaxo-Herb Dose: 50 mg Time(s) taken: 11 pm	□Yes □No Medication(s): Dose: Time(s) taken:	□Yes □No Medication(s): Dose: Time(s) taken:	□Yes □No Medication(s): Dose: Time(s) taken:	□Yes □No Medication(s): Dose: Time(s) taken:	□Yes □No Medication(s): Dose: Time(s) taken:	□Yes □No Medication(s): Dose: Time(s) taken:	□Yes □No Medication(s): Dose: Time(s) taken:
15. Comments (if applicable)	I have a cold							

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Appendix H

Nighttime Mobile Phone Use Diary

Question	Yes	No	No. times	Hrs.	Mins.
1. Did you use your mobile phone between the time you went to bed and when you got up this morning?	☐	☐			
2. If yes, what features did you use **on your phone**? (Mark all that apply.)					
a. Made or received a phone call	☐	☐			
b. Sent or received a text message (such as What'sApp, Kik, Telegram, Messenger, etc.)	☐	☐			
c. Used social media (such as YouTube, Snapchat, Instagram, Twitter, Tumblr, Askfm, Facebook, Pinterest, etc.)	☐	☐			
d. Listened to music/podcast	☐	☐			
e. Played games (online games or games downloaded onto the phone)	☐	☐			
f. Watched movie/TV (using services such as YouTube, NetFlix, Vimeo, Hulu, Amazon Prime Video, Sling TV, Google Play Movies, iTunes)	☐	☐			
g. Browsed the internet for other reasons	☐	☐			
h. Used another technology function **on the mobile phone**	☐	☐			
3. Did you use **any other electronic devices** between the time you went to bed and when you got up this morning? (Mark all that apply.)					
a. Computer	☐	☐			
b. TV	☐	☐			
c. Tablet	☐	☐			
d. Game console	☐	☐			
e. Other? (specify) ______________________	☐	☐			
4. If you used your mobile phone between the time you went to bed and the time you got up this morning, when did you use your phone? (Mark all that apply.)					
a. I used my phone after getting into bed before falling asleep	☐	☐			
b. I was awakened during the night by my phone and then used it	☐	☐			
c. I woke up during the night for another reason and used my phone	☐	☐			
d. I used my phone when I woke up for the day and before I got out of bed	☐	☐			

Appendix I

Institutional Review Board Approval

PennState Health
Milton S. Hershey Medical Center

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Human Subjects Protection Office
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APPROVAL OF SUBMISSION

Date: November 1, 2019

From: Julia Kennedy,

To: Cynthia Snyder

Type of Submission:	Initial Study
Title of Study:	Mobile phones in the bedroom: Impact on adolescent sleep
Principal Investigator:	Cynthia Snyder
Study ID:	STUDY00013329
Submission ID:	STUDY00013329
Funding:	Not Applicable
IND,IDE, or HDE:	Not Applicable
Documents Approved:	• Actiwatch instructions_Snyder.docx (0.01), Category: Data Collection Instrument • Consolidated sleep diary_Snyder.docx (0.01), Category: Data Collection Instrument • Data Collection Record_Individual_Snyder.docx (0.01), Category: Data Collection Instrument • Data Collection Record_Snyder.docx (0.01), Category: Data Collection Instrument • Demographics questionnaire_Snyder.docx (0.02), Category: Data Collection Instrument • Eligibility Questionnaire_Snyder_v2.docx (0.02), Category: Data Collection Instrument • HRP-580_HSPO Consent Form_Snyder_track changes_v3.pdf (0.04), Category: Consent Form • HRP-591 - Protocol for Human Subject Research_Snyder_track changes_v3.pdf (0.07), Category: IRB Protocol • HRP-598 - Research Data Plan Review Form_Snyder_track changes_v4.pdf (0.05), Category: IRB Protocol • MEQ_Snyder.docx (0.02), Category: Data Collection

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	Instrument • MPPUS_Snyder.docx (0.02), Category: Data Collection Instrument • MPPUS-10_Snyder.docx (0.02), Category: Data Collection Instrument • Nighttime mobile phone use questionnaire_Snyder.docx (0.02), Category: Data Collection Instrument • SPAQ_Snyder.docx (0.02), Category: Data Collection Instrument • Study intro script_v2.docx (0.02), Category: Other
Review Level:	Expedited

On 11/1/2019, the IRB approved the above-referenced Initial Study. This approval is effective through 10/31/2020 inclusive. You must submit a continuing review form with all required explanations for this study at least 45 days before the study's approval end date. You can submit a continuing review by navigating to the active study and clicking 'Create Modification / CR'.

If continuing review approval is not granted before 10/31/2020, approval of this study expires on that date. Attached are stamped approved consent documents. Use copies of these documents to document consent.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within CATS IRB (http://irb.psu.edu). These requirements include, but are not limited to:

- Documenting consent
- Requesting modification(s)
- Requesting continuing review
- Closing a study
- Reporting new information about a study
- Registering an applicable clinical trial
- Maintaining research records

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APPROVAL OF SUBMISSION

Date: January 21, 2020

From: Samantha Adams,

To: Cynthia Snyder

Type of Submission:	Modification
Short Title:	Modification #1 for Study Mobile phones and adolescent sleep
Full Title of Study:	Mobile phones in the bedroom: Impact on adolescent sleep
Principal Investigator:	Cynthia Snyder
Study ID:	STUDY00013329
Submission ID:	MOD00022350
Funding:	Not Applicable
IND,IDE, or HDE:	Not Applicable
Documents Approved:	• HRP-591 - Protocol for Human Subject Research_Snyder_track changes_v5.pdf (0.09), Category: IRB Protocol
Review Level:	Expedited

On 1/21/2020, the IRB approved the above-referenced Modification. This approval is effective through 10/31/2020 inclusive. You must submit a continuing review form with all required explanations for this study at least 45 days before the study's approval end date. You can submit a continuing review by navigating to the active study and clicking 'Create Modification / CR'.

If continuing review approval is not granted before 10/31/2020, approval of this study expires on that date. Attached are stamped approved consent documents. Use copies of these documents to document consent.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB

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APPROVAL OF SUBMISSION

Date: March 13, 2020

From: Samantha Adams,

To: Cynthia Snyder

Type of Submission:	Modification
Short Title:	Modification #2 for Study Mobile phones and adolescent sleep
Full Title of Study:	Mobile phones in the bedroom: Impact on adolescent sleep
Principal Investigator:	Cynthia Snyder
Study ID:	STUDY00013329
Submission ID:	MOD00022963
Funding:	Not Applicable
IND,IDE, or HDE:	Not Applicable
Documents Approved:	• Data Collection Record_Snyder_03_01_2020.docx (0.02), Category: Data Collection Instrument • HRP-580_HSPO Consent Form_Snyder_03_01_2020.pdf (0.05), Category: Consent Form • HRP-591 - Protocol for Human Subject Research_Snyder_03_12_20.pdf (0.11), Category: IRB Protocol
Review Level:	Expedited

On 3/13/2020, the IRB approved the above-referenced Modification. This approval is effective through 10/31/2020 inclusive. You must submit a continuing review form with all required explanations for this study at least 45 days before the study's approval end date. You can submit a continuing review by navigating to the active study and clicking 'Create Modification / CR'.

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- Closing a study
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APPROVAL OF SUBMISSION

Date: March 18, 2020

From: Samantha Adams,

To: Cynthia Snyder

Type of Submission:	Modification
Short Title:	Modification #3 for Study Mobile phones and adolescent sleep
Full Title of Study:	Mobile phones in the bedroom: Impact on adolescent sleep
Principal Investigator:	Cynthia Snyder
Study ID:	STUDY00013329
Submission ID:	MOD00023170
Funding:	Not Applicable
IND,IDE, or HDE:	Not Applicable
Documents Approved:	• HRP-591 - Protocol for Human Subject Research_Snyder_03_18_20.pdf (0.12), Category: IRB Protocol • HRP-598 - Research Data Plan Review Form_Snyder_3_18_20.pdf (0.06), Category: IRB Protocol
Review Level:	Expedited

On 3/18/2020, the IRB approved the above-referenced Modification. This approval is effective through 10/31/2020 inclusive. You must submit a continuing review form with all required explanations for this study at least 45 days before the study's approval end date. You can submit a continuing review by navigating to the active study and clicking 'Create Modification / CR'.

If continuing review approval is not granted before 10/31/2020, approval of this study expires on that date. Attached are stamped approved consent documents. Use copies of these documents to document consent.

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- Requesting continuing review
- Closing a study
- Reporting new information about a study
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APPROVAL OF SUBMISSION

Date: March 18, 2020

From: Samantha Adams,

To: Cynthia Snyder

Type of Submission:	Modification
Short Title:	Modification #4 for Study Mobile phones and adolescent sleep
Full Title of Study:	Mobile phones in the bedroom: Impact on adolescent sleep
Principal Investigator:	Cynthia Snyder
Study ID:	STUDY00013329
Submission ID:	MOD00023183
Funding:	Not Applicable
IND,IDE, or HDE:	Not Applicable
Documents Approved:	• Signature page telephone consent.pdf (0.01), Category: Consent Form
Review Level:	Expedited

On 3/18/2020, the IRB approved the above-referenced Modification. This approval is effective through 10/31/2020 inclusive. You must submit a continuing review form with all required explanations for this study at least 45 days before the study's approval end date. You can submit a continuing review by navigating to the active study and clicking 'Create Modification / CR'.

If continuing review approval is not granted before 10/31/2020, approval of this study expires on that date. Attached are stamped approved consent documents. Use copies of these documents to document consent.

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- Closing a study
- Reporting new information about a study
- Registering an applicable clinical trial
- Maintaining research records

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CONSENT FOR RESEARCH
Penn State College of Medicine
Penn State Health

Title of Project: Mobile phones in the bedroom: Impact on adolescent sleep

Principal Investigator: Cynthia Snyder, MSN, RN

Address: 905 W. Governor Rd
Suite 320
Hershey PA 17033

Telephone Numbers: Weekdays: 8:00 a.m. to 5:00 p.m. (717) 572-5771.

Subject's Printed Name: ______________________________

We are asking you to be in a research study.

Whether or not you take part is up to you. You can choose not to take part. You can agree to take part and later change your mind. Your decision will not be held against you, and there will be no penalty or loss of benefits to which you are entitled.

This form gives you information about the research. Please ask questions about anything that is unclear to you and take your time to make your choice.

Some of the people who are eligible to take part in this research study may not be able to give consent because they are less than 18 years of age (a minor). Instead we will ask their parent(s)/guardian(s) to give permission for their participation in the study, and we may ask them to agree (give assent) to take part. Throughout the consent form, when we say "you", we mean you or your child.

1. Why is this research study being done?

This research is being done to find out about the behaviors, sleep patterns, and attitudes and beliefs of adolescents who use mobile phones within the bedroom setting after lights out.

Approximately 40 people will take part in this research study at Penn State Health Hershey Medical Center.

2. What will happen in this research study?

This study will include 1 study visit and one additional week of collecting data. The study visit will be conducted by the principal investigator in the pediatric/adolescent ambulatory clinic. You will be asked a series of questions to determine whether you can take part in the study. This will occur prior to signing the consent form. If you are eligible to participate in this study, you will need to sign this consent form before you can take part in any research procedures. Visit 1 will include: learning how to use the online data collection system, completing several questionnaires, learning how to use and care for the wrist actigraphy device (similar to a fitness tracker) to monitor your sleep patterns, and learning how to provide data for the 7 day study period. The wrist actigraphy device is a small non-invasive device, similar to a wristwatch, that is worn on the non-dominant wrist. The device records your activity patterns to measure your sleep timing and the amount of sleep time you obtain. You will receive a separate instruction sheet for use and care of your actigraphy device. You will leave Visit 1 wearing a wrist actigraphy device to measure your sleep, with a pre-paid mailer to return the wrist actigraphy device. During the next 7 days, you will wear the wrist actigraphy device all the time, and will complete short questionnaires 2 times each day. You will receive a text message every day at a time you select, as a reminder to complete the daily questionnaires. There is a risk of failure of the wrist actigraphy device to record data over part or all of the 7-day collection period. If you feel the device is not working, you should contact the principal investigator as soon as possible for instructions. Following the 7 day data collection period, you will place the wrist actigraphy device in the pre-paid mailer and ship to the principal investigator. You may also return the wrist actigraphy device in person. You will receive an email communication from the principal investigator when the actigraphy device is received following your participation in the study. In the event that you do not return the wrist actigraphy device, your data will not be able to be included in the research study. For questionnaires, you are free to skip any questions that you would prefer not to answer. Study procedures are shown in the following chart:

Pre-screening	Eligibility questionnaire (3 items; less than 5 minutes)
Visit 1 About 1-1 ½ hours	Complete questionnaires: Demographics questionnaire (4 items; less than 5 minutes) Mobile Phone Problem Use Questionnaire-10 (10 items; 5 minutes) Mobile Phone Problem Use Questionnaire (1 item; less than 5 minutes) Morningness/Eveningness Scale for Children (10 items; 5 minutes) Sleep Practices and Attitudes Questionnaire (34 items; 5 minutes) Wrist actigraphy device instruction for use and device return Daily diary data collection instruction; self-select a time for daily reminders
Next 7 days	Wear wrist actigraphy device Complete questionnaires: Consensus Sleep Diary (8 items in morning; 5 items in evening: less than 5 minutes for each part) Nighttime Mobile Phone Use Diary (4 items: less than 5 minutes)
After 7 day data collection period	Return wrist actigraphy device via pre-paid mailer or in person

What are my responsibilities if I take part in this research?

If you take part in this research, your major responsibilities will include:

- Completing a series of questionnaires
- Wearing a wrist device to measure your sleep for 1 week (7 days)
- Completing a daily diary on sleep and mobile phone use

- Returning the wrist actigraphy device via pre-paid postal mailer or in person

3. What are the risks and possible discomforts from being in this research study?

There is a risk of loss of confidentiality if your information or your identity is obtained by someone other than the investigators, but precautions will be taken to prevent this from happening. The confidentiality of your electronic data created by you or by the researchers will be maintained as required by applicable law and to the degree permitted by the technology used. Absolute confidentiality cannot be guaranteed.
Although uncommon, there is a risk that the actigraphy device you will be wearing for this study may cause you minor discomfort. The area of skin under the watch may get itchy and cause minor irritation. You will be instructed in proper cleaning procedures to reduce your chance of this happening or you may wear a wrist band between your skin and the watch.

4. What are the possible benefits from being in this research study?

4a. What are the possible benefits to me?

You will not benefit from this research study.

4b. What are the possible benefits to others?

Medical science may gain further understanding of the factors related adolescents' use of mobile phones during the night and how it impacts their sleep.

5. What other options are available instead of being in this research study?

You may choose not to be in this research study.

6. How long will I take part in this research study?

If you agree to take part, it will take you about 7 days to complete this research study. You will be asked to visit the research site __1__ time.

7. How will you protect my privacy and confidentiality if I decide to take part in this research study?

7a. What happens to the information collected for the research?

Efforts will be made to limit the use and sharing of your personal research information to people who have a need to review this information. Reasonable efforts will be made to keep the personal information in your research record private. However, absolute confidentiality cannot be guaranteed, and there may be situations where disclosure is required by law.

In our research files at Penn State Health (PSH) and Penn State College of Medicine (PSU) we will include these identifiers: your name, phone number, electronic mail address, Penn State Health medical record number, and a code number.

- A list that matches your name with your code number will be kept in a password protected computer file in Cynthia Snyder's office.
- Your research records will be labeled with your code number, and will be kept in a safe area in Cynthia Snyder's research office.

In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

We will do our best to keep your participation in this research study confidential to the extent permitted by law. However, the following people/groups may check and copy records about this research.

- The Office for Human Research Protections in the U. S. Department of Health and Human Services
- The PSH/PSU Institutional Review Board (a committee that reviews and approves research studies) and
- The PSH/PSU Human Subjects Protection Office
- The PSH/PSU Research Quality Assurance Office

7b. What will happen to my research information and/or samples after the study is completed?

Your information that are collected as part of this research will not be used or distributed for future research studies, even if all of your identifiers are removed.

7c. How will my identifiable health information be used?

In general, under federal law (including the Health Insurance Portability and Accountability Act – HIPAA or privacy laws) your health information is private. By signing this form, you are authorizing us to collect, use, and disclose your identifiable health information, sometimes referred to as "Protected Health Information" or "PHI" under HIPAA, for the purposes of this research study. We will use and disclose your information only as described in this form, in the PSH Privacy Notice, and as may be required or allowed under the applicable privacy laws.

The research team may use the following health information:

- Past, present, and future medical records, including identifiable information
- New health information from tests, procedures, visits, interviews, or forms filled out as part of this research study.

The following people/groups may see, use, and share your identifiable health information:

- PSH/PSU research staff involved in this study
- The PSH/PSU Institutional Review Board (IRB), a group of people who review the research study to protect subjects' rights and welfare
- The PSH/PSU Human Subjects Protection Office
- The PSH/PSU Research Quality Assurance Office

- Non-research staff within PSH/PSU who need this information to do their jobs (such as for treatment, payment (billing), or health care operations)
- Federal and state agencies (such as the U.S. Food and Drug Administration, the Office for Human Research Protections, the Department of Health and Human Services, the National Institutes of Health, and other U.S. or foreign government bodies that oversee or review research)
- People or groups that we hire to do work for us, such as data storage companies, insurers, and lawyers
- Organizations that provide independent accreditation and oversight of hospitals and research
- Public health and safety authorities (for example, if we learn information that could mean harm to you or others, we may need to report this, as required by law)
- Researchers from other campuses of Penn State University who are part of this study

These groups may also review and/or copy your original PSH/PSU records while looking at the results of the research study. It is possible that some of the other people/groups who receive your health information may not be required by Federal privacy laws to protect your information. We share your information only when we must, and we ask anyone who receives it from us to protect your privacy.

Sometimes a Principal Investigator or other researcher moves to a different institution. If this happens, your identifiable health information may be shared with that new institution and their oversight offices. PHI will be shared securely and under a legal agreement to ensure it continues to be used under the terms of this consent and HIPAA authorization.

We may remove identifying information from your protected health information. Once we do this, the remaining information will not be subject to the privacy laws. Information without identifiers may be used or disclosed with other people or organizations for purposes besides this study.

Because research is an ongoing process, your permission for the use, storage and sharing of your health information will continue indefinitely.

Your privacy rights:

- You have the right to refuse to sign this form that allows us to use and share your health information for research; however, if you don't sign it, you will not be able to take part in this research study.
- You have the right to withdraw your permission for us to use or share your health information for this research study. If you want to withdraw your permission, you must notify the person in charge of this research study in writing using the address on the front of this form. Once permission is withdrawn, you cannot continue to take part in the study.
- If you withdraw your permission, we will stop collecting health information about you for this study; we may continue to use and share your health information that we

already have if it is necessary for safety and scientific soundness of the research study; and we will not be able to take back information that has already been used or shared with others.

- You have the right to see and get a copy of your health information that is used or shared for treatment or for payment. However, you may not be allowed to see or copy certain health information that is a part of this research study. This is only for the period of the study. You will be allowed to see that information when the entire research study is complete.

8. What are the costs of taking part in this research study?

8a. What will I have to pay for if I take part in this research study?

There is no cost to you for taking part in this study.

9. Will I be paid to take part in this research study?

You will receive up to $100 in electronic gift card(s) for your participation in this research study. You will receive a $25 gift card for completion of visit 1, a $25 gift card for returning the wrist actigraphy device following your 7-day data collection period, and an additional $10-50 gift card for providing 5-7 days of actigraphy and diary data ($10 for 5 days, $25 for 6 days, and $50 for 7 days). If you do not complete the study for any reason, you will be paid for the visits you have completed.

10. Who is paying for this research study?

Funds from the Penn State University College of Nursing will be used to support this research.

11. What are my rights if I take part in this research study?

Taking part in this research study is voluntary.

- You do not have to be in this research.
- If you choose to be in this research, you have the right to stop at any time.
- If you decide not to be in this research or if you decide to stop at a later date, there will be no penalty or loss of benefits to which you are entitled.

During the course of the research you will be provided with any new information that may affect your health, welfare or your decision to continue participating in this research.

12. If I have questions or concerns about this research study, whom should I call?

Please call the head of the research study (principal investigator), Cynthia Snyder at (717) 572-5771, if you:

- Have questions, complaints or concerns about the research.
- Believe you may have been harmed by being in the research study.

You may also contact the research protection advocate in the PSH Human Subjects Protection Office (HSPO) at (717) 531-5687 if you:

- Have questions regarding your rights as a person in a research study.
- Have concerns, complaints or general questions about the research.
- You may also call this number if you cannot reach the research team or wish to offer input or to talk to someone else about any concerns related to the research.

You may visit the Penn State College of Medicine's Clinical Research web site at http://med.psu.edu/clinical-research/faqs for:

- Information about your rights when you are in a research study;
- Information about the Institutional Review Board (IRB), a group of people who review the research to protect your rights; and
- Links to the federal regulations and information about the protection of people who are in research studies. If you do not have access to the internet, copies of these federal regulations are available by calling the HSPO at (717) 531-5687.

INFORMED CONSENT AND AUTHORIZATION TO TAKE PART IN RESEARCH

Signature of Person Obtaining Informed Consent

Your signature below means that you have explained the research to the subject or subject representative, provided the subject or subject representative an opportunity to discuss and consider whether or not to participate in the research, and have answered any questions about the research.

________________________________ ___________ _______ _________________

Signature of person who explained this research Date Time Printed Name
(Only approved investigators for this research may explain the research and obtain informed consent.)

Signature of Person Giving Informed Consent and Authorization

Before making the decision about being in this research you should have:

- Discussed this research study with an investigator,
- Read the information in this form, and
- Had the opportunity to ask any questions you may have.

Your signature below means that you have received this information, have asked the questions you currently have about the research and those questions have been answered. You will receive a copy of the signed and dated form to keep for future reference.

Signature of Parent(s)/Guardian for Child

By signing this consent form, you indicate that you permit your child to be in this research and authorize your child's information to be used and shared as described above.

____

Printed name of child

____________________________	__________	______	________________
Signature of Parent/Guardian	Date	Time	Printed Name

☐ Parent

☐ Individual legally authorized to consent to the child's general medical care. (See note below.)

Note: Investigators are to ensure that individuals who are not parents can demonstrate their legal authority to consent to the child's general medical care. Contact legal counsel if any questions arise.

ASSENT FOR RESEARCH

The research study has been explained to you. You have had a chance to ask questions to help you understand what will happen in this research.

You Do Not have to be in the research study. If you agree to participate and later change your mind, you can tell the researchers, and the research will be stopped.

You have decided: **(Initial one)**

___ To take part in the research.

___ NOT to take part in the research.

__________________________________	______	_________________________
Signature of subject	Date	Printed Name

Appendix J

Study Measurement Instrument Psychometrics

Measure	Cronbach's α	Published α
M/E Scale for Children	0.53	0.82[a]
MPPUS	*	0.92 (full scale)[b]
MPPUS-10	0.77	0.85[c]
SPAQ	0.71 (3 subscales)	0.63 (16 subscales)[d]
Sleep Self-Efficacy	*	*
Importance of Sleep	0.69[#]	0.64
Sleep and Health	0.75[#]	0.80

Note. M/E Scale for Children = Morning/Eveningness Scale for Children; MPPUS = Mobile Phone Problem Use Scale; MPPUS-10 = Mobile Phone Problem Use Scale-10; SPAQ = Sleep Practices and Attitudes Questionnaire. [a] Carskadon & Acebo, 1992; [b] Bianchi & Phillips, 2005; [c] Foerster, Roser, Schoeni, & Roosli, 2015; [d] Grandner, Jackson, Gooneratne, & Patel, 2014. *Not calculated for single item scale. [#]Some questions for full scale were eliminated due to adult content not appropriate for adolescents.

VITA

Cynthia K. Snyder

53 Trail Rd S | Elizabethtown, PA 17022 | cgordner73@gmail.com

EDUCATION

2020	PhD	Nursing, Pennsylvania State University, University Park, PA
2014	BSN	Nursing (second degree completion), Grand Canyon University, Phoenix, AZ
2013	MSN	Nursing Education, (BS-MSN Bridge) Grand Canyon University, Phoenix, AZ
1980	BS	Chemistry, Moravian College, Bethlehem, PA
1975	Diploma	Nursing, St. Luke's Hospital School of Nursing, Bethlehem, PA

PROFESSIONAL EXPERIENCE

Registered nurse | Adult and pediatric critical care | Pediatric endocrinology ambulatory care | 1975-present

HONORS AND AWARDS

- Sigma Theta Tau International, Beta Sigma chapter, Research award, 2019
- Penn State University College of Nursing, PhD Doctoral Student Organization Student Award, 2019
- Nursing Research and Clinical Scholarship Award, Penn State Health Hershey Medical Center, 2018, 2020

RESEARCH EXPERIENCE/TRAINING

- Pennsylvania State University College of Medicine | Independent study mentor Julio Fernandez-Mendoza, PhD | secondary data analysis, population-based cohort study of sleep in adolescents | 2017-2018
- Pennsylvania State University College of Nursing | Independent study mentor Anne-Marie Chang, PhD | Sleep measurement instruments |2018
- Clinical research coordinator, Penn State Health, Hershey Medical Center, Hershey, PA | 2002-2019

SELECTED PUBLICATIONS

- Fernandez-Mendoza, J., Bourchtein, E., Calhoun, S. L., Puzino, K., **Snyder, C. K.,** He, F., Vgontzas, A. N., Liao, D., & Bixler, E. O. (2020). Natural history of insomnia symptoms in the transition from childhood to adolescence: Population rates, health disparities and risk factors [Manuscript submitted for publication]. Penn State Health Milton S. Hershey Medical Center.
- **Snyder, C. K.**, & Chang, A. M. (2019). Mobile technology, sleep, and circadian disruption. In M. Grandner (Ed.), *Sleep and health* (pp. 159-170). London, UK: Academic Press.
- Kitko, L., McGhan, G., Murphy, J. L., **Snyder, C. K.,** & Penrod, J. (2018). Carolyn Weiner and Marilyn J. Dodd: Theory of Illness Trajectory. In M. Alligood (Ed.). *Nursing theorists and their work* (9th Ed., pp. 477-489). St. Louis, MO: Elsevier.

SELECTED PRESENTATIONS

- **Snyder, C. K.,** Fernandez-Mendoza, J., Gaines, J., Calhoun, S. L., Vgontzas, A. N., Liao, D., & Bixler, E. O. "Association of circadian preference, sleep-wake patterns and night-to-night variability with evening and morning cortisol levels in adolescents". Peer-reviewed poster presented at SLEEP2018 (Associated Professional Sleep Societies), Baltimore, MD, June 5, 2018.
- **Snyder, C. K.** "Connectedness: A qualitative concept analysis". Peer-reviewed poster presented at Translating Research to Innovations in Practice, Hershey, PA, May 11, 2018