Individual and social influences on videogaming and sleep in adolescents

by

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Thesis

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Summary

Current and future cohorts of adolescents face a new and unique developmental challenge managing their requirements for adequate sleep alongside an increasing digitally connected society. This has led to the emergence of electronic media devices in the bedroom and displacement of sleep. Cross-sectional research suggests that Australian adolescents are obtaining insufficient sleep. The extent to which this is due to the high levels of engagement in digital technologies among adolescents is unclear. Despite the existence of models outlining the mechanisms theorised to explain the influence of electronic media on sleep there has been limited testing of such models and a limited attention to the role of individual factors. Such models are also generalised to all electronic media and it is unclear how specific types of technology (e.g., videogaming) are associated with poor sleep in adolescents.

The current thesis provided a general overview of normative sleep and suggested that, for adolescents, environmental factors are a key determinant of poor sleep (Chapter 1). Subsequently the influence of environmental factors such as technology, and more specifically videogaming, on adolescent sleep was outlined (Chapter 2). Prior to addressing the gaps in the literature established in Chapter 2 (i.e., how electronic media impacts upon adolescent sleep), the thesis aimed to confirm that Australian adolescents are currently experiencing insufficient sleep. In Chapter 3, this was done through a survey study which corroborated findings within the literature about adolescent sleep patterns and habits and described the degree to which clinical sleep insufficiency occurs in Australian adolescents and if adolescents are able to recognise sleep insufficiency. Additionally prior to investigating how electronic media impacts upon adolescent sleep Chapter 4 aimed to outline social factors associated with videogaming behaviour in adolescents.

On the basis of the results from previous chapters (3, 4) and previous literature a model outlining how videogaming affects the bedtime, and thus sleep, of adolescents was formed

(Chapter 5). In Chapter 5 it was established that “flow” and “parental regulation” of electronic media were key factors associated with videogaming duration and bedtimes in adolescents. However, the findings garnered from previous chapters were based on correlational research and as such it was important to confirm the findings that individual factors such as flow have a negative impact on sleep in adolescents through experimental methodology. Therefore, an experimental study was conducted in Chapter 6 which established that, for a subset of adolescents, when flow occurred during videogaming they selected later bedtimes.

Chapter 7 summarises the findings of the current thesis, the theoretical and clinical implications and discusses the limitations and scope of its findings. The results complement an emerging evidence base which suggests it is the role of technology as a form bedside media which largely explains the negative association with sleep. Additionally the results not only demonstrated the important role of displacement as a mechanism to explain the effect of electronic media on sleep but outlined how displacement may occur during engagement with a specific form of electronic media, videogaming. Through the novel identification of factors (flow, parental regulation) which make it more likely electronic media, such as videogaming, will have a negative impact on sleep, and the mechanisms through which this occurs, the current thesis is able to make practical suggestions for how adolescents and parents may negate the influence of these factors.

Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed Date: 26th May 2017

Lisa Smith, BSc (Hons), MSc

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List of Manuscripts and Publications in thesis

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Smith, L. J., Gradisar, M., & King, D. L. (2015). Parental influences on adolescent video game play: a study of accessibility, rules, limit setting, monitoring, and cybersafety. *Cyberpsychology, Behavior, and Social Networking*, *18*(5), 273-279.......

Smith, L. J., Gradisar, M., King, D. L., & Short, M. (2017). Intrinsic and extrinsic predictors of video-gaming behaviour and adolescent bedtimes: the relationship between flow states, self-perceived risk-taking, device accessibility, parental regulation of media and bedtime. *Sleep Medicine*, *30*, 64-70...

Smith, L.J., King, D.L., Richardson, C., Roane, B., & Gradisar, M. (under review) Mechanisms influencing bedtimes during videogaming in a sample of adolescents: the role of flow states, game difficulty and heart rate ....

Glossary of Abbreviations

AASM	American Academy of Sleep Medicine
ABS	Australian Bureau of Statistics
ACMA	Australian Communication and Media Authority
AIFS	Australian Institute of Family Studies
AM	anti meridian
ANOVA	analysis of variance
ASHS	Adolescent Sleep Hygiene Scale
AUD	Australian Dollar
BISQ	Brief Infant Sleep Questionnaire
BLT	bright light therapy
BMI	body mass index
BPM	beats per minute
BT	bedtime
CARE- 24	Cognitive Appraisal of Risky Events- 24 item
CI	confidence interval
CSHQ	Children’s Sleep Habits Questionnaire
CT MAX	core body temperature maximum
CT MIN	core body temperature minimum
CVD	cardiovascular disease
DASS-21	Depression Anxiety and Stress Scale- 21 item
DLMO	dim light melatonin onset
DSPD	delayed sleep phase disorder
DV	dependent variable
DVD	digital video disk

EEG	electroencephalography
EMG	electromyography
EOG	electrooculography
ESS	Epworth Sleepiness Scale
f	female
FPS	first person shooter
FSS	Flow State Scale
GABA	gamma-aminbutyric acid
Gen Y	Generation Y
Gen X	Generation X
GEQ	game engagement questionnaire
HD	high definition
hr	hour
HR	heart rate
Hz	Hertz
IBM$^{©}$	International Business Machines
IP	internet protocol
ISI	Insomnia Severity Index
ISS	insufficient sleep syndrome
ISQ	Infant Sleep Questionnaire
IV	independent variable
LED	light emitting diode
LSD	Least Significant Difference (Post Hoc Test)
m	male
M	mean

Md	median
min	minute
mg	milligram
MnPN	median preoptic nucleus
mo	months
MV	mediator variable
n	number
N1	non-rapid eye movement sleep stage 1
N2	non-rapid eye movement sleep stage 2
N3	non-rapid eye movement sleep stage 3
n.d.	no date
NHMRC	national health and medical research council
NREM	non-rapid eye movement
NSF	National Sleep Foundation
OSA	obstructive sleep apnoea
PC	personal computer
PDSS	Pediatric Daytime Sleepiness Scale
PM	post meridian
PS3	PlayStation 3
PSAS-C	Presleep Arousal Survey for Children
PSG	polysomnography
PghSD	Pittsburgh Sleep diary
POA	pre-optic area
PSQ	Pediatric Sleep Questionnaire
REM	rapid eye movement

S1	non-rapid eye movement stage 1 sleep (Rechtschaffen & Kales)
S2	non-rapid eye movement stage 2 sleep (Rechtschaffen & Kales)
S3	non-rapid eye movement stage 3 sleep (Rechtschaffen & Kales)
S4	non-rapid eye movement stage 4 sleep (Rechtschaffen & Kales)
SAD	seasonal affective disorder
SCN	suprachiasmatic nuclei
SD	standard deviation
SDSC	Sleep Disturbance Scale for Children
SE	standard error
SEIFA	Socio-Economic Indexes for Areas
SES	socioeconomic status
SOL	sleep onset latency
SPSS©	statistical package for the social sciences
SRSQ	Sleep Reduction Screening Questionnaire
SSHS	School Sleep Habits Survey
SSR	Sleep Self-Report
Stage R	AASM REM sleep
SWS	slow wave sleep
TST	total sleep time
TV	television
UK	United Kingdom
URL	Uniform Resource Locator
USA	United States of America
USD	United States Dollar
VAS	visual analogue scales

VG	videogaming
vlPOA	ventrolateral preoptic area
WASO	wake after sleep onset
WPSAD	What Parents Say and Do
YMCA	Young Men’s Christian Association

Thesis Aims

To summarise the research aims for the current thesis are:

Research Aim 1 (Study One; Chapter 3). To establish current adolescent sleep problems and patterns

Research Aim 2 (Study Two; Chapter 4): To identify and profile the videogaming behaviours of adolescents and establish the relationship between these videogaming behaviours and an adolescent’s social environment (e.g., parental control/regulation of technology use).

Research Aim 3 (Study Three; Chapter 5): To investigate the relationships between, the videogaming behaviour, intrinsic factors and extrinsic factors and sleep of adolescents

Research Aim 4 (Study Four; Chapter 6): To explore the mechanisms (e.g., arousal, displacement) by which individual factors influence the relationship between videogaming and the sleep of adolescents.

CHAPTER 1: The Measurement, Composition, Function, Lifespan Changes and Influences upon Sleep

The Measurement, Composition, Function, Lifespan Changes and Influences upon Sleep

Overview

Poor sleep in adolescents can be a concern, not only for the adolescent themselves, but for their parents and the wider social and societal circle in which they function. Poor sleep during adolescence can influence their developmental trajectory, having significant consequences for their later social and occupational outcomes (Gregory et al., 2005). A number of factors have been noted to contribute to poor sleep in adolescence, including individual (i.e., biological, psychological) and societal factors (i.e., sociocultural). The influence of digital media (e.g., the internet, social media, computer/video/console games, TV) on the sleep of adolescents has, recently, gained more attention in both the media and in research alike. However, there is a dearth of evidence in this area and many questions about how these technologies interact with the sleep of adolescents remain to be answered. Before beginning to answer these questions it is important to present a thorough overview of what is sleep (including stages of sleep and common models of sleep), why we need sleep and what happens if we don't get enough (that is, the physical, emotional and social consequences of poor/reduced sleep). The overview will conclude with a discussion of the above questions in relation to adolescence.

What is Sleep?

Lay conceptualisations of sleep typically describe sleep as a unitary period whereby we fall asleep and remain asleep until either our body, or an alarm clock transitions us into wakefulness (Moorcroft & Belcher, 2003). Sleep however, is far from a distinct block and consists of many stages including the nonREM (nREM) stages 1-5 and REM sleep, between which periods of wakefulness can occur (Carskadon & Dement, 2011).

Cortical Regulation of Sleep

Sleep is regulated by a number of cortical structures. The pre-optic area is one of the areas implicated in the cortical regulation of sleep. The pre-optic area (POA) and basal forebrain feature the largest number of neurons that show ‘sleep active’ discharge patterns, i.e., they show an increase in activity during sleep onset and sleep as compared to wakefulness. These sleep active neurons are particularly dense, in the ventrolateral preoptic area (vlPOA) and the median preoptic nucleus (MnPN) subarea of the POA (Szymusiak, Gvilia & McGinty, 2007). According to Szymusiak and colleagues (2007), sleep active neurons act to promote sleep through inhibitory projections to other neurons and contain both an inhibitory neuro-modulator (galanin) and an inhibitory neurotransmitter gamma-aminbutyric acid (GABA).

Biological models of sleep regulation

The first model to outline how sleep is biologically regulated is the two process model introduced by Borbély (1982). According to this model sleep is regulated by two somewhat independent processes, a homeostatic mechanism (Process S) and a circadian rhythm system or ‘pacemaker’ (Process C). The interaction between the ‘circadian pacemaker’ and sleep wake cycle promotes consolidation of sleep and wakefulness and facilitates transition between sleep and wakefulness (Dijk & Cziesler, 1995).

Process S, the homeostatic sleep drive mechanism, is sleep/wake dependent, rising during waking and declining during sleep (Borbély, 1982). Process S (also known as sleep need, sleep pressure or sleep drive) continues to rise during the day; it is relieved only by a sleep period (Achermann, 2004). Slow wave sleep (SWS) is thought to be a physiological indicator of sleep need as longer durations of prior wakefulness increase amount of SWS (Borbély, Baumann, Brandeis, Strauch, & Lehmann, 1981). Consistent with this view, there has found to be an increase in SWS after sleep deprivation (Brunner, Dijk, & Borbély, 1993) and a reduction of SWS in subsequent sleep periods following a nap (Werth, Dijk, Achermann, & Borbély, 1996; Feinberg, Maloney, & March, 1992).

Process C, the circadian system, is independent of sleep and wake, and prior amounts of sleep or wakefulness will not influence the timing of this system (Borbély & Achermann, 1999). The circadian system occurs over 24 hours as demonstrated in ‘forced desynchrony’ protocols where individuals are devoid of cues to external time (Dijk & Czeisler, 1994). The circadian system is regulated by the suprachiasmatic nucleus (SCN) located within the hypothalamus and serves as the brain’s ‘master clock’ (Saper, Scammel, & Lu, 2005). The SCN was found to be the neural location of circadian rhythms after animal studies demonstrated that legions of this area resulted in a disruption of the circadian rhythm system (Eastman, Mistlberger, & Rechtschaffen, 1984; Pickard & Turek, 1982).

Melatonin, core body temperature and plasma cortisol are biological markers of the circadian system (Klerman, Gershengorn, Duffy, & Kronauer, 2002). Cortisol is considered a marker of behavioural activation and greater than 50% elevation in levels can occur in response to bright light (Leproult, Colecchia, L’Hermite-Balériaux, & Van Cauter, 2001). Although, cortisol is a potentially useful marker of the circadian rhythms, it has been shown to have larger variance than other methods such as melatonin (Klerman et al., 2002), thus will not be discussed at length.

Melatonin rhythm is not influenced by sleep or activity and as such is a reliable marker of circadian phase position, measurable using Dim Light Melatonin Onset (DLMO), the obtaining of a melatonin sample under dim light conditions (Lewy & Sack, 1989). In addition, using DLMO can readily identify individuals with phase delay or phase advances of the circadian rhythm system, as well as those with chronobiological disorders such as delayed sleep-wake phase disorder (American Academy of Sleep Medicine, 2014; Pandi-Perumal et al., 2007).

A consistent relationship has been demonstrated between circadian phase and core body temperature, for individuals with normally entrained circadian rhythms, core body temperature peaks during late afternoon (CT MAX) and dips (CT MIN) towards the end of a sleep episode (Aschoff, 1983). Normal entrainment, for which there is response to 'zeitgebers' or 'time givers', is a key feature of the circadian system (Roenneberg, Daan, & Merrow, 2003). Light is considered as one of the most powerful zeitgebers (Aschoff, Daan, & Honma, 1982).

There have been individual differences identified in circadian rhythms, the most common of which is 'morningness' versus 'eveningness'. Morning types have been found to have a significantly earlier peak in core body temperature than evening types (Horne & Ostberg, 1977). As mentioned earlier core body temperature is a key indicator of circadian rhythms. This classification of morning versus evening types has also been commonly referred to as larks versus owls, respectively. There is also a relationship between morningness/being a 'Lark' and eveningness/being an 'Owl' and alertness. Larks are typically those who wake earlier and are more alert during the morning, as compared to Owls who wake later and are more alert in the evening (Horne & Östberg, 1977).

How can sleep be measured?

Objective Measures for the Classification of Sleep

Polysomnography

The various stages of sleep are characterised by different electroencephalography (EEG) amplitudes, differences in electromyography activity (EMG) and electrooculography (EOG). These measurements are collectively known as polysomnography (PSG) and measure different electrophysiological aspects of sleep. EEG measures field potentials from the cortex, EOG measures the difference in electric potential from electrodes in the retina with the movement of each eye able to be recorded separately when electrodes are placed to the left and right of each eye, and EMG measures muscle tone (Furman & Wuyts, 2012; Pace-Shott, 2009). Polysomnography can used to distinguish stages of sleep and sleep from wakefulness. For example, using an EEG there will be differences in alpha activity between wakefulness and sleep stages (Rama, Cho, & Kushida, 2006). EEG, EMG and EOG activity are now standard ways of scoring the electrophysiological aspects of sleep (Keenan & Hirshkowitz, 2011).

The PSG method of scoring sleep mentioned was developed by Kales and Rechtschaffen (1968) and remains the gold standard for recording sleep architecture. However, within the last ten years the American Academy of Sleep Medicine (AASM & Iber, 2007) have introduced their criteria for measuring sleep. There are a number of differences between the two criteria, which is thought to have particular relevance to scoring the sleep of children (Novelli, Ferri & Bruni, 2010). Differences between these criteria may make it difficult for researchers to compare previous studies conducted using Kales and Rechtschaffen (1968) criteria with newer studies that use AASM criteria (Novelli et al., 2010). The major changes is that the Kales and Rechtschaffen stages of 1-4 have been reclassified as N1, N2 and N3, with N3 representing slow wave sleep and amalgamating stages S3 and S4. REM sleep is referred to in the AASM system as Stage R (Novelli et al., 2010).

Novelli and colleagues demonstrated that in a sample of children (6-16 yrs) that there were a number of differences between Kales and Rechtschaffen criteria as compared to AASM criteria. Minutes spent in N1 (AASM) were more than minutes in S1, less time was spent in N2 and R (AASM) than in S2 and REM (Kales & Rechtschaffen, 1968), sleep onset latency (SOL) was shorter with AASM criteria and there were significantly more stage shifts using AASM criteria. Differences in how sleep is scored have also been observed in adults (Moser et al., 2009). Moser and colleagues found that in adults, percentage of total time spent in particular stages differed between AASM as compared to Kales and Rechtschaffen (1968;

Stage 1/N1, Stage 2/N2 & SWS/N3 & S4). Consequently, researchers should be mindful that the approach they use to score the sleep of their participants is likely to impact significantly upon the results

Actigraphy

In addition to PSG, a common way to objectively measure sleep is actigraphy. This method commonly utilises devices worn on the wrist known as actigraphic watches. Actigraphic devices sense movement and these movements are used to classify sleep or wake (Martin & Hakim, 2011). Actigraphy uses this method of sensing movement, as during sleep there is less movement than during wakefulness (Ancoli-Israel et al., 2003). An actigraphic watch contains a minute acceleration sensor which converts these physical movement patterns into digitalised representations (Sadeh, Hauri, Kripke, & Lavie, 1995). Actigraphy may represent an alternative to the invasive and time consuming PSG (Martin & Hakim, 2011).

Actigraphy can be scored with multiple different algorithms, depending on the manufacturer and what type of sleep scoring software is provided. Using actigraphy, sleep can either be scored as a single pass or using rescoring rules (Tryon, 2004). Rescoring involves rescoring periods of sleep as wake if it meets specific criteria. An example of such an algorithm is to rescore particular length of sleep period as wake if it is preceded by a particular amount of wake time, e.g. 1 min of sleep will be scored as wake if it is preceded by 4 minutes wake, 3 minutes sleep by 10 minutes wake and 4 minutes sleep by 15 minutes wake (Cole, Kripke, Gruen, Mullaney, & Gillin, 1992). For longer sleep periods, e.g. 6 and 10 minutes, Cole and colleagues also suggest the sleep episode can be re-scored as wake if it is surrounded by 10 (for 6 min) or 20 minutes (for 10 min) of wake time. Employing rescoring rules is argued to remove artifacts in the data and improve the quality of sleep-wake scoring (Tilmanne, Urbain, Kothare, Wouwer, & Kothare, 2009).

There is some disagreement amongst researchers regarding the ability of actigraphy to replace PSG as a method of measuring sleep (Blackwell et al., 2008; Cellini, Buman, McDevitt, Ricker, & Mednick, 2013; Yun et al., 2010). Numerous validation studies have been conducted comparing actigraphy to both objective and subjective measures (Meltzer, Walsh, & Peightal, 2015; O'Hare et al., 2015; Paquet, Kawinska, & Carrier, 2007; Sánchez-Ortuño, Edinger, Means, & Almirall, 2010; Sivertsen et al., 2006). Enough validation studies have been conducted that despite the limitations of actigraphy, such as overestimating TST and sleep efficiency and underestimating wake (e.g., Sivertsen et al., 2006) it is still a useful method to assess sleep-wake patterns. Sadeh and colleagues (1995) concluded that actigraphy can distinguish between sleep and wake states and is also useful for clinical populations who are sleep disturbed (Sadeh et al., 1995). Sadeh conducted a further review which concurs with earlier findings and also suggests that actigraphy is a sensitive enough method to evaluate the success of treatment of sleep disorders, such as pharmacological and non-pharmacological treatments (Sadeh, 2011). However, Sadeh does also acknowledge some of the main limitations of actigraphy, such as poor detection of wakefulness during sleep episodes, and recommends the use of actigraphy alongside other assessment methods, either objective or subjective (Sadeh, 2011).

Furthermore, Sadeh (2011) also questions the validity of actigraphy in 'special' populations. Although he does not specifically mention children and adolescents, some studies have indicated that there are potential methodological issues with the sole use of actigraphy as a sleep measurement tool in this population (Short et al., 2012). The difficulties using actigraphy with children and adolescents is thought to stem from a number of reasons including, children (in particular infants) move more during sleep, and adolescent boys move more during sleep than adolescent girls (Short et al., 2012; Horne & Biggs, 2013). Short and colleagues argue that despite actigraphy being an 'objective' measure it should not be assumed that it is more valid and reliable than other commonly used subjective methods, such as sleep diaries. They compared the use of actigraphy to sleep diaries and found that actigraphy is problematic to use with adolescents due to an overestimation of WASO. Furthermore they found that the scoring accuracy of actigraphy differed across gender (overestimation of WASO in boys) and puberty (underestimation of TST in more mature boys).

Other objective measures

Although PSG and actigraphy are the most common measures to assess elements of sleep, diagnose sleep disorders and assess treatment efficacy for these disorders, a number of other objective measures can also be used. These measures include bed sensors, arm sensors, eye-lid movement sensors, a sleep watch, a remote device, and observation (Van de Water, Holmes, & Hurley, 2011). However, it is argued that although promising, these technologies, which are considered more ‘user friendly’ (p. 198), are only at the prototypical stage and although promising, that actigraphy still emerges as the most reliable, valid and appropriate measure for outside the laboratory evaluation of sleep (Van de Water et al., 2011).

Subjective measures for the classification of sleep

Questionnaires

There are plethora of questionnaire measures for assessing sleep, with different questionnaires existing for use with adults, adolescents, children, and infants and across special populations. Lewandowski, Toliver-Sokol and Palermo (2011) conducted a review into evidence based measures of sleep in paediatric populations and reviewed their psychometric properties. They broadly grouped questionnaires into those who measure daytime sleepiness, sleep habits/hygiene, sleep initiation, sleep maintenance and quality, sleep related attitudes/cognitions and multi-dimensional measures (those that measure several sleep related domains).

Using an evidence-based criteria developed by the Society of Pediatric Psychology Assessment Task Force (Cohen et al., 2008) Lewandowski and colleagues (2011) rated four multidimensional measures, one measure of sleep initiation, maintenance and quality (The Infant Sleep Questionnaire (ISQ; Morrell, 1999) and one measure of daytime sleepiness (The Pediatric Daytime Sleepiness Scale; PDSS; Drake et al., 2003) as well-established. The four multidimensional measures rated as well-established by Lewandowksi and colleagues were as follows; the Brief Infant Sleep Questionnaire (BISQ; Sadeh, 2004), the Children's Sleep Habits Questionnaire (CSHQ; Owens, Spirito, & McGuinn, 2000), the Pediatric Sleep Questionnaire (PSQ; Chervin, Hedger, Dillon, & Pituch, 2000), and the Sleep Disturbance Scale for Children (SDSC; Bruni et al., 1996). No measures of sleep habits were rated as well-established.

The most highly rated measure of sleep habits by Lewandowski and colleagues was the Adolescent Sleep Hygiene Scale (ASHS; LeBourgeois, Giannotti, Cortesi, Wolfson, & Harsh, 2005), which was classified as 'approaching well-established'. Additionally, no measures of sleep related beliefs and cognitions were rated as well-established; the Presleep Arousal Survey for Children (PSAS-C; Gregory et al., 2008) was rated as 'approaching well-established'. They argued that both these measures need expansion of their validation, rating it as 'moderate' (Lewandowski et al., 2011). Additionally, two multidimensional measures were also rated as 'approaching well-established', the Sleep Self-Report (SSR; Owens, Maxim, Nobile, McGuinn, & Msall, 2000) and the Sleep Habits Survey (SHS; Wolfson & Carskadon, 1998; Wolfson et al., 2003).

Sleep diaries

Sleep diaries are a subjective measure, commonly used in clinical practice. Individuals are typically asked to specify a number of key sleep parameters which can be used to assess and track treatment effects (Bootzin & Engle-Friedman, 1981). For example, time spent asleep in bed, time taken to fall asleep (SOL), bedtime, wake-time and any awakenings during the night (i.e., wake after sleep onset; WASO). These parameters are then used to calculate total sleep time (TST) and sleep efficiency. Sleep diaries are usually able to be completed accurately by most patients attending clinical settings. However, parents/guardians of younger children typically complete the sleep diaries on their behalf (Horne & Biggs, 2013). A notable advantage of sleep diaries is their ease of implementation in a clinical setting; cost-effectiveness, and ability to measure a wide range of sleep parameters across various contexts (Sadeh, 2015).

However, sleep diaries alone may not always provide an accurate assessment of sleep, Adults with insomnia have been shown to underestimate their TST and overestimate SOL (Carskadon et al., 1976). In contrast to patients with insomnia, a notable proportion (20%) of patients with hypersomnia have been found to overestimate the amount of sleep they obtain, thus preventing adequate identification of sleep insufficiency in this clinical group (Tomita et al., 2013). Larger differences between sleep diary and PSG data have been obtained for narcoleptic patients as compared to controls (Rogers, Caruso, & Aldrich, 1993). Moreover, despite the sleep diary being referred to as the gold standard for subjective measures, there is a lack of standardisation of the sleep diary and although researchers agree upon the core parameters (WASO, SOL, TST, sleep efficiency) which should be included, there is less consensus on format (Carney et al., 2012).

Evidence that sleep diaries comparing the efficacy of sleep diaries to objective measures is mixed. Comparison of the sleep diary measure, The Pittsburgh Sleep Diary (PghSD) and actigraphy and PSG indicated that the PghSD was comparable to measures of sleep timing and quality as measured by actigraphy (Monk et al., 1994). In older adults, sleep diaries correlate with actigraphy for sleep onset but not for total sleep time (carers would significantly overestimate TST; Hoekert, Riemersma-van der Lek, Swaab, Kaufer, & Van

Someren, 2006). This overestimation of sleep has also been found for the parents of infants (So, Michael Adamson, & Horne, 2007). However, in a group of blind subjects differences were found between actigraphy and sleep diaries across most sleep parameters, with shorter SOL, increased WASO, and increased TST, being observed using actigraphy (Lockley, Skene, & Arendt, 1999). Short and colleagues (2012) observed significantly large differences in adolescents between actigraphic and sleep diary estimates on WASO and TST; actigraphic estimates of WASO exceeding sleep diary estimates by over 1 hour. Actigraphic estimates of TST were also 1 hour and 25 minutes less than sleep diary estimates and 2 hours less than parental report. Indeed, parental report of adolescents' sleep has been shown to be poor (Short, Gradisar, Lack, Wright, & Chatburn, 2013).

Stages of Sleep

As mentioned above, stages of sleep can be broadly categorised into non-rapid eye movement (NREM) and rapid eye movement (REM). NREM sleep has four stages (Stages 1-4); with stages 3 and 4 commonly known as slow-wave sleep (SWS; Rama et al., 2006). The majority of total sleep time (75-80%) consists of NREM sleep. Stage 1 sleep occurs predominantly in the transition from wakefulness to other stages and accounts for 3-8% of total sleep time. Stage 2 occurs after 10-12 minutes of stage 1 sleep and accounts for the largest proportion of total sleep time (45-55%). Stages 3 and 4 of sleep account for 15-20% of total sleep time (Rama et al., 2006).

According to Rama and colleagues (2006) stage 1 sleep is characterised by a decrease in EMG activity and slow rolling eye movements (shown by EOG). Alpha activity (8-13 Hz) diminishes during stage 1 sleep; the highest amplitude EEG activity in stage 2 sleep is in the theta range (4-8 Hz). Stage 2 sleep sees the appearance of delta waves (0.5-4 hz). Stage 2 sleep is also characterised by sleep spindles (a 12-14hz waveform lasting 0.5 seconds minimum) and K-complexes (a waveform with two components that last more than 0.5

seconds; negative followed by positive wave). Stages 3 and 4 are characterised by high-amplitude slow-wave activity, with moderate levels in stage 3 and higher levels in stage 4. REM typically occurs 60-90 minutes after NREM sleep onset and accounts for 20-25% of total sleep time. REM sleep is characterised by mixed-frequency EEG activity with slower alpha activity than wakefulness (1-2 hz slower) and theta waves. REM sleep consists of tonic and phasic stages (Rama et al., 2006).

As previously mentioned, sleep is not one distinct period. Sleep is cyclical and approximately four to six NREM-REM sleep cycles will occur within any given sleep episode - a NREM-REM cycle will occur every 90 to 110 minutes (Rama et al., 2006). Particular sleep stages are more likely to occur at different periods throughout a sleep episode, early cycles are more likely to consist of slow-wave sleep and later ones by REM sleep (Rama et al., 2006).

Why do we sleep?

There are several broad explanations for why humans sleep; we sleep to consolidate memories (Born, Rasch & Gais, 2006; Sejnowski & Destexche, 2000; Wagner, Gais, Haider, Verleger, & Born, 2004), that sleep serves a restoration function (Bonnet & Arand, 1996; Irwin, 2002), and that sleep serves an energy conservation function (Maquet, 1995). Other researchers have postulated about the functions of specific stages of sleep. For example, it has been argued that in REM sleep there exists a reverse learning mechanism which functions to enable individuals to forget their dreams (Crick & Mitchinson, 1983).

Restorative Hypothesis

Adequate sleep supports proper functioning of the immune system (Gamaldo, Shaikh, & McArthur, 2012; Irwin, Wang, Campomayor, Collado-Hidalgo, & Cole, 2006; Mullington, Simpson, Meier-Ewert, & Haack, 2010). Sleep may enhance immune system function through the regulation of inflammatory markers or cytokines. IL-1 beta, TNF-alpha, IL-6 and

C-reactive protein (CRP) are significantly affected by the amount of sleep an individual obtains (Mullington et al., 2010). In adults, partial sleep deprivation (being awake from 11PM-3AM) increases capacity of monocytes (a type of white blood cell) to express IL-6 and TNF relative to a baseline period of no sleep loss (Irwin et al., 2006). This suggests only a brief period of sleep loss is needed to elevate inflammatory markers. Elevation of inflammatory immune markers has important implications for health following sleep deprivation. Elevation of inflammatory cytokines has been observed in a number of diseases including cardiovascular disease (Kanda & Takahashi, 2004; Kofler, Nickel, & Weis, 2005; Mendall et al., 1997), alzheimers disease (Cacquevel, Lebeurrier, Cheenne, & Vivien, 2004; Mrak, Sheng, & Griffin, 1995; Singh & Guthikonda, 1997), depression (Dowlati et al., 2010; Raison, Capuron, & Miller, 2006; Schiepers, Wichers, & Maes, 2005), cancer (Chen et al., 1999; Dranoff, 2004; Yamamura, Modlin, Ohmen, & Moy, 1993) and autoimmune diseases (Blanco, Palucka, Pascual, & Banchereau, 2008; Dinarello, 1992). A possible mechanism for these diseases might lie in the immunosuppressive consequences of elevated cytokine levels as a response to stress (Elenkov & Chrousos, 1999). Consistent with this view, epidemiological and lifetime prevalence studies indicate that, individuals who consistently get less sleep over their life time, or have chronic sleep conditions (e.g., sleep apnoea, chronic insomnia, restless legs syndrome), are at increased risk for a number of diseases including diabetes, obesity, heart disease and increased mortality (Reichmuth, Austin, Skatrud, & Young, 2005; Shankar, Koh, Yuan, Lee, & Mimi, 2008; Shankar, Syamala & Kalidindi, 2010; Vgontzas et al., 2009).

The restorative hypothesis of sleep function has been extended to argue that sleep represents a restorative function because sleep represents a chance for our brains to ‘take out the trash’ by clearing waste (Xie et al., 2013). Xie and colleagues found that in mice both natural sleep and anaesthesia increased cortical interstitial space by more than 60% and argued this increase in interstitial space allows for the clearance of beta-amyloids and other compounds. Xie and colleagues also describe this system as the ‘glymphatic system’ as it functions in a similar way to which the lymphatic system removes metabolic bi-products throughout the body.

Memory consolidation hypothesis

This specific hypothesis argues that sleep has both memory consolidation/learning functions in addition to energy conservation functions. The synaptic-homeostasis hypothesis puts forth that regulation of brain synaptic weight is the primary function of sleep (Tononi & Cirelli, 2006). According to Tononi and Cerilli (2006) the synaptic-homeostasis hypothesis is linked to process S. During wakefulness, alongside the accumulation of sleep pressure (process S), there is an increase in synaptic strengths which reaches a peak just before sleep onset. During sleep there is a synaptic ‘downscaling’, enabling energy saving, space saving and assisting learning and memory. Synaptic downscaling is thought to facilitate learning and memory by enhancing signal to noise ratios in relevant neural circuitry (Tononi & Cerilli, 2006). However, as Born et al. (2006) highlight, this hypothesis fails to account for experimental evidence that demonstrates sleep can be beneficial for previously weak associations (e.g., Kuriyama, Stickgold, & Walker, 2004).

Different sleep stages consolidate specific types of memories. Slow wave sleep aids consolidation of memories dependent on hippocampal consolidation whereas REM sleep aids consolidation of non-hippocampal dependent memories (Born et al., 2006). Born and colleagues view this to be due to the differences between sleep stages in the secretion of neurotransmitters and neurohormones. It should be noted that some proponents of the view that sleep serves to facilitate memory consolidation into long term memory argue that it is unlikely that sleep exists solely for this function and is likely to have other functions, such as restoration (Born et al., 2006).

Energy conservation hypothesis

A correlation between metabolic rate and sleep serves as a key source of evidence supporting the energy conservation hypothesis of sleep (Shapiro & Flangan, 1993). Metabolic rate represents the expenditure of energy; the higher the metabolic rate the more energy an individual is expending. A reduction in metabolic rate from between 5-25% is thought to occur in sleep relative to wake (Shapiro & Flanagan, 1993). According to Shapiro and Flangan (1993), slow wave sleep, which occurs in the first few hours of sleep, is most associated with energy conservation as this is the time during which oxygen consumption, heart rate and body temperature decline. Early animal studies showed a relationship between the metabolic rate of a species and the duration of sleep, animals with higher metabolic rate sleep longer (e.g., Zepelin & Rechtschaffen, 1974).

What happens if we don’t get enough sleep?

Sleep deprivation studies support the primary reasons for sleep in humans (restorative, memory, and energy conservation). Diminished capacity across these areas is associated with sleep deprivation. Sleep loss is associated with long-term health consequences, such as reduced immunity. The effects of sleep loss on cognition, learning and memory can be immediate. Early studies on the consequences of sleep loss showed a link between reduced sleep duration and accuracy and response speed on a vigilance task (Taub & Berger, 1973). Sleep deprivation impairs memory across multiple domains, including working memory, long-term memory, and episodic memory/temporal memory (Chee & Choo, 2004; Drummond, Anderson, Straus, Vogel & Perez, 2012; Fishbein, 1971; Harrison & Horne; 2000; Jiang et al., 2011; Vecsey, Park, Khatib, & Abel, 2015).

Much early sleep deprivation research comes from animal research, namely mice. In this population it has been demonstrated that deprivation of one stage of sleep, REM sleep, can result in the mice exhibiting temporary retrograde amnesia when tested 30 mins or 3 hours after REM deprivation (Fishbein, 1971). REM sleep has also been demonstrated to be important for episodic memory relative to SWS. Performance on the ‘What-where-When’ task, a measure of spatial, temporal and factual episodic memory, is significantly poorer after REM as compared to SWS deprivation (Rauchs et al., 2004). Consistent with this, sleep deprivation negatively affects temporal but not recognition memory. Harrison and Horne (2000) demonstrated that after 36 hours of sleep deprivation adult participants were able to adequately describe if they had seen a face before (recognition memory) but were not able to accurately discriminate between if they had seen the face on list A or list B (temporal memory). However, in contrast Zanini et al. (2012) found that after two nights of sleep deprivation, participants free recall was unimpaired regardless of word position.

There are reduced neural activations in the verbal memory network after a period of sleep deprivation (Chee & Choo, 2004). Individuals with insomnia have also been studied to demonstrate the link between sleep deprivation and memory. The working memory of people with primary insomnia is highly compromised under cognitive load but comparable to controls when completing a no load easy task (Cellini et al., 2013). Sleep deprivation also affects the components of visual working memory uniquely. Total sleep deprivation impairs performance on a filtering task (i.e., an individual’s ability to ignore distractor stimuli in a visual task) but not working memory capacity per se (Drummond et al., 2012). Similarly, chronic sleep restriction (of 5 days) in adolescents (13-16 years) and young adults (18-20 years) does not significantly impair accuracy in working memory tasks, but impairs reaction times on these tasks (Jiang et al., 2011).

In addition to the functional deficits caused by sleep deprivation, sleep loss is associated with poor mood. Much of the evidence linking poor sleep and affect samples individuals with insomnia. Meta-analytic evidence indicates that non-depressed individuals with insomnia, compared to individuals with no-sleep difficulties, have a two-fold higher risk of developing depression (Baglioni et al., 2011). Similarly, insomnia has been shown to be both a state (present when the disorder is present) and trait (present when the disorder is not present) marker of anxiety. In a population based study (N=25,130), individuals with insomnia at baseline and follow-up experienced significantly more anxiety than both individuals without insomnia at baseline or follow-up as well as individuals with insomnia at baseline or follow-up only (Necklemann, Mykletun, & Dahl, 2007). A single night of sleep deprivation (36 hours total wakefulness) results in significantly poorer subjective assessments of anxiety (Sagaspe et al., 2006). Sleep deprivation, of greater than 48 hours sustained wakefulness, also significantly worsens feelings of tension, anger, vigour, fatigue, and confusion, and increases somatic complaints and paranoia (Kahn-Greene, Killgore, Kamimori, Balkin, & Killgore, 2007; Lieberman, Tharion, Shukitt -Hale, Speckman & Tulley, 2002). The relationship between sleep deprivation and poor mood is associated with changes in SWS. Individuals who experienced three consecutive nights of sleep continuity disruption via forced nocturnal awakenings had a significant reduction in positive mood than individuals who had restricted sleep due to delayed bedtimes (Finan, Quartana, & Smith, 2015). Moreover, Finan and colleagues observed that participants who experienced interrupted sleep (via forced nocturnal awakenings) had significantly greater decrease in SWS between baseline and the first night of sleep deprivation than subjects who experienced sleep deprivation from delayed bedtime. Finally, sleep deprivation can have more significant consequences for some groups. Partial sleep deprivation (awake from 23:00 to 03:00) significantly worsens self-reported pain, depression and anxiety in those with rheumatoid arthritis as compared to healthy controls (Irwin et al., 2012). The developmental stage of an adolescent also influences the degree to which sleep deprivation impacts upon mood and affect. Following two nights of partial sleep deprivation early adolescents (10-13 yrs) rated their most threatening worry as more threatening, but this difference was not observed in mid-adolescents (13-16 yrs.) or adults

(30-60 yrs; Talbot, McGlinchey, Kaplan, Dahl, & Harvey, 2010). Recent research by Short and Louca (2015) found that sleep deprivation affected mood more broadly than worry alone. One night of sleep deprivation worsened depression, anger, confusion, anxiety, vigour, and fatigue in a group of adolescents (14-18 yrs) and female adolescents also experienced greater confusion following sleep deprivation than their male peers (Short & Louca, 2015). Meta-analytic evidence from Lovato and Gradisar (2014) also indicates that adolescents with major depression experience longer SOL, more nocturnal awakenings, and lower sleep efficiency than either non-clinical samples or adolescents in remission from depression. This supports the view that sleep disturbances are predictive in the development of depression in adolescents (Lovato & Gradisar, 2014). Overall, research suggests that sleep deprivation is problematic for mood states not only in healthy adult controls but is particularly problematic for individuals who experience chronic sleep loss, chronic health conditions, young adolescents and females during adolescence.

In both adults and children/adolescents there is an established link between poor sleep and risk of obesity (Cappuccio et al., 2008; Patel & Hu, 2008). Meta-analytic evidence demonstrates that across the lifespan that for one hour of sleep change there is a -0.57 to -0.12 unit change in BMI (Capuccio et al., 2008). In adults, sleep loss also is associated with, increased risk of hypertension (Bruno et al., 2013; Palagini et al., 2013), cardiovascular disease (CVD; Cappuccio, Cooper, D'Elia, Strazzullo, & Miller, 2011; Grandner, Sands-Lincoln, Pak., & Garland, 2013; Sofi et al., 2014), neurological disease, e.g., stroke, multiple sclerosis, Alzheimer's disease (Palma, Urrestarazu, & Iriarte, 2013; Wulff, Gatti, Wettstein, & Foster, 2010), obesity/type 2 diabetes (Ohkuma et al., 2013; Shan et al., 2015; Spiegel, Knutson, Leproult, Tasali, & Van Cauter, 2005), negatively affects the reproductive health of both males and females (Labyak, Lava, Turek, & Zee, 2002; Santamaria, Prior, & Fleetham, 1998; Schmid, Hallschmid, Jauch-Chara, Lehnert, & Schultes, 2012) and reduces life expectancy (Grandner et al., 2013; Sofi et al., 2014). Meta-analytic evidence demonstrates that, even after controlling for other risk factors, insomnia, short sleep duration or sleep deprivation is associated with increased risk of hypertension (Palagini et al., 2013). Short sleep duration alone is associated with a 45% increase in risk of mortality due to CVD (Cappuccio et al., 2011). A dose-response has been indicated between sleep duration and risk of developing type 2 diabetes (Shan et al., 2015). Men with obstructive sleep apnoea (OSA) have reduced serum testosterone levels (Santamaria, Prior, & Fleetham, 1988). However, it is important to note that the relationship between some sleep disorders and poor health outcomes can be bi-directional, research conducted on the link between OSA and type 2 diabetes suggests that OSA contributes to insulin resistance and conversely that diabetes can accelerate the progression of OSA (Aurora & Punjabi, 2013).

In children the relationship between bedtime and BMI is mediated by sedentary leisure activities (Busto-Zapico, Amigo-Vázquez, Peña-Suárez & Fernández-Rodríguez, 2014). Busto-Zapico and colleagues found that not only was bedtime a significant predictor of higher BMI, it also predicted reduced TST and lead to children being more sedentary, this was in turn a significant predictor of a higher BMI. However, some research suggests the relationship between sleep and weight may not be equal for both genders, reduced sleep duration predicts BMI and waist circumference in boys but not girls (Eisenmann, Ekkekakis, & Holmes, 2006; Knutson, 2005). The relationship between poor sleep and weight in adolescents may be influenced by health behaviours, adolescents without adequate sleep (< 6 hours per night) engage in significantly fewer health related behaviours such as healthy diet, regular exercise and effectively managing stress (Chen, Wang, & Jeng, 2006). However, review of research in this area yields an inconsistent relationship between shortened sleep duration and weight and is argued to have a number of methodological limitations including, use of sleep measures with questionable reliability, difference in the findings of prospective as compared to cross-sectional studies and a failure to statistically adjust for the role of depression (Guidolin & Gradisar, 2012).

Poor sleep in children and adolescents also affects educational attainment. Insufficient sleep, poor sleep quality and sleepiness are associated with poorer academic performance, this effect is stronger during early adolescence (Dewald, Meijer, Oort, Kerkhof, & Bogels, 2010). Poor sleep during both the weekends and during weeknight’s impacts negatively on academic attainment (Roberts, Roberts, & Duong, 2009). Adolescents typically make up for sleep debt by napping during school, which undoubtedly affects school performance and engagement (Calamaro, Mason, & Ratcliffe, 2009). In addition to affecting engagement in education, sleepiness in adolescents has been found to be related to poorer executive functioning abilities (Anderson, Storfer-Isser, Taylor, Rosen, & Redline, 2009). This is particularly worrying as executive functioning abilities are vital for success in educational environments (Healey & Fisher, 2011).

Alongside the costs to the individual of sleep deprivation negative consequences can be observed at the societal level. The three main areas through which sleep can impact on society include its effects on safety, productivity, and well-being (Hillman & Lack, 2013). Twenty-eight hours of sleep deprivation yields a performance and accuracy level on measures of cognition (e.g., vigilance, reaction time, hand-eye co-ordination, divided attention, coding and memory) that is functionally equivalent to a blood alcohol concentration of 0.05 (the legal limit for operating a vehicle in Australia; Williamson & Freyer, 2000). Moreover, accidents that occur during times of maximum sleepiness are overrepresented in accidents, with accidents that occur during 2-7am representing 41.6% of total accidents (Leger, 1994). The total costs of accidents due to sleepiness was estimated by Leger (1994) to be between $43.15 billion and $56.02 billion (USD). At the productivity level, Rosekind et al. (2010) found that individuals with “insufficient sleep syndrome” (ISS) or insomnia (who had shorter

TSTs, longer SOLs and more WASO) had significantly poorer ability to perform their work tasks than individuals in either the ‘at risk’ group or the ‘good sleepers’, particularly in regards to time management ability. Individuals in the insomnia group also self-reported significantly greater negative effects of sleep-related fatigue on their attention, decision making and memory in the work-place than ISS, at risk or good sleeper groups. The estimated cost of sleep loss, secondary to OSA, on productivity is $3132 million AUD (Hillman & Lack, 2013). Finally, as previously mentioned, there is high co-morbidity between sleep disorders and mood disorders and individuals with a sleep disorder are at increased risk for developing a mood disorder (Baglioni et al., 2011). Depression is thought to cost the Australian economy $12.6 billion (AUD) per calendar year, predominantly due to reduced productivity or increased job turnover (LaMontagne, Sanderson, & Cocker, 2011). A significant proportion of the societal costs of reduced productivity due to mood disorders can be attributable to either to the effects of sleep on mood or a result of sleep loss exacerbating underlying mood disorders. However, the calculations of costs of sleep loss on society may be an underestimation; most of the research used to calculate economic societal costs focuses on research from clinical populations and does not include consideration of the costs related to sleep loss in people without a sleep disorder (Hillman & Lack, 2013).

How much sleep do we need? (Individual differences and sleep)

There is a large variation in how long people actually sleep for, how much sleep they need and at what times they go to bed and wake up (Hirschowitz et al., 2015). A number of factors influence how much sleep we need including age/developmental stage, gender, and individual differences, e.g. chronotype, lifestyle (Driver & Taylor, 2000; Gradisar et al., 2011; Hirschowitz et al., 2015; Kredlow, Capozzoli, Hearon Calkins, & Otto, 2015; Taillard, Philip, & Bioulac, 1999). The AASM recommends that adults should obtain *at least* 7 or more hours per night, with less than 7 hours associated with negative health outcomes.

However, they also acknowledge some individual variation in this need specifically for those with medical conditions (Watson et al., 2015). Guidelines also released in 2015 by the National Sleep Foundation (NSF; Hirschowitz et al., 2015) also outline recommended sleep durations for individuals throughout the lifespan (see Fig 1.1); this figure illustrates that throughout the lifespan there is variation in the recommended amounts of total sleep which can be obtained with this variation decreasing with age. Newborn guidelines have a variation in range of 8 hours, as compared with a range of only 4 hours in adulthood (26-64 years). Therefore, as a consequence of this range, when considering how much sleep an individual needs there must be consideration of other influencing factors alongside age or developmental stage.

Figure 1.1 *has been removed due to copyright restrictions*

Image available at: https://sleepfoundation.org/sites/default/files/STREPchanges_1.png

Fig 1.1. Recommended sleep duration based on age/developmental stage

During adolescence, the primary factor influencing how much sleep an adolescent obtains is the timing of their circadian rhythm (Hagenauer, Perryman, Lee, & Carskadon, 2009). Adolescents typically experience a delay in their circadian rhythms coupled with a slowing in the accumulation of sleep pressure, which makes it difficult to fall asleep at a socially desirable time, but have fixed occupational demands similar to adulthood in the form of school start-times (Carskadon, 2011). The mix of factors which leads to this conflict between biological and social needs is referred to as ‘the perfect storm’ (Carskadon, 2011). However, South Australian research indicates only 20% of adolescents are obtaining 9 of hours sleep or more (Short, Gradisar, Lack, Wright & Dohnt, 2013). Sleeping in on weekends to ‘catch-up’ on sleep debt accumulated throughout the school week and a resulting inability to fall asleep early enough at the start of the following school week, has been identified as a perpetuating mechanism of adolescent sleep difficulties (Taylor, Wright & Lack, 2008).

Older adults typically require less sleep than other developmental stages. Guidelines for older adults (e.g., Hirschowitz et al., 2015) indicate adults over 65 may be able to obtain as little as 5 hours sleep per night. Older adults (65-76 yrs.) may also be more robust to the effects of sleep deprivation. As compared to younger adults older adults show less cognitive impact (attentional failures, slowed reaction times) and experience less unintentional sleep episodes following sleep deprivation (Duffy, Willson, Wang, & Czeisler, 2009). However, sleep changes during older adulthood presents their own unique challenges for this population. Age related decline in sleep need and timing are significant contributors to insomnia during older adulthood (Ancoli-Israel & Ayalon, 2006; Klerman & Dijk, 2008).

Chronotype is a key determinant of how much sleep people need across the lifespan. Individuals within a developmental stage may have different sleep needs because of their chronotype. Variation in chronotype is observed in toddlers as young as 30 months (Simpkin et al., 2014). An individual’s chronotype describes their diurnal preference and classifies individuals along a dimension of ‘morningness’ to ‘eveningness’ based on their ideal sleep timing. Morning chronotypes are typically described as ‘larks’ and evening chronotype as ‘owls’. In adolescents and adults across the lifespan (17-80 yrs) an evening chronotype has been associated with a greater sleep need but less time in bed during the week, and later bedtimes and wake-times on the weekends (Taillard et al., 1999). Individuals with evening chronotypes therefore accumulate a sleep debt during the week and make up for this during the weekends, a phenomenon described as ‘social jetlag’ (Wittmann, Dinich, Merrow, & Roenneberg, 2006).

In addition to the differences in diurnal preference, individuals may also differ on their sleep need and can be categorised as ‘short’ or ‘long’ sleepers. Sleep duration, across a population shows a bell-shaped distribution (Figure 1.2; Roenneberg, 2012). The majority of the population (60%) obtaining between 7.5 to 8 hours of sleep per night, however there are more short sleepers (< 7 hours) than long sleepers (>9 hours; Roenneberg, 2012). Aside from age, a key factor that influences if a person is a ‘short’ or ‘long’ sleeper is genetics (Allebrandt et al., 2013; He et al., 2009; Pellegrino et al., 2014). The p.Tyr362His, a variant of the BHLHE41 gene, is a genetic determinant of short sleep (Pellegrino et al., 2014). Using a twin study protocol, Pellegrino and colleagues (2014) found that individuals with this variant slept for one hour less than their twin, and following sleep deprivation had significantly fewer performance impairments and required a significantly shorter recovery sleep period (8.5 vs 9.5 hrs). Genetics also plays a role in individual vulnerability to the adverse effect of sleep loss. Following sleep deprivation, individuals with a polymorphism of the PER 3 gene (5 rather than 4 copies of the sequence on both chromosomes) demonstrated poorer cognitive performance (attentional failures) than those without the extra copy (Groeger et al., 2008).

Figure 1.2 *has been removed due to copyright restrictions*

Figure 1.2. Average sleep duration (hours) as a percentage of the population (Roenneberg, 2012)

Other factors which influence how much sleep an individual ‘needs’ on any given night are variable day-to-day, exercise (Driver & Taylor, 2000; Kredlow et al., 2015), sleep history (or amount of sleep obtained on previous nights) and periods of illness all affect sleep need (Bryant, Trinder, & Curtis, 2004). Exercise is associated with increased total sleep time (Driver & Taylor, 2000). However, some research suggests that in healthy young adults that vigorous exercise does not increase sleep need, as defined by total sleep duration, but that it increased time spent in stage 1 or 2 sleep (light sleep) as compared to those who did not engage in any exercise (Wong, Halaki & Chow, 2012). Kredlow and colleagues (2015) suggest the effects of sleep on exercise might be moderated by individual factors (e.g. age, sex and baseline fitness) and exercise factors (type, time of day, duration), and found that the effect of exercise on sleep was not moderated by intensity. ‘Sleep history’ affects how might sleep an individual needs on any given night. If an individual obtains a less than an optimal amount they will become ‘sleep restricted’, the following day sleep pressure will accumulate and followed by a ‘recovery sleep’. Experimental sleep deprivation studies, where participants typically are preventing from sleeping for two or more days, show that following a period of recovery sleep (or one or two days) an individual’s sleep pattern will return to baseline quickly (Carskadon & Dement, 1981). There is also individual variation across how people respond to sleep deprivation, including performance deficits and also how much recovery sleep they require (Belenky et al., 2003; Van Dongen, Maislin, Mullington, & Dinges, 2003). This variation in performance deficits following sleep deprivation can also be observed in occupational settings (Van Dongen & Belenky, 2009).

How much sleep do we get?

A number of bodies (e.g. National Sleep Foundation, American Centre for Disease Control) have made recommendations about how much sleep people should be getting across the lifespan. However, concerns remain that people may not be getting enough sleep, this may also differ across countries and across the lifespan. Sixty-three percent of young adults (17-30 yrs) across 24 countries (N= 17, 465) slept between 7 to 8 hours (Steptoe, Peacey, & Wardle, 2006). Steptoe and colleagues (2006) found that for young males the lowest TST was observed in Japan (6.20 hrs) and the highest in Romania (8.04 hrs). Similarly for young females, those in Japan obtained the lowest average TST (6.09 hrs) and the highest average TST for young females was observed in Bulgaria (8.00 hrs). Table 1.3 gives the average sleep obtained for young adults across the 24 countries surveyed as part of the International Health and Behaviour Study (Steptoe et al., 2006). Krueger and Friedman (2009) surveyed USA adults aged 18 or older, data were drawn from the 2004-2007 waves of the National Health Interview Survey (N= 110,441). Most participants in this survey reported obtaining 6 (20.5%), 7 (30.8%) or 8 (32.5%) hours average sleep. Notably fewer participants reported obtaining either side of this, with only 7.8% of participants obtaining 5 or less hours a sleep and only 8.5% obtaining 9 or more hours average nightly sleep duration.

In general, there are societal concerns over how much sleep the adult population obtain (Arlington, 2017). However, Bin, Marshall and Glozier (2012) challenge the assertion that modern society is impacting negatively upon sleep during adulthood. Bin and colleagues conducted a systematic review of 12 sleep duration studies conducted over the past 40 years (1960s-2000s) across 15 countries and found that in some countries (Bulgaria, Poland, Canada, France, Britain, Korea, and the Netherlands) sleep had actually increased over the past 40 years (between 0.1–1.7 min per night each year). For other countries (Japan, Russia, Finland, Germany, Belgium, and Austria), in which sleep had decreased, the amount was so minimal (0.1–0.6 min per night each year) it would be unlikely to be related to any negative individual or population level health outcomes, e.g. increased mortality, obesity, cardiovascular disease (Bin et al., 2012). Overall, research on how much sleep adults get is consistent with recommended sleep durations as outlined by the NSF (Hirshkowitz, 2015).

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Figure 1.3. Average sleep obtained by young adults (17-30) across 24 countries from the International Health and Behaviour Study (Steptoe et al., 2006).

Older adults typically obtain less sleep than during other developmental stages. Sleep obtained in older adulthood ranges between 5 and 7 hours a night, as compared to the 6.5 to 8.5 typically obtained in younger adulthood (Ohayon, Carskadon, Guilleminault, & Vitiello, 2004). This may be due to increased nocturnal awakenings and changes in pre-awakening sleep architecture, e.g. more non-REM and stage 2 sleep (Dijk, Duffy & Czeisler, 2001). The amount of sleep obtained across the lifespan appears to gradually decline before individuals enter older adulthood. Hume, Van and Watson (1998) observed that young adults (20-34 yrs) obtained an average TST of 458 minutes but by age 35-49 yrs, this had decreased to 422 minutes per night and further declined to 412 minutes in older adulthood (50-70 yrs). Gender also significantly influences how much sleep adults obtain across the lifespan. Women undergoing menopause can have disrupted sleep as a result of insomnia due to hot flushes, mood disorders and sleep disordered breathing, sleep disruption during pregnancy is also common (Moline, Broch, Zak, & Gross, 2003).

In children and adolescents, the concerns that individuals may not be consistently meeting recommended sleep durations for optimal health and functioning appear more founded. Olds, Maher, Blunden, and Matricciani (2010) found that Australian children and adolescents aged 9-10 yrs obtained an average of 10.5 hours a sleep on school nights and weekends but that this declined to 9 hours on school nights and 9.5-10 hours on weekends by age 16-17 yrs. However, although on average children and adolescents were obtaining enough sleep, Olds and colleagues (2010) demonstrated that when comparing sleep across the week that children and adolescents did not meet the recommended amount of sleep, as suggested by the American Central of Disease Control (ACDC). Children and adolescents did not obtain these guideline amounts for 17% of school nights and 20% of weekends (Olds et al., 2010). These data were however obtained from the 1985 Australian School Health and Fitness Survey and may not reflect current Australian trends in sleep. More recent data obtained by Short et al. (2013) indicated that adolescents (13 to 18 yrs) obtained only 8 hrs 17 minutes (range= 58 minutes) during the week and 8 hrs and 40 minutes (range= 80 minutes) on the weekends. Following the recommendations by the NSF (2006) that categorise adolescent sleep as optimal if greater than 9 h, borderline if between 8–9 hours, or insufficient if less than 8 h, Short and colleagues concluded that many adolescents may be obtaining insufficient sleep. The study conducted by Short and colleagues (2013) may give more accurate estimates than Olds et al (2010) as they categorised school nights as Sunday to Thursday nights rather than Monday to Friday. In the USA, as compared to Australia, adolescents appear to get significantly less sleep. Carskadon (1990) found that, for week-night sleep, 10 year olds self-reported obtaining 9 hours 45 minutes sleep but that this had declined to 7 hours and 41 minutes by age 15, and further declined to 7 hours 3 minutes by age 18. Carskadon (1990) argues that the sleep duration obtained by adolescents in the USA is highly influenced by the earlier school start times truncating the sleep period.

Conclusion

The subject of this thesis is adolescent sleep. Therefore, this final section will summarise the key factors which influence adolescent sleep and outline the next chapter of the thesis. It was previously stated that adolescent sleep is impacted on by the bioregulatory processes of delayed circadian rhythms and slowed accumulation of sleep pressure and genetics (early vs late risers). Adolescent sleep, can also be influenced by environmental factors which may include bedroom factors (e.g., temperature, noise) as well as pre-bedtime behaviours such as exercise, use of stimulants, such as caffeine or tobacco, and technology use (Bartel, Gradisar & Williamson, 2015). Similar to adulthood, mood states such as anxiety or depression are associated with sleep difficulties during adolescence (Alfano, Zakem, Costa, Taylor, & Weems, 2009; Ramsawh, Stein, Belik, Jacobi, & Sareen, 2009). Dahl (1996) postulated that early-onset depression could affect sleep during adolescence as negative cognitions (e.g. about self and environment) produce hypervigilance/perceived environmental threat, which can interfere with sleep onset and/or maintenance. However, subsequent research has failed to produce consistent empirical support for this theory or replicate the changes in sleep subsequent to depression observed in adults (Ivanenko, Crabtree, & Gozal, 2005). A meta-analytic review conducted by Lovato and Gradisar (2014) clarifies the relationship between depression and sleep in adolescents. Upon reviewing 23 studies on sleep disturbance and depression during adolescence (12–20 yrs.), they found that although adolescents with depression did experience more nocturnal wakefulness, there was little support for depression as a predictor of adolescent sleep difficulties and that sleep disturbances most likely act as a pre-cursor to depression (Lovato & Gradisar, 2014). As such, this suggests that depressive mood states are not a key predictor of adolescent sleep difficulties but do remain a negative outcome of sleep difficulties further enforcing the importance of adequate sleep during adolescence.

If internal factors such as mood states are not a key determinant of sleep difficulties during adolescence this suggests a role for environmental factors impacting on adolescent sleep. Bartel and colleagues (2015) conducted a meta-analysis, which aimed to tackle the dearth of evidence indicating which factors protect or harm adolescent sleep. Tobacco, computer use, evening light, a negative family environment, and caffeine were all associated with decreased total sleep. Computer use was also associated with later bedtimes alongside videogaming, phone, and internet use (Bartel et al., 2015). The review by Bartel and colleagues provides important evidence indicating the role of technology on influencing sleep during adolescence. However, further research is needed to clarify how technology is influencing sleep during adolescence and factors which impact on this relationship. Ultimately, a clearer understanding of the mechanisms shaping the relationship between technology and sleep will allow clinicians, parents and adolescents to minimise the effect technology can have on sleep, and in particular bedtimes. Prior to investigating the role technology use (e.g., videogaming) can have on adolescent sleep, it is important to establish an updated picture of current adolescent sleep (e.g., a ‘baseline’) as a point of comparison. Therefore, establishing current adolescent sleep problems and patterns, and if there have been any recent changes, will comprise the first research aim of this thesis.

Technology use and the increase thereof represents a significant new challenge for individuals and researchers alike. Individuals do not have an innate knowledge of how to have a relationship with technology that is optimal for our health. Due to the relatively new emergence of technological devices and the increasing morphing of devices into ever more invasive, subtle and integrated forms (e.g., Google glasses, smartphone watches), this presents an important and unique challenge for researchers to grapple with how these devices impact upon health outcomes such as sleep, both in the short and long-term. The next section of this thesis will present an overview of empirical research on technology and sleep. There will be a focus on adolescents, a discussion of the emergence and integration of one form of technology, computer and console games, and the impact videogaming has upon adolescent sleep, and identify directions for further research to be investigated during this thesis.

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CHAPTER 2: The Effect of Technology use on Adolescent Sleep: A focus on Videogaming, Individual Mechanisms and Sleep.

The effect of technology use on adolescent sleep: A focus on video-gaming, individual mechanisms and sleep.

Overview

The previous chapter outlined the myriad of factors that impact on sleep across the lifespan, but more importantly for the scope of this thesis, the individual, social and biological factors which impact on sleep during adolescence. The term "perfect storm" (Carskadon, 2011) has been used to outline how these social and biological factors shape sleep during adolescence. The perfect storm model suggests that adolescents are not obtaining the recommended amount of sleep due to a mix of these factors. Adolescents have a natural tendency for their circadian rhythms to delay and "the accumulation of sleep homeostatic pressure slows during puberty" (p. 641) which in combination with school start times and "psychosocial factors such as self-selected bedtimes, response to academic pressure, and the availability and use of technology and social networking in the evening also push for a delay in the timing of sleep" (p 644) and a subsequent truncation of the sleep period during adolescence (Carskadon, 2011).

Despite the recognition that technology use may be impacting negatively upon sleep during adolescence, data on technology use habits of adolescents suggests that (i) adolescents continue to use technology at a rate that is on the increase (ABS, 2011; Rideout et al., 2010; Rideout et al., 2016), (ii) adolescents use technology close to bedtime or in the bedroom (Arora, Broglia, Thomas, & Taheri, 2014; Calamaro, Mason & Ratcliffe, 2009; National Sleep Foundation, 2011, 2014), and/or (iii) use multiple types of technology simultaneously (Calamaro et al., 2009). The impact of technology use on sleep during adolescence is a burgeoning area of research as researchers, clinicians and parents alike recognise the potential negative outcomes. As such, a full review of the impact of technology use on sleep during adolescence is beyond the scope of the current chapter, as there have been a number of recent reviews conducted which aggregate the evidence base on the technology use and sleep of adolescents (e.g., Bartel, Gradisar & Williamson, 2015; Cain & Gradisar, 2010; Hale & Guan, 2015). Instead, the current chapter will outline the broad findings from these recent reviews on technology and sleep during adolescence to highlight how technology affects sleep (e.g., the mechanisms; Cain & Gradisar, 2010). Furthermore there is minimal experimental research focusing specifically on videogaming and sleep during adolescence, which comprises 1 hour and 21 minutes of leisure time of USA adolescents, and is a social pastime for almost a third of USA adolescents (Rideout et al., 2010). The current chapter will also review this evidence as well as highlight the methodological and theoretical limitations of the limited research on videogaming and sleep. Addressing these limitations will form the aims for the thesis.

Technology and sleep: A summary of comprehensive, systematic reviews and meta-analyses.

The review conducted by Cain and Gradisar (2010) provided a comprehensive review of the impact of technology or “electronic media” on the sleep of children and adolescents and outlined a model theorising the mechanisms behind this relationship. Van den Bulck (2010) also published a review in the same year which indicated that displacement of sleep was a key mechanism negatively influencing sleep during adolescence. Although the review by Van den Bulck (2010) suggests key ways that the media use of adolescents may effect sleep, media use as behaviour (displacement and media use as a sleep aid) and media as exposure (media as excitement, fear effects due to violence), environmental factors (e.g., media availability & the family system), the review does not formalise these pathways into a formal model with clear testable hypotheses as per the Cain and Gradisar (2010) model. The Cain and Gradisar review identified 36 peer reviewed papers on this topic. Types of electronic media reviewed included, television viewing, computer use, electronic gaming, internet use, mobile use and music. They concluded that the most consistent effects of excessive electronic media use on the sleep of children and adolescents appeared to be delaying bedtime and obtaining shorter total sleep. Furthermore, as a result of this review, Cain and Gradisar proposed a theoretical model (Fig 2.1) of the potential impact of electronic media on the sleep of children and adolescents. In brief, their model suggested a number of potential mechanisms that moderate or mediate the relationship between social factors (e.g., age, parental media boundaries and SES), media behaviour (e.g., presence of electronic media in the bedroom, daytime and bedtime usage of electronic media) and sleep. The three suggested mechanisms included; the direct displacement of sleep by electronic media (displacement hypothesis; van den Bulck, 2010), increased arousal due to electronic media use (arousal hypothesis; Higuchi, Motohashi, Liu, & Maeda, 2005) and that the light emitted by electronic media delays circadian rhythms (circadian rhythm hypothesis). The model put forward by Cain and Gradisar proposes a number of hypotheses and several subsequent experimental studies have tested components of their model (e.g., King et al., 2013; Ivarsson, Anderson, Åkerstedt, & Lindblad, 2009, 2013). However, the model is limited in that, with the exception of age, there are no intrinsic or individual factors within the model. At this stage, the model remains largely theoretical and expansion/clarification of the model in future research is an important research agenda.

The model by Cain and Gradisar (2010) has since been expanded to include additional moderating factors and more detailed outcomes (Fig 2.2; Gradisar & Short, 2013). This expanded model suggests that gender is also a key moderator of the relationship between night-time technology use and sleep outcomes, with boys and girls having different technological use habits. In comparison to Cain and Gradisar, the updated model also specifically references that sleep problems include later bedtimes, longer SOL, less TST and more nocturnal awakenings. They also specify the daytime impairments that arise from these include increased tiredness and sleepiness.

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Figure 2.1. Theoretical model proposed by Cain and Gradisar (2010) outlining the mechanisms by which electronic media may negatively impact upon the sleep of children and adolescents.

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Figure 2.2. Updated model outlining the mechanisms by which electronic media may negatively impact upon the sleep of children and adolescents (Gradisar & Short, 2013).

A more recent review into the relationship between technology use and sleep of adolescents and school-aged children was conducted by Hale and Guan (2015) who took a similar approach to Cain and Gradisar (2010). They "concisely update the only known [i.e. Cain & Gradisar, 2010] prior systematic literature review that summarized the literature on the associations between screen time exposure and a range of sleep outcomes" (pg. 50). Technology use was analysed per type of screen (e.g., television, videogames, computers and mobile use). This type of analysis is important as single studies often analysed the relationship between the broad concepts of "screen time" or "media use" thereby limiting the conclusions which could be reached. Hale and Guan reviewed studies conducted between 1999 and 2014- a total of 67 studies. Studies were included for review if they investigated the relationship being any of the types of screen time and the following sleep outcomes; sleep timing, sleep duration (i.e., TST), sleep quality or SOL. Of the 67 studies included for review, the number of studies investigating specific types of screen time were; television viewing

(42), computer screen use (31), video game screen use (21), multiple screen use (16) or an aggregate of screen time (11). The authors highlight that this is an increase of 31 studies since the Cain and Gradisar study was conducted in 2010, which indicates a rising popularity of the research field focussing on the effects technology and sleep during adolescence. However, despite a spike in research studies published during this time there is a disappointing number of experimental studies or studies testing the Cain and Gradisar (2010) model.

Hale and Guan identified that results on the relationship between television viewing and SOL were mixed, but TV watching was associated with significantly delayed bedtime and shortened TST. The authors note that comparison of studies on computer use was flawed due to varied usage of computers subsumed under “computer use”, such as social networking, studying or videogaming, activities which may have very different effects on the sleep of adolescents. For mobile phone use, most studies found a significant relationship between mobile phone use and bedtimes and TST, but less conclusions were able to be reached in regards to SOL as only two studies investigated this relationship. Finally, for the studies investigating the relationship between videogaming and sleep, most studies (81%) found a significant relationship with delayed bedtime or shorter TST. However, much like other forms of technology, the association between videogaming and SOL was not as strong, with less (51%) studies finding a significant positive correlation between videogaming and SOL.

Expanding upon previous reviews, Bartel and colleagues (2015) conducted a meta-analytic review of 41 studies published between 2003 and 2014 in order to identify the risk and protective factors, (including technology), influencing the sleep of adolescents. This meta-analytic approach allowed the comparison of technology against other factors that influence adolescent sleep, the identification of which factors are harmful, and to what extent. Studies were included for meta-analytic review if participants were aged between 12 and 18 years, measured bedtime, SOL and/or TST, and were conducted in the 11 years prior to 2014. A number of different types of technology use were found to positively correlate with bedtime including, internet use, computer use, mobile phone use and videogaming. No types of technology use were found to significantly and meaningfully correlate with SOL (i.e., $r>0.10$). However, the authors note that computer use was not able to be included in the meta-analysis for SOL as there was only one study investigating this relationship. Finally, Bartel and colleagues found that only one type of technology use (i.e., computer use), was significantly correlated with reduced TST. The authors argued that the findings support the displacement hypothesis (Cain & Gradisar, 2010), with the greatest association being between increased technology use and delayed bedtimes. Overall, videogaming formed one of the five types of technology use identified as a risk factor for the ‘sleep’ of adolescents, but television did not (Bartel et al., 2015). Therefore, research should ideally concentrate on the effects of the types of technology, such as videogaming, identified as risk factors.

In summary, there are some subtle differences between the findings of Bartel and colleagues (2015) and Huan and Gale (2015), particularly around the influence of television viewing. However, it is apparent from both reviews that videogaming emerges as a consistent factor negatively influence the sleep of adolescents, and forming a ‘risk’ factor for bedtime. Additionally, all three reviews (Cain & Gradisar, 2010; Bartel et al., 2015; Hale & Guan, 2015) conclude that TST, but more so bedtime, are the sleep parameters most consistently impacted on by technology use. The results of these reviews form an important first step identifying the strength of this relationship, however, due to their broad approach, are unable to determine more specific details of the relationship between technology use during adolescence and its subsequent effect on sleep. Specifically, these reviews were not able to delve into the details of each study on technology and sleep. As such, the following section will focus on the experimental research investigating the relationship between videogaming and sleep during adolescence in order to elucidate some of the causal (and moderating) factors, and possible mechanisms, which may be driving this negative association between videogaming and sleep during adolescence.

Videogaming and sleep during adolescence: A review of the experimental evidence

One of the first experimental studies conducted investigating the relationship between exposure to videogaming and sleep during adolescence was conducted by Dworak, Schierl, Bruns and Strüder (2007). Dworak and colleagues exposed 11 school-aged children and adolescents (M= 13.45; SD= 1.04 yrs) to “excessive” television viewing or video game play for 60 minutes between 6 and 7 pm. The videogame adolescents were exposed to was *Need for Speed—Most Wanted* (Electronic Arts, Redwood City, CA0), and for the television condition participants were able to choose from *Harry Potter and the Prisoner of Azkaban*, *Star Trek: Nemesis*, and *Mary Higgins Clark’s Loves Music, Loves to Dance*, which were deemed “subjectively exciting” (p. 979). Dworak and colleagues found that neither television nor video game exposure had any effect on TST or awakenings during the night. Videogame exposure significantly increased SOL by 21.7 minutes relative to baseline and time in stage 2 sleep but decreased the amount of slow wave sleep obtained relative to the basal condition. Dworak and colleagues argue their findings may reflect the fact that videogames may cause arousal of the central nervous system and therefore account for some of the observed changes in sleep architecture and lengthened SOL. As such, the study provided some support for the development of the arousal hypothesis (Cain & Gradisar, 2010). However, as Dworak and colleagues did not directly measure autonomic arousal (e.g., Heart Rate [HR], blood pressure or respiration), it cannot be firmly concluded the mechanism between their findings and sleep changes were the result of arousal. Additionally, as participants went to bed between 8.30 pm and 9.30 pm (meaning that media exposure occurred between 1.5 and 2.5 hours before bedtime), this could be potentially minimising the effect that the media exposure had on the participants as media use close to bedtime is associated with later bedtimes and reduced TST (Orzech, Grandner, Roane, & Carskadon, 2016). Moreover, as the duration of media exposure was time limited (60 mins) and not close to bedtime, this minimised any opportunity for media displacement of bedtime (therefore extrapolating the findings to provide any evidence to the displacement hypotheses set out by Cain & Gradisar, 2010). This truncated media exposure also does not reflect media habits of adolescents across a broader age range (12-18 yrs), as 82% of adolescents engage in television viewing after 9pm and 55% engage in videogaming (Calamaro et al., 2009). Finally, as some adolescents (13-18 yrs.) play media up to 73 minutes per day (Marshall, Gorely, & Biddle, 2006), the operationalism of the media exposure (60 mins) as “excessive” does not appear accurate.

Research conducted by Weaver, Gradisar, Dohnt, Lovato and Douglas (2010) aimed to test the arousal mechanism associated with pre-sleep videogaming on SOL when sleep was attempted at regular bedtimes. Adolescent participants were aged between 14 and 18 years (M= 16.6; SD= 1.1 yrs) and were considered “evening types”. Participants were exposed to two media conditions, “active videogaming” (*Call of Duty 4: Modern Warfare*; Infinity Ward, 2007) or “passive television viewing” (DVD *March of the Penguins*; Warner Independent Pictures, 2005) for 50 minutes prior to their typical bedtime. The authors argue that videogaming is “active” due to its interactive nature and direct response to stimuli as opposed to television viewing which is “passive” as it requires only observation. HR was measured throughout each activity and analysed at baseline, half way through media exposure (25 minutes) and upon conclusion of media exposure. Cognitive arousal was measured using Electroencephalography (EEG). Weaver and colleagues found that adolescents took significantly longer (7.5 mins) to fall asleep during the active videogaming condition relative to the passive TV watching (3 mins) and reported feeling less subjectively sleepy. However, “active videogaming” had no effect on HR. In contrast to Dworak et al.

(2007), no effects on sleep architecture were observed. Overall, the study by Weaver and colleagues provided mixed support for the arousal hypothesis (i.e., effect via EEG but not HR). Although, SOL was lengthened, the authors acknowledged, this was not a clinically meaningful increase (i.e., 4.5 min). The authors attribute their lack of an observed effect of videogaming on HR to time-lag between videogaming and HR measurement and suggest future studies should measure HR in parallel with videogaming.

A subsequent study by King et al. (2013) further tested the arousal hypothesis (Cain & Gradisar, 2010). Adolescent participants in this study were exposed to either 50 or 150 minutes of videogaming directly before bedtime. King and colleagues deemed the 150 minutes condition as “prolonged” as this was greater than 2 standard deviations above the mean game play duration during adolescence (Marshall et al., 2006) and as such reflects a more robust operationalism of “prolonged” or “excessive” than the study by Dworak et al. (2007). Participants played *Warhammer 40,000: Space Marine* (THQ, Agoura Hills, CA, USA) on a PlayStation 3 (PS3) console across both conditions. *Warhammer 40,000: Space Marine* is a third-person shooter rapid action game with strong violence and was played in single-player mode. Prolonged videogaming (150 mins), as compared to regular videogaming (50 mins), resulted in significantly reduced TST (27 mins) and sleep efficiency (7 %) as well as lengthened SOL (17 mins). There was also no significant differences in participants subjective mood states between conditions, but a significant difference in participants subjective “satiation’ was observed, with significantly higher post-game satisfaction and lower desire to continue videogaming reported in the prolonged condition. Although King and colleagues observed changes to objective sleep parameters due to prolonged gaming, no differences in HR were observed between regular or prolonged videogaming. Therefore, their results were unable to provide clear support for the arousal hypothesis (Cain & Gradisar, 2010). King and colleagues posit that the effect of videogaming on sleep may operate through an alternative mechanism (e.g., displacement or cognitive arousal).

Videogaming and sleep experiments: The emergence of moderating factors

Most recently, experimental research on videogaming and sleep during adolescence has begun to focus on how individual factors impact upon this relationship (Ivarsson et al., 2013, Reynolds et al., 2015). To date, the individual factors investigated include the perception of negative consequences of risky events on bedtime (Reynolds et al., 2015) and the impact of prior videogaming experience on arousal at bedtime.

An individual factor studied by researchers in the area of videogaming and sleep is “gaming experience”, where adolescents were defined as “high exposure” to videogames (played 3 hrs or more per day) or “low exposure” (played 1 hr or less per day). Ivarsson and colleagues (2013) aimed to investigate if videogaming experience influenced autonomic arousal and sleep quality subsequent to playing either a violent or non-violent videogame. As discussed earlier, previous studies (e.g. King et al., 2013; Weaver et al., 2010) have been unable to produce robust support for the arousal hypothesis (Cain & Gradisar, 2010). Similarly, when Ivarsson and colleagues conducted an earlier study (2009) they were unable to yield support for this hypothesis. Ivarsson and colleagues (2009) gave 19 adolescents aged 12-15 years (M= 13.3; SD= 0.7 yrs) violent (*Manhunt*; Rockstar Games, 2004) and non-violent (*Animaniacs*; Ignition Entertainment, 2005) videogames to play in their homes over two nights for two hours each night between 8 and 10 pm. They were instructed to go to bed at 10.30pm. Although the low frequency component of heart rate volume and power was significantly higher when adolescents engaged in violent videogaming, this had no effect on subjectively perceived sleep difficulties, or on sleep parameters (bedtime, sleep latency and wake time). It is possible that the 30 minute delay between cessation of gaming and enforced bedtimes in the Ivarsson et al. (2009) study allowed the reduction of autonomic responses due to gaming and as such no observable effect on sleep was found. Nevertheless, the strengths of this study were that (i) this provided the first cardiovascular evidence of physiological arousal in adolescents, (ii) in the home environment, and importantly (iii) opened the way for exploration into moderating factors between videogaming and sleep.

In 2013, Ivarsson and colleagues expanded upon their previous work by giving 30 adolescent males (aged 13-16 yrs; SD= 0.9), who differed in their gaming experience, a violent and non-violent game to play for 2 hours (between 8 and 10pm with no breaks) for two nights in their home. Ivarsson and colleagues (2013) found physiological and emotional reactions, as well as sleep outcomes, differed across game condition (violent vs non-violent) due to gaming experience. Low-exposed participants had significantly higher heart rates during sleep in the violent as compared to non-violent condition, but high-exposed participants did not. Low-exposed participants also experienced significantly higher levels of perceived sadness after playing the violent videogame as compared with the non-violent videogame, but high-exposed participants did not. Finally, low-exposed participants experienced lower sleep quality after playing the violent videogame as compared with the non-violent videogame, but high-exposed participants did not. Furthermore a number of differences were observed between the sleep of high exposed as compared to low exposed participants regardless of game condition (violent/non-violent). High exposed participants reported shorter sleep-onset latencies and felt more alert than low exposed participants. Ivarsson and colleagues argue the differences in autonomic responses and sleep parameters to game violence between low exposed and high exposed gamers may be due to physiological sensitisation that occurs with gaming experience and that “future studies should collect more data about background characteristics of the participants” (Ivarsson et al., 2013, p. 395).

The most recent experimental study conducted investigating the relationship between videogaming and sleep in adolescents aimed to investigate how the individual factor of “risk-taking perception” affected technology use and subsequent bedtimes. Reynolds and colleagues gave 21 adolescents aged 15-20 yrs. (M=17.6; SD= 1.8 yrs) a 5 hour videogaming opportunity prior to bedtime. Participants played *BioShock Infinite* (PlayStation 3, rated MA15+) a single-player story-based game. They assessed risk-taking using a modified version of the Cognitive Appraisal of Risky Events (CARE- 24; Fromme, Katz, & Rivet, 1997) which assesses how likely an adolescent feels they would be to experience a positive (expected benefits) or negative outcome (expected risks) as a consequence of engaging in a risky activity. Reynolds and colleagues found that adolescents went to bed later if they perceived fewer negative consequences of risky behaviour. Risk-taking behaviour during adolescence is suggested by Reynolds and colleagues to support the displacement hypothesis (Cain & Gradisar, 2010), and is an important exploration of the individual factors that influence the relationship between videogaming and sleep during adolescence.

In conclusion, despite initial exploration through a variety of experimental studies, the exact pathways through which videogaming affects the sleep of adolescents has not been clearly elucidated. Similarly, initial studies (e.g. Ivarsson et al., 2013, Reynolds et al., 2014) highlight individual factors (risk-taking and videogaming experience) that may influence this relationship. Intrinsic factors are those within the adolescent themselves and extrinsic factors are those external to the adolescent, such as social factors or parenting. Cain and Gradisar (2010) suggest that extrinsic social factors, such as parental control, may predict media habits and therefore predict sleep problems and daytime functioning. Further exploration of both intrinsic individual factors and extrinsic social factors will allow expansion of the Cain and Gradisar (2010) model. Additionally, exploration of which intrinsic or extrinsic factors have the most influence on videogaming and sleep during adolescence will allow identification of possible intervention points to mitigate the negative experience of videogaming on sleep experienced by some adolescents. The current thesis will make an unique contribution in the field of videogaming and sleep during adolescence by aiming to address some of the gaps in the area, specifically the identification of intrinsic and extrinsic factors that influence videogaming behaviour and sleep, comparison and expansion of the pathways suggested by Cain and Gradisar (2010) and further exploration of the interaction between individual factors (e.g. videogaming experience), game-factors and sleep during adolescence.

Study 1 (Chapter 3) attempts to take a recent ‘snapshot’ of Australian adolescents’ sleep patterns, sleep problems, and daytime dysfunction. Similarly, Study 2 (Chapter 4) takes a ‘snapshot’ of adolescents’ videogaming behaviours and parental influences. Study 3 (Chapter 5) uses a survey approach to integrate these areas of videogaming and ‘sleep’, as well as incorporating influential intrinsic (e.g., risk-taking) and extrinsic (e.g., parental involvement) factors involved in adolescents’ gaming behaviours and sleep. Finally, Study 4 (Chapter 6) uses an experimental laboratory approach to investigate the unique contribution of an intrinsic factor (discovered in Study 3) on adolescents’ self-selected bedtimes after videogaming. This thesis culminates in an overall Discussion that will synthesise these findings into the existing literature, and discuss the theoretical and clinical implications of them.

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CHAPTER 3: Later to Bed, but not Easy to Sleep: Recent Sleep Patterns, Problems and Functioning in Australian Adolescents

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Research Aim 1:

To establish current adolescent sleep problems and patterns

Author Contributions

LS contributed to study design, literature search, data collection, statistical analysis, results interpretation and manuscript preparation. KB, CH & MS contributed to data collection and manuscript preparation. MG contributed to study design, results interpretation and manuscript preparation.

Smith, L.J., Bartel, K., Huang, C., Short, M.A., & Gradisar, M (under review). *Later to Bed, but not Easy to Sleep: Recent Sleep Patterns, Problems and Functioning in Australian Adolescent*s……..

Abstract

Objective: Whilst Australian adolescents may obtain more sleep than their Asian and North American peers, the current Australian literature is limited in how sleep is operationalised, as well as a paucity of research examining daytime consequences or adolescents' subjective experience of sleep problems. The current study aimed to obtain quantitative aspects of the sleep of Australian adolescents (e.g., total sleep time; self-perception of sleep problems).

Participants: 324 high-school and university students (83% F; M= 16.4; SD=1.9yrs).

Methods: Adolescents completed an online survey about their usual sleep patterns (modified SSHS), daytime functioning (Sleep Reduction Screening Questionnaire), and perceived sleep difficulties (Insomnia Severity Index).

Results: Adolescents reported mean school night sleep below the recommended guideline of 8-10 hrs (M=7 h 55 mins, SD=141.5 min). School night bedtimes and weekend out-of-bed times became later with age. No gender differences were found. Approximately 44% of adolescents experienced daytime symptoms of sleep restriction, yet only 27% reported having a sleep problem. A self-perception of having sleep problem was associated with poorer sleep (later bedtimes and longer sleep latency).

Conclusions: The results indicate sleep restriction is common among adolescents. However, adolescents demonstrate poor awareness of recognising when they experience clinically significant poor sleep. This has implications for broad community sleep education and the clinical management of sleep disorders in adolescents.

Keywords: adolescents, sleep, bedtimes, daytime functioning, sleep problems.

Introduction

Sleep during adolescence is influenced by intrinsic (e.g., sleep timing, circadian delay, slowed sleep pressure accumulation) and extrinsic factors (e.g., psychosocial pressures [academic, social media/networking or videogaming], societal pressures [school start times]), factors described as ‘the perfect storm’ for poor and insufficient sleep (Carskadon, 2011). The socio-emotional and physical consequences of sleep restriction during adolescence are well acknowledged (Araújo & Almondes, 2014; de Bruin, van Run, Staaks, & Meijer, 2017; Huang et al., 2016; Hysing, Haugland, Stormark, Bøe, & Sivertsen, 2015; McMakin et al., 2016; Sadeh, Gruber, & Raviv, 2003), and thus it is important to observe what is the current state of sleep for those living in their second decade.

Recent sleep guidelines (National Sleep Foundation 2015 report; Hirshkowitz et al., 2015) indicate that adolescents (14-17 yrs) should obtain between 8-10 hrs sleep per night. Indeed, empirical studies have shown adolescents who obtain <8hrs sleep have poorer working memory performance (Gradisar, Terrill, et al., 2008) and are at risk for injury or other risky behaviours, such as alcohol or drug use, sexual activity, or suicidal ideation (McKnight et al., 2011; Stallones, Beseler, & Chen, 2006). Meta-analytic evidence suggests Australian teenagers may be obtaining more sleep (approx. 30-45 mins) than their peers in North America and Asia (Gradisar, Gardner, & Dohnt, 2011). However, these meta-analytic data were gathered more than half a decade ago, and due to the inference that adolescents may be obtaining less sleep over time (Dollman, Ridley, Olds & Lowe, 2007), it is important to provide up-to-date snapshots of Australian adolescents’ sleep.

At present, there are minimal data on adolescent sleep in the Australian population, and what limited evidence exists contains inconsistencies. Estimates of sleep duration in Australian adolescents ranges from below 8 hrs (7. 70 hrs; Raniti et al., 2017), ~8 hrs (8 hr 17 min; Short, Gradisar, Gill, & Camfferman, 2013), close to 9 hrs (8.7 hrs; Chen et al., 2014), to over 9 hrs (Eisenmann, Ekkekakis, & Holmes, 2006; Olds, Maher, Blunden, & Matricciani, 2010). This may be in part due to inconsistencies in the operationalism of school night versus weekend nights (Olds et al., 2010; Lushington et al., 2015; Short et al., 2013; Tremaine, Dorrian, & Blunden, 2010; Warner, Murray, & Meyer, 2008). The current study will define school nights as Sunday through Thursday, and weekend nights as Friday and Saturday, allowing clearer comparisons to previous Australian and international literature.

However, it is not just the amount of school night sleep that adolescents are obtaining which is important, as it is only the so called ‘one side of the coin’. Sleep restriction is shown to impact the daytime functioning of adolescents (Shochat, Cohen-Zion, & Tzischinsky, 2014). However, the extent to which Australian adolescents experience daytime consequences from insufficient sleep remains unclear. Large-scale Australian studies (e.g., Dollman et al., 2007; Olds et al., 2010) have not investigated the impact of sleep upon daytime functioning or used limited measures of daytime functioning (e.g., mood only; Raniti et al., 2017). Less total sleep and/or later bedtimes are associated with worse daytime functioning, risky behaviours (criminal activity, substance use), and poorer emotional and academic outcomes (Asarnow et al., 2014; McGlinchey & Harvey, 2015) indicating that bedtime as well as total sleep are important variables to consider (Short et al., 2013). Therefore, the current study will investigate the degree to which adolescents also experience daytime dysfunction.

A further limitation of studies assessing the sleep of Australian adolescents is the lack of attention given to adolescents’ perceived difficulties with their sleep. For example, a meta-analysis of adolescents’ sleep found that their own perceptions of their sleep do not necessarily align with clinically used measures of sleep difficulties (Gradisar et al., 2011). Specifically, 22% of adolescents reported a sleep latency of >30 mins, however only 16% reported a difficulty with initiating sleep (Gradisar et al., 2011). Consistent with these meta-analytic findings, 66% of Australian adolescents have been identified as having a symptom indicative of a sleep problem (e.g., total sleep time <8 hrs; sleep latency >30 min), but only one third of this sample (23.1%) identified themselves as having a sleep problem (Short et al., 2013). Our own sleep intervention work with adolescents in schools shows that in order for adolescents to be motivated to change their behaviours around sleep, they first need to identify whether they have a sleep problem (Bonnar et al., 2015; Cain, Gradisar & Moseley, 2011). Therefore, it is important to not only know about how much sleep adolescents are obtaining, and the associated daytime dysfunction, but whether they perceive that they have a sleep problem.

The objective of the present study was to obtain current data of both the quantitative (i.e., total sleep time, sleep latency) and 'qualitative' aspects (i.e., difficulty initiating sleep) of adolescents' sleep. This is crucial to provide broad information to base both broad (e.g., school-based) and individualised (e.g., clinic) sleep interventions, to help to reduce the unmeasured social and economic costs of sleeplessness in this segment of Australians (Hillman, Murphy, Antic, & Pezzullo, 2006).

Methods

Participants

A total of 324 high-school (N= 256) and university students (N= 67) ranging in age from 14-20 yrs (M= 16.4; SD=1.9yrs, 83% F) participated in the current study. Recent sleep timing data indicate that the end of adolescence occurs around ~20 years of age (Roenneberg et al., 2004). Analysis of the wake-times of University participants as compared to high-school participants showed no significant differences, $t(320)=-1.59$, $p=0.11$, suggesting weekday morning education constrained the sleep opportunity of both participant groups equally. Ethics approval was granted by the Flinders Social and Behavioural Research Ethics Committee and the Department of Education and Child Development, South Australia.

Design and Procedure

Students from six South Australian High Schools (Grades 9 through 11) and Flinders University (Undergraduate Psychology students) participated (through their internet browser on personal laptops) in an online survey administered using a shortened URL (*bit.ly*) linked to Qualtrics online software. Private and public schools in the Adelaide metropolitan regions were approached via email for participation. Sites were selected based on principal's agreement (i.e., opportunity sampling). Data were gathered between May 2015 and March 2016 during academic terms.

As reflective of adolescent's capacity to consent but insufficiency to authorise research (NHMRC, 2015), informed consent was obtained from parents (written) and school principals, and written assent was obtained for high school students. Prior to commencement of the survey, adolescents were given a written and verbal outline of their rights to withdraw. The survey took approximately 30 min during class time. Informed consent for university students was obtained by emailing participants consent forms and their subsequent completion of the online survey.

Measures

Sleep parameters

Total sleep time (TST), bedtime, sleep-onset latency (SOL), and wake-time and out-of-bed time across weeknights (Sun-Thurs) and weekends (Fri-Sat) were obtained from a modified School Sleep Habits Survey (SSHS; Wolfson et al., 2003; Short et al., 2013), a measure designed for use on high–school aged adolescents between grades 9 to 12.

Daytime functioning and chronic sleep reduction

To assess adolescents' daytime functioning in relation to nocturnal sleep, we used the Sleep Reduction Screening Questionnaire (SRSQ; van Maanen, et al., 2014), a 9-item questionnaire with good internal consistency (chronbach's alpha= 0.79). The SRSQ measures daytime symptoms rather than sleep directly (e.g., *Do you have enough energy during the day to do everything? Do you have trouble getting up in the morning?*) thereby accounting for individual sleep need (van Maanen et al., 2014). Items were scored on a 3-point Likert scale, with scores of 1 indicating the item was not endorsed and higher scores of 3 indicating the item was more highly endorsed. Higher scores on this index indicate a more chronic level of sleep reduction, with scores of 17.3 or greater indicating a clinical level of sleep reduction (van Maanen et al., 2014).

Sleep difficulties

Given quantitative measures of sleep (e.g., sleep latency) do not completely capture adolescents' perceptions of their ability to fall asleep, the question assessing difficulty falling asleep was drawn from the Insomnia Severity Index (ISI; Morin, Belleville, Bélanger, & Ivers, 2011), a 5-point Likert scale with higher scores indicating a greater difficulty falling asleep (1= no difficulty through to 5= very severe difficulty). In addition, adolescents were asked about self-perceived sleep problems, "*Do you think you have a sleep problem?*"("*Yes*" or "*No*").

Statistical Analysis

Parametric (*t*-tests, ANOVA) and non-parametric (Chi-square, Mann-Whitney U) tests were used to test group differences (age, gender, sleep problem). A series of 2x3 ANOVAs were conducted to investigate age and gender effects on sleep variables using IBM$^{©}$ SPSS$^{©}$ Statistics Version 20 (analysed by author LS). Data were imported directly from Qualtrics online software. Participants were grouped into age category (age; 14-15; 16-17 and 18+ yrs). Due to the small number of participants aged over 18 years, participants aged 18, 19 or 20 yrs were grouped into the same age category. Participants were also grouped into those with or without a sleep problem (self-reported). Non-parametric tests were used for analysis involving two categorical variables (e.g. age, gender, perception of sleep problem). Missing data for all variables ranged from 0 to 3.7 %. Effect sizes calculated were the standardised measure Cohen's *d*; effect sizes of .2, .5 and .8 indicate a small, medium and large effect size, respectively (Cohen, 1988). Visual inspection of histograms was conducted to confirm normality.

Results

Sleep patterns and school-night versus weekend sleep habits

Descriptives, *t*-statistics and effect sizes for bedtime (BT), sleep onset latency (SOL), wake-time (WT), and the time when adolescents got "out of bed" (OOB) and total sleep time (TST) are shown for both school nights and weekends in Table 3.1. Differences between school-night and weekend sleep variables were significant (p <0.01) for all sleep variables. Compared to school nights/days, adolescents went to bed significantly later on weekends, rose significantly later, and had significantly later out-of-bed times on weekends, and slept significantly longer on weekends (effect sizes ranged from medium-to-large, with the exception of SOL and TST, where the effect sizes were small or negligible). SOL was also significantly shorter on weekends, however, this was a mean difference of only 5 min, and thus not clinically insignificant.

Table 3.1

Mean (SD) school night, weekend sleep variables (from SSHS) and within-subjects t-test statistics

Sleep Variable	School-Nights	Weekends	*t*-value	Cohen's *d*
Bedtime	10: 44 pm (123.82)	11:52 pm (123.82)	-18.83	.82
Sleep latency (min)	30.8 (26)	26.0 (24)	3.73*	-.20
Wake-Up Time	6:55 am (82 min)	9:17 am (157 min)	-26.82*	1.8
Out-Of-Bed Time	7:14 am (81 min)	10:03 am (181 min)	-29.55*	2.0
Total sleep time	7 h 43 mins (106 min)	8 h 42 mins (122 min)	-13.51*	.01

Note: Cohen's *d* of .2, .5 and .8 indicate a small, medium and large effect size (Cohen, 1988), respectively; SSHS= school sleep habits survey (Wolfson et al., 2003). *p<.001,

Age and Gender differences in sleep patterns

A series of 2 (gender; M, F) x 3 (age; 14-15; 16-17 and 18+ yrs) ANOVAs were conducted to investigate age and gender effects on key sleep variables. Significant main effects of age were only observed for bedtimes on school nights, and wake-up times on weekends, with a trend towards significance for weekend bedtimes (*p*=.06). There were no main effects of age for all other sleep variables. Post-hoc analyses (LSD) indicated a significant difference between school-night bedtimes across age groups, with 16-17 yr. olds and 18+ yr. olds going to bed during the school-week significantly later than 14-15 yr. olds. Post-hoc analyses (LSD) also showed that 16-17 year olds were waking significantly later on weekends than 14-15 year olds. No main effects were observed for gender for any sleep variables (school nights/weekends).

Table 3.2

Main effects of age on school-night and weekend sleep variables.

	14-15 yrs (SD; mins)	16-17 yrs (SD; mins)	18 yrs+ (SD; mins)	*F*	*p*
School Night					
Bedtime	10:18 pm (124.2)	10:50 pm (113.7)	11:00 pm (124.7)	4.60*	.01
Sleep onset latency	28.2 mins (22.0)	31.6 mins (26.3)	32.6 mins (30.7)	.36	.70
Wake-time	6:50 am (88.2)	6:56 am (60.8)	7:00 am (107.2)	.27	.76
Out-of-bed time	7:00 am (59.9)	7:12 am (62.5)	7:37 am (115.2)	1.47	.23
Total sleep time	8 h 02 min (143.0)	7 h 35 min (135.2)	7 h 34 mins (159.3)	1.04	.35
Weekend					
Bedtime	11:28 pm (151.3)	11:59 pm (143.3)	11:58 pm (149.5)	1.69	.19
Sleep onset latency	21.91 (17.1)	27.15 (26.7)	27.04 (23.6)	.97	.38
Wake-time	8:57 am (150.6)	9:25 am (152.3)	9:11 am (164.0)	3.61*	.03
Out-of-bed time	9:45 am (177.8)	10:10 am (176.0)	9:55 am (187.0)	2.50	.08
Total sleep time	9 h 06 min (155.6)	8 h 37 min (156.7)	8 h 49 min (142.2)	.60	.55

Note: $*p<0.05$

Chronic sleep reduction during adolescence and daytime symptoms

Scores on the SRSQ were analysed to investigate adolescent experience of daytime symptoms indicative of chronic sleep reduction. Adolescents had an average score on the SRSQ of 17.33 (SD= 1.84), marginally above the clinical cut-off score of 17.3 (van Maanen et al., 2014) and 44.1% of adolescents experienced daytime symptoms of sleep restriction in the clinical range. The most highly endorsed items in the SRSQ scale (range 1 to 3) were adolescents having difficulty waking up in the morning (M= 2.27, SD= 0.70), feeling sleepy during the day (M=2.48, SD=0.64) and not having energy during the day (M=2.22, SD=0.74). However, there was no significant differences between adolescents with a perceived sleep problem on the SRSQ (M= 17.43, SD= 1.78) and those without (M=17.28, SD= 1.87) in their experience of chronic sleep restriction, *t*(322) = 0.66, *p*= 0.51.

Perceived sleep difficulties and adolescent sleep habits

In the current sample, 27.1% of adolescents indicated they had a sleep problem. The lengthy school-night sleep latency mean of 30.8 mins, above the clinical cut-off for insomnia (Lichstein, Durrence, Taylor, Bush, & Riedel, 2003). Indeed, Figure 3.1 shows that 81% of adolescents endorsed some level of difficulty initiating sleep. On weekends, when adolescents went to bed significantly later, their average sleep latencies were under the 30 min cut-off. As such, adolescents appear to have greater difficulty falling asleep on weeknights as compared to weekends, and this was significantly more pronounced for adolescents who experienced ‘moderate-to-severe’ perceived sleep difficulties (Fig 3.2). Adolescents who self-reported a moderate difficulty falling asleep took 30 minutes to fall asleep during the week as compared to 20 minutes across the weekend, $z = -3.18$, p=.001. Adolescents who self-reported a severe difficulty falling asleep took 60 minutes to fall asleep during the week as compared to 35 minutes across the weekend, $z = -2.99$, p=.003. Degree of perceived sleep difficulty significantly predicted length of sleep latencies across both school nights, $F(4, 311) = 55.62$, $p<0.001$ and weekends, $F(4, 311) = 16.93$, $p<0.01$.

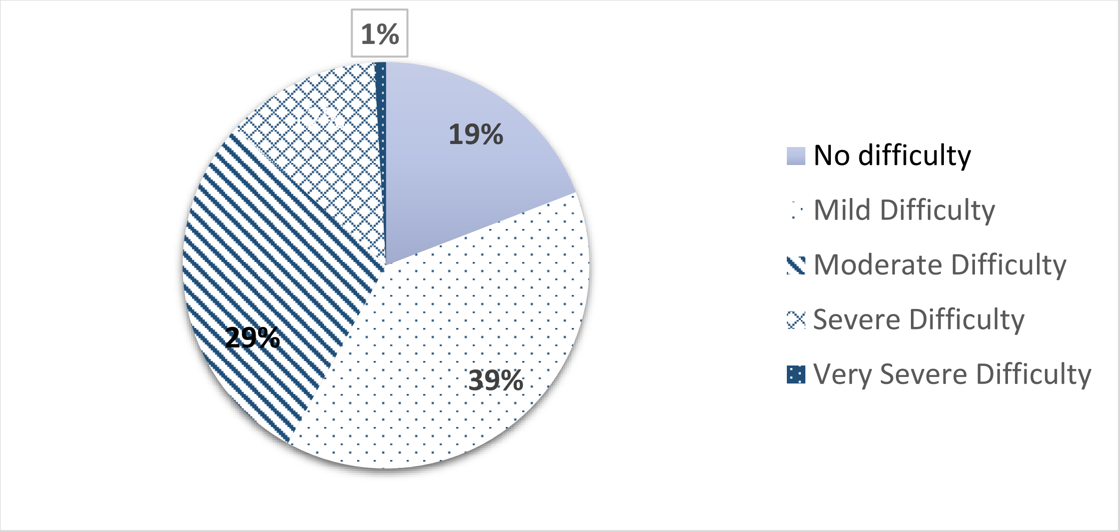

Figure 3.1. Adolescent difficulties falling asleep

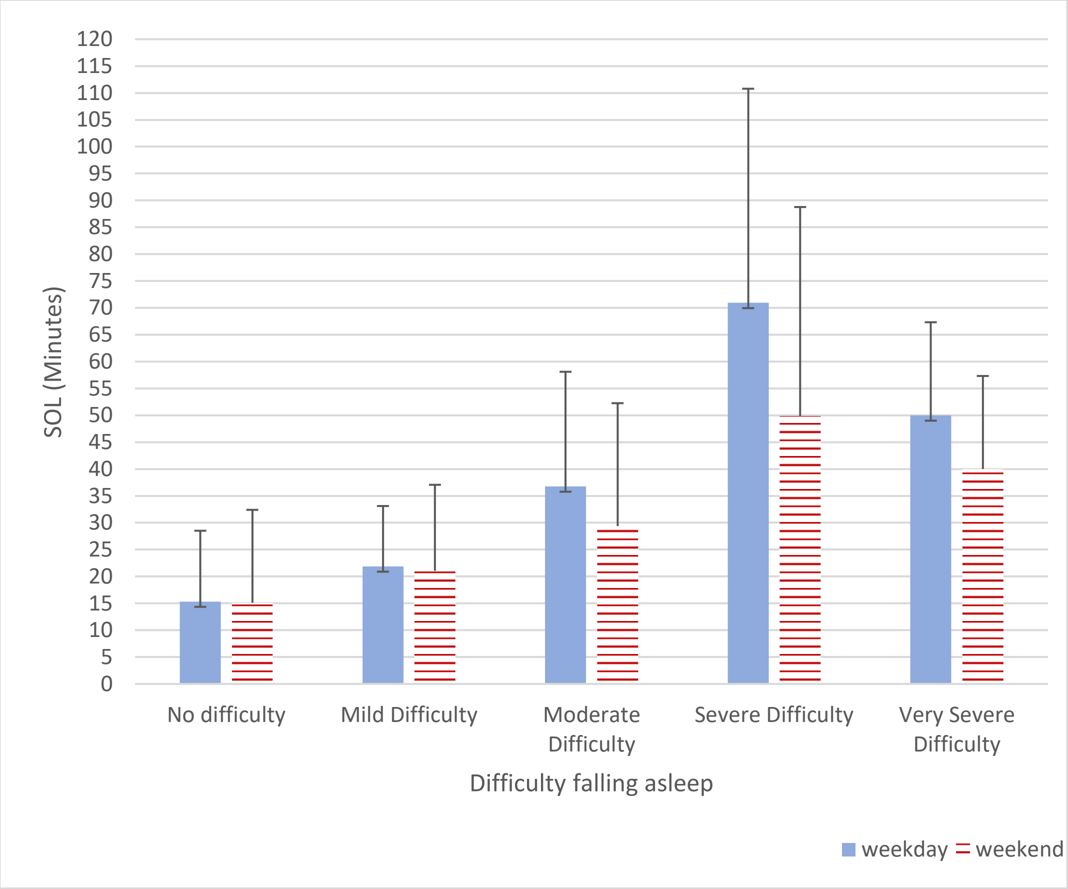

Figure 3.2. Relationship between self-perceived difficulties falling asleep and sleep onset latencies during adolescence

A Chi-Square test for independence (with Yates Continuity Correction) indicated no significant association between gender and perception of a sleep problem, *x*2(1, n = 324) =

.08, p = .77, *phi*= .025. Similarly, a Mann-Whitney U-test revealed no significant difference between the age of adolescents who self-reported a sleep problem (*Md*= 16 years, n = 91) and those who did not self-report a sleep problem (Md= 16 years, n = 228), *U* = 10255.5, *z* = -.16, *p* = .87 *r* = -.01.

Further analyses (independent sample t-test) were conducted to investigate the sleep habits of adolescents with self-reported sleep problems compared to those without (see Table 3.3). Significant differences were observed for all sleep variables during the week. However, on the weekends significant differences were observed for all sleep variables with the exception of wake times during the week for adolescents with or without a sleep problem. Effect sizes varied; weekday sleep onset latencies yielded a large effect size. Similarly on weekend nights sleep onset produced the highest effect size but this was of a medium size.

Table 3.3

Relationship between self-reported sleep problems and sleep habits (school-nights and weekends)

	No sleep problem (SD; mins)	Sleep problem (SD; mins)	T	Cohens-d	*p*
School Night					
Bedtime	10:31 PM (136.63)	11:09 PM (136.62)	3.76	-.46	<.001
Sleep onset latency	24 mins (17.52)	48 mins (35.08)	8.10	-.87	<.001
Wake-time	06:55 AM (74.36)	06: 56 AM (98.71)	0.23	-.03	.82
Out-of-bed time	07:10 AM (73.75)	07:24 AM (96.16)	2.49	-.29	.01
Total sleep time	7 h 56 mins (137.33)	7 h 3 mins (136.74)	-5.16	.65	<.001
Weekend					
Bedtime	11: 35 PM (206.98)	12:14 AM (279.25)	2.27	-.26	.02
Sleep onset latency	21 mins (17.67)	38 mins (33.51)	5.76	-.63	<.001
Wake-time	09:07 AM (152.33)	09:43 AM (161.27)	3.19	-.39	.002
Out-of-bed time	09:49 AM (169.91)	10:38 AM (196.44)	3.73	-.45	<.001
Total sleep time	9 h 7 mins (138.93)	8 h 38 mins (180.39)	-2.52	.30	.01

N.B. Cohen’s *d* of .2, .5 and .8 indicate a small, medium and large effect size (Cohen, 1988), respectively

Discussion

The current study aimed to obtain contemporary data of the quantitative and ‘qualitative’ aspects of the sleep of Australian adolescents. Significant differences were observed in the self-reported sleep patterns (weekday and weekend) of adolescents across all sleep parameters, with the exception of total sleep time. This significant change in self-reported sleep patterns between weekday and weekend sleep patterns of adolescents appears primarily driven by bedtimes, with bedtime being the sleep parameter with the largest effect size. Consistent with this, bedtimes were the self-reported sleep parameter most consistently affected by age, with bedtimes becoming later across each age group, particularly during the week.

The self-reported sleep patterns of Australian adolescents in the current study were also associated with significant daytime symptoms. A notable percentage (44.1%) of adolescents were found to experience daytime symptoms associated with clinical sleep restriction. However, this was not associated with self-perception of a sleep problem, with a much lower percentage (27.1%) of adolescents indicating they experienced a sleep problem. Differences were observed across almost all sleep-parameters (with the exception of out-of-bed times during the school week and total sleep time) for adolescents with as compared to those without a sleep problem. Finally, most adolescents (81%) in the current study indicated self-perceived difficulties falling asleep, suggesting many are in need of intervention.

One of the main aims of the current study was to update the literature in regards to sleep patterns for Australian adolescents, specifically by using clearly operationalised definitions of weekday versus weekends. The current study found that Australian adolescents obtained 7 hrs and 43 mins of total sleep per weeknight, and 8 hrs 42 mins total sleep across the weekend, which aligns with the more recent estimates of the sleep obtained by Australian adolescents (e.g., Short et al., 2013, Raniti et al., 2017). This indicates that similar operationalism of weekday versus weekend yields similar estimates of sleep habits and is therefore an important methodological consideration when measuring the sleep obtained by Australian adolescents.

The current study also aimed to document the degree to which Australian adolescents experience daytime symptoms due to their current sleep habits. We identified a notable percentage of adolescents (44.1%) were experiencing negative daytime symptoms (e.g.

difficulty waking in the morning, daytime sleepiness, lacking energy during the day), consistent with previous Australian estimates that 49% of adolescents had elevated levels of daytime sleepiness (Short et al., 2013).

Finally the current study aimed to identify the subjective experience of adolescents' sleep difficulties, which may be viewed as an important consideration for why (or why not) adolescents seek treatment (Gradisar et al., 2011). Perceived sleep difficulties were correlated with clinical indicators of adolescent sleep difficulties (e.g., sleep onset latency). Specifically, adolescents who perceived themselves to have a greater difficulty falling asleep took longer to fall asleep, both during the weekdays and the weekends. Adolescents who perceived themselves to have a sleep problem also went to bed later, (both weekdays and weekends), and woke significantly later on weekends. However, due to school start times, no significant difference was observed for weekday wake times. This suggests adolescents use weekends to "catch-up" on sleep and is consistent with international research (Taylor, Wright, & Lack, 2008).

Limitations

The current study used a cross-sectional design and convenience sampling to establish a relationship between sleep patterns and daytime functioning, as well as self-perceived sleep difficulties in Australian adolescents. As such, no causal inferences can be made about the direction of these relationships. Furthermore, some measures used were subjective/self-report based (e.g., daytime functioning). Therefore, no conclusions can be drawn about the degree to which adolescents are experiencing broader occupational or social impairments as a result of their sleep habits, such as poorer academic functioning (e.g., Asarnow et al., 2014; Wolfson and Carskadon, 1998). Additionally, as data were gathered from South Australia (which represents ~ 7% of the total Australian population; ABS, 2017), the sample is limited in its generalisability to all Australian adolescents. We also note that, the sample is largely female, and as such may limit the generalisability to male adolescents in Australia.

Clinical Implications

The findings of the current study indicate that most adolescents are not currently obtaining ‘optimal sleep” as per Australian or international sleep guidelines. Current guidelines (e.g., Hirshkowitz et al., 2015; Sleep Health Foundation, 2015) stipulate that adolescents should obtain between 8-10 hrs of total sleep per night, however the current study found, on average, that Australian adolescents are obtaining sleep below this optimal cut-off range. These findings suggest that current knowledge about the consequences of poor sleep during adolescence, and strategies about maintaining optimal sleep (e.g., sleep hygiene, not sleeping-in on weekends), do not seem to be reaching adolescents as no notable difference has been observed in the sleep obtained by Australian adolescents since recent estimates (e.g., Short et al., 2013). Furthermore, the majority of Australian adolescents (81%) indicate difficulties falling asleep. In combination, these two findings suggest that perhaps a more global intervention strategy for treating sleep difficulties is warranted among Australian adolescents.

Conclusions

The key aim of the present study was to obtain updated data of both the quantitative and qualitative aspects of the sleep of Australian adolescents. It was found that Australian adolescents were sleeping less than the minimum amount required for optimal sleep, notably more adolescents endorsed specific difficulties with falling asleep than having a global sleep difficulty, almost a half of Australian adolescents experience negative daytime symptoms which may be the result of poor sleep and the self-perception of a sleep difficulties was associated with differences in sleep habits, such as later bedtimes and the time taken to fall asleep. Limitations of the current study included the cross-sectional nature of the design, convenience sampling and reliance on self-report measures. Further implications identified were the need to investigate more global treatment of sleep difficulties for Australian adolescents.

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CHAPTER 4: Parental Influences on Adolescent Videogame play: a Study of Accessibility, Rules, Limit Setting, Monitoring, and Cybersafety

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Research Aim 2:

To identify and profile the videogaming behaviours of adolescents and establish the relationship between these videogaming behaviours and an adolescent's social environment (e.g., parental control/regulation of technology use).

Author Contributions

LS contributed to study design, literature search, statistical analysis, results interpretation and manuscript preparation. MG contributed to study design, results interpretation and manuscript preparation. DK contributed to results interpretation and manuscript preparation.

Smith, L. J., Gradisar, M., & King, D. L. (2015). Parental influences on adolescent video game play: a study of accessibility, rules, limit setting, monitoring, and cybersafety. *Cyberpsychology, Behavior, and Social Networkin*g, *18*(5), 273-279.

Abstract

Introduction: Adolescents' videogaming is increasing at a rapid rate. Yet, little is known about what factors contribute towards more hours of gaming per week, as well as what factors may limit or protect adolescents from excessive gaming. The aim of the present study was to examine associations between adolescents' accessibility to videogaming devices, the locations played (i.e., bedroom, shared rooms), parental regulation of technology use, and the amount of hours spent videogaming during the week (weekdays vs. weekends).

Materials and Methods: Adolescents (N=422; age=16.3 ± 2.0 yrs., 41% m) completed an online questionnaire battery, including demographics, videogaming behaviours (e.g., hours played weekdays/weekends, time-of-day played, devices owned, locations played, etc.), and a questionnaire measuring aspects of parents' regulation of gameplaying (e.g., rules, limit-setting, co-gaming).

Results: Accessibility to the adolescents' own devices, but not shared devices or device portability, was predictive of hours gaming on weekdays and weekends. Location (i.e., bedroom) was associated with increased gaming across the week. Parents discussing cybersafety was predictive of lower hours of gaming (weekdays & weekends), however, limit-setting, monitoring and co-gaming showed no significant effects.

Discussion: Adolescents' access to their own gaming-equipped devices, as well as gaming in their bedrooms were linked to increased hours of gaming. Our findings suggest that in order to curb the increase in hours gaming, parents are advised to delay the ownership of adolescents' devices, encourage use in shared rooms, and discuss aspects of cybersafety with their teenage children.

Introduction

Australian adolescents interact daily with digital media across multiple settings (e.g., school/home), people (e.g. peers/family), devices (e.g., smartphones/gaming consoles, etc.), and for various reasons (e.g., education/socialisation), earning them descriptions of '*children of* the digital revolution' or 'screenies' (ABS, 2011a; ABS, 2011b; Olds, Ridley & Dolman, 2006). Computer gaming (standalone/online) is one social pastime for many Australian adolescents (Olds, & Abbott, 2013; Straker, Smith, Hands, Thomas & Martin, 2010) who play anywhere between 2-18 hrs/wk. (King, Delfabbro, Zwaans, & Kaptsis, 2013; Olds et al., 2006; Thomas & Martin, 2010) and often longer on weekends than weekdays (King, Delfabbro, Zwaans, Kaptsis, 2014; Olds et al., 2006). Although several benefits of gaming exist e.g., foreign language acquisition (García-Carbonell, Rising, Montero, & Watts, 2001), enhanced executive functioning, attention, visual-spatial abilities (Dye, Green, & Bavelier, 2009; Kuhn et al., 2014), lower risky sexual behaviour (Casiano, Kinley, Katz, Chartier, & Sareen, 2012), social relationships (Cole & Griffiths, 2007;Coyne, Padilla-Walker, Stockdale, & Day, 2011), fitness (Perron, Graham, Feldman, Moffett, & Hall, 2011); it is not without unwanted consequences e.g., aggression (Anderson et al., 2008; Anderson et al., 2010), negative family/peer relationships (Padilla-Walker, Nelson, Carroll, & Jensen, 2010), poor academic achievement (Anand, 2007; Dumais , 2008; Hastings et al., 2009), higher BMI (Desai, Krishnan-Sarin, Cavallo, & Potenza, 2010; Vandewater, Shim, & Caplovitz, 2004), sleep disturbance (Ivarsson M, Anderson M, Åkerstedt T, Lindblad, 2013; King et al., 2013). This study aimed to identify contributing factors to the rapid growth of internet gaming of Australian youth (e.g., 35% increase over 3 yrs; ABS, 2011a), as well as factors which may curb this growth.

Accessibility, Portability and Location

Accessibility (i.e., access to devices equipped for gaming) may be one factor explaining adolescents' gaming behaviour. Recent reports claim 95% of Australian adolescents have access to at least one game-equipped device in their home (e.g., tablet, smartphone, personal computer [PC], games console; Brand, 2011), and 1 in 4 adolescents own a mobile phone (Lenhart, 2012). However, it is not known whether access to shared devices is limited by competing with others (parents, siblings), and furthermore, whether or not they *use* these devices for gaming. The context of gaming is another potential contributing factor. Up to 50% of adolescents have a console in their bedroom, and 1 in 3 possess a bedroom PC (NSF, 2006; Rideout, 1999). However, limited research suggests that such access to a bedroom console or computer can distinguish pathological and non-pathological gamers (Choo et al., 2010), predicts overall computer use (Patriarca, Di Giuseppe, Albano, Marinelli, & Angelillo, 2008), and relates to increased time spent in the bedroom which discourages family contact (Bovill & Livingstone, 2001). We therefore aim to describe the gaming behaviour of adolescents (i.e., hours/week and time-of-day played, game-equipped devices owned, locations played), and investigate whether accessibility to and location of gaming-equipped devices predicts adolescents' gaming.

Parental Regulation in Adolescents' Gaming

One important factor that may limit adolescents' gaming behaviour is parental regulation. Regulation of adolescent's media use can be defined by two distinct types; restrictive mediation (i.e., *when* an adolescent could or could not use a certain media) or conversational ('positive') mediation (i.e., a parent talking to the adolescent about a specific media issue; Bovill & Livingstone, 2001). Both types of mediation are less common for the single-user devices (e.g., PC) than for shared-user devices (e.g., TV), that is, when an adolescent has their own PC, parents are more likely to use restrictive mediation (Bovill & Livingstone, 2001). When parents give their children directions and guidelines about how to engage with the internet (e.g., authoritative parenting style) it has been shown this predicts levels of children's internet usage (Ihmeideh & Shawareb, 2014). Furthermore parental rules about internet use (e.g., not giving out personal information or talking to strangers in chatrooms) and good communication with parents (e.g., telling parents when receiving unsolicited and inappropriate junk mail) is related to decreased likelihood of risky internet-related behaviour (Liau, Khoo, & Hwaang, 2005). However, the aforementioned research does not take account the perspective of the adolescent (i.e., how the adolescent feels limits have been imposed upon their internet and online activities). Qualitative research performed over a decade ago found that 90% of Australian children were aware of family rules for computer use (Downes, 2002). Yet, despite updated government advice for parents on online safety (e.g., cyberbullying, social networking, sexting, mobile phone safety, offensive and duration of time spent online; Australian Communication and Media Authority [ACMA], n.d.), there is no current knowledge on the extent to which such mediation practices are being applied to Australian adolescents' gaming behaviour, and their impact on controlling actual gaming activity.

The Present Study

Despite widespread and growing videogaming in Australian adolescents (ABS, 2011a), the literature is limited due to a restricted age range (Olds et al., 2006; Wake, Hesketh, & Waters, 2003), focusing on adults (Brand, 2011; Wang, 2001), addiction (King, Delfabbro, Zwaans & Kaptsis, 2013), based on overseas data (Johansson & Go¨testam, 2004; Tejeiro et al., 2002), requires updating (ABS, 2011; Thomas & Martin, 2010; Wang, 2001), or focuses on 'screen time' as a general concept to the exclusion of gaming (Olds, Maher, Ridley & Kittel, 2010). This study therefore aimed to present an updated picture of how Australian adolescents are engaging with computer games across adolescence (12-20 yrs.), with a specific focus on factors increasing (i.e., accessibility, portability) or decreasing (parent regulation) its level of use.

Materials and Methods

Participants

Adolescents (N= 422; age=16.3 ± 2.0 yrs., 41% m) were recruited from South Australian high schools and from Flinders University. Most adolescents (69%) lived with both parents, 76 % were of Oceanian ethnicity (e.g. Australian, Australian Aboriginal or other South-Pacific Islander), and lived in higher SES areas[1]. Adolescents provided informed consent through proceeding past the information page to the survey. The study was approved by the Flinders University Social and Behavioural Research Ethics Committee and the Department of Education and Child Development.

Materials and Procedure

Demographic data (D.O.B, gender, postcode [SES], living situation, ethnicity) were initially collected from adolescents. Gaming behaviour comprised of several aspects, including time-of-day gaming usually occurred, and duration (hours played). Accessibility comprised how many devices adolescents' owned, how many accessed within their household, their portability (e.g., laptop/tablet/smartphone=portable), location where games played (e.g., bedroom), and the number of hours played without a break.

Parental regulation of media usage was assessed via the 7-item questionnaire 'What Parents Say and Do' (WPSAD; King & Delfabbro, under review). Adolescents were asked about: if they had been talked to by parents about cyber safety (yes/no), parental rules and limit setting for (i) online content, (ii) length of time spent online, and (iii) presence of media devices in the bedroom and physical monitoring of media use by parents. Except for questions with binary responses (i.e., cybersafety, all other questions had responses ranging

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[1] SEIFA score=7.13 (range=1-10; higher scores = higher SES).

from *Never* (0) to *Always* (4). Total scores ranged from 0 to 20, with higher scores indicative of more stringent parental regulation of media and internet use. Internal consistency of the WPSAD was acceptable (α=0.61). The response rate was 72%. Adolescents were reimbursed at the end of the survey by making a AUD$1 donation to a charity of their choice from a list of youth well-being charities. University students received course credit for their participation.

Statistical analysis

A series of correlational analyses were conducted to determine which aspects of accessibility were associated with gaming behaviour. As the data violated assumptions for parametric tests of association (i.e., Pearson’s product moment correlation) point biserial correlations were conducted for correlations containing a dichotomous variable. For all other correlations spearman’s rho was conducted. Multiple regressions were conducted to identify the strongest predictors of hours adolescents spent gaming during weekdays and weekends.

Results

Gaming behaviour of Australian adolescents

During weekdays, most adolescents (56.6%) played computer games between 5-8pm or 8-11pm (40.8%; Fig 4.1A). Weekend gaming time was more evenly distributed (Fig 4.1B), with most adolescents playing in the evening (8-11pm; 47.4%). Daily time spent gaming during weekdays (2.85±2.5 hrs) was significantly shorter than daily time spent gaming on a weekend day (3.49± 2.7 hrs), $t(395)=7.50$, $p<0.001$ (Figure 4.2). The majority of adolescents (64.9%) played computer games for over 1 hour (range=<1 to 4 or more hrs) without a break.

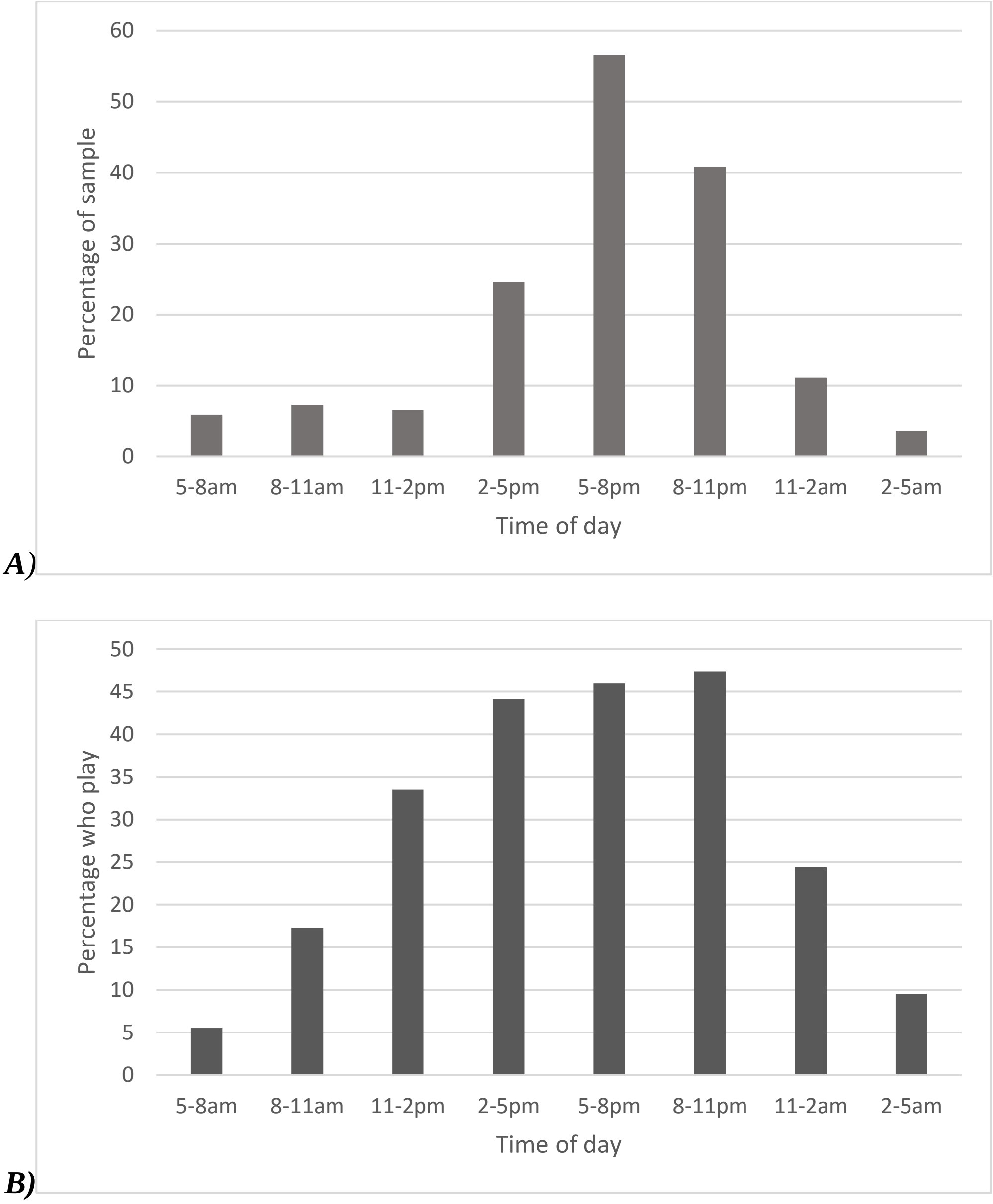

Figure 4.1. Time of day adolescents play computer games during (A) weekdays and (B) weekends.

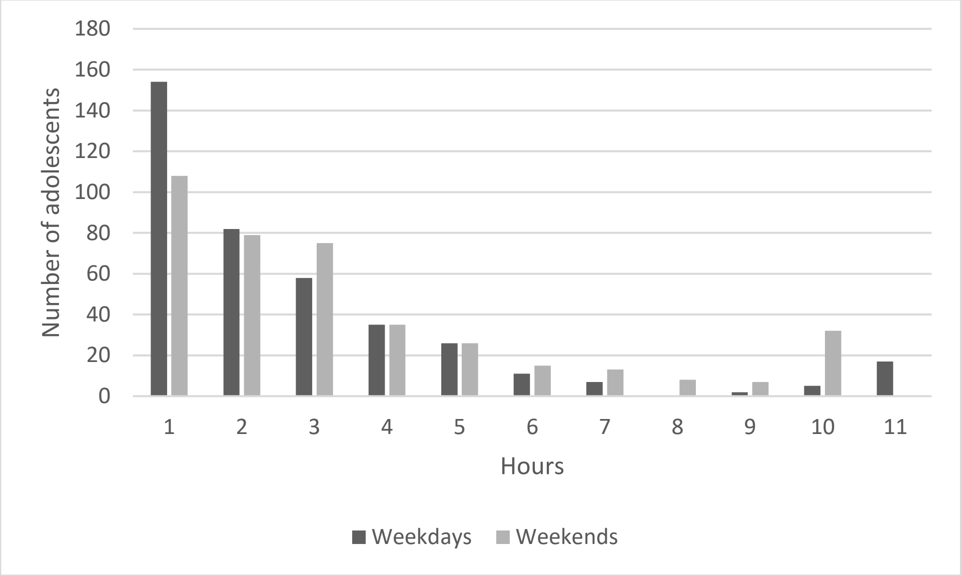

Figure 4.2. Time spent playing computer games during weekdays (dark bars) and weekends (light bars)

Accessibility of gaming devices

On average, households contained 6 media devices; 2 of these belonging to adolescents (i.e., 33%; range 1-5 devices). Adolescents use a variety of devices to play computer games (see Figure 4.3). For most adolescents (84.8%), a media device is available to use in their bedroom. Bedroom computers are commonly used to play computer games, with 63.7% using the media device they have in their bedroom to play computer games.

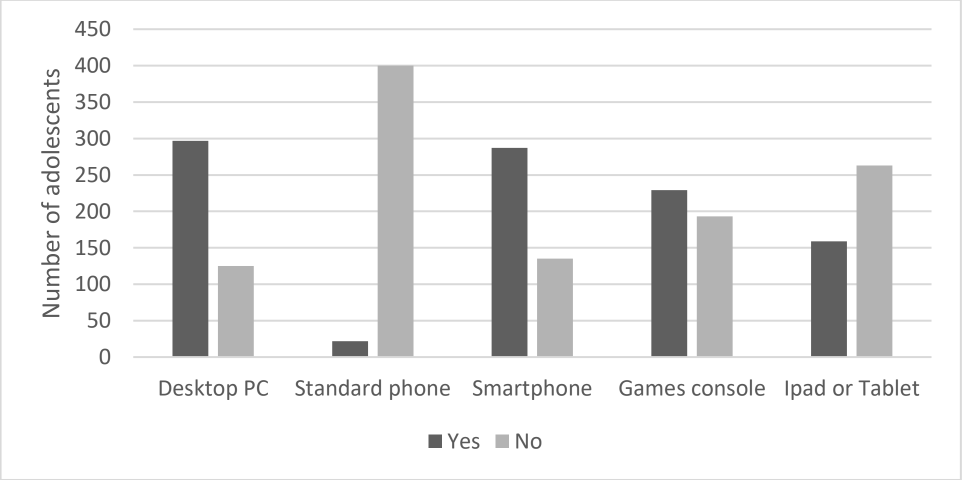

Figure 4.3. Devices adolescents use to engage in gaming, independent of location.

Parental regulation of access to gaming devices

Figure 4.4 presents adolescents' responses to parental regulation of media use. Despite the majority of parents talking to their adolescents about cybersafety (Figure 4A), the vast majority of adolescents reported their parents '*rarely*' or '*never*' limit their online content, or time online (Figures 4.4B and 4.4D, respectively). The majority of adolescents (about 2 in every 3) reported that parents allowed them to play computer games in their bedroom (Figure 4.4C).

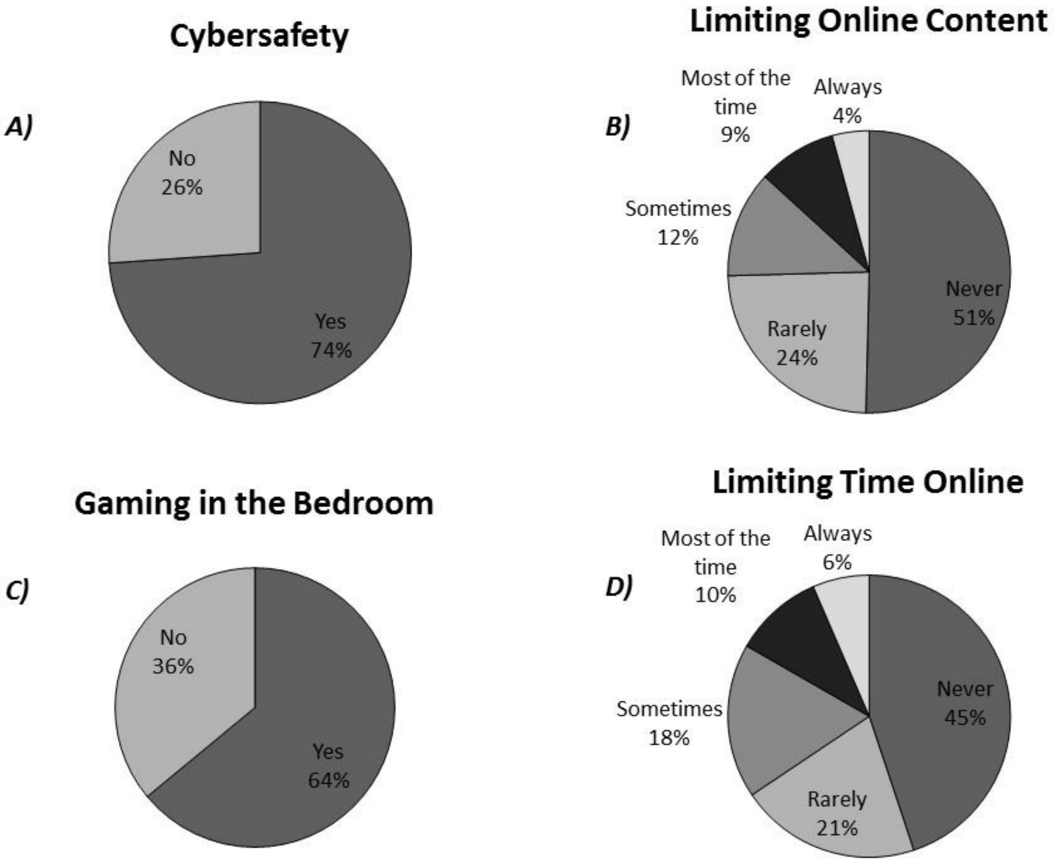

Figure 4.4. Parental regulation of adolescent media use

Associations between accessibility, portability, and parental regulation with computer gaming

Table 4.1 presents bivariate correlations between accessibility (access to media devices), location (device in bedroom), and portability (type of device). Hours spent gaming across the week were correlated with adolescents’ access to their own devices. Simply possessing a computer in the bedroom (i.e., location) was not associated with hours spent gaming, whereas using the computer for gaming was associated with gaming time. Contrary to expectations, portable devices (phones, tablets) were not significantly correlated with hours spent gaming, yet PCs and consoles were both significantly correlated with gaming time. Significant correlations were found between all parental regulation variables and the number of hours spent gaming (weekdays and weekends), with the exception of parent limit-setting of time online, as well as limiting the use of media in the bedroom.

Table 4.1

Correlations between portability, parental supervision, and hours gaming.

	Hours spent gaming	
	Weekdays	**Weekend**
Media devices household	.073	.145*
Media devices own	.258*	.324*
Computer in bedroom	-.045	022
Computer in bedroom used to game	-.342*	-.358*
PC	-.242**	-.350**
Console	-.238**	-.316**
Smartphone	.077	.119*
Phone	-.096	-.061
Tablet	.010	.016
Parent talk cyber	-.172**	-.183**
Online limits what (content)	-.156**	-.132**
Online limits long (time)	-.068	-0.14
Limits Media bed	.096	.045*
Online physical presence	-.252**	-.211**
Online see what doing	-.148**	-.099*

Note: Point-biserial correlations used against outcome variables (hours spent gaming), except for number of media devices in household and owned (Spearman's correlations); *=p<.05; **=p<.01.

Standard multiple regressions were used to explore which variables were uniquely and significantly associated with weekday and weekend hours spent gaming. The first model conducted for weekday computer gaming explained 19.5% of the variance in hours of computer gaming, *F*(14,321)= 5.57, *p*<.001. The variable explaining the largest variance in gaming time was the number of media devices owned by the adolescent (β=.20, *p*=.002). Other significant predictors included; using a computer in the bedroom to play games (β = -.15, *p*=.011), using a console device for gaming (β = -.11, *p*=.04), and having a parent that discussed cybersafety (β = -.11, *p*=.045). The second model conducted for weekend computer gaming explained 30% of the variance, *F*(14,321= 9.85, *p*<.001). As with the first model, the number of media devices owned by the adolescent was the strongest predictor (β =.23, *p*<.001). Other significant predictors differed from the first model, and included using a PC (β =-.19, *p*=.001), console device (β = -.16, *p*=.002) or a smartphone (β =.14, *p*=.004) for gaming, as well as having a parent that discussed cybersafety (β = -.10, *p*=.043).

Discussion

The current study examined a range of factors that may influence adolescents' gaming behaviour, including device accessibility and portability, as well as parental regulation of gaming. The portability of devices has been suggested to contribute to increased levels of internet usage (ABS, 2011a), however it was unknown if this also applied to gaming behaviour. The current study found that, overall, portability of devices (e.g., iPads, smartphones) was not a key factor determining gaming behaviour of Australian adolescents. This was consistent with research demonstrating that gaming represents only 2% time spent on social networking sites, a dominant use of more portable devices (ABS, 2011a; ACMA, 2013), as compared with 78% time spent for social-based activities (Hughes & Morrison, 2013).

Parental monitoring is often considered a useful strategy to control or limit adolescents’ gaming. However, it was found that parental discussion of cybersafety was the only significant predictor of the number of hours adolescents spent gaming on both weekdays and weekends. Although small significant correlations were found between hours spent gaming with parents being physically present whilst online, parents limiting online content, and parent seeing what adolescents were doing online, these strategies did not predict adolescents’ gaming in regression models. This finding could be argued to be due to shared variance between differing parental strategies. However, despite three quarters of adolescents stated their parents had spoken to them about cybersafety, it is concerning that 75% of adolescents also reported their parents rarely or never limited online content, and 74 % rarely or never enforced limits on time online. ‘Mediation’ parental regulation has been found to predict levels of internet usage (Eastin, Greenberg, & Hofschire, 2006; Ihmeideh & Shawareb, 2014; Valcke, Bonte, De Wever, & Rots, 2010), but this relationship did not apply to this sample of Australian adolescents, despite Australian guidelines suggesting parents should “consider implementing family agreements about the amount of time your children can spend online” (ACMA, n.d. p. 8). In contrast 80-90% of parents in 2011 reported they supervised their child or adolescents use of the internet (ABS, 2011a). There appears to be a notable disconnect between what parents say and what parents do, or at least what adolescents say, when it comes to limit setting around their media use. The present study was unable to determine reasons behind this discrepancy, thus further investigations should identify crucial barriers to parental media limit setting (e.g., social support; Lampard, Jurkowski, & Davison, 2013).

The key components of accessibility significantly influencing adolescent gaming behaviour (weekdays & weekends) were the number of devices owned, and having access to a computer in the bedroom to play games. Consistent with previous research (NSF, 2006; Rideout, 1999), it was found that a majority of adolescents (64%) had access to a gaming device in their bedroom. However, our findings indicated that a larger number (64% vs 33-50%; (NSF, 2006; Rideout, 1999) of adolescents have gaming accessible devices in their bedrooms than in previous research, and more importantly are using them to play games. The current study has extended current knowledge of the influence of this gaming accessibility demonstrating this influences the gaming behaviour of Australian adolescents. Unfortunately, it appears many parents are providing their adolescent children with accessibility to gaming-capable devices to ensure parental privacy is maintained or to provide adolescents with escapism (Livingstone, 2007).

Limitations and Future Directions

The present study had some limitations that warrant caution in interpreting results. First, the study employed a self-report survey, which relied on adolescents' perspectives. Including a parent-report would help to validate adolescents' reports. Another limitation was the sample was primarily comprised of students from high SES areas, which has been argued to be a key factor in the 'digital divide' which drives access to media (Livingstone & Helsper, 2007). As a counterpoint, the increasing affordability and high number of gaming devices available in secondary trading markets over the last several years may have reduced the digital divide across socio-economic divisions. The current study aimed to assess the influence of contributing factors that increase gaming, and limiting factors. However, our study did not assess social motivations which is an established contributing factor to gaming during adolescence (Cole & Griffiths, 2007; Colwell & Kato, 2003; Domahidi, Festl, & Quandt, 2014; Trepte, Reinecke, & Juechems, 2012). Parents may themselves form a social influence on adolescents (e.g., through ‘co-gaming’ or ‘co-using’; Coyne et al., 2011; Sook-Jung & Young-Gil, 2007), or may apply both co-gaming and restrictive mediation depending on their expected behavioural outcome (Nikken & Jansz, 2006). The extent to which supervisory or limiting parental practices are more effective than co-gaming techniques as a way for parents to limit amount of time spent playing computer games during adolescence remains unclear and warrants further investigation.

Conclusion

Videogaming is a common activity among adolescents with the potential for negative consequences if uncontrolled (Smyth, 2007). Although there is growing recognition of adolescent videogaming as a potential clinical problem (King & Delfabbro, 2013), there have been few empirical studies that examine the influence of protective parenting practices. The present study has identified several key contributing and limiting factors that influence the gaming behaviour of adolescents, which deserve more attention in future research studies. The key findings were that playing on a console and gaming on a higher number of gaming-equipped devices were associated with more hours of gaming, whereas parental discussion of cybersafety was associated with reduced hours of gaming. Further research should explore psychosocial barriers to limit setting (e.g., inconsistent parenting styles, conflictual parent-child relationships), so parents are ultimately better informed in ways to promote gaming in healthy moderation and reduce the potential risks for excessive gaming.

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CHAPTER 5: Intrinsic and extrinsic predictors of videogaming behaviour and adolescent bedtimes: the relationship between flow states, self-perceived risk-taking, device accessibility, parental-regulation of media and bedtime

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Research Aim 3:

To investigate the relationships between, the videogaming behaviour, intrinsic factors and extrinsic factors and sleep of adolescents.

Author Contributions

LS contributed to study design, literature search, data collection, statistical analysis, results interpretation and manuscript preparation. MG contributed to study design, results interpretation and manuscript preparation. DK contributed to results interpretation and manuscript preparation. MS contributed to results interpretation and manuscript preparation.

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Abstract

How computer games affect the time at which adolescents go to bed is of growing research interest, however, the intrinsic individual and extrinsic sociocultural factors that mediate the relationship between gaming and sleep has received minimal attention. This paper investigates how gaming duration mediates the relationship between intrinsic factors (perception of risky events, flow) and extrinsic factors (parental regulation, media accessibility) and adolescent bedtime. Adolescents (N= 422; age=16.3± 2.02 yrs, 41% M) from six metropolitan schools and Flinders University completed a questionnaire battery. More flow states (*r*=.34, *p*<.01) and increased accessibility (*r*=.21, *p*<.01) significantly predicted longer gaming duration whereas greater parental regulation (*r*=-.15, *p*<.01) predicted fewer hours spent playing videogames. Additionally, higher perception of the negative consequences of risk-taking (r= .14, p <.01) significantly predicted later bedtimes in adolescence. The relationship between flow and bedtime during adolescence was fully mediated by gaming duration (b=.142, *p*<.001), whereas the association between parental regulation and bedtime was independent of gaming duration. Flow and parental regulation of media were identified as key points for clinical intervention to decrease the duration of gaming of adolescents, thus promoting earlier bedtimes.

Introduction

Computer and videogaming are a prevalent social pastime for adolescents (Griffiths & Hunt, 1995; Griffiths, Davies, & Chappell, 2003). A recent survey of Australian adolescents aged 14-17 yrs reported that 74% use a computer to go online, 90% use the internet for entertainment purposes[3] and 84% of Australians aged 16-25 play computer or videogames (ACMA, 2014; Brand, Borchard, & Holmes, 2008). It is widely documented that devices for videogaming are becoming more available to adolescents in private settings, such as the bedroom. In the USA, 51% of children have access to 2 or more electronic devices in their bedroom and 72% have at least one electronic device in their bedroom, of which a tablet or computer was common (National Sleep Foundation, 2014). Computer gaming during adolescence has been linked to some negative outcomes, including poorer social relationships, lower academic achievement, higher body weight, and addiction (Hastings et al., 2009; Padilla-Walker, Carroll, & Jensen, 2010; Vandewater, Shim, & Caplovitz, 2004). Notably, poorer sleep resulting from gaming excess has been suggested as a mediator of the impairments in social and occupational functioning during adolescence (Cain & Gradisar, 2010; Wolfe et al., 2014). Reduced sleep is also linked to negative socio-emotional outcomes, including reduced concentration and memory abilities, increased daytime tiredness, anxiety, depression and poor inhibitory control (Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010; Manni et al., 1997; Rossa, Smith, Allan, & Sullivan, 2014; Wolfson & Carskadon, 2003).

Videogaming has been proposed to affect sleep through three possible mechanisms (Cain & Gradisar, 2010; Gradisar & Short, 2013); (i) the displacement of sleep (Eggermont & Van den Bulck, 2006), (ii) increasing mental/emotional/physical arousal (Ivarsson, Anderson, Åkerstedt, & Lindblad, 2009), and (iii) influencing 24-hr circadian rhythms/alertness due to bright light from screens (Higuchi, Motohashi, Liu, & Maeda, 2005). However, laboratory and field experiments have found little to no effect from gaming on young people's sleep.

Experimental studies comparing engaging and violent videogaming against control conditions (e.g., performing mental arithmetic, documentary viewing, and animated videogames) have identified extended sleep latency in the range of 3.1 to 6.9 (minutes; Higuchi et al., 2005; Ivarsson, Anderson., Åkerstedt, & Lindblad, 2013; Weaver, Gradisar, Dohnt., Lovato, & Douglas, (2010). An experimental study that involved longer duration of videogaming before bedtime (50 min vs 150 min) lengthened sleep latency by only 3.5 minutes in a group of experienced gamers (played on average 17 hours per week; King et al., 2013). Likewise the effects of gaming on sleep duration are modest (Higuchi et al., 2005; Ivarsson et al., 2013; King et al., 2013). This empirical evidence aligns with new meta-analytic data showing that videogaming shows no relationship with both sleep onset latency and sleep duration (Bartel, Gradisar, & Williamson, 2015). Yet this meta-analysis (Bartel et al., 2015) and recent laboratory evidence (Reynolds et al., 2015) not only suggests videogaming delays bedtime, as per the displacement hypothesis (Eggermont, & Van den Bulck, 2006) but that intrinsic and extrinsic factors (e.g., SES, parental control, age) may also play a role (Cain & Gradisar, 2010). Delaying bedtimes, particularly during the week, can alter the timing of an adolescents' sleep and circadian rhythm (Crowley & Carskadon, 2003; Taylor, Wright,& Lack, 2008) could create difficulties getting to school in a timely manner, shortening the time available prior to school to achieve adequate nutritional intake (e.g. skipping breakfast), requiring after school naps therefore reducing chances to engage in social clubs or sports or similarly causing them to sleep in on weekends to 'catch up' on missed sleep (Taylor et al., 2008) resulting in missed opportunities to engage in morning scheduled activities.

Gaming factors

Later bedtimes appear to be the sleep parameter most consistently associated with longer duration of playing computer games therefore consideration of what factors predict the length of time an adolescent plays computer games is crucial to enable earlier bedtimes during adolescence. Accessibility, defined as the number of devices an adolescent owns, is the stronger predictor of how long an adolescent spends playing computer games during weekdays and weekends (Smith, Gradisar, & King, 2015). Higher quantities of bedroom technologies have also been shown to lead to reduced sleep duration in adolescents (Arora, Broglia, Thomas, & Taheri, 2014). As gaming duration reduces the amount of sleep obtained by adolescents due to the displacement of sleep (i.e., later bedtime; Wolfe et al., 2014), and accessibility predicts gaming duration (Smith et al., 2015), accessibility can be seen as an important precursor in explaining the relationship between gaming and sleep during adolescence.

Intrinsic factors

Intrinsic factors are those within the adolescent themselves that are related to how they experience computer gaming and thus may be associated with gaming and sleep for these adolescents. Few studies looking at gaming and sleep in adolescents look at individual or intrinsic factors, although it has been argued that “future studies should collect more data about background characteristics of the participants” (Ivarsson et al., 2013 p. 395). Adolescence is noted as a period of heightened risk-taking due to a lack of maturation in socio-emotional brain regions, resulting in reduced cognitive control and a propensity for thrill-seeking (Steinberg, 2004). When adolescents are given unrestricted computer gaming without parental regulation, those with lower perceptions of the negative consequences of risk-taking play for longer and self-select later bedtimes (Reynolds et al., 2015). Reynolds and colleagues suggest adolescents with lower perceptions of the negative consequences of risk-taking may be more likely to use technology later in the night, therefore displacing sleep (Reynolds et al., 2015). The extent to which an adolescent is inclined towards risk-taking therefore represents an important factor which may mediate the relationship between computer gaming and sleep.

‘Flow’ may also predict an adolescent’s ability to break away from an enjoyable game therefore displacing sleep. Flow is a subjective positive state of intense immersion in an activity that has been described as “flowing from one moment to the next, in which he is in control of his actions, and in which there is a little distinction between self and environment, between stimulus and response, between past, present, and future” (Csikszentmihalyi., Larson, & Prescott, 1977 p34). An individual’s flow experience predicts their behavioural intentions towards engaging in technology (Hsu, & Lu, 2004). Adolescents typically underestimate how long they spend playing computer games (i.e., rating videogaming as shorter in duration than reading; Tobin, & Grondin, 2009). Flow states, in adults, enhance one’s loyalty to games and sustain gameplay via creating optimal and enjoyable experiences (Choi, & Kim, 2004). Flow states are experienced in 89% of adults who play for as little as 5 or more hours per week (Hoffman & Nadelson, 2010). There has been limited research on flow in adolescent samples, despite adolescents experiencing flow to a greater degree than adults (Rau, Peng, & Yang, 2006; Voiskounsky, & Wang, 2014). As adolescents who experience flow states experience time distortion (Tobin, & Grondin, 2009), adolescents who experience flow when gaming may be more likely to have their sleep displaced due to losing track of time and having later bedtimes.

Extrinsic factors

Extrinsic factors are those external to the adolescent, such as social factors or parenting and have been suggested to play a role in media usage during adolescence (Cain & Gradisar, 2010). Parental monitoring and limit-setting has an important role in assisting adolescents to break away from gaming. As a result of in-game experiences such as flow, which causes time distortion, both novice and experienced adolescent gamers have difficulty breaking off without external intervention (Rau et al., 2006). Parents also play an important role in regulating pre-sleep gaming through the enforcement of limits and boundaries (Van den Bulck & Van den Bergh, 2000). Australian data suggest that parental involvement in adolescent media use is relatively limited. A study by Smith and colleagues found that 75% of adolescents' parents 'rarely' or 'never' limited their online content, or location, or time of use (Smith et al., 2015). Furthermore, more stringent parental limit setting (i.e., content, physical presence, ability to see online activity, and speaking to adolescent about cybersafety) were predictive of reduced time adolescents spent playing computer games on weekdays and weekends (Smith et al., 2015). However, it is unclear if parental regulation of media usage/gaming will predict adolescent bedtimes.

The Present Study

We aim to test a single comprehensive model (see Figure 5.1), based on available evidence, of how gaming affects the bedtime (and thus sleep) of adolescents. The model integrates precursors of gaming behaviour (i.e., accessibility), key components of gaming behaviour (duration) suggested to be predictive of bedtime and theoretically supported mechanism (i.e., mediators) of this relationship (risk-taking, flow and parental regulation). We will also provide additional support to established pathways (i.e., displacement) between gaming behaviour and bedtimes (Van den Bulck, 2010). Moreover, by assessing which factors (risk-taking, flow and parental limit setting) are key predictors of gaming and sleep, the current study will identify ideas for intervention for adolescents whose poor sleep is associated with their gaming behaviour.

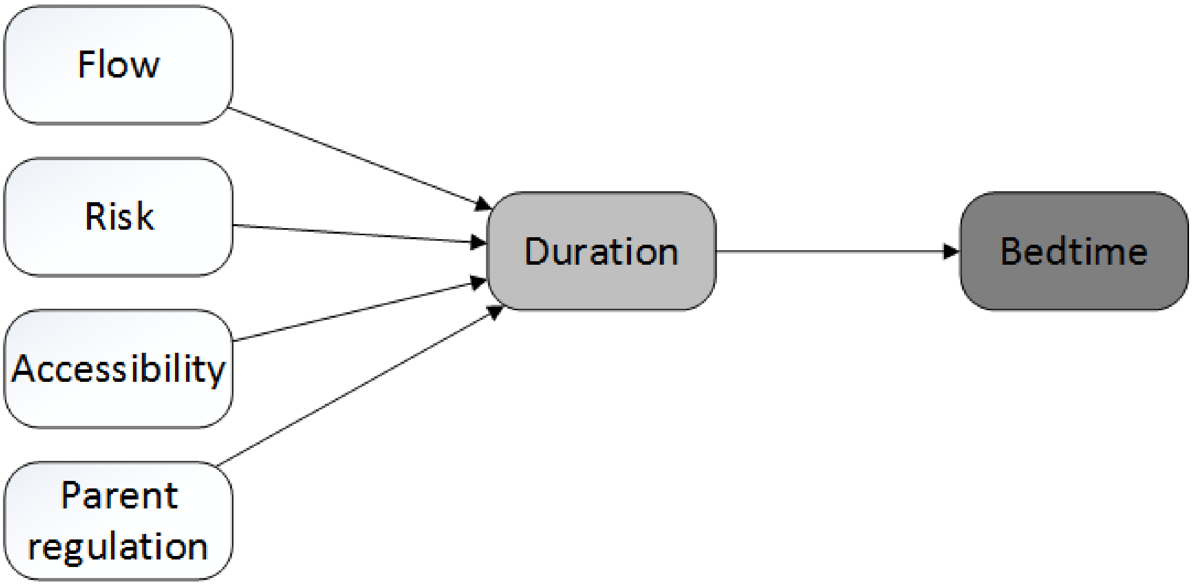

Figure 5.1. Proposed model of how aspects of gaming predict adolescent sleep and the mediator of this relationship. Risk= perceptions of negative consequences of risk-taking; Flow = Flow states experienced whilst playing computer games; Accessibility= number of devices owned; Parent regulation= monitoring and rule setting about media use.

Methods

Participants

South Australian adolescents (N= 422; age=16.3± 2.02 yrs, 41% M) were recruited from five Adelaide metropolitan high schools (4 public schools & 1 private school) and from Flinders University. Inclusion criteria was age between 12-20 years; other than age no further specific exclusion criteria were applied to participant's, e.g. co-morbid mental health conditions. During weekdays, most adolescents (56.6%) played computer games between 5-8pm or 8-11pm and played for 2.85 hrs (±2.5). The age range chosen reflects common conceptualisations that adolescence (defined by biological sleep markers, neuropsychological structure/function and social roles) extends beyond 18 years (Bennett & Baird, 2006; Degner, 2006; Giedd et al., 1999; Roenneberg et al., 2004; Steinberg, 2009, 2011). The majority of adolescents lived with both parents (69%), were Oceanian (e.g. Australian, Australian

Aboriginal or South Pacific Islander) in ethnicity (76%), and lived in high SES areas[2]. Young adults in Australia, typically remain residing at home with their parents rather than in dormitories whilst attending University and therefore, experience a home environment with parental controls similar to adolescents attending high school (Reynolds et al., 2015). Informed consent was provided by adolescents proceeding past the introductory page of the online survey and participants were able to withdraw by closing down the browser window. Ethics approval for the study was granted by the Flinders University Social and Behavioural Research Ethics Committee and the Department of Education and Child Development. Adolescents were reimbursed at the end of the survey by making an AUD$1 donation to a charity of their choice from a list of youth well-being charities. University students received course credit for their participation. Response rate for the survey was 72% (survey completed after viewing of information page).

Materials

Gaming behaviour

Accessibility was conceptualised as the number of devices owned by an adolescent (Smith et al., 2015). Duration was assessed by asking adolescents '*How many hours do you play computer games per weekday?*' Participant's responded by selecting from the options of less than 1 hour, 1-2 hours, 2-3 hours , 3-4 hours up to 10 hours of more of gaming per weekday.

Extrinsic and Intrinsic factors

'What Parents Say and Do' (WPSAD): The relationship between parental regulation, gaming and sleep was assessed via the WPSAD questionnaire (King, n.d.). This 8-item questionnaire asks adolescents if their parents had discussed cyber-safety (yes/no), or set rules and limits for online content, use and accessibility, and engaged in physical monitoring

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[2] SEIFA score=7.13 (range=1-10; higher scores = higher SES).

of media use and parent's own media behaviour (see Supplementary File). However, as the present study was interested in parental regulation, items 7 and 8 (parent's media behaviour) were not included in analyses. All questions had responses ranging from *Never* (0) to *Always* (4), except for questions with binary responses (i.e., cybersafety). Total scale scores ranged from 0 to 20, with higher scores indicative of more stringent parental regulation of media and internet use. Internal consistency of the WPSAD was α= 0.76. Adolescents were also asked about parental limit setting on their bedtimes (parent-set bedtime) using the following question: '*do your parents set your bedtime on weeknights'*? '

Cognitive Appraisal of Risky Events (CARE): The relationship between perception of risk-taking, gaming and sleep was assessed using a modified version of the CARE (Fromme, Katz, & Rivet, 1997), using only the modified expected risks scale of the CARE, as in previous research only expected risks (not expected benefits) predicted gaming behaviour and bedtime (Reynolds et al., 2015). Adolescents were asked how likely is it that they would experience some negative consequence (expected risks; e.g., *become sick, be injured, lose money, suffer legal consequences, fail a class, or feel bad about yourself if they engaged in risky activity*). Adolescents were asked about 16 risky activities (e.g., playing drinking games, not studying or working hard enough or mixing drugs and alcohol). Responses ranged from 1 (*not at all likely*) to 7 (*extremely likely*) in response to the likelihood of negative consequences of the risky activity (expected risks). Total scores for the expected risks subscale range from 6-42 with higher scores indicative of lower risk-taking behaviour. The internal consistency for the expected risks scale in this study was α=0.95.

Game Engagement Questionnaire (GEQ): The relationship between flow, gaming and bedtime was assessed using the flow subscale of the GEQ (Brockmyer et al., 2009). Adolescents were asked 9 questions that measure the flow dimension of game engagement, for example, '*If someone talks to me I don't hear'*, '*I feel like I can't stop playing'* and

'*Playing seems automatic'*. Items are scored on 3-point Likert scale (*No/Sort of/Yes*). Possible scores range from 9 to 27 with higher scores indicating higher levels of engagement with computer gaming. Internal consistency for the GEQ has been found to be high in previous research (α= 0.96) and in the current study (α= 0.91).

Outcomes

Bedtime was the sleep parameter of interest in the current study, drawn from a modified version of the School Sleep Habits Survey (Wolfson & Carskadon, 1998). Bedtime was assessed by asking adolescents to specify the bed hour, minute and meridian they went to bed on weekdays.

Statistical analyses

The mediation model outlining that duration of gaming mediates the effects of the predictor variables (Flow, Accessibility, and Parental Regulation and Risk) was tested using the standard procedure for mediation (Baron & Kenny, 1986). The assumption that each independent variable within a mediation model should be significantly related to the mediator variable (MV; gaming duration) was tested using Pearson's correlations, as well as confirming the MV (gaming duration) was correlated with the DV (school night bedtime). To test mediation, a series of linear regression analyses were conducted in the following order: (1) relationship between the independent variable (IV) and the mediator variable (MV), (2) relationship between the MV and the dependent variable (DV), (3) The IV and DV controlling for covariates (age, gender), and (4) a reduction in the relationship between IV and DV after controlling for MV and covariates (age, gender). Sobel's test was also conducted to determine if the reduction in the relationship between the IV and the DV (after controlling for MV and covariates) was significant. Factor analysis was conducted on the WPSAD to determine if parental regulation of gaming was a unitary factor. In line with

Cattell's scree test[48] there was a clear break after the first component, which meant a one factor variable was retained for analysis.

Results

Adolescents, on average, went to bed at 10.59 PM on school nights, played games during school nights for 2 hrs and 44 min (SD=2.33 hrs) and owned 3 of their own media devices (M=3.25, SD=2.2) (see Table 5.1). Table 5.2 presents the Pearson's correlations between intrinsic and extrinsic factors (IV), gaming duration (MV), and bedtimes (DV). IVs related to both the MV (gaming duration) and the DV (bedtime) included flow and parental regulation. Although risk-taking was related to school night bedtimes, it was not correlated with gaming duration. Accessibility was related to gaming duration, yet not to bedtimes. With the removal of risk and accessibility, all pre-conditions for mediation were met for the IVs of flow and parental regulation (Baron & Kenny, 1986).

Table 5.1

Means and standard deviations of intrinsic and extrinsic factors mediating gaming and mediating and outcome variables

Variable	**M**	**SD**	**Range**
1. Flow	12.99	3.94	8-24
2. Accessibility	3.25	2.20	0-18
3. Parental Regulation	7.64	4.40	1-21
4. Risk	71.97	33.31	20-134
5. Gaming duration (per day)	2.74	2.33	1-11
6. School night bedtime (hr, meridian)	10.59 PM	1.47	8:00PM-6:00AM

Table 5.2

*Correlations among flow, accessibility, parental regulation, risk, gaming duration and school night bedtime (Note. N= 366 *p<.01. **p<.05)*

Variable	**1**	**2**	**3**	**4**	**5**	**6**
1. Flow	1.0	.153*	-.132**	.060	.340*	.171*
2. Accessibility	-	1.0	-.044	-.006	.209*	-.010
3. Parental Regulation	-	-	1.0	-.172*	-.150*	-.249*
4. Risk	-	-	-	1.0	-.070	.139*
5. Gaming duration	-	-	-	-	1.0	.142*
6. School night bedtime	-	-	-	-	-	1.0

The findings from the linear regressions indicated that both flow, $F(1,364)=47.48$, $p< 0.001$, and parental regulation, $F(1, 364) = 8.37$, $p = 0.004$, accounted for a significant amount of variance in gaming duration (11.5% and 2.2%, respectively), supporting criterion 1 for mediation. In accordance with criterion 2, gaming duration accounted for a significant amount of variance in school night bedtime (2.0%), $F (1, 364) = 7.46$, $p = 0.007$. Two separate linear regressions were conducted for the two IVs (flow, parental regulation), with age and gender entered as covariates, in accordance with step 3 of mediation. Age and gender accounted for a significant amount of variance in week night bedtime (14.9%). Flow explained an additional 2.9% of the variance, $F (1, 359) = 12.71$, $p <0.001$, and parental regulation accounted for an additional 0.9% of the variance in bedtime, $F (1, 359) = 4.04$, $p=0.045$. In the final step where gaming duration was entered as the MV between the IVs and the DV (whilst controlling for covariates), reductions were found in the standardised beta coefficients for both IVs (see Table 5.3). However, Sobel's test indicated that partial mediation occurred for flow, with an indirect direct effect between flow and bedtime via gaming duration. A beta co-efficient of .140 in the final stage of the mediation also indicates a direct association between flow and bedtime. A significant relationship exists between parental regulation and bedtime which becomes non-significant when gaming duration is introduced - however, the sobels test was also not significant, suggesting, the drop in the effect size was not large enough to warrant mediation.

Table 5.3

Test of mediational relationships (controlling for age and gender)

	Standardised Beta Coefficients (b)				
Mediational Chain: **IV→MV→DV**	IV→MV	MV→DV	IV→DV	IV→DV/MV	Sobel's Test of the Significance of Mediation (z)
1. Flow	.340***	.142**	.177***	.140**	2.14*
2. Parental Regulation	-.150**	.142**	-.109*	-.085	1.14

Note. N-366. DV= school night bedtime; IV= independent variable (Flow, Parental Regulation); MV= mediator variable (gaming duration). *p<.05. **p<.01. ***p<.001.

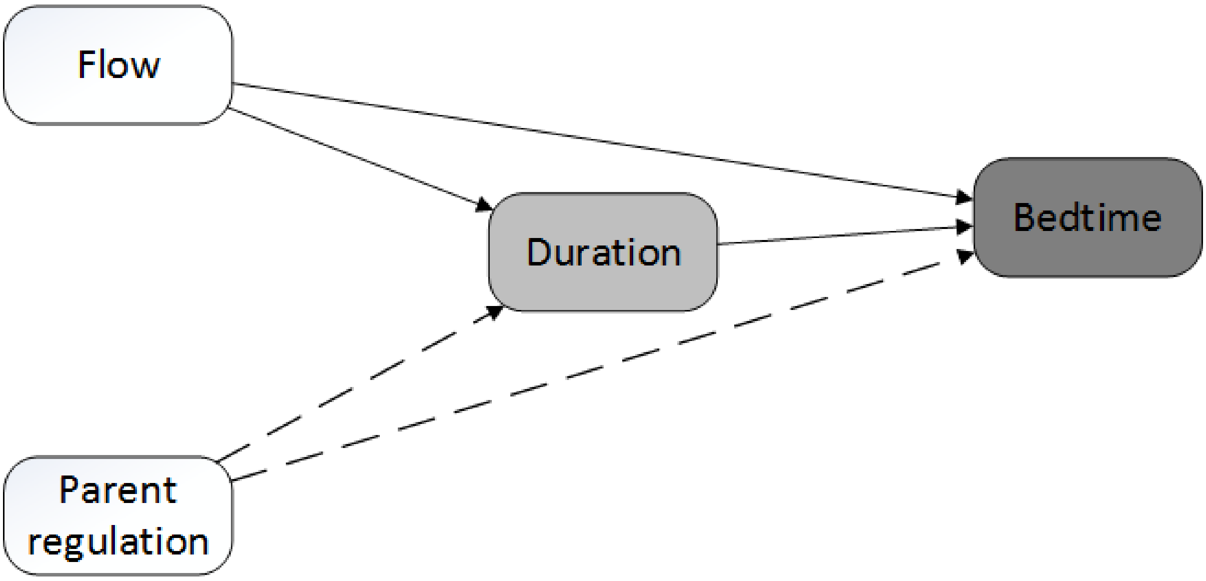

Figure 5.2. Final model of intrinsic and extrinsic predictors of the relationship between gaming and sleep. Within the final model- solid line= significant relationship, dotted line= not significant relationship

Discussion

The current study investigated the role of intrinsic (i.e., flow, risk) and extrinsic factors (i.e., parental regulation, accessibility) on the gaming behaviour and bedtime of adolescents. It was found that risk, although significantly correlated with bedtime, did not correlate with gaming duration. Similarly, accessibility was significantly correlated with duration of gaming but not with bedtime. With flow and parental regulation remaining as predictors, mediation analysis demonstrated that the effect of parental regulation on bedtime was not dependent on the amount of time an adolescent spends playing computer games, whereas the relationship between flow and bedtime was partially mediated by the length of time an adolescent spent playing computer games- there was also a direct link between flow and bedtime. This study is, to our knowledge, the first to demonstrate that flow experiences are an important intrinsic predictor when considering the mechanisms through which gaming is associated with adolescent bedtimes (Cain & Gradisar, 2010). The current study provides an empirically supported model specific to gaming that identifies the key intrinsic and extrinsic factors that predict what time adolescents are going to bed (Bartel et al., 2015).

Overall, the current study demonstrates that flow states are a key predictor of how long an adolescent spends gaming and what time they go to bed. The significant links between flow, gaming duration and bedtime suggests adolescents have difficulties breaking away from gaming, thus providing further empirical support for the displacement hypothesis of delayed bedtimes due to technology use (Cain & Gradisar, 2010; Eggermont & Van den Bulck, 2006; Gradisar & Short, 2013; Reynolds et al., 2015; Van den Bulck, 2010) and a key point for intervention (see *Clinical Implications* section below). However, flow also has its own direct relationship with bedtimes, suggesting there may be other possible mechanisms other than gaming duration (e.g. time distortion).

Risk, or the extent to which adolescents perceive the consequences of risk, is another understudied factor when investigating the association between the technology use and sleep of young people. The current study found that adolescents who perceived more negative consequences from risk had later bedtimes and also that perception of risk had no significant correlation with duration of gaming. Both the direction of the relationship between risk perception and bedtime and the lack of relationship between risk and gaming duration were inconsistent with Reynolds and colleagues who found that adolescents who failed to perceive consequences of risk played computer games for longer and chose later bedtimes (Reynolds et al., 2015). The discrepancy between these findings may be accounted for by differences in design and participants, for example Reynolds and colleagues obtained their findings within a controlled experimental setting where bedtime was measured objectively, game type was consistent across participants and participants were all male. Furthermore, these findings suggest that perception of risk may predict the time an adolescent goes to bed, but possibly through multiple activities not measured in the current study (e.g., phone use; Bartel et al., 2015). Adolescents might also be particularly poorer risky decision-makers when in groups than alone. When in peer groups adolescents focus more on the benefits (rather than costs) of risky decision making and make riskier decisions (Gardner & Steinberg, 2005). Therefore when adolescents are connected to peers via online games they might play for longer due to socially-facilitated risk perception. There is a plethora of survey studies of technology use and sleep in young people (Hale & Guan, 2015), yet little consideration other factors that are associated with technology use and sleep, such as personality characteristics or perception of risk-taking (Reynolds et al., 2015). Future research of pre-bedtime activities should consider incorporating assessments of perception of the consequences of risk and absorption and engagement in gaming (flow), other feasible intrinsic factors that may provide a more thorough understanding of what predicts the bedtimes of adolescents.

Accessibility was viewed to be an important predictor of gaming behaviour (Smith et al., 2015), however in the current study it did not predict bedtimes. Having multiple devices is simply not enough to predict adolescent bedtimes, and other factors (e.g., flow) appear to play a greater role. Although adolescents have high exposure to electronic media (ACMA, 2014; NSF, 2014; Rideout, Foehr, & Roberts, 2010), limited research has investigated the outcomes of high accessibility to media on adolescents' bedtimes. An adolescent owning a greater number of media devices (e.g. PlayStation, TV, smartphone, tablet, and laptop) is arguably a precursor to higher media usage (Smith et al., 2015). Parents are likely to be the facilitators of purchasing media devices, thus boundaries around media ownership could play an important role in how accessibility is associated with the development of an adolescents' gaming behaviour.

Parental regulation, broadly referred to in the scientific literature as parental mediation (Lee & Chae, 2007; Nikken & Jansz, 2006; Schaan & Melzer, 2015; Vaala & Bleakley, 2015), predicts the media consumption of children and adolescents. For example, restrictive mediation strategies by mothers, and evaluative strategies (discussion of the reality of the content of media) by the father, predict the computer game usage of girls (Van den Bulck & Van den Bergh, 2000). Similarly, the current study found that parental regulation strategies significantly predicted the amount of time spent playing computer games, regardless of gender. As children move into adolescence, parental regulation might be an important predictor of adolescents' gaming behaviour, as the child's age has been shown to be the strongest predictor of parental mediation of videogaming (Nikken & Jansz, 2006). The current study extends previous research on parental mediation of media usages in children and adolescent by investigating the outcomes (i.e., bedtime) of parental mediation of gaming. Although we found parental regulation predicted bedtime, parental regulation was not associated with bedtime due to parental regulation of gaming duration. Thus, although the present study supports the notion that reduced parental regulation is associated with lax bedtimes (Gangwisch et al., 2010; Short et al., 2011), it appears parents do not fully exercise parental controls by regulating their adolescent child's computer game playing. Parents may be able to exercise a greater control over the timing of game-play if they set a time-point when to stop playing computer games at night (e.g. at 9pm or 10pm); this would be helpful for ensuring adequate bedtimes of adolescents as it could remove the displacement of bedtime due to gaming close to bedtime.

Clinical Implications

The model tested in the present study identified two key areas through which adolescent gaming might be curbed to reduce the association with later bedtimes. Flow states are by definition absorption and immersion in an activity (e.g. media, computer gaming), which can cause time distortion (Tobin & Grodin, 2009) and result in difficulty with breaking away and ceasing that activity. Enabling an adolescent to break-away may enable an earlier bedtime. Two key ways to enforce breaks are parental monitoring and/or software solutions (e.g. micropause programs). Parental monitoring may include a) physical presence in the same room as the adolescent when playing computer games, b) observing what adolescents are doing online, c) setting limits to online content, d) setting limits about the duration of time spent online, e) and speak to them about cybersafety (Australian Institute of Family Studies, 2015). However, our study indicates that currently these guidelines are minimally employed by parents and this was significantly associated with both gaming duration and bedtimes of adolescents in Australian population.

With regard to flow, software solutions/programs (e.g., SmartBreak, WorkRave, WorkPace) to enforce breaks, and therefore interrupt flow, could be sourced from the occupational health and safety field. Such software programs are employed to enforce employees to take short breaks to prevent the onset of fatigue and musculoskeletal issues, and enforcement of pauses yields more breaks from computer usage than would occur by the user naturally (Slijper, Richter, Smeets, & Frens, 2007). Alternatively, more readily accessible devices such as alarm clocks could be employed by parents (Reynolds et al., 2015). Future research should focus on how the relationship between flow, gaming and bedtime, could be mitigated by such interruption strategies (e.g., within game consoles (e.g., X-Box 360; Microsoft, 2015), game patches, or external parental interruption) but that there is a balance between limit setting and flow which still allows maintenance of player enjoyment. Finally, whilst flow was found to be a key predictor of gaming and bedtimes, future studies should investigate flow's relationship with other pre-bedtime activities (e.g., social networking, reading, etc.).

Limitations

The current study provides empirical support for the displacement hypothesis (Van den Bulck, 2010) with longer time spent gaming being related to significantly later bedtimes. However, the question of causation needs to be considered, specifically if media is causing adolescents to go to bed later or if they are choosing go to bed later because they are unable to fall asleep and therefore use media of their choosing to fill this gap (Tavernier & Willoughby, 2014). Due to the cross-sectional nature of the current research we are unable to determine the direction of the effect between gaming behaviour and investigating how intervening in gaming behaviour would impact on self-selected bedtimes would help to answer the above mentioned question. The current research could be complemented by the use of objective measures of computer game playing, for example experience sampling methods which have been well utilised to document flow experiences (Moneta, 2012) or adolescents "checking in" with researchers (e.g. via a telephone call) to confirm bed and wake times (with date and time stamps on these telephone calls; Short et al., 2011) to provide objective measures of bed, wake time and TST- which is preferred over actigraphic methods as concerns have been documented about the reliability for measuring sleep during adolescence (Short et al., 2012). The findings of the present study were also drawn from preliminary analysis of the WPSAD measure, assessment of the reliability of findings involving the concept of parental regulation will require further psychometric validation of the WPSAD scale. The findings may also be limited by a lack of explicit reference to computer gaming within the WPSAD scale, however a general parenting approach to media regulation may be more informative and easier for participants to recall and we have no theoretical reason to expect that a parent would not set similar time limits on similar media e.g., unlimited social media but not games. Generalisability of current findings could also be improved by recruiting adolescents from across the socio-economic spectrum.

Conclusion

The key intrinsic factor predictive of bedtime during adolescence was flow, which was fully mediated by gaming duration. The relationship between external factors (i.e., parental regulation) and bedtime was independent of gaming duration. The finding that flow is a key predictor is novel and as such requires replication using survey and experimental methods. Moreover, research testing the feasibility of manipulations of flow states and parental regulation in ensuring earlier bedtimes and thus healthier sleep are warranted. The current study adds to a small but growing body of literature in this field and provides a clinically useful model indicating possible points of intervention to reduce gaming duration, therefore reducing the likelihood that gaming will displace other activities such as sleep. Tackling such issues of causation will be vital for researchers to guide clinicians working with adolescents with both sleep difficulties and who engage in sustained gaming, particularly at night, to form evidence-based treatment protocols.

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CHAPTER 6: Mechanisms Influencing Older Adolescents’ Bedtimes during Videogaming: The Roles of Game Difficulty and Flow

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Research Aim 4:

To explore the mechanisms (e.g., arousal, displacement) by which individual factors influence the relationship between videogaming and the sleep of adolescents.

Author Contributions

LS contributed to study design, literature search, data collection, statistical analysis, results interpretation and manuscript preparation. DK contributed to design, results interpretation and manuscript preparation. CR contributed to data collection and manuscript preparation. BR contributed to design and manuscript preparation. MG contributed to study design, data analysis, results interpretation, and manuscript preparation.

Smith, L.J., King, D.L., Richardson, C., Roane, B., & Gradisar, M. (under review) *Mechanisms influencing bedtimes during videogaming in a sample of adolescents: the role of flow states, game difficulty and heart rate*

CHAPTER 6: Mechanisms influencing Older Adolescents Bedtimes during Videogaming

Abstract

A relationship between evening technology use and sleep has been established, and models suggest various mechanisms to explain this relationship. Recent updates to these models also suggest the influence of individual difference factors, such that the relationship between technology and sleep varies between young people. Flow is an experience of immersion and time distortion that could vary between adolescents when using technology. The aim of the present study was to investigate the effects of flow on the self-selected bedtimes of adolescents when videogaming. 17 older adolescent, experienced videogamers (age=15.9±0.83 yrs) played a new videogame on two school-night evenings in a sleep laboratory. Game difficulty was set to 'hard' one evening (flow condition), and the other set to 'easy' (disrupted flow). Measures of trait and state flow were taken, along with heart rate during videogaming, and bedtime measured objectively with real-time cameras. An interaction effect for heart rate indicated an elevated heart rate in the easy condition after 150-min of gaming (p<.02). No significant differences were found in bedtimes between the easy and hard conditions (p=.77). Adolescents high on trait flow played for longer and selected significantly later bedtimes than their low trait flow peers, but only for the hard (flow) condition (12:22 A.M vs 10:53 P.M, p=.004). Likewise, adolescents with high state flow went to bed significantly later than those low on state flow (12:24 PM vs 10:52 PM, p=.001), again, only in the hard condition. These findings suggest that individual and situational characteristics may amplify the effects of technology use on the 'sleep' of adolescents, and provides support for the displacement of bedtime hypothesis.

Introduction

Over recent decades, society has witnessed dramatic changes in young people’s pastimes. For example, around twice as many children and adolescents use Facebook daily these days than play sport (Macpherson, 2013). Videogaming has been present over many decades, yet is also an increasingly popular activity and social pastime during adolescence, with increases between 12-35% over the past few years (ABS, 2011; Flamberg, Pike & Woodrick, 2015). Average daily videogame usage of adolescents is at least 1 hr duration (Brand & Todhunter, 2015; Rideout, 2016), yet 1 in 3 adolescents play videogames between 3 and 9 hrs daily on weekdays (Smith, Gradisar, & King, 2015). Consistent with increased usage is that technological devices are also becoming more accessible. Accessibility to sole owned media devices (but not shared devices) predicts the number of hours spent videogaming on weekdays and weekends (Smith et al., 2015). It is therefore unsurprising that the expansion of videogaming during an adolescent’s day has the potential to displace (i.e., delay) their bedtime, and thus sleep (Van den Bulck, 2010; Cain & Gradisar, 2010; Exelmans & van den Bulck, 2017). Delayed bedtimes in the context of fixed wake-up times (e.g., due to school) that occur during adolescence can lead to the truncation of the sleep period and sleep restriction (Carskadon, 2011), which in turn can have negative socio-emotional, cognitive and functional consequences (Beebe, 2011; Dewald, Meijer, Oort, Kerkhof, & Bögels, 2010; Shochat, Cohen-Zion, & Tzischinsky, 2014). However, although school week wake-up times remain fixed for adolescents, there is individual variability in extrinsic (e.g., parent-set bedtimes, access to technology) and intrinsic factors (e.g., perception of the consequences of risky events), which may influence bedtimes, and therefore sleep timing and total sleep time (Ivarsson, Anderson, Åkerstedt, & Lindblad 2013; Reynolds et al., 2015; Short et al., 2011; Smith et al., 2015). Identifying which adolescents may be ‘at risk’ is important to prevent detrimental effects on their overall health and well being.

A recent systematic review reported that videogaming is associated with both delayed bedtimes and reduced sleep quantity in adolescent samples (Hale & Guan, 2015). Quantification of these studies shows a small effect of increased use of videogaming with delayed bedtimes (mean weighted r=0.12), yet a negligible effect with sleep (r=0.03; Bartel, Gradisar, & Williamson, 2015). Detailed analysis of experimental studies shows minimal influence of videogaming on sleep quantity (+2.9-10 mins; Higuchi, Motohashi, Liu, & Maeda, 2005; -7.3 mins; King et al., 2013). However, emerging evidence suggests that individual differences play an important role in the bedtimes of adolescents playing videogames. Adolescents who perceive fewer negative consequences of risky events self-select significantly later bedtimes (Reynolds et al., 2015), and "high exposed" videogamers experience reduced bedtime alertness as compared to "low exposed" videogamers following violent videogaming (Ivarsson, Anderson, Åkerstedt, & Lindblad 2013). Thus, it has been suggested that "*future studies should collect more data about background characteristics of the participants*" (Ivarsson et al., 2013, p. 395). The current study aims to investigate the degree to which a new individual difference factor may explain the relationship between videogaming and adolescents' bedtimes.

'Flow' has been identified as a key intrinsic factor influencing the duration of videogaming and the time at which adolescents choose to go to bed (Smith, Gradisar, King, & Short, 2017). Flow is defined as a psychological state whereby an individual experiences flowing "*from one moment to the next, in which he is in control of his actions, and in which there is a little distinction between self and environment, between stimulus and response, between past, present, and future*" (Csikszentmihalyi, Larson, & Prescott, 1977, p.34). Flow states are typically experienced during enjoyable and engaging activities including, but not limited to, reading and technology use, and time distortion may be experienced by individuals when immersed in a flow state (Rau, Peng, & Yang, 2006; Skadberg & Kimmel, 2004, Tobin

& Grodin, 2009; Wood, Griffiths & Park, 2007). It is proposed that technology use, such as videogaming, creates an optimal flow state when there is a balance between difficulty or challenge of the media, and the skill of the player (Sherry, 2004). Flow may therefore be an important factor influencing the relationship between videogaming and sleep, due to the fact adolescents lose track of time and therefore bedtime can be displaced.

Flow can be further differentiated into ‘trait flow’ and ‘state flow’. Trait flow is the innate disposition for an individual to experience flow during activities, whereas state flow is the extent to which flow is experienced in a particular activity (Jackson, Eklund, & Martin, 2010). Moreover, trait flow is closely linked to personal characteristics (e.g., extraversion; Heller, Bullerjahn & von Georgi, 2015). The distinction between trait and state flow has been made during various engaging activities, such as music and sport (Chirico, Serino, Cipresso, Gaggioli, & Riva, 2015; Marsh & Jackson, 1999). However, despite research demonstrating the existence and importance of flow during technology use and videogaming (e.g. Rau et al., 2006; Smith et al., 2015; Wood et al., 2007), to our knowledge, no studies have investigated the extent to which flow experiences are more trait driven (i.e., individual factor) or state driven (i.e., engendered by the conditions of the environment). The current study will investigate the degree to which trait and state flow experiences influence videogaming duration, and in turn, adolescents’ self-selected bedtimes, in a controlled laboratory environment.

We expect that game difficulty will be related to the amount of flow (state and trait) experienced during videogaming. This is based on the findings that flow is produced by a balance of challenge and skill (Sherry, 2004). Indeed, game developers are acutely aware of sustaining users engagement by using artificial intelligence (i.e., dynamic game balancing), that automatically balances the game experience away from boredom (too easy) and frustration (too challenging; Andrade et al., 2005). Therefore, we expect when skill is held constant, for example in a sample of experienced videogamers, that differences in boredom/challenge (e.g., ‘easy’ vs ‘hard’) will produce differing amounts of flow. Secondly, we anticipate that there will be a positive relationship between state or trait flow experiences and self-selected bedtimes after videogaming. This proposition is based on research which demonstrates that flow states are related to time distortion during videogaming (Rau et al, 2006; Skadberg & Kimmel, 2004, Tobin & Grodin, 2009; Wood et al., 2007). If adolescents experience time distortion during time-naïve conditions, this time distortion will lead to a displacement of bedtime.

Methods

Participants

We recruited 17 male and female participants (M= 15.9±0.83, 15-17 yrs, m=12, f=5) through Facebook advertising, Flinders University website advertisements, and via emailing local Adelaide metropolitan high schools. The minimum age criterion of 15 yrs was chosen to ensure adolescents were able to play the MA15+ rated game. Adolescents completed a 20-min screening telephone interview. Screening comprised of questions on videogaming behaviour (Gamer Experience Survey; Boot, Kramer, Simons, Fabiani, & Gratton, 2008), sleep patterns and general health (General Information and Health Questionnaire; King et al., 2013; Weaver, Gradisar, Dohnt, Lovato, & Douglas, 2010). and mood (Depression Anxiety and Stress Scale: DASS-21; Lovibond & Lovibond, 1995). Inclusion criteria were; age between 15-17 yrs; no prior experience with the videogame; being a “good sleeper” (i.e., weekday bedtime within 1.5 standard deviation of 10.30pm (mean=10:16pm±64.6 mins; Short, Gradisar, Lack, Wright, & Dohnt, 2013; sleep latency <30 min, Buysse, Ancoli-lsrael, Edinger, Lichstein, & Morin, 2006; a self-perceived sleep difficulty staying or falling asleep of less than 2 nights/wk); and being an “experienced gamer” (self-rated active, frequent or expert videogame player, 76.5 % played “*frequently*” or “*often*”; and/or playing >1 hr of videogames/day; mean=9.8±8.1 hrs/wk). Exclusion criteria were; clinical levels of anxiety or depression; evidence of a sleep disorder (e.g., delayed sleep-wake phase disorder, insomnia, and/or restless legs syndrome); excessive caffeine consumption (>200mg per day; Pollak & Bright, 2003; Orbeta, Overpeck, Ramcharran., Kogan, & Ledsky, 2006); any cigarette, drug, or alcohol consumption (Johnson & Breslau, 2001; Patten, Choi, Gillin, & Pierce, 2000; Pieters, Van Der Vorst, Burk, Wiers, & Engels, 2010); or medications known to affect sleep (Wilson & Argyropoulos 2005). Informed consent was obtained from all adolescents' parents/guardians. Ethical approval was granted by the Flinders University Social and Behavioural Research Ethics Committee.

Design

The current study used a within-subjects design. The independent variable was game difficulty (easy, hard). The dependent variable was self-selected bedtime.

Materials

Technology use

Rise of the Tomb Raider (Square Enix, 2015) was chosen as it was a newly released (<6 mo), novel, single-player story-based game, which is thought to increase engagement in the experimental protocol (e.g., Cowley, Charles, Black, & Hickey, 2008; King et al., 2013; Reynolds et al., 2015). *Rise of the Tomb Raider* was one of very few games available that enabled manual manipulation of game difficulty (i.e., free from dynamic game balancing; Andrade et al., 2005). The average minimum completion time of 14-15 hrs (Connolly, 2015; How long to beat, 2016), was >9 hrs of total game play allowed across the 2 laboratory testing nights, and is a similar completion time to other games used in previous videogaming-and-sleep studies (Reynolds et al., 2015).

Self-selected bedtime

Bedtimes were defined as the time adolescents turned off the game console and TV in order to initiate sleep. Bedtimes were recorded in ‘real time’ via live video camera monitoring (TECHview IP Camera Model QC-3832 for Windows; infrared lens, viewing angle of 80° and vision up to 15m), and were defined as the time adolescents turned off the game console and TV.

Flow

Two subjective measurements of flow were obtained. Trait flow was assessed using the Game Engagement Questionnaire (GEQ; Brockmyer et al., 2009), a 19-item self-report measure with four subscales (absorption, flow, presence and immersion). The GEQ uses a 3-point Likert scale (*no* = 1, *maybe* = 2, *yes* = 3), which assesses how adolescents usually feel when playing video or computer games. Example items include ‘*I feel like I can’t stop playing*’ and ‘*Playing seems automatic*’. Higher scores mean higher trait flow. Internal consistency for the GEQ is high, ranging from between α= 0.85-0.91 (Brockmyer et al., 2009; Smith et al., 2017). In the current study internal consistency was α= .85. When the sample was split into two, no significant differences were found in the usual school-night bedtimes between those low (10:16 PM ± 80.1min) and high (10:34 PM ± 53.7min) on trait flow, *t*(13)=0.84, *p*=.34.

State flow was assessed using the Flow State Scale (FFS, Jackson, 1995). The FSS is a 36-item measure which yields a total flow score, and 9 subscales of flow; challenge-skill, action-awareness, clear goals, unambiguous feedback, concentration, sense of control, loss of self-consciousness, transformation of time and autotelic experience. Adolescents were asked to rate the items in relation to their videogaming experience. Responses were rated on a 5-point Likert Scale, from 1= *strongly disagree* through to 5 = *strongly agree*. Example items include ‘*The way time passed seemed to be different from normal*’, ‘*I performed* *automatically*', and '*I was completely focused on the task at hand*'. Higher scores indicate higher levels of state flow. Internal consistency for the FSS has been good in previous work, α =0.83 (Jackson & Marsh, 1996), and the current study, α=0.79 -0.96[3]. A moderate correlation were found between the FSS (state) and GEQ-F (trait) measures in the hard condition: *r*(15)=0.46, *p*=.08, but not the easy condition, *r*(15)=0.07, *p*=.80, suggesting some overlap, yet distinction between the two variables.

Heart rate

Heart rate was used as a proxy objective measure for flow states, as previous research has demonstrated a link between heart rate and self-reported flow (i.e., greater flow states approximate lower heart rates; Drachen, Nacke, Yannakakis & Pederson, 2010). Heart rate (in beats per minute (BPM)) was measured using Polar RS800CX and Polar RS400 watches. Both models use a WearLink wireless transmitter, were activated in 'free training' mode, and were shown in heart rate view, which displayed speed/pace/calories stopwatch and heart rate. Additionally, both the RS800CX and RS400 models have identical accuracy (±1%) and heart rate measuring range (15-240 BPM; Polar RS400 & RS800CX manuals). The watch was activated by researchers simultaneously to the start of game play, and recording ceased upon morning waking. This allowed measurement of heart rate across game play and up to self-selected bedtimes. Heart rate data were binned into 10-min intervals, and analysed using the Polar Protrainer v.5 software (Polar Electro; Kempele, Finland). This approach of measuring heart rate across multiple time points during game play is more refined than some previous studies (e.g., Weaver et al., 2010) and is consistent with more recent research (e.g., King et al., 2013). Recent research on the relationship between flow and HR demonstrates that flow is associated with moderate (rather than high or low) sympathetic arousal, but has a linear relationship with parasympathetic arousal (Peifer, Schulz, Schächinger, Baumann, & Antoni,

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[3] The two alpha values represent assessments for each of the two experimental conditions.

2014). HR rather than heart rate variability (HRV) was analysed as we wished to compare subsequent findings to research conducted within the same laboratory (King et al., 2013).

Visual analogue scales

A series of 100 mm visual analogue scales (VAS) were provided to adolescents in the morning to assess their enjoyment of the game (i.e., "*I enjoyed videogaming/I did not enjoy videogaming*", and "*I wanted to keep videogaming/I did not enjoy videogaming*"), and sleep quality ("*poor/excellent*"), respectively. Motivations for self-selected bedtime were assessed by response to the question "*Why did you decide to sleep when you did*", with response options, '*I felt sleepy*', '*I wanted to be rested for the next day*', '*I had enough of the game*' and '*I was conscious it was getting late*'. Participants placed a marker along a continuous line from *Agree* (=0) to *Disagree* (=100) in response to each of the questions, and each item was scored as the distance from the left end of the line to the marker.

Procedure

Adolescents attended the Flinders University Sleep Laboratory for testing on 2 separate weeknights within the same calendar week, spaced at least 1 night apart to prevent carry-over effects (e.g., sleepiness from previous night's sleep restriction). Data collection occurred during the school terms between May and August 2016. Weeknights were chosen to ensure adolescents would have motivation to self-select a bedtime that was balanced between their desire to continue game playing and their need to get enough sleep for school the next day. Upon arriving at the laboratory at 8:00PM, adolescents were shown to their sound-attenuated temperature-controlled bedroom, allowed to change into night attire, given written instructions of the experimental protocol, chose two low caloric snacks (e.g., crackers and cheese dip, crisps), fitted with their HR monitors and chest straps, and given an opportunity to ask any questions. Caffeine and technology use (i.e., laptops, tablets or mobile phones). and physical activity were restricted upon their arrival. Adolescents began playing the videogame on an Xbox One console from 8.30PM, sitting on their bed[4]. Consoles were connected to a 32-inch LED flat screen TV (1366 x 736 HD resolution). Bedrooms were dark with the exception of a small lamp emitting low-level warm light (450 lumens, <10 lux; Hioki Lux Meter; Hioki E.E. Corporation, Nagano, Japan). Bedroom doors were closed from 8:30PM, and adolescents were monitored via web-streaming IP cameras until their self-selected bedtime.

Adolescents played two difficulty levels (‘*Adventurer*’=Easy, or ‘*Seasoned Raider*’=Hard) across the 2 testing nights (condition difficulty). Condition order was counterbalanced across participants. Mann-Whitney *U*-tests indicated no effect of testing order on self-selected bedtime, $U= 30$, $z= -.58$, $p = .56$; $U= 28$, $z= -.37$, $p = .71$. Play was unrestricted until 1:00AM where adolescents were instructed to turn off consoles, in order to obtain a minimum amount of sleep for school (Yang, Kim, Patel, & Lee, 2005). Upon finishing videogaming for the evening, adolescents were given the Flow State Scale (FSS; Jackson, 1995) to complete. Participants were woken at 7:00AM the following morning, given breakfast, dressed, and completed the visual analogue scales. Adolescents were collected by parents/guardians from 8:00AM onwards. On the second morning, in addition to the VAS, adolescents were given a written debriefing sheet and remuneration (AUD$50 gift voucher). A total of 18 participants were enrolled in the study, however 1 participant was excluded from the 2nd night of the study due to failure to engage in the protocol.

Results

A 2 (condition: easy v hard) x 28 (time: 10-min intervals) repeated-measures ANOVA was conducted on HR data during videogaming as a manipulation check to confirm that flow was induced. A significant interaction was found between ‘condition’ and ‘time’, *F*(27,432),

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[4] Consoles and television screens were placed beyond the foot of the bed.

=1.71, *p*=.02 (Figure 6.1). HR in the hard condition remained lower regardless of length of videogame play, however, HR elevated after approximately 150 min in the easy condition.

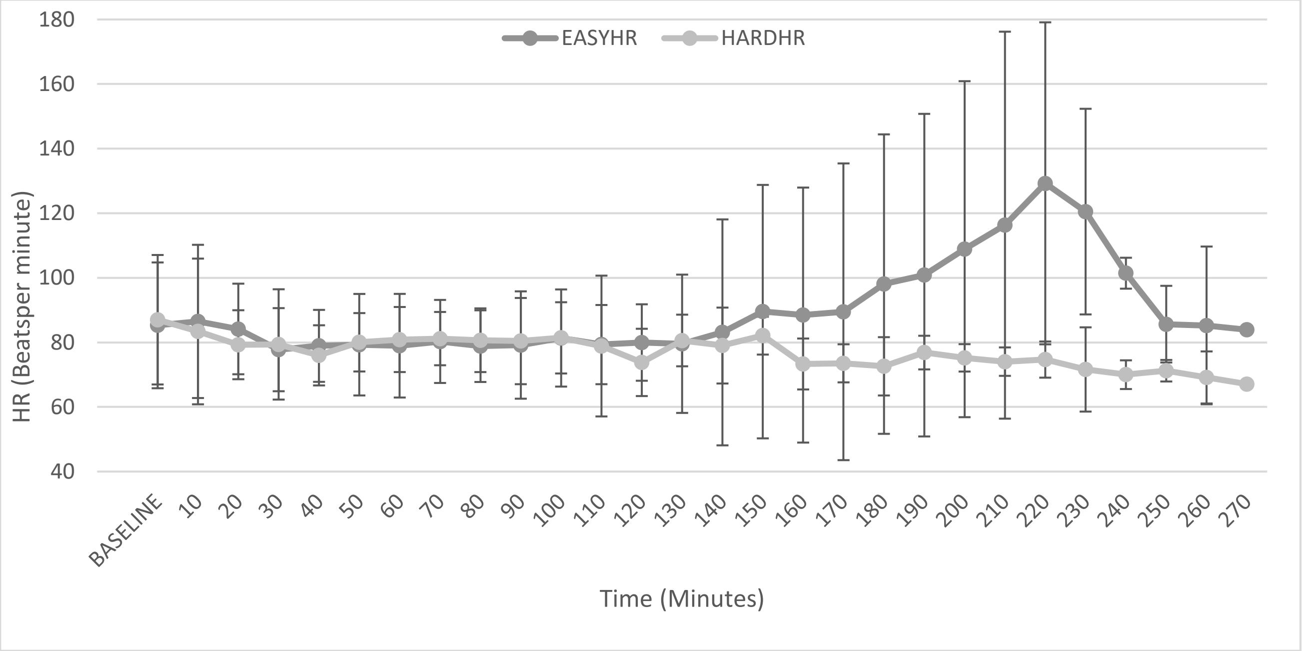

Figure 6.1. The effect of game condition and length of game play (time) on heart rate (HR). Note: errors bars = standard errors; each participant's HR data anchored to the beginning of game play.

A paired sample *t*-test on FSS scores (state flow) showed no significant differences between the easy (M= 147.5, SD= 40.6) and hard conditions (M=134.4, SD= 27.3), *t* (13) =1.48, *p* = .16, Cohen's *d*=0.39. No significant correlations were observed between HR and FSS scores in either the easy, *r*(12)= 0.03, *p* = .93, or hard conditions, *r*(14)=-.22, *p*=.45. No significant correlations were found between GEQ-F (trait flow) scores and HR in the easy, *r*(12)=0.08, *p*=.80, or hard conditions, *r*(15)=-0.26, *p*=.35.

For the easy condition, bedtimes were not correlated with HR, *r*(13)=0.24, *p*=.44, FSS (state) scores, *r*(16)=0.07, *p*=.81, or GEQ-F (trait) scores, *r*(15)=0.34, *p*=.21. For the hard condition, bedtimes showed a moderate negative correlation with HR that approached significance, *r*(16)=-0.42, *p*=.11, and significant positive correlations with FSS, *r*(14)=0.71, *p*=.004, and GEQ-F scores, *r*(14)=0.66, *p*=.01. However, a paired samples *t*-test showed there was no significant difference between self-selected bedtimes during the easy (M= 11:37 PM, SD= 93.1 min) as compared to the hard condition (M=11:32 PM, SD= 107.3 min), *t*(15) =0.29, *p* = .77. The mean difference of 5 min shows there was no meaningful difference in bedtimes between both game conditions.

As previous research has emphasised a focus on individual differences (Ivarsson et al., 2013), we explored whether self-selected bedtimes varied due to individual differences in trait or state flow (Figure 6.2). When a median split was applied to GEQ-F (trait) data (i.e., low vs high trait flow), an independent samples *t*-test showed no differences in bedtimes in the easy condition (low trait = 11:20 PM ± 104.0min; high = 11:56 ± 81.5min), *t*(13)=1.23, *p*=.24, however, adolescents with higher trait flow self-selected significantly later bedtimes (12:22 A.M ± 74.8min) than those with lower trait flow (10:53 P.M ± 79.0min) in the hard condition, *t*(12)=3.61, *p*=.004. Likewise, a median split was performed on FSS (state flow) data. During easy gameplay, no significant differences were found between adolescents low (11:46 PM ± 102.3min) or high (11:29 PM ± 78.6min) on state flow, *t*(15)=0.62, *p*=.54; however, adolescents high on state flow during the hard game play went to bed significantly later (12:24 PM ± 84.6min) than those low in state flow (10:52 PM ± 67.4min), *t*(14)=4.06, *p*=.001.

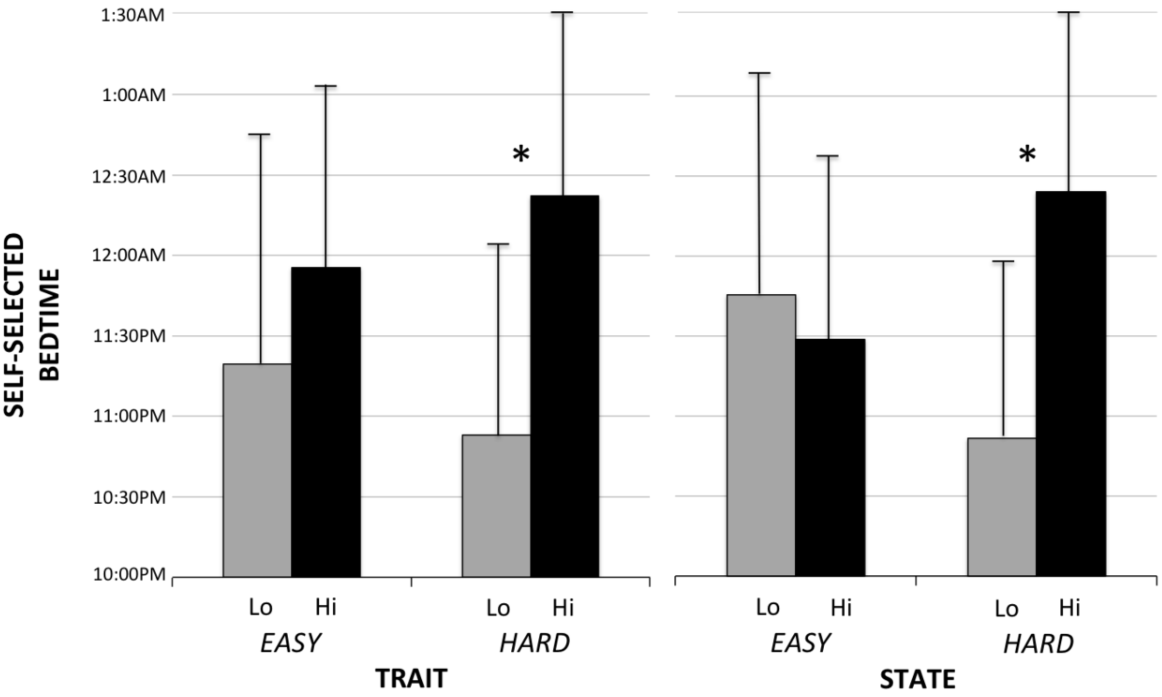

Figure 6.2. The effect of state and trait flow on self-selected bedtimes during easy and hard videogaming difficulty. * = significant difference between adolescents low and high on flow.

Motivations for gaming cessation and for self-selected bedtimes

Adolescents experienced high enjoyment during videogaming, a high desire to keep videogaming and did not experience gaming satiety (Table 6.1). A series of paired-sample *t*-tests indicated no significant differences across ‘hard’ or ‘easy’ conditions on these measures. Adolescents were motivated by sleepiness, needing to be rested for the next day’s commitments, and had an awareness of the late hour when self-selecting bedtimes. A series of paired-sample *t*-tests indicated no significant differences between adolescent’s desire to be rested and time conscientiousness across ‘hard’ or ‘easy’ conditions. However participants reported being significantly less motivated by feeling sleepy when self-selecting bedtimes during ‘hard’ videogaming as compared to ‘easy’ videogaming, $t(16) = 2.49$, $p = .024$.

Table 6.1

Motivations to cease videogaming (Means (SDs), t-statistics)

	Easy videogaming	**Hard videogaming**	***t*-statistic**
Enjoyment	1.84 (2.58)	1.72 (1.96)	.16 (n.s)
Cessation desire	3.07 (2.51)	2.73 (2.38)	.41 (n.s)
Satiety	7.27 (2.35)	6.08 (3.45)	1.24 (n.s)
Feeling sleepy	2.92 (3.11)	4.99 (3.49)	-2.49*
Desire to be rested	3.40 (2.72)	4.41 (3.12)	-1.58
Time conscious	2.54 (2.61)	3.51 (3.53)	-.98

Note: **p* <.05; Lower scores indicate that participants agreed they self-selected their bedtimes due to feeling sleepy, wanting to be rested and were conscious of the time.

Discussion

For several years, empirical research has taken a simplified approach to examining the association between technology use and sleep in young people (Cain & Gradisar, 2010; Hale & Guan, 2015; Van den Bulck, 2010). However, emerging research (e.g., Reynolds et al., 2015; Ivarsson et al., 2013) suggests individual difference factors (e.g., risk-taking, gamer experience) may play an important role in influencing the relationship between videogaming and sleep during adolescence, but that these are under-investigated (Ivarsson et al., 2013). We have previously identified a new factor, flow, which showed in a survey of 422 adolescents that greater trait flow was related to longer videogame duration and later bedtimes (Smith et al., 2017). In the present laboratory study, there was evidence that trait flow was again linked to later self-selected bedtimes (as was state flow), which, due to its possible mechanism of time distortion (Rau et al., 2006; Skadberg & Kimmel, 2004, Tobin & Grodin, 2009; Wood et al., 2007) may impact negatively on sleep subsequent to videogaming.

Based on the notion that more difficult videogames would create a balance between challenge and skill for the experienced videogamer (Sherry, 2004), we predicted that flow would be induced during the hard difficulty level. Flow has been shown to be negatively related to heart rate (i.e., the greater the flow, the lower the heart rate; Drachen et al., 2010). We found that heart rate remained at consistent low levels during videogaming in the hard condition (i.e., when there was a match between challenge and the videogamer's skill). Yet, when our sample of experienced videogamers were provided with the same videogame, with difficulty set to 'easy', heart rate significantly increased after 150min (2hrs 30 min) of gameplay. This suggests that flow was disrupted, possibly due to a mismatch between game challenge and the player's skill. However, in our study, both self-reported state and trait flow were not significantly related to heart rate in the present study. The extent to which sustained periods of videogaming impacts physiological measures, such as heart rate, has been measured by a small number of studies (Ivarsson et al., 2009; 2013; King et al., 2013). These studies suggest that some game factors, such as content (e.g., violence), significantly predict heart rate during videogaming, but that other game factors (e.g., duration) do not. The current study broadens this limited area of research by the discovery that disrupting flow may have an eventual impact on adolescents' physiology during videogaming. Increased arousal has been suggested as a key mechanism through which technology use may impact sleep (Cain & Gradisar, 2010; Gradisar & Short, 2013) and the current study provides some support for this mechanism.

We found that simply providing a situation of disrupting flow (i.e., providing an easy game difficulty that is below players' skill level) was not enough in and of itself to influence self-selected bedtimes of adolescents in our sample. Instead, adolescents' with high levels of trait flow selected a bedtime ~1.5 hrs later than their low trait flow counterparts. Yet, this only occurred during a situation that engendered optimal flow conditions for these experienced gamers (i.e., hard game difficulty). When flow conditions were disrupted (i.e., easy game difficulty), high trait flow adolescents went to bed 36 min later than their low trait flow peers. These abovementioned differences were discerned using a self-reported measure (the Game Engagement Questionnaire; Brockmyer et al., 2009) that was administered amongst screening questionnaires, and then, ~1-2 weeks later, observing adolescents turning off their game to attempt sleep via an objective measure (i.e., real-time camera viewing). This provides some support for the short-term stability of trait flow and its unique contribution to adolescents bedtimes immediately after videogaming. Similarly, adolescents self-reported their state flow experiences after each night of videogaming. The findings show that adolescents who reported high state flow went to bed significantly later than their low state flow peers, but only when flow conditions were optimal (i.e., hard condition; bedtime difference ~ 1.5 hrs). These findings provide stronger support for the displacement hypothesis (i.e., pre-bedtime activities displacing sleep; Van den Bulck, 2010) as a mechanism linking technology use and ‘sleep’. Interestingly, no significant differences in bedtimes occurred during the easy game difficulty condition (bedtime difference = 17 min). Another way of viewing these findings, is that regardless of whether adolescents reported high or low state flow scores, when the game difficulty was easy, bedtimes were not meaningfully different.

When designing the present study, we learned that very few console videogames are now delivered with manual difficulty level settings. Conversely, game developers are increasingly automating game difficulty, which tailors the balance between challenge and enjoyment for each individual player (Andrade et al., 2005). Whilst videogames are meant to be an enjoyable pastime, ‘dynamic game balancing’ can create optimal flow conditions, which can make it difficult for some gamers to stop. This may be a contributing factor to excessive gaming at the expense of engaging in other important areas of life (i.e., social, vocational, occupational, health). At this extreme end, adolescents may be at risk of developing Internet Gaming Disorder (IGD; American Psychiatric Association, 2013). While we acknowledge that the majority of adolescents are unlikely to develop IGD, we note that the implications from our study are that it is not just adolescents high on trait or state flow who need to improve their self-regulation, but there is an onus on game developers to be cognisant of the potential harms from flow induced by dynamic game balancing.

Also of note was that adolescents selected later bedtimes in the laboratory than when they are usually at home. This may be due to the lack of time devices in the sleep laboratory setting, which may have created time distortions associated with flow experiences (Rau et al., 2006; Skadberg & Kimmel, 2004, Tobin & Grodin, 2009; Wood et al., 2007). However, bedtimes in the laboratory during easy game difficulty conditions (i.e., when flow was likely disrupted), were still later than adolescents' usual bedtimes in their home environment. Thus, it may be that adolescents' usual bedtimes are influenced by their parents. Although older adolescents do no usually have a parent-set bedtime (Gangwisch et al., 2010; Short et al., 2011), we nevertheless suspect many adolescents would not risk being caught videogaming beyond midnight on a school night, nor take part in excessive gaming on consecutive school nights. Findings from visual analogue scales in the present study indicated that adolescents were primarily motivated to choose bedtimes based on social obligations (i.e., school the next day), and thus it is likely that this is a more conscious decision in the home environment. However, aside from self-regulation, guidelines about videogaming are almost exclusively focused on parents reviewing the classification or content of the game (Australian Government, n.d.). Non-government agencies have suggested broader guidelines for videogaming use which mirrors many of the government suggestions for online/internet use e.g. placing limits on content and duration (Dupon, 2016). However neither government or non-government advice or guidelines take account of the emerging evidence base, which suggests that a number individual factors (risk-taking, gamer experience, flow) may explain the negative impact that videogaming has on sleep or tailor their advice to account for individual risk factors. Expansion of government based guidelines around healthy technology use to have releVance to videogaming as a specific form of media and to account for individual variation or risk are certainly warranted.

Limitations

Although the findings from the present laboratory study concur with our previous survey findings (Smith et al., 2017), replication of these studies is nevertheless needed in order to raise confidence in the notion that high flow states during videogaming lead to later bedtimes. Within-subjects designs in a controlled laboratory setting can assist in reducing individual and external confounds, respectively, however they suffer with their external validity. Thus, independent studies with larger samples are warranted. Also, conducting similar studies in the field (i.e., home environment) would assist in translating these laboratory findings to the real-world, and has been performed in previous videogaming-and-sleep studies (e.g., Ivarsson et al., 2013). The present study's overarching aim was to examine the effect of the individual difference factor, flow, on adolescents' bedtimes. We did not measure the subsequent sleep of adolescents, nor their daytime functioning the next day. Sleep and functioning are also aspects of technology-and-sleep models (Cain & Gradisar), and thus also require further examination.

Conclusion

Videogaming is broadly acknowledged to have negative effects on sleep (Cain & Gradisar, 2010; Hale & Guan, 2015). The present study extends our knowledge by the discovery of a novel individual factor – flow - which influences the relationship between videogaming and sleep during adolescence. Flow was found to predict self-selected bedtimes during 'hard' game difficulty conditions, where there was a balance between challenge and skill. Similarly, our proxy physiological measure (i.e., low heart rate) indicated adolescents were more likely to experience flow states when there was a balance between challenge and skill. Although the experimental design of the study limits extrapolation of the findings to real-world videogaming behaviour, the finding of another individual difference factor being a key determinant of the impact videogaming has on ‘sleep’ is an important one. As such, recommendations about moderating videogaming behaviour for game development companies, parents and young people should be expanded to account of these individual factors, and mitigate the negative impact of videogaming on sleep during adolescence.

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CHAPTER 7: Discussion

Discussion

Summary of findings

The current thesis highlights the important role of individual differences in the link between videogaming and sleep in adolescents. Concordance of survey and experimental research in the present thesis suggests that, although sleep difficulties experienced by adolescents are common, specific individual risk factors (e.g., “flow”) may likely determine the impact of videogaming on bedtimes, and potentially sleep, during adolescence.

Survey data on adolescent sleep patterns in Study 1 illustrated the broad and significant nature of sleep difficulties in adolescents. Australian adolescents commonly experienced a number of negative daytime symptoms, such as difficulty waking in the morning, daytime sleepiness, and a lack of energy during the day. Additionally adolescents were also obtaining lower than the recommended nightly sleep duration (Short et al., 2013). The truncated sleep duration obtained by adolescents was found to be associated with late bedtimes, which were positively correlated with age. That is, the older the adolescent, the later they go to bed. Although this is not a new finding, it still corroborates previous meta-analytical findings (r = 0.63, weeknight; r= 0.68, weekend; Gradisar et al., 2011), and shows that community education over the last few years has not made an impact on adolescents’ bedtimes.

Survey data on adolescent videogaming behaviour in Study 2 revealed both individual and social factors were predictive of hours spent videogaming. Accessibility (i.e., number of devices owned by an adolescent) and location (i.e., presence in a bedroom) of electronic devices were the key individual factors identified. Parental discourse about cybersafety was the key social variable correlated with adolescent videogaming frequency, with adolescents whose parents discussed cybersafety spending significantly less time videogaming than adolescents whose parents did not. The data also revealed quantitative information about adolescent gaming habits. Australian adolescents were most likely to play videogames during the evening, play longer on weekends, and play for over an hour.

Importantly, survey data on adolescent sleep and videogaming in Study 3 expanded current knowledge of the relationship between videogaming and sleep in the context of extrinsic and intrinsic factors. Accessibility and parental regulation were key extrinsic factors identified. A novel intrinsic factor, flow, was identified. Results indicated that a tendency to experience flow when videogaming was predictive of both increased videogaming duration and later bedtimes. The relationship between flow and bedtime was also mediated by gaming duration. Contrary to previous literature (Reynolds et al., 2015), adolescents who perceived more negative consequences from risk had later bedtimes.

Experimental research (Study 4) tested the causal relationships between intrinsic factors (i.e., flow), adolescents' videogaming, and bedtimes, as previous research (Study 3; Smith et al., 2017) was correlational, ergo, not able to test the direction of effect. It was found that when the pre-conditions for flow were engendered in the hard game difficulty condition (i.e., balance between challenge and skill), adolescents who have a disposition to experience flow (i.e., high trait flow) self-selected significantly later bedtimes. Additionally, game difficulty elicited physiological reactions from adolescents during extended videogaming (i.e., after 150 min). During "hard" videogame play, adolescents experienced significantly lower heart rates than during "easy" videogame play. Finally, those high on state flow self-selected later bedtimes, suggesting both person (trait) and situation (adolescents' state, game difficulty) are influential on evening media usage.

How the current thesis extends knowledge of sleep and videogaming behaviour during adolescence

Overall, the current thesis extends knowledge of adolescents' 'sleep', particularly those residing in Australia (Study 1). Specifically, (i) the sleep patterns of Australian adolescents and the relationship to daytime functioning, (ii) the subjective experience of sleep difficulties, and (iii) the relationship between objective and subjective experience of sleep difficulties (Smith, Bartel, Huang, Short, & Gradisar, under review). The thesis also extends the scope of the peer-reviewed data documenting videogaming behaviour of Australian adolescents (Study 2). Such data were often limited to description of frequency of videogaming, subsumed within a general concept of "screen time" (Burke et al., 2006; Hardy, Dobbins, Booth, & Denney-Wilson, 2006), outdated (e.g. Olds et al., 2006), or contained within the grey literature† (ABS, 2011a; ABS, 2011b; Australian Institute of Family Studies; AIFS, 2016; Brand, Borchard, & Holmes, 2009; Brand & Todhunter, 2015).

The operationalisation of weekday versus weekend days during the collection of survey data was an important methodological consideration in Study 1 (Smith, Bartel et al., under review). Previous to the current study, there were large discrepancies, of ~2 hours, between the estimates of sleep duration obtained by Australian adolescents (Eisenmann et al., 2006; Raniti et al., 2016; Short et al., 2013). The current thesis aligned with more recent estimates (Raniti et al., 2016; Short et al., 2013), with similar methodological operationalisation of weekend versus weekday sleep, and supports current knowledge of sleep patterns by indicating this is a replicable and robust finding. We can therefore, subsequent to the findings of the current thesis, be more confident in the reliability of recent estimates that Australian adolescents obtain approximately 8 hours of weekday sleep (+/- 18 mins). For those adolescents obtaining under 8 hours, this is less than the optimal recommended sleep duration (Hirshkowitz et al., 2015). Obtaining fewer than 8 to 8.5 hrs sleep is associated with poor functional consequences in adolescents, for example an increased risk of injury or other risky behaviours, such as alcohol or drug use, sexual activity, or suicidal ideation (McKnight et al., 2011; Stallones, Beseler, & Chen, 2006) and poorer working memory performance (Gradisar, Terrill, Johnston, & Douglas, 2008).

The relationship between poor sleep habits in adolescents and negative socio-emotional outcomes is well established (Araújo & Almondes, 2014; de Bruin, van Run, Staaks, & Meijer, 2017; Huang et al., 2016; Hysing, Haugland, Stormark, Bøe, & Sivertsen, 2015; McMakin et al., 2016). However, there has remained a dearth of research on the effects of poor sleep on the daytime functioning of Australian adolescents (Dollman et al., 2007; Olds et al., 2010, Raniti et al., 2016). Study 1 (Smith, Bartel et al., under review) addressed this gap in the literature, as it documented both the number of Australian adolescents who experienced negative daytime consequences secondary to reduced sleep duration, and the relationship between quantitative sleep habits, as well as indicators of a clinical sleep problem, and self-perception of sleep difficulties. Prior to this thesis, there were few published studies using Australian data which investigated these relationships (Short et al., 2013; Wolfe et al., 2014). The finding that Australian adolescents sleep less than recommended (Hirshkowitz et al., 2015), and commonly experience sleep restriction, is consistent with international research which indicates significant associations between sleep parameters (e.g., BT, SOL, TST) and symptoms of chronic sleep reduction (Bartel et al., 2016). Furthermore, the high number of adolescents (44.1%) experiencing daytime symptoms of chronic sleep reduction (e.g., daytime sleepiness) is also consistent with international estimates of daytime sleepiness experienced by South-American, Asian and US adolescents (Moore et al., 2009; Perez-Chada et al., 2007; Rhie, Lee, & Chae, 2011).

Digital technologies, such as videogaming, are a rapidly changing field. Devices have become more affordable, and therefore more accessible, which is a key factor driving frequency of use (Study 2; Smith et al., 2015). Although the adaptation and embracing of digital technology among Australian adolescents was clear (ABS, 2011a; ABS, 2011b; Olds et al., 2006), the vital factors influencing their videogaming behaviours had not be elucidated. Study 2 (Smith et al., 2015) was novel within the peer-reviewed literature in its documentation of the relationship between individual (e.g., device accessibility), social factors (e.g., parental regulation or restriction of technology) and videogaming behaviour in Australian adolescents. Overall, Study 2 (Smith et al., 2015) provided important peer-reviewed evidence to support some of the suggestions made about parental monitoring of media during adolescence contained in the grey literature (AIFS, 2016). Study 2 also expanded upon previous peer-reviewed evidence, such as that by Thomas and Martin (2010), which gave a limited description of the videogaming/media habits of Australian adolescents (focused only on frequency, duration of participation and activity type).

Videogaming can reduce sleep duration in adolescents (Arora et al., 2014; Calamaro et al., 2009; Hale & Guan, 2015; Wolfe et al., 2014). Despite previous research demonstrating the relationship between social factors (e.g., parental regulation; Study 3; Smith et al., 2015) and videogaming behaviour in adolescents, the relative contribution of these factors as compared to other factors (i.e., individual factors) remained unknown. Additionally, as discussed, recommendations exist within the grey literature (AIFS, 2016) that parents should "regulate" media use of children and adolescents, but little is known about the relationship between parental regulation, videogaming behaviour and sleep. Furthermore, it became clear with recent findings of adolescents technology use and 'sleep' (e.g., Bartel et al., 2015), that videogaming was more influential with bedtime than other aspects of sleep (i.e., sleep onset latency). Study 3 (Smith et al., 2017) developed and tested a comprehensive model which integrated precursors of gaming behaviour (i.e., accessibility), key components of gaming behaviour (i.e., duration) suggested to be predictive of bedtime, and theoretically supported mechanisms (i.e., mediators) of this relationship (risk-taking, flow and parental regulation). Adolescents typically experience time distortion when videogaming (Rau et al., 2006; Tobin, & Grondin, 2009, Voiskounsky, & Wang, 2014). However, Study 3 (Smith et al., 2017) produced novel findings demonstrating a relationship with bedtime.

Despite previous experimental research suggesting that individual factors influence the relationship between videogaming and bedtime and/or sleep (Ivarsson et al., 2009, 2013; Reynolds et al., 2015), there existed no published experimental studies which investigated the influence of flow. Study 4 (Smith et al., under review) delivered novel findings as, within a controlled laboratory environment, flow (trait and state) were found to be unique individual predictors determining the impact of videogaming on adolescents' bedtimes. This is consistent with earlier survey research (Study 3; Smith et al., 2017), and research that indicates time distortion is a common aspect of flow experienced by adolescents whilst videogaming (Rau et al., 2006; Tobin, & Grondin, 2009, Voiskounsky, & Wang, 2014).

Recent research (Exelmans & Van den Bulck, 2017) suggests that a type of individual difference, self-regulatory failures, may explain media induced sleep displacement. Exelmans and Van den Bulck (2017) found that lower levels of self-control were significantly associated with more bedtime procrastination and this was mediated by habitual TV viewing. The findings of the current thesis that flow displaces bedtime in adolescents (Study 3; Smith et al., 2017; Study 4; Smith et al., under review) also suggest, consistent with Exelmans and Van den Bulck (2017), that cognitive control or self-regulatory processes may influence the relationship between media (e.g., videogaming) and sleep in adolescents. Self-control during media use requires a balance between short-term pleasures of media use and the potential costs to long-term goals (Hoffman, Reinecke & Meier, 2016). Enjoyment is integral to the experience of flow (Sherry, 2004), and as such mitigating the influence of flow on bedtimes in adolescents (Smith et al., under review) may require engagement of cognitive control mechanisms to evaluate the costs (e.g., to sleep) of extended engagement with electronic media. Neurocognitive theories of flow posit that the reward inherent in flow states results from "synchronization of attentional and reward networks under condition of balance between challenge and skill" (Weber, Tamborini, Westcott-Baker, & Kantor, 2009, p. 412).

Therefore, as adolescents have limited maturation of their cognitive control system, they are more prone to their behaviour (e.g., videogaming duration, bedtime selection) being influenced by reward, rather than cognitive control processes (Geier, 2013; Van Leijenhorst et al., 2010). This therefore leads to increased videogaming duration and displacement of bedtimes (Study 3; Smith et al., 2017; Study 4; Smith et al., under review).

Overall, the following new knowledge can be derived from the findings of the current thesis:

- As Australian adolescents continue to experience reduced sleep duration and negative daytime consequences they are therefore continuing to experience insufficient sleep.
- Australian adolescents have limited awareness of when they are experiencing the negative consequences of insufficient sleep.
- Parents may be experiencing significant barriers to implementing recommended restrictions of electronic media for Australian adolescents.
- Suggestions that adolescents engage in the use of “bedside media” also applies to Australian adolescents.
- A new novel individual factor “flow” significantly affects gaming duration and bedtimes in adolescents.

Theoretical Implications

Poor sleep and negative daytime consequences among Australian adolescents

The presence of daytime sleepiness and associated symptoms coupled with short sleep duration provides evidence that adolescents are obtaining insufficient sleep (Owens, 2014). Elevated levels of daytime sleepiness are observed among individuals with shorter sleep duration (Owens, Dearth-Wesley, Lewin, Gioia, & Whitaker, 2016). Self-reported sleepiness during the day and a need for assistance in waking are key features of daytime sleepiness

(Owens, 2014). Two of the three most highly endorsed items within Study 1 (Smith et al., under review) were ‘difficulty waking up in the morning’ and ‘feeling sleepy during the day’. The finding that 41% of Australian adolescents self-report daytime symptoms suggestive of insufficient sleep is consistent with both international (e.g., de Souza Vilela, Bittencourt, Tufik, & Moreira, 2016) and Australian research (Short et al., 2013).

The findings of the current thesis (Study 1; Smith et al., under review) are, however, inconsistent with research conducted on a similar sample (Urner, Tornich, & Bloch, 2009). Urner and colleagues found that both high school and university students reported being moderately impaired by fatigue, but levels of daytime sleepiness (Epworth Sleepiness Scale [ESS] scores = 8-8.9) were not of clinical significance (i.e., ESS >10; Johns, 1991). In contrast, the findings from the current thesis (Study 1; Smith et al., under review) showed that, a significant number (44.1%) of Australian adolescents experience sleep restriction within the clinical range (i.e., a score of > 17.3 on SRSQ [range 9-27]). This discrepancy in findings may be due to differences in the underlying dimensions measured by the questionnaire, with the ESS measuring underlying concepts specific to sleepiness, such as daytime sleepiness, subjective sleep propensity in active situations, and subjective sleep propensity in passive situations (Kim & Young, 2005). This compares to the Sleep Reduction Screening Questionnaire (SRSQ), which, in addition to the sleepiness factor, measures shortness of sleep, loss of energy, and irritation (van Maanen et al., 2014). Thus, the current study’s addition to our knowledge will be added to an existing model of adolescent sleep below, alongside the next important influential factor.

Location and accessibility of media devices and sleep

Across many devices, electronic media has become smaller, more portable, and accessible. The home television was introduced in 1946 and became commonplace in the 1960s (DeFleur & Ball-Rokeach, 1989). This was followed by the home PC in the mid-late 1970s-including the introduction of the Apple II in 1977 and the Atari in 1979, portable computers (“laptops”) in the 1980s, such as the Compaq and the Macintosh portable, palm pilot and similar in the 1990s. In more recent decades this has been followed by the first camera phone (Sony SH04) in 2000, the Apple iPhone in 2006, the Apple iPad in 2010, and most recently “wearables” such as the Apple watch in 2015 (Timeline of Computer History, 2017).

Research suggests that although ownership of media devices by an adolescent is negatively associated with sleep outcomes (Schweizer Berchtold, Barrense-Dias, Akre, & Suris, 2017; Smith et al., 2017), it is not purely the accessibility of these devices, but how this accessibility translates into usage patterns, which has a significant relationship with bedtimes (Bartel et al., 2015, 2016; Calamaro et al., 2009, Smith et al., 2015, 2017). In adults, mobile phones have become “bedside media”, with using phones after lights out leading to “time shifting”, with the entire sleep period shifted later (Exelmans & van den Bulck, 2016, p. 98). The majority of Australian adolescents (84.8%) have a media device available to use in their bedroom, and 63.7% use a computer in their bedroom to play computer games (Study 2; Smith et al., 2015). Having a computer in a bedroom which is used to play computer games is associated with increased usage (Study 2; Smith et al., 2017) and subsequent later bedtimes (Study 3; Smith et al., 2017). This is problematic for adolescent sleep, as devices which are accessed in the bedroom are more likely to be negatively associated with sleep (i.e., decrease in total sleep time [TST]; Cain & Gradisar, 2010; Hale & Guan, 2015). There is a dose-dependent relationship between devices accessed in the bedroom and sleep parameters for young people (Gamble et al., 2014). Additionally, the meta-analysis by Bartel and colleagues (2015) found that phones, computers, and videogaming, but not televisions, were associated with later adolescent bedtimes. A broadcast television is predominantly accessed in the living room, with 68 % of Australians accessing broadcast television in the living room (Blodget, 2013). It is therefore unsurprising that such media which is not accessed in the bedroom was not negatively associated with sleep among adolescents.

“Bedside media” (Exelmans & van den Bulck, 2016) use, particularly during adolescence, appears to be somewhat unregulated by parents. The majority of adolescents (about 2 in every 3) reported that parents allowed them to play computer games in their bedroom (Study 2; Smith et al., 2015). This “bedside media” use often occurs after 9pm. Calamaro and colleagues found that after 9pm, 34% of adolescents used a mobile phone for text messaging, 44% talked on the telephone and 24% played computer games - with an average of four technology activities being engaged in after 9pm (Calamaro et al., 2009). Furthermore, Calamaro et al. (2009) found that increased media use after 9pm was associated with reduced total sleep time. Sleep onset latency in adolescents has also been shown to be significantly lengthened by multiple electronic device use within an hour of bedtimes (Hysing et al., 2015). Australian adolescents typically cease mobile phone use at 10.04pm and internet use at 9.50pm (Bartel et al., 2016), which is within 1 hour of their weeknight bedtimes (Study 1; Smith, Bartel et al., under review). Worryingly, Bartel and colleagues (2016) also found that the time at which adolescents stopped using mobile phones or accessing the internet was the strongest predictor of later bedtimes. Overall, the results of the current thesis (Study 2; Smith et al., 2015, Study 3, Smith et al., 2017), alongside previous empirical studies (Bartel et al., 2015, 2016; Calamaro et al., 2009), suggest that the combination between accessibility of media devices in the bedroom and minimal parental regulation could be contributing to use of media close to bedtime (i.e., “bedside media”), which in turn, is associated with poorer sleep outcomes.

Additionally, the perfect storm model of Carskadon (2011) places electronic media (i.e., screen time and social networking) as integral psychosocial factors responsible for delaying adolescent bedtimes. However, the model does not detail videogaming, nor does it elucidate the mechanisms through which electronic media delays bedtimes. Incorporating videogaming as a type of electronic media and psychosocial factor is important as many adolescents use bedroom computers to videogame, and do this close to bedtime, suggesting videogaming is a key type of "bedside media" (Study 2; Smith et al., 2015). As such, the Carskadon (2011) model has been amended (see Fig 7.1) to reflect the importance of videogaming as a psychosocial factor delaying bedtime. However, the findings of the current thesis also specify vital individual and social factors (i.e., flow and parental regulation of electronic media) that are associated with increased use of electronic media and later bedtimes. The Carskadon model has limited scope to integrate such findings, and thus, further thesis findings will be integrated into more detailed models that focus specifically on technology and sleep in adolescents (Cain & Gradisar, 2010; Gradisar & Short, 2013).

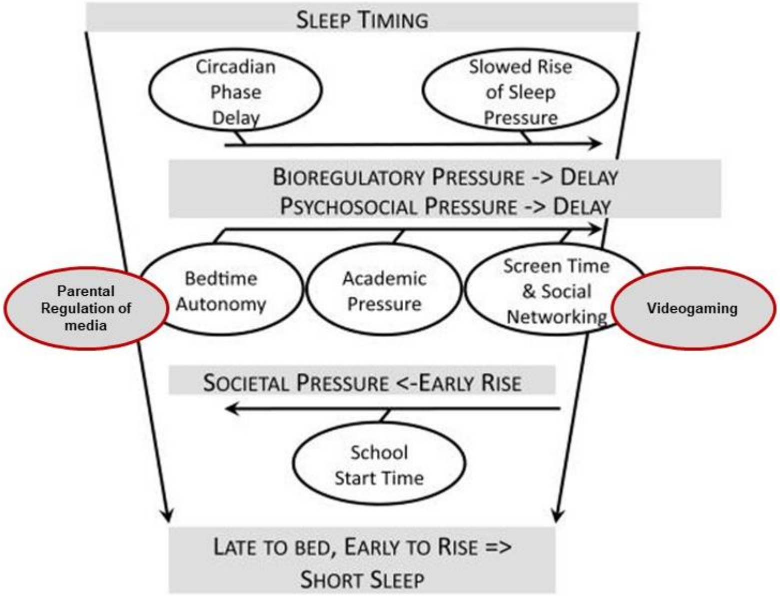

Figure 7.1. Videogaming in a perfect storm: expanded version of Carskadon (2011) model of biopsychosocial factors and sleep

Flow, immersion and time distortion during videogaming

Videogames are argued to have the ideal conditions to produce flow and ‘‘the flow experience of videogames is brought on when the skills of the player match the difficulty of the game" (Sherry, 2004, p. 328). The results of the current thesis were consistent with models of flow and videogaming (Ellis, Voelkl & Morris, 1994). Study 3 (Smith et al., 2017) revealed that a tendency to experience flow whilst videogaming is significantly associated with increased gaming duration and in turn later bedtimes. Study 4 (Smith et al., under review) showed that flow experiences were more likely under specific conditions. Adolescents who were high in state and trait flow went to bed significantly later during "hard" (but not easy) videogaming conditions than adolescents who were low in either state or trait flow. Adolescents who were high in one aspect, selected bedtimes in the middle of the range. This suggests, consistent with the theoretical literature on dimensions of flow (Jackson et al., 2010), that a key aspect of how flow impacts on the relationship between videogaming and sleep may be due to its influence as an individual trait *or* a state. This thesis (Study 4: Smith et al., under review) provides novel theoretical findings elucidating the contribution of both state and trait (dispositional) flow to videogaming experiences among adolescents.

Loosing track of time (time distortion) is reported as one of the key factors associated with individual motivation to engage in videogaming (Wood et al., 2007). Wood and colleagues also found that almost all (99%) videogamers experienced some degree of time distortion, and that this was more likely to occur in the evening compared to the afternoon or the morning. Consistent with literature that demonstrates 'time loss' is a common outcome of videogaming (Wood et al., 2007; Rau et al., 2006), results of the current thesis show that adolescents did not report being time conscious as a reason for gaming cessation (Study 4: Smith et al., under review). However, there were some discrepancies between the present thesis results (Study 4: Smith et al., under review) and that of Wood and colleagues (2007). Wood and colleagues found that games that were more complex and immersive were more likely to result in time loss. However, results of the current thesis showed that adolescents did not report being time conscious as a reason for gaming cessation during either hard or easy game play. It should be noted that the study by Wood et al. (2007) was self-report and the aforementioned findings experimental, which may explain the discrepancy. Alternatively, Study 4 (Smith et al., under review) was conducted using a single videogame genre (action, first-person), whereas Wood and colleagues (2007) reported "many players highlighted either particular games or game genres that were more likely to facilitate losing track of time" (p. 41).

Models of technology and videogame use

Cain and Gradisar (2010) suggested three potential mediators (displacement, arousal and circadian) of the relationship between media behaviours and sleep problems, which were assimilated from existing hypotheses and claims in the scientific literature (i.e., Higuchi et al., 2005; van den Bulck, 2004; Eggermont & Van den Bulck, 2006). Media use may contribute to sleep problems through, (i) media use directly displacing sleep (displacement; Van den Bulck, 2004; Eggermont & Van den Bulck, 2006), (ii) media use causing increase mental/emotional/physiological arousal (arousal; Higuchi et al., 2005), or (iii) bright light exposure delaying the circadian rhythm (circadian rhythm). The model was updated in 2013 (Gradisar & Short, 2013) to include the sleep parameters (bedtimes, sleep latency, total sleep time, wake after sleep onset) affected by electronic media use. Despite this, the model remains largely theoretical and limited empirical studies (King et al., 2013; Ivarsson et al., 2009, 2013; Reynolds et al., 2015) have tested its applicability. The results of the current thesis (Study 3, Smith et al., 2017; Study 4; Smith et al., under review) yielded empirical data that supports the displacement hypothesis, and provides partial support for the arousal hypothesis. Therefore, the following sections will discuss the application of the results from the current thesis to each of the mechanisms (with the exception of circadian hypothesis) within models of technology use and sleep in adolescents (Cain & Gradisar, 2010; Gradisar & Short, 2013),

Displacement

Evidence to support the displacement hypothesis (Van den Bulck, 2004; Eggermont & Van den Bulck, 2006) can be garnered from research that indicates that media use delays bedtimes (Bartel et al., 2015; Eggermont & Jan Van den Bulck, 2006; Smith et al., 2017). Within the current thesis, support for the displacement hypothesis is indicated by the results of Study 3 (Smith et al., 2017) that indicate videogaming duration has a direct association with adolescent weeknight bedtimes. This finding is also consistent with meta-analytic research by Bartel and colleagues (2015) who found videogaming was one of the media types which held a convincing relationship with bedtimes, and research by Eggermont and Van den Bulck, (2006) who found videogaming as a sleep aid was associated with later bedtimes on weeknights. The results of Study 3 are novel in their extension of the Cain and Gradisar (2010) model, as the results demonstrate the predictions of the model are applicable to specific electronic media (i.e., videogaming) plus additional influential factors (e.g., individual differences in flow).

More recently, the displacement hypothesis has been expanded to specify which sleep parameters are displaced through electronic media use. Exelmans and van den Bulck (2017) refer to a “two-step model of sleep displacement”. Firstly, bedtime is displaced through media use, and secondly, sleep onset is delayed by technology use after bedtime. The findings of the current thesis (Study 3; Smith et al., 2017) alongside meta-analytic data (Bartel et al., 2015) are consistent with the first step of the model (Exelmans and van den Bulck, 2017). The results of the current thesis (Study 3, Smith et al., 2017; Study 4; Smith et al., under review) add to the theoretical models provided by both Cain and Gradisar (2010) and Exelmans and van den Bulck (2017) as the results expand our understanding of *how* media use displaces sleep (i.e., “Step 1”; Exelmans & van den Bulck, 2017).

The current thesis proposed a novel individual factor ‘flow’ to explain *how* media use displaces sleep. Research consistently demonstrates that when individuals enter flow states they lose track of time and that this process of time distortion occurs during videogaming (Rau et al., 2006; Skadberg & Kimmel, 2004, Tobin & Grodin, 2009; Wood et al., 2007). This may be an underlying factor explaining *how* media use displaces bedtime. Study 3 (Smith et al., 2017) found that individuals with a higher trait disposition to experience flow during videogaming spent longer videogaming and subsequently had later bedtimes. Study 4 (Smith et al., under review) further expanded our understanding of the processes underlying the impact of electronic media use on adolescent bedtimes. The results of this study indicated that that when the preconditions for flow during videogaming were present (i.e., balance between challenge & skill) adolescents who were high in state and trait flow self-selected significantly later bedtimes than adolescents who were lower in either. This suggests that displacement of bedtime following videogaming may be due to both individual factors (trait flow) and game factors (matching skill to ability).

Arousal

The arousal hypothesis suggests that electronic media negatively affects sleep in adolescents. As such media may cause physiological arousal, this leads adolescents to have difficulty relaxing and subsequently initiating sleep (Cain & Gradisar, 2010). The impact of arousal during engagement in electronic media, such as videogaming, on sleep is usually measured through the use of heart rate for arousal and EEG for sleep (Fleming & Rickwood, 2001; Higuchi et al., 2005; Ivarsson et al., 2009; 2013, King et al., 2013, Smith et al., under review; Weaver et al., 2010). The effect of flow on adolescent videogaming experience and subsequent bedtimes was also assessed using heart rate as a proxy measure (Drachen et al., 2010). The results of Study 4 (Smith et al., under review) indicated heart rate remained significantly lower when the preconditions for flow were met. Low heart rates are indicative of lower physiological arousal akin to reduced activity within the sympathetic nervous system and heightened activity within the parasympathetic nervous system (Robinson, Epstein, Beiser, & Braunwald, 1966). This suggests that adolescents do not always experience heightened physiological arousal when videogaming but they may do so under certain conditions, i.e., during a mismatch between challenge and skill (Smith et al., under review). When there is a mismatch between the challenge provided by a game and the player's skill, this is akin to boredom or anxiety (Ellis et al., 1994). This may account for the observed patterns of heart rate differences across game difficulty levels (Study 4; Smith et al., under review), as a relationship between anxiety/stress and elevated heart rate is well documented (e.g., Cutherbert et al., 2003; Freyschuss, Hjemdahl, Juhlin-Dannfelt, & Linde, 1988; Knight & Rickard, 2001; Tyrer, Lee & Alexander, 1980; Watkins, Grossman, Krishnan, & Sherwood, 1998; Wilkinson et al., 1998). However, despite differences in physiological responses across game conditions, no differences in bedtimes were observed across 'easy' vs 'hard' conditions, as suggested by the Cain and Gradisar (2010) model. The current thesis therefore supports the component of the theory proposed by Cain and Gradisar (2010) that electronic media can cause increased physiological arousal (under certain conditions), but not that there is a relationship between physiological arousal and sleep outcomes (i.e., bedtime) in adolescents.

Previous to the current thesis, a small number of studies have provided empirical data testing the arousal component of the Cain and Gradisar (2010) model (i.e., the hypothesis that increased arousal may be a mechanism by which media, such as videogaming, negatively impacts on sleep; De Valck, Cluydts, Pirrera, 2004; Higuchi et al., 2005; Ivarsson et al., 2009; 2013; King et al., 2013; Weaver et al., 2012). King and colleagues (2013) found that despite longer periods of videogaming, reduced sleep efficiency and total sleep time, physiological arousal was not the mechanism through which this was occurring. Similarly, Ivarsson and colleagues (2009) found that although game type (violent vs. nonviolent) elicited significant differences in heart rate variability, no differences in sleep parameters were observed as a result. However, in a subsequent study, Ivarsson and colleagues (2013) found that different physiological reactions were exhibited depending on a player's level of experience. Sleep quality was lower for non-experienced players during violent videogaming, but the reverse was true for experienced players. The results of the current thesis (Study 4; Smith et al., under review) also found that, similar to Ivarsson and colleagues (2009), heart rate differences can be elicited by game factors (e.g., game difficulty, degree of violence) but similar to King and colleagues (2013) these are not associated with changes in sleep parameters. Overall, the results of the current thesis and previous research (Ivarsson et al., 2009; 2013; King et al., 2013) do not provide strong support for the arousal hypothesis. The findings of the current thesis are integrated below into recent models of technology and sleep in adolescents (Gradisar & Short, 2013).

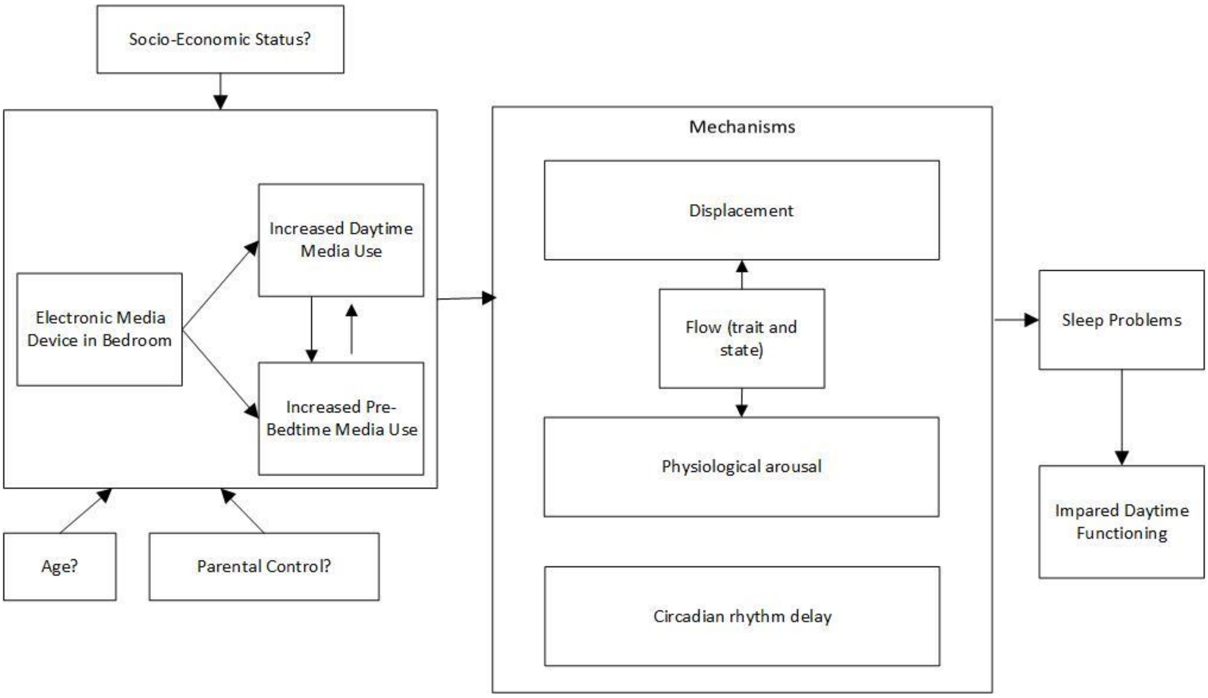

Figure 7.2: Mechanisms between videogaming and sleep: an expansion of the Cain and Gradisar (2010) model.

Clinical Implications

Guidelines about technology are contained within sleep hygiene recommendations, which represent a core component of treatment for both clinical sleep disorders (e.g., insomnia, DSPD) and across the general adolescent population (Gradisar et al., 2011; Gradisar & Short, 2013; Lack, Wright & Bootzin, 2009). As parental regulation of media (Study 3; Smith et al., 2017; Smith et al., under review) and flow are key factors influencing adolescent sleep, this has a number of implications for how recommendations may be adjusted. These adjustments focus on enhancing and supporting parents to mitigate the influence of unhealthy technology use (e.g., "bedside media") on adolescent sleep, and assisting adolescents to recognise when they are at risk of technology impacting negatively on their sleep. However, these adjustments require ongoing consideration of the digital rights of children and adolescents, including the right to information and media of their choice as per Article 17 of the UN Convention on the Rights of the Child (Livingstone & Third, 2017).

Currently research that documents an association between parental regulation and technology use in children and adolescents, and subsequently suggests parental regulation as an intervention focus, is largely cross-sectional (Brindova et al., 2014; Carlson et al., 2010; Cheng, Koziol, & Taveras, 2015; Jago et al., 2012; Ramirez et al., 2011; Totland et al., 2013). Interventions that have focused on psychoeducation for parents to minimise adolescent screen time have produced conflicting results. An RCT by Babic and colleagues (2016) found that parental psychoeducation via newsletters (e.g., strategies to manage conflict arising from screen time rules, no screen based media in bedrooms) did not reduce recreational screen-time in adolescents. However, other RCTs using identical strategies (i.e., parental newsletters) found reductions in screen time, which was mediated by adolescents' enhanced autonomous motivation to reduce their screen time (Smith, Morgan et al., 2017). Nonetheless, psycho-education for parents about sleep has shown promising results (Bonnar et al., 2015). Bonnar and colleagues (2015) found that parental involvement in sleep education leads to adolescents obtaining more sleep, reduced sleep latency, and enhances motivation to reduce sleeping-in on weekends. The mechanism via which psychoeducation of parent's leads to improvement in adolescent sleep parameters is yet unspecified (Gayes & Steele, 2014). However, parents applied more restrictive (i.e., limits about content or duration of media) or active (i.e., commenting/discussing media content) mediation strategies when they feared negative behavioural effects of videogaming, which could include reduced sleep and its negative psychosocial sequelae (Nikken & Jansz, 2006). Employment of restrictive media techniques by parents leads to reduced videogaming duration and earlier bedtimes (Smith et al., 2015), and as such is an important area for clinical intervention.

Parents may have a direct influence on the time at which adolescents go to bed (Bartel et al., 2015; Gangwisch et al., 2010; Short et al., 2011), and can also exert influence on adolescents' bedtime through restriction of videogaming duration (Study 3; Smith et al., 2017). Government recommendations about technology use during adolescence state parental monitoring should include a) a physical presence in the same room as the adolescent when playing computer games, b) observing what adolescents are doing online, c) setting limits to online content, d) setting limits about the duration of time spent online, e) and speaking to them about cybersafety (AIFS, 2016). However there may be some barriers to parents employing regulation of technology use as "the vast majority of adolescents reported their parents '*rarely*' or '*never*' limit their online content, or time online" (Smith et al., 2015, p.3).

Parent regulation of electronic media may be able to improve adolescent bedtimes when this regulation is focused on "bedside media" (Bartel et al., 2015; Study 3; Smith et al., 2017; Eggermont & Van den Bulck, 2006). Previous recommendations suggest that "all devices, cell phones and other portable devices (e.g., iPods, iPads) should be removed near and/or bedtime" (Gradisar & Short, 2013, p.124). Children and adolescents who engage in more bedside media have significantly later bedtimes (Bartel et al., 2015; Mindell, Meltzer, Carskadon, & Chervin, 2009, Thorleifsdottir, Björnsson, Benediktsdottir, Gislason, & Kristbjarnarson, 2002, Van den Bulck, 2004). As the presence of electronic media (e.g., computers) in the bedroom is associated with increased use within an hour of bedtime (Study 1; Smith, Bartel et al., under review; Study 2; Smith et al., 2015), parents may be able to employ restrictive media strategies by setting a “media blackout” time of *at least one hour* before desired bedtime. As parental restriction of media has a direct relationship with duration of videogaming (Study 2; Smith et al., 2015), which in turn has a direct association with adolescent bedtimes (Smith et al., 2017), truncation of the duration of bedside media usage is a plausible area for parental intervention (Gradisar & Short, 2013; Olds et al., 2006).

Parents may also be able to mitigate the influence of videogaming (or other electronic media) on adolescent bedtimes by breaking the “flow chain”. Adolescents who engage in videogaming are unable to break away from videogaming leading to time distortion, extended duration of videogame play, and later bedtimes - via the displacement mechanism (Cain & Gradisar, 2010; Exelmans & van den Bulck, 2017; Study 3; Smith et al., 2017; Study 4; Smith et al., under review). Specifically, the “flow chain” may be broken by adjustment of game factors, such as game difficulty, which are associated with engendering flow (Sherry, 2004; Smith et al., under review). As game conditions which engender flow are associated with later bedtimes (Smith et al., under review), parents paying attention to conditions which are more likely to yield flow states, such as high challenge in the presence of high skill during novel videogaming.

Modifying the “type” (i.e., flow preconditions) of videogaming may represent a more palatable intervention for parents who struggle with placing restrictions on electronic media (Smith et al., 2015). However, the majority of games at present appear to be automated in their difficulty level (https://ebgames.com.au/). When videogame difficulty is automated, parents and/or adolescents cannot select a difficulty level to minimise flow experiences and displacement of bedtimes. Therefore, game developers may represent an important area for intervention to promote instillation of manual adjustments of difficulty within games to give parents and/or adolescents more control. Manual manipulation of game difficulty may help to minimise the impact of flow on bedtimes in adolescents (Smith et al., under review). Game developers may also be praised when there is manual manipulation of game difficulty. For example, application of a “sleep friendly” stamp of approval to games which manufacturers would be able to use for game promotion. As the videogame (*Rise of the Tomb Raider*©) used in the current thesis (Study 4; Smith et al., under review) allowed such manual manipulation, it would be an example of a “sleep friendly” videogame for adolescents.

Specific adolescents may be more at risk of videogaming impacting negatively upon their sleep, as adolescents higher in trait flow were more likely to self-select later bedtimes, especially when the pre-conditions for flow were met (i.e., hard game difficulty; Smith et al., under review). Therefore, parental regulation strategies or advice directly to adolescents themselves should include identification of this individual risk factor (i.e., high trait flow). As this is likely to require extended discourse between the parent and adolescent, this may represent an important active mediation strategy to complement recommended restrictive mediation strategies (Nikken & Jansz, 2006). Research from the current thesis (Study 4; Smith et al., under review) suggests the flow subscale of the game engagement questionnaire (Brockmyer et al., 2009) may be sufficient to predict self-selection of bedtimes after videogaming in adolescents, and therefore, due to the reduced burden of using a subscale (9 items vs.19 items for full scale), may represent a useful screening tool for identification of adolescents at risk of the negative impact of flow on bedtimes. Scores of greater than 16 represent adolescents who score above the median and scores greater than 19 represent adolescents in the upper quartile and be categorised as *high* and *very high* in the flow subscale (GEQ-F) respectively.

Additionally, research from adults (Exelmans & Van den Bulck, 2016b) suggests that self-regulation is an important area for intervention as it may explain media induced sleep displacement. As adolescents typically have more immature pre-frontal control systems (Geier, 2013; Van Leijenhorst et al., 2010), enhancement of self-regulatory capacities in adolescents may help them minimise the negative relationship between videogaming (or other media) and bedtimes. In a non-clinical sample of adolescent's, mindfulness-based therapy enhances cognitive control (Schonert-Reichl et al., 2015). Therefore, clinicians working with adolescents with sleep difficulties associated with electronic media use may consider therapies, such as mindfulness, which enhance cognitive control skills in adolescents.

Limitations and directions for future research

There are several limitations that need to be acknowledged so the thesis' findings can be placed into context within the current empirical literature. First, the experimental study (Study 4; Smith et al., under review) required manipulation of the underlying components theorised to produce flow (i.e., challenge, skill), thus required utilising self-selection sampling with its inherent self-selection bias. However, similar sampling is commonly utilised within the field (Ivarsson et al., 2013; King et al., 2013). Additional sample limitations included that, across all the survey studies and experimental study, adolescents were from South Australia, which represents a smaller sub-population of Australia than some other states, comprising only approximately 7% of the total population (ABS, 2017). Nonetheless important findings about adolescent sleep and/or technology habits have been gained from literature using South Australian only samples (Olds et al., 2006; Short et al., 2011; Short et al., 2013). The final sample limitation is the small (N=17) experimental sample size which reduces external validity and generalisability of findings. However, the sample size is consistent with similar laboratory studies within this field of inquiry (Heath et al., 2014; Ivarsson et al., 2009; King et al., 2013; Reynolds et al., 2015).

Second, subjective measures were used across the survey studies (Smith, Bartel et al., under review, Smith et al., 2015; Smith et al., 2017) due to the requirement for large sample sizes. As the sample sizes for the thesis surveys (Smith, Bartel et al., under review; Smith et al., 2015, Smith et al., 2017) ranged from N=324 to N=422, objective measures such as actigraphy would not have been practicable. Obtaining 300 to 400 actigraphic watches simultaneously would have incurred significant financial costs not able to be subsumed within doctoral level funding. Alternatively, collecting data on smaller samples (e.g. 10-20 at a time) would have lengthened the duration of data collection and thereby incurred substantial delays to thesis completion, or minimised the amount of data able to be gathered. Although an objective measure, actigraphic data is also not without its limits. Compared to PSG, actigraphy underestimates total sleep time (TST; Johnson et al., 2007). Actigraphy has also been found to underestimate TST and wake after sleep onset (WASO) as compared to sleep diaries (Short et al., 2012). Utilisation of consumer owned devices (e.g. Fitbit, Jawbone Up, sleep apps) was not employed as a method of data collection due to their lack of validation against objective measures (e.g. “the gold standard” PSG) and (for wearables) their low wake detection accuracy, misidentification of wake as sleep, and overestimation of TST and sleep efficiency (Lee & Finkelstein, 2015). A review of 42 smartphone applications available on the Apple store or Google Play found that, despite many of these applications using actigraphic data, “no existing sleep-related application available for smartphones is based on scientific evidence” (Behar, Roebuck, Domingos, Gederi & Clifford, 2013).

Bedtime, rather than sleep latency or TST, is the sleep parameter more associated with videogaming in adolescents (Bartel et al., 2015). Therefore, as bedtime can only be objectively measured in the laboratory, an experimental study (Study 4; Smith et al., under review) was vital to corroborate survey findings of the current thesis (Study 3; Smith et al., 2017). Additionally, a limitation of the survey bedtime data is that operationalisation of bedtime has been subject to amendments. Exelmans and Van den Bulck (2017) suggest that previous definition of bedtimes were conflating going to bed with going to sleep, and that bedtime should be defined as the time individuals decide to go to bed - and thus a distinct concept from “shut-eye” time (the time individuals decide to go to sleep).

Subjective methods used in the current thesis are prone to common method biases such as measurement context effects, particularly when predictor and criterion variables are obtained from the same individual (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). Podsakoff and colleagues (2013) recommend that measurement of predictor and criterion variables be separated temporally. This strategy was employed within the experimental study (e.g., trait flow (predictor)) was measured at baseline and other criterion variables (e.g., state flow, HR, bedtime) measured weeks later within the laboratory. Separating assessment of sleep and technology use temporally is important within this field as it allows conclusions to be drawn about the temporal relationship between the two. Prospective studies have recently demonstrated that increased technology use (e.g., social networking, TV use) can be explained directly by an increase in sleep disruptions or problems (Tavernier & Willoughby, 2014; Vernon, Modecki, & Barber, 2017). Finally, a third major limitation was the isolation of videogaming as a sole activity within a laboratory setting. Videogaming is an activity commonly engaged in alongside other electronic media (Calamaro et al., 2009), and therefore this isolation of videogaming restricts ecological validity as it may not reflect common electronic media usage patterns of adolescents.

Attention to replication of the findings from the current thesis is vital to establish confidence in their reliability. Specifically, the findings (Study 3; Smith et al., 2017; Study 4;

Smith et al., under review) in the area of individual differences. Although the current thesis demonstrated through both survey and experimental methodology some initial confidence in the individual factor ‘flow’ as an underlying mechanism influencing videogaming and sleep in adolescents, it failed to replicate effects of other individual difference variables in the literature (Reynolds et al., 2015). On a large sample, the current thesis was not able to replicate the finding that adolescents who perceived less negative consequences of risk engage in longer durations of videogaming and subsequently select later bedtimes (Reynolds et al., 2015; Smith et al., 2017). This might be due to different research designs (i.e., experimental laboratory (Reynolds et al., 2015) vs survey (Smith et al., 2017). As such, future research is needed to address the discrepancies between the findings of the current thesis and that of Reynolds and colleagues (2015), as well as independently verify the role of flow in videogaming and sleep in adolescents.

The first area specified for future research concerns developing confidence in the finding that flow is an important individual difference factor influencing the relationship between technology use and sleep in adolescents (Smith et al., 2017; Smith et al., under review). Further confidence in this finding could be obtained through experimental research aiming to disrupt the “flow chain”. Study 4 (Smith et al., under review) engendered the pre-conditions for flow and found that this impacted on the length of game play and self-selected bedtimes. Study 4 was designed to disrupt flow by decreasing the challenge (i.e., easy game difficulty). Future research could instead *increase* the challenge, with a view to disrupting flow processes.

As discussed above, the findings from Study 4 have limited ecological validity (i.e., low sample size) and therefore a larger field study conducted in the home of adolescents is an important next step. Such a design will be able to assess if, outside the laboratory and alongside other forms of technology, that flow is a process influencing technology use and sleep in adolescents, and therefore of clinical/applied relevance. Moreover, such a design would have scope to not only establish a baseline influence of parental regulation, but assess efficacy of parental-regulation interventions.

The second area identified for future research focuses on the accessibility or portability of media devices and their relationship to sleep. The presence of technologies in the bedroom (“bedside media”), such as videogaming, has been identified as a key predictor of poor sleep across the lifespan (Exelmans & van den Bulck, 2017; Gamble et al., 2014; Hysing et al., 2015; Smith et al., 2017). Recommendations exist that such devices should be removed at or near bedtime (Gradisar & Short, 2013). However, electronic media devices are becoming increasingly integrated to our person, as can be witnessed with the emergence of wearables. *Gen Y* (birth year mid-1980s to mid-1990s) and *Gen Z* (birth year mid-1990s to early 2000s) are the largest adopters of wearable technologies such as smartwatches (Fleming, 2015). As such, future research may need to consider not only how the presence of electronic media within the bedroom may influence sleep but how the presence of that *within the bed* may influence sleep. Recommendations about bedroom removal of technologies may become limited in scope or uptake (e.g., Gradisar & Short, 2013), as devices move closer to our person with each subsequent generation. A further conundrum for researchers to solve is that these wearable devices commonly purport to help users improve their sleep (Sleep Better, 2017), despite a strong evidence base identifying the negative relationship between electronic media and sleep (Bartel et al., 2016; Cain & Gradisar, 2010; Calamaro et al., 2009; Exelmans & van den Bulck, 2017; Smith et al., 2017), and yet no peer reviewed evidence to support their use to manage sleep disturbances (Jeon & Finkelstein, 2015).

The third key area identified for future research concentrates upon mitigation of flow during videogaming for adolescents. As flow appears to be a mechanism influencing videogaming duration in adolescents and impacting upon subsequent bedtimes (Smith et al., 2017, Smith et al., under review) it has been identified in the present thesis as crucial for intervention to minimise displacement of bedtimes in adolescents. Unpublished research (Perry, 2013) aimed to investigate if flow states and related time distortion could be minimised through the presence of a clock whilst videogaming. Presence of a clock was not found to impact on self-selected bedtimes or flow states. Nonetheless, this remains an important area for future research. Previous suggestions include software that enforces pauses during videogaming, thus breaking the immersion inherent in flow states (Smith et al., 2017). As previously mentioned, other plausible areas include integration of advice about flow states into parental psychoeducation about technology and sleep, and advising parents to enforce pauses as part of their restrictive media strategies. Overall, research should focus on determining which strategies work to minimise the ‘flow chain’ (time distortion, displacement, later bedtimes) and subsequently which strategies are the most effective.

A fourth area specified for attention relates to the empirical testing of the Cain and Gradisar (2010) model. The emerging evidence base (Bartel et al., 2015; Exelmans & van den Bulck, 2017; Smith et al., 2017, Smith et al., under review) points to the fundamental influence of displacement as an explanation for the negative relationship between electronic media and sleep in adolescents. Limited support exists for the arousal mechanism in its relationship between technology use and sleep (Bartel & Gradisar, 2017). Moreover, although the displacement mechanism has garnered the strongest empirical support, no research has been conducted to date which assesses the relative contribution of each mechanism within the Cain and Gradisar (2010) model. Recent suggestions specify that research should focus on the interactions between mechanisms (e.g., arousal and displacement) as bright screens are suggested to increase alertness (arousal) and therefore lead adolescents to use electronic media beyond their usual bedtimes (Bartel & Gradisar, 2017).

Finally, on the basis of the findings of the current thesis (Study 3; Smith et al., 2017; Study 4; Smith et al., under review) and previous literature, a number of individual difference factors have been identified, including (i) self-control, (ii) ego-depletion, (iii) gamer experience, (iv) risk-taking, and now (v) flow (Exelmans & Van den Bulck, 2016b; Exelmans & Van den Bulck, 2017b; Ivarsson et al., 2013, Reynolds et al., 2015; Smith et al., 2017; Smith et al., under review). A recent model of technology use and sleep (Fig 7.3; Bartel & Gradisar, 2017) suggest flow and habituation as moderating factors. Overall, future research is needed to establish which of the aforementioned individual difference factors demonstrate a robust association with technology use and sleep adolescents. The relationship between these individual difference factors and specific technology types also needs to be determined. For example, do flow experiences occur when adolescents are engaged in other types of technology (e.g., social media) and do these impact sleep in the same way as flow processes during videogaming? Is adolescent perception of the consequences of risk associated with increased engagement in other forms of technology use, and does this subsequently negatively impact on bedtimes? Arguably, the 2013 statement from Ivarsson and colleagues that “future studies should collect more data about background characteristics of the participants” still holds true (Ivarsson et al., 2013, p. 395).

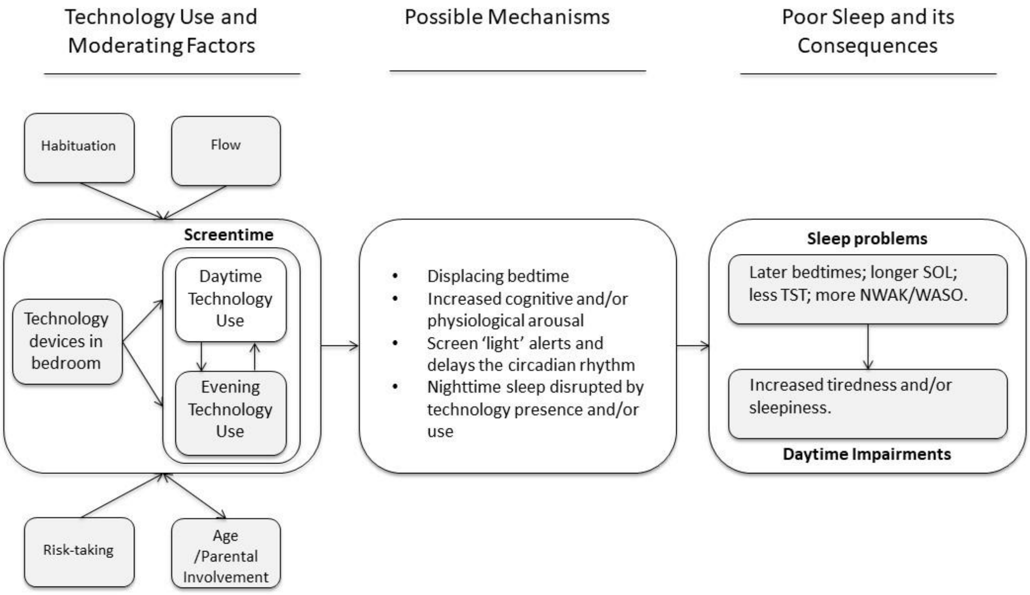

Figure 7.3 Moderating factors of technology use and sleep (Bartel & Gradisar, 2017)

Conclusion

Adolescents are experiencing the effects of insufficient sleep and its related daytime consequences, and commonly engage in unhealthy technology habits through the use of videogaming as bedside media. These unhealthy technology habits can be propagated by minimal parental monitoring of electronic media in combination with the disposition to become immersed in technology and lose track of time - a process which negatively effects sleep through displacing bedtimes.

The importance of flow states whilst videogaming was identified in the present thesis, in both Studies 3 and 4. These findings have notably enhanced our understanding of one reason why bedtime is displaced when adolescents engage in bedside media such as videogaming. It is unlikely as devices become more accessible and portable and closer to our person that digital technologies will move out of the bedroom, and therefore an understanding of how to enable individuals to engage with these technologies whilst minimising negative effects becomes more crucial.

The role of the parent as a significant social influence has been highlighted throughout the thesis. Parents can act not only as gatekeepers or facilitators of adolescents' access to digital technologies, but also as educators about how adolescents can develop and maintain a healthy relationship with their digital technologies. Our role as researchers in future should focus on helping parents and adolescents to reach an equilibrium whereby technology is both embraced with all its social and occupational benefits, whilst being mindful of the inherent risk to sleep and subsequent daytime consequences. This thesis has made important contributions through expanding theoretical models of electronic media and sleep, identifying a new individual difference factor integral in the link between videogaming and sleep, and specification of strategies to enable adolescents to engage in healthier technology use which may ultimately minimise any negative effects of such technologies on the sleep of future adolescents.

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Appendix A: Questionnaire Measures

Appendix A.1: School Sleep Habits Survey- modified (Wolfson & Carskadon, 1998)

Figure out how long you usually sleep on a normal school night and fill it in here (Do not include time you spend awake in bed). Remember to mark hours and minutes, even if minutes are zero)

Hours																	Minutes											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	00	05	10	15	20	25	30	35	40	45	50	55
○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Figure out how long you usually sleep on a night when you do not have school the next day (such as a weekend night) and fill it in here (Do not include time you spend awake in bed). Remember to mark hours and minutes, even if minutes are zero)

Hours																	Minutes											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	00	05	10	15	20	25	30	35	40	45	50	55
○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Enter the time that you go to bed AND wake up on…

a) Weekdays (Mon-Thurs)

Wake Hours												Wake Minutes												Wake Meridian	
1	2	3	4	5	6	7	8	9	10	11	12	0	5	10	15	20	25	30	35	40	45	50	55	AM	PM
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sleep Hours												Sleep Minutes												Sleep Meridian	
1	2	3	4	5	6	7	8	9	10	11	12	0	5	10	15	20	25	30	35	40	45	50	55	AM	PM
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

b) Weekends (Fri-Sun)

Wake Hours												Wake Minutes												Wake Meridian	
1	2	3	4	5	6	7	8	9	10	11	12	0	5	10	15	20	25	30	35	40	45	50	55	AM	PM
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Sleep Hours												Sleep Minutes												Sleep Meridian	
1	2	3	4	5	6	7	8	9	10	11	12	0	5	10	15	20	25	30	35	40	45	50	55	AM	PM
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Appendix A.2: Sleep Reduction Screening Questionnaire (van Maanen et al., 2014)

All questions refer to the previous two weeks.

	No	Sometimes	Yes
1. Do you have trouble getting up in the morning?	○	○	○
2. Do you feel sleepy during the day?	○	○	○
3. Are you immediately wide awake when you wake up?	○	○	○
4. When I am at school for a while I have trouble keeping my eyes open	○	○	○
5. Do you have enough energy during the day to do everything?	○	○	○

6. I am active during the day
○ Agree
○ Partly agree
○ Do not agree

7. I have to struggle to stay awake in class
○ Never
○ Once in a while
○ Often

8. I don't feel like going to school because I feel too tired
○ This never happens
○ This happens once a week
○ This happens more than twice a week

9. I am a person who does not get enough sleep
○ Agree
○ Partly agree
○ Do not agree

Appendix A.3: Insomnia Severity Index (Morin et al., 2011)

The Insomnia Severity Index has seven questions. The seven answers are added up to get a total score. When you have your total score, look at the 'Guidelines for Scoring/Interpretation' below to see where your sleep difficulty fits.

For each question, please CIRCLE the number that best describes your answer.

Please rate the CURRENT (i.e. LAST 2 WEEKS) SEVERITY of your insomnia problem(s).

Insomnia Problem	**None**	**Mild**	**Moderate**	**Severe**	**Very**
1. Difficulty falling asleep	0	1	2	3	4
2. Difficulty staying asleep	0	1	2	3	4
3. Problems waking up too early	0	1	2	3	4

4. How SATISFIED/DISSATISFIED are you with your CURRENT sleep pattern?

Very Satisfied	Satisfied	Moderately Satisfied	Dissatisfied	Very Dissatisfied
0	1	2	3	4

5. How NOTICEABLE to others do you think your sleep problem is in terms of impairing the quality of your life?

Not at all Noticeable	A Little	Somewhat	Much	Very Much Noticeable
0	1	2	3	4

6. How WORRIED/DISTRESSED are you about your current sleep problem?

Not at all Worried	A Little	Somewhat	Much	Very Much Worried
0	1	2	3	4

7. To what extent do you consider your sleep problem to INTERFERE with your daily functioning (e.g. daytime fatigue, mood, ability to function at work/daily chores, concentration, memory, mood, etc.) CURRENTLY?

Not at all Interfering	A Little	Somewhat	Much	Very Much Interfering
0	1	2	3	4

Appendix A.4: What Parents Say and Do (King & Delfabbro, 2016)

Q1 Has a parent ever talked to you about responsible Internet use or "cybersafety"?

- ○ No (1)
- ○ Yes (2)

Q2 How often do your parents make rules or set limits about:

	Never (0)	Rarely (1)	Sometimes (2)	Most of the Time (3)	Always (4)
...what you are allowed to do online? (1)	○	○	○	○	○
...how long you can spend online? (2)	○	○	○	○	○
...using any media devices in the bedroom? (3)	○	○	○	○	○

Q3 How often is at least one of your parents:

	Never (0)	Rarely (1)	Sometimes (2)	Most of the Time (3)	Always (4)
...physically in the same room when you are online at home? (1)	○	○	○	○	○
...able to see what you are doing online when at home? (2)	○	○	○	○	○

Q4 How often do either of your parents play videogames?

- ○ Never (0)
- ○ Rarely (1)
- ○ Sometimes (2)
- ○ Most of the Time (3)
- ○ Always (4)

Q5 Do you think this parent plays too much?

- ○ No (1)
- ○ Yes (2)

Q6 Do you play videogames with your parents?

○ Yes (1)
○ No (2)

Q7 Which parent do you play videogames with the most?

○ Mum (1)
○ Dad (2)
○ Both parents about the same (3)
○ I never play videogames with my parents (4)

Appendix A.5: Cognitive Appraisal of Risky Events (Fromme et al., 1997)

Please read each statement carefully, and then fill in the bubble that corresponds to the value on the scale.

	Very Inaccurate (5)	Moderately Inaccurate (4)	Neither Inaccurate nor Accurate (3)	Moderately Accurate (4)	Very Accurate (5)
Am the life of the party (E) (1)	○	○	○	○	○
Sympathize with others' feelings (A) (2)	○	○	○	○	○
Get chores done right away (C) (3)	○	○	○	○	○
Have frequent mood swings (N) (4)	○	○	○	○	○
Have a vivid imagination (I) (5)	○	○	○	○	○
Don't talk a lot (E) (6)	○	○	○	○	○
Am not interested in other people's problems (A) (7)	○	○	○	○	○
Often forget to put things back in their proper place (C) (8)	○	○	○	○	○
Am relaxed most of the time (N) (9)	○	○	○	○	○
Am not interested in abstract ideas (I) (10)	○	○	○	○	○

Please read each statement carefully, and then fill in the bubble that corresponds to the value on the scale.

	Very Inaccurate (1)	Moderately Inaccurate (2)	Neither Inaccurate nor Accurate (3)	Moderately Accurate (4)	Very Accurate (5)
Talk to a lot of different people at parties (E) (1)	○	○	○	○	○
Feel others' emotions (A) (2)	○	○	○	○	○
Like order (C) (3)	○	○	○	○	○
Get upset easily (N) (4)	○	○	○	○	○
Have difficulty understanding abstract ideas (I) (5)	○	○	○	○	○
Keep in the background (E) (6)	○	○	○	○	○
Am not really interested in others (A) (7)	○	○	○	○	○
Make a mess of things (C) (8)	○	○	○	○	○
Seldom feel blue (N) (9)	○	○	○	○	○
Do not have a good imagination (I) (10)	○	○	○	○	○

Appendix A.6: Game Engagement Questionnaire (Brockmyer et al., 2009)

How often in the last two weeks when you play video/computer games have you experienced the following

	No (1)	Maybe (2)	Yes (3)
I lose track of time (1)	○	○	○
Things seem to happen automatically (2)	○	○	○
I feel different (3)	○	○	○
I feel scared (4)	○	○	○
The game feels real (5)	○	○	○
If someone talks to me, I don’t hear them (6)	○	○	○
I get wound up (7)	○	○	○
Time seems to kind of stand still or stop (8)	○	○	○
I don’t answer when someone talks to me (9)	○	○	○
I feel spaced out (10)	○	○	○

	No (1)	Maybe (2)	Yes (3)
I can’t tell that I’m getting tired (1)	○	○	○
Playing seems automatic (2)	○	○	○
My thoughts go fast (3)	○	○	○
I lose track of where I am (4)	○	○	○
I play without thinking about how to play (5)	○	○	○
Playing makes me feel calm (6)	○	○	○
I play longer than I meant to (7)	○	○	○
I really get into the game (8)	○	○	○
I feel like I just can’t stop playing (9)	○	○	○

Appendix A.7: Gamer Experience Survey

The purpose of this survey is to assess your level of familiarity with videogames and your gaming habits. Please read each question carefully and answer as accurately as possible. Your response to each question represents a critical aspect of this research, so please try to answer each question as best you can. If you have any questions, please ask the experimenter.

Name: ___________________ e-mail address: ___________________

Phone number: ___________________ Age: _____________ Sex:___________

Handedness: Right-handed Left-Handed

Please circle one answer per question.

How many times in the past year have you done the following:

1. Played a PC based video game?

Never Seldom Sometimes Frequently Often

2. Played a console video game system (e.g., Playstation 2, Game Cube, X-Box, etc…)?

Never Seldom Sometimes Frequently Often

3. Played a video game in an arcade?

Never Seldom Sometimes Frequently Often

4. Played an online java-script video game (e.g., www.popcap.com)

Never Seldom Sometimes Frequently Often

5. Do you consider yourself to be an active video game player?

Yes No

6. During an average week, how many hours will you spend playing videogames?
(Please answer using a whole number, e.g. 101 and avoid putting down a range e.g. 100 -200)

7. If you play videogames, at what age did you first begin playing? _____________

8. Do you own a personal computer?
Yes No

9. Please list any videogame systems in your household:
____
____

____

____

10. Please estimate the number of hours per week you :
A. Play PC based videogames: _____________hrs
B. Play console videogames (e.g., Playstation 2, Game Cube, X-Box, etc…): _____________hrs
C. Play videogames in an arcade: __________hrs
D. Play online java-script games (e.g., www.popcap.com): ___________hrs

Specific Game Experience:
How frequently do you do the following:

1. Play DOOM, Quake, Halo, Half-Life, or similar first-person shooters?

Never Seldom Sometimes Frequently Often

2. Play Medal of Honor (any version, e.g. Medal of Honor Allied Assault, Medal of Honor Pacific Assault, etc…)?

Never Seldom Sometimes Frequently Often

3. Play Starcraft, Warcraft, Command and Conquer, Age of Empires, Civilization, Sim City, or similar strategy games?

Never Seldom Sometimes Frequently Often

4. Play Rise of Nations?

Never Seldom Sometimes Frequently Often

5. Play Tetris or variants of Tetris?

Never Seldom Sometimes Frequently Often

6. Play Final Fantasy or similar role-playing videogames?

Never Seldom Sometimes Frequently Often

7. Play simulator videogames (e.g., flight simulator or racing simulator games)?

Never Seldom Sometimes Frequently Often

8. Play The Sims or similar videogames?

Never Seldom Sometimes Frequently Often

9. Play Grand Theft Auto or similar action/platform games?

Never Seldom Sometimes Frequently Often

10. Play sports videogames (e.g., NBA Live, Madden NFL, FIFA Soccer, SSX, Tony Hawk, or similar games)?

Never Seldom Sometimes Frequently Often

11. Play Dance Dance Revolution?

Never Seldom Sometimes Frequently Often

12. Play computer Solitaire, Free Cell, or Minesweeper?

Never Seldom Sometimes Frequently Often

13. Have you ever purchased a video game?

Yes No

14. Approximately how many videogames do you own? ___________ games

15. If you own videogames, please list as many videogames you own in the space provided below.

____
____
____
____
____
____
____
____
____

16. I prefer:
A. Strategy videogames
B. Action videogames
C. Puzzle videogames
D. Role-playing videogames
E. Sports videogames
F. No preference

17. I consider myself:
A. A non-video game player
B. A novice video game player
C. An occasional video game player
D. A frequent video game player
E. An expert video game player

18. Compared to five years ago:
A. I play videogames more frequently now.
B. I play videogames less frequently now.
C. There has been little change in the frequency of my video game playing.

19. Please list the five videogames you have the most experience with. If you have little or no experience with videogames, please write “None”.

____
____
____
____
____
____

Appendix A.8: General Information and Health Questionnaire

This is a general health questionnaire that also asks questions about your sleeping patterns. Where appropriate, please circle the correct response. All the information you provide will remain confidential.

Name: ____
Email address:_ Home phone number:
Mobile phone number:
Address: ____
____

Date of birth: ______________
Gender: Male/Female
Height: cm Weight:_kg

On **<u>weeknights</u>** (Sunday to Thursday nights);

At what time do you usually go to bed at night?

At what time do you usually turn out the lights to go to sleep at night?

After turning the lights out at night to go to sleep, how long does it usually take to fall asleep?

How many nights per week do you have trouble getting to sleep?

Never 1 2 3 4 5 6 7

How many days, across the whole week, do you wake up before you intend to and cannot get back to sleep?

Never 1 2 3 4 5 6 7

On **<u>weekdays</u>** (Monday to Friday mornings);

At what time do you usually wake up **<u>finally</u>**?

At what time do you usually get out of bed?

How difficult is it for you to wake up and get out of bed on <u>weekdays</u>?

1	2	3	4	5
not at all		difficult		very difficult

On the **weekend** (Saturday and Sunday mornings):

At what time do you usually wake up finally?

At what time do you usually get out of bed?

How difficult is it for you to wake up and get out of bed on weekends?

1 not at all	2	3 difficult	4	5 very difficult

Using the scale below please indicate in the boxes below your levels of alertness across a typical day

1 Very alert	2	3	4	5 Not at all alert

7am	8	9	10	11	12pm	1	2	3	4	5	6	7	8	9	10	11	12am

What do you usually do in the hour before bed? (eg, watch television, shower)

____

Do you have any food allergies? Yes/No

If yes, what are they?

Have you travelled across time zones in the last 3 months? Yes/No

If yes: where?

when?

On average, how many caffeinated beverages (eg. Tea, coffee, coke) do you drink per day? ____

On average, how many food products containing caffeine (eg, chocolate bars) do you eat per day?

____

On average, how many alcoholic drinks do you consume per day during the week?

____

On average, how many alcoholic drinks do you consume over the weekend?

____

Do you smoke cigarettes? Yes/No

Do you take any ‘recreational’ drugs? Yes/No

If yes, what substances do you take?

____

how often per week do you take them?

____

Do you take any substance to help you sleep at night (eg, sleeping pills, herbal supplements, Milo)?

If yes: What do you take?

How often per week do you take it?

What amount do you take?

Are you taking any medication which may affect your sleep? Yes/No

If yes, what is it?

Is your sleep disturbed by any of the following conditions?

Hypertension yes/no
Diabetes yes/no
Asthma yes/no
Raynaud’s Syndrome yes/no
Lung or heart disease yes/no
Arthritis yes/no
Pain (e.g., Back pain) yes/no
Headaches yes/no
Restless legs (or arms) yes/no
Night sweats yes/no
Bad dreams yes/no
Other yes/no
specify

Try to answer the following questions as best as possible. It may help if you recall someone mentioning some things about your sleep.

Do you have regular twitching legs (or arms) during your sleep?

[ ] never

[ ] 1 night per week

[ ] 2-3 nights per week

[ ] 4-5 nights per week

[ ] 6-7 nights per week

Please describe if possible

Do you snore in your sleep?

[ ] never

[ ] 1 night per week

[ ] 2-3 nights per week

[ ] 4-5 nights per week

[ ] 6-7 nights per week

Generally, how loud is the snoring?

[ ] light

[ ] moderately loud

[ ] very loud

Does your breathing stop for short periods (eg. 10 - 20 secs) during your sleep?

Never 1 2 3 4 5 6 7

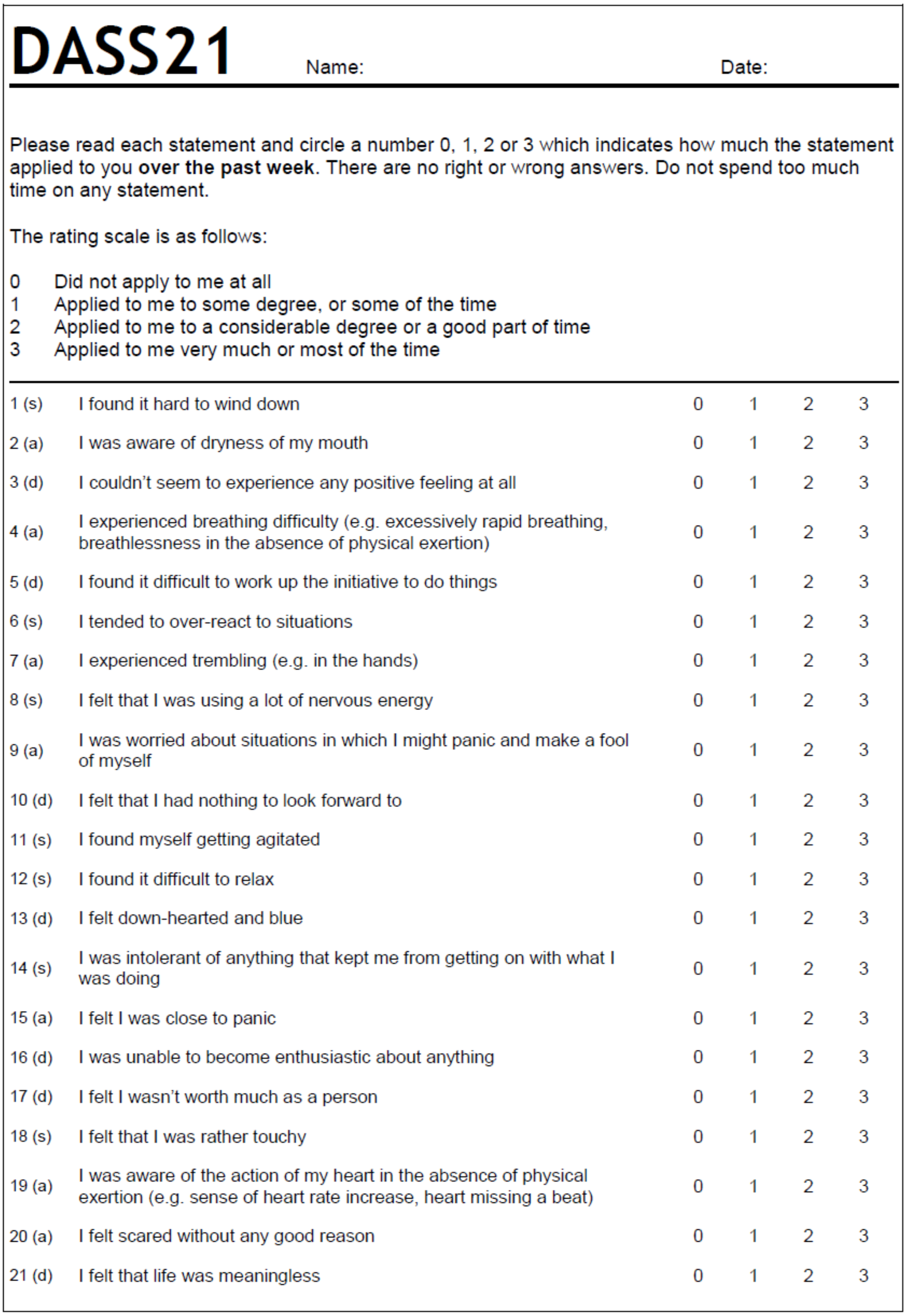
Have any other behaviours been observed?

[ ] no

[ ] yes: Please specify

Thank-you for completing the questionnaire

Appendix A.9: DASS-21 (Lovibond & Lovibond, 1996)



DASS21

Name:

Date:

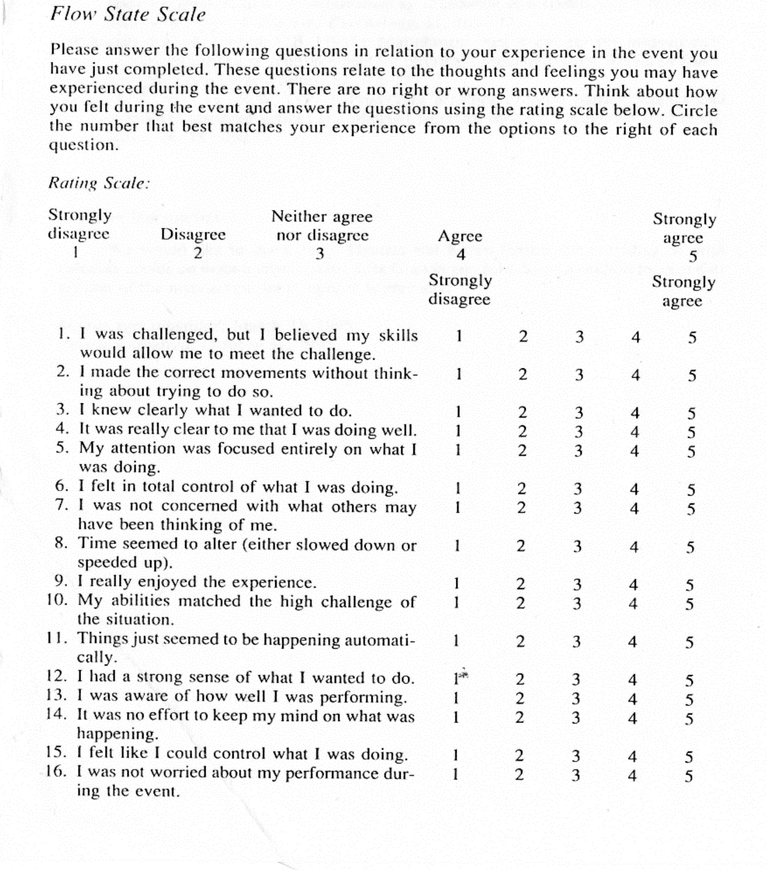
Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you **over the past week**. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0	Did not apply to me at all
1	Applied to me to some degree, or some of the time
2	Applied to me to a considerable degree or a good part of time
3	Applied to me very much or most of the time

1 (s)	I found it hard to wind down	0	1	2	3
2 (a)	I was aware of dryness of my mouth	0	1	2	3
3 (d)	I couldn't seem to experience any positive feeling at all	0	1	2	3
4 (a)	I experienced breathing difficulty (e.g. excessively rapid breathing, breathlessness in the absence of physical exertion)	0	1	2	3
5 (d)	I found it difficult to work up the initiative to do things	0	1	2	3
6 (s)	I tended to over-react to situations	0	1	2	3
7 (a)	I experienced trembling (e.g. in the hands)	0	1	2	3
8 (s)	I felt that I was using a lot of nervous energy	0	1	2	3
9 (a)	I was worried about situations in which I might panic and make a fool of myself	0	1	2	3
10 (d)	I felt that I had nothing to look forward to	0	1	2	3
11 (s)	I found myself getting agitated	0	1	2	3
12 (s)	I found it difficult to relax	0	1	2	3
13 (d)	I felt down-hearted and blue	0	1	2	3
14 (s)	I was intolerant of anything that kept me from getting on with what I was doing	0	1	2	3
15 (a)	I felt I was close to panic	0	1	2	3
16 (d)	I was unable to become enthusiastic about anything	0	1	2	3
17 (d)	I felt I wasn't worth much as a person	0	1	2	3
18 (s)	I felt that I was rather touchy	0	1	2	3
19 (a)	I was aware of the action of my heart in the absence of physical exertion (e.g. sense of heart rate increase, heart missing a beat)	0	1	2	3
20 (a)	I felt scared without any good reason	0	1	2	3
21 (d)	I felt that life was meaningless	0	1	2	3

Appendix A.10: Flow State Scale (FSS; Jackson & Marsh, 1996)



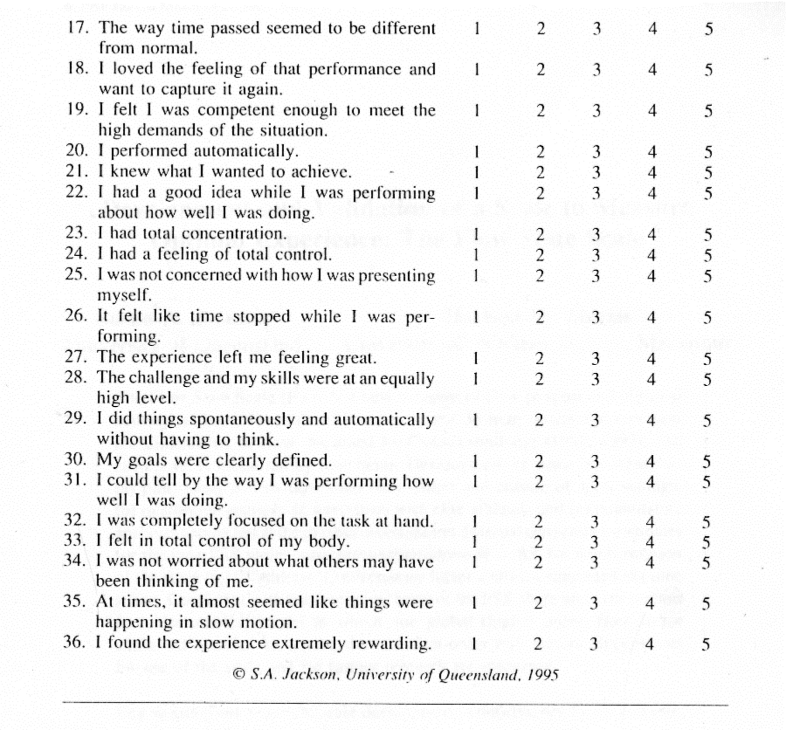
Flow State Scale

Please answer the following questions in relation to your experience in the event you have just completed. These questions relate to the thoughts and feelings you may have experienced during the event. There are no right or wrong answers. Think about how you felt during the event and answer the questions using the rating scale below. Circle the number that best matches your experience from the options to the right of each question.

Rating Scale:

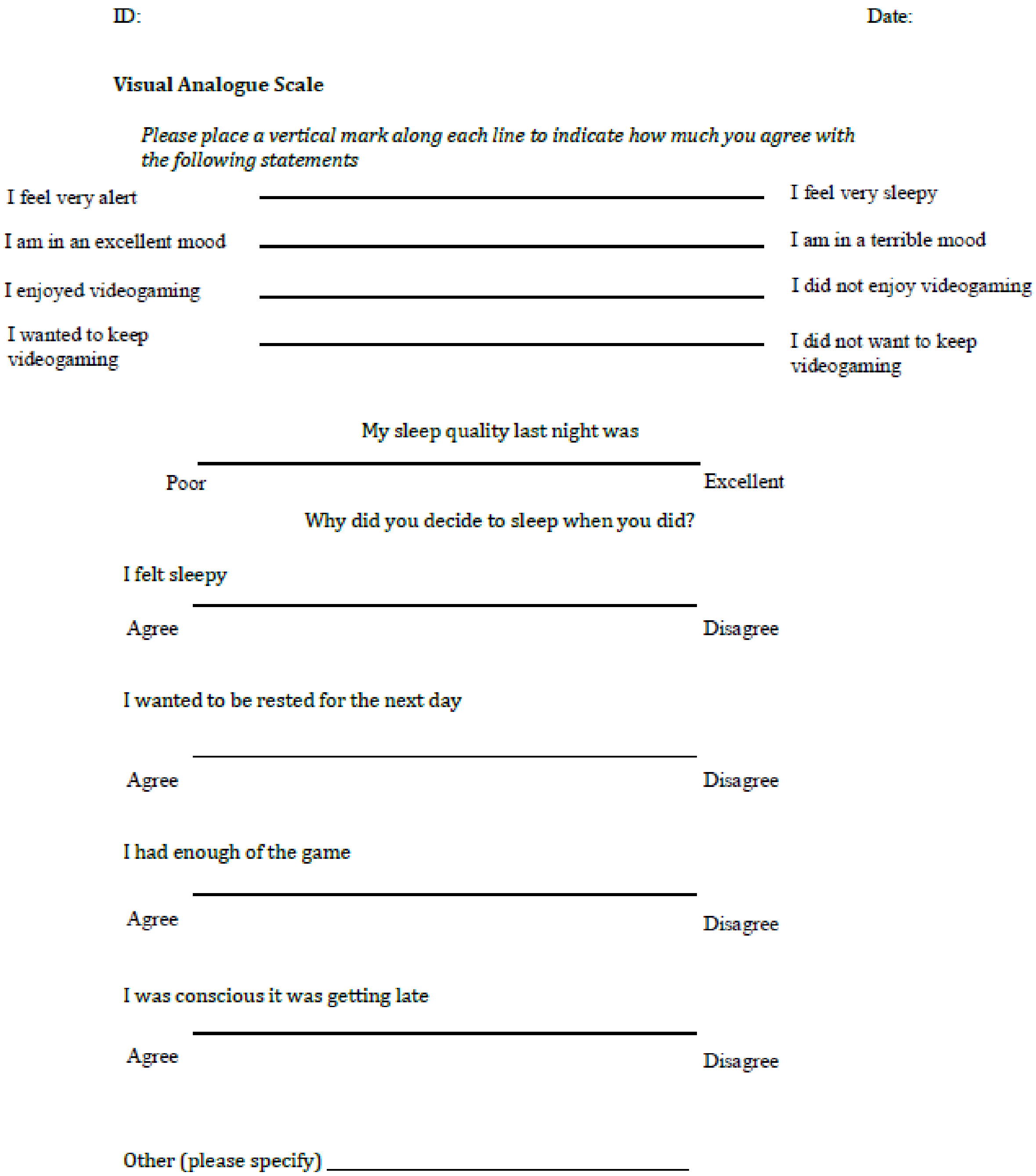
Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1	2	3	4	5

	Strongly disagree				Strongly agree
1. I was challenged, but I believed my skills would allow me to meet the challenge.	1	2	3	4	5
2. I made the correct movements without thinking about trying to do so.	1	2	3	4	5
3. I knew clearly what I wanted to do.	1	2	3	4	5
4. It was really clear to me that I was doing well.	1	2	3	4	5
5. My attention was focused entirely on what I was doing.	1	2	3	4	5
6. I felt in total control of what I was doing.	1	2	3	4	5
7. I was not concerned with what others may have been thinking of me.	1	2	3	4	5
8. Time seemed to alter (either slowed down or speeded up).	1	2	3	4	5
9. I really enjoyed the experience.	1	2	3	4	5
10. My abilities matched the high challenge of the situation.	1	2	3	4	5
11. Things just seemed to be happening automatically.	1	2	3	4	5
12. I had a strong sense of what I wanted to do.	1	2	3	4	5
13. I was aware of how well I was performing.	1	2	3	4	5
14. It was no effort to keep my mind on what was happening.	1	2	3	4	5
15. I felt like I could control what I was doing.	1	2	3	4	5
16. I was not worried about my performance during the event.	1	2	3	4	5



17. The way time passed seemed to be different from normal.	1	2	3	4	5
18. I loved the feeling of that performance and want to capture it again.	1	2	3	4	5
19. I felt I was competent enough to meet the high demands of the situation.	1	2	3	4	5
20. I performed automatically.	1	2	3	4	5
21. I knew what I wanted to achieve.	1	2	3	4	5
22. I had a good idea while I was performing about how well I was doing.	1	2	3	4	5
23. I had total concentration.	1	2	3	4	5
24. I had a feeling of total control.	1	2	3	4	5
25. I was not concerned with how I was presenting myself.	1	2	3	4	5
26. It felt like time stopped while I was performing.	1	2	3	4	5
27. The experience left me feeling great.	1	2	3	4	5
28. The challenge and my skills were at an equally high level.	1	2	3	4	5
29. I did things spontaneously and automatically without having to think.	1	2	3	4	5
30. My goals were clearly defined.	1	2	3	4	5
31. I could tell by the way I was performing how well I was doing.	1	2	3	4	5
32. I was completely focused on the task at hand.	1	2	3	4	5
33. I felt in total control of my body.	1	2	3	4	5
34. I was not worried about what others may have been thinking of me.	1	2	3	4	5
35. At times, it almost seemed like things were happening in slow motion.	1	2	3	4	5
36. I found the experience extremely rewarding.	1	2	3	4	5

Appendix A.11: Visual Analogue Scales



ID: Date:

Visual Analogue Scale

Please place a vertical mark along each line to indicate how much you agree with the following statements

I feel very alert	______________________	I feel very sleepy
I am in an excellent mood	______________________	I am in a terrible mood
I enjoyed videogaming	______________________	I did not enjoy videogaming
I wanted to keep videogaming	______________________	I did not want to keep videogaming

My sleep quality last night was

Poor ______________________ Excellent

Why did you decide to sleep when you did?

I felt sleepy

Agree ______________________ Disagree

I wanted to be rested for the next day

Agree ______________________ Disagree

I had enough of the game

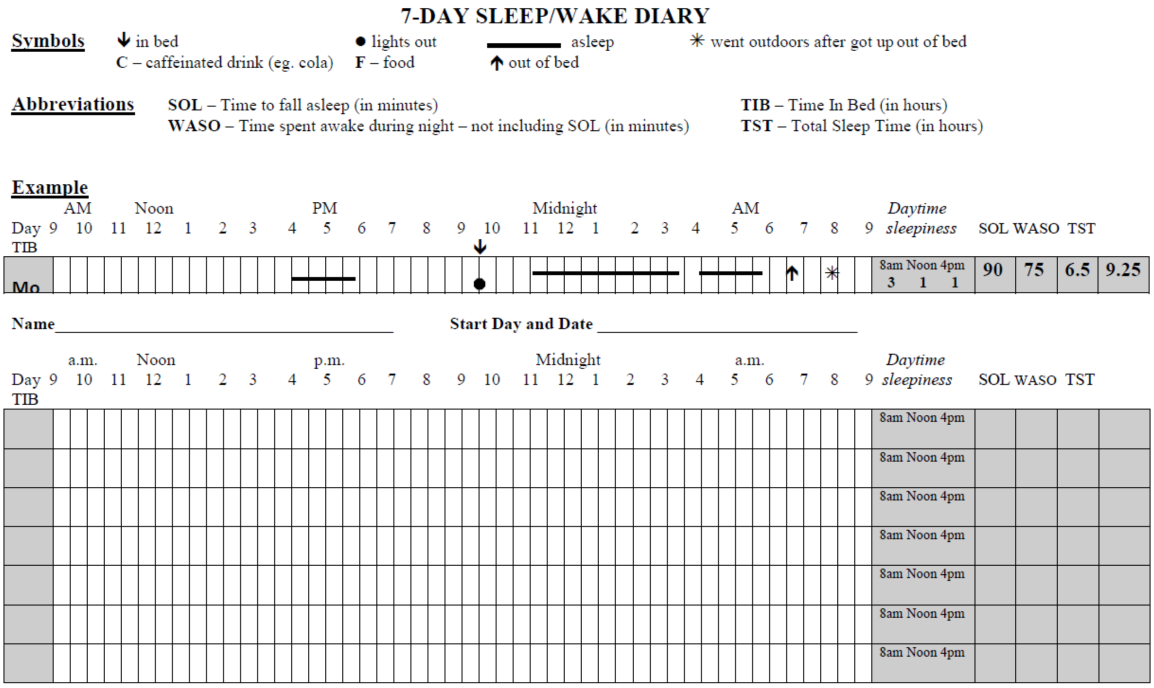
Agree ______________________ Disagree

I was conscious it was getting late

Agree ______________________ Disagree

Other (please specify) ______________________

Appendix A.12: Sleep Diary



7-DAY SLEEP/WAKE DIARY

Symbols
↓ in bed
C – caffeinated drink (eg. cola)
● lights out
F – food
▬ asleep
↑ out of bed
✳ went outdoors after got up out of bed

Abbreviations
SOL – Time to fall asleep (in minutes)
WASO – Time spent awake during night – not including SOL (in minutes)
TIB – Time In Bed (in hours)
TST – Total Sleep Time (in hours)

Example

AM Noon PM Midnight AM
Day 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 *Daytime sleepiness* SOL WASO TST
TIB

Day / TIB	Daytime sleepiness	SOL	WASO	TST	
Mo	8am Noon 4pm 3 1 1	90	75	6.5	9.25

Name____________________________ **Start Day and Date** ____________________________

a.m. Noon p.m. Midnight a.m.
Day 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 *Daytime sleepiness* SOL WASO TST
TIB

Day / TIB	Daytime sleepiness	SOL	WASO	TST	
	8am Noon 4pm				
	8am Noon 4pm				
	8am Noon 4pm				
	8am Noon 4pm				
	8am Noon 4pm				
	8am Noon 4pm				
	8am Noon 4pm				

Appendix B: Recruitment Advertisements (Chapter 6)

Computer Gaming and Sleep during Adolescence

The School of Psychology in Flinders University is conducting a paid research study investigating how computer gaming affects the sleep of teenagers.

Participating in the study will involve attending the sleep laboratory at Flinders University for 2 nights spaced approximately 1 week apart from 6pm to 8am on these nights. Food and drinks to be provided.

We are looking for people who are:

- Aged 15-17 years
- A good sleeper
- Do not consumer excessive caffeine or take recreational drugs
- Have not travelled overseas in the past 3 months

If you are interested in participating in this study, please contact Mrs Lisa Smith:

Email: lisajoanne.smith@flinders.edu.au
**A brief initial phone screening will be conducted to determine your eligibility for the study after returning a parental consent form.

Videogaming & Sleep Study

We are studying the effects of videogaming on sleep.
We are seeking male and females aged 15 – 17
years old to participate in our study.

Participation involves:

- Completing screening questionnaires via the phone
- 2 nights (e.g. Tues & Thurs) spaced a night apart in the Flinders Uni Sleep lab where:
  - You'll be asked to play new release videogames
  - Complete some questionnaires
  - You'll stay overnight
  - Meals and snacks will be provided

After your 2 nights in the Sleep Lab, we will give you a $50 Westfield gift voucher for your participation.

If interested, please contact principal researcher:
Lisa Smith: lisajoanne.smith@flinders.edu.au

Appendix C: Parent and Participant Information Forms (Chapter 6)

Lisa Smith

School of Psychology

GPO Box 2100
Adelaide SA 5001

Tel: 08 82012732
lisajoanne.smith@flinders.edu.au

CRICOS Provider No. 00114A

INFORMATION SHEET
FOR PARENT/GUARDIAN

Researchers:	**Supervisor(s):**
Lisa Smith (Lead researcher) Michelle Short Chelsea Reynolds Goriza Micic Cele Richardson Psychology Department Flinders University	Associate Professor Michael Gradisar Professor Leon Lack Psychology Department Flinders University

Description and purpose of the study

This study is part of the project entitled '*Videogaming and sleep'.* This project will investigate the relationship between how engaging videogames are and the effect this has on sleep and the body. This project is supported by Flinders University Psychology department. This project aims to find out if a more engaging videogame experience leads to poorer sleep.

What will they be asked to do?

Your child is invited to attend the Flinders University Sleep Laboratory on two separate testing nights, from 8pm to 8:15am the following morning. They will be asked to wear a wrist monitor whilst playing a new video game, rated MA. They will be asked to complete a few questionnaires before playing the videogames and a few questionnaires following the videogaming. A reimbursement for your participation of $50 will be provided to your child after participation. Participants will be provided with some snacks. Participants will also need to bring with them pyjamas, toiletries, and anything they will need for the following school day. Video cameras used during testing will be turned off whilst participants change attire. It should be noted that shower facilities will be unavailable in the morning, therefore participants should shower before arriving for the study. Participants will need to be dropped off at the Sleep Lab, room 137 Social Sciences South. A map is provided to you with the room highlighted, and there will signs directing you to the lab.

What benefit will my child gain from being involved in this study?

Your child will be able to enjoy playing the video game for hours on the 2 nights in the Sleep Lab. After study completion your child will also be able to understand how psychology and sleep research can be performed.

Will my child be identifiable by being involved in this study?

No. The data your child provides will be assigned a number not a name.

Are there any risks or discomforts if my child is involved?

We do not anticipate any significant risks. There may be some small discomfort if your child does not get enough sleep, but the researchers will monitor their safety if this happens. If your child wishes to withdraw from the study during testing (i.e. at night) you will need to collect them from the laboratory. Support services should your child experience emotional distress include HeadSpace (1800 650 890) and Youth Beyond Blue (1300 22 4636, 24 hours) .

How do I agree that my child can participate?

A consent form accompanies this information sheet. If you agree that your child can participate please read and sign the form and give to your child to bring to their first visit to the Sleep lab. Your child will not be allowed to participate without a signed parental consent form.

Thank you for taking the time to read this information sheet and we hope that you will accept our invitation to be involved

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (#7127). For more information regarding ethical approval of the project the Executive Officer of the Committee can be contacted by telephone on 8201 3116, by fax on 8201 2035 or by email human.researchethics@flinders.edu.au

APPENDIX C: Parent and Participant Information Forms

Lisa Smith
School of Psychology
GPO Box 2100
Adelaide SA 5001
Tel: 08 82012732
lisajoanne.smith@flinders.edu.au
CRICOS Provider No. 00114A

INFORMATION SHEET FOR PARTICIPANTS

Researchers:	**Supervisor(s):**
Lisa Smith (Lead researcher) Michelle Short Chelsea Reynolds Goriza Micic Cele Richardson Psychology Department Flinders University	Associate Professor Michael Gradisar Professor Leon Lack Psychology Department Flinders University

Description of the study:
This study is part of the project entitled '*Videogaming and sleep'*. This project will investigate the relationship between how engaging videogames are and the effect this has on sleep and the body. This project is supported by Flinders University Psychology department.

Purpose of the study:
This project aims to find out if a more engaging videogame experience leads to poorer sleep.

What will I be asked to do?
You are invited to attend the Sleep laboratory on two separate nights, from 8pm to 8:15am. You will be asked to wear a wrist monitor whilst playing a new video game. Video cameras used during testing will be turned off whilst you change attire. You will be asked to complete a few questionnaires when you finish playing the video game. A reimbursement for your participation of $50 will be provided for participation.

What benefit will I gain from being involved in this study?
You will be able to enjoy playing the video game on the 2 nights in the Sleep Lab. After study completion you will also be able to understand how psychology and sleep research can be performed to answer questions we are interested in understanding.

Will I be identifiable by being involved in this study?
No. The data you provide will be assigned a number, not your name.

Are there any risks or discomforts if I am involved?
We do not anticipate any significant risks. There may be some small discomfort if you do not get enough sleep, but the researchers will monitor your safety if this happens.

How do I agree to participate?
Participation is voluntary. You may answer 'no comment' or refuse to answer any questions and you are free to withdraw from the study at any time without effect or consequences. A consent form accompanies this information sheet. If you agree to participate please have your parents/guardians read and sign the form and bring it to your first visit to the Sleep lab.

How will I receive feedback?
Outcomes from the project will be summarised and given to you by the researchers if you request.

Thank you for taking the time to read this information sheet and we hope that you will accept our invitation to be involved

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (#7127). For more information regarding ethical approval of the project the Executive Officer of the Committee can be contacted by telephone on 8201 3116, by fax on 8201 2035 or by email human.researchethics@flinders.edu.au

Appendix D: Further Information Form (Chapter 6)

Lisa Smith
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GPO Box 2100
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lisajoanne.smith@flinders.edu.au
CRICOS Provider No. 00114A

FURTHER INFORMATION SHEET

The results of the screening questionnaire you completed indicated that you may be currently experiencing some level of emotional distress. If you feel you would like some more information you may find the following resources helpful:

Youth Beyond Blue
https://www.youthbeyondblue.com
1300 22 4636 (24 hours)
(Online chat support and email support also available)

Headspace
http://headspace.org.au/headspace-centres/adelaide/
1800 650 890
Online chat support available at https://www.eheadspace.org.au

You may also choose to speak to your parents or a trusted adult about how you are feeling. Talking to your GP may also be helpful.

Yours sincerely,

Lisa Smith
Lead Researcher/Provisional Psychologist (PSY0001814734)

Appendix E: Parental Consent Form (Chapter 6)

Flinders
UNIVERSITY

PARENTAL CONSENT FORM FOR CHILD PARTICIPATION IN RESEARCH

(By experiment)

Videogaming and Sleep

I …..

being over the age of 18 years hereby consent to my child ....

participating, as requested, in the ………………………………… for the research project on ……………………….

1. I have read the information provided.
2. Details of procedures and any risks have been explained to my satisfaction.
3. I am aware that I should retain a copy of the Information Sheet and Consent Form for future reference.
4. I understand that:
   - My child may not directly benefit from taking part in this research.
   - My child is free to withdraw from the project at any time and is free to decline to answer particular questions.
   - While the information gained in this study will be published as explained, my child will not be identified, and individual information will remain confidential.
   - My child may ask that the recording/observation be stopped at any time, and he/she may withdraw at any time from the session or the research without disadvantage.

Parent/Guardian signature……………………………………Date…………………...

I certify that I have explained the study to the volunteer and consider that she/he understands what is involved and freely consents to participation.

Researcher's name……………………………….…………………….................

Researcher's signature…………………………………..Date…………………….

NB: Two signed copies should be obtained.

Appendix F: Participant Instructions (Chapter 6)

Videogaming and sleep study 2016

Participant Instructions

Night 1

Good evening and thank-you again for participating in the videogaming and sleep experiment. We hope you enjoy your time in the sleep laboratory at Flinders University

You will now have had a tour of the sleep laboratory and be ready to start playing. You will be able to **start playing from 8.30pm**

At 8.30pm a researcher will come into your room and start the *Rise of the Tomb Raider* (*ROTR*) game for you. The researcher will select the difficulty level and then the game can start. You must not change this difficulty level.

You will not have access to your smartphone during the experiment but it will be stored in the main office if you require access to your phone to make emergency calls (e.g. to a parent/guardian).

You may leave your room at any time and use the bathroom facilities. You may continue playing ROTR for as long as you like up until 1am. At 1am a researcher will come into the room and ask you to save your game and shut-down the console. You will be awoken by a researcher at 7am if you are not awake.

Please remember to **save your game when you finish playing and complete the questionnaire on your desk.** You may turn on the lamp briefly for this.

At any time during the experiment you may press the red buzzer if you have any questions or difficulties and a researcher will come to your room.

In the morning you will be asked to complete a very short visual questionnaire

Videogaming and sleep study 2016

Participant Instructions

Night 2

Good evening and thank-you again for participating in the videogaming and sleep experiment. We hope you enjoy your time in the sleep laboratory at Flinders University

As per the previous night you will be able to **start playing from 8.30pm**

At 8.30pm a researcher will come into your room and tell you to un-pause the game. The difficulty level will already be selected. You must not change this difficulty level

You will not have access to your smartphone during the experiment but it will be stored in the main office if you require access to your phone to make emergency calls (e.g. to a parent/guardian).

You may leave your room at any time and use the bathroom facilities. You may continue playing ROTR for as long as you like up until 1am. At 1am a researcher will come into the room and ask you to save your game and shut-down the console. You will be awoken by a researcher at 7am if you are not awake.

Please remember to **save your game when you finish playing and complete the questionnaire on your desk.** You may turn on the lamp briefly for this.

At any time during the experiment you may press the red buzzer if you have any questions or difficulties and a researcher will come to your room.

In the morning you will be asked to complete a very short visual questionnaire. You will also be asked to sign that you have received your $50 participant payment (Westfield Voucher).

Appendix G: Debrief Form (Chapter 6)

Lisa Smith
School of Psychology
GPO Box 2100
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Tel: 08 82012732
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CRICOS Provider No. 00114A

DEBRIEFING FORM

Purpose of this study

The goal of this study was to determine if inducing a state of ‘flow’ (when individuals are really absorbed in a computer game) was related to later bedtimes in adolescents. We were interested in whether experiencing more flow was related to later bedtimes. We also wanted to find out about the difference between trait flow (an individual’s general tendency to be absorbed my computer games) and state flow (the actual amount of flow experienced during computer gaming in the study) in terms of how these two factors affect sleep. Finally, we also wanted to find out about the physiological effect of flow states on the body (e.g., heart rate) and if these physiological variables were partly responsible for any relationship between flow states experienced and the amount of sleep obtained after gaming.

If we truly wanted to see how these above mentioned factors influenced adolescents' bedtimes, we needed to conceal this aspect of our study from you. For example to induce a state of flow involves an individual being very absorbed in the activity they are doing, in this case videogaming. If we had told you were interested in how absorbed you were in the video game it may have changed your true behaviour. We apologise for this concealment, yet hope you understand our reasons for it.

If you wish to receive a summary report of the findings of this study please inform the researchers. If you have any further questions or queries please feel free to contact the project supervisor Associate Professor Michael Gradisar (michael.gradisar@flinders.edu.au), Flinders University, School of Psychology.

Yours sincerely,

Lisa Smith
Lead Researcher/Clinical Psychology PhD candidate

This research project has been approved by the Flinders University Social and Behavioural Research Ethics Committee (#7127). For more information regarding ethical approval of the project the Executive Officer of the Committee can be contacted by telephone on 8201 3116, by fax on 8201 2035 or by email human.researchethics@flinders.edu.au