

The impact of prolonged violent video-gaming on adolescent sleep: an experimental study

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Keywords

adolescence, polysomnography, sleep–wake activity, video-games, violent media

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Accepted in revised form 12 September 2012;
received 23 April 2012

DOI: 10.1111/j.1365-2869.2012.01060.x

SUMMARY

Video-gaming is an increasingly prevalent activity among children and adolescents that is known to influence several areas of emotional, cognitive and behavioural functioning. Currently there is insufficient experimental evidence about how extended video-game play may affect adolescents' sleep. The aim of this study was to investigate the short-term impact of adolescents' prolonged exposure to violent video-gaming on sleep. Seventeen male adolescents (mean age = 16 ± 1 years) with no current sleep difficulties played a novel, fast-paced, violent video-game (50 or 150 min) before their usual bedtime on two different testing nights in a sleep laboratory. Objective (polysomnography-measured sleep and heart rate) and subjective (single-night sleep diary) measures were obtained to assess the arousing effects of prolonged gaming. Compared with regular gaming, prolonged gaming produced decreases in objective sleep efficiency (by $7 \pm 2\%$, falling below 85%) and total sleep time (by 27 ± 12 min) that was contributed by a near-moderate reduction in rapid eye movement sleep (Cohen's $d = 0.48$). Subjective sleep-onset latency significantly increased by 17 ± 8 min, and there was a moderate reduction in self-reported sleep quality after prolonged gaming (Cohen's $d = 0.53$). Heart rate did not differ significantly between video-gaming conditions during pre-sleep game-play or the sleep-onset phase. Results provide evidence that prolonged video-gaming may cause clinically significant disruption to adolescent sleep, even when sleep after video-gaming is initiated at normal bedtime. However, physiological arousal may not necessarily be the mechanism by which technology use affects sleep.

INTRODUCTION

Video-gaming is a prevalent pastime among adolescent males in Western industrial countries, with at least 75% playing video-games every week (Desai *et al.*, 2010) and up to 9% reporting an excessive video-gaming habit (Gentile, 2009). Several risks of video-gaming have been documented, including 'addiction' (King *et al.*, 2011), aggressive behaviour (Anderson *et al.*, 2010), attention problems (Swing *et al.*, 2010), depression and anxiety (Mentzoni *et al.*, 2011), poor academic achievement (Smyth, 2007), reduced empathy (Bartholomew *et al.*, 2005), and impaired social functioning (Gentile *et al.*, 2011). Despite survey findings

indicating negative sleep consequences of video-gaming (Eggermont and Van den Bulck, 2006; Oka *et al.*, 2008; Schochat *et al.*, 2010; Suganuma *et al.*, 2007; National Sleep Foundation, 2011), there is scant experimental research evaluating the causality, magnitude and mechanisms of purported effects.

Models have been proposed to explain how electronic media may negatively impact on sleep in several ways, including: (a) direct displacement of normal sleep; (b) increased mental, emotional or physiological arousal; and (c) bright light exposure causing delay of circadian rhythm (Cain and Gradisar, 2010; Gradisar and Short, in press). Available survey-based evidence has suggested that

electronic media may displace sleep; however, the physical effects of pre-sleep video-gaming are not well understood. Experimental studies are necessary for the field to understand the cause-and-effect relationship between technology use and sleep (Gradisar and Short, in press). However, there have been only four experimental studies investigating video-gaming and sleep (Dworak *et al.*, 2007; Higuchi *et al.*, 2005; Ivarsson *et al.*, 2009; Weaver *et al.*, 2010), which surprisingly have documented smaller than expected effects. In Higuchi *et al.*'s study, young adults' ($N = 7$) pre-sleep video-gaming of 2 h 45 mins increased sleep-onset latency (SOL) by 2.3 min, as compared with control conditions. Similar findings were reported in a study of older male adolescents ($N = 13$, aged 14–18 years), with SOL extended by 3.5 min after 50 min of playing a violent video-game (Weaver *et al.*, 2010). Larger effects were reported in a sample of schoolchildren ($N = 11$, aged 12–14 years) with 'excessive' (60 min) video-gaming directly before bedtime increasing SOL by 22 min (Dworak *et al.*, 2007). Finally, no effects on sleep were found for 19 boys (12–15 years) after playing video-games at home; however, they did go to bed later compared with a non-video-game control condition (Ivarsson *et al.*, 2009).

Although the effects of video-gaming on sleep architecture appear to be minimal (Dworak *et al.*, 2007; Higuchi *et al.*, 2005) or negligible (Weaver *et al.*, 2010), it has been noted that the relatively low level of exposure to video-gaming (i.e. 60 min) may be insufficient to produce discernible effects (Weaver *et al.*, 2010). The aim of the present study was to examine the impact of prolonged (i.e. excessive) video-gaming on sleep. It was hypothesised that prolonged exposure (150 min) to a novel violent video-game before bedtime would be more disruptive to adolescent sleep than shorter-duration (50 min) exposure. Specifically, it was predicted that prolonged video-gaming would result in an increase in SOL and subjective alertness before sleep, and a reduction in total sleep time (TST). It was expected that sleep disturbances would be explained by heightened physiological arousal [i.e. heart rate (HR)] due to the fast-paced violent nature of the electronic media. Potential differences in sleep architecture, subjective measures of sleep quality and mood between video-gaming conditions were also examined.

MATERIALS AND METHODS

Subjects

Seventeen males, aged 16 ± 1 years, were recruited via advertisements at an on-campus high school at Flinders University, Adelaide, South Australia. Inclusion criteria were: males, aged 15–17 years, good physical health, no medications, no serious psychopathological symptomology, 'evening type' sleeping activity, and no current sleep disorders or complaints. Male subjects were selected because they spend more than three times as much time playing video-games (Desai *et al.*, 2010), and are four times more likely to be excessive video-gamers than females (Gentile, 2009).

Evening type was defined as a score of 16–41 on the Owl and Lark Questionnaire (Horne and Östberg, 1976). Participants' mean score on this measure was 31.1 (SD = 4.9). Adolescents were required to be 'regular' video-game players. Regular was defined as playing video-games every week in the preceding 3-month period. This was to ensure that participants were sufficiently familiar with video-games and gaming devices, such that normal gaming behaviour would be observed (as opposed to observing learning to master video-gaming, i.e. skill acquisition). Adolescents reported having played video-games for an average of 7.9 ± 3.4 years, and to currently play 17.7 ± 6.1 h of video-games per week. Informed consent was obtained from all subjects and their parents. The project was approved by the Flinders University Social and Behavioural Ethics Committee.

Experimental conditions and procedure

Each subject underwent two testing nights, 1 week apart, at the Flinders University Sleep Laboratory. Prior to testing nights, adolescents undertook an afternoon familiarisation session—including introduction to polysomnography, bedrooms and gaming equipment—to minimise 'first-night' effects on sleep (Gradisar *et al.*, 2006). Subjects were exposed to either 50 or 150 min of video-gaming (counterbalanced) directly before bedtime on each testing night. Fifty minutes of video-gaming exposure was considered 'normal', given males aged 13–18 years play video-games between 34 and 76 min day⁻¹ (Marshall *et al.*, 2006). Video-gaming for an uninterrupted 150 min period was considered 'prolonged' (i.e. >2 SDs above the mean). The study was conducted on weekdays during the school term, from October to November 2011.

Adolescents arrived at the sleep laboratory after school (15:30 hours), where physical activity, naps and caffeine consumption were restricted. Upon arrival, they engaged in normal after-school routines (e.g. converse, read, do homework) in a shared waiting lounge. A 7-day sleep diary was completed for the week prior to the initial testing night, and the week between testing nights, enabling calculation of mean school night bedtimes. Diaries were used to schedule pre-sleep video-gaming and bedtime. At 18:00 hours, an evening meal was provided, and all electronic media (e.g. laptops, mobile phones) were removed. Subjects changed into night gear, and polysomnographic and HR measures were affixed.

On each testing night, subjects played the video-game (*Warhammer 40 000: Space Marine*; THQ, Agoura Hills, CA, USA) on a PlayStation 3® (PS3) console. This video-game contained rapid action and 'strong violence' according to its age-restricted classification (MA15+). The Australian commercial release of the video-game coincided with the commencement of data collection; thus, the novelty and appeal of the video-game was not compromised by practice effects. All participants reported that they had not previously played the video-game. Each subject was assigned a private bedroom

with a single bed and video-gaming apparatus. Subjects created a personal profile on the PS3 in order to resume the game without losing progress on the subsequent testing night. Adolescents were instructed to maintain a semisupine position in bed during video-gaming. Distance to the television (2 m), sound level (80 dB), bedroom light (<30 lux) and temperature (24 ± 1 °C) were controlled across conditions. Video-gaming was scheduled to conclude 10 min before the subjects' usual bedtime to enable a check of polysomnographic and HR instruments, assess mood and subjective sleepiness, and allow the subject to use the bathroom. HR was recorded from the start of video-gaming to the following morning. Polysomnographic data were recorded from lights out to the next morning. Morning waking (lights on) occurred at 07:00 hours.

Mann–Whitney *U*-tests indicated no significant effect of order of testing nights on study variables of subjective and objective SOL, TST and sleep efficiency, $P = 0.350$ – 0.875 . Sleep history was also assessed as a potential confounding variable. A paired samples *t*-test indicated no significant difference in bedtime on each testing night ($\Delta M = 7.3$ min, $t = 0.74$, $P = 0.47$). Similarly, comparison of sleep diary data on weekdays preceding testing nights indicated no significant differences in mean time in bed ($t = 0.04$, $P = 0.96$), TST ($t = 0.70$, $P = 0.49$) and SOL ($t = 0.57$, $P = 0.58$). Night-time awakening could not be assessed as only one participant reported an awakening on one night preceding the testing night.

Data recording and analysis

Electroencephalogram, electrooculography and electromyography measurements via a portable Compumedics Somte (Compumedics, Melbourne, Vic., Australia) assessed SOL, TST and sleep architecture [e.g. slow-wave sleep (SWS) and rapid eye movement (REM) sleep]. Measurements of sleep architecture included minutes and percentage of each stage of sleep (Stages 1–4, REM) in addition to TST. Polysomnographic data were analysed retrospectively using computerised software (PSG, E-Series; Compumedics, Melbourne, Australia). Consistent with previous research (Weaver *et al.*, 2010), SOL was calculated as the latency (min) from lights out to the first of three consecutive epochs (one epoch = 30 s) of any stage of sleep (Rechtschaffen, 1968). Sleep efficiency was calculated using the formula: [(time asleep/time in bed) $\times$ 100].

Heart rate in beats min^{-1} (BPM) was assessed by a Polar RS800CX WearLink® and wireless transmitter, and analysed using the Polar Protrainer v.5 software (Polar Electro; Kempele, Finland). The transmitter enabled time markers, such as at the start and finish of video-gaming. The software yielded HR measurements in 5-s intervals, binned into 5-min intervals during each phase of the experiment. This approach was a refinement of past methods, such as measuring HR at a single time-point

(Higuchi *et al.*, 2005) or at three time-points only (Weaver *et al.*, 2010).

Questionnaire sleep measures were administered after video-gaming, and on the morning after each testing night. The Stanford Sleepiness Scale assessed subjective level of sleepiness directly after video-gaming (Hoddes *et al.*, 1973). Subjects indicated their mood (i.e. frustration, excitement, enjoyment, boredom, interest) after video-gaming by marking a line representing a continuum from 0 (i.e. 'not at all') to 10 (i.e. 'extremely'). Subjects were asked if they had played for 'long enough' and how much longer (in min) they would have continued video-gaming. A single-night sleep diary administered within 15 min of waking provided a subjective measure of SOL, TST and sleep quality.

RESULTS

Sleep variables and video-gaming exposure

Table 1 presents a summary of statistical comparisons of sleep–wake activities for the two video-gaming conditions. Sleep–wake parameters after prolonged video-gaming were negatively affected as compared with regular video-gaming. However, not all observed effects reached statistical significance. After prolonged video-gaming, TST decreased by 27 ± 12 min, sleep efficiency decreased by $7 \pm 2\%$ and subjective SOL increased by 17 ± 8 min, as compared with regular video-gaming. These differences were moderately sized (i.e. Cohen's $d = 0.59$ – 0.63). Polysomnographic measurement recorded a 3.5-min increase in SOL in the prolonged video-gaming condition. Despite a moderate effect size, this result was neither statistically significant nor clinically meaningful. Sleep architecture (SWS and REM sleep) in minutes or percentage time spent in sleep phase did not differ significantly between the two experimental conditions. However, a small effect for SWS and a near-moderate effect for REM sleep were found in the expected direction. Likewise, a moderate effect was found for self-reported sleep quality, with poorer ratings occurring after the prolonged video-gaming condition.

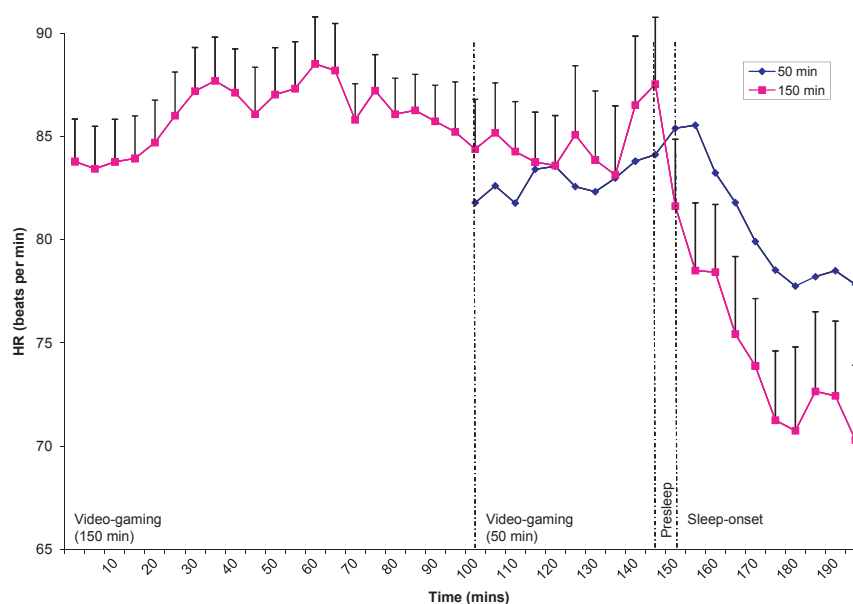
Sleep variables and physiological arousal

Fig. 1 plots the HR trajectories for each condition during video-gaming, pre-sleep and sleep initiation phases. During video-gaming, subjects' HR was predominantly in a state comparable to normal rest (i.e. ≤ 85 BPM; Palatini, 1999). Repeated-measures ANOVAs were conducted to assess the significance of change in HR in each condition during: (a) video-gaming; and (b) sleep onset. The within-subjects factor of 'Time' was converted to ratio measurements at equivalent intervals during video-gaming [i.e. from time 1 (baseline) to time 6 (endpoint)]. HR measurements were converted to mean ratings within 5-min intervals during the sleep-onset phase.

Table 1 A comparison of sleep–wake activity resulting from regular (50 min) versus prolonged (150 min) video-gaming exposure

Variable	V-G: 50 min		V-G: 150 min		$M_1 - M_2$	P	Cohen's <i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Polysomnography							
SOL (min)	12.6	13.3	16.1	19.4	3.5	NS	0.21
Stage 1 (min)	8.0	6.4	7.1	6.9	0.9	NS	0.14
Stage 2 (min)	132.7	38.7	129.9	48.5	2.8	NS	0.06
Stages 3 + 4 (SWS)	164.3	47.4	153.2	47.5	11.0	NS	0.23
REM sleep (min)	113.6	21.9	101.0	28.9	12.6	NS	0.48
TST (min)	418.6	42.9	391.3	49.1	27.3	<0.05	0.59
Sleep efficiency (%)	88.9	8.8	81.9	12.9	7.0	<0.05	0.63
Survey and sleep diary							
Sleepiness rating (PS)	4.2	1.5	4.6	1.4	0.4	NS	0.28
SOL (min)	22.0	18.8	39.1	36.1	17.1	<0.05	0.59
Sleep quality (/5)	2.7	1.0	2.3	0.4	0.6	NS	0.53
TST (min)	427.8	49.3	416.5	51.7	7.3	NS	0.22
Restedness (/10)	4.9	2.1	4.5	2.1	0.4	NS	0.26

NS, non-significant; SOL, sleep-onset latency; SWS, slow-wave sleep; TST, total sleep time; V-G, video-gaming.

**Figure 1.** Mean and standard error of heart rate (HR) trajectories (BPM) during video-gaming, pre-sleep and initiation of sleep onset.

A 2 (Condition: 50, 150 min) $\times$ 6 (Time: 5-min intervals) repeated-measures ANOVA assessed HR differences during video-gaming. No main effects for Condition ($F_{1,30} = 2.43$, $P = 0.13$), Time ($F_{5,150} = 1.17$, $P = 0.33$) or the interaction effect of Time $\times$ Condition ($F_{5,150} = 0.65$, $P = 0.66$), were observed. A 2 (Condition: 50 min, 150 min) $\times$ 8 (Time: baseline, then at 5-min intervals for 40 min) repeated-measures ANOVA assessed HR differences following lights out. No significant main effects of Condition ($F_{1,25} = 0.31$, $P = 0.59$) or Time $\times$ Condition ($F_{7,175} = 0.36$, $P = 0.92$) were evident. However, there was a significant main effect of Time ($F_{7,175} = 7.10$, $P < 0.001$, Cohen's $d = 1.29$), indi-

cating that, as expected, significant declines in HR occurred following lights out, independent of video-gaming condition.

Sleep variables and mood differences

Table 2 presents subjects' subjective mood after video-gaming. Mood did not differ significantly between the prolonged and regular video-gaming conditions. However, subjects appeared 'satiated' in the prolonged condition, reporting greater satisfaction and less desire to continue playing. The size of these effects was moderate to large (Cohen, 1992). Follow-up analyses revealed that, in the

Table 2 Mood levels after video-gaming exposure on experimental nights

Variable	V-G: 50 min		V-G: 150 min		$M_1 - M_2$	P	Cohen's d
	M	SD	M	SD			
Mood state (/10)							
Enjoyment	6.5	1.0	6.5	1.5	0.0	NS	0.00
Excitement	6.0	1.4	6.3	1.9	0.4	NS	0.18
Frustration	3.2	3.3	5.1	3.3	1.9	NS	0.58
Boredom	3.4	2.3	3.3	2.5	0.1	NS	0.04
Curiosity	5.5	1.6	6.0	1.5	-0.5	NS	0.32
Cognitive							
Played 'long enough'?* (/4)	2.3	1.2	3.4	0.8	1.1	<0.01	1.08
Extra time? [†] (min)	37.7	43.4	14.1	18.9	23.6	<0.01	0.71

*Scoring: 1, no; 2, somewhat; 3, almost; 4, yes.

[†]Item: 'How much longer would you have liked to play?'.

NS, non-significant; V-G, video-gaming.

regular video-gaming condition, desire to continue video-gaming was significantly positively correlated with subjective SOL ($r = 0.49$, $P < 0.05$) and objective SOL ($r = 0.62$, $P < 0.01$), but was not related to subjective sleepiness. Subjective excitement was significantly positively correlated with subjective SOL ($r = 0.72$, $P < 0.001$), but was not related to subjective sleepiness or objective SOL.

DISCUSSION

The present study found that prolonged violent video-gaming (150 min) led to a 27-min decrease in adolescents' TST and a 7% sleep efficiency decrease, as compared with regular video-gaming (50 min). This sleep efficiency reduction fell below the clinically accepted cut-off of 85% used to indicate several sleep disorders (e.g. insomnia). Objective SOL increased by 3.5 min, although subjects were able to fall asleep within healthy limits (i.e. <30 min; Espie *et al.*, 2001). Prolonged video-gaming had no significant effect on sleep architecture, yet a small effect was found for SWS and a near-moderate effect for REM sleep. Indeed, the 12.6-min REM sleep reduction in the present study is strikingly similar to that found in a previous study (12.8-min REM sleep reduction; Higuchi *et al.*, 2005). Interestingly, mood and the desire to continue video-gaming were positively correlated with SOL in the regular video-gaming condition. These data confirm epidemiological survey findings (Eggermont and Van den Bulck, 2006; Li *et al.*, 2007; Suganuma *et al.*, 2007) and provide further evidence of the negative influence of video-gaming on adolescents' sleep-wake activity.

Theoretical models have proposed several mechanisms by which electronic media may negatively impact on sleep (Cain and Gradisar, 2010; Gradisar and Short, in press). The present study assessed the mechanism of increased physiological arousal following video-gaming. The non-significant differences in HR indicate that physiological arousal did not account for differences in TST and efficiency in the

present study. Adolescents' HR during engagement in video-gaming was within normal limits for resting state (i.e. ≤ 85 BPM). It is therefore proposed that the impact of video-gaming on sleep may operate via an alternative mechanism than the disturbance of resting HR. Further research should assess alternative physiological mechanisms that may be impacted by video-game play, with possible effects on sleep.

Prolonged video-gaming reduced adolescents' sleep efficiency to below the established clinical cut-off used to indicate sleep disruption (i.e. <85%; Buysse *et al.*, 2006). In contrast, sleep efficiency after regular video-gaming was within the normal range. This finding suggests that prolonged video-gaming may pose a clinically significant risk to TST, even when sleep is initiated at normal bedtime. Polysomnographic recording identified an average sleep reduction of 27 min. A habitual pattern of prolonged video-gaming, such as on weeknights, may therefore result in sleep restriction and poor sleep quality among adolescents. Chronic sleep reduction has significant implications for adolescents' academic functioning (Dewald *et al.*, 2010). It is possible that sleep efficiency was lowered in both conditions due to participants sleeping in a novel environment; however, this does not detract from the significant reduction in sleep efficiency caused by the prolonged video-game exposure.

The present study also suggests that video-gaming may disrupt sleep by displacing sleep time (i.e. delaying bedtime). Subjects reported significantly lower satisfaction with the duration of video-gaming after 50 min as compared with 150 min, desiring a further 37 min (compared with 14 min more for the 150 min condition) to feel they had played 'long enough'. Therefore, unmonitored regular video-gaming seems unlikely to be self-limiting (i.e. cease at normal bedtime). This finding is consistent with qualitative research reporting almost no amount of time is subjectively considered 'long enough' for adolescent video-gamers (King and Delfabbro, 2009). The desire to continue video-gaming was significantly correlated to objective SOL in the regular

video-gaming condition, suggesting cognitive engagement with a video-game may affect sleep onset when pre-sleep video-gaming activity is considered insufficient.

Past polysomnographic studies of video-gaming and sleep vary in terms of sample characteristics, measures, and type and duration of exposure. In Dworak *et al.*'s (2007) study of 10 children aged 12–14 years, video-gaming for 60 min reduced SWS and increased SOL by 22 min relative to control. Changes in HR, blood pressure, respiratory rate and energy expenditure were observed, suggesting sleep impairments were due to increased arousal of the central nervous system. By comparison, studies using samples of older adolescents and adults reported the impact of pre-sleep video-gaming on sleep (e.g. SOL) was significant but minimal (2.3 min, Higuchi *et al.*, 2005; 4.5 min, Weaver *et al.*, 2010). The present study's results (SOL diff = 3.5 min) is consistent with these findings, suggesting the impact of video-gaming on sleep may be more pronounced among persons of early childhood age (i.e. < 15 years). It is possible older adolescents' physical maturation, as well as broader experience of violent media engagement, may partly account for the observed cognitive and physical desensitisation to violent game-playing.

Limitations

Notwithstanding the present study's strengths, several limitations should be highlighted. First, laboratory studies have inherent difficulties in creating a video-gaming context of sufficient ecological validity to generalise observed effects. This study employed a novel video-game that involved violent action, interactivity and bright light. However, some aspects of normal video-gaming exposure may have been absent or recreated differently in the laboratory. Similarly, subjects' motivations may have been affected by factors, such as: (a) having to play for research purposes; (b) a less familiar video-gaming system or user interface; and (c) having to play on a temporary player profile with no prospect of long-term advancement in the game. Another limitation was a lack of a condition involving no video-gaming. However, given that 50 min of video-gaming has minimal impact on adolescent sleep (Weaver *et al.*, 2010), it was considered appropriate to compare this low level of exposure with a prolonged video-gaming condition. Additionally, given the high prevalence of weeknight video-gaming activity among male adolescents (Desai *et al.*, 2010), a testing night involving no exposure to electronic media may have been classifiable as 'media deprivation' rather than a true control. Nonetheless, further research involving a no video-game condition may be informative for understanding the extent of these effects. Although the sample size was larger than the majority of polysomnographic studies in this area of research, a larger sample would have enhanced the study's statistical power. Finally, the results of this study may only be generalised to evening-type older male adolescents, with no concurrent sleep difficulties and who currently play video-games. Similarly, the results may

apply only to solitary video-gaming behaviour, and not necessarily to online and/or social video-gaming that has opportunities for competition and social rewards.

CONCLUSIONS

Prolonged video-gaming before normal bedtime caused a clinically significant reduction in adolescent sleep time. It may be extrapolated that long-term or repeated prolonged video-gaming may produce cognitive deficits associated with chronic sleep reduction (Dewald *et al.*, 2010). However, the underlying mechanistic pathways of electronic media effects on adolescent sleep remain somewhat unclear. These data suggest older male adolescents tend to play video-games of a fast-paced and violent nature in a state of physiological calm. Physiological arousal did not differ significantly between regular and prolonged video-gaming exposure, thus other modes of action need to be investigated (e.g. delaying bedtime). Male adolescent subjects played the fast-paced and violent video-game in a state of physiological calm. Thus, the proposed sleep-affecting mechanism of altered physiological arousal was not supported. Alternative mechanistic pathways should be explored. Further empirical research may grant insights into how excessive video-gaming can cause sleep disruption. Such evidence may guide clinicians in developing standards in assessment and treatment of sleep and health-related risks associated with prolonged video-gaming.

ACKNOWLEDGEMENTS

The authors wish to thank the 17 adolescents who volunteered their school nights to play video-games and sleep in our laboratory. This study received financial support from the School of Psychology and Faculty of Social and Behavioural Sciences, Flinders University.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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