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Pediatrics 2007;120;978
DOI: 10.1542/peds.2007-0476

ARTICLE

Impact of Singular Excessive Computer Game and Television Exposure on Sleep Patterns and Memory Performance of School-aged Children

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The authors have indicated they have no financial relationships relevant to this article to disclose.

ABSTRACT

OBJECTIVE. Television and computer game consumption are a powerful influence in the lives of most children. Previous evidence has supported the notion that media exposure could impair a variety of behavioral characteristics. Excessive television viewing and computer game playing have been associated with many psychiatric symptoms, especially emotional and behavioral symptoms, somatic complaints, attention problems such as hyperactivity, and family interaction problems. Nevertheless, there is insufficient knowledge about the relationship between singular excessive media consumption on sleep patterns and linked implications on children. The aim of this study was to investigate the effects of singular excessive television and computer game consumption on sleep patterns and memory performance of children.

METHODS. Eleven school-aged children were recruited for this polysomnographic study. Children were exposed to voluntary excessive television and computer game consumption. In the subsequent night, polysomnographic measurements were conducted to measure sleep-architecture and sleep-continuity parameters. In addition, a visual and verbal memory test was conducted before media stimulation and after the subsequent sleeping period to determine visuospatial and verbal memory performance.

RESULTS. Only computer game playing resulted in significant reduced amounts of slow-wave sleep as well as significant declines in verbal memory performance. Prolonged sleep-onset latency and more stage 2 sleep were also detected after previous computer game consumption. No effects on rapid eye movement sleep were observed. Television viewing reduced sleep efficiency significantly but did not affect sleep patterns.

CONCLUSIONS. The results suggest that television and computer game exposure affect children's sleep and deteriorate verbal cognitive performance, which supports the hypothesis of the negative influence of media consumption on children's sleep, learning, and memory.

www.pediatrics.org/cgi/doi/10.1542/peds.2007-0476

doi:10.1542/peds.2007-0476

Key Words
television, computer game, children, sleep patterns, cognitive performance, polysomnographic study

Abbreviations
VVM—visual and verbal memory test
TST—total sleep time
SWS—slow-wave sleep
REM—rapid eye movement
SOL—sleep-onset latency
ADHD—attention-deficit/hyperactivity disorder

Accepted for publication May 23, 2007

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

In WESTERN INDUSTRIAL countries, television and computer game consumption take up a large part of children's time awake. The proportion of television users among children who are aged 9 to 16 years ranges from 98% to 100%.[1] Some studies have indicated that excessive television and video game consumption could result in psychiatric symptoms such as aggressive behavior,[2–4] attention problems,[5] hyperactivity,[6] scholastic problems,[7,8] and somatic complaints.[3,9,10] Despite this knowledge, average media consumption of the children in this age group is >4 hours/day.[7] Furthermore, these sedentary activities are frequently associated with significant behavioral consequences,[9,11–13] including decreased physical activity and physical fitness,[14] poor eating habits,[15] and obesity,[3] and could impair development in childhood and adolescence.[10,16–19]

Despite the enormous progress in media research, there is insufficient knowledge about the effects of singular excessive media exposure on behavioral states and sleep patterns in children. Most examinations focused on long-term effects of media exposure on children's well-being, and only a few studies examined the effects of television and computer consumption on children's sleep quality.[20–23] Negative effects on sleeping behavior, such as sleep-onset delay,[20,21] night waking,[22] sleep anxiety,[24] and shortened sleep duration,[22,23] were observed in recent studies and suggest that media exposure could impair sleep quality. Finally, watching television ≥3 hours/day during adolescence elevates the risk for frequent sleep problems in early adulthood.[25]

Sleep is essential for children's health and development and possibly plays an important role in learning and memory.[4,26] Neuroscientific theories support the notion that emotions could influence learning processes.[27] Especially recently acquired knowledge is very sensitive in the subsequent consolidation period, and what the children emotionally experience within the hours after learning influences it decisively. The influence of interactive media consumption on emotions was also established. Thus, it could be hypothesized that television and computer game consumption after a learning period could impair memory consolidation and performance. The purpose of this polysomnographic study was to evaluate direct short-term effects of singular excessive television and computer game consumption on sleeping patterns and cognitive performance of school-aged children.

METHODS

Participants

Eleven male children volunteered to participate in this study (age: 13.45 ± 1.04 years; height: 1.64 ± 0.09 m; weight: 48.23 ± 5.97 kg; BMI: 17.82 ± 1.29 [all means ± SD]). Children and their parents for this study were volunteers from 8599 families who previously were recruited for and participated in the Healthy Sleep for Cologne Children study, an epidemiologic study of sleeping behavior and sleep complaints in children. All participants were junior high school children in the first grade. Participants were selected in random order after fulfillment of the following criteria: age between 12 and 14 years, great health, no medications, German nationality, and male gender. Only male participants were selected for this study because previous studies indicated that menstrual cycle phase as well as oral contraceptive could influence sleeping behavior. In precocious girls, these factors could influence nocturnal sleep. In addition, media research studies indicate that boys spend more than twice as much time playing video games as girls do; therefore, video game playing is a greater impact factor in boys' leisure time. After consideration of the mentioned criteria, 3580 children were contacted with detailed information regarding the study setting; a total of 1321 consenting children gave a response rate of 36.9%. All participants and parental authorities signed informed consent forms and completed a medical questionnaire before the experiment. They were informed that they could quit the study at any stage. All participants showed good health status and had no sleep complaints. Participants were instructed to refrain from additional physical activity, passive body warming (eg, taking a warm bath or shower), and sleep during the day on the experimental days. They did not consume any kinds of caffeine, nicotine, or alcohol, and they were not exposed to a large stress load.

Experimental Design

Each participant underwent 3 investigation days in a randomized, crossover manner. The interval between the experiments was exactly 1 week. On 2 different experimental days, children were exposed to 2 types of media. On 1 occasion, they played interactively a computer game (*Need for Speed—Most Wanted*; Electronic Arts, Redwood City, CA) for 60 minutes. Recent studies suggest that this is nearly the average time per day that children spend playing computer games.[21] Furthermore, the participants watched a subjectively exciting video film on television. Every participant could choose from among 3 films (*Harry Potter and the Prisoner of Azkaban*, *Star Trek: Nemesis*, and Mary Higgins Clark's *Loves Music, Loves to Dance*) but was not allowed to have seen the film before the experimental day. Media exposure occurred between 6:00 PM and 7:00 PM (2–3 hours before bedtime). This time of day was selected because the children have usually finished their homework at that time and start their leisure time. Under control conditions, the participants adhered to their normal daily patterns but were not allowed to watch television or play computer games.

Four to 5 hours before bedtime, when children usually did their homework, a visual and verbal memory test (VVM) was conducted on each experimental day (Swets Test Services, Frankfurt am Main, Germany). The test served to determine the short-term and longer-term memory of visuospatial and verbal materials and was subdivided into 2 subtests. For examination of the memory performance in the visually spatial area, a map with a marked path was shown to the children for 2 minutes. Immediately after this, the participants were asked to draw the path on such a map from memory. The second subtest served to examine the memory of facts. In this case, text that included names, numbers, and terms was presented for 2 minutes. After the presentation, the facts were immediately (T1) asked for in writing. Both tests were repeated after each experimental day within a 24-hour interval (T2) without renewed attraction. The raw analyzed results of the 2 subtests were intended for the 2 test times. A calculation of the loss of memory performance for every subtest was conducted by the following formula: $T1 - T2 = [(T2 - T1)/T1] \times 100$.

Data Recording and Analysis

Before participant went to bed, polysomnographic measurements were conducted using a portable sleep data recorder (Varioport-SLP 2.0; Becker Meditec, Karlsruhe, Germany). An expert affixed the electrodes between 7:30 PM and 8:30 PM and removed them after participants awoke in the morning. The participants were also instructed to adhere to their normal evening routines and to go to bed and to get up at their usual time. General bedtime was between 8:30 PM and 9:30 PM, when the room light was turned off. Morning waking was between 6:00 AM and 7:00 AM. During the study nights, the participants slept in their own homes and always under the same timing and temperature conditions to standardize sleeping conditions for each participant. They were also instructed to adhere to their normal evening routines and fill in a sleep diary. The sleep diary contains questions about daytime sleepiness, subjectively rated sleepiness, and subjectively rated awakenings. An adaptation night was assigned on the day before the experiment to reduce the possible "first-night effect."

The monitoring montage consisted of 3 electroencephalograph channels (C3-A2, C4-A1, and Oz-A2), bilateral electrooculograph, and submental chin electromyography. The measuring procedure followed the standards for performance and evaluation of polysomnographic studies of the pediatric group in the German Sleep Society.[28]

Each polysomnograph was scored by Somnolyzer 24x7 (Siesta Group, Vienna, Austria). The system included a raw data quality check, a feature extraction algorithm (density and intensity of sleep/wake-related patterns, eg, sleep spindles, δ waves, slow eye movements, and rapid eye movements), a feature matrix plausibility check, a classifier designed as an expert system, and a rule-based smoothing procedure for start and ending of stages. In addition, a structured quality control by 2 experts including a visual correction was accomplished. Studies showed that 2 Somnolyzer 24x7 analyses revealed an inter-rater reliability close to 1, representing an overall agreement of 99.4% (Cohen's κ: 0.991). This confirms that the variability induced by the quality control procedure, whereby ~1% of the epochs are changed, could be neglected.[29]

For each polysomnograph, a number of measurements of sleep architecture and sleep continuity were derived. Measurements of sleep architecture included minutes and percentage of total sleep time (%TST) of stage 1 sleep, minutes and %TST of stage 2 sleep, minutes and %TST of stage 3 sleep, minutes and %TST of stage 4 sleep, minutes and %TST of slow-wave sleep (SWS; stages 3 + 4 sleep), and minutes and %TST of rapid eye movement (REM) sleep. Continuity measurements consisted of TST, sleep-onset latency (SOL), latency of stage 1, latency of stage 2, latency of stage 3, latency of stage 4 and REM sleep, wake time after sleep onset and sleep efficiency.

Statistical Analysis

Statistical analyses for significant differences of the natural sleep cycle data were performed by using repeated-measurements analysis of variance and Bonferroni test as a posthoc test. A paired *t* test was used to analyze vigilance test (VVM) data. We used SPSS 12.0 (SigmaStat Statistical Software, Chicago, IL) and Statistica 7.1. software (StatSoft, Tulsa, OK) for Microsoft Windows. The significance level of all statistical tests was set at $P < .05$.

RESULTS

All sleep parameters showed normal distributions. Because 1 of the children was dyslexic, only the tests and polysomnographs of the 10 healthy participants were analyzed. TST remained unchanged among the 3 experimental nights. Mean TST was 511.80 ± 44.44 minutes. The results showed a significant ($P < .05$) decrease in sleep efficiency after only television exposure (Table 1). SOL increased significantly ($P < .05$) after computer game stimulation compared with basal conditions. Under baseline conditions, SOL was 10.83 ± 8.33 minutes. Significant increases to 32.50 ± 25.67 minutes ($P < .05$) were detected after computer game playing. No effect was found after television exposure. Also, significant prolongations in latent periods to stage 2 and stage 4 were observed only after interactive computer game playing ($P < .05$).

Table 2 provides the means and SDs of the participants for sleep-architecture parameters on experimental days. Especially computer game playing resulted in a shift of sleep stages (Fig 1). Participants spent significantly ($P < .05$) more time in sleep stage 2 compared with basal conditions (Fig 2). Case-wise data showed

TABLE 1 **Sleep-Continuity Parameters on Experimental Days**

Parameter	Basal Conditions, Mean (SD)	Computer Game Playing		Television Viewing	
		Mean (SD)	*P*	Mean (SD)	*P*
Sleep efficiency (%TST)	94.81 (2.86)	92.70 (4.23)	.210	90.74 (3.19)[a]	.005
Wake time after sleep onset, min	8.60 (8.60)	10.90 (17.53)	.997	16.65 (17.85)	.773
SOL, min	10.83 (8.33)	32.50 (25.99)[a]	.034	24.61 (21.04)	.939
Stage 1	10.83 (8.33)	28.89 (21.90)	.053	21.11 (14.33)	.817
Stage 2	12.83 (8.67)	34.83 (25.99)[a]	.032	28.28 (20.00)	.999
Stage 3	22.61 (9.59)	43.94 (25.62)	.052	36.22 (20.74)	.996
Stage 4	25.00 (10.11)	47.39 (26.46)[a]	.049	39.11 (21.85)	.998
REM	119.39 (44.79)	157.00 (36.55)	.058	130.06 (47.20)	.244

[a] $P < .05$.

TABLE 2 **Sleep-Architecture Parameters on Experimental Days**

Parameter (%TST)	Basal Conditions, Mean (SD)	Computer Game Playing		Television Viewing	
		Mean (SD)	*P*	Mean (SD)	*P*
Stage 1	2.88 (1.91)	2.30 (0.81)	.749	2.93 (1.44)	.628
Stage 2	42.79 (7.45)	46.91 (4.63)	.140	45.00 (5.99)	.998
Stage 3	10.29 (2.46)	9.41 (3.28)	.999	8.27 (2.38)	.999
Stage 4	23.20 (5.14)	19.40 (4.12)	.304	21.51 (4.02)	.997
SWS	33.49 (5.14)	28.81(4.54)[a]	.026	29.78 (4.47)	.999
REM	20.85 (6.25)	21.98 (5.07)	.998	22.29 (4.44)	.998

[a] $P < .05$.

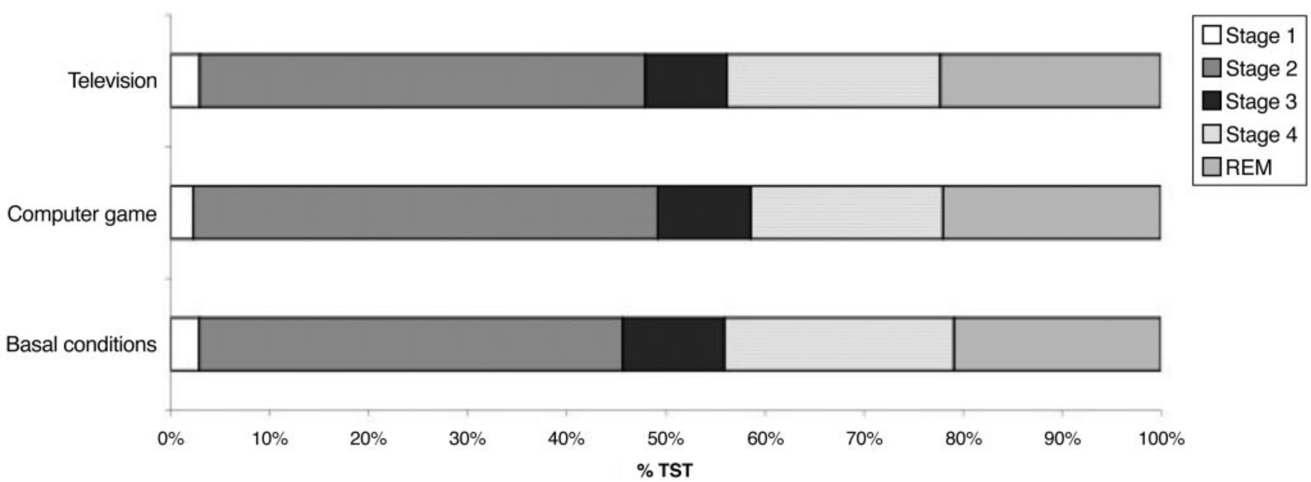

FIGURE 1
Sleep stages as a percentage of TST in subsequent sleep at basal conditions and after playing computer games and viewing television.

considerable increases over 50.0 minutes of stage 2 sleep in 7 children. In contrast, after television exposure, none of the participants showed increases 50.0 minutes in stage 2 sleep compared with basal conditions. Furthermore, percentage distribution of sleep stages showed a significant decrease in SWS after computer game consumption related to basal conditions ($P < .05$; Fig 3). Also, a more detailed analysis of case-wise data supports the explicit effects of computer game consumption on SWS. Declines of SWS >5.0% were observed in 7 participants; 2 of these reached >10.0% (10.02% and 13.27%). Conversely, only 1 participant showed decreased SWS proportions >5.0% after television consumption compared with basal conditions. There were no significant changes in either the absolute duration or the relative proportion of REM sleep. Also, the evaluation of the sleep diary resulted in no significant differences among the experimental days (Fig 3).

Visual and Verbal Memory Test

The evaluation of the visual and verbal memory test yielded a negative influence of the computer game exposure on the verbal memory for facts. Computer game playing led to a significant ($P < .01$) decline of the verbal memory performance (−46.83 ± 18.32) compared with basal conditions (−18.09 ± 24.78). In addition, case-

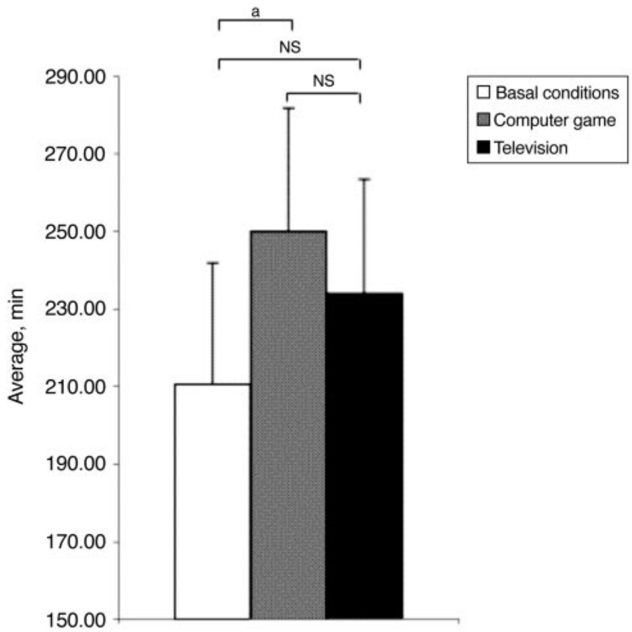

FIGURE 2
Average (±SE) minutes of non-REM stage 2 sleep at basal conditions and after playing computer games and viewing television. [a] $P < .05$.

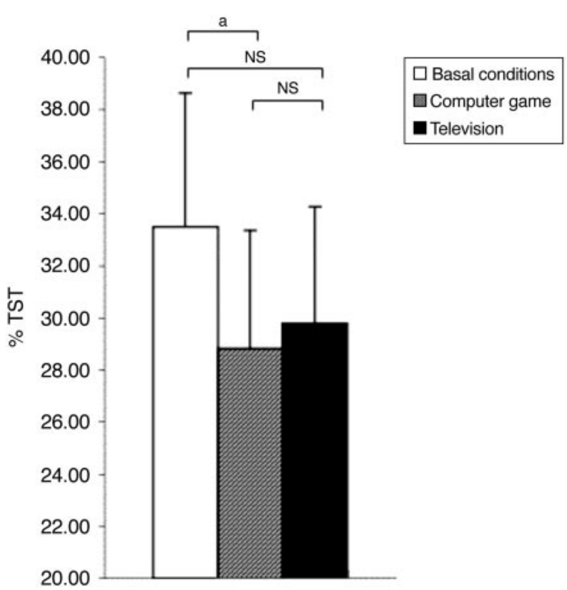

FIGURE 3
Distributions of SWS as a percentage of TST at basal conditions and after playing computer games and viewing television. [a] $P < .05$. NS indicates not significant.

wise data showed declines >20.0% in 8 participants. In contrast, no significant changes were observed after television exposure after which only 2 participants showed a decline of verbal memory performance >20.0%. Cognitive performance in the visuospatial area did not differ among the experimental days (Fig 4).

DISCUSSION

This study demonstrates that singular excessive media exposure affects children's sleep architecture, sleep continuity, and verbal memory performance. Particularly, interactive computer game consumption resulted in prolonged SOL, more sleep time in stage 2, less SWS as a percentage of TST in subsequent sleep, and declines in verbal memory performance; therefore, our results provide supplementary evidence for a negative influence of excessive media consumption on children's sleep, health, and performance.

Most previous studies observed long-term term correlations between television viewing, computer game playing, and Internet use and general health problems, whereas our study proves singular excessive short-term effects; nevertheless, our findings are consistent with previous studies and support that there is a negative influence of excessive media consumption on health and well-being. Excessive media consumption was associated with an elevated risk for psychiatric and social problems such as aggressive behavior,[2,4,30] attention problems,[5] hyperactivity,[2] and scholastic problems.[8] Also, links have been suggested with certain somatic complaints[10] resulting from the sedentary execution of media consumption in children's leisure time, including decreased levels of physical activity and physical fitness,[12] poor eating habits,[23] and an increased risk for obesity.[7]

Unfortunately, only a few studies have assessed the effects of media consumption on children's sleep.[20–24] Recent results showed increased SOL,[20,21] an elevated risk for midnight waking,[20] difficulties in falling asleep, and a reduced sleep quality[22,24,25] after television and computer game consumption. Poor sleep quality was associated with mental health problems, inferior school performance, and somatic complaints. Sleep difficulties were significantly associated with both behavioral problems, such as school attendance problems, and higher levels of tiredness.[22] It has also been found that excessive television viewing may be connected with diverse sleep disturbances during adolescence.[22] The presence of a television in the child's bedroom results in significant modifications of sleep–wake parameters, especially related to bedtime and sleep duration,[22] and thus is the most powerful predictor of overall sleep disturbance and bedtime resistance.[24,31]

To our knowledge, only 1 study[32] previously examined the effects of media consumption (computer game playing) on sleep patterns in children. In accordance with Higuchi et al,[32] we used polysomnographic measurements to define sleep stages and sleep latencies. In both studies, a significant increased SOL after singular excessive computer game playing was observed compared with control conditions. Contrary results were detected in sleep stages. Whereas Higuchi et al[32] noticed less REM sleep and no changes in SWS after computer games, we detected more sleep in stage 2 and reduced amounts of SWS but no effects on REM sleep. The decrease in SWS after computer game playing in this

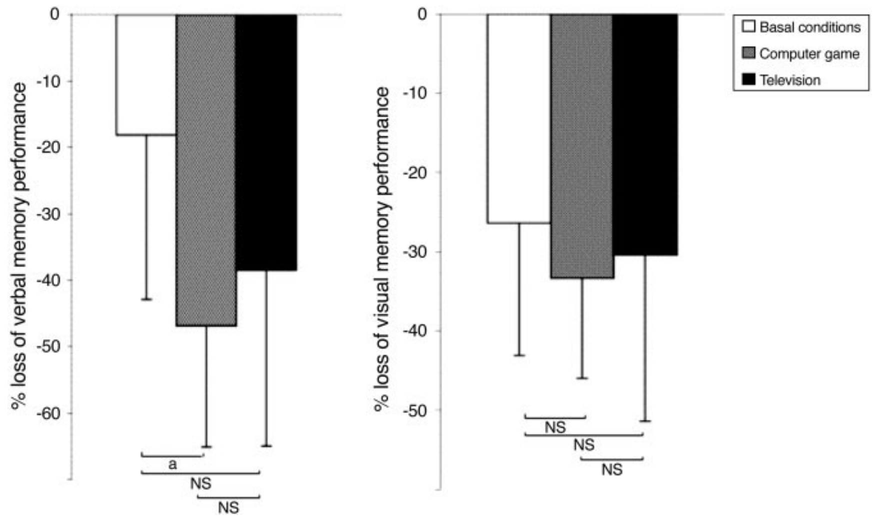

FIGURE 4
Percentage abatement of visual and verbal memory performance at basal conditions and after playing computer games and viewing television. [a] $P < .01$. NS indicates not significant.

study may reflect children's high arousal state. Differences in the age of the participants, type of computer game, place and type of polysomnographic measurements, and sleep time may be reasons for the different observation.

Possibly, different claims of television and computer game consumption on the central nervous system were decisive for alterations of children sleep. Previous studies showed different effects of television viewing and video game playing on several physiologic parameters.[33] Unlike television viewing, which expends the same energy as sitting quietly, interactive video game consumption results in significant increases in various physiologic and metabolic variables in young children, including heart rate, blood pressure, respiratory rate, energy expenditure, and ventilation, and thus a higher arousal state of the central nervous system.[33] The magnitude of these changes was below standard physical exercise and national health recommendations and did not affect metabolic, cardiovascular, pulmonary, homodynamic, and endocrine systems in the whole body and the brain as physical activity does.[34] A higher arousal state within the hours before sleeping could influence subsequent sleep.

Another interesting finding was a significant decline of verbal memory performance after computer game playing compared with basal conditions. Modern neuroscientific theories support the notion that strong emotional experiences, such as computer games and thrilling films, could decisively influence learning processes. Because recently acquired knowledge is very sensitive in the subsequent consolidation period, emotional experiences within the hours after learning could influence memory consolidation considerably.[26,35] Interactive video games are challenging, sometimes frustrating, exciting, and often surprising, and during playing, individuals may experience a range of emotions accompanied by physiologic changes. In addition, studies with positron emission tomography scans showed a significant release of the neurotransmitters dopamine and norepinephrine in the brain during video game playing.[36] Dopamine as well as norepinephrine are thought to be involved in learning, reinforcement of behavior, emotion, and sensorimotor coordination and thus able to influence memory processing decisively.

Evidence in molecular genetics, neurophysiology, and the cognitive neuroscience supports an important role for sleep in learning and reprocessing of memories.[35,37] Only a single night of restricted sleep led to impaired cognitive functions, such as abstract thinking and verbal creativity in children.[38] Presumably, both REM and SWS are involved in the consolidation process, in which SWS is particularly favorable to explicit memory traces.[37] It has been proposed that during SWS, the lower acetylcholine levels facilitate the transmission of information from the hippocampus back to the cortex. High acetylcholine levels during REM sleep would allow the neocortex to undergo a process of reanalysis and thereby develop new feed-forward representations for behavior.[39] Because computer game exposure resulted in likewise reduced amounts of SWS, our observations support the hypothesis for the role of SWS in explicit memory consolidation.

Video viewing did not affect visuospatial and verbal memory performance. It could be assumed that the media content is responsible for subsequent effects on sleep and memory performance. Afterward, none of the participants judged the chosen film as very thrilling, indicating that the thrilling factor of the selected films was not high enough for the children. Results showing that exposure to adult media content may have a stronger impact than media exposure time supported this notion.[8] In general, just 13% of the young people in this age group have parental control with rules about the content of their media consumption.[7] Especially adult (violent/sexual) media content and associated individual excitement could affect sleep and learning in children.[40]

It could be hypothesized that media exposure influences memory processing in decisive ways: temporary through emotional influences on the consolidation process as well as disrupted SWS and in the long-term by a chronic diminution of physical activity. An inverse relationship between time spent using video games and daily physical activity has already been observed. Positive effects of physical exercise on brain structures, functions, and memory processing[34] were examined in recent studies and supported by cross-sectional observations that showed a positive association between physical activity and academic and accompanied improvements of concentration and classroom behavior.[18] Finally, our results could provide a plausible explanation concerning the effects of media exposure on poor school completion and especially poor reading skills, derived from the results of the VVM.

This study supports the influence of singular excessive media consumption on both sleep and cognitive performance in children. In addition, the impact of media on children's health and well-being is widely recognized and considered a serious problem in modern society. Our results were supported by previous studies that observed that movie, television, and video game use during the middle school years was uniformly associated with a negative impact on school performance.[8] Also, children with lowest grades spend more time playing video games and less time reading than those with the best grades.[7] Additional examinations confirmed that excessive television viewing in early childhood was associated with a higher subsequent risk for development of attention-deficit/hyperactivity disorder (ADHD).[5]

Limiting young children's exposure to television as a medium during formative years of brain development may reduce children's subsequent risk for developing ADHD and social and scholastic problems.[5,8] Children spend one third of their life in sleep, indicating the importance of sleep for children's development and health; therefore, the negative effects of excessive media consumption may be a significant concern. Our findings add experimental support to the importance of parental limits on media content and time. Additional work is needed to determine relationships among time, content, and type of media affecting children's health, sleep, and memory and to give advice for useful contact with entertainment media.

CONCLUSIONS

Our data indicate that excessive media consumption, especially computer game playing, impairs sleep patterns and verbal cognitive performance in children. Because children's sleep-related problems seem to be highly persistent; prevalent; and associated with somatic complaints, psychiatric symptoms, especially behavioral and emotional symptoms, attention problems such as hyperactivity, and scholastic problems, they constitute a considerable and growing health problem among children and therefore should receive more attention. This study demonstrates that more effort should be directed to screening sleep disturbances after media consumption, helping parents to perceive the negative effects of media consumption on health and sleep and to provide adequate guidance for their children when needed.

ACKNOWLEDGMENTS

This work was supported by the Institute of Motor Control and Movement Technique and the Institute of Sports, Media and Communications and performed at the Institute of Motor Control and Movement Technique (German Sport University Cologne).

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