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REGULAR ARTICLE

Playing a violent television game affects heart rate variability

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Abstract

Objective: To investigate how playing a violent/nonviolent television game during the evening affects sympathetic and parasympathetic reactions during and after playing as well as sleep quality during the night after playing.

Subjects and Methods: In total, 19 boys, 12–15 years of age, played television games on two occasions in their homes and participated once without gaming. Heart rate, heart rate variability (HRV) and physical activity were measured during gaming/participating and the night to follow using a portable combined heart rate and movement sensor. A sleep diary and questionnaires about gaming experiences and session-specific experiences were filled in.

Criteria for Selection of Games: Violent game involves/rewards direct physical violence (no handguns) against another person, and nonviolent game involves/rewards no violence; same game design ('third-person game'); conducted in the same manner; no differences concerning motor activity; similar sound and light effects; no sexual content, violence against women or racial overtones.

Results: During violent (vs. nonviolent) gaming, there was significantly higher activity of the very low frequency component of the HRV and total power. During the night after playing, very low frequency, low frequency and high frequency components were significantly higher during the violent (vs. nonviolent) condition, just as total power. There were no significant differences between the three conditions (violent/nonviolent/no gaming) with respect to an index reflecting subjectively perceived sleep difficulties. Nor was there any difference between violent and nonviolent condition for any single sleep item.

Conclusion: Violent gaming induces different autonomic responses in boys compared to nonviolent gaming – during playing and during the following night – suggesting different emotional responses. Subjectively perceived sleep quality is not influenced after a single gaming experience. Future studies should address the development of the autonomic balance after gaming over longer time than a night, physiological adaptation to frequent gaming and potential gender differences.

INTRODUCTION

Playing television/computer games is today one of the dominating leisure activities for teenagers, especially boys. Television games and computer games are in many ways alike and will be called television games in this article. The technique can be utilized for several important purposes, as for health promotion. However, a number of adverse effects have been associated with gaming: first, playing may turn into an activity that dominates the life of the teenager, minimizing time for other activities such as school and peer relations (1). In a Norwegian survey, 4.2% of the 12- to 18-year-old boys reported a behaviour that could be categorized as 'pathological playing' and 9.8% as 'at-risk playing' (2). Second, many studies – mainly concerning short time effects – have indicated that violent games may induce violent and aggressive behaviour (3–5). In one study, increased levels of aggressive behaviour were reported even after up to half a year in highly exposed children (6). Third, cognition may be influenced; a negative effect on verbal memory performance has been demonstrated the day after having played a video game (7). Fourth, playing television games seems to be related to less sleep and consequently elevated reported tiredness (8). Sleep-onset latency is prolonged after playing games, even compared to television viewing (7,9,10).

It is well established that playing may affect parameters like respiratory rate, cardiovascular reactivity, blood pressure and oxygen consumption (3,11). Such reactions provoked by playing at night may theoretically contribute to the sleep problems. This may be valid especially for violent

Abbreviations
HR, heart rate; HRV, heart rate variability; VLF, very low frequency; LF, low frequency; HF, high frequency; LF/HF, low frequency/high frequency ratio; TP, total power.

games since arousal seems to be stronger than when playing nonviolent games (12). Heart rate variability (HRV) is a comparably novel measure of stress reactivity. The variation of intervals between consecutive heartbeats reflects the autonomic regulation of the heart and balance between sympathetic and parasympathetic activation (13). The amount of variability is influenced by neurophysiological maturation and consequently age. It increases during early postnatal life and then starts to decrease already in childhood (14). Further, the effect of breathing on the heart rate is more pronounced at younger ages, just as sympathetic activity, which decreases between 5 and 10 years of age (15).

The heart rate is regulated by different systems. These systems differ in speed (i.e. cycle time), and commonly three speed intervals – or frequency bands – are studied: The vagally mediated signals, where breathing is the main contributor, have the shortest cycle time of about 2.5 to 6.7 sec, corresponding to the high frequency band (HF, 0.15–0.4 Hz). The low frequency band (LF, 0.04–0.15 Hz), corresponds to a cycle time of 6.7–25.0 sec, and is most often claimed to be a marker of sympathetic tone and closely associated with blood pressure regulation. The slowest cycle (>25 sec) is referred to as very low frequency (VLF, <0.04 Hz) and seems to reflect thermoregulatory systems (16) and renin–angiotensin systems (17) and also depends on physical activity (18) and parasympathetic outflow (19). In HRV analysis, the signal strength (power) reflecting activity in the regulatory system corresponding to each of these three frequency bands is measured and expressed in milliseconds squared (ms^2) (13). Total power (TP) is the summarized activity for all three frequency bands.

This study aimed at investigating how playing a violent/nonviolent television game during the evening affects sympathetic and parasympathetic reactions during and after playing as well as sleep quality during the night after playing.

SUBJECTS AND METHODS

Procedure

In total, 22 boys, 12–15 years of age (mean age 13.3, standard deviation [SD] 0.7) – recruited from a school in the centre of Stockholm – were invited to play television games on two occasions (violent game/nonviolent game) in their homes and participate one evening without playing at all. There were at least 6 days between the occasions, with the order of conditions systematically changed between individuals. The experiments started on a weekday evening and ended the next morning. The participants were instructed not to participate in any physical activities after school, to avoid beverages containing caffeine after noon, to finish dinner before 6.30 pm, and go to bed at 10.30 pm. The games were played between 8 and 10 pm, and the boys were instructed not to take any breaks while playing. During the nonplaying occasion, the participants were instructed not to watch any exciting sports or action television programs and not to play television games. The games were played on Microsoft XBOX consoles brought by the research assistant. The participants were encouraged to get acquainted with the game during half an hour before starting to play.

Physiological outcome measures

Heart rate, HRV and physical activity were measured using a combined heart rate and movement sensor (Actiheart, Cambridge Neurotechnology, Ltd., Papworth, UK) with good reliability and validity (20). This sensor, a small portable rechargeable unit, was applied on the chest, where it registered (and stored) ECG information. The information of interbeat intervals was exported from the Actiheart device and fed into a computer with software for filtering and calculations (21).

Questionnaires

A validated sleep diary adjusted to children was used (22) to be filled in the morning after each session. The initial questions concerned bed time, sleep latency and rising time. The following questions concerned alertness at bed time and rising time to be answered on a nine-grade scale with labels on every second step from 'very alert' to 'very sleepy, struggling against sleep, hard to keep awake' (Karolinska Sleepiness Scale (23)).

Further questions referred to perceived stress, difficulties in falling asleep, sleep quality, calm sleep, premature awakening, number of awakenings, time spent awake, sleep throughout, sleep depth, ease of awakening and perceived rest, with a five-step scale with response alternatives from 'not at all' to 'very much'. The last questions were multiple choice questions about disturbances during sleep, the cause of awakening in the morning, if any dream may have influenced the sleep and finally an open question about any particular incidents during night. A sleep quality index was calculated using the items: difficulties in falling asleep, sleep quality (phrased 'how was your sleep?') and calm sleep. An awakening index was calculated using the items: slept throughout, ease of awakening and perceived rest.

Before the experiments, the participants filled in a questionnaire about gaming experiences: hours per week (total time and time for violent games), first experience of violent game and emotional impact from playing violent game (yes/no: calm, stressed, worried, alert and irritated). After each gaming session, the participants filled in another questionnaire: distance (centimetres) from television screen, audio volume (no/low/middle high/high level, dichotomized in the analysis), previous experiences of the game in focus (yes/no), difficult to play (yes/no) and report of any deviations from the instructions (own words).

Television games

By the help of experienced gamers, two games were selected following preformulated criteria (modified after Anderson (4)):

- Violent game involves – and rewards – direct physical violence against another person, and nonviolent game involves no violence.

- No differences between games concerning frustrating elements, other stressors, attraction and difficulty.
- The main character should be shown on the screen and controlled by a remote control by the player ('third-person game').
- Both games must be conducted in the same manner.

Two more selection criteria were used for both ethical reasons and defining the type of violence:

- No sexual content, violence against women or expressions of racism.
- No use of handguns.

In the violent game – Manhunt (Rockstar Games, 2004) – the player is a murderer, sentenced to death. His only chance to survive is to kill everyone he meets by beating and kicking. Simple weapons are available like plastic bags and baseball bats stolen from the people he kills. The game takes place in an abandoned area where criminals dwell during night time. It is presented in a detailed, naturalistic fashion. There is a constant murmur. Fighting sounds and sounds like footsteps follow the actions of the characters.

The nonviolent game – Animaniacs (Ignition Entertainment, 2005) – takes place in different movie genre environments. The aim is to find all the stolen Edgar statuettes and rescue the forthcoming Edgar gala. The game occurs during day time, with the exception of the illustrated horror movie genre. Both characters and surroundings give a cartoon-like impression. In a few episodes, a stick is used in a violent manner but – with one exception – it is used against objects or non-human characters. The background music is neutral and sounds vary with the circumstances.

There were no significant differences when the selected games were tested before the study was performed with an Actiwatch (Cambridge Neurotechnology Ltd., Cambridge, UK), a small wrist-worn device containing an accelerometer that is optimized for effective inference from wrist activity. However, in the nonviolent game, the activity showed a continuous pattern, and in the violent game, the pattern was more fluctuating.

The participants were offered headphones and were instructed to use a comfortable volume. Colours, contrast and brightness were adjusted in the laboratory by use of a lux meter and similar adjustments were used for each home television screen. The same television was used for both playing occasions.

Statistics

A logarithm transformation was applied in all statistical computations to normalize the distribution of HRV data. Group comparisons were performed using a one-way within-subjects analysis of variance (ANOVA), a two-way within-subjects ANOVA and dependent samples *t*-tests. Correlations between sleep, report and experience items versus HRV data were computed using a bivariate Pearson correlation. All statistical analyses were made using the statistical package SPSS for Windows (version 15.0; Chicago, IL, USA).

RESULTS

After exclusion of three subjects with incomplete recordings, data from 19 individuals were analyzed further. Activity (torso movement) during the play did not differ between the two playing conditions, but there were significantly more movements during the evening without play ($t = 2.642$, $p = 0.015$ and $t = 2.666$, $p = 0.014$).

Ten participants reported that the violent game was more difficult than the nonviolent game, but this did not affect heart rate or HRV significantly ($F_{1,17} = 0.000–3.75$; nonsignificant [NS]), just as there were no correlations between HRV outcomes and the following continuous variables: playing violent games ($r = -0.45–0.204$), time since start of playing violent games ($r = -0.331–0.441$) and distance from the television screen ($r = -0.016–0.407$). Along the same line, there were no correlations between HRV outcomes and the following dichotomized variables: emotional impact from playing violent game ($F_{1,17} = 0.003–2.75$; NS); low/high level of sound ($F_{1,17} = 0.001–2.56$; NS); previous experiences of the game in focus ($F_{1,17} = 0.003–2.13$; NS). The LF/HF ratio during nonviolent gaming was significantly correlated with total hours per week for playing games ($r = -0.456$, $p < 0.05$). There were no other correlations between total hours of gaming per week and HRV outcomes ($r = -0.441–0.268$).

During the 2 hours of playing, TP and VLF were significantly higher in the violent condition (Table 1).

During the night after playing, higher activity was registered for the violent condition on TP, VLF, LF and HF (see Table 2). There were also significant differences between night hours. No significant interactions were found.

During sleep latency, there were no group differences concerning heart rate ($t = -0.32$; NS). In Figures 1–6, the development of the frequency/activity during sleep after having played violent/nonviolent game is presented for heart rate, TP, VLF, LF, HF and LF/HF.

In comparisons with the nongaming evening, the mean activity of HRV was lower during violent gaming and even

Table 1 Heart rate and heart rate variability mean and standard error during play of violent/nonviolent game

	Violent game		Nonviolent game			
	Mean	SE	Mean	SE	t	p
HR	78.8	2.32	77.3	2.64	−1.00	0.330
TP	2932	280	2168	226	−3.36	0.003
VLF	1591	145	1059	106	−4.70	0.000
LF	893	100	738	97	−1.73	0.102
HF	427	65	353	59	−1.21	0.244
LF/HF	2.64	0.31	2.45	0.26	−1.01	0.325

t = t-value; p = significant level, based on logarithmic transformation of data. Beats per minute; milliseconds squared.

Table 2 Results from ANOVA for heart rate and heart rate variability during night after playing. Effects of game and hour of sleep and G × H interaction

	Game			Hour			Game × hour		
	df	F	p	df	F	p	df	F	p
HR	1,18	1.69	0.210	5,14	5.58	0.005	5,14	0.88	0.519
TP	1,18	10.96	0.004	5,14	7.82	0.001	5,14	1.18	0.368
VLF	1,18	10.28	0.005	5,14	11.69	0.000	5,14	0.91	0.501
LF	1,18	9.75	0.006	5,14	4.30	0.014	5,14	1.69	0.201
HF	1,18	12.42	0.002	5,14	2.93	0.052	5,14	1.25	0.338
LF/HF	1,18	0.08	0.786	5,14	2.27	0.105	5,14	1.90	0.159

df = degrees of freedom; F = F-ratio; p = significant level, based on logarithmic transformation of data.

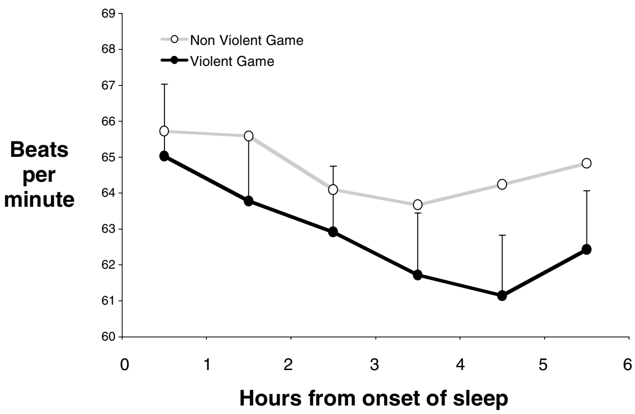

Figure 1 Heart rate in beats per minute during night hours presented as mean and standard error for the violent game condition for each hour of the sleep period.

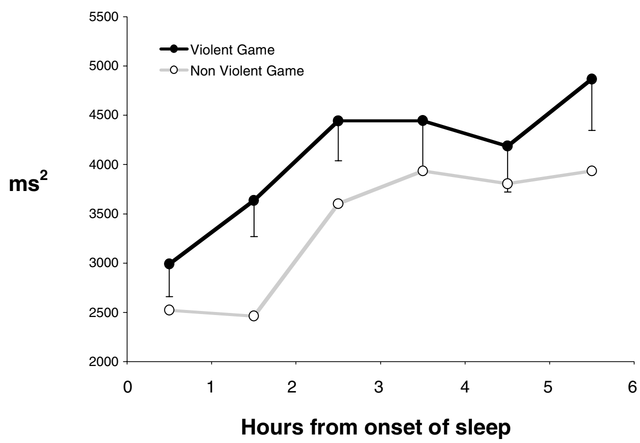

Figure 2 Total power in heart rate variability in milliseconds squared during night hours presented as mean and standard error for the violent game condition for each hour of the sleep period.

lower for nonviolent gaming, significant in the nonviolent condition for HR ($p < 0.05$), TP ($p = 0.01$), VLF ($p < 0.01$) and LF/HF ($p < 0.01$), and in the violent condition for LF/HF ($p < 0.01$). During the night, there were

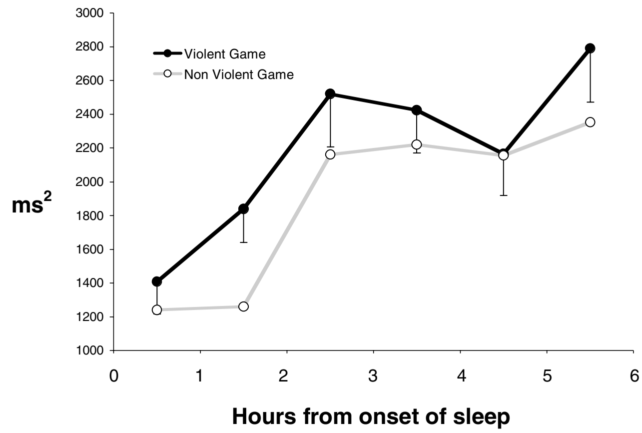

Figure 3 Power in VLF in milliseconds squared during night hours presented as mean and standard error for the violent game condition for each hour of the sleep period.

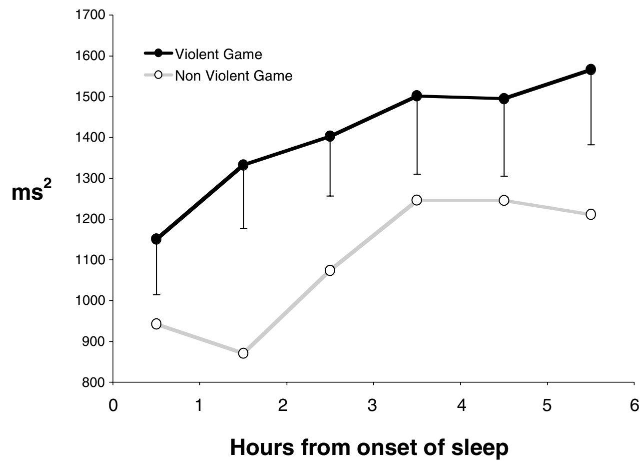

Figure 4 Power in LF in milliseconds squared during night hours presented as mean and standard error for the violent game condition for each hour of the sleep period.

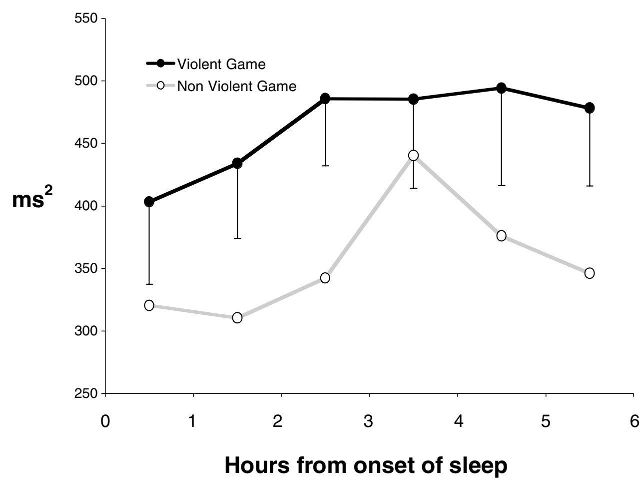

Figure 5 Power in HF in milliseconds squared during night hours presented as mean and standard error for the violent game condition for each hour of the sleep period.

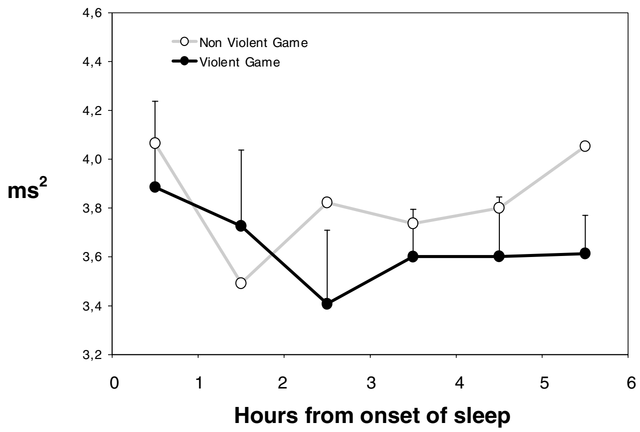

Figure 6 Ratio of LF power and HF power during night hours presented as mean and standard error for the violent game condition for each hour of the sleep period.

two significant differences: HR was lower (62.9) after violent gaming than in the nongaming condition (66.3, $p < 0.05$), and after playing a nonviolent game, VLF was lower (1915) than in the nongaming condition (2161, $p < 0.05$).

There were no significant differences between the three conditions with respect to the sleep quality index (4.27 ± 0.16 violent game, 4.51 ± 0.1 nonviolent game and 4.33 ± 0.17 no game; $F_{2,17} = 2.772$; NS), awakening index (3.39 ± 0.18 violent game, 3.61 ± 0.2 nonviolent game and 3.51 ± 0.21 no game; $F_{2,17} = 0.666$; NS), length of sleep (8.108 ± 0.175 violent game, 8.091 ± 0.148 nonviolent game and 8.381 ± 0.114 no game; $F_{2,17} = 1.397$; NS), sleep latency (0.34 ± 0.059 violent game, 0.225 ± 0.048 nonviolent game and 0.247 ± 0.045 no game; $F_{2,17} = 2.0345$; NS) and difficulties in falling in sleep (4.289 ± 0.207 violent game, 4,526 ± 0.160 nonviolent game and 4.0 ± 0.229 no game; $F_{2,17} = 2.5$; NS). Nor was there any difference between violent and nonviolent condition for any single item. For 3 out of 20 items, there were significant differences in comparisons with the nongaming evening: the time of going to bed was significantly later after both the violent game ($p < 0.01$) and nonviolent game ($p < 0.05$). After the nonviolent game, the time of rising was significantly earlier ($p < 0.05$) and it was significantly easier to fall asleep ($p < 0.05$).

DISCUSSION

In this experimental study, boys – 12–15 years of age – played one violent and one nonviolent television game during two different evenings in their homes. HRV was registered from before playing until after waking up the next day. In the violent condition (compared to nonviolent), a number of significant observations during the night were made: higher activity of the VLF component (related to various autonomous functions), higher power of LF (suggesting sympathetic activation) as well as higher HF (indicating vagal activation). There was also a higher activity of the VLF component during violent (compared to nonviolent) gaming.

The physiological representations of VLF are not yet completely understood even if it has been linked to different systems/functions (see above), and it has even been questioned if it reflects a specific physiological process (13). Still, low VLF is recognized as an important prognostic indicator of cardiac diseases like congestive heart failure (24) and acute myocardial infarction (25). It also mediates the negative effect of depression on survival after acute myocardial infarction (26). One tentative hypothesis is that the high VLF activity during violent playing may be a reflection of parasympathetic activity evoked by disgust rather than by an urge to fight, which would rather have resulted in signs of arousal like increased heart rate (27).

The dominating impression from the ECG recordings during sleep after violent gaming is the overall increased activity compared to the nonviolent condition. The LF/HF ratio (supposed to reflect sympathetic/vagal balance) was the same as in the nonviolent condition, and HR was actually lower after violent gaming, in spite of the higher LF activity, than in the nonviolent condition. These effects may possibly be due to residual activity in the autonomic nervous system or to reactions related to sleep effects of gaming such as nightmares.

In terms of sleep quality, the increased LF and VLF activity may indicate a higher sympathetic activity and sleep fragmentation (28). On the other hand, this should have been reflected in a reduced HF activity (29). The results are difficult to interpret, but do not seem to suggest disturbed sleep. The lack of sleep disturbance after violent gaming is also evident from the similar ratings of sleep quality and state on awakening for the two conditions. Any effect of undue arousal before bedtime should also have been seen in longer sleep latency or as more difficulties in initiating sleep.

Some limitations need to be considered. The choice of performing the study in the homes of the boys without any presence of supervision/observation implies less control over the playing procedure. The setting also implies lack of possibility to correlate HRV activity to specific sequences of the game. The use of an actigraph still brings about a check that playing was performed along the suggested lines. The choice of setting also means that playing was performed in a life-like way, which contributes to the validity of our findings. Gender-related differences concerning cardiovascular reactivity have been well established (30), and HRV reactions to gaming in girls may be quite different from what we observed in this study group of only boys. The social context of gaming and attitudes to violence are other aspects hypothetically contributing to gender differences.

CONCLUSIONS

Violent gaming between 8 and 10 pm induces different autonomic responses compared to nonviolent gaming – both during playing as well as during the following night – suggesting different emotional responses and possibly different needs of recovery. Subjectively perceived sleep quality was not influenced after a single gaming experience.

There is a need for more knowledge on temporal aspects – how physiological processes develop over longer time than one night, and how subjects adapt to frequent gaming – as well as the relation between measured biological responses and perceived emotional reactions, and the relations between physiological findings and more practical/clinical standpoints. Obviously, there is also a need for studies involving females.

Due to our findings, the noninvasive and well-accepted procedure and the need for more knowledge, we conclude that analyzing HRV seems to be a useful approach for future studies on the impact of violent contents in television games.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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