PSYCHO-PHYSIOLOGICAL REACTIONS TO VIOLENT VIDEO GAMING

Experimental studies of heart rate variability, cortisol, sleep and emotional reactions in teenage boys

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ABSTRACT

Playing violent video games may provoke aggression. Psycho-physiological methods may provide knowledge about the underlying psychological processes. Most previous studies have been performed in laboratory settings at daytime with adults. Thus the aim of this thesis was to investigate psycho-physiological (autonomic and HPA related reactions), sleep-related and emotional responses in teenage boys to playing a violent and a non-violent video game at home before going to sleep. In Study I the autonomic responses differed between the violent and the non-violent game during playing and more distinctly during sleep. In Study II the HPA axis was not affected by video gaming at all. In Study III, the effect of habits of playing violent games was assessed (≤ 1h/day and ≥ 3h/day). High versus low experience of violent gaming were related to different autonomic, sleep-related and emotional processes at exposure to a violent and a non-violent game, during playing and during sleep. The present thesis demonstrated that violent and non-violent games induce different autonomic responses during playing and – more distinctly – during sleep. Frequent gaming seems to influence physiological, sleep-related and emotional reactions, possibly as an expression of desensitization processes.

Keywords: video gaming, media violence, autonomic nervous system, heart rate variability, HPA axis, cortisol, sleep quality, emotional reactions, desensitization, teenagers.

SAMMANFATTNING PÅ SVENSKA

Bakgrund

När ny teknik för underhållningsmedia - som TV- och datorspel - utvecklas är det många som oroas, vanligen angående eventuella skadliga effekter. En stor andel av spelen som finns att tillgå innehåller någon form av våld, vilket tycks locka många tonårspojkar. Debatten om våldfokuserade spel har funnits lika länge som det har funnits spel, men även om oron (och även forskningen i sig) har anklagats för moralpanik så visar många studier som ägnat sig åt att mäta effekter av spel att våldsfokuserade spel har ett starkt samband med olika former av aggressioner. Detta samband har visat sig bestå när man kontrollerat för psykisk hälsa, tidigare aggressivitet, uppväxtförhållanden och socioekonomisk status. Våldfokuserade spel har också visat sig ha en avtrubbande effekt gentemot sådant som i vanliga fall väcker empati, både i experimentella och longitudinella studier.

Den vanligaste metoden att mäta effekter av våldfokuserande spel är att mäta psykologiska faktorer som emotioner, kognitioner och beteende. Men våldsspel kan också tänkas ha fysiologiska konsekvenser. För att mäta fysiologiska reaktioner kan man undersöka kroppens olika anpassningssystem som det autonoma nervsystemet och HPA-axeln. Det autonoma nervsystemet är det system som reglerar bland annat hjärtfrekvensen och står utanför viljans kontroll. HPA-axeln består av hypotalamus (H), hypofysen (P) och binjurebarken (A) och dess utfallsvariabel är vanligtvis dess slutprodukt kortisol. Sömnen som är en viktig mekanism för återhämtning är känslig för belastningar och det kan tänkas att sömnen påverkas av våldsspel, särskilt om spelandet äger rum på kvällen. Även om debatten om våldsspel vanligen handlar om barn och unga så har de flesta undersökningar gjorts på vuxna i laboratorium under dagtid.

Det övergripande syftet med denna avhandling var att experimentellt undersöka psykofysiologiska (dvs. hjärtfrekvens [HR] hjärtfrekvensvariabilitet [HRV] och kortisol), sömnrelaterade och känslomässiga reaktioner hos tonårspojkar på att spela våldsfokuserat spel i sitt hem på kvällen innan de går och lägger sig.

De specifika syftena med delstudierna var

I. Att undersöka hur två timmars spel av 1) våldsfokuserat och 2) icke våldsfokuserat spel på kvällen påverkade HR och HRV under spel och under sömnen följande natt. Även självrapporterad sömn undersöktes.

II. Att undersöka hur två timmars spel av 1) våldsfokuserat och 2) icke våldsfokuserat spel på kvällen påverkade kortisolnivåerna efter spelandet och nästa morgon.

III. Att undersöka hur vana av att spela våldsspel påverkade HR och HRV under spelande och följande natt av 1) våldsfokuserat och 2) icke våldsfokuserat spel under kvällen, samt hur självrapporterad sömn och emotioner påverkades.

Metod

Två undersökningar med inomindividsdesign utfördes med pojkar, 12-16 år gamla, rekryterade från kommunala skolor. Pojkarna fick spela spel med våld (Manhunt) och utan våld (Animaniacs) i sina hem under två olika vardagskvällar mellan klockan 20 och 22. I den första undersökningen (artikel I och II) deltog 19 respektive 21 pojkar med varierande erfarenhet av spel där de fick bära hjärtmätare från och med innan spelandet till och med nästa morgon, ta salivkortisolprov efter spel och nästa morgon och fylla i en sömndagbok nästa morgon. Utfallsvariabler: HR, HRV, kortisol och självskattad sömn. I den andra undersökningen (artikel III) - med samma design - deltog 30 pojkar där hälften brukade spela våldsspel tre timmar eller mer och den andra hälften en timme eller mindre per dag. Utfallsvariabler var HR, HRV, självskattad sömn och emotioner.

Resultat

Resultatet från första studien (artikel I och II) visade att typ av spel gav upphov till signifikant olika mycket HRV-aktivitet under spelandet och med mer distinkta skillnader under natten. Resultatet visade inga skillnader mellan betingelserna i sömnkvalitet eller i kortisolnivåer. Den andra studien (artikel III) resulterade i signifikanta interaktionseffekter mellan spelvana och typ av spel - i HR (under sömnen), i självskattad sömnkvalitet och emotionellt (”sadness”). Den ovana gruppen fick signifikant högre hjärtfrekvens (både under spel och sömn), sämre sömnkvalitet och mer negativa emotioner av det våldfokuserande spelet än av det icke våldsfokuserande spelet. De två olika spelen gav inte upphov till några skillnader i reaktioner i någon av de ovan nämnda utfallsvariablerna bland dem som var vana att spela våldsfokuserande spel.

Slutsatser

Resultaten tyder på att det autonoma nervsystemet påverkas olika av spel med och utan våld under spelandet och mer uttalat under natten efter spel. Dock verkar inte kortisolnivåerna påverkas av typ av spel. Skillnaderna mellan de autonoma och kortisolrelaterade reaktionerna kan förklaras av att spelsituationen (oavsett våld eller inte) i sig är kontrollerbar vilket har en skyddande effekt på reaktioner i HPA-axeln men inte på det autonoma nervsystemet. Skillnader i reaktioner mellan spelen tycks inte uppstå hos dem som är vana att spela mycket våldsspel - troligtvis som en konsekvens av ”avtrubbning”. Avtrubbning genom exponering för obehagliga stimuli är en dokumenterat effektiv teknik i regleringen av emotioner och beteenden i terapeutiska sammanhang.

En begränsning med dessa studier ligger i användandet av olika spel för de två betingelserna där andra faktorer än våldsinnehåll kan påverka resultatet. Dock var - förutom våldet - likheten i spelstil en viktig faktor vid valet av spel. I övrigt hade faktorer som svårighetsgrad, mängd rörelse, avstånd till skärmen, ljudvolym och hur roliga spelen upplevdes ingen betydelse för resultaten. Vidare kan personligheten i de olika grupperna i den andra studien ha varit en faktor som skulle kunna tänkas påverka resultaten. I dessa studier gjordes inga personlighetstester. Däremot visade hjärtmätningen - som till viss del kan avslöja personlighetsdrag som kan vara av betydelse för denna typ av mätningar - inget som tyder på att grupperna skilde sig åt angående personlighet.

Styrkan hos dessa studier ligger i dess syften, det vill säga att låta den grupp (ungdomar) som kan tänkas vara känsliga för våldsspelseffekter, spela i sin naturliga miljö under den tid på dygnet då spel troligtvis har som störst påverkan på sömnen. Betydelsen av avhandlingen kan relateras till ökningen av andelen tonårspojkar som spelar "för mycket" (mer än tre timmar per dag) och att våldsinslag i spel ökar generellt. En praktisk betydelse är att vi har visat att metoden med att analysera hjärtfrekvensen och hur denna varierar är användbar för att påvisa fysiologiska reaktioner vid spelande. Detta öppnar möjligheter för framtida forskning med kompletterande och fördjupade frågeställningar.

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LIST OF STUDIES

The present doctoral thesis is based on the following studies:

Study I: Ivarsson, M., Anderson, M., Åkerstedt, T., & Lindblad, F. (2009). Playing a violent television game affects heart rate variability. *Acta paediatrica*, *98*(1), 166-172.

Study II: Ivarsson, M., Anderson, M., Åkerstedt, T., & Lindblad, F. (2009). Playing a violent television game does not affect saliva cortisol. *Acta Paediatrica*, *98*(6), 1052-1053.

Study III: Ivarsson, M., Anderson, M., Åkerstedt, T., & Lindblad, F. (2013). The effect of violent and nonviolent video games on heart rate variability, sleep, and emotions in adolescents with different violent gaming habits. *Psychosomatic medicine*, *75*(4), 390-396.

Erratum in: Ivarsson, M., Anderson, M., Åkerstedt, T., & Lindblad, F. (2011). Playing a violent television game affects heart rate variability. Corrigendum. *Acta Paediatrica*, *100*(9), 1283.

CONTENTS

ABBREVATIONS

ANS	Autonomic nervous system
HF	High frequency
HPA	Hypothalamic-pituitary-adrenal
HR	Heart rate
HRV	Heart rate variability
LF	Low frequency
LF/HF	Low frequency/high frequency ratio
PSNS	Parasympathetic nervous system
SCAS	The Swedish Core Affect Scales
SNS	Sympathetic nervous system
SQ	Sleep quality index
TP	Total power
VLF	Very low frequency
WAKE	Awakening index

INTRODUCTION

When new techniques for entertainment media are developed, concern typically arises about adverse effects, especially for frequent consumers/users. As for television, there has been a continuous debate about these matters. Worries about "watching too much" concern, for example, the problem that children now engage less in traditional activities such as spontaneous play, social interaction with peers, and physical activities which are thought to promote development. Exposure to television violence has also been presumed to provoke aggression, both in the short and the long term. In spite of mockery of such worries, which are often referred to as moral panic, there is considerable scientific support for the aggression-promoting effect of watching violent TV programs frequently during childhood (Huesmann, Moise-Titus, Podolski, & Eron, 2003) as well as during early adulthood (Johnson, Cohen, Smailes, Kasen, & Brook, 2002).

In the last 20 years, video gaming has become one of the most popular leisure activities of children and teenagers in the Western world (Anderson, Gentile, & Buckley, 2007; Entertainment Software Association, 2013; Swedish Media Council, 2013). Many video games contain some kind of violent content (Haninger, Ryan, & Thompson, 2004; Thompson & Haninger 2001) that seems to be an attractive feature to teenagers (Griffiths, Davies, & Chappell, 2004). Although there is an ongoing debate within the gaming research community, an overall conclusion of the research measuring causality seems to be that violent gaming is associated with a number of adverse effects such as increased aggressive behaviour, thoughts and emotions, as well as lowered prosocial behaviour – both across culture and gender (Anderson et al., 2010). Furthermore, results from a growing number of studies have shown that prolonged, habitual playing of violent games may increase aggression (Barlett, Harris, & Baldassaro, 2007) and might have a desensitizing effect on stimuli that usually evoke empathy (Bartholow, Bushman, & Sestir, 2006; Bushman & Anderson, 2009; Fanti, Vanman, Henrich, & Avraamides, 2009; Krahé et al., 2011).

There are different methods of studying effects associated with violent video gaming. The most used methods have cognitive, emotional, and behavioural dimensions. Psycho-physiological methods may provide underlying physiological knowledge about the psychological processes. One way to study physiological reactions to exposure to violent gaming is to measure arousal and distress responses. Distress can be balanced by recovery, and since sleep is a key mechanism for recovery, it may be of interest to study how it might be affected, especially if gaming takes place in the evening.

Thus the general aim of this thesis was to experimentally investigate psycho-physiological (i.e. Heart Rate [HR], Heart Rate Variability [HRV] and cortisol), sleep-related and emotional responses in teenage boys to playing a violent video game at home in the evening before going to sleep.

The specific aims of the sub-studies were:

I. To investigate how two hours of playing 1) a violent (VG) and 2) a non-violent video game in the evening affected HR and HRV during play and the sleep during the subsequent night. Also self-reported sleep was investigated.

II. To investigate how two hours of playing 1) a violent and 2) a non-violent video game in the evening affected cortisol levels after playing and the next morning.

III. To investigate the impact of violent gaming habits on HR and HRV during playing and during sleep after two hours of playing 1) a violent and 2) a non-violent video game in the evening, as well as self-reported sleep quality and emotions. The hypotheses were that the heart rate parameters (HR and HRV) would differ between the groups and that the less exposed gamers would report lower sleep quality and more negative emotions in relation to the violent game than the highly exposed gamers.

BACKGROUND

Video gaming

The electronic gaming industry is one of the most rapidly growing media businesses in the world. According to the Swedish Games Industry, sales of video games in Sweden came to more than 140 million SEK in 2012 (Swedish Game Industry, 2013). In the US, sales of video games and equipment came to more than 20 billion dollars in 2012 (Entertainment Software Association, 2013). Action, sports and shooter games are the top three game genres.

Most games are played in a similar way, with some kind of screen and a device for control on computers, consoles, phones and other handheld apparatus. In this thesis, all such games will be referred to as video games. Games can be played individually, or with others. Playing with others is possible by playing on the same device in the same (physical) place or by connecting computers or gaming devices together in a local network (LAN; Local Area Network). A LAN can vary in size from two to thousands of gaming devices in so-called LAN parties. In the latter, the participants usually bring their own computers and play multiplayer games together for a few days. Playing with others is also possible on the Internet when gamers from different locations participate in role-playing games in MMORPGs (Massively multiplayer online role-playing game) that involve a large number of players interacting in a virtual world. MMORPGs are ongoing, and continue as long as anyone is playing. Individuals can enter and leave the game at any time.

Video gamers

Even though people of all ages play games, gaming is mostly associated with childhood and teenagers. In the ages between nine and 12 years, 32 per cent of children in Sweden play games every day, while among the 13 to 16-year-olds the corresponding figure is 24 per cent. Among boys aged between nine and 12 years, 24 per cent play more than three hours a day (“high consumers”) and among the 15-year-old boys, the proportion is 50 per cent (Swedish Media Council, 2013). Many children and teenagers have gaming equipment of their own. Among 9-16-year-olds in Sweden, about 60 per cent have a computer and about 45 per cent have a game console in their bedroom (Swedish Media Council, 2013). In the U.S., the corresponding proportions among 8 – 18 year olds are 36 (Riedout, Foehr, & Roberts, 2010), and 43 per cent, respectively (Roberts & Foehr, 2008).

Men and boys spend significantly more time playing video games than women and girls (Chou & Tsai, 2007; Ng & Wiemer-Hastings, 2005; Riedout et al., 2010; Roberts & Foehr, 2008; Swedish Media Council, 2013). Boys aged 12-14 spend in general almost seven hours a week playing video games while girls play less than one hour per week (Olson et al., 2007).

Video gaming and motives

One of the reasons for playing video games seems to be to recover after exposure to stressful situations and strain (Reinecke, 2009). Other reasons seem to be the excitement and fun of competing and winning, to socialize with friends, to manage and experience emotions, and to combat boredom (Olson et al., 2007). Violent content seems to be particularly attractive to young boys (Griffiths et al., 2004, Lemmens, Bushman & Konijn, 2006). Enjoyment is a recurring reason and the social community that many online games offer seems to be an appealing component (Cole & Griffiths, 2007; Durkin & Barber, 2002; Griffiths, Davies, & Chappell, 2003; Jansz & Martens, 2005; Ng & Wiemer-Hastings, 2005). However, even though video gaming can be rewarding and fun (Olson et al., 2007), heavy users may also experience the online gaming they are engaged in as an obligatory commitment, more like work than entertainment (Yee, 2006).

Video gaming and beneficial effects

The techniques of gaming can be applied for a variety of purposes, from relaxation and having fun to learning. Examples of educational purposes are games published by worldwide health, peace and environmental issue organizations where players can learn about issues such as environmental threats and famine by taking on good missions. Another example is Foldit, an online game that engages non-scientists all around the world in solving scientific problems about protein structures (Cooper et al., 2010). Prosocial games, based on cooperation, seem to influence the players to behave more prosocially and less antisocially (Gentile et al., 2009; Greitemeyer & Osswald, 2009).

Game technology progress is fast and it seems that the technological advancements increase video game players' involvement (Ivory & Kalyanaraman, 2007). Given the appeal of games to children, gaming techniques can be used to stimulate a variety of desirable outcomes. At school, games can be useful and serve as a motivating teaching tool (Prensky, 2002). Games can also be used for psychotherapeutic purposes, for example, to expose phobic patients to aversive stimuli (Wilkinson, Ang & Goh, 2008).

Games created without any therapeutic or pedagogic aims can have advantageous effects as well. One example is physically interactive games that seem to enhance physical fitness, motor skills and motivation for physical exercise (Papastegiou, 2009). A number of cognitive abilities, such as spatial attention, have been shown to improve when playing shooter games (Wu et al., 2012), the ability to detect objects in briefly flashed displays when playing action games (Green & Bavelier, 2003; Green & Bavelier, 2006), and multitasking when playing strategic action games (Sun, Ma, Bao, Chen, & Zhang, 2008). Such influence may even improve professional skills, as illustrated by a study on medical students. Those who were skilled in video gaming showed an increased spatial ability when they attended a keyhole surgery class (Rosser et al., 2007).

Video gaming and adverse effects

Much of the debate about children's gaming habits concerns their potentially adverse impacts. The concerns have given rise to a growing number of studies investigating if gaming can be addictive, impair academic achievements, affect body weight, induce aggression, reduce empathy, impair sleep or induce undesirable psycho-physiological effects. The following text presents previous studies on these effects.

Addiction

The negative effects of gaming are generally related to the time spent playing and excessive use of whatever may indicate addiction. There seems to be general agreement that spending more than 20 hours per week engaged with any single form of media (such as video gaming) might be labelled as excessive use or "problematic playing" (Parsons, 2005; Swedish Media Council, 2005). In Sweden, it is estimated that about 35 per cent of all 9 – 16 year olds boys are excessive users (≥ 3 hours/day) (Swedish Media Council, 2013). In a Norwegian survey from 2004, 4.2 per cent of the 12 – 18 year old boys reported a behaviour that was categorized as "pathological playing" and 9.8 per cent were categorized as "at risk playing" (Johanson & Götestam). A survey from 2009 found that eight per cent of 8 – 18 year-olds in the US displayed addictive patterns of playing as defined by criteria derived from the Diagnostic and Statistical Manual of Mental Disorders (DSM – IV) (Gentile, 2009). However, the concept of gaming addiction is controversial due to the lack of obvious consequences that exist for other addictions such as addiction to drugs (Wood, 2007), and the unclear boundary between dependence and engagement (Charlton, 2002).

Academic achievement

The results from studies on the effects of video gaming on school performance are inconsistent. Some studies have shown no, or even positive influences on school performance (Durkin & Barber, 2002; Griffiths et al., 2003). Other findings have shown that the negative effect on academic achievement is related to the overall amount of time spent on video gaming (Hastings et al., 2009; Jaruratanasirikul, Wongwaitaweewong, & Sangsupawanich, 2009; Weis & Cerankosky, 2010). As mentioned above, studies have shown that gaming may improve cognitive functions (Green & Bavelier, 2003; Green & Bavelier, 2006; Sun et al., 2008; Wu et al., 2012).

Body weight

Findings regarding the relationship between body weight and gaming are inconsistent as well. Studies have shown that gaming may (Ballard, Gray, Reilly, & Noggle, 2009), or may not, be associated with overweight (Wack & Tantleff-Dunn, 2009). Gaming seems to be associated with increased food intake (Chaput et al., 2011) as well as altered metabolic processes – perhaps as a consequence of physiological arousal, which would tend to decrease the risk of becoming overweight (Ballard, Hamby, Panee, & Nivens, 2006; Wang & Perry, 2006).

Violent media and aggression

There is a growing amount of research on the effects of violent media in general and most of the research has focused on violence in television and movies. Studies have shown that watching violent television during childhood is associated with aggressive behaviour later in life (Boxer, Huesmann, Bushman, O'Brien, & Moceri, 2009; Christakis & Zimmerman, 2007). Other studies have shown that this association seems to remain after controlling for potential confounders, e.g. socioeconomic status, intellectual ability, aggressive personality traits and different parenting factors (Huesmann et al., 2003; Johnson et al., 2002). The perceptions of the world might be affected as well. For example, frequent viewers of violent television seem to overestimate the prevalence of real-world crime (Riddle, Potter, Metzger, Nabi, & Linz, 2011). A theoretical explanation of the link between exposure to violent media and aggression is the social learning theory of Bandura (1986). The theory argues that violent behaviour is learned by imitation of attractive, rewarded models such as aggressive heroes in movies.

One of the differences between watching motion pictures and playing video games is that gamers take an active role that might serve as a self-protecting strategy to process violent content (van Mierlo & van den Bulck, 2004). Another difference is that violence featured in movies often shows the real consequences of violence (Smith, Lachlan, & Tamborini, 2003) – although it should be noted that technical developments open up possibilities for more realistic violence in games (Anderson et al., 2007). On the other hand, gaming violence is more often rewarding and repetitive (Smith et al., 2003), both of which may increase the risk of aggressive behaviour (Huesmann et al., 2003). For example, an experiment showed that boys behaved more aggressively in a free play session after playing a violent game compared to those who just watched when the same game was played by someone else (Polman, Castro, & van Aken, 2008).

Violent video games and aggression

Since many games contain elements of sex and violence, most of the games on the market are age-rated (Smith et al., 2003). The system of age ratings is used to ensure that the content of games is suitable for different age groups. It is not an officially authorized regulation; it is a recommendation, directed to caregivers. Despite the age-rating system, many games rated for teenagers still involve violent actions such as fighting, injuring and killing other characters (Haninger et al., 2004). Moreover, many children play games recommended for older groups, and the time of gaming also seems to be positively correlated with use of games meant for older players (Olson et al., 2009). In many of the bestselling games the violence is serious, unpunished and glorified (Smith et al., 2003).

The concerns about whether or not violent games are associated with aggression have given rise to a growing number of studies, with a variety of designs. Numerous cross-sectional studies have been performed in this area, most demonstrating associations between violent gaming and behaviours such as fighting, bullying and hostility (Gentile & Gentile 2008; Gentile, Lynch, Linder, & Walsh, 2004; Möller & Krahé, 2009 Olson et al., 2009). However, the brief review to follow will focus on experimental and longitudinal studies.

Experimental studies

A number of experimental studies have found what seem to be causal relationships between violent games and subsequent aggressive thoughts (Anderson et al., 2004; Eastin, 2006), aggressive emotions (Panee & Ballard, 2002; Williams, 2009) aggressive self-concept (Bluemke, Friedrich, & Zumbach, 2010), physically aggressive intentions (Krcmar, Farrar, & McGloin, 2011), violent action during game play (Panee & Ballard, 2002), state hostility (Arriaga, Esteves, Carneiro, & Monteiro, 2006; Arriaga, Esteves, F, Carneiro, & Monteiro, 2008) and hostile expectations (Bushman & Anderson, 2002). In such experimental studies, longer durations of gaming seem to imply increased risks of aggression (Barlett et al., 2007). Aggressive personality traits also seem to increase the risk of manifestations of aggression even more (Anderson & Dill, 2000; Arriaga et al., 2006; Giumetti & Markey, 2007). Some studies show that even a short exposure to violent gaming may be influential, as demonstrated in experimental studies of gaming for periods of 12 and 20 minutes (Anderson et al., 2004: Krcmar, Farrar, & McGloin, 2011).

Nevertheless, there are reasons for caution when generalizing the results of experiments since laboratory studies have some inherent difficulties in creating contexts of sufficient ecological validity for such generalization (Ravaja, 2004). Furthermore, it should be noted that it is difficult to operationalize the concept of aggression in an experimental setting for ethical reasons, since it is impossible to measure the actual outcome – such as physical aggression. Instead, a variety of proxy measures of aggression have been applied such as delivery of imagined electric shocks, sound blasts and hot-sauce serving. The use of proxy methods complicates the interpretation of findings since it is difficult to estimate the validity of such measures (Ferguson & Kilburn, 2009). Along the same lines, it is difficult to know to what extent aggressive "free play" (as mentioned above) is a relevant measure of actual aggression (Polman et al., 2008).

Longitudinal studies

Although gaming technology is relatively new, a number of studies with at least two occasions of measurement with different time frames have examined the longitudinal effects of violent gaming with similar results as experimental and cross-sectional studies. For example, a study from 2009 demonstrated that violent gaming habits predicted norms concerning aggressive behaviour and the tendency to interpret ambiguous interactions as hostile (hostile attribution bias) 30 month later (Möller & Krahé, 2009). Anderson and colleagues (2008) revealed that previous habitual violent video gaming predicted later physical aggression, even after controlling for previous aggressiveness. Furthermore, it seems as if the more frequently adolescents play violent games during early adolescence, the higher the violence and delinquency rates at the age of 14 (Hopf, Huber, & Weiss, 2008). A study from 2006 concluded that children highly exposed to violent games became more aggressive and less helpful up to one year later (Anderson et al., 2007). Family-related factors seem to be influential in different ways. Other studies showed that parental support may have a modifying effect on adverse associations between exposure to violent games and aggression (Anderson et al., 2007; Wallenius & Punamäki, 2008). The authors suggested that good parent-child communication may moderate the link between game violence and direct aggression.

Violent video games, desensitization and empathy

A possible explanation for the aggression-promoting effects is desensitization. The process of desensitization by repetitive exposure to aversive stimuli is a well-used technique in regulating emotions and behaviours in therapeutic interventions (Weersing & Weisz 2002). The same process seems to be relevant when playing video games that include aversive elements. Several studies support the hypothesis that repeated exposure to violent video games has a significant desensitizing effect on stimuli that usually evoke empathy, such as violence against a victim. This has been shown both in correlation studies (Funk, Baldacci, Pasold, & Baumgardner, 2004; Funk, Buchman, & Jenks, 2003) and in experimental studies (Bartholow et al., 2006; Bushman & Anderson, 2009; Fanti et al., 2009; Krahé et al., 2011).

In 2010, a meta-analysis was published summarizing the results from 136 (published and unpublished) papers on the association between violent video games and aggression, empathy and prosocial behaviour (Anderson et al., 2010). These papers used various methods and had different designs, and they included data from 130,296 participants. The associations seemed to occur across culture, gender and ages, regardless of study design. The strongest results were found in the longitudinal studies and in studies with the highest scientific quality.

Video gaming and sleep

Sleep is a period of recovery through physiological and psychological processes that have different restorative functions (Šušmáková, 2004). Sleep can be measured both physiologically and by self-reports. One physiological method is polysomnography which objectively assesses the presence of sleep and its depth during the period of assessment. The method involves electrodes being pasted to the head, where they continuously record electrical activity in the cortex (electroencephalography – EEG), eye movements (electrooculography – EOG) and muscle tone in skeletal muscle (electromyography – EMG) and heart rhythm (electrocardiography – ECG). Another physiological method is to measure patterns of movement, since different movements are related to different sleep stages (Sadeh & Acebo, 2002). The device that is used is a so-called Actiwatch, worn round the wrist like a wristwatch. The amount of movement permits periods of sleep and wakefulness to be distinguished, and the measurements can generate data about time spent in bed, sleep duration, sleep latency and numbers of awakenings. Self-reported sleep is measured by surveys about sleep in general and by sleep-diaries that are completed in the morning on waking.

Sleep is vulnerable to arousing situations (Kim & Dimsdale, 2007) and disturbed sleep can have a variety of physiological and psychological consequences. Health may also be affected. For instance, poor sleep can affect the immune system (Majde & Kryger, 2005) and increase the risk of several diseases, such as diabetes, obesity, hypertension, myocardial infarction and stroke (van Reet et al., 2000). Psychologically poor sleep has been associated with emotional instability (Baglioni, Spiegelhalder, Lombardo & Riemann, 2010) and impaired concentration, memory function and performance (Walker & Stickgold, 2006).

A number of studies have examined the effects of video gaming on sleep, and it seems that gaming is related to prolonged time to fall asleep (Alexandru et al., 2006), later bedtime (Eggemont & Van den Bulck, 2006; Oka, Suzuki, & Inoue, 2008), shorter duration of sleep (BaHammam, Bin Saeed, Al-Faris, & Shaik, 2006; Eggemont & Van den Bulck, 2006; Oka et al., 2008), lower quality of sleep (Mesquita & Reimão, 2007), and elevated reported tiredness (Eggemont & Van den Bulck, 2006) – especially if the playing device is present in the bedroom (Oka et al., 2008; Van den Bulck, 2004). Only a few studies have been experimental, using polysomnography. One of them was performed by Dworak and colleagues (2007) examining sleep patterns and memory performance after playing a racing video game or watching a film, both for periods of 60 minutes at home. The results showed prolonged sleep-onset latency and impaired memory after playing the video game compared to watching the film. Another study found that prolonged (only violent) gaming, compared to shorter gaming (150 and 50 minutes) before sleep induced lower sleep efficiency, poorer sleep quality and shorter sleeping time (King et al., 2013). These findings may be explained by different aspects of the experimental situation: increased arousal in general caused by an interesting and stimulating activity; the violent content; and the exposure to a light screen. There are reasons to be careful when measuring the effects of video gaming on sleep since bright light exposure may induce a delay in falling asleep (Higuchi, Motohashi, Liu, & Maeda, 2005). Although the number of studies on sleep and gaming is growing, no study seems to have specifically compared the sleep effects of violent games and non-violent games.

Psycho-physiology

Psycho-physiological reactions to external challenges can be expressed as changes across different systems, with a function of maintaining homeostasis. Homeostasis is a term for various mechanism that act together to keep an organism in a healthy equilibrium. A related concept is allostasis, which describes the adaptive capacity to maintain homeostasis through change (McEwen & Stellar, 1993). The theory of allostasis explains how individuals react psychologically and physiologically to changes. Various factors or stimuli elicit different patterns of activation of the body's various systems. (McEwen, 2006). Maintenance of homeostasis is thus an active allostatic process that includes various systems. In challenging or threatening situations the different systems are activated with the purpose of adapting the individual to the situation by redistributing different types of resources that aim to facilitate adaptation. If the systems become overloaded and the process of activation cannot be stopped, adaptability is compromised, which may lead to suboptimal functioning and health challenges.

One of the main systems for adaptation is the autonomic nervous system (ANS) which regulates the functions that are not under the influence of will. It has two subsystems, the sympathetic nervous system (SNS) and the parasympathetic nervous system (PSNS). Another main regulatory system is the hypothalamic-pituitary-adrenal (HPA) axis.

Autonomic nervous system and cardiovascular regulation

The cardiovascular system is one of the systems that the ANS controls. The various functions of ANS affect the fine tuning of each new heartbeat to adjust blood pressure (BP) by regulating the frequency and power of the contractions of the heart muscle (Kaplan & Talajic, 1991). SNS and the PSNS act antagonistically and affect the cardiac impulse formation in two distinct ways; activation of SNS increases HR, while activation of PSNS decreases HR. The interaction – or the net effect – regulates the instantaneous HR.

The SNS part of the ANS is involved in the homeostatic processes that regulate the BP and body temperature and mobilize energy. It can be stimulated by physical movements and by stressful or threatening situations that require increased blood flow (Berntson et al., 1997). Signals of the SNS are transmitted by the sympathetic chain (nerve clusters along the spine) to large parts of the body, and affect most body organs. Activation of the SNS also stimulates the medulla of the adrenal glands to release epinephrine and norepinephrine into the blood. Epinephrine and norepinephrine increase HR and thereby BP. Reactions in the SNS are described as if they transform the body into what is called "fight or flight mode" (Jansen, Van Nguyen, Karpitskiy, Mettenleiter, & Loewy, 1995). The term describes two different physiological ways to respond to threats or challenges. If it is possible to defeat the threat, the reaction is offensive, but if the threat is perceived as overwhelming, the reaction is defensive (Henry, 1992).

PSNS is linked to anabolic – regenerative processes (Camm et al., 1996) – and is active during rest and sleep for recovery of the body. PSNS is expressed through the vagus nerve, which is the body's longest cranial nerve. It runs through the neck, chest cavity and diaphragm and ends in the upper part of the abdominal cavity. The vagus nerve mainly consists of sensory (afferent) nerve fibres, which communicate information about peripheral states to the central nervous system. Since the effect of its transmitter, acetylcholine, is short (because acetylcholine is rapidly hydrolysed) quick adjustments in time between heartbeats can be achieved within one or two beats (Camm et al., 1996). When PSNS activation decreases, HR returns to its original level within a few seconds. SNS is slower, with an increase in HR to a stable frequency occurring 20 – 30 seconds after sympathetic stimulation (Hainsworth, 1995). The intrinsic rate of the heart is between 80 and 110 beats per minute and is regulated by its internal impulse formation cells (Jose & Collison, 1970). However, since the normal resting HR is lower – 50 to 100 beats per minute – the conclusion is that the PSNS (vagus) is dominant in relation to the SNS. The parasympathetic inhibiting function on HR is called the vagal brake.

HR is affected by breathing, mediated by changes of pressure in the thorax (chest) that affect the blood flow to the heart. The system that regulates the BP compensates for the pressure changes by adjusting the HR via the PSNS. The influence of breathing on HR is typically pronounced in young people and declines with age (Umetani, Singer, McCraty, & Atkinson, 1998).

PSNS and SNS affect the impulse formation of the heart by fine tuning of the temporal cardiac activity (Sayers, 1973). The resulting differences in fluctuations of the heart rate have become known as Heart Rate Variability (HRV).

Heart Rate Variability – HRV

Methodological aspects of HRV

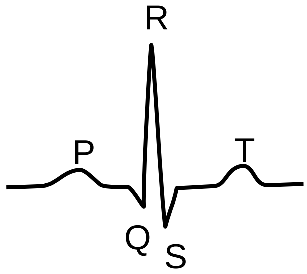

Figure 1. Schematic representation of QRS complex

Measurements of HRV require that the time distance between successive heartbeats can be identified. One way to measure the cardiovascular activity is to use electrocardiography (ECG) which is a method of examining the heart's electrical potential activity over time from the body surface. Each heartbeat generates a number of waves: P, Q, R, S and T-waves due to the electrical activity generated by the conduction system of the heart muscle (Figure 1). A heartbeat starts just before the P-wave, but the R-wave peak is usually used in psychophysiological research because of its high and clear amplitude. A large number of QRS complexes are required for a meaningful analysis of the underlying regulation of cardiac rhythm. A sampling rate (samples/second) above 100 Hz is generally considered satisfactory (Camm et al., 1996).

There are other terms that describe the phenomenon of variability: Cycle Length Variability, Heart Period Variability, RR variability and RR interval tachogram. Although those terms may be more consistent with the fact that it is the interval between consecutive beats that is analysed rather than HR itself, HRV has become the most commonly used term (Camm et al., 1996).

It is important that the analysis of HRV is based only on normal RR intervals. As little as one per cent of abnormal intervals may change results significantly (Storck, Ericson, Lindblad, & Jensen-Urstad, 2001). However, a normal ECG often includes abnormal RR intervals with either a methodological or a physiological origin. This means that abnormal RR intervals should be addressed by removing them or by interpolation – depending on the method of assessment and frequency focus (Lippman, Stein, & Lerman, 1994).

HRV measurements are neither painful nor invasive and the equipment is relatively inexpensive. The equipment is easy to wear and enables long-term ambulatory registration as well as short-term registration in the laboratory. HRV is relatively unaffected by placebo effects and studies have shown low intra-individual differences over time (Bigger, Fleiss, Rolnitzky, & Steinman, 1992; Kleiger et al., 1991; Van Hoogenhuyze et al., 1991). Since the eighties, HRV has regularly been used to predict and diagnose a variety of cardiac and non-cardiac conditions such as hypertension, quadriplegia (loss of function due to spinal cord injury), heart failure, diabetic neuropathy and myocardial infarction (Camm et al., 1996).

HRV data can be analysed in several ways but the two most common are time domain analysis and frequency domain analysis. The easiest method is the time-domain analysis measuring heart rate fluctuations around the mean value. Variables are calculated as mean values, which can be used for comparisons between different periods or between the longest and shortest NN ("normal to normal") intervals (Camm et al., 1996). For longer measurement periods – such as 24-hour measurements – the amount of data becomes unmanageably large, which necessitates further statistical analysis. Calculations can be done in two ways; from the direct measurements of NN or HR, or from differences between NN intervals. The most straightforward variable is the standard deviation of NN intervals (SDNN). SDNN reflects all the cyclic components that cause variance in the period of measurement. The method is sensitive to differences in duration between different measurements because the total variance decreases over time, making it important that the registration times are the same each time. To avoid the duration sensitivity of SDNN, SDANN can be used. It is the standard deviation of NN intervals calculated on five-minute intervals which allows averages to be calculated for use in comparisons under different conditions.

If the differences between NN intervals are to be measured, the RMSSD (Root Mean Square of Successive Differences in RR intervals), NN50 (number of interval differences that exceed 50 milliseconds) or pNN50 (the proportion between NN50 and number of NN intervals) can be used.

SDNN is the time-domain analysis that is recommended for calculation of total HRV (Camm et al., 1996). For the calculation of long-term components the SDANN is recommended, and RMSSD for the calculation of short-term components. The latter is preferable to pNN50 and NN50 when it comes to making use of differences in NN intervals since RMSSD have better statistical properties (Camm et al., 1996). Obviously the method should be adapted to the purpose of the measurements and the various methods cannot replace each other for short- or long-term measurements. It is important, however, to clarify whether the analysis is based on direct measurement of NN intervals, instantaneous HR, or differences in NN intervals (Levy & Zieske 1969).

The frequency domain analysis (introduced by Sayers, 1973) is used to visualize the underlying systems that give rise to variation in HR. The variation is not random; it occurs with some regularity – or rather, several regularities – and requires a more complex analysis than time domain data. The rhythms are usually quantified by subdividing them into different frequency bands, and are measured in milliseconds squared (m^2). To calculate different frequencies in the total variance, the time domain function is transformed to frequency domains by Fourier transformation to identify the frequencies that together give rise to the variance. Symbolically, this can be compared to separating and identifying different notes – frequencies – from a musical chord.

The highest frequency band (HF - High Frequency) means frequencies between 0.15 and 0.4 Hz corresponding to 9 – 24 cycles/minute or 2.5 – 6.7 sec./cycle. LF (Low Frequency), means frequencies between 0.04 and 0.15 Hz with a rate between 2.4 and 9 cycles per minute (6.7 – 25 sec./cycle). VLF (Very Low Frequency) includes frequencies up to 0.04 Hz and corresponds to 2.4 cycles per minute (25 seconds or more). Sometimes an Ultra-Low Frequency (ULF) is used, with a frequency range from 0 to 0.0033 Hz, corresponding to 0.2 cycles per minute with cycle times of five minutes or longer (Stein & Klieger, 1999).

Figure 2a describes the principle of three frequencies corresponding to HF – 0.25 Hz (15 cycles/min), LF – 0.1 Hz (6 cycles/min) and VLF – 0.016 Hz (1 cycle/min). Figure 2b illustrates a combination of the three frequencies. Figure 2c illustrates the amount of variance represented by the area under each spectral peak (y-axis) in the three frequencies which is proportional to the square of the amplitude of the original signal (x-axis) after Fourier transformation. As with skewed data in general, data from the different frequency ranges should be log transformed before further statistical analysis.

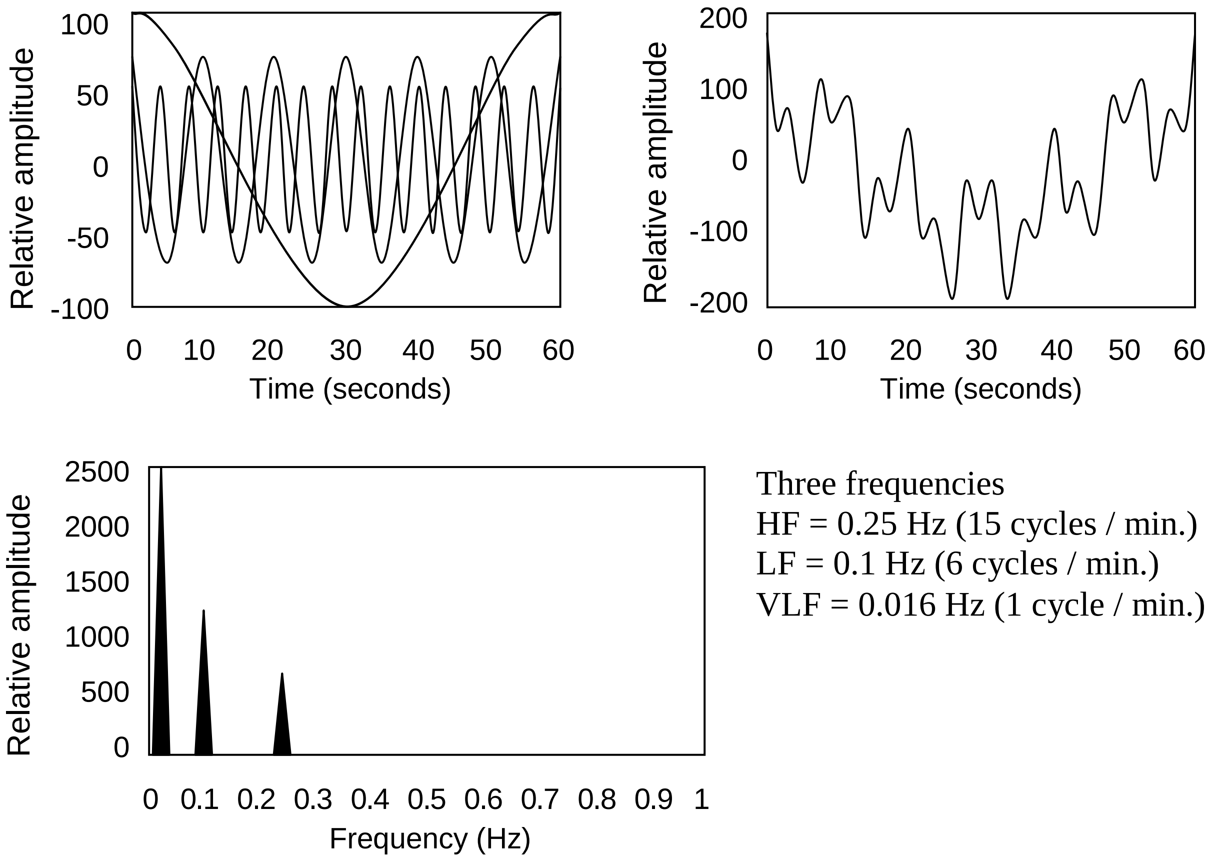

Figure 2. Top left: three sinusoidal signals: one cycle/minute, six cycles/minute and 15 cycles/minute on the same scale. Top right: the same three signals are combined into one signal. Bottom left: spectral analysis of the combined signal (Stein, Bosner, Kleiger, Conger, & Louis, 1994).

The definitions of different frequency ranges vary between reports. The definitions used in this thesis are those recommended by the Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology (Camm et al., 1996). In relation to the total variation, LF and HF represent only five per cent of the total power in long-term recordings; the remaining 95 per cent represents VLF and ULF. In frequency analysis the concept 'Total Power' is also used, which is the total variance of all variations in HR including HF, LF, VLF and ULF. It is the same measurement as the above-mentioned SDNN (Camm et al., 1996).

LF and HF vary with conditions. For instance, the amount of LF increases with 90° slope standing, mental challenges and moderate exercise in healthy subjects (Malliani, Pagani, Lombardi, & Cerutti, 1991; Rimoldi et al., 1990). HF increases during controlled respiration (Bernardi et al., 2000), cold facial stimulation (diving reflex) (Hayashi, Ishihara, Tanaka, Osumi, & Yoshida, 1997), rotation (Doweck et al., 1997) and exposure to rotating auditory stimuli (Roy et al. 2012). The respiratory rate may influence the interpretation of the HRV analysis. Thus, under study conditions when the respiratory rate is expected to vary substantially, it is advisable to control for its variation. For example, a low respiratory rate may appear within the LF band (Bernardi et al., 2000). Another important factor to control is physical activity (primarily in long-term measurements) since it may influence HRV, especially in the lower frequencies, which are most sensitive to movements (Bernardi et al., 1996).

Interpretation of HRV - basic aspects

There seems to be consensus regarding the physiological correlates of HF (Camm et al., 1996). The boundaries of HF are determined by the normal respiratory rate (nine and 24 breaths per minute) (Vaschillo, Lehrer, Rishe, & Konstantinov, 2002). Respiration is associated with PSNS and HF is thus considered as reflecting PSNS. It has been experimentally possible to identify vagal activity as a contributor to activity in the HF band by using electric vagal stimulation, blockade of muscarinic receptors (which binds acetylcholine) and vagotomy (Akselrod et al., 1981; Malliani et al., 1991).

There are different viewpoints on the interpretation of LF. One standpoint is that the LF reflects SNS (Malliani et al., 1991). It has also been suggested that LF may reflect both sympathetic and vagal influences (Akselrod et al., 1981). (See also below, “An alternative interpretation of HRV – the polyvagal perspective”) Previously the LF/HF ratio has been applied as a hypothetical expression of the balance between SNS and PSNS – where a decrease in the ratio may either indicate a power increase in SNS or a reduced regulation of PSNS (Pagani et al., 1986).

The VLF and ULF bands are assumed to reflect slower functions such as thermal regulation, the renin-angiotensin system (BP and blood volume regulation) (Akselrod et al., 1981; Bonaduce et al., 1994), the circadian rhythm (ULF) (Stein & Asmundson, 1994) and physical activity (Bernardi et al., 1996). They have mainly been associated with the parasympathetic outflow (Talyor, Carr, Myers, & Eckberg, 1998). Although the VLF and ULF are variables with uncertain underlying causes, they have a significant clinical predictive value for diseases (Bigger et al., 1992).

It should be noted that HRV is a reflection of how the heart activity is influenced by underlying neuronal processes, not a reflection of the processes themselves. A common misunderstanding regarding HRV components is that they measure autonomic tone (the power of activity). HRV components are measurements of the regulation of the autonomic activity reflected in the output signals from the heart, not the autonomic activity (tone) itself (Malik & Camm, 1993).

Psychological aspects of HRV

During the last few decades, HRV analysis has been used increasingly in social science research partly thanks to improvement of the method, which has been continuously influenced by the digital development. Several aspects of individual psychological functioning have been studied. Low power in the HF band has been associated with difficulties concerning emotional regulation (Appelhans & Luecken, 2006) and high output (sinus arrhythmia) with constructive coping strategies (Fabes & Eisenberg, 1997). A number of studies have shown an association between increased HF and adaptive abilities to handle distress and to exhibit more prosocial behaviour such as comforting sad peers (Fabes, Eisenburg, & Eisenbud, 1993; Fabes, Eisenberg, Karbon, Troyer, & Switzer, 1994). A recently published study found a positive correlation between HF and the ability to identify emotions in others (Quintana, Guastella, Outhred, Hickie, & Kemp, 2012). HRV (RMSSD) seems to decrease more during cognitive performance (attention and memory) compared to resting (Hansen, Johnsen, & Thayer, 2003).

Measurements of HRV have been applied in relation to a variety of psychiatric diagnoses. Post-traumatic stress disorder (PTSD) has been associated with decreasing activity in the HF band and increasing activity in LF (Cohen et al., 1997) and patients with autism have generally decreased vagal activity (HF) (Goodwin et al., 2006; Toichi & Kami, 2003).

HRV measurements have also been applied in biofeedback treatment. Biofeedback is a method in which physiological processes such as BP, muscle tone and HR are used to allow the patient to visualize the influence of respiration. The idea is to practice and learn a favourable breathing method, and the technique seems to be effective for a variety of symptoms and diseases such as depression, coronary heart disease, fibromyalgia, pain, asthma and chronic obstructive pulmonary disease (COPD) (Yucha & Montgomery, 2008). According to Paul Lehrer and co-workers (2004), the method can be used as a complement to, or in some cases even as a substitute for, traditional medical treatment. Numerous studies have shown that meditation and yoga exercises affect HRV by increased activity in the HF band and a decrease in the LF band (Takahashi et al., 2004; Wu & Lo, 2008; Sarang & Telles, 2006).

An alternative interpretation of HRV - the polyvagal perspective

As previously mentioned, there are different opinions about how HRV data should be used for the interpretation of underlying ANS processes. Steven Porges has presented a model for interpreting HRV data, the polyvagal theory (Porges, 1995). The polyvagal theory draws on an evolutionary model of explanation regarding the neurophysiological development of autonomic regulation and autonomic response repertoire. One part of the response repertoire is the "fight and flight" reaction, while another involves the "freeze" reaction. The latter is characterized by immobility with increased attention triggered in life-threatening situations (Bracha, 2004). The evolutionary (adaptive) explanation is to reduce the risk of detection by predators whose visual systems are more suited to moving stimuli than stationary. Another part of the evolutionary response repertoire is social behaviour, where the polyvagal theory highlights the features of the neural regulation of the ANS that distinguish us mammals from reptiles, and explains how these features work as a biological basis of social behaviour – the so-called social nervous system (Porges, 1995).

Physiologically, the polyvagal theory is based on the fact that the vagus nerve is composed of two types of nerve fibres, myelinated and unmyelinated. The myelinated nerve fibres originate from the nucleus ambiguus (NA) and the unmyelinated originates from the dorsal motor nucleus (DMNX). The myelinated nerves are phylogenetically younger than the unmyelinated and occur only in mammals (Porges, 1995). The myelinated nerve fibres have evolved through involvement in what may be considered as one of the most complex of all environments, the social. The nucleus ambiguus is also the origin of efferent nerve fibres involved in the regulation of muscles in the face, the vocal chords, the eyelids and the middle ear. These muscles are obviously all of crucial importance for communication (e.g. facial expressivity, prosody and intonation) and perception (extracting the human voice from background sounds) – and thereby also important prerequisites for social interaction (Porges, 2007).

The myelinated part of the vagus is active in safe environments and situations while the unmyelinated part reacts in situations that are threatening. Nerve impulses are transported at different speeds in the two different vagus nerve fibres. In the myelinated nerves the speed is fast, 3 – 15 m/sec compared to the thinner unmyelinated nerves with a speed of 1 – 3 m/sec (Cheng & Powley, 2000). The high speed of the myelinated nerve fibres depends on the myelin sheet itself and that the nerve fibres are normally thicker than the unmyelinated nerve fibres.

According to Porges (1997) the different systems of the ANS are hierarchically organized where the social system is the primary one that is active in safe environments and situations and promotes or permits social interaction. If the environment or the situation is insecure or frightening, the fast social inhibitory system is set aside and the "fight and flight" system (SNS) may be activated; both these system responses result in increased HR. If the situation is life threatening – as in a serious injury – the older myelinated function will be activated.

Translated to HRV and frequency bands, Porges (2007) suggests that the new system of myelinated nerves causes the variance within the limits of the HF spectrum and the unmyelinated nerve signals causes the variance that can be found in the LF spectrum. Since both the myelinated and unmyelinated nerves are part of the vagus nerve, it means that both HF and LF are measures that can be associated with vagal activity – i.e. that they reflect activity in PSNS.

ANS and video gaming

Measurements of the regulation of the heart and the cardiovascular system in general have previously been used in gaming studies. For instance, video games have been used as stressors in studies on cardiovascular risk factors, due to their ability to increase BP (e.g. Markovitz, Raczynski, Wallace, Chettur, & Chesney, 1998). Some studies suggest that violent games have a stronger effect than non-violent games (Baldaro et al., 2004; Pannee & Ballard, 2002) with a dose-response relation between violence and BP (Ballard & Wiest, 1996). BP seems to decline with continuous gaming – regardless of content – both in the short term during gaming, and in the long run with repeated gaming (Ballard et al., 2006). In general, playing videogames seems to increase HR (Borusiak, Bouikidis, Liersch, & Russell, 2008; Wang & Perry, 2006). Two meta-analyses including arousal (HR & BP) in response to violent games have shown modest but significant effect sizes ($r+ \geq 0.2$) (Anderson, 2004; Anderson & Bushman, 2001). HR seems to increase especially if the violence in the game is realistic (Barlett & Rodeheffer, 2009), includes sequences with blood (Barlett, Harris, & Bruey, 2008), and if the characters in the game are human (Bleumke et al., 2010).

Another method to assess ANS reactions of playing video games is to measure electrical skin conductance (or “galvanic skin response”, GSR). In general, video gaming seems to be arousing, and GSR reactions seem to be quite similar at exposure to violent and non-violent games (Carnagey, Anderson & Bushman, 2007). However, previous violent, as compared to non-violent, gaming may induce significantly different GSR reactions during subsequent exposure to emotionally arousing stimuli (Carnagey et al., 2007; Staude-Müller, Bliesener, & Luthman, 2008).

HRV and video gaming

In gaming studies, designs including HRV measurements are rare. One study showed an increase of HRV (total power) when playing a relaxing game compared to controls (Russoinello, O'Brian, & Parks, 2009). Another study showed both increasing and decreasing HRV (R-R) as responses to different arousing events in a non-violent game (Ravaja, Saari, Salminen, Laarni, & Kallinen, 2006). One study applied HRV measurements for investigating reactions to media violence (Maass, Lohaus, & Wolf, 2010). Four groups of boys between 11 and 14 years of age were watching a TV program or playing video games with or without violent content in their homes during the daytime. The violent game caused significantly lower HRV (SDNN) compared to the other conditions of non-violent game, violent TV program and non-violent TV program.

HPA axis – cortisol

One important system for adaptation is the HPA axis consisting of the hypothalamus (H), the pituitary gland (P) and the adrenal cortex (A). The hypothalamus produces a corticotropin-releasing hormone (CRH), which signals to the pituitary to release the adrenocorticotropic hormone (ACTH), which in turn signals to the adrenal cortex to release cortisol. Cortisol is secreted into the bloodstream and is regulated through negative feedback by decreasing the secretion of CRH and ACTH (Carrasco, & Van de Kar 2003). Cortisol, which is a steroid hormone, plays a key role in the central nervous system with multiple functions such as regulation of cardiovascular activity, metabolic processes, energy supply to the brain and muscles, and the immune system. Receptors of cortisol are found in almost all bodily tissues (McEwen, 2007; Hruschka, Kohrt & Worthman 2005; Fries, Dettenborn, & Kirschbaum, 2009). Cortisol is secreted following a diurnal cycle. In the early morning hours, before waking up, the cortisol levels start to increase and reach their highest levels about 30 min after waking (Pruessner et al., 1997). After the morning peak, the levels decrease steadily during the day and through the night, until they rise again the next morning (Fries et al., 2009). This rhythm is established early in life, probably already during the first months (de Weerth, Zijl, & Buitelaar, 2003) with gradually slightly decreasing levels during the first years of life (Watamura, Donzella, Alwin, & Gunnar, 2003). Cortisol secretion fluctuates with the seasons, with elevated levels during the spring and summer months (Persson et al., 2008). The highest concentrations of cortisol are found in the blood, but cortisol also occurs in other bodily fluids such as saliva (Kirschbaum, & Hellhammer 2000). Saliva samples are preferable for several reasons. Firstly, there is a high correlation ($r = 0.89$) between saliva and blood levels of cortisol, and saliva cortisol well reflects the biologically active substance in blood (Umeda et al., 1981). Secondly, saliva sampling is a non-invasive method compared to blood sampling which might be stressful for the participant and affect the results (Kirschbaum, & Hellhammer 2000). Furthermore, plastic tubes are used for saliva collection, usually with cotton rolls used, and the sampling can easily be handled by the subjects themselves – like children.

Cortisol levels may increase with challenges. For instance, in a study of test performance in 6^{th} and 9^{th} graders, perceived stress was correlated with an increase of cortisol levels during the test (Lindahl, Theorell, & Lindblad, 2005). With challenges the increased cortisol levels mobilize energy by increasing blood glucose (and free fatty acids) in the blood. The mediators that promote adaptation in the aftermath of acute situations may also turn out to contribute to overburden, the so called allostatic overload, referring to the wear and tear on human physiology when exposed to overwhelming stressors (McEwen, 2007). A first sign of overload might be changes in the HPA functioning, with elevated cortisol levels over a prolonged period of time. The increased levels are normally caused by a delay in the diurnal level decline after the morning peak (Björntorp, 2001). Elevated cortisol levels can cause a number of physiological impairments such as type 2–diabetes (Rosmond & Björntorp, 2000), obesity (Epel et al., 2000), unhealthy blood pressure (hypertension) and heart disease (Rosmond, Dallman, & Björntorp, 1998).

If overwhelming challenges or threats continue and the bodily systems are activated to a chronic extent, the functioning of the HPA axis may be permanently altered, with reduced responsiveness as a consequence (Miller, Chen, & Zhou, 2007). This means that the ability to elevate the cortisol levels in the morning may decline and the levels will eventually end up being low and inflexible (Björnstorp, 2001). For example, lowered cortisol levels have been found in individuals suffering from PTSD (Yehuda, Golier, & Kaufman, 2005). During prolonged activation where HPA activity finally deteriorates, studies on animals have shown that the SNS seems to act in a compensating manner to maintain the cortisol release (Dallman, 1993; Epel et al., 2000; Rosmond et al., 1998). The consequences of this may change the blood circulation (hemodynamic effects) resulting in increased BP and changes in the metabolism which can lead to abdominal obesity.

However, stressful situations do not always lead to altered levels of cortisol. In a review of associations between perceived stress and different cortisol measures in adult studies it was concluded that most results were non-significant (Halford Jonsdottír, & Eek, 2012). Several psychological factors can modulate reactions. One of the factors is self-esteem, which has a moderating effect on the HPA axis (measured by cortisol levels) in challenging situations such as speaking in public (Pruessner, Hellhammer, & Kirschbaum, 1999). Another factor that may regulate reactions to challenging events is the perceived predictability of a situation. A number of studies have shown that the perception of control is associated with lower levels of cortisol (Bollini, Walker, Hamann, & Kestler, 2004; Dickerson & Kemeny, 2004; Kirschbaum & Hellhammer, 1989).

HPA axis and video gaming

Video gaming may activate the HPA axis. There are only a handful of studies investigating the association between cortisol levels and gaming. It seems that built-in music in games may increase cortisol levels (Herbért, Béland, Dionne-Fournelle, Crête, & Lupien, 2005), but most studies have demonstrated unchanged or even reduced levels during gaming (Denot-Ledunois, Vardon, Perruchet, & Gallego, 1998; Herbért et al., 2005; Sharma, Khera, Mohan, Gupta, & Ray, 2006; Skosnik, Chatterton, Swisher, & Park, 2000). The reduced levels in these studies may be an expression of the gradually decreasing levels during the day, following a normal diurnal cycle. The only study considering violent content was conducted by Maass and colleagues (2010), and it measured cortisol levels (and HRV, see above) associated with violent and non-violent content in video games and TV movies. The cortisol levels were not associated with the violent game, but with the violent TV movie. Short time exposure, low or no violence, and inappropriate choice of time for sampling may complicate the interpretation of the lack of association between cortisol and violent gaming.

Rationales

When this thesis was planned, some aspects of previous gaming research were considered to be particularly important:

The general debate on violent gaming usually focuses on effects in children and teenagers, but the majority of studies include young adults (university students). The issue of development may be highly relevant since physiological reactions differ between ages (Umetani, et al., 1998).

Usually, games are played at home, but most studies had been performed in laboratory settings. Physiological reactions may differ between exposures in the everyday environment and in the laboratory (Ravaja, 2004), which means that experiments in a natural setting, such as at home, are likely to yield higher external validity.

Any effects can be influenced by the length of playing (Barlett, et al., 2007) and many games can be played for hours. However, in several studies the gaming exposure had been limited to a few minutes. Longer exposure may provide more ecologically valid results.

Arousing events affect sleep, especially if they occur just before bedtime (Åkerstedt, Kecklund, & Axelsson, 2007) but most gaming studies have been conducted during the daytime. It is probable that most teenagers play in the evening, which suggests that studies should be performed in the evenings in order to assess the effects of gaming on sleep.

Many gaming studies use a ‘between groups’ design. However, physiological variables fluctuate more between individuals than within individuals (Reeves &

Geiger, 1994). Such bias will be minimized using a ‘within individual’ design in which individuals serve as their own controls (Ravaja 2004).

The design of a study is usually adapted to its primary outcome measures. Most gaming studies have included arousal as a control variable or as a covariate to other main variables (Ravaja, 2004) such as personality dimensions or aggression. This means that associations (or non-associations) with arousal might not be generated in a completely satisfactory manner.

METHODS

Procedure

After approval from the Regional Ethical Review Board was obtained, principals at public schools without any specific pedagogical or ideological orientation were contacted regarding recruitment of study participants. The principals who approved the participation arranged contact with class teachers interested in allowing their pupils to be informed about the study. At the recruitment meetings, the teachers were offered a lecture/discussion of about 45 minutes for their class about gaming and stress. The students who were interested in participating received an envelope to take home to their parents with information about the study and the games, information about the Personal Data Act (legal directives which aim to prevent the violation of personal integrity in the processing of personal data), consent forms for parents and participants, and a prepaid envelope for mailing the documents back. Parents were contacted to make an appointment. When times were set, the families received a letter or an e-mail as a confirmation, along with instructions about the experiment (see below).

Studies I and II were conducted at the same time, with almost the same participants (see below). The participants in Studies I and II were invited to participate on three weekday evenings in their homes: one evening playing a violent video game, one evening playing a non-violent video game, and one evening not playing at all (control occasion). In Study III (with other participants) there were only the two occasions of video gaming. There were at least six days between the occasions, with the order of conditions systematically changed between individuals. The experiments started on a weekday evening (Monday to Thursday) 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 to go to bed at 10.30 pm.

The games were played on Microsoft XBOX consoles brought and installed by the author on the TV sets in the participants' homes. The participants were encouraged to become familiar with the game for half an hour before starting to play. The games were played between 8 and 10 pm, and the boys were instructed to choose a level of difficulty adjusted to their experience and skilfulness, to restart the game from the beginning if they got stuck, and not to take any breaks during play. During the non-gaming occasion, the instruction was the same regarding the day prior to the gaming evenings. The participants were also told not to watch any exciting sports or action television programs or to play any video games during the evening.

Prior to the first gaming session, in all studies, questionnaires about the first experience of violent video games were filled in. In the first Study (I and II) questions were asked about hours playing video games per week (total for all games and total just for violent games). They were also asked yes/no questions about previous emotional impact when playing violent games (calmness, stress, worry, alertness and irritation). Any influences of these variables on the outcome measure were analysed. In Study III, questions were asked about daily hours spent playing violent games, and the names of the games most frequently played during the last month. The answers were used for decisions on inclusion in the study.

After gaming, questions were asked about distance (centimetres) between themselves and the television screen, audio volume (no/low/middle high/high level, dichotomized in the analysis), previous experiences of the game in focus (yes/no), if the game was difficult to play (yes/no), if it was fun to play (yes/no, [Study III]), and participants were also asked to report of any deviations from the instructions (in their own words). The torso movement (vertical acceleration measurement) was recorded with the Actiheart® (see above). Any influences of these variables on the outcome measure were analysed.

In study II the participants were instructed to perform saliva sampling for cortisol analysis (see below) at 7.30 PM (sample 1), 10.00 PM (sample 2), immediately after waking up the next morning (sample 3) and 30 minutes later (sample 4). Further instructions were to keep the swabs in their mouth until soaked with saliva and then note the time on the sampling tube.

After the installation of devices and having provided the information, the author left the subject's home and the boy was left to play alone without monitoring. The next morning the participants brought the equipment to school where the author picked it up.

Study participants

The participants in Studies I and II (12 – 15 years of age, M = 13.3, SD = 0.7) were recruited from a school in the centre of Stockholm. Out of the 22 participants, data were excluded from three participants in study I because of incomplete recordings and one participant in Study II due to incomplete saliva samples.

Prior to Study III a list of the most violent games (n = 24) on the market were compiled with the help of staff at gaming cafés and game stores. Boys who played any of the games on the list for three or more hours per day, and boys playing one hour or less per day were invited to participate in the study. The study participants (13 – 16 years, SD = 0.9) were recruited consecutively from different schools in the area of Stockholm. Due to the difficulties involved in recruiting high-frequency gamers, approximately 500 boys had to be approached before this group was fully recruited. Out of the 45 boys who responded positively, 15 were excluded, since they did not fulfil the selection criteria.

Data were collected from April until December 2006 in Studies I and II, and in Study III from April 2009 until January 2010.

Video games

The selection of games was based on the following four best practice criteria for research on violent gaming formulated by Anderson (2004).

1. The violent game involves – and rewards – physical and close up violence against another human being (i.e. not by using long distance weapons).

2. The non-violent game involves no violence.

3. There were no differences between the games concerning frustrating elements, other stressors, attraction and difficulty.

4. Both games had to be conducted in the same manner – in this case the main character should be shown on the screen and controlled by a remote control by the player ('third person game').

Further selection criteria were used both for ethical reasons and to define the type of violence:

5. Games should contain no sexual content, no violence against women and no expressions of racism.

To be able to select proper games, the author consulted experienced players and played a large number of games. Two games were selected, Manhunt (Rockstar Games, 2004) and Animaniacs (Ignition Entertainment, 2005).

In the violent game – Manhunt – the player is a murderer who has been sentenced to death and his only chance of surviving is to kill everyone he meets by beating and kicking them. Simple weapons are available such as plastic bags and baseball bats stolen from the people he kills. The game takes place in an abandoned area where criminals dwell during the night time. The environment in the game is presented in a detailed, naturalistic fashion and there is a constant murmuring. Sounds follow the actions in the game, such as sounds of footsteps and fighting.

The non-violent game – Animaniacs – takes place in different movie genre environments. The aim is to find stolen 'Edgars' (representing the Oscars) statuettes and save the forthcoming Edgar gala. The story of the game unfolds during daytime, with the exception of the illustrated horror movie environment, which takes place at night. 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 episode of violence against human characters is depicted in a humorous way. The background music is neutral, and sounds vary with the circumstances.

Before data collection the amount of movement required to play the games was tested with an Actiwatch® (Cambridge Neurotechnology Ltd., Cambridge, UK) which is a small wrist-worn device containing an accelerometer that is optimized for effective movement tracking from wrist activity. The pattern of activity was continuous during the play of the non-violent game, and fluctuated during the violent game, but overall there was no significant difference. The games differed in colours, light contrast and brightness and were adjusted in the laboratory by use of a lux meter, and similar adjustments were made to each home television screen. The participants were offered headphones and were instructed to use a subjectively comfortable audio volume.

Outcome measures

Autonomic measurements: studies I and III

To assess autonomic reactions, HR and HRV were measured using a combined HR and torso movement sensor (Actiheart®; Cambridge Neurotechnology Ltd, Papworth, UK) applied by the author. This sensor, a small portable rechargeable unit, was applied on the chest where it registered (and stored) the inter-beat intervals measured from the R-wave maximum of one beat to the R-wave maximum of the next, with a sampling frequency of 128 Hz. The registration went on from the start of playing until the next morning. The R-R intervals of the entire registration were exported (without any editing) from the Actiheart® device into the software used for further calculations (Storck et al., 2001). In the software a linear interpolating algorithm was used to reduce the impact of ectopic beats in the calculations. Five-minute periods with more than 4 per cent ectopic beats were identified by the software and omitted from further analyses. Consecutive 5-minute segments were re-sampled at 2 Hz, producing a linear trend that was subtracted from the array of data before the spectral analysis. From the R-R intervals, five variables were calculated: HR from the time domain; the power of the different frequency bands; HF (0.15 - 0.4 Hz), LF (0.04 - 0.15 Hz) and VLF (<0.04 Hz) expressed in milliseconds squared; and the ratio of LF/HF.

Both HR and HRV parameters were calculated by the software for 5-minute intervals. R-R intervals of more than 2000 milliseconds cannot be detected by the Actiheart® device, and 5-minute intervals with R-R intervals of 2000 milliseconds or longer were considered as signal loss (electrode or cable failure) and omitted. Periods of self-reported breaks were also omitted. The remaining intervals were aggregated into a "game period" of about two hours, and six separate "sleeping periods" (one hour each) in Study I and a whole night period of four hours in Study III. The averages for these periods were calculated. The periods of playing games was basically identified by self-reports, but points of time were validated by the absence of gross motor activity as indicated by the movement sensor of the Actiheart®. Start of sleep was defined according to a similar combination of self-report and movement validation. With the intention of collecting information on equally long periods in all participants, end of sleep was defined as six hours in Study I and four hours in Study III, measured from the start of sleep since those were the shortest periods of complete HRV measurements during sleep in each study.

Cortisol: Study II

To measure cortisol, saliva analysis was used. The samples were collected by swabs (Salivette; Sarstedt Inc, Rommelsdorf, Germany) that were centrifuged and frozen at minus 70° C. All samples were analysed according to the manufacturers´ instructions, using the Spectria Cortisol (125I) kit from Orion Diagnostica, Espoo, Finland (Hansen, Garde, Christensen, Eller, & Netterstrøm, 2003). The within- and between assay coefficient of variation never exceeded 5.0 and 10.0 per cent, respectively.

Sleep measures: Studies I and III

To measure sleep a validated sleep diary adjusted for children and adolescents was used (Åkerstedt & Gillberg, 1990; Kecklund & Åkerstedt, 1997), which was completed in the morning after each session. The initial questions concerned bedtime, sleep latency, wake-up time, and rising time. The following questions concerned alertness at bedtime 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 [Åkerstedt & Gillberg, 1990]). Subsequent questions referred to the number of awakenings (0≥5), time spent awake (from ‘‘no time’’ to ‘‘more than one hour’’), perceived stress, premature awakenings, and sleep depth, with a five-step scale with response alternatives from ‘‘not at all’’ to ‘‘very much.’’ The questionnaire also included multiple-choice questions about disturbances during sleep, the cause of awakening in the morning, whether any dream may have influenced the sleep and, finally, an open question about any particular incidents during the night. Furthermore, questions about difficulty falling asleep, sleep quality (phrased ‘‘how was your sleep?’’), and sleep calmness constituted a sleep quality index (SQ). Questions about duration of sleep, ease of awakening, and perceived rest were used as an awakening index. The items later used in the two indices were graded using a five-step scale, with response alternatives from ‘‘not at all’’ to ‘‘very much.’’

Emotional reactions: Study III

On the first occasion before playing in Study III, an adjusted version of the Swedish Core Affect Scale (SCAS) questionnaire (Västfjäll, Friman, Gärling, & Kleiner, 2002) was used, reflecting reactions when playing violent games in general. The questionnaire contained questions about feeling sad, angry, glad, worried, nervous, dispirited, calm, tense, irritated, rushed, satisfied, stressed, and refreshed. The questions were answered on a four-grade scale with response alternatives ranging from ‘‘not at all’’ to ‘‘very much.’’. Ten of the items could be reduced into two components using principal component analysis. The two components, labelled anxiety and emotionality, accounted for 53 per cent of the variance, and the former included worried, nervous, calm (reversed), tense, rushed, and stressed, and had a Cronbach α value of .76. The emotionality component included angry, glad, irritated, and satisfied with a Cronbach α of .68. The three remaining items, sad, dispirited, and refreshed, did not load on the two components and were separately analysed. The same questionnaire was completed after each game session to capture reactions to the current game, and the responses were analysed according to the pattern described above (two indices and three items).

Statistical Analysis

Logarithm transformation was applied on HRV and cortisol data to normalize the distribution of data in all studies. In Study III the data from emotion, affect and sleep were also log transformed with the exception of number of awakenings, which was square root transformed because there were many zero reports.

One-way within-subjects analysis of variance (ANOVA), two-way within-subjects ANOVA and dependent sample *t*-tests were used to analyse comparisons between conditions and groups. Pearson’s bivariate correlation coefficients were computed to analyse the associations between variables.

SUMMARY OF RESULTS

Study I

Summary of the design

Nineteen boys played a violent and a non-violent video game for two hours (between 8-10 AM) on two occasions in their homes and also participated once without gaming. HR and HRV (VLF, LF and HF) and physical activity were measured during gaming/participating and during sleep the following night. A sleep diary and questionnaires about gaming experiences and session-specific experiences were completed.

Main findings[1]

There was significantly higher activity concerning torso movements in the non-playing condition compared to the gaming conditions (t = 2.642, p = 0.015 and t = 2.666, p = 0.014). Due to these differences, the non-playing condition was excluded from the HRV analysis since physical activity may highly influence HRV measures.

During the two hours of playing, TP and VLF were significantly higher in the violent condition compared to the non-violent condition (Table 1).

[1] After the first study had been published an error was discovered in the software used for HRV analyses. This error led to frequency ranges (VLF, LF and HF) that differed from the ranges proposed in the Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology (Camm et al., 1996). When this error was discovered the software was corrected and measurements were recalculated. After the statistical re-analysis we were able to conclude that this error only led to small changes in the results – not affecting the major conclusions – as stated in the published erratum (Ivarsson, Anderson, Åkerstedt, & Lindblad, 2011). The results presented below are recalculated according to the formula described in the corrigendum.

Table 1 Heart rate and heart rate variability mean and standard errors while playing violent/non-violent game. Beats per minute; ms^2.

	Violent Game		Non-violent Game			
	Mean	SE	Mean	SE	*t*	*p*
HR	78.8	2.32	77.4	2.62	-0.93	0.357
TP	5737	539	4280	435	-3.74	0.002
VLF	2802	277	1788	186	-4.83	0.000
LF	1696	153	1460	160	-2.10	0.050
HF	1238	177	1030	164	-1.44	0.167
LF/HF	1.84	0.20	1.83	0.19	-1.161	0.874

Note. *t* = *t*-value, *p* = significance level, based on logarithmic transformation of data.

During the sleep after playing (Figure 3 – 8), VLF, LF and HF components were significantly higher during the violent condition compared to the non-violent condition, as was the TP. There were main effects of hours of sleep on all HRV variables except HF. There were no interaction effects between the games and the separate hours of sleep (Table 2).

Table 2 Results of ANOVA for heart rate and heart rate variability during night after playing. Effects of game and sleeping hours and Game*Hour interaction.

	Game			Hour			Game * Hour		
	df	*F*	*p*	*df*	*F*	*p*	*df*	*F*	*p*
HR	1,18	1.781	0.199	5,14	4.0	0.018	5,14	0.79	0.577
TP	1,18	9.95	0.005	5,14	9.14	0.000	5,14	0.90	0.508
VLF	1,18	8.72	0.009	5,14	18.30	0.000	5,14	0.39	0.848
LF	1,18	9.82	0.006	5,14	4.12	0.016	5,14	0.48	0.787
HF	1,18	8.52	0.009	5,14	2.35	0.095	5,14	2.50	0.081
LF/HF	1,18	2.54	0.129	5,14	4.43	0.013	5,14	0.04	0.999

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

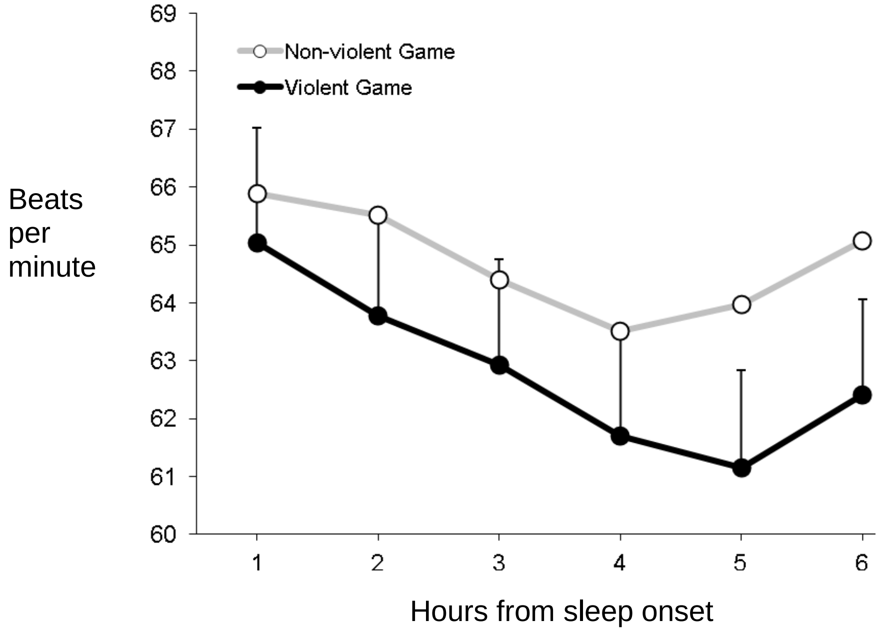

Figure 3 Heart rate in beats per minute during night hours presented as mean and standard errors for the violent game condition for each hour of the sleep period.

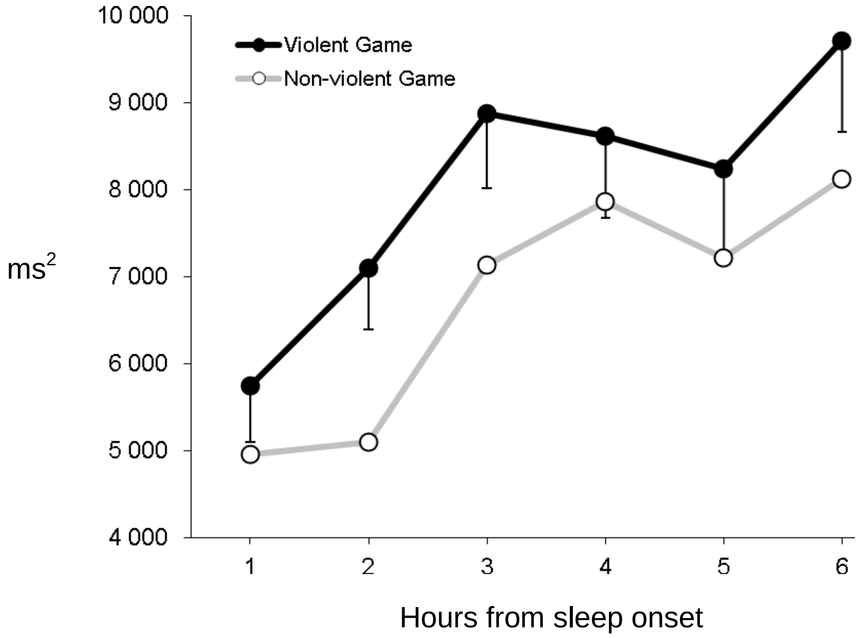

Figure 4 Total power in heart rate variability in ms^2 during night hours presented as mean and standard errors for the violent game condition for each hour of the sleep period.

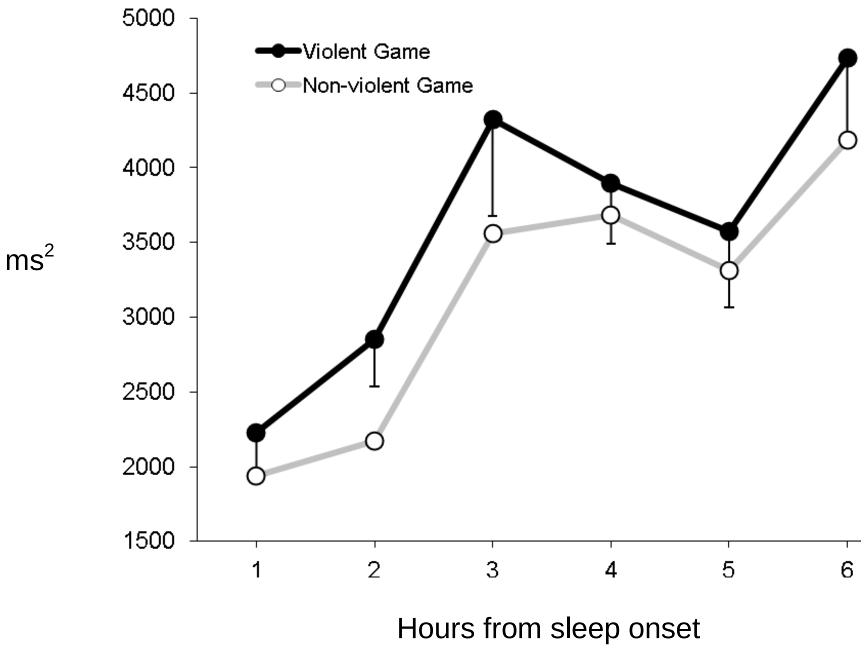

Figure 5 Power in VLF in ms^2 during night hours presented as mean and standard errors for the violent game condition for each hour of the sleep period.

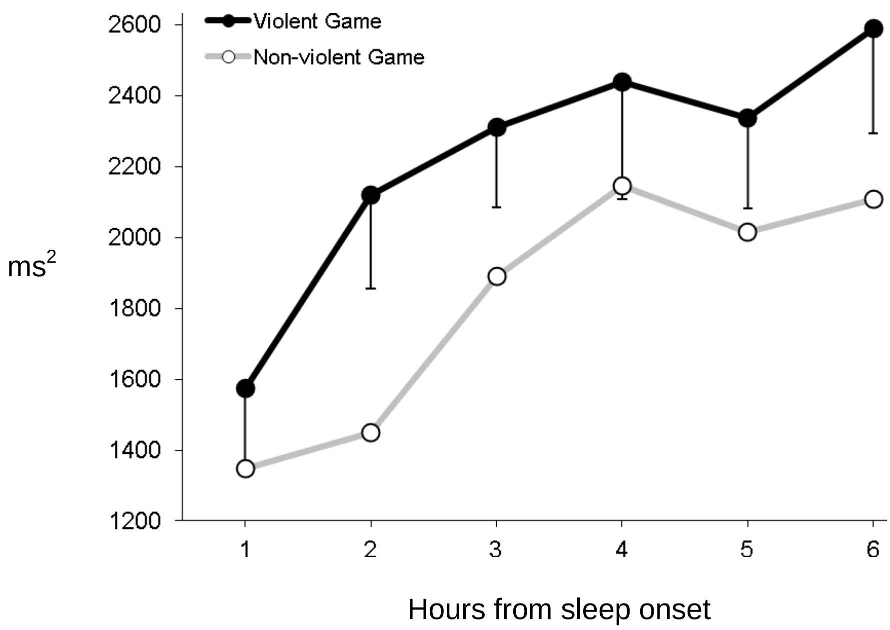

Figure 6 Power in LF in ms^2 during night hours presented as mean and standard errors for the violent game condition for each hour of the sleep period.

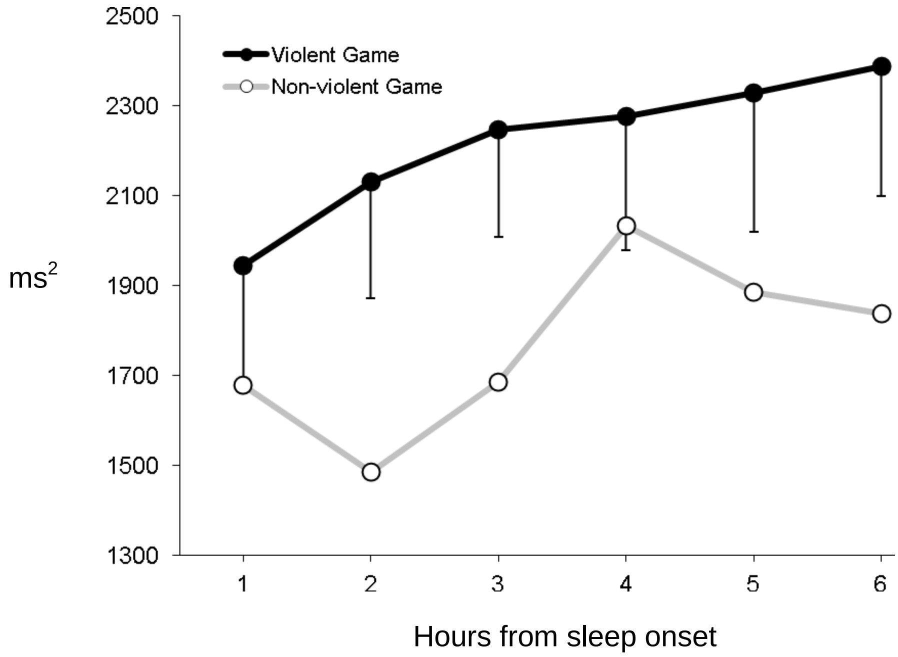

Figure 7 Power in HF in ms^2 during night hours presented as mean and standard errors for the violent game condition for each hour of the sleep period.

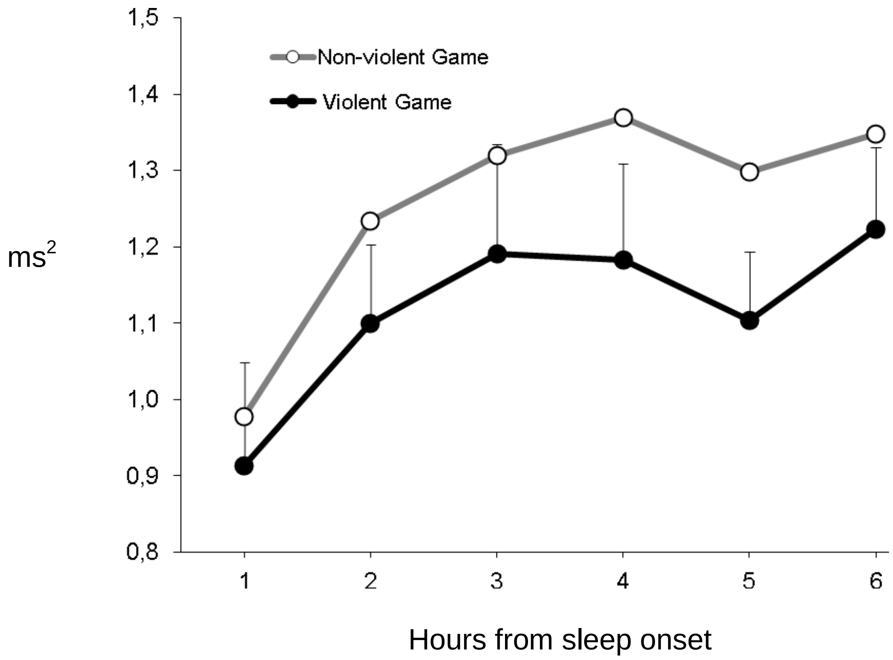

Figure 8 Ratio of LF power and HF power during night hours presented as mean and standard errors for the violent game condition for each hour of the sleep period.

There was no difference between the violent and non-violent condition with respect to any single sleep item. Nor were there any significant differences between the three conditions (violent/non-violent/no gaming) with respect to any index reflecting subjectively perceived sleep difficulties.

To summarize, violent gaming during the evening induced different autonomic responses compared to non-violent gaming. These were expressed to some degree during playing but more distinctly during the following night.

Study II

Summary of the design

Twenty-one boys played a violent and a non-violent video game for two hours (between 8 – 10 AM) on two occasions in their homes and participated once without gaming. The participants provided saliva samples four times, at 7.30 PM, 10.00 PM, immediately after waking up the next morning and 30 minutes later.

Main findings

As expected, there were significant differences in cortisol levels between the four sampling points ($F_{3,18} = 79.76$, $p = 0.000$) but not between the two conditions ($F_{1,20} = 0.17$, $p = 0.683$), and no significant interaction between the points for sampling times and condition ($F_{3,18} = 0.34$, $p = 0.799$). Figure 9 shows the mean cortisol levels at each sampling point for the three conditions (violent/non-violent/non-gaming). Non-gaming levels are plotted for reference but were not part of the statistical analysis (ANOVA).

To summarize, the HPA axis was not affected by video gaming, no matter whether the game was violent or not.

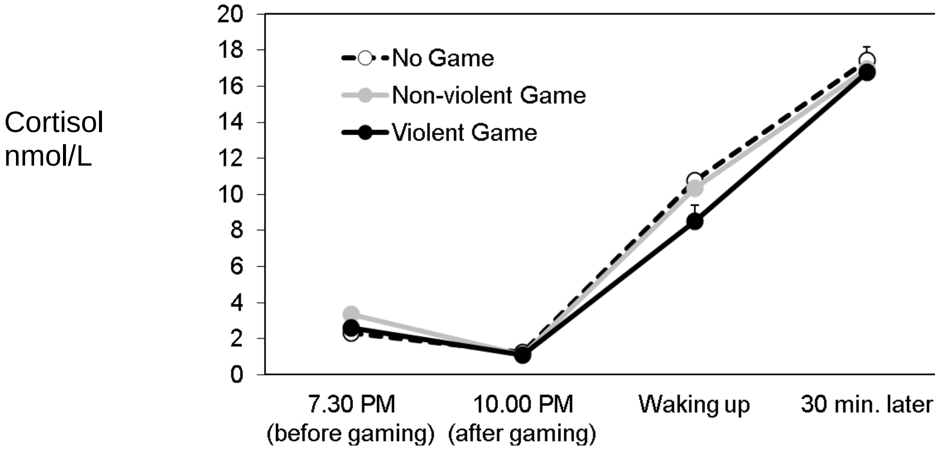

Figure 9 Means of salivary cortisol levels (nmol/L) for each point in time.

Study III

Summary of the design

Thirty boys, 15 of them with less exposed (<1 h/d) and 15 with highly exposed (>3 h/d) to violent games, played a violent and a non-violent video game for two hours on two different evenings (between 8 and 10 AM) in their homes. Heart rate (HR) and HR variability (VLF, LF and HF) were registered during playing and during sleep the following night. A questionnaire about emotional reactions was administered after the gaming sessions, and a sleep diary was completed on the following mornings.

Main findings

During the two hours of playing there was a significant main effect of gaming on HR ($F_{1,28} = 4.43$, $p = 0.044$) (Figure 10) with a significant difference between the conditions within the less exposed group for HR ($p = 0.018$). During sleep there were significant interaction effects between group and condition for HR ($F_{1,28} = 9.56$, $p = 0.004$) (Figure 10), VLF ($F_{1,28} = 7.40$, $p = 0.011$) (Figure 11) and for LF/HF ($F_{1,28} = 4.32$, $p = 0.047$) (Figure 12). Individual HR data during playing and sleep in both groups and for both conditions are presented in Figure 13.

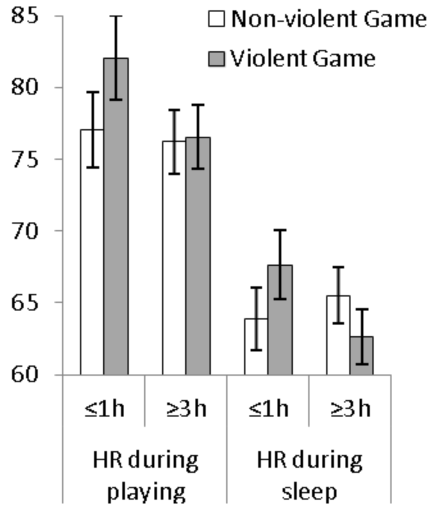

Figure 10 Heart Rate in beats per minute during playing and during sleep after playing (means and standard errors).

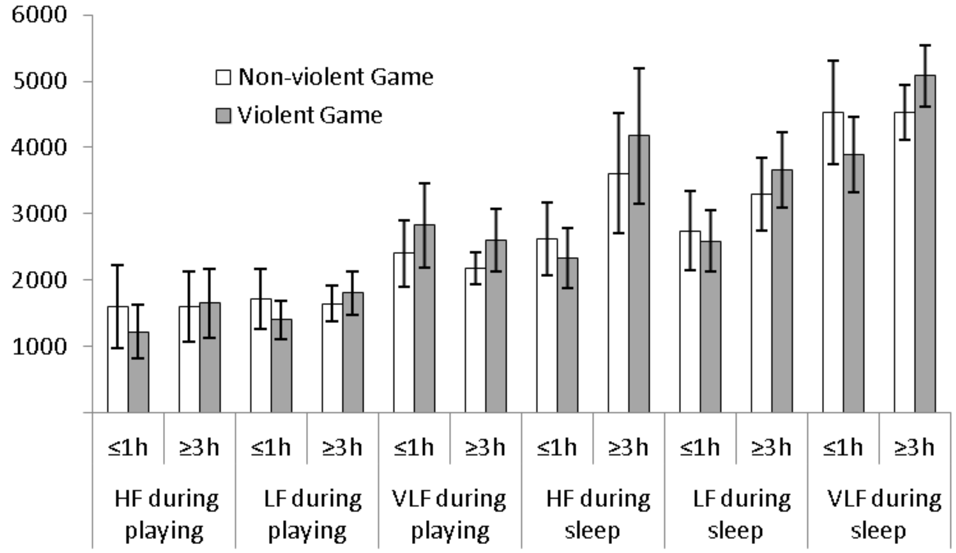

Figure 11 Power in HF, LF and VLF in milliseconds squared during playing and during sleep after playing (means and standard errors).

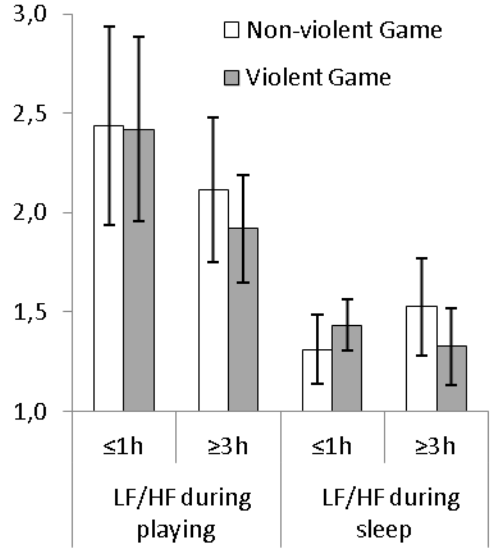

Figure 12 Ratio of LF power and HF power during playing and during sleep after playing (means and standard errors).

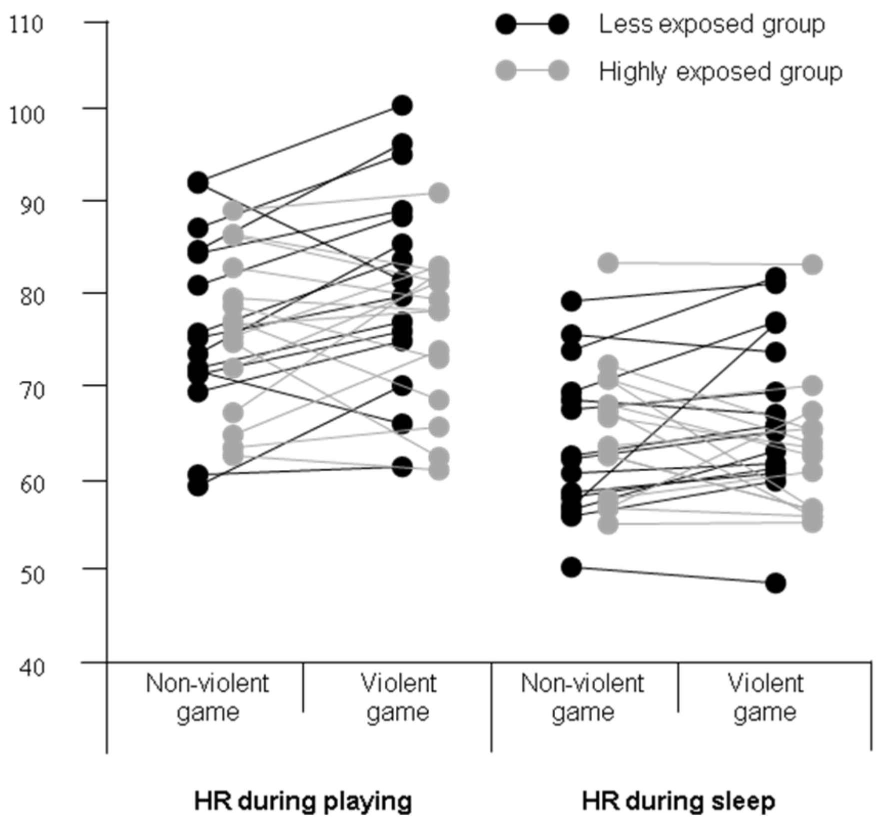

Figure 13 Plots of heart rate (HR) in the low- and highly exposed groups during playing and sleep after playing a violent and a non-violent game.

For alertness at bedtime (Figure 14), there was an interaction effect of gaming and condition ($F_{1,24}$ = 4.35, p = 0.024, one-sided test) with a significant difference within the less exposed group between the two gaming conditions (p = 0.023, one-sided) and a significant difference within the non-violent condition between the groups (p = 0.041, one-sided). For sleep quality (index) (Figure 15), there was also an interaction effect of gaming and condition ($F_{1,28}$ = 3.51, p = 0.036, one-sided), with a significant difference within the group of less exposed gamers between the gaming conditions (p = 0.025, one-sided) and a significant difference within the violent condition between the groups (p = 0.020, one-sided).

There were significant main effects of group for sleep latency (Figure 16), ($F_{1,28}$ = 3.10, p = 0.045, one-sided), alertness at rising time (Figure 14), ($F_{1,28}$ = 3,52, p = 0.036, one-sided), and awakening index (Figure 15), ($F_{1,28}$ = 3.38, p = 0.039, one-sided). The violent game elicited significantly higher stress at bedtime than the non-violent game in both groups (Figure 14), ($F_{1,28}$ = 5.87, p = 0.011, one-sided).

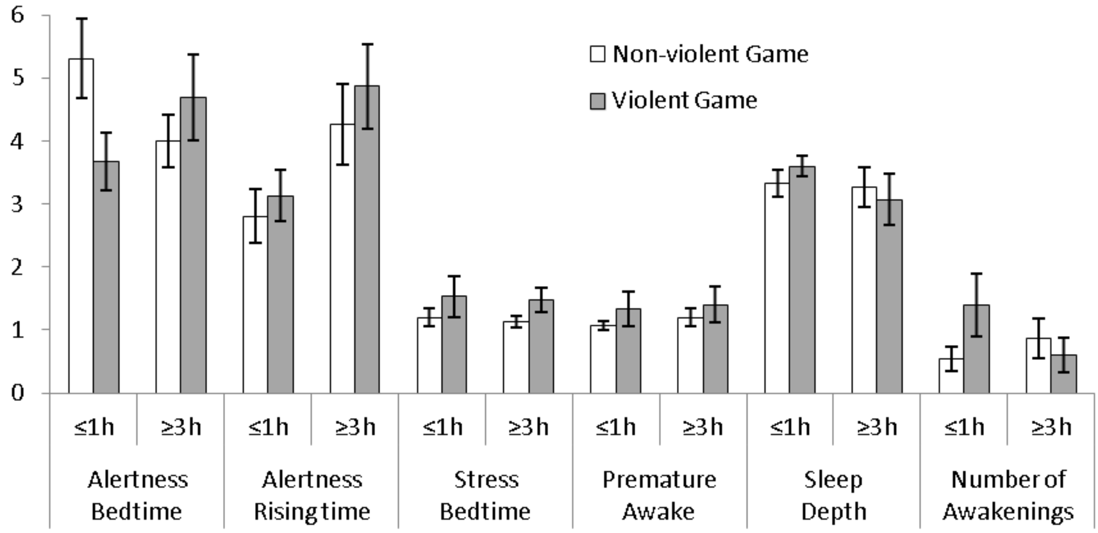

Figure 14 Scores of Alertness at Bedtime and Rising time, Stress Bedtime, Premature Awakening, Sleep Depth and Number of Awakenings (means and standard errors).

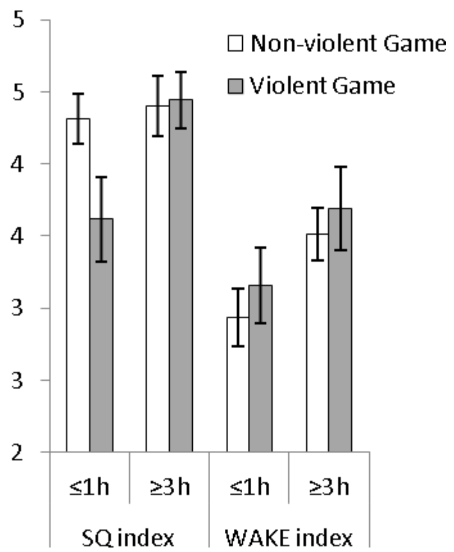

Figure 15 Sleep Quality index (SQ) and WAKE index (means and standard errors).

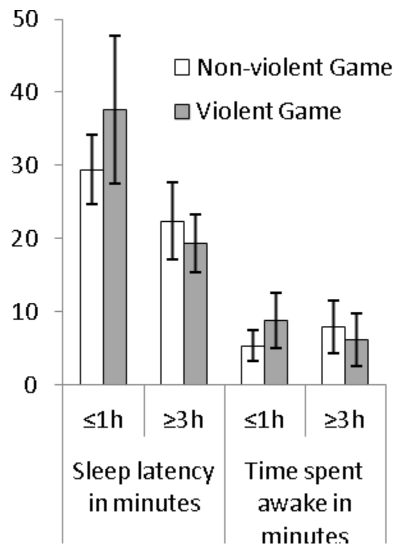

Figure 16 Sleep latency and Time spent awake in minutes during night (means and standard errors).

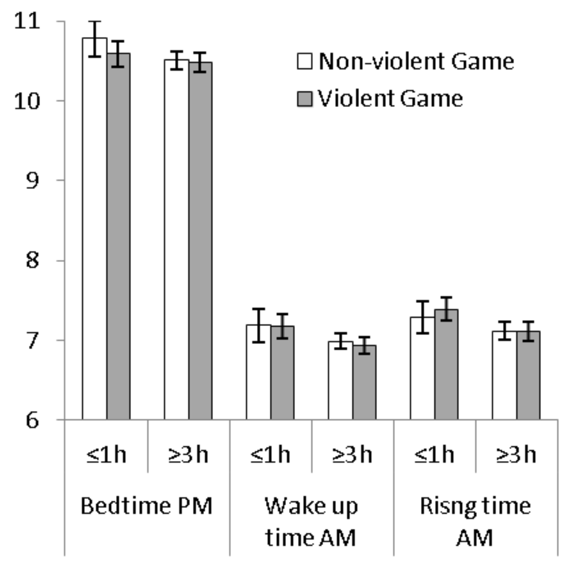

Figure17 Bedtime (PM), Wake up time and Rising time (AM) (means and standard errors).

For emotion variables (Figure 18), there was a significant interaction effect of group and gaming condition for perceived sadness ($F_{1,27} = 6.29$, $p = 0.009$, one-sided), with significantly higher levels after playing the violent game compared with the non-violent game within the less exposed group ($p = 0.028$, one-sided). The was a significant main effect of group for feeling refreshed ($F_{1,27} = 3.41$, $p = 0.038$, one-sided), and a main effect of condition for anxiety index ($F_{1,27} = 13.44$, $p = 0.001$, one-sided).

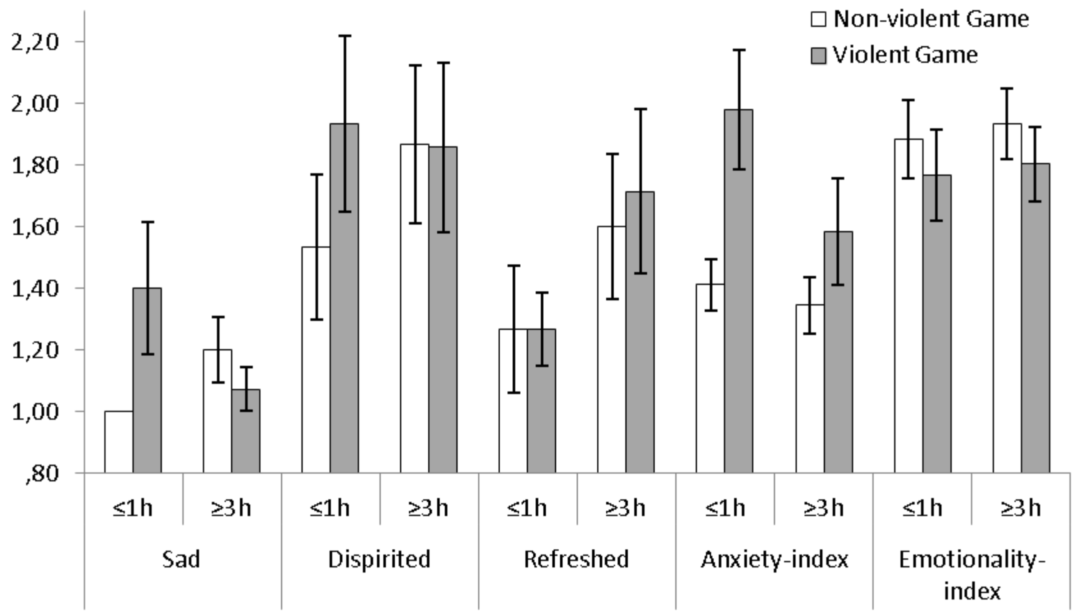

Figure 18 Scores for perceived Sadness, Feeling dispirited, Feeling refreshed, Anxiety-index and Emotionality-index after playing (means and standard errors).

To summarize, high versus low experience of violent gaming were related to different physiological, sleep-related and emotional processes on exposure to violent gaming.

DISCUSSION

The general aim of the present thesis was to use an experimental design to investigate psycho-physiological responses to violent video games in a natural setting among teenage boys before their going to sleep. After a discussion of the main findings of the empirical studies', the results across the studies and variables are discussed. Next, methodological considerations are provided. Finally, conclusions and future directions are considered.

Discussion of each sub-study

Study I

The first study aimed to investigate how two hours of playing a violent and a non-violent video game in the evening affected HR and HRV while playing and during sleep the following night, as well as the sleep quality. There were different autonomic responses to playing a violent video game compared to a non-violent game. The differences increased during sleep the subsequent night, but there were no differences in subjectively perceived sleep quality.

The theoretical framework that was used during Study I was "The Task Force, Guidelines Heart rate variability from of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology" (Camm, 1996) suggesting that the LF and HF components reflect SNS and PSNS activity, respectively. From that perspective the results would indicate a higher sympathetic activity (Sforza, Pichot, Cervena, Barthelemy, & Roche, 2007). Consequently, the discussion of this article stated: "... HR was actually lower after violent gaming, in spite of the higher LF activity, than in the non-violent condition." Along the same lines we wrote: "In terms of sleep quality, the increased LF and VLF activity may indicate a higher sympathetic activity and sleep fragmentation." If the Porges' polyvagal perspective had been applied at the time, the result could have been interpreted in a different way (Porges, 2007). This theory suggests that LF – just like HF – reflects vagal activity. Taking this into consideration, it is possible to interpret the lack of HR changes as an expression of increased sympathetic activity counterbalanced by increased vagal activity. See further discussion below.

Another main finding was the increased differences concerning the HRV variables between the conditions during sleep compared to the period of gaming. These increased differences in reactions may possibly be related to sleep effects of gaming, such as nightmares, or to residual activity in the autonomic nervous system. However, despite the increased autonomic activity, subjective sleep quality was not affected. The results are more likely to be due to residual activity in the ANS, as will be discussed below.

The conclusion from Study I is that violent video gaming in the evening induces different autonomic responses than non-violent gaming – both during playing as well as during the following night – suggesting the two types of gaming induce different physiological and emotional responses and possibly different needs of recovery. However, the quality of sleep was not influenced.

Study II

The second study aimed to investigate the impact of games with and without violence, played in the evening, on the HPA axis. The result showed no differences in cortisol levels between the violent and the non-violent condition.

The violent game did not induce higher cortisol levels than the non-violent condition. One hypothesis is that the exposure was too short to affect the cortisol levels. Since cortisol levels are secreted into saliva within minutes (Ulrich-Lai & Herman, 2009), the two hours were certainly not too short a time to capture any increase. The duration of exposure was also longer than in most previous studies in the field. Another explanation for the lack of cortisol response to the violent game is that the violent game may not have been violent enough to induce activation of the HPA axis. However, the violent game used was definitely violent. At the time when the study was designed it was one of the most violent games available on the market. It was banned in several countries (Australia, Canada, Germany and New Zealand) due to its violent content. Furthermore, the mean cortisol levels actually decreased during both violent and non-violent gaming. However, even if levels decrease, a small activation of the HPA axis may be obscured by the physiological diurnal rhythm, with a gradual decrease during the evening. Also, the player's expectations may explain elevated values before the experiment (Blomqvist et al., 2007), which may also obscure reactivity to gaming. Therefore, it is important to have a condition without gaming for comparisons. Such analyses showed no differences between the three conditions (violent gaming, non-violent gaming and no gaming), thereby further supporting the conclusion that gaming does not affect cortisol levels.

Physiological reactions are evoked by specific stressors characterized by a certain quality or intensity (Hansen et al., 2003). Video gaming in general may simply not be the kind of stimulus that activates the HPA axis. One explanation may be that the threats are – to some degree – predictable and manageable. This can be illustrated by the results from Maass and colleagues (2010) showing raised cortisol levels caused by watching the violent TV movie but not by playing the violent video game. This may indicate that violent content in media may affect the cortisol levels but during gaming, the control itself – literally – over the course of events may have a protective or restraining effect on the HPA axis. This is in line with earlier studies indicating the mediating effect of predictability and control on HPA axis responses (Bollini et al., 2004; Dickerson & Kemeny, 2004; Henry, 1992; Kirschbaum & Hellhammer, 1989).

To conclude: the HPA axis does not seem to be affected by violent gaming. Reactions to corresponding real-life events may be quite different. These may involve life-threatening challenges, but unlike the gaming situation, the subject lacks the ability to control events.

Study III

The last study demonstrated higher HR during playing of the violent game compared to the non-violent game. During sleep there were interaction effects of habit and game for HR and LF/HF with higher HR and LF/HF in the violent condition compared to the non-violent condition within the less exposed group, and a reversed direction in the highly exposed group.

The results for HR and the LF/HF ratio seem to be logical from an assumption that playing a violent game is less arousing to a highly exposed gamer than to a less exposed gamer due to the processes of desensitization. Findings of physiological desensitization have been reported previously. For instance, Carnagey and colleagues (2007) demonstrated that previous violent – as compared with non-violent – gaming was associated with less arousal (measured by galvanic skin response and HR) at exposure to real-life violence even after controlling for trait aggressiveness. Bartholow and colleagues (2006) studied EEG-reactions and found that the event-related brain potential showed lower amplitude in the P300 component (associated with activation of the aversive motivational system) for ”chronic” violent gamers when exposed to violent images.

The polyvagal theory (Porges, 2001; Porges 2007) posits that the input from the PSNS to the heart is conducted in two decelerating ways by the two branches of the vagus nerve reflected by LF and HF. The higher ratio of LF/HF after the violent game in the less exposed group may reflect a stronger activation of the older more primitive vagus branch. The HRV results are further discussed below.

The understanding of the results during sleep due to the short period of only four hours of measurements needs to be addressed. Data on longer sleep periods may have brought up complementary information of interest but since four hours was the shortest period of complete HRV measurement it had to be accepted.

The function of sleep is vulnerable to arousing situations (Kim & Dimsdale, 2007) and consequences of disturbed sleep are well documented. Previous studies have shown that gaming in general is related to a prolonged time to fall asleep (Alexandru et al., 2006) and lower quality of sleep (Mesquita & Reimão, 2007). The sleep-related results from this study add to previous findings by demonstrating the effects of violent content as well as of previous gaming experiences. The less exposed group reported significantly lower sleep quality after the violent game than after the non-violent game. The highly exposed group had shorter sleep latency, were more alert the next morning, and scored higher on the WAKE index than the less exposed group. The violent game elicited more stress at bedtime in both groups and it seems as if the violent game in general caused some kind of exhaustion. However, the exhaustion did not seem to be of the kind that normally promotes good sleep, but rather was a stressful factor that could impair sleep quality (Urponen, Vuori, Hasan, & Partinen, 1988), especially for the less exposed gamers. According to Åkerstedt and coworkers (1994) good sleep quality is a matter of the time required to fall asleep, and a subjective feeling of good or poor sleep. The interaction effects of group and game were significant for the same aspects (Alert at Bedtime, and the Sleep Quality index).

Research on violent games is usually focused on emotions associated with aggression (e.g. Anderson & Dill, 2000; Bushman & Anderson, 2002). In this study other emotions were investigated. The less exposed gamers reported more sadness than highly exposed gamers during the violent as compared to the non-violent condition. After violent gaming, both groups reported more emotions related to the Anxiety index than after non-violent gaming, especially the less exposed group. The results suggest that violent games may induce more adverse emotions in gamers with low experience than in gamers with high experience of violent gaming.

To experience emotions is one of the benefits of playing violent video games (Jansz, 2005). This may also be a reason why violent video games are so attractive to teenage boys (Griffiths et al., 2004). The gaming situation may provide a safe and rewarding setting to experience all kinds of emotions where the gamers can have control over and select the emotional situations. This kind of freedom can be appealing when one is in the age of identity creating – especially to adolescent boys (Jansz, 2005; Ryan, Rigby, & Przybylski, 2006). Violent and hyper-masculine characters in the games seem to be particularly attractive to adolescent males to identify with (Konijn, Nije Bijvank, & Bushman, 2007). Violent content in games may thereby be a primary reason for enjoyment of video games (Barnett et al., 1997). On the other hand, violent content in games seems to induce more anxiety than non-violent content – as shown by the current and previous results (Baldaro, et al., 2004). However, it does not seem that the anxiety makes boys reject those kinds of games. On the contrary, the anxiety may lead to the appealing process of catharsis – to get rid of tension (Ferguson, Olson, Kutner, & Warner, 2010). The less exposed group reported more sadness after the violent game. In the long run, excessive playing of violent video gaming may lead to a decline of anxiety and sadness induced by violent games.

The fact that the highly exposed group reported better sleep quality and less sadness in the violent condition offers some support to the desensitization hypothesis, a mechanism that has also been described in earlier studies showing that prior exposure to violent games may induce emotional desensitization to stimuli that usually evoke empathy (Funk et al., 2004). The process of desensitization by exposure to aversive stimuli is a documented effective technique in regulating emotions and behaviours in therapeutic interventions (Weersing & Weisz, 2002).

To conclude: the extent of previous violent gaming experience seems to be related to the different physiological, sleep-related and emotional processes that occur at exposure to video games; processes which vary depending on whether the games are violent or not. The processes across the various systems seem to be an effect of desensitization. An alternative hypothesis is that the results may be explained by selection bias, see below.

Synthesis of findings across studies

HRV, Studies I and III

In the first study, the violent gaming as compared to non-violent gaming was associated with increased HF and LF activity during the night after gaming, whereas HR was unaffected. In study III the violent gaming was associated with increased HR during playing, especially in the less exposed group, but there were no differences in LF and HF. The increased HR in study III could be interpreted as an expression of an imbalance of the ANS toward sympathetic activation, which may have been counterbalanced by increased vagal activity expressed by the increased HF and LF in study I, with no change in HR as a consequence. The results from study III indicate that there was no such counterbalance. The reason for these different patterns related to increased sympathetic activity may be understood in different ways. First, it should be remembered that the design, research questions, and study groups were similar but not identical. Second, as Porges (2007) points out, HRV data tend not to be statistically stationary, either across individuals or over time. Third, the impact of the violent game may have changed over time with a gradual adaptation in this age group to more realistic and severe characteristics of violent games and/or a more advanced technology (Barlett & Rodeheffer 2009; Ivory & Kalyanaraman, 2007).

The results can be compared with the results from one previous study in the field with a similar design, namely Maass and colleagues (2010). The authors of that study report a reduction in HRV activity when playing a violent game compared to a non-violent game. Their results thus seem to contradict our findings, but two major differences between our studies need to be considered, the type of violence exposure and the HRV approach. Maas and her coworkers utilized an action-adventure game (King Kong) where the player fights against prehistoric beasts. Thus the games do not display any violence against or between humans. As the HRV outcome variable the authors chose SDNN, which "reflects all the cyclic components responsible for variability in the period of recording" (Camm et al., 1996). A vast amount of the total variance of HRV consists of VLF. Since the physiological representations of VLF still do seem to be completely understood (Camm et al., 1996) it is difficult to draw any conclusions about autonomic activation from these data

In both Studies I and III some effects were delayed, meaning that most of the significant findings were recorded during sleep. Arousal-related shifts in the autonomic balance may occur quite slowly, as demonstrated in an experimental study on mental stress where sympathetic activation (as expressed by peripheral resistance) remained elevated during 45 minutes of recovery (Steptoe et al., 2003). Moreover, it is well known that perceived excitement during the evening may affect sleep adversely (Åkerstedt et al., 2007). The findings demonstrate not only the inertia of the ANS but also that the physiological processes may be detectable hours after the exposure to a challenging event. It is hard to tell whether this indicates that sleep is a very sensitive indicator of challenges or if similar ANS reactions would have been evoked if the games had been played at an earlier time during the day.

The elevated HR while playing the violent game in the less exposed group may be interpreted as an autonomic activation caused by apprehension when facing an unfamiliar and difficult task (Hansen et al., 2003). However, the pattern of differences remained, and was even stronger during sleep, which challenges this interpretation since the autonomic activation tends to return to a normal level of activity within a few minutes after exposure to apprehension demands (Hansen et al., 2003).

As mentioned above, according to the polyvagal theory (Porges, 2001; Porges 2007) the decelerating input from the PSNS to the heart takes place in two different ways, and involves the two branches of the vagus nerve. The phylogenetically younger myelinated vagus branch, reflected by the HF frequency band, has a calming function and balances sympathetic influences. This regulatory system is found only in mammals and is related to more advanced processes such as communication. The unmyelinated vagus branch, reflected by the LF band, is phylogenetically older and related to more primitive reactions like the freezing response to threat. The balance between the two PSNS branches is reflected in the LF/HF ratio. One may thus speculate that a higher LF/HF ratio – reflecting a shift of balance between the two vagal branches – indicates stronger activation of the more primitive system, which in turn may be seen as a result of exposure to a more demanding stressor. Such an interpretation would fit well with the higher ratios in the violent condition for less exposed gamers and lower ratios for highly exposed gamers in study III.

Finally, the different length of periods of sleep measurements between Studies I and III may explain the differences in the HRV parameters between the studies. However, since there were no significant interaction effects of type of games and time points during sleep in study I, it can probably be ruled out as explanation.

To conclude; violent and non-violent games seem to induce different autonomic reactions especially during sleep after gaming. The differences seem to be more pronounced in individuals with a low degree of previous experience of violent gaming. A high degree of previous experience of violent gaming seems to have a desensitizing effect.

HRV and Cortisol

The differences between cortisol and HRV outcomes – demonstrating differences in autonomic reactions, but not in cortisol levels to the violent and the non-violent games – is in line with previous findings that neurosympathetic and adrenocortical systems may react differently to stressors, depending on the variations in quality and intensity of the stressor (Hansen et al., 2003). This seems to be consistent with the seemingly contradictive results from a study showing that a violent TV movie triggered higher cortisol values than a violent game while the violent game induced a stronger autonomic reaction than the violent TV movie (Maass et al., 2010). One hypothetical explanation of such different reaction patterns is that the passivity and lack of control that characterize watching TV, evoke different physiological responses than the activity and potential control that characterize gaming.

HRV, violent media and social interaction

The results of the current studies inspire discussion of possible associations between autonomic reactions, violent gaming and social interaction. According to the polyvagal theory the ANS is hierarchically organized with a primary social system that is active in safe environments and situations that promote social interaction (Porges, 1997). This is due to the PSNS regulation of the structures involved in communication. In an insecure or frightening situation, the fast social inhibitory function (PSNS) is set aside in favour of the "fight and flight" system (SNS), with increased HR. If the situation gets worse or life threatening – as in a serious injury – the older unmyelinated function of the PSNS (LF) will be activated. According to Porges (2003), these functions seem to constitute a system for continuous evaluation of environments and situations, the so-called neuroception. This means that a threatening or challenging stimulus (like a violent game) might put an individual into a state where the more primitive systems are turned on (Cohen et al., 2000). Under such circumstances the ability for social interaction is limited, at least partly as a consequence of reduced activity of the phylogenetic younger branch of the vagus. One crucial aspect of social interaction is to recognize emotions in others. In experiments, this ability has been reduced when playing violent video games (Kirsh & Mounts, 2007) and in subjects with prior high exposure to violent media (Kirsh, Mounts, & Olczak, 2006). Hypothetically, the polyvagal perspective may offer a new way of understanding these results and other associations between violent media and social interaction such as increased relational aggression (ignoring, exclusion, spreading rumours) (Möller & Krahé, 2009), lowered empathy (Funk et al., 2004; Funk et al., 2003), increased tendency to exploit others (Sheese & Graziano, 2005) and lowered prosocial behaviour (Bushman & Anderson, 2009; Fraser, Padilla-Walker, Coyne, Nelson, & Stockdale, 2012; Ostrov, Gentile, & Crick, 2006).

Methodological considerations

Strengths

The strength of the studies in this thesis can be attributed to the rationales for the thesis. Firstly, the studies were not conducted with adults, but with teenagers who were at an age that raises most concern about the effects of gaming. Second, the advantage of carrying out an experiment under everyday conditions as compared to a laboratory setting improves ecological validity as compared to most of the previous research. Thirdly, the boys played for two hours, which is in line with common habits in this age group of boys (Swedish Media Council, 2013). Fourth, the experiments were not conducted in the daytime but in the evening, which supposedly is the time of day when games are usually played. Finally, the boys were their own controls, i.e. everybody played both games which minimized bias due to individual differences.

Limitations

Most limitations of the studies are related to the choice of games, the design and the selection of participants. Even though the ambition was to find games that were as similar as possible apart from a component of violence, it should be acknowledged that this is probably an impossible task. With the aim of minimizing these problems, I interviewed experienced gamers before selection and controlled for a number of aspects during playing. Nevertheless, the cartoon-like style may imply different reactions than more realistic games (Barlett & Rodeheffer, 2009). Another factor might be differences in difficulty between the games. The differences may affect emotional and adaptive reactions (Denot-Ledunois et al., 1998) which in turn affect the HRV parameters. In the first study the participants reported that the violent game was more difficult than the non-violent game, but this did not affect any of the outcome variables. In the last study the participants did not report any difference in difficulty between the two games. Although some differences thus can be identified it should be noted that much effort was put into finding games that were as similar as possible within the commercially available supply as regards important features such as style of play and difficulty level.

The design did not allow for separating effects related to specific events and features in the games. This ruled out the possibility to correlate the levels of HRV or cortisol with specific sequences of the games or to changing qualities (such as complexity and characteristics of violence) of the game over time. In general, the decision to perform the studies in the homes of the boys after providing instructions, but without supervision/observation implies less control over the playing procedure. For the same reason it was impossible to identify any baselines. However, information about motor activity provided by the HRV device suggested no impact on the outcomes related to movement.

The recruiting process may have introduced selection bias. For example some personality factors may be related to the motivation to participate in this kind of study or not. Additionally, the parents who agreed to their child's participation may have been concerned about their child's gaming and considered that these types of studies were important. Earlier studies have shown that involvement of parents may have a favourable impact on aversive effects of violent games (Wallenius & Punamäki, 2008). Furthermore, the extent of violent gaming may be associated with personality traits such as aggressiveness (Scarpa & Raine, 1997). Similarly, prior psychological trauma may attract people to violent and intense experiences like violent games (Al-Krenawi, Graham, & Kanat-Maymon, 2009). There are no background data to disprove any of these biases but the data from Study III on group comparisons offer some guidance. There were no differences between groups for HR- and HRV-related outcomes. Since the cardiac system is a valid reflection of relevant differences (Sirois & Burg, 2003) these results to some degree limit the magnitude of any influence from selection bias.

The results cannot be generalized to boys of other ages or to girls due to the decision to limit the participants to 12 – 15-year-old boys. The reason for examining only boys of that age was that they are the ones who play the most violent video games (The Swedish media council, 2010). Girls do not seem to be as attracted to violent games as boys are (Möller & Krahé, 2009; Olson et al., 2007).

Gender-related differences concerning cardiovascular reactivity have been well established (Kudielka et al., 2004) and HRV reactions to gaming in girls may be quite different to what was observed in these study groups of only boys. However, there is a growing interest among girls in games that traditionally have been regarded as most appealing to boys (Lee, 2006), which suggests that girls should be included in future studies.

Due to high intra-individual variations (Almeida, Piazza, & Stawski, 2009), cortisol samples should ideally be collected over several days for each participant. In the current study, saliva was collected during the experimental days only, which makes the levels more vulnerable to variations within each subject. The measurements were conducted across different seasons, which could conceivably contribute to the levelling of the cortisol concentrations across occasions due to season effects (Persson et al., 2008). However, it is highly unlikely that seasonal individual variations over time distorted the results since the focus was on individual differences over a relatively short time. Moreover, the orders of conditions were counterbalanced across subjects.

The aspects of compliance with cortisol sampling should be considered. The participants were carefully instructed since they administered the sampling by themselves. Thus it was not possible to verify whether the instructions were followed or not. For example, a delay in the morning samples could obscure the characteristic morning increase due to the rapid changes in cortisol concentration during early morning hours.

A limitation of the use of self-reports – such as sleep diaries – is their subjective character. Still, the use of self reports of sleep is relevant due to the limitations of laboratory studies, such as the restricted ability to generalize to everyday life. Further support for our choice is the satisfactory correlation between self-reported sleep and objective measurements (Keklund & Åkerstedt, 1997; Wolfson et al., 2003; Åkerstedt, Hume, Minors, & Waterhouse, 1994).

Statistical comments

In Study III a number of analyses were performed, implying a certain risk of statistical Type I error. The key analyses were the interactions between type of game and group, yielding 28 F-ratios of which seven were significant. Thus 25 per cent of the analyses were significant, which clearly exceeds the five per cent that would be expected by chance alone.

The reason for applying one-sided tests to the sleep and emotion data was due to the hypothesis about the direction of the associations based on previous empirical findings (Alexandru et al., 2006; Barlett et al., 2007; Dworak et al., 2007; van Den Bulck, 2004; Weaver et al., 2010; Williams, 2009).

Ethical aspects

One ethical consideration is related to the selection of the violent game that was rated for players aged 18 years and older although the participants in this study were younger than this. Since many children play games that are not rated for their chronological age (Rideout et al., 2010) the use of age-appropriate games would have created another dilemma by not being ecologically valid.

Future directions and conclusions

Even though the design can be regarded as ecologically relevant – quite similar to everyday gaming without any adult observing or interfering – complementary laboratory studies would be advisable, allowing for more strictly regulated and monitored experimental conditions. There are several variations in the nature of games due to aspects such as style of playing, speed, visual appearance, complexity, violence and degree of realism. When measuring differences in reaction to one aspect – such as violence – the differences due to the other the aspects might be a threat to the validity (Barlett & Rodeheffer, 2009). Thus, it is a challenge to find designs that allow different aspects to be studied separately. Along the same lines, games are complex and include a variety of events, with both arousing and relaxing qualities within each game. This may obscure effects during long-lasting gaming sessions. Such considerations should encourage the use of monitored experiments correlating reactions (e.g. in HR, HRV and SCR) with sequences with specific characteristics. The HPA axis was not affected by the exposure to violent gaming in this study. However, it is hard to predict the long-term effects that violent gaming might have on the HPA axis. Therefore, it would be interesting to investigate any possible differences in cortisol levels or patterns in heavy users of violent games, since prolonged exposure to stressful events may alter the function of the HPA axis (Miller et al., 2007).

The first conclusion is that playing a violent game seems to induce different autonomic reactions than a non-violent game. Secondly, the most significant physiological reactions did not appear during gaming but during sleep. These findings demonstrate the inertia of the ANS, meaning that physiological processes may be detectable hours after exposure. Third, the HPA axis does not seem to be affected by one short exposure to violent gaming. Fourth, high – as compared to low – experience of violent gaming seems to be related to different physiological, sleep-related and emotional processes that occur on exposure to violent video games. Thus, excessive violent gaming may have a desensitizing effect – physiologically, in relation to sleep quality, and emotionally, on subsequent exposure to violent game content. Few studies have considered the process of desensitization itself, its prerequisites, and if the process is reversible. The polyvagal perspective (Porges 1995) might shed light on the relation between violent gaming and the process of desensitization to violence. The relevance of such studies should also be seen from the perspective of the growing amount of violent content in video games (Smith et al., 2003), and a gradually increasing proportion of excessive gamers (playing more than three hours a day) over the last years. When the studies were planned, the proportion of 12 – 16-year-olds engaged in excessive gaming was less than 10 per cent (Swedish Media Council, 2005). Since then, the proportion has increased to 44 per cent among 13 – 16-year-old boys (Swedish Media Council, 2013). This means that what was previously considered as excessive gaming is today average gaming.

We have no idea how, or if the phenomenon of gaming will develop – probably it can neither be predicted nor stopped. Most likely, the relation and attitude to media and games will continue to change – which will offer new challenges to the parents, but also to the society. The challenges are not only about the consequences of too much gaming, such as reduced time for other things such as school work. One can only speculate about the social consequences, especially associated with violent gaming, such as changes in the capacity for social interaction and the shift of attitudes towards violent behaviour. Hopefully, this thesis provides insights into the new direction of technical and societal developments and will inspire further research in the future that will probably also offer opportunities that are unknown to us today.

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