THE IMPACT OF VIOLENT VIDEO GAMES ON EXECUTIVE FUNCTIONING AND AGGRESSION

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled

THE IMPACT OF VIOLENT VIDEO GAMES ON EXECUTIVE FUNCTIONING AND AGGRESSION

Presented by Christopher R. Engelhardt

A candidate for the degree of Master of Arts

And hereby certify that in their opinion it is worthy of acceptance.

Professor Bruce D. Bartholow

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I would like to dedicate this master’s thesis to my family. I would like to thank my mom for her support, guidance, love and showing me how to be a good person. I would like to thank my dad for his positive attitude, confidence and willingness to help me improve not only at sports, but also academics. I also want to specifically thank my brother, Jonathan, who has always been - and always will be - my best friend, serving as my inspiration to develop a more nuanced understanding of how individuals are affected by violent video games. Without each of you, the opportunities I have experienced in graduate school would not have been possible.

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Executive Functioning	EF
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Tower of Hanoi	TOH
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Behavior Rating Inventory of Executive Functioning-Adult Version	BRIEF-A
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Aggression Questionnaire	AQ
Caprara Irritability Scale	CIS
Electroencephalogram	EEG
Microvolts	µV
Research Assistant	RA
Analysis of Variance	ANOVA

ABSTRACT

Previous research suggests a causal link between violent video games and aggression (Anderson; 2004; Anderson & Bushman, 2001), but the underlying mechanisms remain unclear. Here, even-related brain potentials (ERPs) were recorded from 83 undergraduates who were randomly assigned to play a nonviolent or violent video game for 20 min prior to completing a go/no-go spatial Stroop task and an impulsive aggression task. Task order was manipulated between subjects. Results showed that, relative to nonviolent video game participants, violent video game participants had difficulty with cognitive control, but only after an intervening aggression task. Violent video games also caused increases in post-game aggressive behaviors, but only for dispositionally angry and low executive functioning (EF) participants. Trait aggressiveness also was found to moderate the relationship between violent video game exposure and both evaluative and regulatory control. These findings underscore the importance of individual differences in understanding violent media effects on both aggression and neurocognitive function.

INTRODUCTION

Since 1972, when scientific evidence had accumulated to the point where government officials expressed concern about the effects of viewing violent media (see Surgeon General's Scientific Advisory Committee on Television and Social Behavior, 1972), evidence of a causal link between media violence and aggression has only grown stronger (e.g., Bushman & Anderson, 2001; Hearold, 1986; Hogben, 1998; Huston et al., 1992; National Institute of Mental Health, 1982; Paik & Comstock, 1994; Wood, Wong, & Chachere, 1991). Although the general effects of violent media on aggression have been well documented, there are theoretical reasons to think that exposure to violent video games may foster more aggression than other forms of violent media (e.g., violent television). For example, violent video games are thought to promote identification with violent characters, provide the opportunity to actively participate and solidify aggressive scripts (Anderson & Dill, 2000).

Given their immense popularity (Elmer-Dewitt, 1993), video games increasingly have become the focus of researchers' attention, especially because many of the most popular games have violent themes (Dietz, 1998). The general consensus among media researchers is that exposure to violent video games, either acutely or after long-term exposure, increases aggressive thoughts, feelings and behavior and decreases prosocial behaviors. The average effect size of violent video games on aggressive behaviors ranges from .15 to .24 (Anderson, 2004; Anderson & Bushman, 2001; Anderson et al., 2010; Sherry, 2001).

Theoretical Explanations of the Violent Video Games and Aggression Link

Anderson & Bushman (2002) proposed the General Aggression Model (GAM) in an effort to consolidate a number of domain-specific models of aggression. The GAM suggests that inputs (person and situation variables) interact to jointly influence present internal states (affect, cognition, and arousal). Present internal states then serve as the basis for appraisal and decision processes, which can be impulsive or thoughtful. Briefly, as applied to the literature on violent video games and aggression (see Carnagey & Anderson, 2003), the GAM suggests that violent video games increase aggressive behavior and decrease helping behavior by temporarily (after a single exposure) or chronically (after repeated exposures) altering levels of aggressive cognition, aggressive affect and/or physiological arousal (Anderson, 2004; Anderson & Bushman, 2001). According to the GAM, aggressive behavior may best be predicted by focusing on the person within a situation (Anderson & Bushman, 2002). In other words, analogous to how not all individuals exposed to lead-based paint experience intelligence deficits, not all individuals exposed to violent video games show increases in aggression (Huesmann, 2010). More specifically, individuals who possess particular personality characteristics (e.g., anger) may be more susceptible to situational cues (i.e., violent video games) than individuals who do not possess those characteristics.

Two recent studies tested the GAM, the results of which suggest that trait anger and aggressive personality moderate the relationship between violent video games and aggression. In one study, participants played either a nonviolent or violent video game and were then asked to complete ambiguous story stems assessing aggression. Participants who played a violent video game completed hypothetical stories more aggressively, but only if the participants were high in dispositional anger (Giumetti & Markey, 2007). In another study, self-reported aggressive delinquent behavior predicted an aggressive personality style, but only for individuals with greater exposure to violent video games (Anderson & Dill, 2000). Taken together, these two studies suggest that violent video games affect different people differently. We also believe that, in addition to trait anger and aggressive personality, individual differences in executive functioning (EF) ability will moderate the relationship between violent video games and aggression.

Executive Functioning, Frontal Lobe Functioning, and Aggression

One of the most intriguing faculties of human beings is their ability to self-regulate behavior. EF, most broadly, can be defined as the “processes that control and regulate thought and action” (Friedman et al., 2006, p. 172). Although the structure of EF is debated, an emerging perspective from cognitive science (Miyake, Friedman, Emerson, Witzki, & Howerter, 2000) holds that EF is made up of a small number of related but theoretically and empirically distinct cognitive abilities, the most relevant of which in the current context is inhibition control. Inhibiting a prepotent response is one’s ability to stop dominant or automatic responses when necessary. In the lab, inhibition often is measured using a “go-no go” task (see, e.g., Weafer & Fillmore, 2008), in which participants are asked to respond to a stimulus on the majority of trials (e.g., a rectangle filled with green) but to withhold that response on a proportion of trials whenever a different stimulus is presented (e.g., a rectangle filled with red). Thus, participants develop a prepotent tendency to respond but must also inhibit or overcome that behavioral tendency when required. The notion being advanced here - that the effects of violent video games on aggression and inhibition control will be greater for individuals low in EF - derives from substantial evidence linking impaired EF and increased aggression. For example, Giancola (2000) proposed a conceptual framework linking executive functioning capacity and aggression. Giancola asserted that people with low executive functioning capacity will find it difficult to disengage from aggressive impulses. In support of this view, neuropsychological (e.g., Malloy, Noel, Longabaugh, & Beattie, 1990), neurophysiological (e.g., Barrat, Stanford, Thomas, & Felthous, 1997), behavioral neurological (e.g., Blake, Pincus, & Buckner, 1995) and neuroimaging (e.g., Goyer et al., 1994) studies corroborate the link between executive functioning and aggression by documenting a relationship between low executive functioning and aggressive behavior. Although Giancola's model primarily is meant to explain effects of alcohol on aggression, the basic tenets of the model also might apply to understanding effects of other environmental stimuli, such as exposure to violent video games, on increased aggression. That is, impaired executive functioning capacity may be both a mediator (i.e., facilitates aggression by disrupting inhibitory control) and moderator (i.e., higher likelihood of aggression among persons with low executive control) of aggression. According to the model, these relationships should hold only for impulsive (not instrumental) aggression. Other researchers also link factors that limit executive control to increased aggression. For example, Baumeister and Boden (1998) suggest that the proximate cause of aggression may be the failure of self-regulation. That is, prior to observing a behavior, some agent of executive control must "sign off" on the decision. However, if executive control resources are depleted or otherwise out of balance following violent video game exposure (e.g., if response activation is stronger than response inhibition), behaviors necessitating cognitive or behavioral control (e.g., aggressive behaviors) should be more likely to surface and be expressed.

Executive functioning processes are thought to be regulated and controlled by the frontal lobes in the brain (Friedman et al., 2006). People with frontal lobe damage typically perform well on neurophysiological tests and IQ tests, but generally perform poorly on tasks of executive functioning ability such as the Wisconsin Card sorting task (WCST) or the Tower of Hanoi (TOH) task (Miyake et al., 2000). If executive functioning abilities are associated with the regulation of behavior, and are also thought to associated with the frontal lobes in the brain (Friedman et al., 2006), it stands to reason that there should be a link between the brain’s frontal lobes (i.e., executive functioning) and problems with self-regulation (e.g., inhibition control or aggression). Indeed, for over 50 years, a relationship between frontal lobe functioning and aggression has been thought to exist (Hawkins & Trobst, 2000). Hawkins and Trobst also discussed how frontal lobe damage contributes to violence. More specifically, the inability to inhibit inappropriate actions may propel someone toward violent actions. For example, Grafman et al., (1996) suggested that when “schema-like” knowledge (e.g., rules of social behavior) is activated, the frontal lobes regulate the inhibition of prepotent responses, such as primitive reactions such as aggression. In contrast, if the frontal lobes have difficulty accessing schema-like knowledge, inhibition of primitive reactions is less likely to transpire, which could facilitate aggression or problems with self-regulatory behavior. We believe that to the extent violent video games activate aggressive schema-like scripts (Anderson & Bushman, 2002; Huesmann, 1986), these scripts should be more difficult to inhibit (i.e., lower self-regulatory or cognitive control) for people lower in EF.

Neural Correlates of Cognitive Control

Recent models of executive control from cognitive neuroscience posit a two-component structure of control, mediated by distinct neural systems. Botvinick Braver, Barch, Carter and Cohen (2001) posited that control is mediated by two complimentary processes: an evaluative process responsible for continuously monitoring ongoing behavior and the environment for potential conflict, and a regulatory system that engages cognitive control to overcome such conflicts when they arise. When conflict is detected by the evaluative system, the level of conflict is first evaluated and then passed along to the regulative system, which is responsible for engaging control according to the extent of conflict detected by the evaluative system.

Several lines of work have provided evidence that activation of the evaluative component of cognitive control is mediated by activity of the anterior cingulate cortex (ACC), located on the medial surface of the frontal lobe (e.g., LaBerge, 1990; Posner & DiGirolamo, 1998). For example, numerous studies point to heightened ACC activation in contexts where conflict is likely, such as when prepotent responses must be overridden. Using Positron Emission Tomography (PET), Pardo, Pardo, Janer, and Raichle (1990) noted greater ACC activation on incongruent trials relative to congruent trials in a typical color-naming version of the Stroop task (Stroop, 1935). Bush et al. (1998) noted similar findings when using a counting version of the Stroop. Overriding prepotent responses also is required in “go/no-go” tasks. Using functional magnetic resonance imaging (fMRI), Casey et al. (1997) had half of their participants respond (“go”) to individually presented letters, such as X, and to not respond (“no-go”) to other, less-frequently presented letters, such as O. The remaining participants experienced all "go" trials. Results indicated greater ACC activation for those in the go/no-go condition.

Once conflict is evaluated by the evaluative system mediated by the ACC, other structures in the frontal cortex, such as the dorsolateral prefrontal cortex (DLPFC), are responsible for implementing cognitive control in order to overcome the conflict so that appropriate responses can be made. The interplay of the ACC and DLPFC in regulating behavior in conflict situations has been demonstrated by Kerns et al. (2004). These authors measured fMRI while participants completed a Stroop task. Their findings indicated enhanced ACC activation on incongruent trials, followed by enhanced DLPFC activation on trials in which participants were able to overcome the conflict and respond correctly.

Similar studies conducted with event-related brain potentials (ERPs) have identified components associated with the evaluative and regulative aspects of control. In particular, the stimulus-locked N2 measured during conflict-related tasks (e.g., Stroop) is believed to reflect the evaluative control function of the ACC, occurring prior to emission of behavioral responses on correct-response trials (van Veen & Carter, 2002). The conflict-related N2 is largest at fronto-central scalp locations and also is hypothesized to emanate from the ACC in response to conflict. On correct response trials in which conflict is high (e.g., incompatible Stroop trials), the correct and incorrect response channels are simultaneously activated, with the correct response selection eventually presiding over the incorrect response (Bartholow et al., 2005; Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhoff, 2003; van Veen & Carter, 2002). Other physiological evidence suggests that the N2 can also be observed on trials requiring inhibition, which has led to the hypothesis that the N2 is an index of inhibitory control (Bokura, Yamaguchi, & Kobayashi, 2001; but see Bruin, Wijers, & van Staveren, 2001).

The negative slow wave (NSW) component, in contrast, has been implicated as a reflection of the regulative component of cognitive control (Bartholow, Dickter, & Sestir, 2006; Curtin & Fairchild, 2003; West & Alain, 1999, 2000). The NSW typically is enhanced on trials in which a high degree of conflict was successfully resolved and the correct response was made (e.g., incongruent Stroop trials; see West & Alain, 1999), leading to the hypothesis that this component reflects the engagement of cognitive control resources. The NSW is fairly widely distributed, but typically is prominent at frontal and fronto-central scalp cites relatively late in a trial epoch, after the more phasic ERP components (e.g., P300) have resolved (Curtin & Fairchild, 2003**;** West & Alain, 1999, 2000). Manipulations known to impair cognitive control have been shown to reduce the amplitude of the NSW on correct-response trials. For example, in a classic Stroop task, intoxicated participants exhibited smaller NSW amplitudes on incongruent trails than did sober participants (Curtin & Fairchild, 2003). Similarly, Bartholow et al. (2006) found that intoxicated participants showed dramatically smaller NSW amplitude than placebo participants on correctly inhibited ‘stop’ trials within a go-stop inhibition task. Such data suggest that regulatory control processes are reduced for those participants in which control is required.

The Present Study

The aim of the current study was to investigate the impact of brief exposure to violent video games on EF, self-regulatory abilities, and neural correlates of evaluative (N2) and regulatory (NSW) control. The notion that playing a violent (relative to a nonviolent) video game might impair executive control (for certain individuals) is derived from at least two lines of reasoning. First, as discussed previously, considerable work supports a causal connection between playing violent video games and increases in aggression (e.g., Anderson, 2004; Anderson et al., 2010; Bushman & Huesmann, 2001; *Joint Statement,* 2001). Another substantial body of work indicates that impaired executive control often contributes to aggressive behavior (e.g., Barret et al., 1997; Blake et al., 1995; Giancola, 2000; Goyer et al., 1994; Malloy et al., 1990). Thus, at least one possibility is that these processes are related (i.e., that post-game aggression is related to impaired executive control), but perhaps only for certain individuals (Anderson & Bushman, 2002). Second, many of the actions used in playing violent video games are impulsive, requiring quick activation of responses (e.g., to "shoot") in order to avoid being killed by the opposing game characters. To the extent that repeated activation of responses leads to a temporary relative "priming" of the behavioral activation system at the expense of the behavioral inhibition system, certain individuals who play violent game players could have difficulty overcoming prepotent response activation tendencies for a time following the game.

In the current study, participants were randomly assigned to play either a violent or nonviolent video game for 20 minutes. Participants then engaged either in an executive control task (a go/no-go spatial Stroop task), in which congruent, incongruent, and response inhibition trails were shown while ERPs were recorded, or an aggression task, in which participants had the opportunity to blast another participant with noxious noise. Because more recent research suggests that the acute effects of violent video game exposure on aggressive behavior tend to be relatively short-lived, probably less than 9 minutes (Sestir & Bartholow, submitted; Barlett, Branch, Rodeheffer, & Harris, 2009), task order (i.e., Stroop task first or aggression task first) was included as a between-subjects factor.

Primary hypotheses focus on the possibility that playing a violent video game for 20 minutes could lead to a temporary imbalance in executive control, either by generally depleting executive resources or by producing an imbalance between response activation and response inhibition tendencies. ERP measures of evaluative and regulative control during the spatial Stroop will serve as online indices of the implementation of evaluative and regulatory control. For instance, failure of inhibitory control on no-go trials could be due to an impairment of the evaluative system to detect the conflict between prepotent response activation and the need to inhibit responses. Alternatively, it could be that conflict detection is relatively intact, but that implementation of control (i.e., the regulative system) is ineffective. To the extent that either or both of these processes are less effective following violent game play, this could help to account for hypothesized increases in aggressive behavior following violent games for particular individuals.

Hypotheses

Aggression. The primary hypothesis for the aggression measure is that participants high in trait physical aggressiveness, anger , or low in EF abilities who play a violent video game will express more aggression (i.e., select louder noise blasts for the ostensible other participant) than participants who play a nonviolent game. However, on the basis of previous research indicating that violent game effects on aggression measured in the laboratory can be short-lived (Sestir & Bartholow, 2008; Sestir & Bartholow, submitted), it is possible that this effect will emerge only (or most dramatically) for participants who complete the aggression measure immediately following game play.

Stroop performance. The main hypothesis of this study is that, relative to playing a nonviolent video game, playing a violent video game will impair executive functioning abilities associated with the regulation of attention and action, resulting in impairment of performance on the spatial Stroop task to be used here, in two possible ways. First, if conflict regulation is impaired overall by playing a violent game, participants would be expected to have more difficulty with incompatible relative to compatible trials. This could be manifested in both increased error rates on incompatible trials in the violent game condition as well as exacerbation of the typical compatibility effect in reaction time (i.e., slower responses on incompatible compared to compatible trials). Second, to the extent that inhibitory control is impaired following a violent video game, low EF participants in that condition would be expected to make more inhibition errors (i.e., responding on “no-go” trials) than participants in the nonviolent game condition.

ERP predictions. To the extent that playing violent video games impairs control of attention and action, this effect is likely to emerge in the level of activity of the conflict monitoring system and its influence on behavioral control. Specifically, the conflict elicited by incompatible trials should be more difficult to overcome after playing violent relative to nonviolent video games. In other words, the conflict monitoring system is likely to be less effectively implemented on incompatible trials in the violent game condition. It is therefore predicted that those in the violent game condition will exhibit smaller N2 amplitude on incompatible “go” trials than will participants in the nonviolent game condition. Furthermore, the N2 typically is larger on “no-go” than on “go” trials.

Here, however, it is predicted that this difference will be attenuated among those in the violent compared to the nonviolent game condition. Furthermore, to the extent that violent game players are less able to implement cognitive control resources to overcome conflict on incompatible trials, it is also predicted that playing violent games will result in smaller NSW amplitudes on correct, incompatible trials compared to playing nonviolent games.

Method

Participants

Eighty-three participants (21 women) ranging in age from 18 to 22 ($M = 19.0$; $SD = 1.0$) at the University of Missouri completed the experiment in exchange for partial course credit. Participants were predominantly right-handed (as determined by the Edinburgh handedness inventory; Oldfield, 1970) with normal to corrected vision. Participants were recruited through an internet sign-up system listing the current study under the title "Video games, media, and reaction times." Participants were randomly assigned to a specific game within game condition. Gender was balanced within all experimental conditions.

Measures

Video games. All video games were played on the Playstation 3 console system. The violent video games included *Mortal Kombat vs. DC Universe* (rated Teen for blood, suggestive themes and violence), *Resident Evil 5* (rated Mature for blood and gore, intense violence and strong language), *Killzone 2* (rated Mature for blood and gore, intense violence and strong language), *F.E.A.R. 2: Project Origin* (rated Mature for blood and gore, intense violence, partial nudity, sexual themes and strong language) and *Call of*

Duty: Modern Warfare 2 (rated Mature for blood, drug reference, intense violence and language). The nonviolent games included *MotorStorm* (rated Teen for language and violence), *NCAA Basketball 2009* (rated E for everyone), *Sid Meier's Civilization Revolution* (rated Everyone 10+ for alcohol and tobacco reference, mild suggestive themes and violence), *Little Big Planet* (rated Everyone for comic mischief and mild cartoon violence), and *Ferrari Challenge* (rated Everyone).

Although some violent video game research has utilized only one violent and non-violent game per condition (e.g., Bartholow & Anderson, 2002; Kirsch, 1998), the current research utilized multiple games per condition so results are more readily generalizable to the population of violent and nonviolent games, respectively (see Bushman & Anderson, 2002; Wells & Windschitl, 1999).

Aggression. Aggression was measured using a version of the competitive reaction time task (CRT; Taylor, 1967). In a typical CRT, participants are led to believe they will compete with a confederate on a series of trials, ostensibly to determine which participant is able to respond more quickly to various stimuli. Following each trial, the "loser" (actually, wins and losses are pre-determined) receives some type of noxious stimuli (e.g., noise blast), the intensity of which is allegedly determined by the "winner" prior to a given trial.

In the current study, participants recommended both the duration and decibel level (intensity) an "ostensible other" would listen to a noxious noise blast prior to a one-trial CRT. A single trial was used to avoid tit-for-tat matching, one shortcoming often noted with paradigms similar to multiple-trial CRTs (Axelrod, 1984; Gouldner, 1960). The task of the participant was to indicate (via button press) the color of a square as quickly and accurately as possible. This method provided a relatively quick measure of aggression, important to the current study because the violent video game effect is believed to be of relatively short duration (see Sestir & Bartholow, 2010; Barlett et al., 2009). Variations of the CRT measure also have been used in previous research investigating violent video games (e.g., Bartholow & Anderson, 2002).

Cognitive Control task. . Participants completed a version of a spatial Stroop task similar to that used in previous research (Salthouse, Toth, Hancock, & Woodward, 1997). In a typical spatial Stroop task, participants are asked to respond to the direction of an arrow (i.e., right or left), regardless of where it appears on the screen (i.e., the right or left side) via button press. Usually, participants are much quicker (and more accurate) to make a response when the arrow direction and side of the screen match (compatible trials) than when the arrow direction and side of the screen mismatch (incompatible trials). The difference in reaction times between trial types has been labeled the "compatibility effect."

The version of the task used in the current study differs in two important respects. First, the probability of congruent versus incongruent ("go") trials was manipulated. That is, 50% of the total trials were congruent 'go' trials, and 25% of the remaining (total) trials were incongruent 'go' trials. Second, in order to directly model inhibition control, the remaining 25% of trials included "no-go" trials. To differentiate between trial types, participants were informed that "go" trials are trials in which the arrow heads are 'filled-in', whereas "no-go" trials are trials that have 'open-headed' arrows. On 'go' trials, participants were instructed to press a button on a response box indicating the direction in which the arrow is pointing (left or right), regardless of the side of the screen on which the arrow appears. On “no-go” trials, participants were instructed to withhold a response and simply wait for the next trial to begin.

Each trial began with a fixation cross presented in the center of the screen for 1 second, followed by a blank screen for 200 ms. Following the blank screen, the stimulus (i.e., arrow) was presented for 150 ms on either the left or ride side of the screen. Participants had a total of 600 ms from the onset of the stimulus to make a response. If the participant did not make a response within this response window, a “too slow” feedback screen appeared for 200 ms, indicating to the participant that a quicker response is required. Thus, on trials where the participant did not respond within the response window, these trials were 200 ms longer than trials where a response was made within the response window. Inter-trial intervals varied randomly between 200 and 400 ms. The entire task consisted of 512 trials (1 block of 32 practice trials; 5 blocks of 96 experimental trials). Experimental blocks were divided into 32-trial segments, which repeated 3 times during a given block. The number of trial types within a block follows from the trial type proportions. That is, on the majority of trials, participants encountered congruent “go” trials (50% of trials within a block; 24 compatible-left; 24 compatible-right). Less frequently, participants encountered incongruent “go” trials (25% of trials within a block; 12 incompatible-left, 12 incompatible-right). The remaining 25% of trials were “no-go” trials (6 compatible-left “no-go”; 6 compatible-right “no-go”, 6 incompatible-left “no-go”, and 6 incompatible-right “no-go”). The relative infrequency of incongruent “go” trials ensured that participants utilized cognitive control to a greater extent in order to respond correctly than if incongruent and congruent trials were equiprobable (Nieuwenhuis et al., 2003). Also, the relatively high frequency of “go” compared to “no-go” trials ensured that participants’ prepotent tendency was to activate a response on each trial, making inhibition more challenging on “no-go” trials (see Nieuwenhuis et al., 2003).

Materials

Executive functioning. Subjective ratings of executive functioning ability were measured with the Behavior Rating Inventory of Executive Functioning–Adult Version (BRIEF-A) (Roth, Isquith, & Gioia, 2005). This survey asked respondents to indicate whether they never, sometimes or often engage in a list of behaviors. The BRIEF-A is a 75-item scale, including 9 subscales referred to as inhibit (8-item; α = .73; e.g., “I have trouble sitting still”), shift (6-item; α = .78; e.g., “I have trouble changing from one activity or task to another”), emotional control (10-item; α = .90; e.g., “I have angry outbursts”), self-monitor (6-item; α = .78; e.g., “I talk at the wrong time”), initiate (8-item; α = .79; e.g., “I have trouble getting ready for the day”), working memory (8-item; α = .80; e.g., “I forget what I am doing in the middle of things”), plan/organize (10-item; α = .85; e.g., “I get overwhelmed by large tasks”), task monitor (6-item; α = .74; e.g., “I make careless errors when completing tasks”) and organization of materials (8-item; α = .96; e.g., “I am disorganized”). A behavior regulation index (BRI) was derived by aggregating the inhibit, shift, emotional control and self-monitor scores (α = .93), a metacognition index (MI) was derived by aggregating the initiate, working memory, plan/organize, task monitor and organization of materials scores (α = .94) and a global executive composite (GEC) was derived by aggregating the BRI and MI scores (α = .96). Higher composite scores reflect increased difficulty with the executive functioning ability.

Trait aggressiveness. Trait-level aggressiveness was measured with the 29-item Aggression Questionnaire (Buss & Perry, 1992). The Aggression Questionnaire (AQ) is composed of 4 subscales: 1) Physical Aggression (9-item; α = .78; e.g., “If somebody hits me, I hit back”), 2) Verbal Aggression (5-item; α = .85; e.g., “I can’t help getting into arguments when people disagree with me”), 3) Anger (7-item; α = .84; e.g., “Some of my friends think I’m a hot-head”), and 4) Hostility (8-item; α = .77; e.g., “At times I feel I have gotten a raw deal out of life”). Responses were made on a Likert scale ranging from 1 (*Extremely uncharacteristic of me*) to 7 (*extremely characteristic of me*). Higher scores on this measure index higher levels of trait aggressiveness (e.g., Bushman & Wells, 1998; Harris, 1996). The AQ has demonstrated good reliability in previous work (α = .88).

Trait Irritability. Participants also completed the Caprara Irritability Scale (CIS; Caprara et al., 1985). This 30-item questionnaire measures the willingness to engage in quick or impulsive reactions toward a perceived provocation. Example items such as “I easily fly off the handle with those who don’t listen or understand” will be rated from 1 (*this doesn’t characterize me at all)* to 5 (*this characterizes me very well*). For the current study, 4 items tapping aggressive behaviors (e.g., “I seldom strike back even if someone hits me first) will be excluded to ensure CIS scores reflect hostility rather than aggression, similar to previous research (Bartholow et al., 2005). The irritability scale has had an alpha of .81 in previous research (Caprara et al., 1985).

Violent video game experience (VVE). Similar to previous research (e.g., Anderson & Dill, 2000; Bartholow et al., 2006; Bartholow, Sestir, & Davis, 2005), participants completed a questionnaire assessing their previous exposure to violent video games. Participants listed their five favorite video games, which were then followed by three questions rating the listed games in terms of how often they play each game, the violence of each game's content and the violence of each game's graphics. For the "how often" question, participants listed the average amount of time they spent playing each game in terms of hours per week. The violent content question was anchored from 1 (*little or no violent content)* to 7 (*extremely violent content)*. Parallel anchor points were used for the violent graphic question. For each listed game, scores on the content and graphic scales were summed and then multiplied by the "how often" rating. Composite VVE scores were then created by aggregating across games. The VVE measure has demonstrated adequate reliability (α >.80) in previous research (Anderson & Dill, 2000; Bartholow et al., 2006).

Demographics. Participants were asked to indicate their gender, age, race, religion, religiosity, political orientation, college standing (e.g., freshman), and college GPA.

Electrophysiological Recording

The electroencephalogram (EEG) were recorded from 32 electrodes fixed in an electrode cap (Electro-cap International, Eaton, OH) at standard locations over the frontal, fronto-central, central, centro-parietal, and parietal scalp areas. All EEG electrodes were referenced online to the right mastoid (average mastoid references were derived offline). EEG was continuously recorded and stimulus-locked ERP epochs of 1400 ms were derived offline (referenced to 200 ms pre-stimulus baseline). EEG was amplified using Neuroscan Synamp amplifiers and filtered on-line at .05-40 Hz at a sampling rate of 1000 Hz. Impedance were kept below 10 kΩ. Ocular artifacts (i.e., blinks) were removed from the EEG using a regression-based procedure (Semlitsch, Anderer, Schuster, & Presslich, 1986). Trials containing voltage deflections of ± 75 microvolts (µV) after ocular artifact rejection were rejected prior to averaging. Off-line averages were derived according to participant, electrode, and stimulus conditions, and low-pass filtered at 18 Hz (24 dB roll-off).

ERP Component Measurement

As mentioned previously, three components were of primary interest in this research. The N2 typically emerges as a prominent negativity in the stimulus-locked ERP 200-400 ms post-stimulus (see Bartholow et al., 2008; Kopp et al., 1996; Nieuwenhuis et al., 2003), and tends to be larger on no-go trials than on go trials (e.g., Kopp et al., 1996). The NSW generally appears as a more tonic negative shift in the waveform that occurs later (e.g., 600-1000ms post-stimulus), after the more phasic ERP components have resolved (see Bartholow et al., 2006; Curtin & Fairchild, 2003; West & Alain, 1999, 2000). Each component was identified via visual inspection of the condition-averaged stimulus-locked and response-locked ERP waveforms, respectively. Based on this visual inspection, component-specific epochs were identified and the amplitude values within those epochs were determined using an automated procedure. For the N2, analyses will be based on the largest negative-going peak within the respective component-specific epoch. For the NSW, given its more tonic nature, the average (mean) amplitude value within the epoch of the component were used in analyses.

Procedure

Before arrival, each participant (tested individually) was randomly assigned to both a game (violent or nonviolent) and task order (aggression first or Stroop first) condition. That is, participants were either randomly assigned to the violent, aggression first (*n* = 21), violent, Stroop first (*n* = 21), nonviolent, aggression first (*n* = 21) or nonviolent, Stroop first (*n* = 20) condition.

Upon arrival, participants were informed the study sought to investigate the relationship between types of media and reaction times to various stimuli. Participants were led to believe they would (at some point) engage in a brief competition against another participant, but that most of the experiment would be completed individually. Since participants were tested individually and the other participant was never present at the onset of the experiment, participants were informed that if the other participant does not arrive, the competition portion could not be completed. After giving consent, the experimenter explained that "because you are the first to arrive, you will have an opportunity to randomly assign yourself to one of two ERP labs by flipping a coin". Before allowing the participant to toss the coin, the experimenter explained that it was indeed a fair coin by showing the head side, followed by the tail side. After flipping the coin, participants were led to believe (with a bogus experiment sheet) they randomly assigned themselves to a particular lab. In actuality, all participants were assigned to the same lab.

Once seated in the ERP lab, participants first completed the executive functioning (Roth, Isquith, & Gioia, 2005), trait aggressiveness (Buss & Perry, 1992) and trait hostility (Caprara et al., 1985) measures on a computer. The experimenter then entered the lab, turned off the computer screen and asked participants to complete the VVE (Anderson & Dill, 2000) measure and exited the lab. While participants completed a paper-and-pencil version of the VVE measure, the experimenter, now in the control room, loaded the previously recorded 'other participant' video. After participants verbalized to the experimenter they had completed the VVE measure, the experimenter returned to the lab. Upon entering, the experimenter chatted with the participants about the games they listed, giving the impression that the experimenter had not been in the control room for a brief period of time (generally 1-2 min.). Next, the experimenter said he wanted to check and see if the other participant had arrived, which was accomplished by communicating with a research assistant (RA) in the adjacent control room through an intercom system. Once the RA confirmed the other participant had arrived, the RA asked the experimenter if it would be okay to ask the 'other' participant to temporarily skip the surveys and start on the subsequent tasks. The experimenter agreed, citing that the experiment would progress more smoothly if both participants were on the same page for the competition portion. The experimenter then informed participants they would now have an opportunity to interact with the person in the other lab (via camera) because psychological studies often use deception, and because we suggested that according to previous research, seeing the other participant increases the likelihood you will take the competition seriously. Using a series of voice and timing cues, the RA started to play the video of the 'other' (always matched for gender). Quickly after the RA starting playing the video in the control room, the experimenter turned on the participant's computer, revealing what appeared to be the other participant (getting comfortable) in the other lab. When the video first loaded, the other participant appeared as if he (or she) was looking around the room, so the experimenter made a comment about how the other participant might not realize the camera is operating. After a few seconds elapsed, a cue (in the video) prompted the experimenter to ask (over the intercom), "can you guys see us now"? A man in the video, of which the participant could only see half, then replied "yea, we can see you guys now”. Next, the experimenter asked the participant to try and wave to the other participant. Once the participant waved, the experimenter returned to the intercom and asked if the other participant could “wave back to us”. After the other participant appeared to return the wave, the experimenter turned off the monitor. Every attempt was made to ensure the video appeared in real time (i.e., make it believable).

Following the video interaction, participants were fitted with an ERP cap. Next, participants were told that we would now like them to play their randomly assigned video game for a brief period of time. Before game play, participants received instructions on how the game pad interacted with the gaming environment (e.g., the left thumb stick moves your character, the right thumb stick makes your character look in different directions, etc.). Once participants felt comfortable with the controls (after about 2-3 min.), the experimenter allowed participants to play the assigned video game, without interruption, for a period of 20 minutes. After 20 minutes, the experimenter returned to the lab, asked for the controller and turned off the Playstation console. Immediately following the gaming session, participants transitioned to their randomly assigned task order condition (i.e., aggression first or cognitive control task first).

If assigned to the aggression task first condition, it was explained that it was now time for the competition portion of the experiment. The experimenter instructed participants that we were interested in how the video game they just played may have affected their reaction time abilities. Participants were informed that their task would be to respond to the color of a square via button press, such that if the final square (in a series of three squares) turned blue, we would like them to respond with the number 2 on the keyboard, but if the final square turned green, we would like them to respond with the number 8 on the keyboard. Square colors were counterbalanced across participants. All final squares (either blue of green) were preceded by a red square, yellow square sequence, where the interval between square presentations was 1 second. It was explained that in order to ensure both participants took the competition seriously, each participant would have an opportunity to set noise levels (intensity and duration ranging from 1 to 10, respectively) prior to the competition should the other participant lose. Participants also were informed that should *they* lose, *they* would receive the noise intensity and duration set by the other participant. The experimenter then demonstrated a low-level (level 1), medium-level (level 5), and high-level (level 10) noise blast for periods of 1 second to give the participants a sense of the intensity. Importantly, the experimenter instructed participants that the competition portion lasted only 1 trial, which meant they would have only one opportunity to beat their opponent (i.e., participants would not necessarily worry about retribution). It was explained that winning the competition, and thus having the noise blast sent to the 'other' participant, would be evaluated based on three criteria, the first two of which were speed and accuracy. The third grading criteria, as explained by the experimenter, would be given immediately before the start of the reaction time competition. The experimenter also requested that the participant refrain from setting any noise or duration levels until instructed to set them. Before exiting the room to ostensibly determine if the other participant was ready, the experimenter asked participants if they had any questions. If participants had no questions, the experimenter left the room for a period of 2 minutes and then returned to inform participants the other participant was ready to start the competition. Next, the experimenter returned to the control room, where he first asked (over the intercom) if the 'other' participant was ready. Once enough time elapsed for the ‘other’ to ostensibly respond (the real participant only heard the experimenter’s voice), the experimenter asked the real participants if they were ready. If the participants indicated they were ready, the experimenter informed participants that the final criterion was how *quickly* they set the noise levels. Immediately after informing participants about the final criterion, the experimenter quickly said “3,2,1, go!”. In doing so, we attempted to capture the gut-level, impulsive aggression we feel is largely featured in violent video games (i.e., shoot at everything). After participants set the noise intensity and duration levels, and engaged in the CRT, all participants saw a smiley face appear on the screen, which informed participants they won the trial and the noise blast was delivered to the ‘other’ participant.

If assigned to the cognitive control task first condition, participants first completed the spatial Stroop task. During the practice block, the experimenter watched to ensure participants understood all task parameters (e.g., did not respond to ‘open-headed’ arrows, responded based on the direction of ‘filled in’ arrows). Following the practice session, the experimenter exited the lab, entered the control room and started the ERP recording, and then allowed participants to complete the remaining 5 blocks of the cognitive control task.

Once the second experimental task was completed (aggression measure or cognitive control task), participants completed the demographic survey. Participants were then probed for suspicion (particularly about the ‘other’ participant), debriefed, thanked and dismissed.

Results

Behavioral Analyses

Analytic approach. Because a response deadline was implemented during the cognitive control task the RT data were not significantly skewed, and therefore no transformation of RTs was necessary. For all within subject factors involving more than 2 levels, the Greenhouse-Geiser corrected *p* values are given. Participants who expressed at least 50% doubt that the other participant was not present were excluded from aggression analyses ($n = 4$). Participants with ERP equipment failure ($n = 3$) were excluded from all ERP analyses. To investigate the possibility that individual differences moderate the relationship between Game type and behavior regulation (aggression or inhibition control), separate hierarchical regression models were computed. For all models, the main effect of game and task order (both effect coded) and continuous predictor (mean centered) were entered on step 1, all two-way interactions were entered on step 2, and the 3-way interaction was entered on step 3. Observations with a studentized deleted residual in absolute value greater than 2.5 were dropped from regression analyses (differing depending on the analysis in question; fewer than 2 in all models but one model dropped 6). Only results of theoretical interest are reported.

Aggression (noise intensity). Previous research has indicated that an aggressive personality style (Anderson & Dill, 2000) and dispositional anger (Giumetti & Markey, 2007) moderate the relationship between violent video game exposure and aggression. Baumeister and Boden (1998) also suggested that problems with self-regulation contribute to aggression. Therefore, the acute effects of violent video game exposure on aggression were examined as a function of these three individual differences.

The first model investigated whether trait aggressiveness (from the trait aggression measure; Buss & Perry, 1992) interacted with Game condition and Task order to predict noise intensity. As shown in Table 1, only Trait aggressiveness was a strong predictor of noise intensity on Step 1, indicating that individuals higher in dispositional aggressiveness set higher noise intensity levels. All 2 and 3-way interactions were nonsignificant in this model (see Table 1).

The second model examined whether trait anger (from the trait aggression measure; Buss & Perry, 1992) interacted with Game condition and Task order to predict noise intensity. As seen in Table 2, no main effects were observed. On Step 2, only the Game condition x Anger interaction was significant. Simple slope analyses indicated that for the nonviolent players, the relationship between anger and noise intensity was marginally nonsignificant ($\beta = -.31$; $p = .06$), indicating that individuals higher in trait anger tended to set lower noise levels if they first play a nonviolent video game. In contrast, simple slope analyses for the violent video game players indicated that the relationship between anger and noise intensity was positively related ($\beta = .49$; $p < .01$), indicating that individuals higher in trait anger set higher noise levels if they first play a violent video game. Scatter plots by Game condition may be seen in Figure 1. The 3-way interaction was nonsignificant in this model.

The third model tested whether the problems with behavior regulation (BRI from the BRIEF-A; Roth et al., 2005) interacted with Game condition and Task order to predict noise intensity.[1] As seen in Table 3, this model showed no main effects on Step 1. On Step 2, only the Game condition x Behavior regulation interaction was significant. Simple slope analyses indicated that for nonviolent players, the BRI did not predict noise intensity ($\beta = -.21$; $p = .22$). For the violent players, however, BRI scores positively predicted noise intensity ($\beta = .41$; $p < .01$), suggesting that individuals with greater behavior regulation problems set higher noise intensity, but only if they play a violent video game. Scatter plots by Game condition may be seen in Figure 2. The 3-way interaction was nonsignificant.

Inhibition control. One way violent video games could impair performance on the cognitive control task is by differences in inhibition control. Because we were interested in how EF abilities interact with Game condition and Task order to predict the proportion of errors on inhibition ('no-go') trials, a similar hierarchical model was constructed using the entire EF composite as the continuous predictor (GEC from the BIEF-A; Roth et al., 2005). Results of this analysis showed no main effects (see Table 4). On the second step, only the Game condition x GEC interaction was significant. Note, however, that when all 2-way interactions were included, Step 2 does not contribute to the adjusted R^2 for the model. Simple slope analyses indicated that for the nonviolent video game players, inhibition errors and GEC scores were unrelated, ($\beta = -.23$, $p = .14$). For the violent video game players, errors of inhibition tended to be positively related to GEC scores, ($\beta = .29$, $p = .06$), such that lower EF individuals tend to make more errors of inhibition, but only if they play a violent video game. Because neither slope was significant within game conditions, this significant interaction suggests these two slopes are significantly different from each other. Scatter plots by Game condition may be seen in Figure 3. The three-way interaction was nonsignificant in the model.

Reaction times. A second way violent video games could impair performance on the cognitive control task is by differences in the compatibility effect. To test the hypothesis that the compatibility effect differed as a function of game condition, compatibility effects were analyzed with a 2 (Game condition: violent, nonviolent) x 2

(Task order: Stroop first, aggression first) x 2 (Trial type: compatible, incompatible) x 5 (Block) mixed factorial analysis of variance (ANOVA) with repeated measures on the final two factors. Results of this analysis indicated no main effect of Game condition, $F(1, 79) = 1.46$, $p = .23$, or Task order, $F(1, 79) = .19$, $p = .67$. The analysis showed a main effect of block, $F(4, 336) = 46.17$, $p < .05$, where compatibility effects decreased from Block 1 ($M = 48$ ms) to Block 5 ($M = 43$ ms), and a main effect of Trial type, $F(1, 79) = 457.91$, $p = < .05$, with participants responding quicker to compatible ($M = 352$ *ms*) than incompatible ($M = 400$ *ms*) trials, thus replicating the typical compatibility effect. In addition, a significant Game condition x Task order x Trial type interaction emerged, $F(1, 79) = 5.39$, $p = < .05$. Means associated with this interaction are shown in Figure 4. Because we were specifically interested in investigating the impact of video games on cognitive control, we probed the interaction by analyzing only incompatible trial RTs. Interestingly, within the aggression task first condition only, follow-up contrasts suggested that violent video game participants responded more slowly than their nonviolent game counterparts, $t(40) = 5.51$, $p = .02$. All other incompatible trial RT contrasts were nonsignificant (*t*s < 2.48, *p*s > .11). Thus, the compatibility effect appears to be larger for violent video game participants, but only after an intervening aggression task. No other effects in the overall model were significant (*F*s < 1.84, *p*s > .12).

Error rates. A third way violent video game play could impair performance on the spatial Stroop task is by increasing errors on incompatible ‘go’ trials. To test this hypothesis, the proportion of incompatible errors (i.e., incorrect behavior responses to incompatible trials) were analyzed using a 2 (Game condition) x 2 (Task order) x 5 (Trial block) mixed factorial ANOVA with repeated measures on the third factor. Results of this analysis indicated no main effect of Game condition, $F(1, 79) = .09$, $p = .76$, or Task order, $F(1, 79) = .04$, $p = .84$. The analysis showed a main effect of Block, $F(4, 316) = 4.30$, $p < .01$, indicating that participants committed a greater proportion of errors during the first block ($M = .16$) than final block ($M = .11$). All two-way interactions were nonsignificant (Fs < 1.94, ps > .10). However, a significant Game condition x Task order x Block interaction was evident, $F(4, 316) = 2.53$, $p < .05$. Means associated with this interaction are shown in Figure 5. Visual inspection of the means suggested that although errors for nonviolent game participants appeared to decrease across blocks, this decrease was only apparent when the Stroop was completed first. Therefore, to probe this interaction, the Block x Task order interaction was analyzed separately for violent and nonviolent video game participants. The Block x Task order interaction was significant for the nonviolent video game players, $F(4, 156) = 3.30$, $p = .01$, but not for the violent game players, $F(4, 160) = 0.76$, $p = .55$. To further characterize the pattern of means in this interaction, linear contrasts were computed for each of the 4 game x task order effects as a function of block. These analyses indicated that only participants in the nonviolent game condition who completed the Stroop task first showed a significant linear decrease in errors across blocks 1-5, $F(1, 79) = 13.74$, $p < .01$. Linear trends in all other conditions were not significant (Fs < 2.23, ps > .14).

ERP Analyses

N2 (evaluative control). Previous research has indicated that the N2 is an analogue of evaluative control (Botvinick et al., 2001) and tends to be most pronounced at fronto-central scalp locations (van Veen & Carter, 2002). Visual inspection of the waveforms on correct, incompatible trials for this experiment suggested N2 amplitudes were indeed largest over fronto-central locations. An initial 5 (Coronal location) x 3 (Sagittal location) within-subjects ANOVA confirmed the visual inspection. That is, the Coronal location x Sagittal interaction was significant, $F(8,624) = 28.0$, $p < .0001$. Inspection of the amplitudes suggested that N2 amplitudes were most prominent at the FZ scalp location for both incompatible ‘go’ trials and inhibition trials. To test the idea that playing a violent video game will interfere with the conflict monitoring system, separate hierarchical models predicting N2 amplitudes at FZ on correct only incompatible and inhibition trials were created with trait aggressiveness, anger or GEC included as moderators.

The first model investigated whether trait aggressiveness interacted with Game condition and Task order to predict N2 amplitudes on incompatible ‘go’ trials. As seen in Table 5, no main effects were significant on Step 1. Only the Game condition x trait aggressiveness interaction was significant on Step 2. Simple slope analyses indicated that for the nonviolent video game participants, N2 amplitudes and trait aggressiveness were unrelated ($\beta = .22$, $p = .18$). For the violent video game players, however, N2 amplitudes were negatively related to trait aggressiveness ($\beta = -.37$, $p = .02$), suggesting that physically aggressive individuals experience more conflict on less frequent, incompatible ‘go’ trials, but only if they play a violent video game. Scatter plots by Game condition may be seen in Figure 6. The 3-way interaction was nonsignificant. The second model predicting N2 amplitudes on incompatible ‘go’ trials investigated dispositional anger. Results of this model yielded no main effects of Game condition ($\beta = -.06$, $p = .63$) or Task order ($\beta = -.04$, $p = .70$), but did show a marginally nonsignificant main effect of Anger ($\beta = -.19$, $p = .09$). However, no significant 2 or 3-way interactions with trait anger were observed (βs < .20, *p*s > .09). The third model included the GEC as the individual difference. No main effects of Game condition (β = -.05, *p* = .67), Task order (β = -.01, *p* = .96) or GEC (β = -.06, *p* = .61) were observed. Also, the analysis showed no significant 2 or 3-way interactions (βs < .15, *p*s > .24).

N2 amplitudes at FZ on correctly inhibited 'no-go' trials also were submitted to the same hierarchical regression models. The first model investigated trait aggressiveness. Results showed no main effects (βs < .12, *p*s > .29). The 2 and 3-way interactions also were nonsignificant (βs < .19, *p*s > .13). The second model investigated trait anger. This model showed no main effects (βs < .12, *p*s > .31). Interestingly, only the Task order x Anger interaction was significant on the second step (β = -.23, *p* = .05). The 3-way interaction was marginally nonsignificant (β = .23, *p* = .06). The third model investigated the GEC. This model showed no main effects or 2-way interactions (see Table 6). However, the Game condition x Task order x GEC interaction was significant. To explore this interaction, the 2-way Task order x GEC interaction was analyzed within Game condition. Results showed that the 2-way interaction was significant in the violent (β = .34, *p* = .03) but not nonviolent (β = -.22, *p* = .18) video game condition. Therefore, the interaction was probed next by examining the simple slopes within the violent video game condition as a function of task order. Simple slopes indicated no relationship between the GEC and N2 amplitudes in the aggression-task-first condition (β = -.24, *p* = .31), but GEC was positively associated with N2 amplitudes in the Stroop-task-first condition (β = .45, *p* = .04). This pattern of results suggest that if low EF participants play a violent video game, evaluative control on inhibition trials diminishes (less conflict), but only if the Stroop task is completed immediately following the gaming session. Scatter plots within the violent video game condition may be seen in Figure 7.

NSW (regulatory control). Previous research (Curtin & Fairchild, 2003; West & Alain, 1999, 2000) has indicated that the NSW tends to be most pronounced at frontal, fronto-central and/or central scalp locations. Therefore, similar to the N2 analyses, NSW analyses were conducted at FZ. Visual inspection confirmed that NSW amplitudes were indeed large at the FZ scalp location. To test the idea that playing a violent video game will interfere with the regulatory system, separate hierarchical models predicting NSW amplitudes at FZ on correct only incompatible and inhibition trials were created with trait aggressiveness, anger or GEC as moderators.

The first model investigating NSW amplitudes on incompatible 'go' trials included trait aggressiveness (see Table 7). This model showed a main effect of Trait aggressiveness, suggesting that physically aggressive individuals were better at implementing regulatory control on incompatible 'go' trials. A marginally nonsignificant main effect of Task order also was observed. The main effect of Game condition was nonsignificant. As seen in Table 7, both the Game condition x Trait aggressiveness and Task order x Trait aggressiveness interactions were significant on Step 2. Importantly, the 2-way interactions were qualified by a significant 3-way Game condition x Task order x Trait aggressiveness interaction (Table 7). To explore the source of this interaction, the 2-way Task order x Trait aggressiveness interaction was analyzed within game condition. This analysis showed that the 2-way interaction was significant in both game conditions (βs > .35, *ps* < .03). Therefore, these interactions were next probed by investigating the simple slopes within each factorial condition. For the nonviolent video game participants, trait aggressiveness negatively predicted NSW amplitudes in the aggression task first condition (β = -.67, *p* < .01) but not Stroop task first condition (β = -.34, *p* = .15), suggesting that if physically aggressive participants play a nonviolent video game, regulatory control on incompatible trials increases (more control), but only if the Stroop task is completed second. For the violent video game participants, trait aggressiveness negatively predicted NSW amplitudes in the Stroop task first condition (β = -.63, *p* < .01) but not aggression task first condition (β = .38, *p* = .11), indicating that if physically aggressive participants play a violent video game, regulatory control on compatible trials increases, but only if the Stroop task is completed first. Simple slopes within the game conditions may be seen in Figure 8.

The second model investigated trait anger (see Table 8). Only the main effect of Task order was significant on Step 1. This main effect was driven by Stroop task first participants having smaller (more positive) NSW amplitudes on incompatible 'go' trials than aggression task first participants. However, this main effect was qualified only by a significant Game condition x anger interaction on Step 2. To probe this interaction, the simple slopes were analyzed within game condition. This analysis showed that trait anger negatively predicted NSW amplitudes in the nonviolent video game (β = -.39, *p* = .01) but not the violent video game (β = .17, *p* = .30) condition. These results indicate that dispositionally angry participants show improvements in regulatory control, but only if they play a nonviolent video game. Simple slopes with the game conditions may be seen in Figure 9. The 3-way interaction was nonsignificant in the model (see Table 8). The third model tested GEC. On the first step, only the main effect of Task order was significant. This main effect was once again driven by Stroop task first participants having smaller (more positive) NSW amplitudes on incompatible ‘go’ trials than aggression task first participants (β = .22, *p* = .05). All 2 and 3-way interactions were nonsignificant (βs < .21, *p*s > .10).

Next, the same analyses were conducted for NSW amplitudes on ‘no-go’ trials. The first model tested trait physical aggressiveness. This model showed no main effects (see Table 9). Only the Game condition x Trait aggressiveness interaction was significant on Step 2. However, this 2-way interaction was qualified by a significant Game condition x Task order x Trait aggressiveness interaction. The 3-way interaction was investigated by examining the Task order x Trait aggressiveness interaction within game condition. Results of this analysis showed that the 2-way interaction was significant in the nonviolent video game condition (β = .32, *p* = .05), whereas this 2-way interaction was marginally nonsignificant in the violent video game condition (β = -.31, *p* = .06). Therefore, simple slopes were once again calculated within each factorial condition. In the nonviolent video game condition, trait aggressiveness negatively predicted NSW amplitudes on inhibition trials in the aggression task first condition (β = -.62, *p* < .01) but not Stroop task first condition (β = -.07, *p* = .76), suggesting that if physically aggressive participants play a nonviolent video game, regulatory control on inhibition trials increases (more control), but only for aggression-task-first participants. In the violent video game condition trait aggressiveness positively predicted NSW amplitudes in the aggression task first condition (β = .52, *p* = .02) but not Stroop task first condition (β = .18, *p* = .46), suggesting that if physically aggressive participants play a violent video game, regulatory control on inhibition trials decreases (less control), but only for aggression-task-first participants. Scatter plots by video game condition may be seen in Figure 10.

The second model tested trait anger. This model showed no main effects (βs < .14, *p*s > .25). All 2 and 3-way interactions were nonsignificant (βs < .20, *ps* > .10). The final model included GEC as a moderator. This model showed no main effects (βs < .14, *p*s > .24). Further, the 2 and 3-way interactions all were non-significant (βs < .23, *p*s > .07).

Discussion

The extant literature on violent video games suggests these games increase the risk for aggressive behaviors (Anderson, 2004; Anderson al., 2010 Anderson & Bushman, 2001; Sherry, 2001). These increases in aggression are easily accounted for by the GAM, which suggests that the effects of violent video games on outcome variables (e.g., increases in aggression) are probably best understood by examining the individual within a situation (Anderson & Bushman, 2002).

Consistent with the predictions of the GAM, playing a violent video game caused increases in aggression for participants high in dispositional anger or who experience greater problems with behavior regulation. Inhibition control tended to be more problematic for low EF participants, but only if they play a violent video game. Violent video games also caused larger compatibility effects (i.e., decrements in cognitive control), but only after an intervening aggression task. Interestingly, only participants in the nonviolent, Stroop-task-first condition showed a significant decrease in errors on incompatible trials. The current experiment also showed that acute exposure to violent video games differentially affects evaluative and regulatory systems for certain individuals. Neural correlates of evaluative control showed that physically aggressive participants who played a violent video game exhibited greater evaluative control (more conflict) on incompatible trials, whereas low EF participants who played a violent video game showed diminished evaluative control (less conflict) on inhibition trials, though only in the Stroop-task-first condition. Neural correlates of regulatory control showed that physically aggressive participants who played a violent game exhibit increases in regulatory control on incompatible 'go' trials, but only in the Stroop-task-first condition, whereas participants high in dispositional anger also experienced improvements in regulatory control on these trials, but only if they played a nonviolent video game. Finally, physically aggressive participants who played a violent video game experienced diminished regulatory control on inhibition trials, but only after an intervening aggression task, whereas physically aggressive participants who played a nonviolent video game showed enhanced regulatory control, though only after an intervening aggression task.

Behavioral Effects

In line with previous research, the effects of acute violent video game exposure on aggression appear to be important for certain individuals (Anderson & Bushman, 2002). Although aggressive participants tended to set higher noise levels regardless of experimental condition, participants high in dispositional anger or low in behavior regulation showed increases in aggression, but only if they played a violent video game. These results extend previous work showing that angry participants who play violent video games complete ambiguous stories more aggressively (Giumetti & Markey, 2007). Not only are aggressive thoughts more accessible for angry individuals following acute violent video game exposure, these cognitions might then drive aggressive behavior. To the best of our knowledge, this is the first experiment to demonstrate that EF abilities (e.g., behavior regulation) play a role in determining which individuals are at an increased risk for aggression following acute violent video game exposure. Because participants were under time pressure when selecting the levels of noise intensity (i.e., one analogue for impulsive aggression), we feel the current results both apply to and extend pre-existing models linking low EF to increases in impulsive aggression (Giancola, 2000). It may well be the case that individuals chronically low in EF abilities that play violent video games have even less access to the agent informing behaviors that require executive control (e.g., aggression) (Baumeister and Boden, 1998).

Many psychological theories suggest that cognitive control is a cornerstone of effective self-regulation (e.g., Miyake et al., 2000; Stanovich; 2004). In the Stroop task used here, one laboratory analogue of self-regulation, correct implementation of cognitive control is evident when participants: 1) respond correctly to trials in which conflicting response channels (arrow direction vs. arrow location) are simultaneously activated, 2) disengage from a behavioral response (inhibit) when necessary, or 3) exhibit smaller compatibility effects (smaller RT differences between compatible and incompatible trials). Participants who played a violent video game exhibited no more difficulty with conflicting response strategies (incompatible errors) than nonviolent video game participants. To the contrary, only the nonviolent, Stroop first participants showed a decrease in error rates to incompatible trials, suggesting that nonviolent games also have the potential to affect the rate at which self-regulation may be correctly implemented. This finding suggests that nonviolent video games may not be adequate controls in experimental designs, as they have the ability to elicit their own effects (Sestir & Bartholow, 2010). Consistent with predictions, however, individuals with diminished EF ability who play a violent video game tend to commit a greater proportion of errors on inhibition trials. Perhaps individuals low in EF ability experience greater residual effects on response strategies following the violent games. More specifically, to the extent the behavioral activation system (see Carver & White, 1994) is “primed” by violent video games (i.e., unconstrained activation of the ‘go’ or ‘shoot’ response), it could be possible that participants lower in EF ability have more difficulty accessing the behavioral inhibition system on open-headed arrow trials. Larger compatibility effects also were observed for violent (vs. nonviolent) video game participants, but only if the aggression task was completed first. Though unexpected, two possibilities might help explain this finding. First, following acute exposure to violent video games, having an opportunity to act aggressively prior to engaging in tasks that require cognitive control might represent a special sequence effect. Second, time delays could be important. Because the Stroop task second participants completed the cognitive control task approximately 15 minutes after the video game, the passage of time could account for the larger compatibility effects. These two explanations could be teased apart, for example, by including a condition where nonviolent and violent video game participants either first complete an intervening aggression task or boring, filler task (e.g., drawing a detailed campus map) followed a cognitive control task.

Psychophysiological Effects

Current cognitive neuroscience models of cognitive control posit that control is mediated by evaluative (N2) and regulatory (NSW) components, both of which are thought to be reflected by heightened activity in ACC (Bartholow, Dickter, & Sestir, 2006; Curtin & Fairchild, 2003; van Veen & Carter, 2002; Botvinick et al., 2001; Kiehl et al., 2000; West & Alain, 1999; Carter et al., 1998). Conversely, reduced N2 and NSW amplitudes on high-conflict (less frequent incompatible trials) or inhibition (‘no-go’) trials could be attributed to poorer evaluative and regulatory control, respectively. According to the conflict monitoring hypothesis, N2 amplitudes are sensitive to the conflict associated with both trial type frequency and prepotent response strategy (see Nieuwenhuis et al., 2003; Dickter & Bartholow, 2010). In the current experiment, psychophysiological measures of evaluative and regulatory control differed as a function of video game condition for particular individuals.

Results suggested that whereas physically aggressive participants who play a violent video game experience increases in analogues of evaluative control on high-conflict trials, participants lower in EF abilities show the opposite effect (i.e., decreases in evaluative control) on inhibition trials. Though not predicted, it’s certainly interesting that physically aggressive participants who play a violent game show increases in evaluative control (more conflict) on less frequent trials. One explanation might be that for physically aggressive people, violent video games uniquely activate cognitions consistent with a heightened vigilance of, for example, potential enemies (i.e., conflict detection). As expected, participants lower in EF abilities that play a violent video game show decrements in evaluative control on inhibition trials, but only if they engage in the cognitive control task immediately following the violent video game. In theory, low EF participants possess fewer EF resources. When these low EF participants are taxed by, for example, a violent video game, participants low in EF abilities thus experience greater difficulty with evaluative control on inhibition trials. Because the relationship between EF ability and evaluative control on inhibition trials for participants who played a violent game was only observed during the Stroop task first condition, the short-term effects of violent video games on outcomes of interest should be investigated more systematically (Barlett et al., 2009; Sestir & Bartholow, submitted).

Empirical support for violent video games disrupting the regulatory system for particular individuals also was found. That is, physically aggressive participants showed decrements in regulatory control on inhibition trials, but only in the aggression-task-first condition. This finding once again implies that acting aggressively prior to a cognitive control task might exacerbate problems associated with regulative control for physically aggressive participants. This finding is juxtaposed with physically aggressive participants in the violent video game condition showing better (not worse) regulatory control on incompatible 'go' trials in the Stroop-task-first condition. Although seemingly discrepant, we believe important distinctions can be made between these two trial types. Although both types of trials require cognitive control (i.e., both are less-frequent), inhibition trials also add an additional element to the response selection process (i.e., disengage from the prepotent response of 'go'). It thus appears that physically aggressive participants are better at implementing control when trials are less frequent, but not when these less frequent trials require the inhibition of prepotent response activation (i.e., further processing). That dispositionally angry participants who play nonviolent (but not violent) video games show increases in regulatory control on incompatible trials also is interesting. This result perhaps suggests that to the extent regulatory control is important, recommending nonviolent video games for dispositionally angry participants is prudent.

Taken together, the neural correlates of evaluative and regulatory control are moderated by video game type and particular individual differences (i.e., the person within the situation). The current data suggest that communication between the two systems might become jeopardized if particular individuals play violent video games. More specifically, physically aggressive participants experience both enhances to the evaluative system and decreases to the regulatory system. It could be possible that physically aggressive individuals don't necessarily experience problems when evaluating specific scenarios following acute exposure to violent video games; it's simply that they have more difficulty in situations requiring self-regulation (e.g., a hostile situation involving a physically larger individual).

Conclusions

To the best of our knowledge, this is the first experiment to document how pre-existing EF (cognitive) abilities moderate the relationship between acute violent video game exposure and specific outcomes (inhibition, aggression), largely supporting the idea that people lower in EF ability will find it difficult to disengage from aggressive impulses following certain environmental stimuli (i.e., violent video game exposure) (Giancola, 2000). To date, we also believe this is the only experiment documenting how particular traits (e.g., physical aggressiveness) moderate the relationship between violent video game exposure and psychophysiological markers of evaluative and regulatory control.

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Footnotes

1. We chose to not use the total GEC to predict noise intensity scores because it includes subscales (e.g., organization of materials) that have little or no theoretical relevance to aggression.

Table 1.

Hierarchical Regression Model Predicting Noise Intensity with Trait Aggressiveness, Task Order, Video Game Condition and their Interactions.

Model	Δ Adj. R^2	β
Step 1	.08*	
Game		-.01
Task order		-.11
Trait aggr.		.31**
Step 2	.10	
Game x Task order		-.18
Game x Trait aggr.		.07
Task order x Trait aggr.		.08
Step 3	.11	
Game x Task order x Trait aggr.		.15

Note: Trait aggr. = Trait aggressiveness. Δ Adj. $R^2 =$ change in adjusted R^2 (by adding the step), β = standardized regression coefficient. *$p < .05$. **$p < .01$.

Table 2.

Hierarchical Regression Model Predicting Noise Intensity with Anger, Task Order, Video Game Condition and their Interactions.

Model	Δ Adj. R^2	β
Step 1	.00	
Game		-.01
Task order		-.16
Trait anger		.09
Step 2	.16**	
Game x Task order		-.17
Game x Trait anger		.36**
Task order x Trait anger		-.01
Step 3	.15	
Game x Task order x Trait anger		-.06

Note: Δ Adj. R^2 = change in adjusted R^2 (by adding the step), β = standardized regression coefficient. ** $p < .01$.

Table 3.

Hierarchical Regression Model Predicting Noise Intensity with Behavior Regulation, Task Order, Video Game Condition and their Interactions.

Model	Δ Adj. R^2	β
Step 1	.02	
Game		-.05
Task order		-.18
BR		.13
Step 2	.10*	
Game x Task order		-.20†
Game x BR		.27*
Task order x BR		-.06
Step 3	.06	
Game x Task order x BR		-.01

Note: BR = Behavior regulation. Δ Adj. R^2 = change in adjusted R^2 (by adding the step), β = standardized regression coefficient. †$p < .10$. *$p < .05$.

Table 4.

Hierarchical Regression Model Predicting Proportion of Inhibition Errors with the Global Executive Composite, Task Order, Video Game Condition and their Interactions.

Model	Δ Adj. R^2	β
Step 1	-.03	
Game		-.07
Task order		-.03
GEC		.05
Step 2	.00	
Game x Task order		-.01
Game x GEC		.27*
Task order x GEC		.00
Step 3	.01	
Game x Task order x GEC		-.15

Note: GEC = Global Executive Composite. Δ Adj. R^2 = change in adjusted R^2 (by adding the step), β = standardized regression coefficient. *$p < .05$.

Table 5.

Hierarchical Regression Model Predicting N2 Amplitudes on Incompatible 'Go' Trials with Trait Aggressiveness, Task Order, Video Game Condition and their Interactions.

Model	Δ Adj. R^2	β
Step 1	-.02	
Game		-.05
Task order		-.08
Trait aggr.		-.09
Step 2	.05*	
Game x Task order		.15
Game x Trait aggr.		-.28*
Task order x Trait aggr.		.06
Step 3	.05	
Game x Task order x Trait aggr.		.12

Note: Trait aggr. = Trait aggressiveness. Δ Adj. $R^{2=}$ change in adjusted R^2 (by adding the step), β = standardized regression coefficient. *$p < .05$.

Table 6.

Hierarchical Regression Model Predicting N2 Amplitudes on Inhibition 'No-go' Trials with the Global Executive Composite, Task Order, Video Game Condition and their Interactions.

Model	Δ Adj. R^2	β
Step 1	.00	
Game		.07
Task order		-.15
GEC		.09
Step 2	-.02	
Game x Task order		.00
Game x GEC		.12
Task order x GEC		.07
Step 3	.05*	
Game x Task order x GEC		.30*

Note: GEC = Global Executive Composite. Δ Adj. R^2 = change in adjusted R^2 (by adding the step), β = standardized regression coefficient. *p < .05.

Table 7.

Hierarchical Regression Model Predicting Negative Slow Wave (NSW) Amplitudes on Incompatible 'Go' Trials with the Trait Aggressiveness, Task Order, Video Game Condition and their Interactions.

Model	Δ Adj. R^2	β
Step 1	.12**	
Game		-.01
Task order		.19†
Trait aggr.		-.32**
Step 2	.20*	
Game x Task order		.15
Game x Trait aggr.		.29**
Task order x Trait aggr.		-.22‡
Step 3	.28**	
Game x Task order x Trait aggr.		-.31**

Note: Trait aggr. = Trait Aggressiveness. Δ Adj. R^2 = change in adjusted R^2 (by adding the step), β = standardized regression coefficient. †$p < .10$. ‡$p = .05$. *$p < .05$. **$p < .01$.

Table 8.

Hierarchical Regression Model Predicting Negative Slow Wave (NSW) Amplitudes on Incompatible 'Go' Trials with Trait Anger, Task Order, Video Game Condition and their Interactions.

Model	Δ Adj. R^2	β
Step 1	.04	
Game		-.04
Task order		.23‡
Trait anger		-.11
Step 2	.11*	
Game x Task order		.13
Game x Trait anger		.32**
Task order x Trait anger		-.09
Step 3	.11	
Game x Task order x Trait anger		.11

Note: Δ Adj. $R^{2\,=}$ change in adjusted R^2 (by adding the step), β = standardized regression coefficient. ‡*p* = .05. **p* < .05. ***p* < .01.

Table 9.

Hierarchical Regression Model Predicting Negative Slow Wave (NSW) Amplitudes on Inhibition 'No-go' Trials with Trait Aggressiveness, Task Order, Video Game Condition and their Interactions.

Model	Δ Adj. R^2	β
Step 1	-.02	
Game		-.12
Task order		.09
Trait aggr.		-.01
Step 2	.18**	
Game x Task order		.02
Game x Trait aggr.		.50**
Task order x aggr.		-.15
Step 3	.21‡	
Game x Task order x Trait aggr.		-.22‡

Note: Trait aggr. = Trait Aggressiveness. Δ Adj. R^2 = change in adjusted R^2 (by adding the step), β = standardized regression coefficient. ‡$p = .05$. **$p < .01$.

Figure Captions

1. Noise blast intensity as a function of game condition and trait anger (standardized). More positive trait anger scores reflect greater anger. Analyses showed a significant 2-way interaction, indicating that trait anger tended to negatively predict noise intensity in the nonviolent video game condition, whereas trait anger positively predicted noise intensity scores in the violent video game condition.

2. Noise blast intensity as a function of game condition and problems with self-reported behavior regulation (BRI; Roth et al., 2005) (standardized). More positive behavior regulation index scores reflect greater problems with behavior regulation. Analyses showed a significant 2-way interaction, indicating that problems with behavior regulation positively predicted noise intensity scores in the violent (but not nonviolent) video game condition.

3. Total proportion of inhibition errors as a function of problems with self-reported global executive functioning (GEC; Roth et al., 2005) (standardized). More positive GEC scores reflect greater problems with global executive functioning abilities. Analyses showed a significant 2-way interaction, indicating that problems with inhibition control tended to be more difficult for participants lower in executive functioning abilities if they play a violent (but not nonviolent) video game.

4. Mean reaction times as a function of trial type, game condition and task order. Analysis of these data showed a significant 3-way interaction, indicating that, compared to the nonviolent participants, violent video game participants showed larger compatibility effects, but only if the aggression task was completed first. Agg first = aggression first. Error bars represent ± 1 standard error of the mean.

5. Mean proportion of incompatible ‘go’ trial errors as a function of game condition, task order and block. Analysis of these data showed a significant 3-way interaction, indicating that only participants in the nonviolent, Stroop first condition exhibited a linear decrease in error rates across the cognitive control task. Blk = block. Error bars represent ± 1 standard error of the mean.

6. Peak N2 amplitudes at FZ on incompatible ‘go’ trials as a function of game condition and trait aggressiveness (standardized). More positive trait aggressiveness scores reflect greater trait aggressiveness. Analysis of these data showed a significant 2-way interaction, such that trait aggressiveness negatively predicted N2 amplitudes in the violent (but not nonviolent) video game condition.

7. Peak N2 amplitudes at FZ on ‘no-go’ trials as a function of task order and problems with self-reported global executive functioning (GEC; Roth et al., 2005) (standardized) within the violent video game condition. More positive GEC scores reflect greater problems with global executive functioning abilities. Analyses of these data showed a significant 3-way interaction, largely driven by GEC scores positively predicting N2 amplitudes in the Stroop-task-first (but not aggression-task-first) condition.

8. Mean negative slow wave (NSW) amplitudes at FZ on incompatible ‘go’ trials as a function of game condition, task order and trait aggressiveness (standardized). More positive trait aggressiveness scores reflect greater trait aggressiveness. Analyses showed a significant 3-way interaction, with trait aggressiveness negatively predicting NSW amplitudes in both the nonviolent, aggression-task-first condition and violent, Stroop-task-first condition.

9. Mean negative slow wave (NSW) amplitudes at FZ on incompatible ‘go’ trials as a function of game condition and trait anger (standardized). More positive trait anger scores reflect greater trait anger. Results showed a significant 2-way interaction, indicating that trait anger negatively predicted NSW amplitudes on incompatible ‘go’ trials in the nonviolent (but not violent) video game condition.

10. Mean negative slow wave (NSW) amplitudes at FZ on ‘no-go’ trials as a function of game condition, task order and trait aggressiveness (standardized). More positive trait aggressiveness scores reflect greater trait aggressiveness. Results showed a significant 3-way interaction, suggesting that whereas trait aggressiveness negatively predicted NSW amplitudes in the nonviolent, aggression-task-first condition, trait aggressiveness positively predicted NSW amplitudes in the violent, aggression-task-first condition.

Figure 1

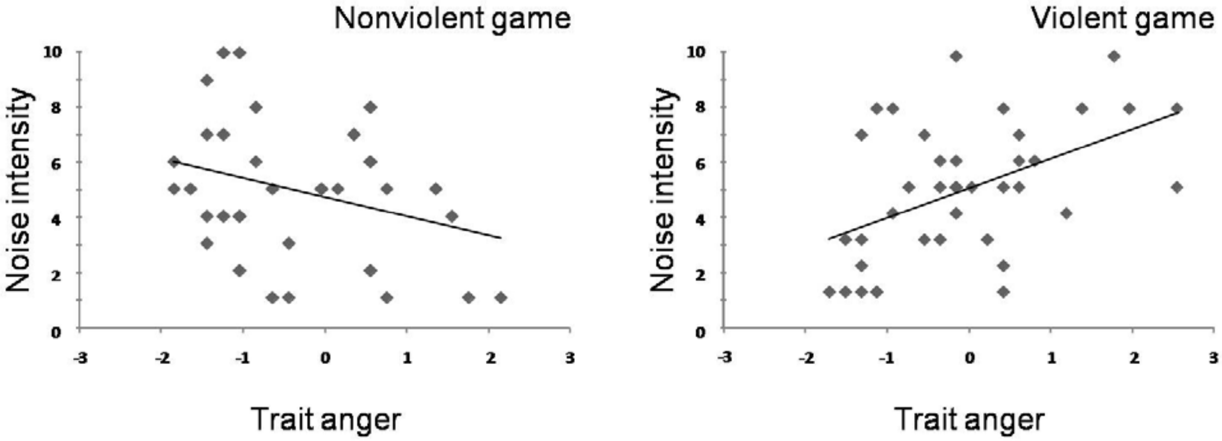

Nonviolent game
Violent game
Noise intensity
Trait anger
0
2
4
6
8
10
-3
-2
-1
0
1
2
3

Figure 2

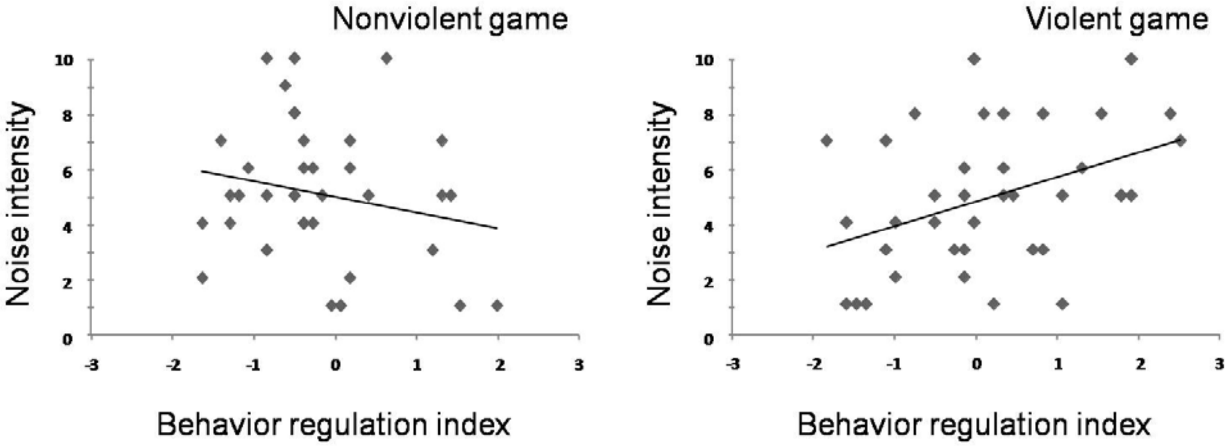

Nonviolent game
Noise intensity
0
2
4
6
8
10
-3
-2
-1
0
1
2
3
Behavior regulation index
Violent game
Noise intensity
0
2
4
6
8
10
-3
-2
-1
0
1
2
3
Behavior regulation index

Figure 3

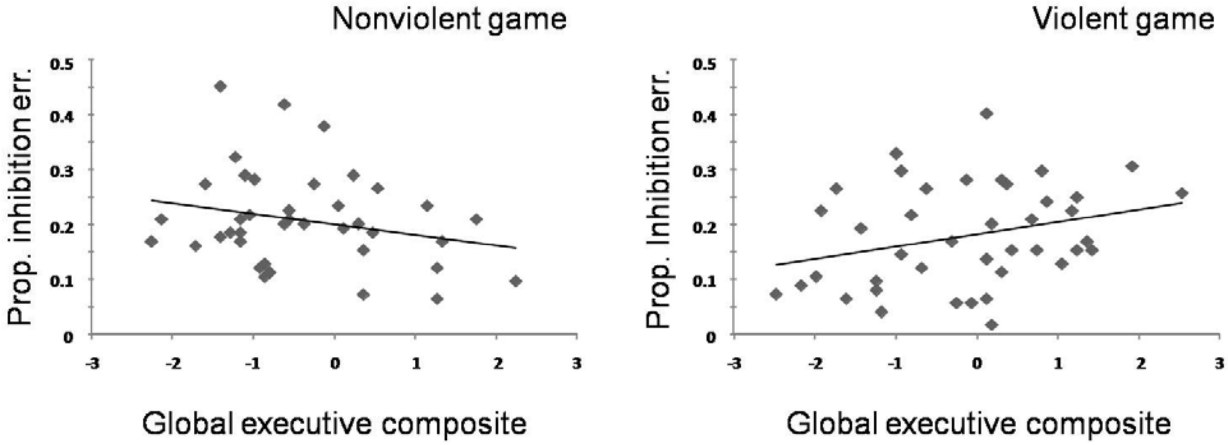

Nonviolent game
Prop. inhibition err.
0.5
0.4
0.3
0.2
0.1
0
-3
-2
-1
0
1
2
3
Global executive composite
Violent game
Prop. Inhibition err.
0.5
0.4
0.3
0.2
0.1
0
-3
-2
-1
0
1
2
3
Global executive composite

Figure 4

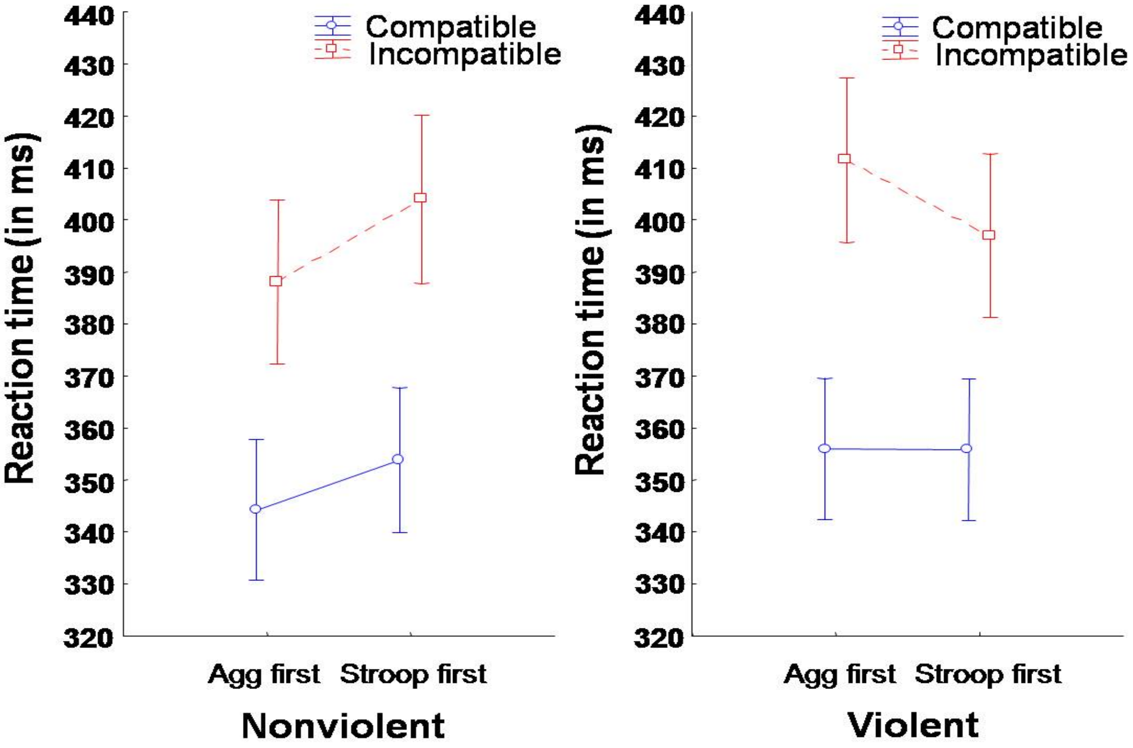

Reaction time (in ms)
440
430
420
410
400
390
380
370
360
350
340
330
320
Compatible
Incompatible
Agg first
Stroop first
Nonviolent
Reaction time (in ms)
440
430
420
410
400
390
380
370
360
350
340
330
320
Compatible
Incompatible
Agg first
Stroop first
Violent

Figure 5

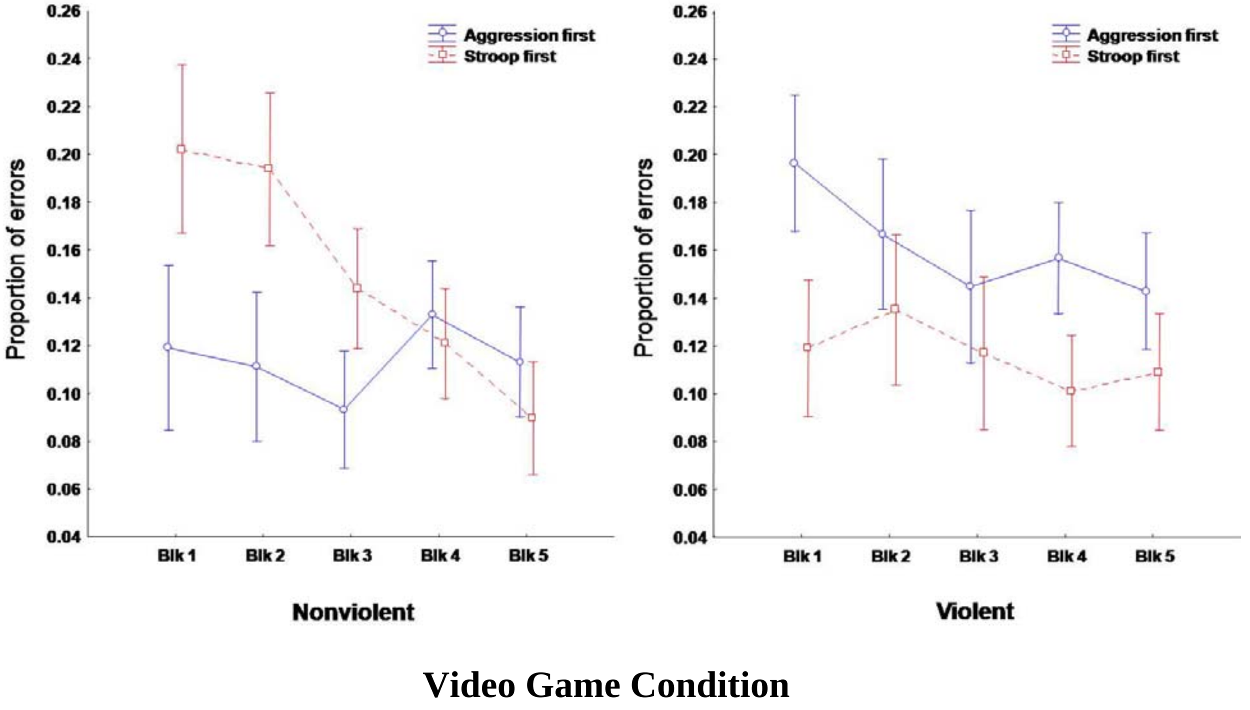
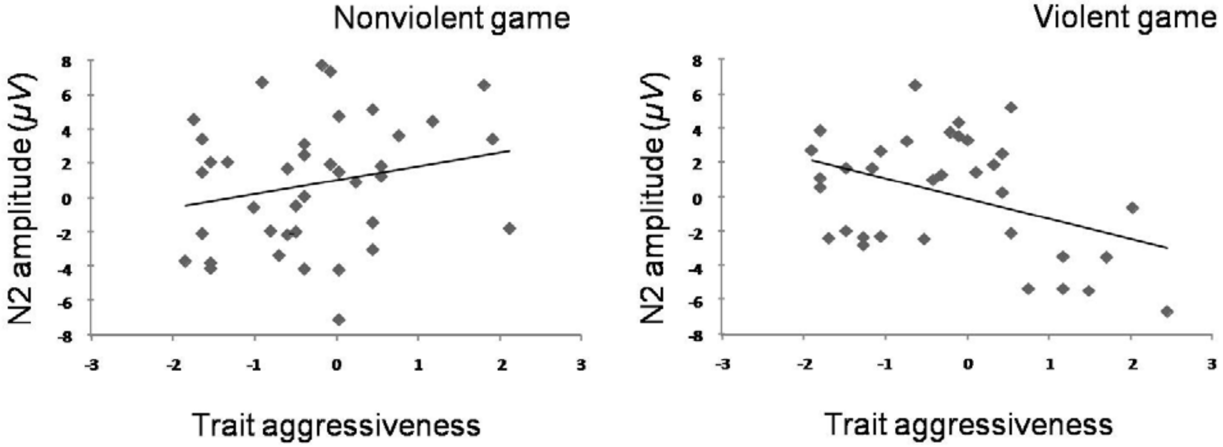

0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
Proportion of errors
Aggression first
Stroop first
Blk 1
Blk 2
Blk 3
Blk 4
Blk 5
Nonviolent
Violent
Video Game Condition

Figure 6



Nonviolent game

Violent game

Figure 7

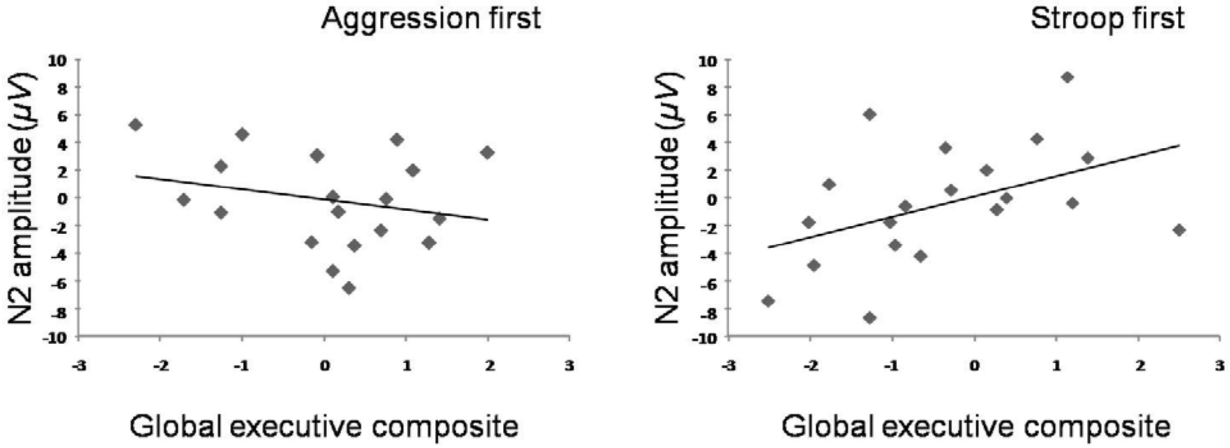

Aggression first
Stroop first
N2 amplitude (μV)
10
8
6
4
2
0
-2
-4
-6
-8
-10
-3
-2
-1
0
1
2
3
Global executive composite

Figure 8

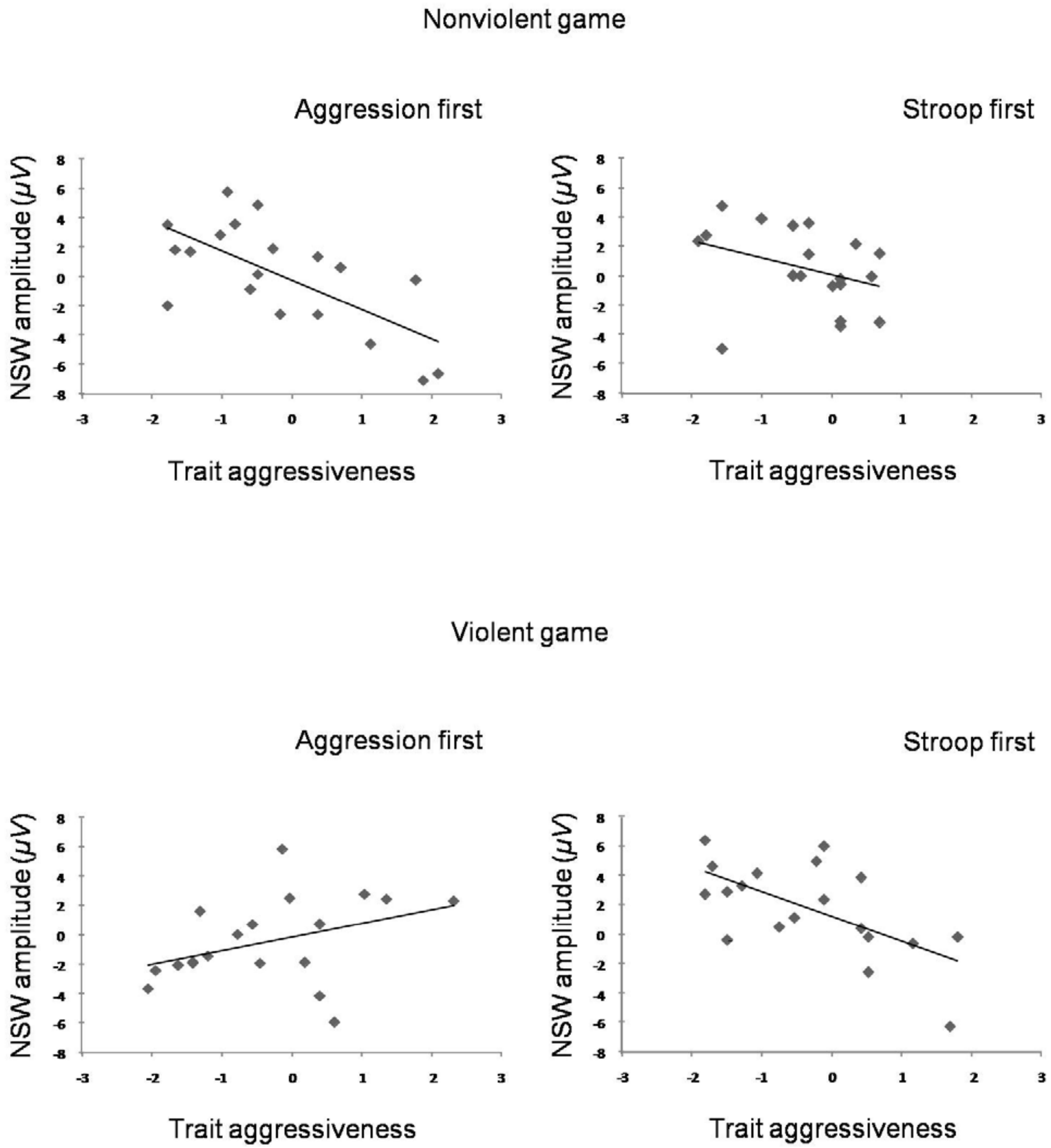

Nonviolent game
Aggression first
Stroop first
NSW amplitude (μV)
8
6
4
2
0
-2
-4
-6
-8
-3
-2
-1
0
1
2
3
Trait aggressiveness
Violent game
Aggression first
Stroop first
NSW amplitude (μV)
Trait aggressiveness

Figure 9

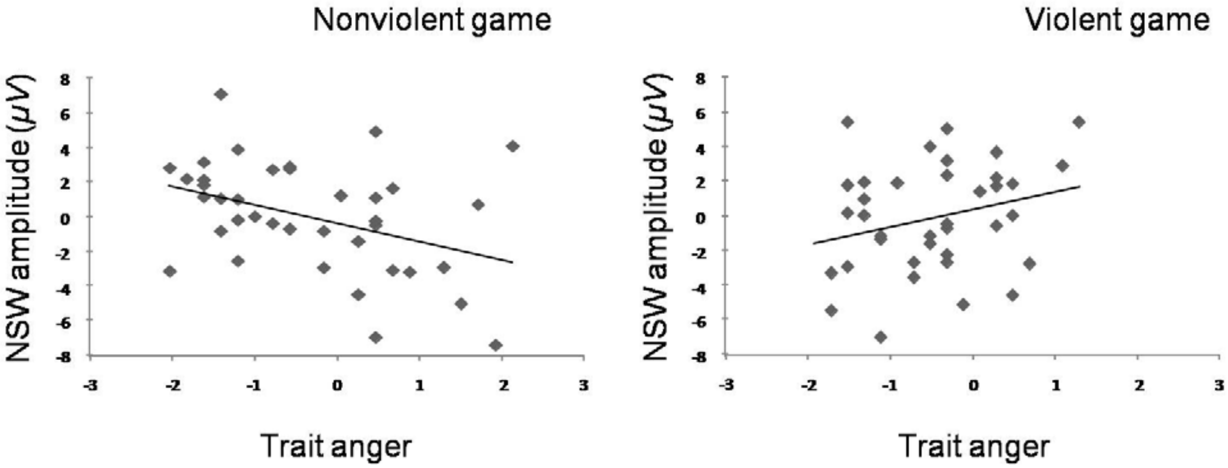
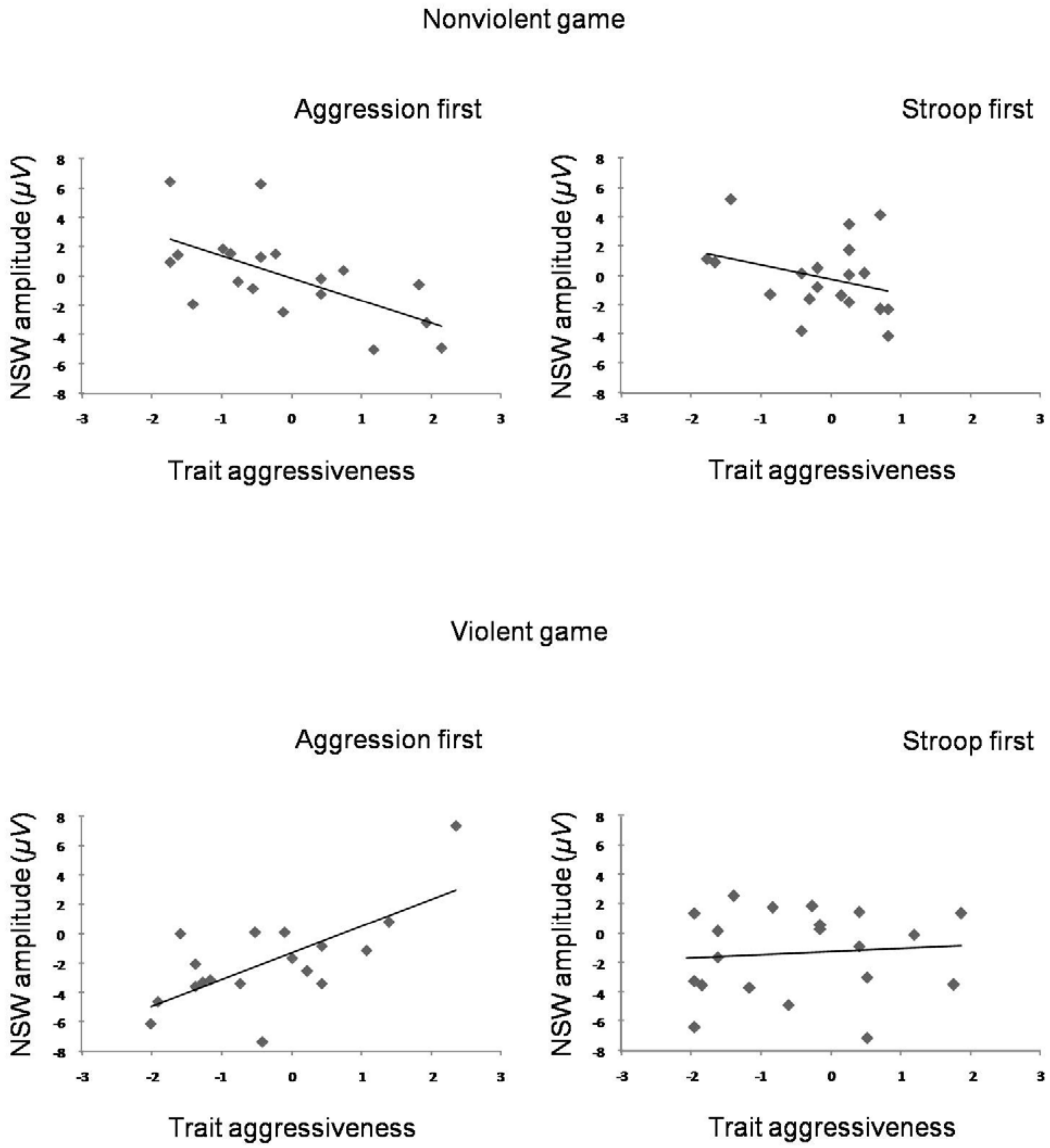

Nonviolent game
Violent game
NSW amplitude (μV)
8
6
4
2
0
-2
-4
-6
-8
-3
-2
-1
0
1
2
3
Trait anger

Figure 10


Nonviolent game
Aggression first
Stroop first
NSW amplitude (μV)
8
6
4
2
0
-2
-4
-6
-8
-3
-2
-1
0
1
2
3
Trait aggressiveness
Violent game
Aggression first
Stroop first
NSW amplitude (μV)
Trait aggressiveness