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Differential Neural Recruitment During Violent Video Game Play in Violent- and Nonviolent-Game Players

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A controversy exists about the effects of violent video game play, with some studies showing "positive" effects on spatial attention, others showing "negative" effects on aggression, and others suggesting that there are no important effects. The present study examined neural recruitment during violent videogame play among 13 late adolescent gamers, half of whom habitually played violent games and half of whom habitually played nonviolent games. Participants played a video game in violent and nonviolent modes while undergoing functional MRI scanning. Nonviolent gamers had an increase in emotional response regions when playing the violent game; violent gamers demonstrated an active suppression of these same regions. In addition, nonviolent gamers showed increases in spatial attention, navigation, and cognitive control regions, whereas experienced violent gamers showed no change from baseline. These results provide neurological support for both aggression desensitization and improvements in spatial attention, but not for the hypothesis that violent games have no appreciable effect.

Keywords: video games, fMRI, spatial attention, desensitization, violent video games

The effect of violent video game play has been an area of controversy in the past decade. Often the public debate revolves around tragedies, such as the Newtown school shooting in 2012. Unfortunately, the popular press often reduces complex issues such as aggression to simplistic statements. For example, although 70% of people agreed that psychology can make major contributions to the debate on video game violence, only 24% agreed that media coverage contributes to better information (Sjöström, Sowka, Gollwitzer, Klimmt, & Rothmund, 2013). A recent content analysis provides supporting evidence that the public view is accurate, demonstrating that public coverage of the scientific research has shifted to a tone that favors ambiguity and conflict among opinions (Martins et al., 2013). Nonetheless, there has been an increasing amount of scientific research that can inform the debate. Several studies have documented short-term increases in aggression and desensitization (e.g., Anderson, 2004; Anderson & Bushman, 2001; Anderson, Gentile, & Buckley, 2007; Anderson et al., 2008, 2010; Bushman & Anderson, 2009; Bushman & Huesmann, 2006; Carnagey, Anderson, & Bushman, 2007), and some have documented long-term effects (Anderson et al., 2007, 2008, 2010; Bartholow, Bushman, & Sestir, 2006; Hopf, Huber, & Weiss, 2008; Moeller & Krahe, 2009), although some researchers have argued

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that these effects are overstated (e.g., Ferguson, 2007a, 2010; Ferguson, San Miguel, & Hartley, 2009; Kutner & Olson, 2008; Straud-Muller, Bliesener, & Luthman, 2008). In addition, other studies have documented several potential benefits of violent video game play (Green & Bavelier, 2003, 2006a, 2006b, 2007). This controversy about whether violent video games have positive, negative, or no important effects has been fueled, in part, by a paucity of experimental research on brain functioning when playing violent games. The present study was designed to examine neural recruitment during violent video game play, as well as to determine whether neural recruitment during game play differs for individuals who primarily play violent or nonviolent games as part of their leisure activities.

The body of research on violent video game play effects on aggression-related variables is becoming sizable. The most comprehensive meta-analysis conducted to date included 136 articles detailing 381 independent tests of association conducted on 130,296 research participants (Anderson et al., 2010). Violent video game play was significantly associated with desensitization, physiological arousal, aggressive cognition and behavior, and with decreased prosocial behavior. These effects fit within several well-tested aggression theories, although most research in this area has been guided by the General Aggression Model (Anderson & Bushman, 2002; Carnagey & Anderson, 2003). This metatheory notes that any aggressive stimulus can (but does not necessarily) have both short-term and long-term effects, especially if it is repeated. The preponderance of research fits this theory well. Critics of this literature, however, have noted that not all studies demonstrate results in support of the hypothesis that violent video games increase desensitization and aggression (Ferguson et al., 2009; Kutner & Olson, 2008; Olson et al., 2007). It seems to us that this is to be expected—not every study should find identical results. Meta-analyses are valuable for precisely this reason, providing estimates of the effect size across all studies (including unpublished studies). It is interesting to note that even the critics' meta-analyses tend to find similar effect sizes, although they interpret them as being of no practical significance (Ferguson, 2007a, 2007b; Sherry, 2001).

A second body of research focuses on what are sometimes called "action" video games (Green & Bavelier, 2003), although in practice, these are usually violent first-person shooter games such as *Unreal Tournament* or *Medal of Honor*. Besides including violent content, action games include high speed, high perceptual and motor load, unpredictability, and an emphasis on peripheral processing. In several training studies, these games have been found to affect multiple aspects of perceptual processing, including multiple object tracking (Green & Bavelier, 2006b), spatial resolution (Green & Bavelier, 2007), and central and peripheral attention skills (Green & Bavelier, 2006a).

Although these studies on violent game effects are often taken by the general public and by social commentators to be contradictory, it is likely that violent games can have effects both on aggression-related and perception-related variables. That is, violent video game playing may simultaneously produce both positive effects (e.g., improvements at a perceptual level) and negative effects (e.g., aggressive inclinations, desensitization; Gentile, 2011). Behavioral studies have tended focus on only one system at a time, either visual perception skills or aggression-related outcomes. To some extent, this is necessary because of the complexity of such behavior studies. In contrast, functional MRI (fMRI) studies of the effects of violent compared with nonviolent video games could find evidence that brain systems involved in both visual attention and aggression are concurrently recruited by video game play.

Prior fMRI studies of video game violence are scarce, and can be classified into one of three categories. One type involves comparing two or more groups of participants who differ in their past experience with media violence, recording fMRI data while each participant performs a series of cognitive and/or affective tasks, such as the Stroop task, which is usually used to measure executive control. For example, Mathews et al. (2005) found that high media violence participants displayed lower anterior cingulate activation during the Stroop task than low media violence participants. A second type of study compares brain activation during different parts (e.g., violent vs. nonviolent) of game play, within the same violent game. Weber, Ritterfeld, and Mathiak (2006) found an active suppression of emotional areas (rostral anterior cingulate cortex and amygdala) as well as increased activity in planning and control areas (dorsal anterior cingulate cortex), specifically around the time of firing a weapon in a violent video game. The third type of study is truly experimental in nature. In this type, participants play a randomly assigned violent or nonviolent video game for a brief period of time (20–30 min), and then perform some tasks while fMRI data are collected. For example, Wang et al. (2009) examined brain activity during a Counting Stroop task and during an Emotional Stroop task. Among their many findings was that participants who had just played a violent game displayed relatively lower functional connectivity between the left dorsolateral prefrontal cortex and the anterior cingulated cortex during the Counting Stroop task. Similarly, Hummer et al. (2010) found that playing a violent video game decreased activity in prefrontal cortex regions thought to be involved in cognitive inhibition, during a Go-No Go task.

Several studies have used electroencephalogram (EEG) data to examine potential associations between violent video games and brain function. For example, event-related potential studies have suggested decreased proactive executive control and increased emotional desensitization to violence among chronic violent video game players (Bailey, West, & Anderson, 2011; Bartholow et al., 2006). In sum, there is evidence that violent and nonviolent video games may have differential effects on fundamental brain activity relating to visual/spatial attention, executive control, and emotional information processing.

These prior studies have been useful in delineating differences between gamers and nongamers, and in suggesting causal effects of violent game play on several aspects of brain function. Nonetheless, important gaps in the literature remain. For example, there is ambiguity about whether observed differences between gamers and nongamers is the result of extensive play of violent games, or the result of extensive play of any type of video game. A related controversy is whether all gamers have similar responses to violent games (Markey & Markey, 2010). Some studies have demonstrated that high violent gamers may have differential brain responses (Bailey, West, & Anderson, 2010; Kalnin et al., 2011), which may be an index of plasticity and long-term change from game play. The present study, therefore, recruited two types of gamers: those who habitually play violent first-person-shooter style games and those who habitually play other less violent styles of games. fMRI data were gathered while each participant played the same first-person game in both violent and nonviolent modes.

Method

Participants

Young adult male computer and video game players (ages: 18–21 years) were recruited via advertisements posted on the Minneapolis campus of the University of Minnesota. Twenty-two right-handed males met the minimum gaming frequency of 10 hr per week and were invited to participate in a behavioral screening session, which involved completing questionnaires assessing video game exposure and symptoms of psychiatric illness, and a short practice session on the video games used in this study. Thirteen individuals (mean age = 19.8 years, range = 18–21 years) were included in the MRI session based on questionnaire measures, and skill with the joystick controls of the video game. Although all of the participants played video games frequently, half of the participants indicted a predominance of violent gaming experience ($N = 7$), and the remaining half indicated a predominance of nonviolent gaming experience ($N = 6$). The violent experience group reported on the screening instrument that the majority of their gaming hours were spent playing violent games (those rated M, for mature audiences). In contrast, the nonviolent experience group reported that the majority of their gaming hours were spent playing less violent games (rated E for everyone, or T for teen). A t test comparing the violence ratings of their three most played games confirmed that the violence exposure was greater for the violent experience group, $t(11) = 5.75$, $p < .001$. All participants were right-handed, had normal or corrected-to-normal vision, and were screened for neurological and psychological disorders. Exclusion criteria included: any Axis I psychiatric illness, current psychoactive medication, history of serious medical illness, neurological illness or head injury, history of claustrophobia, weight greater than 250 pounds, or metal in or on the body. The sample was limited in these ways to ensure that differences in brain activation were not due, for example, to differences in which hand was used to control the game or psychiatric illnesses. Informed consent was obtained, and participants were paid for their time in accordance with the guidelines set by the institutional review board at the University of Minnesota (0611M95968).

Materials and Procedure

Video games. Each participant played both a nonviolent and a violent version of Unreal Tournament, 2004, a first-person shooter game with multiple options for play. Both the violent and nonviolent versions employed the Capture the Flag variant of the game with two teams of players, red and blue, each composed of eight members. Study participants were randomly assigned to either the red or blue team. Other team members were controlled by the computer software. For both games, participants were instructed to move through the environment trying to find and capture the flag of the opposite team. The background scenery used ("December") was identical for both game versions. In the violent game, players were given the additional instruction to shoot and kill any other players that were encountered in the environment, including "friendly fire" toward members of the player's own team. The player carried a flak cannon with a burst pattern that required relatively little aiming or precision to hit a target. Graphics were set to "full gore" mode to maximize violent visual content, including blood splatter and limb amputations. The violent game also involved opportunities for the player to be shot and/or killed by players on the opposite team. In the nonviolent version, participants held a gun-like device that could fire disks that served no purpose (i.e., caused no harm to others in the environment nor any benefit to the individual). In this version, players could not be injured by other players, but did have visual and physical contact with other players and could be injured or killed by falling from a height. Movement within the video environment and firing of weapons was accomplished using an MRI-compatible joystick/button response unit. Hand and arm movements as well as general visual motion were similar across the violent and nonviolent versions of the game.

Players alternated playing the violent and nonviolent games for short blocks of time (45 s per block). Action was paused at the end of each 45-s block and resumed at the same point in the game on the subsequent block of that type (violent or nonviolent). Game play was always followed by a 30-s block of rest (visual fixation point on a black background). Rest conditions allowed the hemodynamic response (and any physiological responses) to return to baseline prior to each gaming condition. Blocks of violent and nonviolent game play were randomly ordered to prevent condition-specific anticipatory responses during the rest conditions (see Figure 1). Although the optimal block duration for fMRI paradigms is typically between 20 and 30 s, a longer block duration was necessary to ensure that participants could engage in the action of the game within each block. This longer block duration is likely to reduce the statistical power of the block design, and to make the detection of task and group differences more challenging. Participants completed four runs of trials, each lasting 7 min, 34 s, with a short break between runs to rest their eyes and hands. A video switch box was used to switch between separate computers running each of the

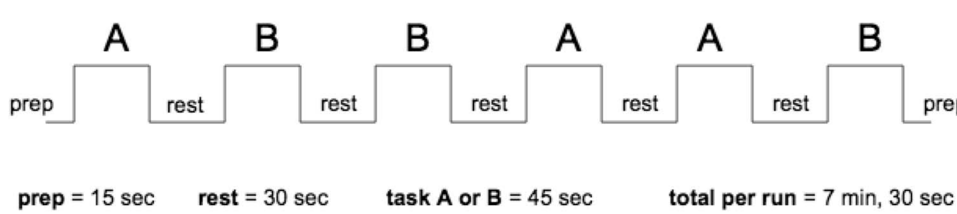

Figure 1. Example of a single run of the block design used in the fMRI paradigm. The nonviolent (A) and violent (B) versions of the game were randomly ordered and separated by period of fixation rest.

task conditions. Both games were reset to the starting state at the beginning of each run.

Questionnaire measures. In the screening session, participants completed a questionnaire assessing general media habits (Gentile, Lynch, Linder, & Walsh, 2004) to confirm the frequency and nature of current video gaming experience. Responses on this questionnaire were used to categorize participants as playing either predominantly violent games or predominantly nonviolent games. Game violence was assessed by participant description of intent to shoot and/or harm others, the presence of blood and gore, as well as an Entertainment Software Rating Board (ESRB) designation of M(Mature). At the conclusion of gaming/MRI session, participants completed several self-report questionnaires, including a postscanning assessment of their reactions to the two games during imaging. This questionnaire included subjective ratings (7-point scale) of the degree of violent content in the two games, as well as perceived physiological arousal, engagement, enjoyment, frustration, and boredom experienced with each game.

MRI scanning. FMRI was performed using a 3-Tesla Siemens Trio whole-body scanner with a single-channel head coil. Each scanning session began with a high-resolution T1-weighted 3D FLASH scan (repetition time = 20, echo time = 4.7, flip angle = 22, field of view = 256, matrix = 256 × 256, slice thickness = 1 mm, 176 slices) for localization of functional data. Brain activation was assessed during violent, nonviolent, and rest conditions using blood oxygenation-level dependent (BOLD) signal across the whole brain. Functional images were acquired in 34 axial slices aligned to the AC–PC plane (repetition time = 2000, echo time = 28, flip angle = 90 degrees, field of view = 200, matrix = 64 × 64, slice thickness = 4 mm, 227 repetitions per run).

Functional image preprocessing and analysis. Structural and functional images were processed using Brain Voyager QX software (Brain Innovation B.V., Maastricht, the Netherlands). All functional volumes were aligned to the first volume in each run, and runs 2 to 4 were aligned to the first run. All volumes were preprocessed using 3D motion-correction, slice scan time correction, and high-pass temporal filtering, and transformed into 1 × 1 × 1 mm isotropic voxels. Individual runs with mean motion >1.5 mm in any plane were excluded from analyses. Functional datasets were coregistered to the individual's T1-weighted structural scan, spatially smoothed (6 mm Gaussian kernel), and transformed into standardized Talairach space for comparison across individuals and groups (Talairach & Tournoux, 1988).

Voxel-wise analyses were performed across all participants as well as between groups using general linear models with random effects. Predictors were generated for violent and nonviolent gaming conditions with the rest condition serving as the baseline comparison. Motion parameters (x, y, z, pitch, roll, yaw) were included as nuisance predictors for each individual.

Group-level statistical analyses were performed in multiple stages. First, we used a random-effects general linear model analysis to examine effects of game version across all participants ($N = 13$). Second, we examined game effects between the two groups of participants, those with experience playing predominantly violent games, and those with experience playing predominantly nonviolent games. These analyses included group differences in BOLD signal for the comparison of video game play with rest (VG + NVG > Rest) and the more specific comparison of violent game play with nonviolent game play (VG > Rest vs. NVG > Rest). Separate analyses for each group were used to clarify similarities and differences in activity between groups. An initial voxel-wise significance threshold of $p < .05$ was cluster-level corrected using cluster sizes determined separately for each map by Monte Carlo simulation (1,000 iterations). A cluster-level threshold of $p < .005$ was used for effects of task. In analyses comparing groups, a more liberal cluster significance threshold of $p < .05$ was used to avoid type II error.

Results

Game Ratings

All participants rated the violent version of the game as containing more violent content than the nonviolent version; $F(1, 10) = 41.06$, $p < .001$. Violence assessments did not differ between groups as a function of prior violent gaming experience; $F(1, 10) = .019$, *ns*. Participants rated the violent game as more physiologically arousing, more engaging, and more enjoyable than the nonviolent game (*p*s $< .005$). These ratings did not vary as a function of prior violent gaming experience. No differences were observed in ratings of frustration or boredom experienced between the two games, or between experience groups (all *p*s $> .15$)

fMRI Activity

Violent versus nonviolent game play. We predicted that several specific regions of interest would be recruited during game play, and might show differential response to the violent or nonviolent play. These included regions associated with spatial attention and navigation (e.g., posterior cingulate cortex, parahippocampal, superior parietal lobule), emotional response (e.g., rostral anterior cingulate cortex, amygdala, insula), and cognitive control (e.g., dorsal anterior cingulate cortex). As predicted, across all participants, periods of violent game play were associated with increased BOLD response in the dorsal anterior cingulate cortex (BA 24/32; $t(12) = 6.29$, $p < .0005$, 2,195 mm^3), right fusiform and lingual gyri (BA 19; $t(12) = 6.88$, $p < .0005$, 472 mm^3), and posterior cingulate cortex (BA 23/31; $t(12) = 5.77$, $p < .0005$, 303 mm^3) relative to nonviolent game play (see Figure 2). Similar effects were observed in regions including medial prefrontal (premotor) cortex, precentral and postcentral gyri, and the cerebellar vermis (see Table 1). Contrary to expectations, no signal differences were observed in the amygdala or other emotion-related brain regions for violent compared with nonviolent game play across all participants.

Violent versus nonviolent gamers. Significant differences in relative signal were observed between groups for game playing compared with baseline activity. Individuals with predominantly nonviolent gaming experience ($N = 6$) showed significantly greater activity than those with violent gaming experience ($N = 7$) in brain regions associated with spatial attention and spatial processing, cognitive control, and emotion processing and regulation. These regions included two clusters within left superior parietal cortex (BA 7; $t(11) = 5.76$, $p < .0005$, 2,245 mm^3, and $t(11) = 5.15$, $p < .0005$, 506 mm^3), as well as clusters in right superior parietal cortex/precuneus (BA 7; $t(11) = 4.21$, $p < .005$, 246 mm^3), right inferior frontal cortex (BA 45; $t(11) = 5.38$, $p < .0005$, 625 mm^3), medial prefrontal and anterior cingulate cortex (BA 9/32; $t(11) = 4.42$, $p < .005$, 826 mm^3), right orbital frontal cortex (BA 45; $t(11) = 4.33$, $p < .005$, 1,781 mm^3), and two clusters within right insular cortex ($t(11) = 3.53$, $p < .005$, 375 mm^3, and $t(11) = 4.66$, $p < .001$, 367 mm^3). Additional regions showing this effect included portions of the cerebellum (see Table 2).

In contrast, participants with violent gaming experience showed larger BOLD signal changes

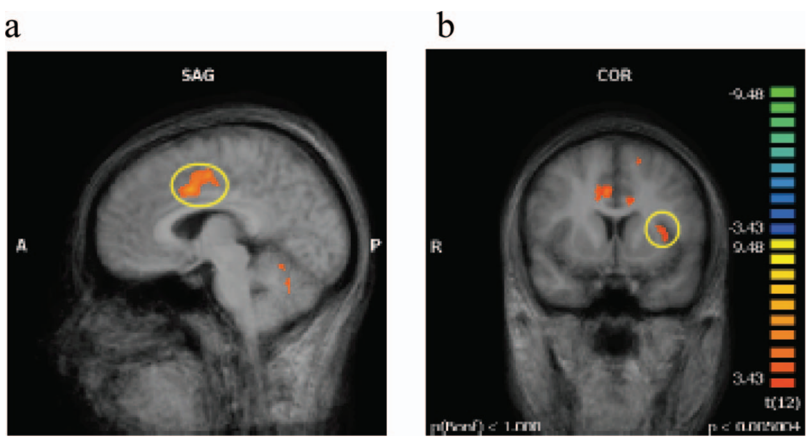

Figure 2. (a) Greater BOLD signal in the dorsal anterior cingulate cortex during violent game play relative to nonviolent game play for all participants ($N = 13$). (b) Greater BOLD signal in the left insula for violent game play relative to nonviolent game play in all participants ($N = 13$). See the online article for the color version of this figure.

Table 1
Brain Regions Showing Increased Activity During Game Play Relative to Visual Fixation Across All Participants

Anatomical region	Hemisphere	BA	x, y, z	mm^3	max *t*
Game play > rest					
Anterior cingulate gyrus	L/R	24/32	6, 2, 41	2,195	8.05
Superior frontal gyrus	L	6	−13, 3, 57	282	6.64
Fusiform/lingual gyri	R	19	15, −57, −11	472	6.02
Posterior cingulate gyrus	R	23/31	12, −28, 37	303	5.89
Medial prefrontal gyrus	L/R	6	−5, −18, 49	436	5.79
Precentral gyrus	L	4	−35, −16, 53	425	4.82
Precentral gyrus	R	4	34, −15, 49	315	5.56
Postcentral gyrus	R	1/3	37, −24, 44	442	4.92
Cerebellar vermis	L/R	—	−6, −56, −20	874	5.31

Note. BA = Brodmann's area; x, y, z = Talairach atlas coordinates.

than players with predominantly nonviolent gaming experience in visual attention and visual object processing regions as well as primary motor systems when playing games compared with fixation rest. These regions included right inferior parietal cortex (BA 40; $t(11) = -3.63$, $p < .005$, 762 mm^3), posterior cingulate gyrus (BA 23/31; $t(11) = -3.91$, $p < .005$, 296

Table 2
Group Differences in the Brain Regions Showing Increased Activity During Video Game Play Relative to Fixation Rest

Anatomical region	Hemisphere	BA	x, y, z	mm^3	max *t*
Nonviolent gamers > violent gamers					
Superior parietal lobule (superior)	L	7	−18, −73, 42	2,245	6.63
Superior parietal lobule (inferior)	L	7	−28, −46, 42	506	5.42
Superior parietal lobule/precuneus	R	7	18, −72, 30	246	3.41
Orbital frontal gyrus	R	—	14, 19, −5	1,781	5.23
Inferior frontal gyrus	R	45	45, 15, 8	625	4.82
Anterior cingulate/medial prefrontal	R	32/9	15, 48, 9	826	4.21
Insula (inferior)	R	—	36, 2, −8	367	4.04
Insula (superior)	R	—	28, 6, 13	375	3.83
Cerebellum	L	—	−20, −74, −26	1,471	4.74
Cerebellum	R	—	43, −64, −25	306	4.83
Cerebellar vermis	L/R	—	−3, −42, −28	365	4.65
Violent gamers > nonviolent gamers					
Inferior parietal lobule	R	40	27, −32, 40	762	−8.33
Superior parietal lobule	L	7	−23, −44, 63	1,019	−5.55
Superior parietal lobule	R	7	19, −59, 49	1,536	−4.39
Posterior cingulate gyrus	L	23/31	−10, −25, 34	296	−3.62
Amygdala	L	—	−28, −5, −24	831	−5.58
Caudate (posterior)	L	—	−23, −34, 7	776	−5.29
Cerebellum	L	—	−1, −27, −30	4,166	−4.98
Middle temporal gyrus	L	20/21	−44, −1, −27	2,031	−5.49
Inferior/middle temporal gyri	L	37/39	−53, −67, 6	402	−5.60
Lingual gyrus	L	18	−18, −75, −4	597	−4.90
Lingual gyrus	L	18	−10, −91, −5	432	−4.62
Fusiform gyrus	L	19	−23, −82, −16	311	−4.00
Postcentral gyrus	L	1/3	−24, −31, 49	291	−3.58
Precentral gyrus	L	4	−29, −12, 36	388	−3.52
Paracentral lobule	R	4/5	2, −39, 65	388	−3.99

Note. BA = Brodmann's area; x, y, z = Talairach atlas coordinates.

mm^3), left fusiform gyrus (BA 19; $t(11) = -4.66$, $p < .001$, 311 mm^3), left lingual gyrus (BA 18; $t(11) = -4.43$, $p < .005$, 432 mm^3, and $t(11) = -4.95$, $p < .0005$, 597 mm^3), left somatosensory cortex (BA 1/3; $t(11) = -4.17$, $p < .005$, 291 mm^3), and left and right primary motor cortex (BA 4/5; $t(11) = -4.06$, $p < .005$, 388 mm^3, and $t(11) = -3.95$, $p < .0005$, 388 mm^3). Similar effects were observed in left middle and inferior temporal gyri, left caudate nucleus, left amygdala, and left cerebellum (see Table 2).

Gamer by game type interactions. Of primary interest in the current article are differences in the brain response to violent and nonviolent games as a function of prior gaming experience. Analyses of these interaction effects revealed group differences in three primary systems: emotion processing and regulation regions, spatial attention and orientation regions, and cognitive control systems (see Table 3). Participants with predominantly nonviolent gaming experience showed greater BOLD responses to the violent than the nonviolent game in emotion-related regions including right amygdala ($t(11) = 4.12$, $p < .005$, 289 mm^3), left and right extended amygdala/putamen ($t(11) = 3.52$, $p < .005$, 405 mm^3, and $t(11) = 3.34$, $p < .01$, 247 mm^3), left and right insula (BA 41; $t(11) = 4.46$, $p < .001$, 325 mm^3, and $t(11) = 3.19$, $p < .01$, 271 mm^3), and multiple regions of medial prefrontal cortex (BA 6/8;

Table 3
Group Differences in the Brain Regions Showing Increased Activity During Violent Game Play Relative to Nonviolent Game Play

Anatomical region	Hemisphere	BA	x, y, z	mm^3	max *t*
Nonviolent gamers > violent gamers					
Amygdala	R	—	15, −10, −15	289	4.83
Extended amygdala/putamen	L	—	−27, −7, −1	405	4.06
Extended amygdala/putamen	R	—	29, −6, −6	247	3.54
Orbital frontal gyrus—medial	L/R	10	4, 51, 1	244	3.72
Orbital frontal gyrus—medial	L/R	10	−5, 45, −3	700	4.05
Anterior cingulate gyrus	L/R	24	−4, 30, 10	841	3.83
Insula	L	41	−40, −33, 19	325	4.24
Insula	R		34, −13, 13	271	3.63
Superior parietal lobule	L	7	−29, −72, 44	305	3.34
Posterior cingulate gyrus	L/R	23/31	2, −33, 33	539	4.14
Posterior cingulate gyrus	L/R	23/31	−8, −21, 29	1,217	6.09
Parahippocampal gyrus	L	35	−18, −39, −2	296	4.73
Inferior parietal lobule/angular gyrus	R	39	36, −67, 28	2,847	4.64
Middle frontal gyrus	R	10	38, 48, 2	289	3.34
Middle frontal gyrus	L	46	−41, 42, 5	674	3.68
Middle frontal gyrus	R	46	45, 36, −1	344	3.53
Middle/inferior frontal gyri	R	9/45	45, 19, 23	497	4.45
Medial frontal gyrus (superior)	L/R	8	0, 36, 26	397	3.38
Superior frontal gyrus	R	6	11, 15, 57	261	3.74
Middle frontal gyrus	R	6/8	36, 5, 47	517	4.35
Middle temporal gyrus	L	21	−57, −33, −5	599	5.79
Middle temporal gyrus	R	21	48, −34, −7	966	5.68
Inferior frontal gyrus	R	42	51, −10, 11	999	5.25
Superior temporal gyrus	L	42	−57, −17, 6	523	5.22
Medial frontal gyrus	L	6	−6, 8, 59	244	4.97
Caudate/superior hippocampus	R	—	34, −19, −6	305	3.56
Cuneus	L	17	−10, −68, 20	965	4.31
Precuneus	L/R	31	5, −66, 26	272	3.96
White matter (cingulum bundle)	R	—	14, 23, 14	344	3.75
Violent gamers > nonviolent gamers					
Postcentral gyrus	R	1	36, −30, 51	1,146	−4.39
Inferior parietal lobule	R	40	50, −29, 47	267	−3.76

Note. BA = Brodmann's area; x, y, z = Talairach atlas coordinates.

$t(11) = 3.95$, $p < .01$, 244 mm^3, and $t(11) = 3.03$, $p < .05$, 397 mm^3; see Figures 3 and 4). Participants with prior violent gaming experience showed the opposite effect (i.e., reduced activity in these same emotion-related regions during the violent game relative to the nonviolent game).

Group differences were also observed in regions involved in spatial attention and navigation, including left superior parietal cortex (BA 7; $t(11) = 3.18$, $p < .01$, 305 mm^3), left and right posterior cingulate cortex (BA 23/31; $t(11) = 3.36$, $p < .01$, 539 mm^3, and $t(11) = 4.42$, $p < .005$, 1,217 mm^3), and left parahippocampal gyrus (BA 35; $t(11) = 3.59$, $p < .005$, 296 mm^3). Individuals with less experience playing violent games showed increased activity in these regions during the violent game relative to the nonviolent game (see Table 3). In contrast, gamers with prior violent gaming experience showed no differences in activity in spatial attention and orienting regions between the two game types.

Finally, participants with low violent gaming experience showed increased activity in cognitive and behavioral control circuits during the violent game compared with the nonviolent game. Specifically, this group showed increased activity in right dorsolateral prefrontal cortex (BA 9/45; $t(11) = 3.35$, $p < .01$, 497 mm^3), and left and right ventrolateral prefrontal cortex (BA 10/46; $t(11) = 5.03$, $p < .0005$, 674 mm^3, and $t(11) = 3.95$, $p < .005$, 289 mm^3, and $t(11) = 4.06$, $p < .005$, 344 mm^3). Participants with prior violent gaming experience showed no difference in activity in these regions between the two game conditions. However, experienced violent gamers showed increased activity in right visual attention (BA 40; $t(11) = -5.00$, $p < .0005$, 267 mm^3) and somatosensory regions (BA 1; $t(11) = -4.11$, $p < .005$, 1,146 mm^3) during the violent game that were not observed in the less experienced group. Additional regions showing group differences by game type are listed in Table 3.

Discussion

This study had frequent gamers play the same video game with the same goal in both violent and nonviolent modes, allowing for direct comparison based on whether the game play included violence or not. In both cases the goal was the same (capture the flag) and

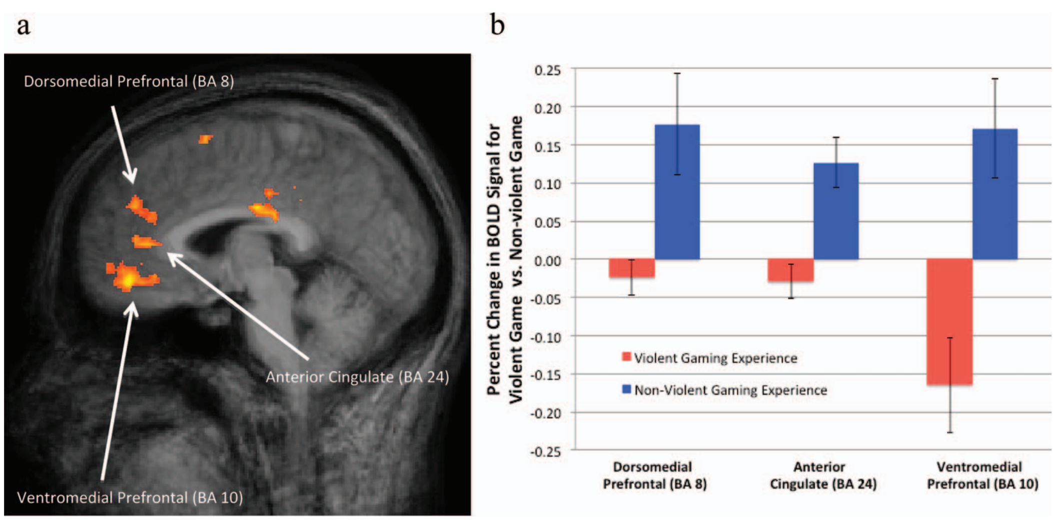

Figure 3. (a) Group differences in BOLD signal change in the dorsomedial prefrontal cortex (BA 8), anterior cingulate (BA 24), and ventromedial prefrontal cortex (BA 10) during violent game play relative to nonviolent game. (b) Percent change in BOLD signal during the violent game relative to nonviolent game for participants with predominantly violent gaming experience (red bars) relative to those with predominantly nonviolent gaming experience (blue bars). See the online article for the color version of this figure.

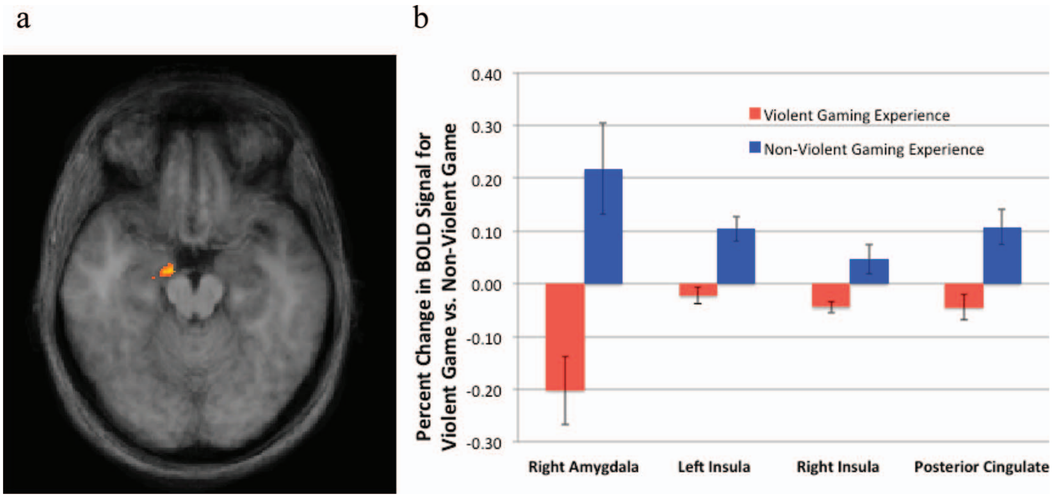

Figure 4. (a) Group difference in BOLD signal change in the right amygdala during violent game play relative to nonviolent game. (b) Percent change in BOLD signal in the right amygdala, left and right insula, and posterior cingulate cortex (BA 31) during the violent game relative to nonviolent game for participants with predominantly violent gaming experience (red bars) compared with those with predominantly nonviolent gaming experience (blue bars). See the online article for the color version of this figure.

the graphics, game controls, and game play were similar, with the primary difference being whether one could kill and be killed by other characters or not. Overall, compared with visual fixation, playing either the violent or nonviolent game increased activity in cognitive control and spatial processing brain regions. Of greater interest, however, are the differences between gamers who have a lot of violent gaming experience and those who do not.

Perhaps the most intriguing result is the difference in activation of neural structures typically associated with the processing of emotion (e.g., rostral anterior cingulate cortex, amygdala, insula) shown in Figures 3 and 4. Participants who do not normally play violent games had an increase in emotion response regions when playing the violent game. This was predicted, as seeing violent images should typically provoke emotions such as fear and disgust. In contrast, high violent game exposure participants displayed an active suppression of these same regions. This may be an indication of a long-term desensitization effect from prior violent game play. This interpretation is supported by a recent study demonstrating that high violent gamers demonstrate lower emotional reaction to negative photos (Montag et al., 2012). This result may also be seen as an adaptive learned functional response. It would be more difficult to be successful in such games if one allowed a strong emotional reaction to each act of violence, similar to how soldiers need to learn to suppress their emotional responses to fighting during war in order to be effective. Regardless of how one frames this interaction, it demonstrates the value of comparing individual differences in game experience. When both groups were combined, it appeared as if the violent game had no effect on emotion regions because the two groups had opposite reactions. This result provides support for aggression theories and meta-analytic findings that greater desensitization and lower empathy are a result of repeated violent game play (e.g., Anderson et al., 2010). Because the two groups perceived similar levels of arousal, frustration, enjoyment, and so forth, this finding cannot simply be due to differential enjoyment of the game.

Participants who do not normally play violent first-person shooter games also showed increases in spatial attention and navigation regions (e.g., posterior cingulate gyrus, parahippocampal; Table 3) and cognitive control regions (e.g., middle frontal gyri; Table 3), whereas experienced violent gamers did not show much change from baseline. This suggests that low violent gamers had to work harder to navigate and plan their actions in the game. In contrast, gamers with greater experience playing in these types of game environments and contexts appear to be more efficient in their navigation and planning. This result provides neurological support for studies demonstrating improvements in spatial attention and processing due to violent "action" game play. Although the goal (capture the flag), the environmental map, and the game controls were identical between the violent and nonviolent conditions, other requirements may be changed when the violent content is allowed, including greater attentional demand, higher visual scanning, greater motor precision with the controls, and so forth. These aspects are likely what underlie the range of neural differences found, but we are not able to know from this study exactly which aspect was related to which outcome.

Some aspects of our findings allow fairly strong causal interpretations, specifically, the main effects of the experimental manipulation of type of game being played (i.e., the violent vs. the nonviolent game). However, findings involving the two different groups of participants (violent gamers vs. nonviolent gamers) are correlational, and therefore warrant greater caution in drawing causal conclusions. Of course, even these results were predicted from and fit well with the overarching causal theories, both for the results on desensitization and the results on attentional processing. Because we were recruiting high gamers, the sample was limited to late adolescent males and it is unclear how well the results would generalize to other populations. The sample for this preliminary study was also limited in size, although it is similar to other fMRI studies of media violence (Mathiak & Weber, 2006; Murray et al., 2006; Weber et al., 2006).

One feature of the present study is particularly important. Because all participants had considerable expertise at playing video games, the obtained differences in between the predominately violent gamers versus the predominately nonviolent gamers cannot be simply attributed to differences in video game experience. That is, unlike most prior studies in this domain, the present study more clearly suggests that obtained differences are associated with type of video game experience, not amount of experience per se.

At a broader level, the current study also addresses the current question about whether playing violent video games has "good" effects, "bad" effects, or no effects. In contrast to the way this argument is usually framed as a dichotomous argument, we found evidence that multiple brain systems are activated simultaneously, providing evidence of both the "positive" effects of violent games on visual/spatial processing and the "negative" effects of violent games on desensitization. These data, however, were not supportive of the alternative hypothesis that violent games have no appreciable effect. Future research should examine longer-term brain changes after experience with violent action video games.

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