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Is It Painful? Playing Violent Video Games Affects Brain Responses to Painful Pictures: An Event-Related Potential Study

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Previous research showed mixed evidence on how violent video game exposure (VVGE) may affect empathy for pain in the brain. This study applied an event-related potential (ERPs) approach to improve understanding of how habitual and short-term violent game play may affect top-down and bottom-up empathy for pain brain responses. A total of 58 male participants with different levels of habitual VVGE performed a pain judgment task before and after 40 min of violent game play while their brain responses were recorded. Results showed that only late cognitive-evaluative ERP responses (P3, P625) were sensitive to the pictures’ painfullness, which were also affected by both habitual VVGE and short-term violent game play. As expected, participants with no habitual VVGE showed an ERP pain effect before game play: higher P3 and P625 amplitudes for painful versus nonpainful pictures. In contrast, a similar ERP pain effect was not observed in participants with high VVGE before game play, suggesting habitual desensitization. Short-term violent game play resulted in lower P3 and P625 amplitudes for painful pictures in the no VVGE group, indicating short-term desensitization. We discuss the observed VVGE desensitization effects in terms of top-down regulation of an empathetic response induced by painful stimuli. Though such adaptation could be beneficial in a violent game environment, possible long-term consequences associated with reduced empathic responsiveness in a social context should be further studied. In all, our findings contribute to the debate on the effects of VVGE on the brain by providing first ERP evidence suggesting empathy for pain desensitization.

Public Policy Relevance Statement
We observed that habitual and short-term exposure to violent video games may decrease players’ brain responses to painful pictures. We found that frequent players of violent video games were less sensitive to painful pictures before playing a violent game in the lab, whereas participants without violent video gaming habits became less sensitive to painful pictures after 40 min of violent game play. While such adaptations could be beneficial for better performance in violent game play, possible long-term consequences for real-life social situations should be further studied.

Keywords: violent video games, desensitization, empathy for pain, ERP

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Suffering of others occurs abundantly in violent video games, providing an interesting environment to study the effects of violent video game exposure (VVGE) on empathy for pain. Although earlier research showed that playing violent video games can be related to lower empathy (Bartholow et al., 2005) and may result in reduced prosocial behavior (Greitemeyer & Mügge, 2014),
Neural mechanisms of empathy for pain desensitization are still poorly understood. The current study aims to fill this gap by investigating whether and how exposure to violent video games affects brain responses to painful pictures, measured with event-related potentials (ERP).

Empathy is a complex psychological construct that plays a key role in social interactions (Coll et al., 2017). Observing the suffering of another person may induce different feelings, ranging from distress and concern to compassion and sympathy, and evoke behavioral tendencies such as willingness to comfort and help, understood together as empathy for pain (Goubert et al., 2009). Although capturing the whole complexity of empathy using self-report measures could be challenging (Vachon et al., 2014), in the current study, we focused on empathy for pain and its neural correlates, allowing a deeper understanding of underlying brain mechanisms when seeing others in pain. A meta-analytic review of functional MRI (fMRI) studies showed that observing others in pain triggered an empathy for pain response in the brain, consisting of activation of brain structures (bilateral anterior insula, medial/anterior cingulate cortex) that are also active while experiencing pain oneself (Lamm et al., 2011). Moreover, evidence from ERP studies showed that observing others in pain elicited higher brain responses (ERP amplitudes) than viewing others in harmless situations (Coll, 2018). ERPs are derived from the scalp-recorded electroencephalogram (EEG) and can provide information about the neural activity that is associated with the processing of sensory input. ERPs have a high temporal resolution and, in the context of empathy for pain research, make it possible to distinguish between an early bottom-up (“automatic”) affective sharing response and a subsequent top-down (“controlled”) evaluative response (Ibanez et al., 2012). Both types of responses have been observed to be enhanced when participants looked at pictures of others being in pain (Coll, 2018; Fan & Han, 2008; Ikezawa et al., 2014; Meng et al., 2012).

In line with these ERP findings, a model of empathy for pain (Goubert et al., 2005) proposes that affective and cognitive empathetic responses depend on bottom-up and top-down processes, respectively. Bottom-up processes are affected by contextual pain cues and features of the painful stimulus, such as looking at blood or facial expressions of pain. Top-down processes include personal knowledge and previous experiences with pain (Jackson et al., 2005).

**Violent Video Games and Empathy for Pain**

Based on the model of empathy for pain (Goubert et al., 2005) and emotion regulation of media effects (Konijn & Achterberg, 2020), exposure to violent video games, which often depict sufferings of virtual characters, may affect empathy for pain responses in different ways. On the one hand, watching painful facial expressions or hearing screams of victims of virtual violent acts may elicit automatic bottom-up affective empathetic responses in players (Konijn et al., 2011). On the other hand, previous experience with playing violent games and awareness that “this is only a video game” may enhance cognitive evaluation, and top-down regulates an initial affective response (see Crone & Konijn, 2018; Konijn & Achterberg, 2020). To test both possible outcomes, the current study examined how exposure to violent video games (both habitual and short-term) affects players’ early and late ERP responses to seeing others in pain.

Previous fMRI evidence suggested that exposure to violent video games may be related to top-down regulation of the limbic brain activity (Montag et al., 2012). Such “a reduction in emotion-related physiological reactivity to (…) violence” is often interpreted in violent media research in terms of desensitization (Carnagey et al., 2007; p. 490). Initially, exposure to media violence could evoke an aversive emotional response, accompanied by physiological changes. However, over time, such an aversive reaction could diminish due to desensitization, affecting both cognitive and affective processes, such as reduced attention to injury severity, which eventually could lead to decreased helping of others (Carnagey et al., 2007).

**Neural Desensitization**

Desensitization effects in the brain have been measured with various neurophysiological measures including ERPs. The most studied ERP component in this context is the P3. Three studies showed a relationship between habitual VVGE and lower P3 amplitudes in response to violent pictures (Bailey et al., 2011; Bartholow et al., 2006; Engelhardt et al., 2011). A similar P3 desensitization effect has been found in an experiment comparing participants with low habitual VVGE who played a violent game to participants who played a nonviolent game (Engelhardt et al., 2011). Another study showed that VVGE was related to reduced N2/P3 amplitudes during an inhibitory control task with emotional faces, indicating that these participants were less affected by emotional stimuli compared to infrequent players (Stockdale et al., 2017). In all, earlier studies have found that both habitual VVGE and short-term violent video game play affect ERP responses, especially the P3 component, to emotionally arousing stimuli by lowering their amplitudes. Whether similar desensitization effects would occur in the context of empathy for pain has not yet been investigated with ERPs.

Such an ERP study would be interesting, especially because existing fMRI evidence on this topic is mixed. For example, a short-term desensitization effect toward painful pictures was found to be present following exposure to a violent movie as compared to a nonviolent movie (Guo et al., 2013). In contrast, a cross-sectional fMRI study, with participants high and low in habitual VVGE (Gao et al., 2017), and a longitudinal fMRI study before and after 2 months of violent video game training (Kühn et al., 2018) did not find such desensitization effect.

Taken together, although most ERP studies showed a desensitization effect as a result of violent gaming (Bailey et al., 2011; Bartholow et al., 2006; Engelhardt et al., 2011; Stockdale et al., 2017), fMRI evidence regarding this effect is inconsistent (Gentile et al., 2016 vs. Gao et al., 2017; Guo et al., 2013; Kühn et al., 2018; Szyck et al., 2017). This lack of consistency in results may be explained by differences in study designs (within vs. between-participants), study types (cross-sectional vs. experimental vs. longitudinal), and VVGE (habitual vs. short-term vs. long-term), as well as by different stimuli, tasks, and neuroimaging techniques (fMRI vs. ERP). Furthermore, problematic in many foregoing experiments on short-term desensitization is that brain activity is often measured only after playing a violent video game (except Gentile et al., 2016; Kühn et al., 2018), which does not allow conclusions about changes in brain activity caused by exposure to a violent game as compared to a before gaming condition.
The Current Study

To address some of the shortcomings of previous studies, we applied a mixed design with ERP measurements both before and after playing a violent video game, while comparing between-participants habitual VVGE. This design allowed us (a) to measure baseline brain reactions to painful pictures (before the game), (b) to control for individual differences in empathy for pain, and (c) to test in one analysis an interaction of habitual exposure to violent video games and short-term effects of violent video game play on empathy for pain desensitization.

The current study used a pain judgment task showing pictures of hands in painful and nonpainful situations. We focused on three ERP components that have been found to show larger amplitudes in response to pictures of painful situations compared to neutral ones: N2, P3, and late positive potential (LPP; Coll, 2018).

The N2 component is a negative deflection occurring approximately 200 to 300 ms post stimulus. This early ERP component is considered to reflect more “automatic” processes, such as attention novelty and affective arousal (Fan et al., 2014), and its amplitude is sensitive to perceptual features of perceived objects (Ibanez et al., 2012), such as first- or third-person perspective of stimuli presentation. In a pain judgment task, the N2 is believed to reflect an early “automatic” process involved in pain perception (Fan & Han, 2008).

The P3 is a positive deflection occurring approximately 300 to 500 ms after stimulus onset. This late ERP component reflects allocation of attention to task-relevant or emotionally salient arousing stimuli (Polich, 2007) and relates to motivational significance (Hajcak & Foti, 2020). Moreover, P3 amplitudes are particularly sensitive to stimuli that elicit aversive reactions (Hajcak et al., 2012), with higher P3 responses reflecting increased engagement of decision-making processes that underlie withdrawal behavior. In contrast, lower P3 amplitudes may suggest weaker activation of aversive motivation, also related to violent video games desensitization (Engelhardt et al., 2011). In the context of painful pictures, higher P3 amplitudes are regarded to reflect “controlled” processes in response to pain observation (Ibanez et al., 2012), such as enhanced evaluation and appraisal of painful situations (Fan & Han, 2008).

The LPP, together with P3, can be considered as an indicator of top-down responses to painful pictures (Fan & Han, 2008). Similar to P3, LPP is also a positive deflection but is observed later and for a longer period of time (approximately 400–800 ms). The LPP is considered to be an index of active emotion regulation (Dennis & Hajcak, 2009), also in the context of empathy for pain research (Decety et al., 2010). Lower LPP amplitudes have been observed following suppression of emotional responses (Moser et al., 2006).

In sum, we expected painful pictures to elicit higher N2, P3 and LPP amplitudes compared to nonpainful pictures, reflecting a pain effect (Hypothesis 1; Coll, 2018; Fan et al., 2014; Fan & Han, 2008; Ikezawa et al., 2014). We further expected that high habitual VVGE would be related to habitual desensitization, (Hypothesis 2; cf., Bailey et al., 2011; Bartholow et al., 2006; Stockdale et al., 2017), which would be reflected in the absence or reduction of an ERP pain effect in those participants who frequently played violent video games in the past 6 months (Hypothesis 2a). In contrast, we expected to observe a “normal” pain effect in participants with low levels of habitual VVGE (Hypothesis 2b). Moreover, we expected that short-term exposure to a violent video game in the lab would result in a reduction of ERP responses to painful pictures from before (baseline) to immediately after game play (Hypothesis 3). This would indicate a short-term desensitization effect, comparable to what was found in earlier ERP and fMRI experiments (Engelhardt et al., 2011; Guo et al., 2013). Finally, we expected an interaction between habitual VVGE and short-term exposure of violent game play (Hypothesis 4). More precisely, we expected to observe in participants low in VVGE a short-term desensitization effect (Hypothesis 4a)—a reduction in ERP amplitudes for painful pictures after playing a violent game, whereas participants high in VVGE were expected to show a habitual desensitization effect (Hypothesis 4b)—no or a reduced pain effect before the game (Engelhardt et al., 2011; Gentile et al., 2016).

Method

Participants

Fifty-eight male university students (M_{age} = 22.41 years; SD_{age} = 3.42; 96.2% Caucasian) participated in this study. EEG data of two participants in the postgame condition were incomplete, and thus, analyses were performed on N = 56. Participants played video games for M = 8.67 (SD = 8.33) hours/week in the past 6 months and had M = 13.48 years (SD = 4.86) of video game history. Participants’ inclusion criteria were as follows: right-handedness, normal or corrected to normal vision, no health problems or cognitive deficits. Only male participants were selected in order to avoid gender as a possible confound variable in the pain judgment task (Han et al., 2008). All participants provided active consent beforehand and received a gift card of €20 after completing the procedure. The study was approved by the institutional ethical review board.

We estimated a minimum N of 46 participants, which is common in empathy for pain ERP research (Coll, 2018). Moreover, N = 46 is comparable to previous ERP studies on VVGE desensitization (Bailey et al., 2011; Bartholow et al., 2006; Engelhardt et al., 2011; Stockdale et al., 2017), using a between-participants design (details in online supplemental materials).

Design

The study was executed in a quasi-experimental mixed design: 2 (Time) × 2 (Pain) × 2 (Perspective) × VVGE. Dependent measures (ERP amplitudes; pain ratings) were tested twice: before and after playing a violent game. Thus, time (pre- and postgame) was a within-participants factor. Two more within-factors related to the pain judgment task stimuli were included: Pain (painful vs. nonpainful picture) and Perspective (picture in first person perspective vs. third person perspective). Finally, participants’ habitual VVGE was used first as a continuous variable and then in follow-up analyses as a between-participants factor: VVGE groups (low vs. high VVGE).

Procedure

Before the experiment, participants completed an online survey, including a video game experience questionnaire and measures of three traits: empathy, physical aggressiveness, and sensation-seeking (see online supplemental materials). Upon arrival to the lab and signing the consent form, they were connected to the EEG recording equipment and performed the pain judgment task. This was followed by 40 min of violent video game play. Immediately after...
violent video game play, they answered a six-item game play experience check and performed the pain judgment task for the second time (Figure 1). The whole lab procedure lasted for about 2 hr.

Materials

The Pain Judgment Task

In the pain judgment task, participants viewed pictures of hands in painful or nonpainful versions of everyday situations (e.g., injuring fingers while cutting a cucumber, hand between slamming door) while their EEG was recorded. The pictures were shown from the first- and third-person perspective to increase the heterogeneity of the pictures, thereby improving ecological validity and reducing potential habituation effects (Canizales et al., 2013). The main task was preceded by a short practice block (14 trials) with a different set of pictures (Meng et al., 2012). In the main task, participants viewed 192 pictures of hands in four conditions: (a) painful first-person perspective (painful 1pp), (b) painful third person perspective (painful 3pp), (c) nonpainful 1pp, (d) nonpainful 3pp (Canizales et al., 2013; Figure S1 in the online supplemental materials). The participants’ task was to categorize each picture as either painful (‘J’ key) or nonpainful (‘F’ key) as accurately as possible. The main task included four test blocks (48 trials per block; details and trial example in Figure 1), separated by 30-s breaks. This was followed by a behavioral pain rating block in which participants rated the same 48 pictures (presented for 1,000 ms) on a 1 to 6 scale (1 = no pain; 6 = very intensive pain).

Violent Video Game Play

All participants played a first-person shooter (FPS) game Call of Duty: Modern Warfare 3 (2011) for 40 minutes. This game is 18+ rated by Pan European Game Information (https://pegi.info/), as it contains “extreme violence, violence toward defenseless people and strong language.” This game is highly popular among gamers (Nielsen, 2017) and was used in previous research on violent video gaming effects (Grizzard et al., 2017).

Participants played on a PlayStation 3 with a game controller and headphones. They were seated at a distance of about 80 cm from a TV screen (size 37”). Because our sample also included gamers inexperienced with violent video games, the game’s difficulty level was set to easy. The consent form informed all participants about the violent game content.

Individual Differences Measures

Habitual VVGE

The VVGE-measure was based on (a) three favorite video games most frequently played by participants in the past 6 months, (b) time spent on those video games (hours/week), and (c) official video game age and violent content ratings (Busching et al., 2015). Each game named by a participant was coded according to the Pan European Game Information. Games with both a violent content label and an age label 12+, 16+, or 18+ were categorized as violent, and all games without a violent content label and with age labels 3+, 7+ and 12+ were categorized as nonviolent. VVGE and non-VVGE were computed as separate variables by summing the time of exposure (hours/week) spent on violent and nonviolent content, respectively. The VVGE score was further used to create two VVGE groups: based on the lowest 25 percentile and highest 25 percentile of VVGE for the purpose of a follow-up analysis enabling a comparison between participants with different VVGE levels (Engelhardt et al., 2011; Gao et al., 2017).

Video Game Play Experience Check

To examine how participants experienced the game, they were asked immediately after the game six questions on a 7-point scale (1 = not at all/strongly disagree, and 7 = extremely/strongly agree) regarding their perceived level of (a) violence in the game, (b) frustration caused by the game, (c) excitement during the game, (d) engagement in the game, (e) interest in the game, and (f) game challenge (Engelhardt et al., 2015).

EEG Recording and Analysis

EEG data were recorded with MATLAB (2010; The MathWorks, Inc., Natick, MA) and a g.tec portable GAMMA system, including a Mobilab amplifier (16-bit sampling resolution). Eight electrodes (active Ag/AgCl) were placed at F3, F4, C3, C4, P3, P4, O1, O2 (Figure S2 in the online supplemental materials) to allow for suitable front-to-back scalp coverage at both hemispheres. The reference electrode was placed on the left earlobe (earclip) and the ground at Cz. Data were recorded with a sample rate of 256Hz.

Data were processed with EEGLab (MATLAB, 2017; The MathWorks, Inc., Natick, MA). EEG data were filtered (0.05–40Hz) with a bandpass filter and epoched (250 ms before and 1,000 ms after stimulus onset), with a baseline correction of 200 ms before stimulus. Improbable EEG data over 3 SD threshold for all channels and within one channel were rejected, as well as data with EEG above 100μV or below –100μV. Artifact rejection resulted in 6.6% rejected trials in the before game play condition and 6.7% in the condition after game play. Trials were averaged separately for each electrode position and for each of the four picture conditions: Painful 1pp, Painful 3pp, Nonpainful 1pp, and Nonpainful 3pp.
Analytical Approach

Pain ratings and mean ERP amplitudes (N2, P3, and LPP) were analyzed as dependent variables in a repeated measures analysis of variance (ANOVA) with four within factors: (a) Time (pregame vs. postgame), (b) Pain (painful vs. nonpainful pictures), (c) Perspective (1pp vs. 3 pp), and (d) Electrode (only ERP data1). Both VVGE and non-VVGE were added as continuous covariates. In case of a significant interaction with VVGE, the main analysis was followed by the same repeated measures ANOVA but then with VVGE as a between factor (low VVGE vs. high VVGE) to visualize and further examine between-group differences. See the online supplemental materials for analyses syntax and main and interaction effects with the Electrode factor.

Results

Individual Characteristics

Video Gaming Habits

On average, participants played $M = 6.38$ hr/week violent video games, and $M = 2.89$ hr/week nonviolent video games. The most frequently played game types were adventure games (34.48%), first-person shooter games (32.76%), and role-playing games (29.31%).

VVGE

VVGE varied between 0 and 38 hr/week (Table S1 in the online supplemental materials), with $M = 6.38$; $SD = 7.97$. For follow-up analyses, participants were divided into two subgroups based on the VVGE distribution, which is common in VVGE research (cf., Engelhardt et al., 2011). The high VVGE group consisted of 14 participants (top 25.2%) who played more than 8.75 hr of violent video games per week. The low VVGE group consisted of 15 participants (bottom 26.8%) with no exposure to violent video games. Thus, participants with higher levels of VVGE perceived the game as less violent, less exciting and less engaging.

Correlations

Correlation analysis between behavioral measures revealed that neither VVGE nor non-VVGE was related to any trait (empathy, aggressiveness, sensation-seeking; Table S3 in the online supplemental materials). Therefore, they were not included in the ERP analyses.

Video Game Play Experience Check

Results of a correlation analysis indicated that the perceived level of game violence ($r = -.36$, $p = .035$), excitement ($r = -.34$, $p = .047$) and engagement ($r = -.41$, $p = .014$) correlated negatively with habitual VVGE (Table S4 in the online supplemental materials). Thus, participants with higher levels of VVGE perceived the game as less violent, less exciting and less engaging.

Main Results

Pain Ratings

Rating data of six participants were missing due to technical failures (either before or after the game), therefore, analysis was performed on $N = 50$. Results of the ANOVA repeated measures analysis indicated that the main effect of Pain was significant, $F(1, 47) = 554.15$, $p < .001$, $\eta_p^2 = .92$, revealing that painful pictures were rated as more painful than nonpainful pictures, thereby validating our stimulus materials (Table 1). Moreover, Pain $\times$ VVGE interaction ($p = .444$, $\eta_p^2 = .01$), Pain $\times$ Time ($p = .586$, $\eta_p^2 = .01$), and Pain $\times$ Time $\times$ VVGE interactions were not observed ($p = .113$, $\eta_p^2 = .05$).

ERP Results

Grand average ERP waveforms at C4 are presented in Figure 2 for both the pre- and postgame conditions (see Figure S3 in the online supplemental materials for ERPs at other electrode positions). All pictures elicited a clear N2–P3 complex over the fronto-central area of the scalp, which was followed by a fronto-central late positive wave with a maximum around 625ms. However, no clear LPP wave was observed at parietal electrodes. To distinguish the fronto-central late positive wave that we observed from the centro-parietal LPP in the literature, we labeled this component after the midpoint of its time window: P625, as is typical in ERP research.

Based on visual inspection, N2 seems larger for 3pp pictures than for 1pp pictures, regardless of the pictures’ painfulness. In contrast, regardless of perspective, both the P3 and the P625 seem larger for painful as compared to nonpainful pictures. These observations were statistically tested for frontal (F3, F4) and central (C3, C4) electrodes. Based on the ERP literature (Coll, 2018; Ibanez et al., 2012) and visual inspection, the following time windows for calculating mean amplitudes were set: N2: 250–340 ms; P3: 350–500 ms; P625: 530–720 ms.

N2. The repeated-measures ANOVA results indicated main effects of Time and Perspective, but no main effect of Pain (Table 1), rejecting Hypothesis 1. N2 amplitudes were larger before the game than after the game and they were larger for 3 pp pictures than for 1 pp pictures. Moreover, the Pain $\times$ VVGE ($p = .427$, $\eta_p^2 = .01$), Pain $\times$ Time ($p = .271$, $\eta_p^2 = .02$), and Pain $\times$ Time $\times$ VVGE interactions ($p = .159$, $\eta_p^2 = .04$) were not significant, rejecting Hypotheses 2, 3, and 4, respectively, for N2.

P3. The repeated-measures ANOVA results indicated a main effect of Pain, as well as a main effect of Time, but no main effect of Perspective (Table 1). P3 amplitudes were higher for painful than for nonpainful pictures, supporting Hypothesis 1, and they were higher before the game than after the game.

Furthermore, although there were no significant Pain $\times$ VVGE ($p = .696$, $\eta_p^2 = .003$) and Pain $\times$ Time ($p = .115$, $\eta_p^2 = .05$) interactions, the Pain $\times$ Time $\times$ VVGE interaction was significant, $F(1, 53) = 9.90$, $p = .003$, $\eta_p^2 = .16$, suggesting that, in accord with Hypothesis 4, the level of habitual VVGE affected the Pain $\times$ Time interaction. To further investigate this interaction, a similar repeated measures ANOVA was performed, but with VVGE

1 The Electrode factor was included to explore whether the effects of Time, Pain, and Perspective differed across the electrodes’ positions.
group (high VVGE vs. no VVGE) as a between-subjects factor instead of a covariate. Apart from the same main effects, this analysis also revealed a significant Pain × Time × VVGE group interaction, $F(1, 26) = 8.10, p = .009, \eta^2_p = .24$. Details of this interaction are presented in Figure 3A.

In the no VVGE group, there was a significant effect of Pain in the pregame condition, $F(1, 26) = 5.74, p = .024, \eta^2_p = .181$, with higher P3 amplitudes for painful pictures ($M = 3.03, SE = .57$) compared to nonpainful pictures ($M = 2.25, SE = .61$). Moreover, amplitudes for painful pictures significantly dropped, $F(1, 26) = 4.44, p = .045, \eta^2_p = .146$, from pre- ($M = 3.03, SE = .57$) to postgame condition ($M = 1.84, SE = .72$). These results suggest short-term desensitization in the no VVGE group as a result of 40 minutes violent game play, supporting Hypothesis 3. In addition, we also observed a significant interaction of Pain × Time ($F(1, 26) = 12.69, p = .001, \eta^2_p = .33$). Details of this interaction are presented in Figure 3B.

In the no VVGE group, there was a significant effect of Pain in the pregame condition only ($F(1, 26) = 10.42, p = .003, \eta^2_p = .286$) with higher P625 amplitudes for painful pictures ($M = 3.89, SE = .56$) than for nonpainful pictures ($M = 2.82, SE = .61$). The effect of Pain was not found in the postgame condition, $F(1, 26) = 1.72, p = .202, \eta^2_p = .062$. Moreover, there was also a significant drop ($F(1, 26) = 22.23, p < .001, \eta^2_p = .461$) observed in the P625 amplitudes for the painful pictures from the pre- ($M = 3.89, SE = .56$) to postgame ($M = .77, SE = .60$) condition. The absence of a Pain effect and lower ERP amplitudes for painful pictures in the postgame condition suggest short-term desensitization as a result of 40 minutes violent game play in the no VVGE group, supporting Hypothesis 3. In addition, we also observed a significant drop in P625 amplitudes for the nonpainful pictures after the game, as compared to before the game condition, $F(1, 26) = 30.01, p < .001, \eta^2_p = .536$.

In contrast, in the high VVGE group there was a significant effect of Pain both in the pregame condition ($F(1, 26) = 4.56, p = .042, \eta^2_p = .149, M_{painful} = 4.42, SE_{painful} = .58, M_{nonpainful} = 3.68, SE_{nonpainful} = .63$) and in the post game condition ($F(1, 26) = 45.39, p < .001, \eta^2_p = .636, M_{painful} = 5.19, SE_{painful} = .62, M_{nonpainful} = 2.82, SE_{nonpainful} = .58$), rejecting Hypothesis 2. Despite that no habitual desensitization effect was observed in the pregame condition, the Pain effect before the game was on average smaller ($M_{difference} = .74$) than after the game ($M_{difference} = 2.37$). Further, changes between pre–post game conditions were not significant for both painful ($p = .273$) and nonpainful pictures ($p = .079$).

### Discussion

#### The Pain Effect

Painful pictures elicited higher P3 and P625 amplitudes than nonpainful pictures, but no main pain effect was observed in N2
These findings partially support Hypothesis 1 and are in agreement with the meta-analysis of Coll (2018), challenging the proposed model of early and late brain responses to viewing others in pain (Fan & Han, 2008; Ikezawa et al., 2014; Meng et al., 2012). Moreover, Coll (2018) suggested that the early component (N2) does not reflect an “affective sharing response,” but rather a bottom-up processing of perceptual features of stimuli. Our results are in line with this suggestion, as the N2 component was affected by the pictures’ perspective and not its’ painfulness. Coll (2018) further stated that only late ERP components (P3 and LPP) are sensitive to observing others in pain, reflecting sustained attentional processes involved in top-down cognitive evaluation of motivationally relevant stimuli (Hajcak et al., 2012). Indeed, in the context of the empathy for pain literature, these late ERP components have also been suggested to reflect emotion regulation processes (Decety et al., 2010; Fan et al., 2014). Therefore, these two late ERP components are particularly interesting in terms of empathy for pain desensitization. Because the P3 and P625 showed similar patterns of results in our study, they are discussed together. Furthermore, although P625 and LPP might not reflect exactly the same processes, they are both believed to be linked to mechanisms involved in emotion regulation.

Habitual and Short-Term Desensitization

As predicted by Hypothesis 4, habitual VVGE was found to moderate the Game by Pain interaction effect of both P3 and P625. Due to this moderating effect, the expected decreases in pain effect from habitual VVGE (Hypothesis 2) and short-term violent game play (Hypothesis 3) were qualified by condition (pre- vs. postgame), and VVGE level (no- vs. high-VVGE group), respectively.

First, in contrast to a clear Pain effect in the no-VVGE group, the P3 pain effect was absent (and the P625 pain effect was smaller) in the high VVGE group before playing the game in the lab, suggesting habitual desensitization. Theoretically, there are two possible explanations of this desensitization effect: lower allocation of attention to emotionally arousing stimuli (Stockdale et al., 2017) or down-regulation of emotional arousal (Decety et al., 2010). In the current empathy for pain context, the second explanation seems more plausible. More specifically, in the Decety et al. (2010) study, it was suggested that physicians who are regularly exposed to painful situations may actively down-regulate their emotional arousal when seeing others in pain, which resulted

![Figure 2](image-url)

**Figure 2**
Event-Related Potential Amplitude for Four Picture Types at the C4 Electrode: The Pregame Condition (A) and the Postgame Condition (B) With Marked Time Windows for Three ERP Components of Interest

*Note.* See online supplemental materials for event-related potentials (ERP) amplitudes at other electrodes. See the online article for the color version of this figure.
in no pain effect, though it was present in a control group. Empathy is an effortful act, and people may try to avoid it to limit its cognitive costs (Cameron et al., 2019). We think that similar to physicians, who are trained to develop coping strategies to perform their work more effectively (Decety et al., 2010), frequent players of violent video games may down-regulate negative emotional arousal when viewing others in pain which may help them to better perform in the game, resulting in the absence of an ERP pain effect.

Second, our study showed a clear short-term desensitization effect (a drop in P3 and P625 amplitudes for painful pictures) as a result of 40-min of violent game play, but only in participants with no habitual exposure to violent video games. A similar effect was also observed in the study of Engelhardt and colleagues (2011) in the group with low habitual VVGE that played a violent game and viewed violent pictures. Further, our finding is in line with earlier research on short-term desensitization effects of exposure to violent media (Guo et al., 2013; Stockdale et al., 2015). Likely because our participants from the no VVGE group were not used to violent content in video games, they may have experienced higher emotional reactions at the beginning of the game evoked by the in-game violence (Gentile et al., 2016). Indeed, results from our experience check showed that lower exposure to VVGE was related to experiencing the game as more violent, exciting, and engaging. However, through the process of 40-min violent game play, they could have “learned” how to down-regulate their (negative) arousal in order to successfully perform in the game, which was reflected by the decreased P3 and P625 amplitudes for painful pictures measured after the violent game play. Indeed, such down-regulation of initial aversive arousal has also been suggested to underlie both short-term (Wang et al., 2009) and habitual fMRI desensitization effects in response to violent video games (Montag et al., 2012).

Finally, we observed an unexpected pain effect in the high VVGE group after playing the game. However, this pain effect was the result of lower P3 and P625 amplitudes to the nonpainful pictures and not to higher P3 and P625 amplitudes for the painful pictures (Figure 3). In other words, the emergence of the ERP pain effect in the high VVGE group might not be related to a “sensitization” effect. Instead, we suggest that it indicates reduced attention toward the nonpainful pictures, which may have become less task-relevant after the violent game play. This interpretation seems in line with some earlier studies showing changes in selective attention for target and nontarget pictures in action (violent) video game players (cf., Green & Bavelier, 2012).

In all, our study improved understanding of the effects of exposure to violent video games on empathy for pain in a few ways. First, by applying the ERP approach we provided first evidence about the effects of VVGE on late (P3, P625) but not early (N2) ERP responses to pain-ful pictures. Second, we applied insights from ERP empathy for pain research to better understand mechanisms of neural desensitization, highlighting the importance of top-down (emotion) regulation processes in explaining desensitization. Finally, and most importantly, we applied a within-participants design combining both short-term and habitual VVGE. This allowed us to compare brain activity both within (before and after the game) and between participants (VVGE groups; Engelhardt et al., 2011; Gentile et al., 2016) to painful versus nonpainful pictures. Such a design provided evidence about the actual change of brain activity before and after playing a violent video game within different VVGE groups. Moreover, by studying the interaction of

Figure 3
Interaction Effect: Time × Pain × Violent Video Game Exposure Group for No Violent Video Game Exposure Group and High Violent Video Game Exposure Group for P3 (A and B) and P625 (C and D)

Note. Significant differences (p < .05) are marked with asterisk (*), with ‘d’ are marked desensitization effects. VVGE = violent video game exposure.
habitual and short-term exposure to violent games we were able to better understand who (no vs. high VVGE group) and when (pre- vs. post-game) was desensitized to painful pictures.

**Limitations and Future Directions**

As explained and substantiated, we have ample reason to believe that short-term exposure to a violent game may result in desensitization in participants who did not play such games before. Nevertheless, one may still debate whether the observed changes in brain responses were actually due to the violence of the game. However, because we have not found significant differences in trait empathy, sensation-seeking, and physical aggressiveness between no VVGE versus high VVGE groups, we rule out individual differences as a possible factor explaining our results. In addition, both the high and no VVGE group had similar levels of exposure to nonviolent games prior to the experiment (Table S2 in the online supplemental materials). This further contributes to our interpretation that the violence in the habitually played games made a difference in the observed changes before the game and not general gaming habits per se.

However, depending on violent gaming habits, the content of a violent game played in the lab may be perceived in a different way (Valkenburg & Peter, 2013). The observation of a negative relationship between VVGE, in-game violence, excitement, and engagement, is actually in line with the desensitization literature (Grizzard et al., 2015). Moreover, it is important to note that no and high VVGE players did not differ in the perceived level of frustration, which should rule out frustration as a possible alternative explanation of the short-term violent game play effect (Przybylski et al., 2014).

To further substantiate this interpretation, future studies could incorporate a nonviolent game condition (Engelhardt et al., 2011) and pretest games from both conditions because they may vary not only in violent content but also in other features. Possible differences in graphics, plot, competitiveness, and so forth, may make effects of two video games very difficult to compare. In line, it is desirable that future experiments would use most similar violent and nonviolent video games, preferably in a within-participants design to limit possible effects of individual differences. Such a within-participants approach can be created by editing a game in both a violent and nonviolent version (Gentile et al., 2016). However, this could come with some important drawbacks: a poor quality of graphics and low game realism, which are essential to elicit physiological arousal (Ivory & Kalyanaraman, 2007)—a key component to observe a desensitization effect (Grizzard et al., 2015). Therefore, we did not use an editable game but instead a game of good quality and realistic graphics (i.e., Call of Duty, 2011). Nevertheless, future research should also replicate our study and use other (violent) video games to increase generalizability of our outcomes.

Finally, our sample size was comparable to related ERP research on VVGE desensitization. However, we did not set any a priori criteria to divide participants to high and low VVGE groups. Because there are no clear guidelines of how much one must be exposed to violence in video games to be assigned to a high VVGE group (cf., Busching et al., 2015), we decided to apply a posthoc approach and run a follow-up analysis to illustrate between-participants differences from the highest and lowest VVGE groups. Future studies could divide participants to the high versus low VVGE groups based on preregistered criteria.

Whereas most research on neural desensitization was conducted with adult samples, an interesting avenue for future research would be to investigate brain reactions to seeing others in pain in younger players of violent video games. Adolescence is a sensitive period for empathy for pain development (Mella et al., 2012) and teenagers may be especially susceptible to media violence effects (Crone & Konijn, 2018).

**Conclusion**

Our findings contribute to the debate on the effects of VVGE by providing the first ERP evidence suggesting empathy for pain desensitization. We improved understanding of how empathy for pain may be affected by VVGE by investigating the top-down and bottom-up ERP responses to painful pictures. Moreover, by applying a within-participants design we showed that both habitual and short-term exposure to violent video games affected brain responses to painful pictures in a different way. We found habitual desensitization before violent game play in frequent players of violent video games and short term-desensitization after playing a violent game in those without habitual experience of playing violent games. These results suggest that both habitual and 40 minutes of violent video game play may trigger top-down regulation of an empathetic response induced by painful pictures. Though such adaptation could be beneficial in a violent video game environment, possible outcomes for real-life social situations should be further investigated.

**References**


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