# Reduced reactivity to fear conditioning and pain tests in persons involved in violent video gaming is influenced by adverse childhood experiences

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## **Funding Information**

This research was supported by a grant of the Deutsche Forschungsgemeinschaft (DFG) awarded to HF (research unit “Research Training Group on the Impact of Adverse Childhood Experiences on Psychosocial and Somatic Conditions Across the Lifespan” (GRK2350/B04).

## **Abstract**

Videogaming, including violent video gaming, has become very common and lockdown measures of the COVID-19 pandemic even increased the prevalence rates. In this study we examined if violent videogaming is associated with more adverse childhood experiences and if it impairs pain processing and fear conditioning. We tested three groups of participants (violent video gamers, nonviolent video gamers, and non-gamers) and examined fear conditioning as well as pain perception during functional magnetic resonance imaging (fMRI). Violent video gamers displayed significantly higher pain thresholds as well as pain tolerance for electric stimulation, pressure pain stimulation, and cold pressor pain measurements compared to nonviolent video gamers and non-gamers. This relationship was moderated by adverse childhood experiences, especially physical neglect. Brain images acquired during the fear conditioning fMRI task showed that violent video gamers display significantly less differential brain activation to stimuli signaling pain versus no pain in the anterior cingulate cortex, the juxtapositional lobule cortex, and the paracingulate gyrus compared to non-gamers. There was also a significant negative correlation between adverse childhood experiences and activation in the precuneus and the intracalcarine cortex for signals of pain versus safety. The results of this study imply that violent video gaming is related to reduced processing of pain and signals of pain in a fear learning task, dependent of adverse childhood experiences. These mechanisms need to be examined in more detail and these data could be helpful in preventing the onset and adverse consequences of violent video gaming.

## **1 INTRODUCTION**

Since the first arcade videogame “Computer Space” in 1971, videogames have greatly expanded their content and popularity (Burnham & Baer, 2003). The video gaming industry counts as one of the fastest growing industries and it showed accelerated growth in the past years due to lockdown measures of the COVID-19 pandemic. In 2020, the annual growth amounted to over 9%, amounting to a 159-billlion-dollar revenue (Wijman, 2020). According to predictions, the video game industry will generate 396 billion dollars in sales by 2023 and will expand to 533 billion dollars by 2027 (Statista, 2023). Violent videogames largely contributed to the growth of this industry. Nearly three billion people worldwide are playing video games on a regular basis and video games with violent content like shooter games are the most popular category with 60% of the players in the age range of 16-24 years, 57% for the age range of 25-34 years, and 48% for the age range of 35-44 years (Statista, 2022).

As the popularity of video games increased over the last 20 years, research on potential consequences of violent video gaming (VVG) also increased. According to Carnagey et al. (2007), exposure to self-executed virtual violence may support habituation to real-life violence. Further findings showed that the consumption of violent video gaming content leads to desensitization and extinction of fear and anxiety reactions towards violent video gaming content (Anderson et al., 2010; Bushman & Anderson, 2009). Teismann et al. (2014) found that participants who played violent video games tolerated pain stimuli longer than participants who played a racing game. Habituation to painful pictures among VVGs was confirmed in a recent experiment via event-related potentials for top-down and bottom-up empathy regarding pain-related brain responses by Miedzobrodzka et al. (2022). Neuroimaging experiments have shown that VVG results in lower activation of the left lateral medial frontal lobe, the limbic system, such as anterior and posterior cingulate cortex, amygdala, hippocampus, thalamus, cerebellum, posterior and superior parietal lobe, and the entorhinal cortex compared to non-gamers (NG) for different tasks such as pain exposure or presentation of pictures with negative emotional content (Montag et al., 2012; Palaus et al., 2017; Wang et al., 2009). Multi-voxel pattern analysis showed that gamers with internet gaming disorder differ in their brain activation during a cue-reactivity fMRI-task from healthy controls with 92.37% accuracy, which suggests excessive gaming is associated with altered patterns of neural activity in the human brain. The most distinct regions identified were the middle frontal gyrus, precuneus, and posterior lobe of the right cerebellum (Wang et al., 2022).

Video gaming, especially violent video gaming, has often been considered as a means of reducing stress, anxiety, and depression, and there is indeed some evidence for such beneficial effects in persons not suffering from gaming disorder (Pallavicini et al., 2022). It is therefore conceivable that persons with adverse events in their childhood are prone to the lures of violent video gaming in an attempt of coping with adverse consequences of such stress. Surveys among the general population show high prevalence rates for subtypes of ACEs like physical (22.9%), emotional (29.1%), and sexual (9.6%) abuse together with physical (16.3%) and emotional neglect (18.4%) (Sethi et al., 2013, 2018). The field of research on the topic of the expected interaction between ACEs and pain processing suggests that ACE is connected to lower pain threshold, but does not reveal impacted pain sensitivity (Tesarz et al., 2015). No particular ACE subtypes were held responsible for the decreased pain threshold, but it was stated that the ACE subtype emotional abuse is connected to increased touch sensitivity and enhanced temporal summation of pain (Tesarz et al., 2016).

The aim of this study was to clarify if individuals playing violent videogames also show impaired fear conditioning as well as higher pain tolerance and pain thresholds compared to individuals playing non-violent videogames and individuals not playing videogames. In classical fear conditioning, a stimulus (conditioned stimulus; CS+) is paired with another stimulus such as pain (unconditioned stimulus; US) that elicits a biologically relevant fear response. By pairing these two stimuli, participants learn to react to the conditioned stimulus in a way they would normally only react to the unconditioned stimulus (unconditioned response, UR) and develop a conditioned response (CR). We used a differential fear conditioning paradigm, where a within group control is used with one stimulus predicting the US (CS+) and another stimulus predicting the absence of the US (CS-), thus allowing for danger and safety signal learning. We predicted that both fear learning and pain perception would be impaired in violent video gamers.

In addition, we sought to clarify the influence of ACEs on these behaviors. We expected ACEs to enhance these maladaptive responses. With respect to pain response in the brain, we assumed that both, the lateral pain network involved in sensory and discriminative capabilities of pain identification (lateral thalamic nuclei, primary and secondary somatosensory and posterior parietal cortices), and the medial pain system involved in pain-related emotional and motivational responses (medial thalamus, anterior cingulate and prefrontal cortices, and insula cortices) would show dampened responses for VVG compared to NVVGs and NGs (Demertzi & Laureys, 2012).

## **2 MATERIALS AND METHODS**

### **2.1 Participants**

We examined 60 participants (23 females; mean age 30, SD 7.90, range 20-58 years). This fear conditioning paradigm in non-gamers yielded a high effect size (d = .80; α = .05) for N=18 per group in previous studies (Flor et al., 2002; Flor et al., 1996; Rothemund et al., 2012). To account for potential loss of data, we recruited 20 participants per group for our experiment: non-gamers (NG; 11 females; mean age 33, SD 7.39, range 21-54 years), nonviolent video gamers (NVVG; 7 females; mean age 30, SD 9.02, range 21-58 years), and violent video gamers (VVG; 5 females; mean age 29, SD 7.02, range 20-43 years). Participants in the VVG group needed to play videogames containing self-executed violence to virtual humans or humanoid beings for 15 hours or more per week for at least the year preceding the testing to qualify for the VVG group. Most common videogames in this group were “Call of Duty”, “Counter Strike”, and “Left 4 Dead”. Participants in the NVVG group needed to play videogames containing no violence for 15 hours or longer per week for at least the year preceding the testing. Strategic games with negligeable third person violence also classified as nonviolent videogames (e.g., “League of Legends”). The most common videogames were “Magic the Gathering: Arena”, “Hearthstone”, and strategic world building games. Participants in the NG group needed to play videogames less than 5 hours per week for at least the year preceding the testing.

Exclusion criteria for the magnetic resonance imaging (fMRI) task and pain assessments were video gaming hours, neurological illness, kidney and liver illness, acute suicidality, peripheral coagulopathy or impacted hematopoiesis, pregnancy or breastfeeding, a pacemaker or other metal inside the body, aneurysmal-clip or related cardio- or prosthetic clips, claustrophobia or a related illness that makes laying in the scanner difficult for the participant, brain damage or risk of seizures, organic brain diseases (e.g. Parkinson’s disease), and epilepsy or seizures in the past.

The local Ethics Committee of the Medical Faculty Mannheim of the University Heidelberg approved the study (approval number 2017-668N-MA), which adhered to the Declaration of Helsinki. Informed consent was obtained from all participants.

### **2.2 Study Procedure**

In the beginning of the study, each participant completed informed consent and self-report questionnaires (see below). The participants were assessed via the Maltreatment and Abuse Chronology of Exposure (MACE; Teicher & Parigger, 2015) in its German adaption (KERF; Isele et al., 2014) and a structured clinical interview based on DSM-5 criteria (SCID-5-CV; Beesdo-Baum et al., 2019). After that, pain threshold and pain tolerance were determined. Pain threshold refers to the transition point from rising sense of pressure to the pain onset point, and pain tolerance refers to the maximum level of pain a participant is able to endure. Pain measurements included electric stimulation during the fMRI experiment and after the fMRI measurement, as well as pressure pain assessment and temperature sensitive stimuli after the fMRI measurement. These pain markers were then used in the subsequent fMRI measurement assessing fear conditioning, where painful stimuli were employed as unconditioned stimuli. The fMRI measurement also included an empathy for pain and a pain processing task, which will be reported in a separate paper. The participants were examined in terms of electromyogram and skin conductance during the whole fear conditioning experiment. Additionally, participants were asked to give ratings of valence, arousal, and contingency after every conditioning phase to check if fear conditioning took place. The overall study procedure is visualized in figure 1 below.



Figure 1. *The overall study procedure including questionnaires and clinical assessment, the fear conditioning task in the functional magnetic resonance imaging (fMRI) scanner and the pain measurements in the laboratory.*

### **2.3 Questionnaires and clinical assessment**

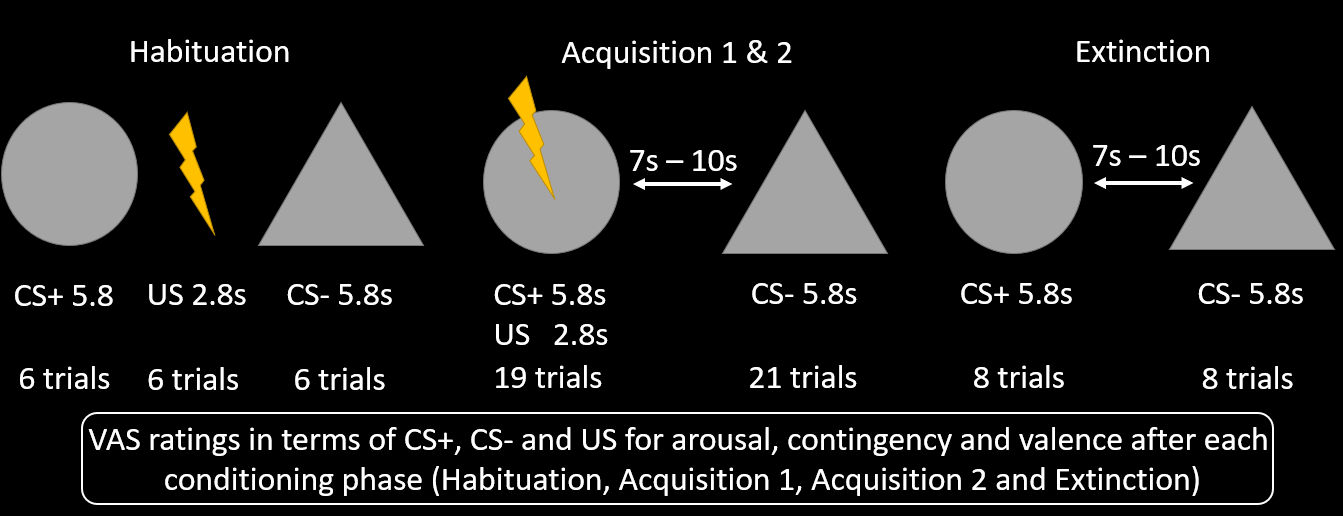
Participants completed the detailed clinical assessment via KERF and SCID-5-CV to assess possible mental disorders. In addition, they answered the German adaption (CTQ; Wingenfeld et al., 2010) of the “Childhood Trauma Questionnaire” (Bernstein et al., 1998), the “Positive and Negative Affect Schedule” (PANAS; Watson et al., 1988), the “NEO Five-Factor Inventory” (NEO-FFI; Costa & McCrae, 1989), the “State-Trait Anxiety Inventory” (STAI-S/STAI-T; Spielberger, 1983), the “Scale for the Assessment of Pathological Computer-Gaming” (CSV-S; Woelfling et al., 2010), the “Trier Inventory for Assessment of Chronic Stress” (TICS; Schulz & Schlotz, 1999), the personality questionnaire “Dirty Dozen” (Jonason & Webster, 2010), the “Empathy for Pain Scale” (EPS; Giummarra et al., 2015), the “Fear of Pain Questionnaire” (FPQ-SF; Asmundson et al., 2008), the German version of the anxiety and depression inventory “Hospital Anxiety and Depression Scale” (HADS; Herrmann-Lingen et al., 2011), and the “Interpersonal Reactivity Index” (IRI; Davis, 1983).

### **2.4 ACE assessment**

The CTQ was the main source for assessing and calculating the level of ACE together with the in-person KERF and SCID-5-CV diagnostics. The CTQ consists of 5 subscales, each rated on a scale from 5 (not or minimal occurred) to 25 (very common and extreme), which are emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect. Each subscale consists of 5 items, rated on a scale of 1 (not occurred) to 5 (very common). The subscale value was computed via the sum-score of these items. Overall, the CTQ displays good internal consistency with a Cronbach α ranging from .62 to .96 across all subscales and good construct validity ranging from .14 to .40 across all subscales.

### **2.5 Experimental design for the fear conditioning task**

The study used an established fear conditioning paradigm, shown to provide adequate conditioning to fearful stimuli (Baeuchl et al., 2019; Fullana et al., 2016; Rothemund et al., 2012; Suarez-Jimenez et al., 2020). In this differential conditioning paradigm, geometrical shapes in the form of a circle and a triangle served as conditioned stimuli, with one stimulus (CS+) predicting the occurrence of a painful unconditioned stimulus (US), while being actually paired with the presentation of the US (CS+c), as well as a condition in which the same conditioned stimuli was not paired with the presentation of the US (CS+uc) to check for hemodynamic responses evoked by the CS+ without the confounding effects of the US. In addition, the other stimulus shape (CS-) signaled the absence of a painful US. In the habituation phase, CS+, CS-, and US were presented 6 times in a pseudo-randomized order. US presentation in this phase served the purpose to allow participants to habituate to the fairly strong US and reduce motion artifacts in the scanner. Next, two identical acquisition phases were presented to the participants. In the acquisition phases, the CS+ was presented 19 times and CS- was presented 21 times each in a pseudo-randomized order. During the acquisition phases, the US was presented 2.8 seconds together with the CS+ representing the fear conditioning. During extinction, the CS+ and the CS- were presented 8 times in a pseudo-randomized order without the presence of the US. The intertrial interval was always 7-10 s. (see Fig. 3). After each phase, participants were asked questions about the US, CS+, and CS- in terms of arousal, contingency, and valence via a visual analogue scale (VAS). These ratings were used to observe if participants experienced the CS+ as a conditioned stimulus and if CS- was distinctively rated and not conditioned to the US. For the ratings the Self-Assessment-Manikin (SAM; Bradley & Lang, 1994) was used and adapted to a 9-point scale reaching from very unlikely (value equals 1 on the scale) to very likely (value equals 9 on the scale).



**Figure 2.** *The four conditioning phases of the fear conditioning experiment. The circle shape serves as conditioned stimuli paired with the unconditioned stimuli (CS+), the triangle shape as conditioned stimuli not paired with the unconditioned stimuli (CS-), and the lightning shape represents the electric stimulus labeled as unconditioned stimuli (US). After each phase, a visual analogue scale (VAS) was presented to obtain ratings in terms of arousal, contingency, and valence for the CS+, CS-, and the US.*

### **2.6 MRI acquisition**

T1-weighted 3D images were compiled for every participant via a 3-Tesla MR-scanner (PRISMA, Siemens Medical Solutions, Erlangen, Germany) with a 64-channel head coil and rapid gradient echo sequence (TR/TE = 3.15/1.37 ms; 160 slices; 1.6 mm isotropic voxel size). MRI data were acquired during the fear conditioning task via a T2-weighted gradient-echo echo planar imaging sequence (TR/TE = 3100/30ms; 51 slices; FOV 192 mm; 2.0 x 2.0 x 2.5 mm voxel size).

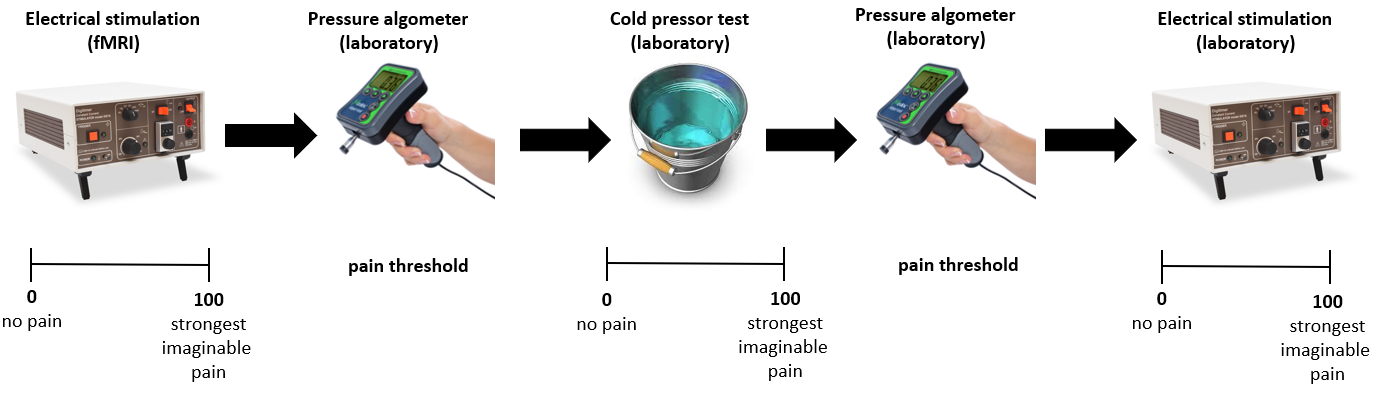
### **2.7 Pain measurements**

In order to assure adequate pain measurement for pain threshold and pain tolerance, different sensory pain markers were assessed in the fMRI and laboratory part of the study. During the fMRI part prior to the fear conditioning experiment, an electric stimulus for the experiment was determined via a cupric electrode connected to a high voltage constant current stimulator (Electric stimulation; Digitimer, DS7A, Welwyn GardenCity, UK). A steadily increasing pain stimulus (50-ms bursts, 12 Hz) was presented to the right thumb of the participants and they were asked to rate the point of pain threshold (first experience of pain) and pain tolerance (point where the pain became unbearable) 3 times. With these data points the targeted pain level was computed via the following formula: pain intensity = pain threshold mean + (pain tolerance mean – pain threshold mean) x 0.8.

After computing the desired pain level, the participants were exposed to the electric stimulus and were asked to rate it on a scale from 0 to 10 where 0 represented “no pain at all” and 10 “the strongest imaginable pain”. The targeted response was 8 and the pain stimulus was adjusted via a manual high voltage constant current stimulator as well as respective participant rating if the first rating was not equal to 8. This computed stimulus was then used in the fear conditioning experiment. In the laboratory part of the study, the electric stimuli were employed to compute pain threshold and pain tolerance in the same fashion.

Additionally, a cold pressor test on the right hand of the participants was conducted. The participant was asked to immerse their hand into an ice water bucket (0-4°C) for up to three minutes. This test was included in the experiment to allow for a more diverse pain threshold and pain tolerance assessment. The participants were asked to rate pain threshold and pain tolerance during the cold pressor measurement and further they indicated the pain intensity every 10 seconds on a scale from 0-100, where 0 represented “no pain at all” and 100 “the strongest imaginable pain”.

Before and after the cold pressor measurement a pressure pain test via a pressure algometer was conducted to measure sensitivity over the muscle. The participants were asked to report their pain threshold while being exposed to constantly increasing pressure via the pressure algometer applied on the left palm between the thumb and the index finger. This measurement was conducted three times before the cold pressor measurement and three times after the cold pressor measurement. A visualization for the sequence of the pain measurements and rating scales can be viewed in figure 3 below.



**Figure 3.** *Sequence of all conducted pain tests across the experiment with respective ratings for every pain test.*

### **2.8 Peripheral psychophysiological recordings**

During the fear conditioning experiment in the MR scanner, pulse and heart rate were assessed using the respective function of a 3-Tesla MR-scanner (PRISMA, Siemens Medical Solutions, Erlangen, Germany). The measurement was conducted during the whole fMRI experiment from the first trial presentation until the last rating to detect any abnormal physical activities that may have to be accounted for (TR = 3100 ms).

### **2.9 Statistical Analyses**

#### **2.9.1 MRI data analysis**

FSL v6.0 was used to analyze the MRI data for the first-level and higher-level analyses and RStudio version 4.1.2 was used to compile the regressor files of the fear conditioning experiment (Jenkinson et al., 2012; RStudio Team, 2020). The fMRI data was preprocessed in terms of motion correction, high-pass temporal filtering (cut-off = 100s) and was brain-extracted using the respective FSL-tool (<http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/BET>). A Gaussian kernel of full-width at half-maximum of 5 mm was used for image smoothing and MNI152\_T1\_2mm standard brain as well as the individual brain extracted MPRAGE were applied for volume registration via FMRIB’s Linear Registration Tool (<http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/FLIRT>). Correlation contrasts to check for interactions and main effects were designed in a full model setup to check the hypotheses regarding the first-level analysis.

The FSL higher-level analysis was used to test for video gaming group differences in brain activation for every fear conditioning phase in the form of independent t-tests with and without the covariate of CTQ-subscales representing ACE-dimensions, as well as for a general correlation between brain activity and CTQ-subscale values. T-tests were conducted via contrast testing on the subject level by using the respective feat-folders of each participant. For video gaming group differences, two respective video gaming groups were selected and contrasted against each another based on the defined first level analysis contrasts. This analysis was then extended by adding each CTQ subscale as a covariate to the analysis one by one. For the general influence of CTQ subscales on the overall sample we conducted a correlation analysis with the whole sample at once, not dividing the sample by video gaming groups. We also merged the acquisition phases 1 and 2 for a follow-up analysis to generate more power. Analysis methods were congruent to the analysis described above; however, we did not use the feat-folders as a whole, but the respective contrasts defined in the first level analysis one by one (Cope-level analysis). We used a mixed effects model: FLAME 1 with a cluster-z-threshold of 3.1 and a cluster-p-threshold of 0.05.

#### **2.9.2 Behavioral data analysis**

Behavioral statistics regarding pain measurements and fear conditioning ratings for valence, arousal, and contingency were conducted with IBM SPSS Statistics 21 (IBM Corp., 2012). To test for group differences between each observed video gaming group at once, regarding the high voltage constant current stimulator electrode stimulation pain test, the cold pressor measurement pain test and the pressure algometer pain test, univariate and multivariate ANOVAs were computed for each pain measurement, because more than two groups were defined in the experimental design and we wanted to analyze the data for single as well as for multiple dependent variables simultaneously. Further linear regression models were used to check for the connection between each CTQ subscale and each pain measurement. Valence, arousal, and contingency ratings for the fear conditioning experiment were analyzed using univariate ANOVAs. To test for a potential moderator effect of ACE on the association between video gaming and pain measurements we conducted several moderation analyses by HAYES via PROCESS v3.2 with ordinary least squares regression, yielding unstandardized coefficients for all effects (Hayes, 2017). For the moderation design we used video gaming groups as independent variable, pain threshold or tolerance of the respective pain tests as dependent variable, and CTQ subscales as moderator variable. We calculated moderations for every possible combination of pain tests and CTQ subscales.

Chi-square analyses were sampled for potential gender, and ACE differences between groups were sampled to assess potential interfering confounding variables regarding the pain measurements and the fear conditioning experiment. The goal was to exclude confounding variables like gender or ACE-level differences between video gaming groups on pain threshold or pain tolerance for each of the conducted pain measurements and for the pain application of the fear conditioning task.

## **3 RESULTS**

### **3.1 Sample Characteristics**

Chi-square tests showed no significant differences for the observed pool of participants between the video gaming groups regarding gender (male vs female distribution; χ²(2) = 3.95, *p* = .136) and ACE levels (ACE in the past vs no ACE in the past; χ²(2) = 3.60, p = .165). An illustration for the means and standard deviations of CTQ subscale values across the different video gaming groups can be seen in Table 1. A one-factorial ANOVAs yielded no significant differences for the CTQ subscales across the video gaming groups for emotional abuse (*F*(2,57) = .51, *p* = .606), physical abuse (*F*(2,57) = 2.19, *p* = .121), sexual abuse (*F*(2,57) = .60, *p* = .555), emotional neglect (*F*(2,57) = .20, *p* = .821) and physical neglect (*F*(2,57) = .66, *p* = .519).

**Table 1**

*Means and standard deviations of each individual CTQ subscale assessing ACE (emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect) for every video gaming group* *(violent video gamer (VVG), nonviolent video gamer (NVVG) and non-gamer (NG))*

|  |  |  |  |
| --- | --- | --- | --- |
| Video gaming group | VVG | NVVG | NG |
| Emotional abuse | 13.00 (*SD*=6.72) | 11.30 (*SD*=6.05) | 11.30 (*SD*=5.71) |
| Physical abuse | 9.45 (*SD*=6.40) | 6.50 (*SD*=2.93) | 7.45 (*SD*=3.56) |
| Sexual abuse | 8.35 (*SD*=6.36) | 6.70 (*SD*=3.50) | 7.65 (*SD*=4.06) |
| Emotional neglect | 13.55 (*SD*=7.53) | 12.25 (*SD*=6.12) | 13.05 (*SD*=6.00) |
| Physical neglect | 9.40 (*SD*=5.79) | 7.65 (*SD*=3.90) | 8.40 (*SD*=4.58) |
| Note. N = 60; N = 20 per video gaming group.  VVG = violent video gamer; NVVG = nonviolent video gamer; NG = non-gamer | | | | |

### **3.2 Pain measurements and video gaming groups**

In terms of the conducted pain measurements, the cold pressor measurement test results displayed significant pain threshold differences for the video gaming groups (*F*(2,26.60) = 5.28, *p* = .012). VVG showed a significantly higher pain threshold in the cold pressor measurement test than NG (36.90, 95%-CI[4.24, 69.56], *p* = .023), but not significantly higher than NVVGs (18.20, 95%-CI[-14.46, 50.86], *p* = .379). NVVG displayed no significant difference for the pain threshold in the cold pressor measurement test compared to NG (18.70, 95%-CI[-13.96, 51.36], *p* = .359).

The cold pressor measurement test also displayed significant pain tolerance differences across the video gaming groups (*F*(2,31.43) = 6.19, *p* = .005). VVG showed significantly higher cold pressor pain tolerances than NG (43.40, 95%-CI[1.20, 84.80], *p* = .038), but VVG did not display significantly higher cold pressor measurement test pain tolerance than NVVG (4.25, 95%-CI[-37.15, 45.65], *p* = .967), and NVVG did not show a significant difference in cold pressor measurement test pain tolerance compared to NG (39.15, 95%-CI[-2.25, 80.55], *p* = .068).

Electric stimulation in the laboratory displayed significant differences in pain threshold across the video gaming groups (*F*(2,56) = 5.70, *p* = .006). VVG showed higher pain thresholds than NG (1.59, 95%-CI[.38, 2.80], *p* = .007) and NVVG (1.28, 95%-CI[.08, 2.47], *p* = .034), but NVVG did not display a significant difference to NG (.32, 95%-CI[-.89, 1.53], *p* = .803). Electric stimulation in the laboratory also showed significant pain tolerance differences across video gaming groups (*F*(2,56) = 3.36, *p* = .042). VVG displayed significantly higher pain tolerance than NG (1.76, 95%-CI[.09, 3.43], *p* = .036), but not significantly higher pain tolerance than NVVG (1.16, 95%-CI[-.49, 2.81], *p* = .215). NVVG also showed no significantly higher pain tolerance than NG (.60, 95%-CI[-1.07, 2.27], *p* = .664). Electric stimulation in the MRI also displayed significant video gaming group differences regarding reaching the targeted pain intensity rating of eight by participants (*F*(2,56) = 4.92, *p* = .011). VVG displayed higher pain intensity ratings than NG (5.20, 95%-CI[.98, 9.42], *p* = .012), but VVG did not show significantly higher pain intensity ratings than NVVG (1.03, 95%-CI[-3.25, 5.30], *p* = .833), and NVVG did not show a significant difference in pain intensity ratings compared to NG (4.17, 95%-CI[-.10, 8.45], *p* = .057).

The pressure algometer test before the cold pressor measurement displayed significant differences in pain thresholds across video gaming groups (*F*(2,34.80) = 4.06, *p* = .026). VVG had significantly higher pain thresholds than NG (20.86, 95%-CI[4.99, 36.72], *p* = .007), but not significantly higher pain threshold than NVVG (11.64, 95%-CI[-4.23, 27.51], *p* = .191). NVVG also showed no significantly higher pain threshold than NG (9.22, 95%-CI[-6.65, 25.10], *p* = .349). Pressure algometer values after the cold pressor measurement also displayed significantly different pain threshold ratings across the video gaming groups (*F*(2,35.02) = 4.83, *p* = .014). VVG had significantly higher pain thresholds than NG (25.12, 95%-CI[7.32, 42.91], *p* = .004), but VVG did not show significantly higher pain thresholds than NVVG (14.09, 95%-CI[-3.70, 31.89], *p* = .146), and NVVG did not show a significant difference in pain threshold compared to NG (11.02, 95%-CI[-6.78, 28.82], *p* = .303).

Results for all conducted pain assessments and respective video gaming group differences can be viewed in Table 2 below.

**Table 2**

*Means and standard deviation derived from one-factorial ANOVA testing for each conducted pain measurement across the video gaming groups*

|  |  |  |  |
| --- | --- | --- | --- |
| Video gaming group | VVG | NVVG | NG |
| Cold pressor measurement pain threshold | M = 48.30  SD = 61.01 | M = 30.10  SD = 41.74 | M = 11.40  SD = 7.84 |
| Cold pressor measurement pain tolerance | M = 92.35  SD = 65.30 | M = 88.10  SD = 63.10 | M = 48.95  SD = 25.19 |
| Electric stimulation pain threshold (laboratory) | M = 4.06  SD = 1.87 | M = 2.78  SD = 1.36 | M = 2.47  SD = 1.40 |
| Electric stimulation pain tolerance (laboratory) | M = 5.93  SD = 2.23 | M = 4.77  SD = 2.20 | M = 4.17  SD = 2.05 |
| Electric stimulation (MRI) | M = 11.32  SD = 5.59 | M = 10.29  SD = 5.85 | M = 6.12  SD = 5.18 |
| Pressure algometer pain threshold pre cold pressor measurement | M = 65.15  SD = 29.14 | M = 53.51  SD = 12.29 | M = 44.30  SD = 17.44 |
| Pressure algometer pain threshold post cold pressor measurement | M = 69.40  SD = 33.25 | M = 55.31  SD = 13.87 | M = 44.29  SD = 18.51 |

Note. N = 60; N = 20 per videogaming group.  
VVG = violent video gamer; NVVG = nonviolent video gamer; NG = non-gamer  
M = mean; SD = standard deviation

We observed significant differences in means between the pain threshold ratings of the pressure algometer test pre cold pressor measurement and pressure algometer test post cold pressor measurement accounting for the entire sample (*p* = .043). However, the only group that showed a significant difference in pain ratings regarding the pressure algometer test before the cold pressor measurement and after the cold pressor measurement was VVG (*p* = .043). VVG showed significantly higher pressure pain endurance after the cold pressor measurement than before. NVVG (*p* = .331) as well as NG (*p* = .995) did not show significant differences for the pressure algometer test pre cold pressor measurement and pressure algometer test post cold pressor measurement. A table containing the results is visualized below.

**Table 3**

*Differences between the pressure algometer test pre cold pressor measurement and pressure algometer test post cold pressor measurement pain threshold ratings for the whole sample as well as divided by groups*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Video gaming group | Whole sample | VVG | NVVG | NG | | |
| Pressure algometer pre cold pressor measurement | M=54.32 SD=22.23 | M=65.15 SD=29.14 | M=53.51 SD=12.29 | M=44.29 SD=17.45 | | |
| Pressure algometer post cold pressor measurement | M=56.33 SD=25.22 | M=69.40 SD=33.25 | M=55.31 SD=13.87 | M =44.29 SD=18.51 | | |
| *t* | -2.07\* | -2.17\* | -1.00 | .01 | | |
| Note. N = 60; N = 20 per video gaming group.  VVG = violent video gamer; NVVG = nonviolent video gamer; NG = non-gamer  \* = *p* < .05 | | | | |  |

### **3.3 Pain measurements and ACE**

The pressure algometer pain threshold pre cold pressor measurement showed a significant predictability of variance by the level of ACE (F (5,54) = 5.58, *p* < .001). Twenty-eight percent of the variance of sensitivity in the pressure algometer test pre cold pressor measurement was explained by the level of ACE. Emotional neglect was the strongest predictor for sensitivity in the pressure algometer test pre cold pressor measurement with respect to the condition of listwise inclusion. Higher levels of emotional neglect were connected to significantly lower scores of pain threshold in the pressure algometer test pre cold pressor measurement. CTQ subscales emotional abuse (β = 1.457; t (54) = 1.964; *p* = .055), physical abuse (β = 1.567; t (54) = 1.897; *p* = .063), sexual abuse (β = .917; t (54) = 1.317; *p* = .193), and physical neglect (β = .704; t (54) = .788; *p* = .434) were also added to the model via listwise inclusion.

The pressure algometer pain threshold post cold pressor measurement also revealed variance predictability of pain threshold ratings by levels of ACE (*F*(5,54) = 4.67, *p* = .001). Twenty-four percent of variance for the sensitivity of the pressure algometer test post cold pressor measurement was explained by the level of ACE. Emotional neglect represented the strongest factor as a single subscale in explaining the influence of ACE on this pain test. Higher levels of emotional neglect were connected to significantly lower scores in terms of pressure algometer threshold for the pressure algometer test post cold pressor measurement (β = -2.253; t (54) = -2.522; *p* = .015). CTQ subscales emotional abuse (β = 1.662; t (54) = 1.873; *p* = .066), physical abuse (β = 1.678; t (54) = 1.740; *p* = .088), sexual abuse (β = 1.189; t (54) = 1.462; *p* = .149), and physical neglect (β = .301; t (54) = .288; *p* = .774) were added to the model via listwise inclusion. CTQ subscales did not significantly predict variance of other pain measurements than the pressure algometer test.

### **3.4 Pain measurements, ACE, and gaming groups**

Next, a moderation analysis was performed to determine whether CTQ subscales moderate the connection between gaming groups and the sensitivity in pain tests. Physical neglect moderated the pain sensitivity in multiple pain tests (see fig. 2). The moderation regarding the pressure algometer test pre cold pressor measurement explained 32.68% of variance (F (3,56) = 9.06, *p* < .001), with a significant interaction between physical neglect and video gaming groups (ΔR² = 11.06%, F (1, 56) = 9.20, *p* = .004, 95% CI [0.611, 2.991]). Conditional effects analyses with simple slope interaction showed non-significant predictor qualities for low levels of physical neglect (- 1 SD; *b* = 2.97, *SE* = 3.74, *t* = .80, *p* = .430). In contrast, a mean level of physical neglect (MEAN; *b* = 9.24, *SE* = 2.98, *t* = 3.10, *p* = .003) as well as high levels of physical neglect (+1 SD; *b* = 17.87, *SE* = 3.98, *t* = 4.49, *p* < .001) were significant moderators for the relation between gaming groups and pressure algometer test pre cold pressor measurement sensitivity. Table 4 below shows the data for this moderation model.

**Table 4**

*Moderation model results for the moderating effect of physical neglect on the relation between the independent variable video gaming groups and the dependent variable pressure algometer test pre cold pressor measurement*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | *b* | *SE(b)* | | *t* | | *p* |
| Constant | 53.72  [48.86; 58.58] | 2.43 | | 22.15 | | < .001 |
| Video gaming group | 9.24  [3.28; 15.20] | 2.98 | | 3.10 | | .003 |
| Physical neglect | .88  [-.17; 1.92] | .52 | | 1.68 | | .100 |
| Video gaming group x Physical neglect | 1.80  [.61; 3.00] | .59 | | 3.03 | | .004 |
| Note. N = 60; N = 20 per video gaming group. | | |  | |

Physical neglect as a moderator also explained 29.13% of variance on the relation between video gaming groups and the pressure algometer test post cold pressor measurement pain threshold (F (3,56) = 7.67, *p* < .001) with a significant interaction between gamer groups and physical neglect (ΔR² = 9.28%, F (1, 56) = 7.33, *p* = .009, 95% CI [0.489, 3.256]). Similar to the pressure algometer test pre cold pressor measurement pain threshold low levels of physical neglect did not show significant conditional effects (- 1 SD; *b* = 4.97, *SE* = 4.35, *t* = 1.14, *p* = .257) but mean (MEAN; *b* = 11.49, *SE* = 3.47, *t* = 3.32, *p* = .002), and high scores (+1 SD; *b* = 20.46, *SE* = 4.64, *t* = 4.41, *p* < .001) served as significant moderators for the relation between gaming groups and pressure algometer test post cold pressor measurement sensitivity. Table 5 below shows the data for this moderation model.

**Table 5**

*Moderation model results for the moderating effect of physical neglect on the relation between the independent variable video gaming groups and the dependent variable* pressure algometer test *post cold pressor measurement*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | *b* | *SE(b)* | | *t* | | *p* |
| Constant | 55.71  [50.06; 61.36] | 2.82 | | 19.74 | | < .001 |
| Video gaming group | 11.49  [4.55; 18.43] | 3.47 | | 3.32 | | .002 |
| Physical neglect | .58  [-.64; 1.80] | .61 | | .95 | | .346 |
| Video gaming group x physical neglect | 1.88  [.49; 3.26] | .69 | | 2.71 | | .009 |
| Note. N = 60; N = 20 per video gaming group. | | |  | |

In addition, the sensitivity of electric stimulation pain thresholds in the laboratory was also moderated by physical neglect. Physical neglect explained 25.17% of variance on the relation between video gaming groups and sensitivity of the electric stimulation pain threshold (F (3,55) = 6.17, *p* = .001) with a significant interaction between physical neglect and gaming groups (ΔR² = 9.78%, F (1, 55) = 7.19, *p* = .010, 95% CI [0.040, 0.270]). Conditional effects of low (- 1 SD; *b* = 0.32, *SE* = 0.31, *t* = 1.05, *p* = .297), mean (MEAN; *b* = 0.82, *SE* = 0.24, *t* = 3.39, *p* = .001) and high (+1 SD; *b* = 1.52, *SE* = 0.36, *t* = 4.25, *p* < .001) physical neglect as focal predictor at values of the moderator showed similar patterns as the previous mentioned pain tests. Table 6 below shows the data for this moderation model.

**Table 6**

*Moderation model results for the moderating effect of physical neglect on the relation between the independent variable video gaming groups and the dependent variable pain threshold markers obtained via electric stimulation in the lab*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | *b* | *SE(b)* | | *t* | | *p* |
| Constant | 3.03  [2.63; 3.42] | .20 | | 15.27 | | < .001 |
| Video gaming group | .82  [.34; 1.31] | .24 | | 3.39 | | .001 |
| Physical neglect | -.08  [-1.18; .02] | .05 | | -1.58 | | .120 |
| Video gaming group x physical neglect | .15  [.04; .27] | .06 | | 2.68 | | .010 |
| Note. N = 60; N = 20 per video gaming group. | | |  | |

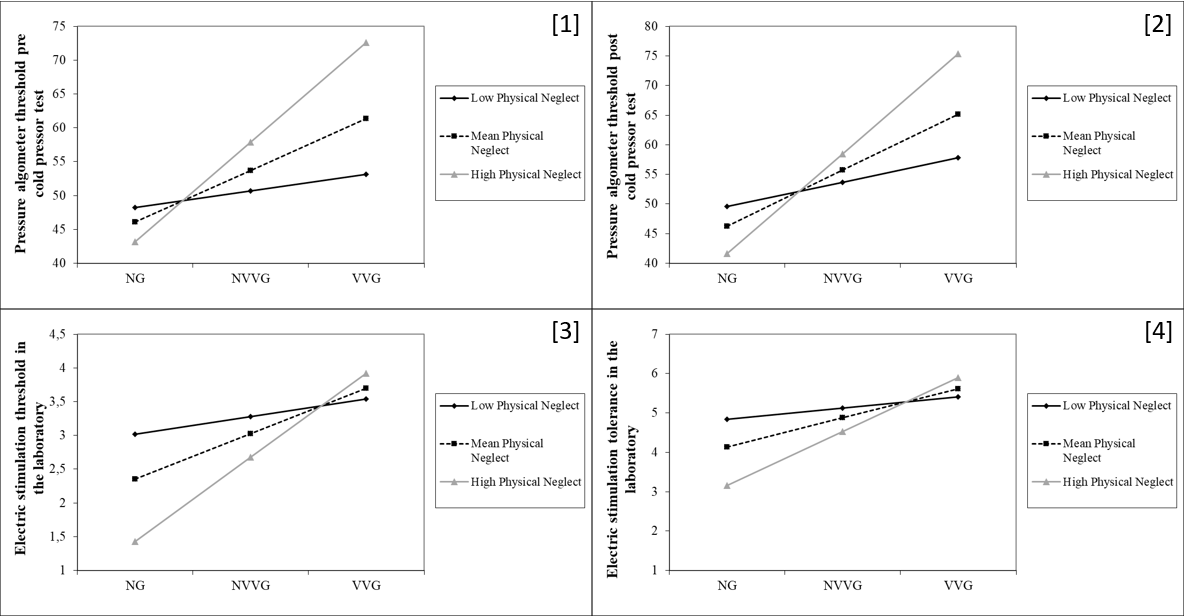
Pain tolerance for electric stimulation in the laboratory was also significantly moderated by physical neglect, and physical neglect explained 17.20% of variance on the relation between gaming groups and this pain test (F (3,55) = 3.81, *p* = .015) with a significant interaction between physical neglect and gaming groups (ΔR² = 6.76%, F (1, 55) = 4.50, *p* = .039, 95% CI [0.009, 0.333]). Similar to the other reported pain tests, low levels of physical neglect did not show significant conditional effects (- 1 SD; *b* = 0.35, *SE* = 0.43, *t* = 0.81, *p* = .423) but mean (MEAN; *b* = 0.90, *SE* = 0.34, *t* = 2.65, *p* = .011) but high scores (+1 SD; *b* = 1.67, *SE* = 0.50, *t* = 3.34, *p* = .002) did. Table 7 below shows the data for this moderation model.

**Table 7**

*Moderation model results for the moderating effect of physical neglect on the relation between the independent variable video gaming groups and the dependent variable pain tolerance markers obtained via electric stimulation in the lab*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | *b* | *SE(b)* | | *t* | | *p* |
| Constant | 4.87  [4.32; 5.43] | .28 | | 17.56 | | < .001 |
| Video gaming group | .90  [.22; 1.56] | .34 | | 2.65 | | .011 |
| Physical neglect | -.08  [-.22; .06] | .07 | | -1.13 | | .265 |
| Video gaming group x physical neglect | .17  [.01; .33] | .08 | | 2.12 | | .039 |
| Note. N = 60; N = 20 per video gaming group. | | |  | |

We obtained no additional moderating effects of CTQ subscales besides physical neglect on the conducted pain tests. All moderation-based interactions are visualized in figure 4 below.



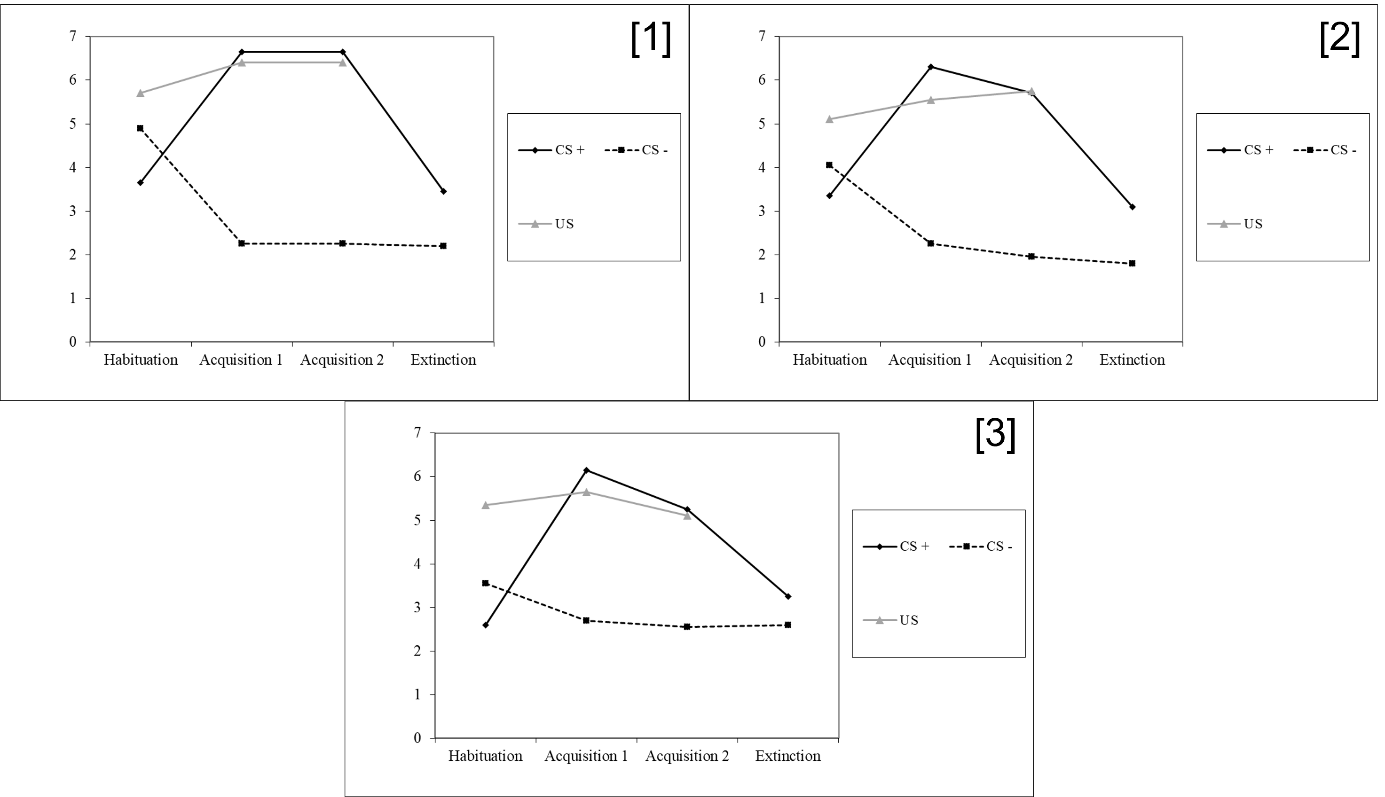
**Figure 4.** *Illustrated moderation of [1] physical neglect (M) – gamer groups (X) – pressure algometer threshold pre cold pressor test (Y); [2] physical neglect (M) – gamer groups (X) – pressure algometer threshold post cold pressor test (Y); [3] physical neglect (M) – gamer groups (X) – electric stimulation threshold in the laboratory (Y); [4] physical neglect (M) – gamer groups (X) – electric stimulation tolerance in the laboratory (Y)*

*NOTE.* X = moderator variable; X = independent variable; Y = dependent variable

VVG = violent video gamer; NVVG = nonviolent video gamer; NG = non-gamer

### **3.5 Arousal, valence, and contingency ratings for the fear conditioning task**

Arousal, valence, and contingency ratings were observed to assess if fear conditioning was induced. Arousal, valence, and contingency ratings indicated successful fear conditioning, because all ratings showed a significant distinction in mean ratings between phases that differed in stimulus presentation due to the conditioning paradigm, and no significant distinctions were observed between the two acquisition phases, which did not differ in the conditioning stimulus paradigm (see Table 8, Table 9, and Table 10). No significant differences for the arousal, valence, and contingency ratings between the video gaming groups were observed, and CS+ and CS- were not correlating in the acquisition phases in terms of ratings of arousal, valence or contingency as designed. Visualization for arousal ratings (see figure 5), valence ratings (see figure 6), and contingency ratings (see figure 7) are listed below.

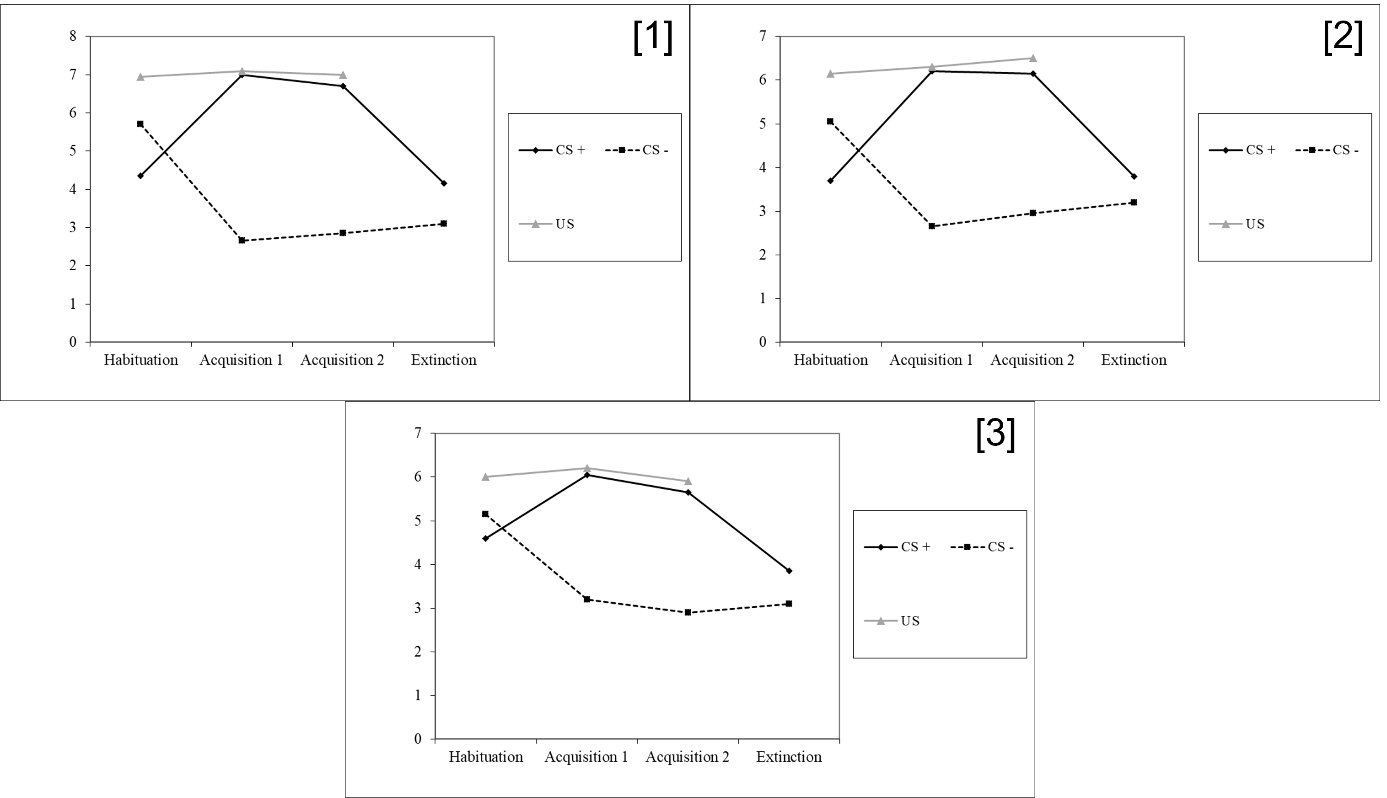


**Figure 5.** *Fear conditioning arousal ratings regarding each fear conditioning phase for [1] violent video gamers, [2] nonviolent video gamers, and [3] non-gamers.*

**Table 8**

*Pairwise comparisons for arousal ratings regarding mean difference between all used conditioning phases for the conditioning stimuli conditioned stimulus paired (CS+), conditioned stimulus unpaired (CS-), and unconditioned stimulus (US)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | CS+ | CS- | US | |
| Habituation - Acquisition 1 | MD= -3.17\*\*\* | MD= 1.77\*\*\* | MD= -.48 | |
| Habituation - Acquisition 2 | MD= -2.67\*\*\* | MD= 1.92\*\*\* | MD= -3.67 | |
| Habituation - Extinction | MD= -.07 | MD= 1.97\*\*\* |  | |
| Acquisition 1 - Acquisition 2 | MD= .50 | MD= .15 | MD= .12 | |
| Acquisition 1 - Extinction | MD= 3.10\*\*\* | MD= .20 |  | |
| Acquisition 2 - Extinction | MD= 2.60\*\*\* | MD= .05 |  | |
| Note. N = 60, MD = mean difference  CS+ = conditioned stimulus paired; CS- = conditioned stimulus unpaired; US = unconditioned stimulus  \*\*\* = *p* < .001 | | | |  |

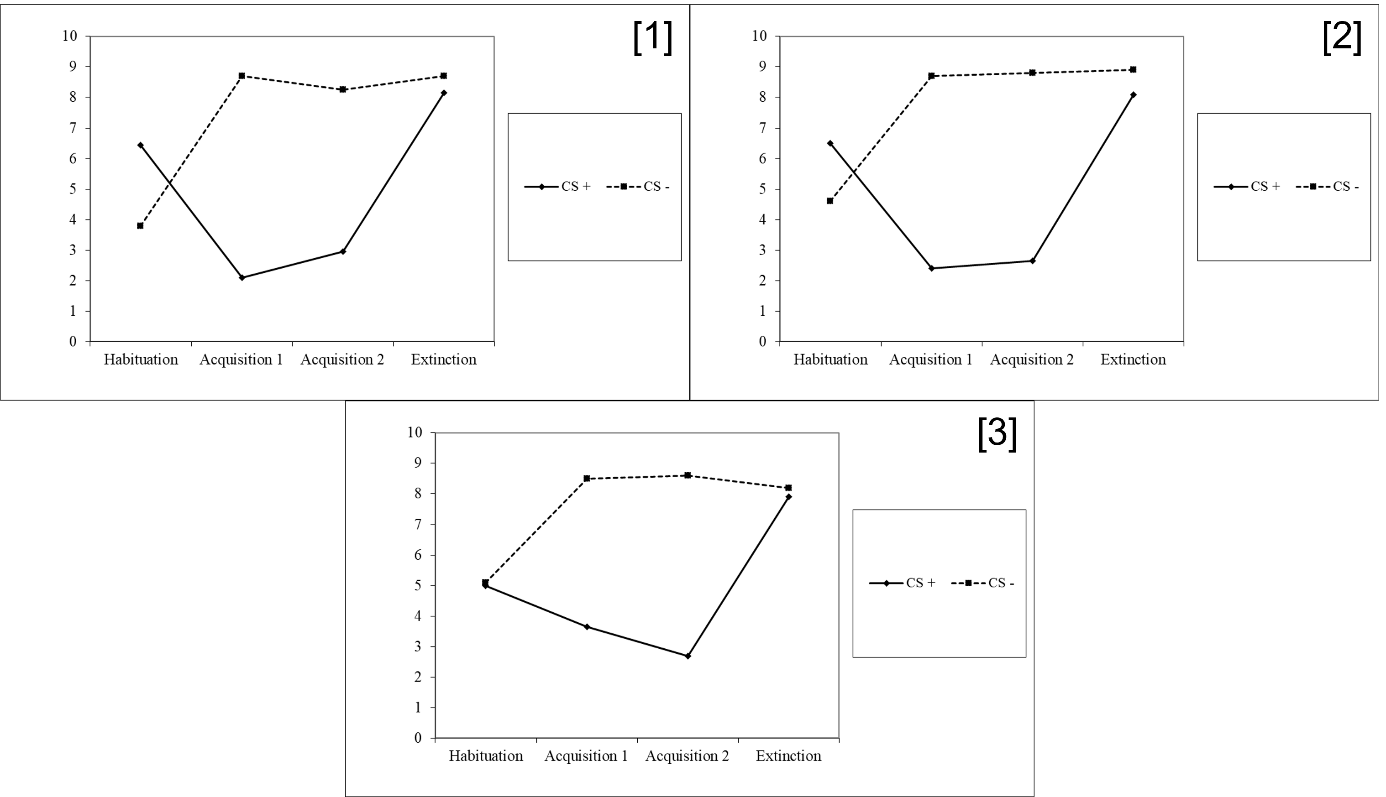


**Figure 6.** *Fear conditioning valence ratings regarding each fear conditioning phase for [1] violent video gamers, [2] nonviolent video gamers, and [3] non-gamers.*

**Table 9**

*Pairwise comparisons for valence ratings regarding mean difference between all used conditioning phases for the conditioning stimuli conditioned stimulus paired (CS+), conditioned stimulus unpaired (CS-), and unconditioned stimulus (US)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | CS+ | CS- | US | |
| Habituation - Acquisition 1 | MD= -2.20\*\*\* | MD= 2.47\*\*\* | MD= -.19 | |
| Habituation - Acquisition 2 | MD= -1.95\*\*\* | MD= 2.40\*\*\* | MD= -.13 | |
| Habituation - Extinction | MD= .28 | MD= 2.17\*\*\* |  | |
| Acquisition 1 - Acquisition 2 | MD= .25 | MD= -.07 | MD= .06 | |
| Acquisition 1 - Extinction | MD= 2.48\*\*\* | MD= -.30 |  | |
| Acquisition 2 - Extinction | MD= 2.23\*\*\* | MD= -.23 |  | |
| Note. N = 60, MD = mean difference  CS+ = conditioned stimulus paired; CS- = conditioned stimulus unpaired; US = unconditioned stimulus  \*\*\* = *p* < .001 | | | |  |



**Figure 7.** *Fear conditioning contingency ratings regarding each fear conditioning phase for [1] violent video gamers, [2] nonviolent video gamers, and [3] non-gamers.*

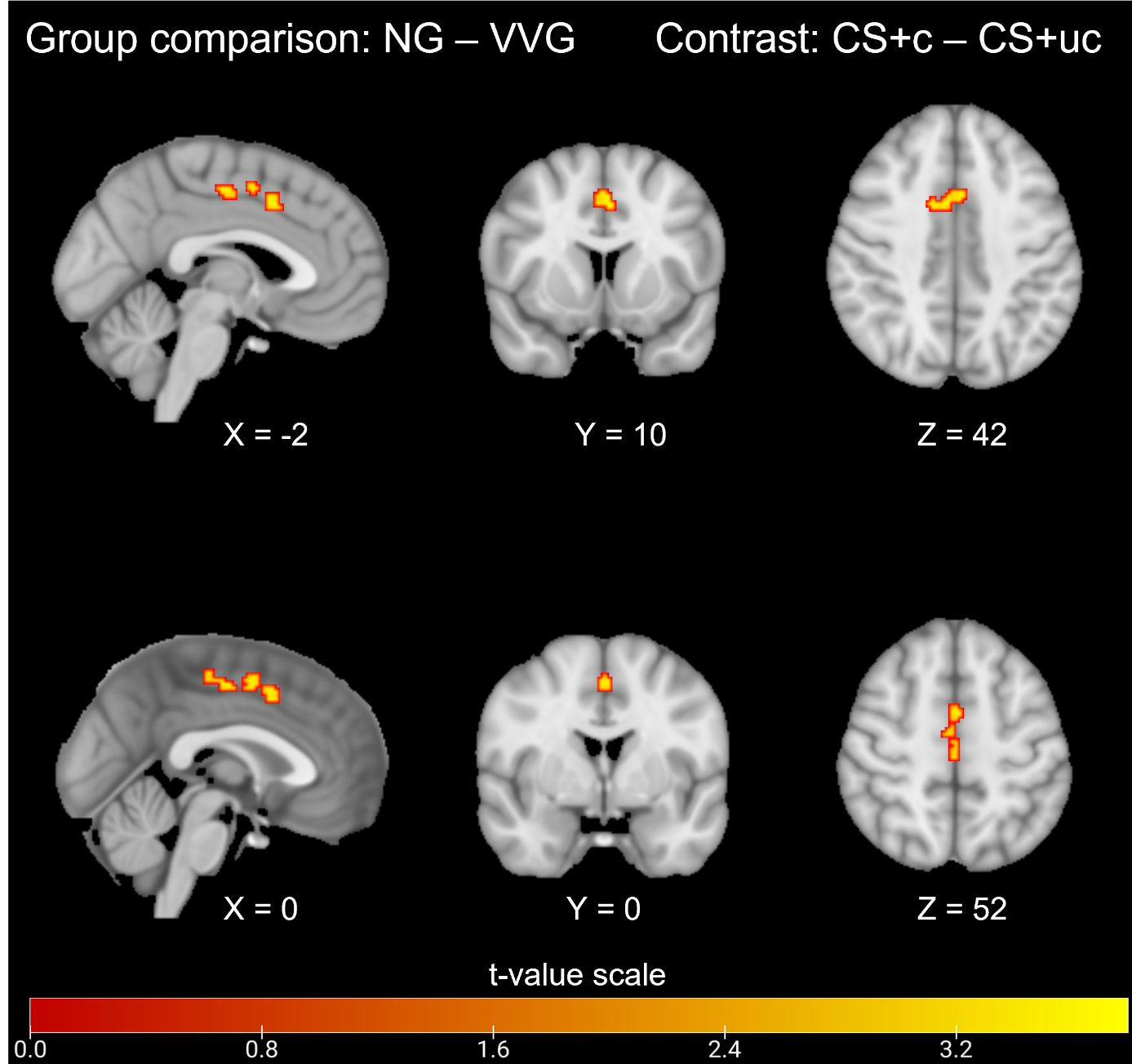
**Table 10**

*Pairwise comparisons for contingency ratings regarding mean difference between all used conditioning phases for the conditioning stimuli conditioned stimulus paired (CS+), conditioned stimulus unpaired (CS-), and unconditioned stimulus (US)*

|  |  |  |
| --- | --- | --- |
|  | CS+ | CS- |
| Habituation - Acquisition 1 | MD= 3.27\*\*\* | MD= -4.13\*\*\* |
| Habituation - Acquisition 2 | MD= 3.22\*\*\* | MD= -4.05\*\*\* |
| Habituation - Extinction | MD= -2.07\*\*\* | MD= -4.10\*\*\* |
| Acquisition 1 - Acquisition 2 | MD= -.05 | MD= .08 |
| Acquisition 1 - Extinction | MD= -5.33\*\*\* | MD= .03 |
| Acquisition 2 - Extinction | MD= -5.28\*\*\* | MD= -.05 |
| Note. N = 60, MD = mean difference  CS+ = conditioned stimulus paired; CS- = conditioned stimulus unpaired; US = unconditioned stimulus  \*\*\* = *p* < .001 | | | |

### **3.6 Brain activation patterns in the fear conditioning paradigm**

Because the conducted fear conditioning experiment used the same stimulus design for Acquisition phase 1 and 2, we combined these phases regarding fMRI data analysis. The most important contrast for fear conditioning is the difference in activation for the presentation of a conditioning cue that is paired with a painful stimulus (CS+c) minus the same conditioning cue, but without it being paired with a painful stimulus (CS+uc). For the combined phase of Acquisition 1 and Acquisition 2 (using the contrast CS+c minus CS+uc), NG showed a significantly higher activation in the ACC, juxtapositional lobule cortex, and paracingulate gyrus compared to VVG. Figure 8 shows brain activation patterns for each significantly active cluster regarding the respective design. Table 11 shows peak voxels (MNI coordinates), *t*-values, and cluster size of brain areas that show significantly higher activations for NG compared to VVG on this contrast. We did not observe significant group differences in terms of respective brain activations regarding an inclusion of NVVG as one of the groups.



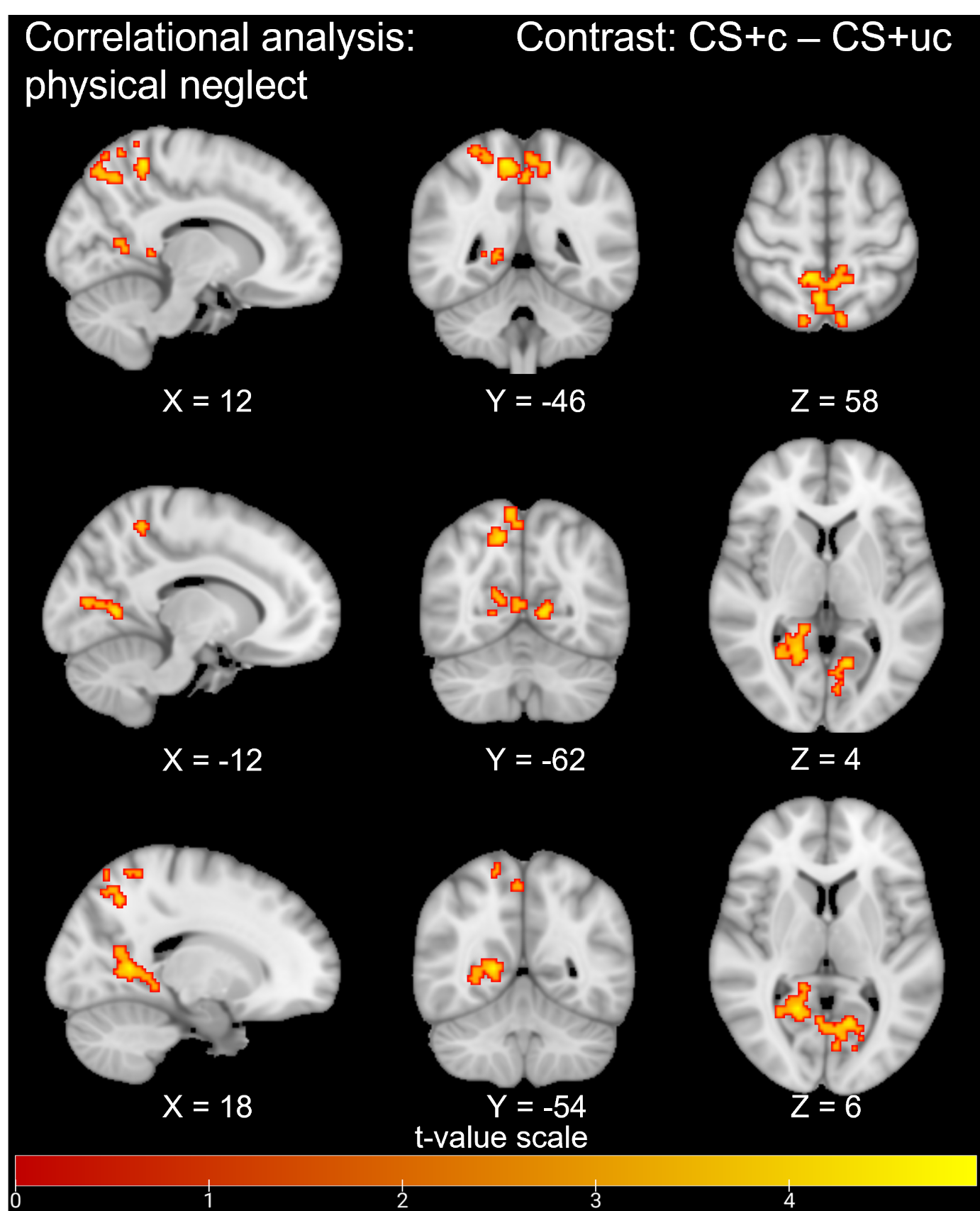
**Figure 8.** *Brain response contrast for the combined Acquisition phase between non-gamer (NG) minus violent video gamer (VVG) on the contrast CS+c minus CS+uc.*

**Table 11**

*Peak voxels (MNI coordinates), t-values, and cluster size of brain areas that show significant higher activations for non-gamers (NG) compared to violent video gamers (VVG) on the contrast CS+c minus CS+uc*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Brain areas | X  (mm) | Y  (mm) | Z  (mm) | | | *t*-values | | Cluster size  voxels | |
| Cingulate gyrus, anterior division | 4 | 6 | 42 | | | 3.52 | | 120 | |
| Paracingulate gyrus | -2 | 11 | 45 | | | 3.68 | |  | |
| Juxtapositional lobule cortex | 4 | 4 | 56 | | | 3.18 | | 95 | |
| Note. N = 60; N = 20 per video gaming group. | | | |  |  | |  | |

Values in the CTQ subscale physical neglect correlated significantly negatively with activation in precuneus and intracalcarine cortex in the same contrast (CS+c minus CS+uc). Figure 9 shows brain activation patterns for each significantly active cluster regarding the respective design. This means that higher values on the CTQ subscale physical neglect were connected to lower brain activation on the conditioning contrast in the shown brain regions and vice versa. Table 12 displays peak voxels (MNI coordinates), *t*-values, and cluster size of brain areas that show significant lower activation with increasing level of physical neglect.



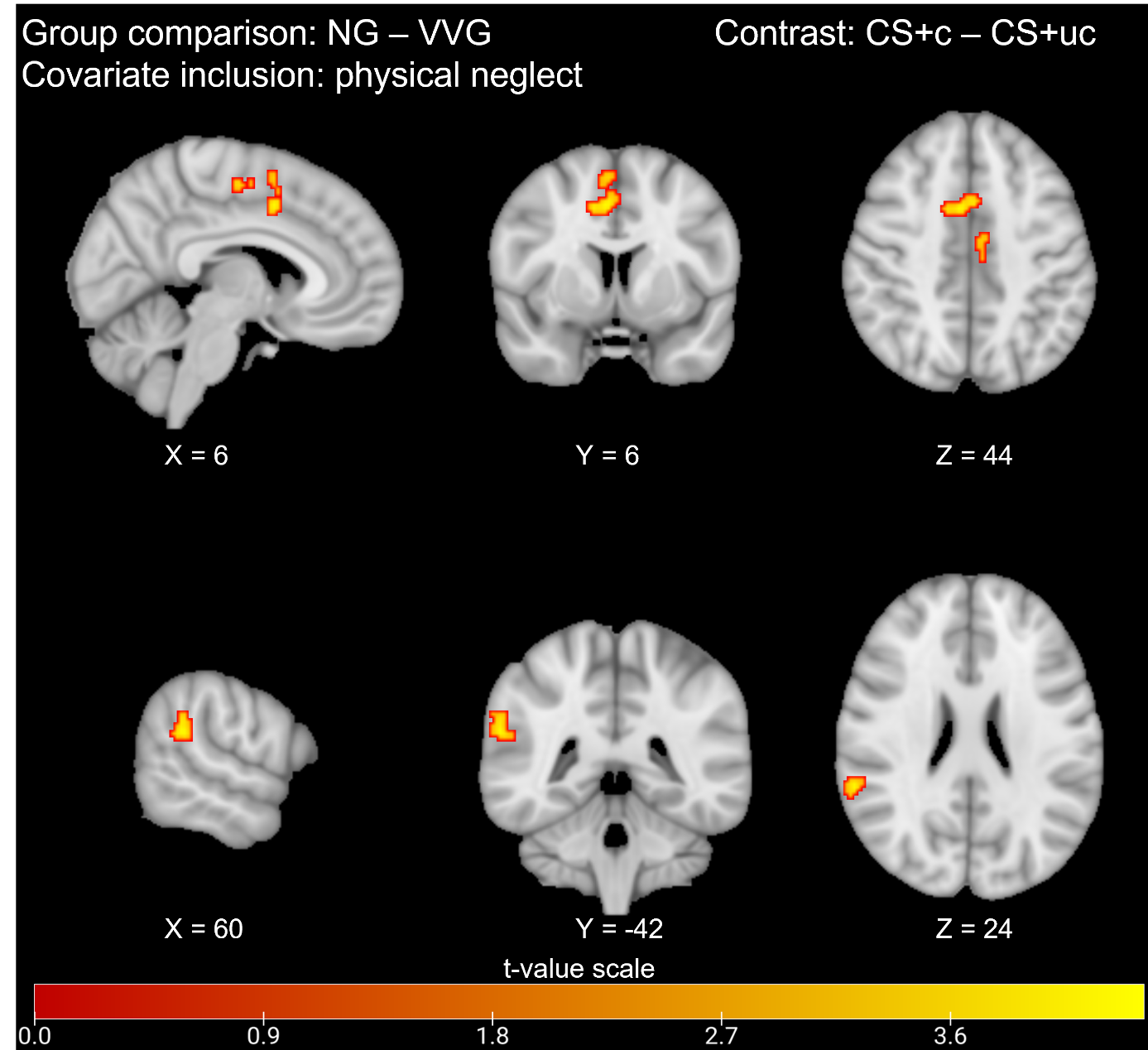
**Figure 9.** *Brain response contrast for the neural correlate in respect to the between-subject variance of the CTQ subscale physical neglect in the contrast CS+c minus CS+uc.*

**Table 12**

*Peak voxels (MNI coordinates), t-values, and cluster size of brain areas that show significant lower activation with increasing level of physical neglect*

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Brain areas | X  (mm) | Y  (mm) | Z  (mm) | | | *t*-values | | Cluster size  voxels | |
| Precuneus | 8 | -46 | 54 | | | 4.42 | | 696 | |
| Intracalcarine cortex | -8 | -72 | 10 | | | 3.91 | | 364 | |
| Precuneous cortex | 20 | 54 | 8 | | | 4.31 | | 286 | |
| Note. N = 60; N = 20 per video gaming group. | | | |  |  | |  | |

In addition to these two analyses, we designed a combined analysis addressing the respective group comparison as well as ACE subscale influence of physical neglect on brain activation in respect to the contrast CS+c minus CS+uc. Therefore, we added physical neglect as covariate to the group comparison of NG minus VVG. Results still displayed significant brain activation patterns for ACC and supramarginal gyrus (posterior division). Figure 10 shows brain activation patterns for each significantly active cluster regarding the respective design. Table 13 visualizes peak voxels (MNI coordinates), *t*-values, and cluster size of brain areas that show significant higher activation in the NG group compared to the VVG group even with physical neglect serving as a covariate.



**Figure 10.** *Brain response of ACC and supramarginal gyrus for the contrast of non-gamers (NG) minus violent video gamers (VVG) with physical neglect as a covariate on the contrast CS+c minus CS+uc.*

**Table 13**

*Peak voxels (MNI coordinates), t-values, and cluster size of brain areas that show significant higher activation in the non-gamer group (NG) compared to the violent video gamer group (VVG) even with physical neglect serving as a covariate*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Brain areas | X  (mm) | Y  (mm) | Z  (mm) | *t*-values | Cluster size  voxels |
| Cingulate gyrus, anterior division | 3 | 7 | 43 | 4.13 | 275 |
| Supramarginal gyrus, posterior division | 62 | -42 | 22 | 3.74 | 94 |
| Note. N = 40; N = 20 per video gaming group. | | | | | | |

Data for the fear conditioning phases habituation and extinction are not reported, as the acquisition phases are the main interest for the conditioning hypotheses, and no significant differences for the video gaming groups or CTQ subscales were observed in these phases. This is also true for the reporting of additional fear conditioning contrasts. As physical neglect showed the most interesting brain activation patterns and was the main interest in reporting pain measurement results, no further CTQ subscales are reported.

## **4 DISCUSSION**

We investigated the connection between video gaming behavior, pain threshold, pain tolerance, fear conditioning parameters, and their interrelationship with ACE. Especially violent video gaming influences and increases pain threshold and pain tolerance for electric, temperature, and pressure-related pain stimuli. VVG showed a significantly higher pain threshold and pain tolerance compared to NGs whereas NVVG did not significantly differ from NG and VVG in pain threshold and pain tolerance in line with previous findings (Anderson et al., 2010; Bushman & Anderson, 2009; Carnagey et al., 2007; Miedzobrodzka et al., 2022). However, NVVG mean values for pain threshold and pain tolerance were between the mean values for NG and VVG. Our data support an associated change in pain sensitivity when the gaming habit contains violent content. According to the findings, there may be a link between self-executed media violence and altered perceptions of pain thresholds and tolerance for diverse pain stimuli. The findings also indicate that addressing violent video gaming behavior may be a beneficial intervention when working with pain patients.

However, the findings may not necessarily suggest or offer evidence for a causal association between self-executed media violence and pain perception. Furthermore, they do not include other possible elements that may influence pain perception, such as genetics, culture, or other environmental factors. As a result, further study is required to demonstrate a causal link and better understand the intricate interaction of the numerous elements that can influence pain perception.

The relationship between violent video gaming and pain sensitivity was moderated by ACE in early childhood and adolescence. The CTQ subscale physical neglect decreased the sensitivity for electric stimulation and pressure algometer pain thresholds as well as pain tolerance among VVG but increased this sensitivity among NG. Furthermore, this effect increased significantly with higher levels of physical neglect and was less pronounced with lower levels of physical neglect. These results suggest that video gaming behavior should be taken into account when sensitivity for pain is considered a relevant marker for therapy among patients with a strong history of physical neglect, for example, in the case of self-harming behavior. Physical neglect among VVG seems to impair the sensitivity for painful stimuli or leads individuals to habituate to the stimuli over time.

In addition, the observed fMRI data for the fear conditioning paradigm complement the behavioral data very well. The fear conditioning task conducted in the fMRI scanner revealed higher brain activation patterns in ACC, paracingulate gyrus, and juxtapositional lobule cortex for NG compared to VVG in the acquisition phase. Similar to the patterns of the behavioral data, the contrast between VVG and NG showed a significant difference in activation patterns. One main area that shows significantly more brain activation in NG than VVG on the contrast of CS+c minus CS+uc, i.e., the difference between a cue paired with pain (CS+c) and the same cue without pain (CS+uc), in the acquisition phases is the ACC, an area that has been identified as relevant in previous video gaming research not related to fear conditioning. Attention, cognitive control, and visuospatial skills are common factors influenced by internet gaming disorder or VVG, and recent multi-voxel-pattern analyses support these findings (Montag et al., 2012; Palaus et al., 2017; Y. Wang et al., 2009; Z. L. Wang et al., 2022). The significantly higher activation in the ACC among NG compared to VVG suggests that NG show more emotional response regarding the fear conditioning stimuli and display more emotion-related learning towards the fear conditioning stimuli, while VVG are less responsive to the anticipation of painful stimuli. This difference in brain activation between NG and VVG did not appear before the acquisition phase. Therefore, it can be assumed that it is characteristic for fear learning. This is also supported by a higher activation in primary and supplementary motor regions in NGs compared to VVGs during fear conditioning. In contrast, VVG did not show significantly different activation patterns compared to NVVG, and NVVG did not display significantly different activations compared to NG. Therefore, the main difference resides in the comparison of VVG and NG.

Furthermore, the contrast of CS+c minus CS+uc during the acquisition phases revealed significantly lower brain activity in precuneus and intracalcarine areas with increasing values of physical neglect. Precuneal and intracalcarine areas are involved in a variety of different functions including stimulus reactivity, affective responses to pain, and visual processing. Interestingly, precuneus differences were also observed by Wang et al. (2022) between participants with internet gaming disorder and healthy controls. This finding may help to clarify inconsistent results from past research in the field of ACE and pain processing, which report higher as well as lower pain sensitivity and attention to painful cues among participants with ACE background (Breite & Rosen, 1999; Li & Wang, 2021; Nanni et al., 2012; Negele et al., 2015; Tesarz et al., 2015, 2016). Our data on the connection between fear conditioning and physical neglect among participants suggest that attention towards painful stimuli or harmful situations may be decreased and reaction time to painful stimuli or harmful situations may be increased among individuals who suffered from strong physical neglect in the past.

In addition, a group comparison between NG and VVG for the acquisition phase while accounting for physical neglect as a covariate revealed higher brain activation for NG compared to VVG in the ACC and the posterior division of the supramarginal gyrus. Our data indicate that physical neglect is related to responding in other brain areas compared to the observed gaming group differences. Adding physical neglect as a covariate to the group comparison between VVGs and NGs did not result in lower activation of ACC. Only motor cortex areas showed reduced activation differences when physical neglect was accounted for. This implies that there is an independent difference between VVGs and NGs in terms of emotional responding and awareness regarding the fear conditioning stimuli. These data implicate that there may be a benefit in therapeutic interventions for patients with violent video gaming background that target skills for self-experienced emotional cue learning and emotional assessment.

For example, recent studies showed differences in terms of multi-voxel pattern analysis between participants with internet gaming disorder and healthy controls (Wang et al., 2022). This kind of research in combination with our own findings could indicate that video gaming is connected to multiple changes in brain morphology and brain activation compared to non-gaming and makes it even more important to look at additional variables connected to video gaming. ACE-related memories are often shaped and influenced by physical pain experience, and with this study the main goal was to gain more insight on the connection gaming behavior could have with the perception of one’s own pain to develop new ideas and possibilities for future ACE-related and possibly even trauma-related therapy. We found that there is indeed an interactional effect of video gaming behavior and trauma experience on various researched parameters like pain threshold, pain tolerance, and development of fear to stimuli in a fear conditioning paradigm.

### **4.1 Limitations**

Although the observed findings are consistent and contribute to our understanding of processes underlying violent video gaming, pain and fear processing and their relation to early childhood trauma, a study with more participants to achieve greater power is needed.

The number of conditioning cues used here was based on studies that were already sufficiently established (Baeuchl et al., 2019; Fullana et al., 2016; Rothemund et al., 2012; Suarez-Jimenez et al., 2020). This is also true for the chosen pain stimuli. While the behavioral assessment showed that electric stimulation is a very efficient cue for the experimental group, it would be interesting to see a replication of the fMRI part of this study with other pain-inducing methods like heat pain to see if violent video gaming and ACE influence not just electric pain response in terms of brain activation but also responses to other types of painful stimuli.

In addition, it would be benefical to observe more physiological markers for future studies in this paradigm like skin conductance responses in addition to behavioral ratings to gain insight about nonconscious aspects of the fear conditioning experience.

Another limitation of the study is that its cross-sectional design does not allow for the establishment of a causal link between adverse childhood experiences and reduced reactivity to fear conditioning and pain tests in persons involved in violent video gaming. Future research should hence focus on longitudinal designs to explore possible causal relationships.

### **4.2 Conclusions**

People that are common violent video gamers and experienced physical neglect in adolescence likely lack average self-experienced pain perception and show lower brain activation in relevant regions when it comes to painful cues of fear conditioning. This might explain tendencies for high-risk or violent behavior among high ACE persons to some extent, especially among violent video gamers (Garrido et al., 2018). More attention to these habits can give insights into why patients are detached from their own experienced pain and give cues on how to support them to develop feelings that are more similar to the general population/control group. As previously mentioned, mindfulness and body awareness training may be of benefit to develop more averaged self-experience pain perception and raise visual awareness in harmful situations. Unfortunately, our study cannot confirm any effectiveness for therapeutic interventions and therefore this is just an idea for future research.

However, this kind of future research is recommended to evaluate the idea that mindfulness and body awareness training could be of benefit for VVG with physical neglect background. In general, this study revealed that violent video gaming has effects on perceived pain sensitivity as well as on pain perception-related brain correlates, and future research on mindfulness and body awareness training with VVG may be a good opportunity to develop effective therapeutic interventions, especially with patients that experienced ACE like physical neglect in the past.

## **AUTHOR CONTRIBUTIONS**

**Herta Flor:** Conceptualization; Funding acquisition; Writing – original draft; Writing – review & editing. **Susanne Becker:** Conceptualization; Funding acquisition; Supervision; Writing – original draft; Writing – review & editing. **Maximilian Penzkofer:** Data curation; Formal analysis; Writing – original draft; Writing – review & editing. **Julia Daub:** Formal analysis; Data curation.

## **CONFLICT OF INTEREST**

All authors declare that they have no conflicts of interest.

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