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Full Length Article

Inside the gamer's mind: How violent video games and emotional dysregulation affect EEG interbrain synchronization

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A R T I C L E I N F O

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A B S T R A C T

Background: Exposure to violent video games influences players' cortical activations. In addition, intra-individual variables like emotional regulation play an important role in the consequences of such exposures. However, most research has studied these relationships at the intra-individual level. Therefore, the present study investigated the effects of violent video games on the interbrain synchronization (IBS) of dyads in which one member played video games, and evaluated IBS differences between high and low-emotionally dysregulated groups.
Methods: Eighteen participants (M = 24.1 ± 2.1) were enrolled in this study. Participants gazed into another person's eyes before playing ("First Direct Gaze"), after playing a violent video game ("Post-VV"), and after playing a nonviolent video game ("Post-NVV") during an electroencephalographic hyperscanning acquisition. Afterward, each participant completed a socio-demographic questionnaire and the Difficulties in Emotion Regulation Scale.
Results: A cluster-based analysis revealed an increased theta IBS Post-VV compared to Post-NVV. A median split was used to define the high emotionally dysregulated ("HED") and low emotionally dysregulated ("LED") groups. Results showed a decreased alpha IBS in the First Direct Gaze, Post-VV, and Post-NVV in the HED group compared to the LED group.
Conclusions: Exposure to violent video games was associated with higher theta IBS, suggesting a greater social attunement, potentially due to a higher perceived dominance and control or due to an effort of managing the emotional activations elicited. In addition, difficulties in emotional regulation could elicit specific alpha activities regardless of exposure to a video game, leading to a lower tendency to attune with another person on this band.
Results from this study should not be generalized to infer that playing any type of video game causes harm to people's brains.

1. Introduction

The use of video games has grown in popularity, with 3.09 billion active players worldwide and a projected growth to 3.32 billion by the end of 2024 (Howarth, 2024). In the face of statistical evidence of this social phenomenon, psychological research has focused extensively on studying the consequences of video game exposure (Harrington & O'Connell, 2016; Shoshani et al., 2021; Wulansari et al., 2020). The type of video games would appear to affect players differently, where playing video games characterized by prosocial activities (e.g., cooperation, reciprocity, solidarity) seems to be associated with better social functioning (Harrington & O'Connell, 2016; Shoshani et al., 2021; Wulansari et al., 2020). When digital games or applications include prosocial content, prosocial scripts are arguably triggered, which induce players to behave prosocially in real life (Greitemeyer & Osswald, 2011; Shoshani et al., 2021). This may lead to prolonged individual changes that affect behavior and personality traits (Gentile et al., 2009; Shoshani et al., 2021).

However, studies on the effects of violent video games have shown contrasting results (Kersten & Greitemeyer & Osswald, 2011; Weber

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et al., 2020). Some literature claims that exposure to violent video games can increase aggression (Anderson & Bushman, 2002, 2018; Gentile et al., 2017; Hébert et al., 2005) and stress (Calvert et al., 2017; Hasan et al., 2013). For instance, the general aggression model (GAM) claims that the violence that characterizes video games consists of a situational factor that influences cognitive, affective, and physiological processes by determining short- and long-term effects on aggressive and social behavior (Anderson & Bushman, 2002, 2018). Also, it appears that exposure to violent video games stimulates the activation of the sympathetic nervous system, causing an attack or flight response that increases the likelihood of becoming aggressive (Gentile et al., 2017).

Previous neurobiological studies have found specific neural correlates associated with exposure to violent video games (Mathiak et al., 2011; Mathiak & Weber, 2006; Montag et al., 2012; Weber et al., 2006). Electroencephalographic (EEG) studies reported reduced P300 elicited by violent images in subjects previously exposed to violent video games compared to participants exposed to non-violent video games, hypothesizing that interaction with violent video games could lead to desensitization to violence (Bartholow et al., 2006; Engelhardt et al., 2011). Similarly, after long-term exposure to violent video games, participants have appeared to show less activation of the frontal area when processing unpleasant stimuli, potentially due to the process of emotional desensitization (Brockmyer, 2022; Montag et al., 2012). The frontal and temporal areas have appeared largely involved in cognitive and emotional processing related to video game exposure (Mathiak & Weber, 2006; Montag et al., 2012; Weber et al., 2006). Furthermore, after being exposed to a violent video game a lower limbic and temporal EEG activation were found in response to social inclusion stimuli (Lai et al., 2019), as well as an association between levels of negative affect with lower activation of the right temporal cortex has been found, suggesting that such activations reflect individuals' strategies in coping with social and emotional states (Mathiak et al., 2011).

Granted, the appropriateness of models based on social learning theory and on the hypothesis that violent video game exposure leads to negative outcomes has been questioned on both theoretical and experimental grounds (Williams & Skoric, 2005). In fact, several studies did not find a relationship between exposure to violent video games and increased aggressive thoughts and behaviors (Ferguson, 2007; Kühn et al., 2019; Wagener et al., 2024), whereas specific personological characteristics may affect the individual's choice of video game genre (Unsworth et al., 2007). In addition, some research has reported that playing violent video games may have positive effects, including decreasing stress, promoting a state of relaxation, and improving mood and visuospatial cognition (Ferguson, 2007; Kersten & Greitemeyer & Osswald, 2011; Porter & Goolkasian, 2019; Wagener et al., 2024). In this regard, it was argued that violent video games might provide players with the opportunity to gain dominance and control in virtual landscapes, diminishing their negative feelings (Villani et al., 2018). Thus, interacting with violent video games might effectively relieve stress, potentially enabling active escapism mechanisms, like projective fantasy and immersion in virtual realities (Kuo et al., 2016).

A recent neurobiological study contradicted the perspective of desensitization of emotion-sensitive brain regions as a result of excessive use of violent video games (Szycik et al., 2017). The lack of association between exposure to violent video games and emotional desensitization has found support in other behavioral studies, suggesting that real and virtual life are processed differently by gamers (Ballard et al., 2003; Read et al., 2016; Regendogen & Herman, 2010). In this context, specific psychological dimensions influence individuals' reactions to video games (Akel et al., 2022; Bartholow et al., 2005). Recent studies highlighted that difficulty with regulating emotions in preschool predicted problematic use of video games and that a lower ability to regulate emotions was associated with a preference for violent video games (Bonnaire & Conan, 2024; Paulus et al., 2021). Emotion dysregulation is theorized as difficulty controlling impulses towards negative feelings, engaging in goal-directed behavior, and utilizing self-regulation skills (Berking et al., 2011; Gratz & Roemer, 2004). Individuals with such difficulties might attempt to cope with negative emotions by playing video games (Blasi et al., 2019; Hemenover & Bowman, 2018; Villani et al., 2018). In this line, it was highlighted in recent years that problematic involvement in video games might be associated with a desire to escape negative emotions (Kneer & Rieger, 2015; Li et al., 2011). However, other studies have supported that exposure to video games may be an emotional regulation strategy (Khou et al., 2016; Villani et al., 2018). For example, long-term exposure to violent video games has been shown to reduce depressive symptoms and hostile feelings (Ferguson & Rueda, 2010).

Still, there is a need to consider that all the neurobiological research that analyzed the effects of video games focused on brain activation at the individual level (Bartholow et al., 2006; Engelhardt et al., 2011; Mathiak et al., 2011; Mathiak & Weber, 2006; Montag et al., 2012; Weber et al., 2006). However, it is necessary to consider that humans are, from birth, embedded in a social context and constantly attuned, both behaviorally and physiologically, to other people so that the organization of the self in a developing brain occurs in the context of a relationship with another brain (Schore, 2003). Consequently, there is a need to study physiological regulatory mechanisms according to an interpersonal neurobiology paradigm that considers the relational mechanisms by which communicating brains synchronize (Schore, 2022). In this regard, neurobiological research has adopted multi-person EEG recordings within the "hyperscanning" paradigm (Montague et al., 2002). Hyperscanning studies have revealed that specific bands' inter-brain synchronization (IBS) can be associated with several intrapersonal and interpersonal processes (Montague et al., 2002). IBS in the theta band (4–7 Hz) has been associated with cooperative activities and positive social interactions (Liu et al., 2021; Venturella et al., 2017). Similarly, there is evidence of increased synchrony in the alpha band (8–12 Hz) between dyads during moments of agreement versus disagreement (van Vugt et al., 2020). In addition, a higher IBS in the alpha band has appeared associated with attentional processes during face-to-face interactions (Mu et al., 2018). Alpha's IBS is evident in interactions characterized by affective and social gestures (Balconi & Fronda, 2020), supporting the hypothesis that it might be associated with attentional capacity directed toward environmental stimuli and, potentially, socio-emotional salience (Zouaoui et al., 2023).

The present study thus aimed to investigate the effects of exposure to violent video games on the degree of theta and alpha IBS in dyads where one member was exposed to video games ("Player") and one member was not ("Non-player"). Specifically, the differences between direct gazes' post-exposure to a violent video game and post-exposure to a nonviolent video game in theta and alpha IBS were assessed. Furthermore, to explore the influence of intra-individual emotional regulation difficulties on IBS, this study evaluated differences between a group with higher levels of emotional dysregulation and a group with lower levels of emotional dysregulation per direct gaze IBS before the video game sessions, post-exposure to the violent video game, and post-exposure to the nonviolent video game.

2. Materials and methods

The Ethical Committee of the Department of Dynamic and Clinical Psychology, and Health Studies, Sapienza University of Rome, approved the present study (protocol number: 0001764). All the participants volunteered and gave their written informed consent according to the Declaration of Helsinki. The researcher explained the procedures to the participants before the study, and all the procedures were performed following ethical guidelines. Participants were free to leave the experiment at any time.

2.1. Participants

Eighteen participants participated in this study. The participants (nine females; M_{age} = 24.1 years, SD_{age} = 2.1 years, range 22–31 years) interacted with a violent video game ("VV") and with a nonviolent video game ("NVV"). The inclusion criteria were an age between 18 and 35 years and playing video games at least once a week, while exclusion criteria were self-reported drug intake and neuropsychiatric, neurological, and past or present health problems (e.g., head injuries). All participants had normal or corrected normal vision. Fifteen participants were students, one was an employee, one was an operator, and one was unemployed. Fifteen participants had graduated, two had high school diplomas, and one had a certificate of secondary education. Moreover, 14 participants were single, and four were in a romantic relationship. None had ever played the video games proposed during the experiment.

2.2. Procedure

This research was conducted in the Department of Dynamic and Clinical Psychology, and Health Studies, Sapienza University of Rome. Each participant completed the informed consent at the beginning of the research. One participant (female student, 25 years old) was recruited to visually interact with all participants without exposure to any video game ("Non-player"). Fig. 1 shows the procedure. Before each trial, the Non-player arrived 5 min before the participant and was accompanied to the room set up for the experiment. Next, the participant ("Player") was accommodated in an adjacent room for the EEG recordings. Afterward, the researcher accompanied the Player to the room for the purpose of the experiment and was seated in a chair placed 1 m away from the one on which the Non-player sat. At first, the dyad was asked to engage for 120 s in a task of direct eye contact ("First Direct Gaze"). Before the interaction, the researcher left the room and returned at the end of the 2 min. Later, participants interacted with a video game (randomized: violent or nonviolent) for 180 s ("First Game Session"). Before starting the game session, the researcher would explain how the game worked; each participant would perform 60 s of testing to familiarize themselves with the software ("First Trial Session"). Subsequently, each Player made direct eye contact ("Second Direct Gaze": Post-violent video game "Post-VV" or Post-nonviolent video game "Post-NVV") with the Non-player for 120 s. Then, the researcher explained how the following game worked, and the participant performed 60 s of testing with the new game ("Second Trial Session"). Subsequently, the Player started a new game session ("Second Game Session") of the same duration (180 s), interacting with a video game of opposite content to that proposed in the first session (violent or nonviolent). Finally, the dyad again established direct eye contact ("Third Direct Gaze": "Post-VV" or "Post-NVV") for 120 s for a third time. During the experiment, the EEG activity of both subjects was recorded.

2.3. Video games

The two-game software used in this experiment was presented on a tablet of 10.2 inches. Both games presented a first-person perspective within a three-dimensional environment. The violent video game used in this study was iSniper 3D Arctic Warfare (Triniti Interactive Limited©), a first-person shooter that allows one to explore a virtual environment to "shoot" people. The game used two areas of the screen: left for orientation control and right for aiming and shooting (Lai et al., 2019). In this video game one aims to "kill" all 20 opponents on the virtual playing field within a time limit. At the beginning of the game, the game arranged each opponent, as well as the target object, in an inverted triangle, indicating the presence of a sniper on that point of the playing field. In this way, the player could select the person to kill, place the crosshairs central to the head of the target, and shoot countless times to kill the target. The higher the accuracy of the shot to the character's head, the higher the score the game gave the player. The participant could see the percentage of "life" left, the time available, and the number of people killed at the screen's top right, center, and left.

The nonviolent video game employed was Archery Shooting Champion (GameLogs©), an archery game. The game used two areas of the screen: the right to position the viewfinder angle and the left to control the movement of a virtual bow. In this game one aims to hit a virtual target within a time limit, shooting the arrow with the bow to reach the target score indicated at the top center of the screen. To reach the goal, the competitor had to hold their finger on the bow to place it in a shooting position and then place the viewfinder in this; finally, pulling the arrow back is enough to leave the finger previously placed on the screen at the bow. The participant could view the accumulated score and each arrow's number in the screen's upper left and right.

The two games had similar purposes, game modes, and element arrangements within the field (i.e., first-person perspective, position of the target shooting tool). The only factor of discrimination was that in the iSniper 3D video game Arctic Warfare, there were virtual people to kill, reducing the game biases to the minimum possible and increasing the experiment's reliability.

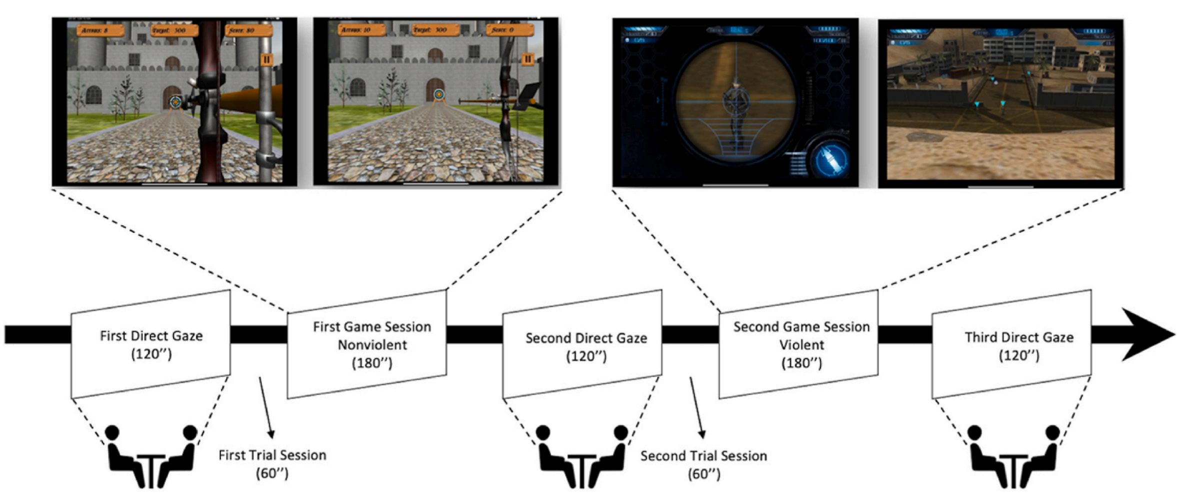

Fig. 1. Schematic description of the experimental procedure.
Note. Each dyad was asked to engage for 120 s in a task of direct eye contact (First Direct Gaze). Subsequently, participants interacted with a video game (randomized: violent or nonviolent) for 180 s (First Game Session). Before starting the game session, the researcher explained how the game worked; each participant then performed 60 s of testing to familiarize themselves with the software (First Trial Session). Subsequently, each Player made direct eye contact with the Non-player for 120 s (Second Direct Gaze). Then, the Player started a new game session of the same duration (180 s), interacting with a video game of opposite content to that proposed in the first session (Second Game Session). Finally, the dyad again established a direct eye contact (Third Direct Gaze) of 120 s.

2.4. Questionnaires

After the experiment, the participants completed a socio-demographic questionnaire and the Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004; Sighinolfi et al., 2010). The DERS is a self-report questionnaire of 36 items. It contains six scales: "Non-Acceptance" (non-acceptance of emotional responses), "Objectives" (difficulty in adopting target-oriented behaviors), "Impulsivity" (or difficulty in controlling impulses), "Awareness" (lack of emotional awareness), "Strategies" (limited access to emotional regulation strategies), and "Clarity" (lack of emotional clarity) (Gratz & Roemer, 2004). The DERS measures the difficulty in regulating emotions of a negative nature and allows one to obtain measurements regarding the dimensions of awareness in the understanding of emotions, acceptance of emotions, ability to control impulsive behaviors and behave following goals and ability to use flexible emotional regulation strategies appropriate to the context and situational demands. In the present study, only the total score, which showed a Cronbach's alpha of 0.87, was used.

2.5. EEG acquisition and preprocessing

The Encephalan Main Syncro EEG system, comprised of two synchronous acquisition and video recording units, acquired the participants' EEG activities (Medikom MTD, Russia). The system included two caps, aligned to nasion, inion, and left and right pre-auricular points, with 19 electrodes arranged according to the international 10/20 system (Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2), the neutral (N) and the two references electrodes (A1 and A2). Two electrooculograms (EOG), one electromyogram (EMG), and one electrocardiogram (ECG) completed the system and were used to record the artifacts. The impedances were maintained below 5 kΩ. The signals were online filtered between 0.5 and 70 Hz, and the sampling frequency was 250 Hz. According to previous studies, the Encephalan-EEGR software was used to suppress the artifacts through an algorithm that suppresses blinking, eye motions, face muscles, and cardiac activity (Petukhov et al., 2020). Then, for each phase (First Direct Gaze, Post-VV, or Post-NVV), the hyperscanning EEG data (related to a dyad) were exported to Python. The open-source library Hyperscanning Python Pipeline (HyPyP; Ayrolles et al., 2021) was used for further analyses and IBS analysis. Specifically, 1-s epochs were created and cleaned using a HyPyP function adapted from Autoreject (Ayrolles et al., 2021; Jas et al., 2017).

2.6. EEG hyperscanning analyses

Alfa (8–13 Hz) and theta (4–8 Hz) frequency bands were considered to evaluate participants' inter-brain synchrony. For each frequency, the phase locking value (PLV) was considered. PLV has been established as a robust technique to analyze the instantaneous phase of two signals in EEG hyperscanning studies. PLV measures inter-brain synchrony by detecting the rhythmicity between the recorded EEG signals of two brains (Balconi & Cassioli, 2022; Burgess, 2013).

2.7. Statistical analyses

HyPyP was used to calculate the PLV values between dyads. Additionally, cluster-level statistics provided by one-way paired t-tests were performed to compare PLVs along the scalp between Post-VV and Post-NVV. Similar to previous research (Deng et al., 2022; Veneziani et al., 2024), a grouping method based on a median split to define the high emotionally dysregulated (HED) and the low emotionally dysregulated (LED) groups was used. Subsequently, independent cluster-based t-tests were also performed to evaluate the differences in IBS between the HED and LED groups. One of the main issues in EEG studies concerns the multiple comparisons problem (MCP) (Piai et al., 2015). Therefore, it is crucial that the implemented statistical tests control the family error rate (i.e., type I error) to cope with the probability of false-positive results (Bennett et al., 2009). To solve the MCP and concurrently preserve the sensitivity, nonparametric statistical tests based on permutations have been proposed (Maris & Oostenveld, 2007) and used in previous hyperscanning EEG studies (Dikker et al., 2021; Wang et al., 2024; Welke & Vessel, 2022). In the present study, the results were corrected using the nonparametric cluster-based permutation test (Maris & Oostenveld, 2007), interpreting only the findings of electrode pairs in clusters exceeding the cluster level threshold ($p < 0.05$). A bootstrap resampling and permutation method was used for cluster statistics ($N = 5000$).

The cluster-level statistical permutation test reduces family-wise error due to multiple comparisons by clustering neighboring quantities with the same effect. Similarly to previous EEG hyperscanning studies (Balconi & Angioletti, 2023, 2024), Cohen's d was considered to evaluate the effect sizes.

3. Results

The 5000 permutations paired *t*-test cluster-based analysis revealed a significant cluster in the theta band, highlighting increased inter-brain synchrony Post-VV compared to Post-NVV (Fig. 2). Table 1S (see Supplementary Materials) reports the results of the significant t-tests between the electrode pairs Post-VV versus Post-NVV in PLVs.

The observed effect sizes indicated a range between a medium and large effect size (0.49 < Cohen's d < 0.95; mean = 0.59). According to the median split method, in the present study, there were nine participants in the HED (six females; M = 23.7; SD = 0.86; range = 23–24) and nine participants in the LED (two females; M = 25.4; SD = 3.55; range = 22–31) groups. The independent t-tests showed a significant cluster in the alpha band, highlighting decreased IBS in the First Direct Gaze, Post-VV, and Post-NVV in the HED compared to the LED group (Fig. 3). Table 2S (see Supplementary Materials) shows the *t*-test results between electrodes' pairs per HED versus LED in PLVs during First Direct Gaze (A), Post-NVV (B), and Post-VV (C).

Regarding effect sizes, for the HED versus LED comparisons in the First Direct Gaze, Cohen's d indicated a range between large and very large effect sizes (|1.18| < Cohen's d < |2.55|; mean = |1.46|). In the Post-NVV, Cohen's d indicated very large effect sizes (|1.48| < Cohen's d < |1.78|; mean = |1.64|). Finally, in the Post-VV, Cohen's d indicated very large effect sizes (|1.08| < Cohen's d < |2.13|; mean = |1.21|).

4. Discussion

The present study investigated the differences in theta and alpha IBS during direct gazes in dyads in which one of the two members had previously been exposed to a violent or nonviolent video games. In addition, it analyzed the differences between people with higher levels of emotional dysregulation and people with lower levels of emotional dysregulation in IBS before and after video game sessions.

The main finding showed a higher IBS in theta activity after exposure to a violent video game compared to after exposure to a nonviolent video game. IBS in theta activity was previously found higher during human-human social interaction activities, such as cooperation and team tasks (Liu et al., 2021), where negative external feedback might induce a lower theta IBS, suggesting its role as an important marker of social cognition and emotional engagement (Balconi et al., 2018; Deng et al., 2023). Interestingly, it was previously theorized that cortical theta activity is associated with the activation of the anterior cingulate cortex, which is strongly connected (Jhang et al., 2018) to the basolateral nucleus of the amygdala, which contributes to emotional regulation (Balconi & Angioletti, 2021; Balconi & Cassioli, 2022). Moreover, theta activity might sustain social empathy and affective-cognitive control (Balconi et al., 2015; Billeke et al., 2013; Knyazev et al., 2016) and has seemed particularly related to the processing of emotionally salient and negatively marked cues (Aftanas et al., 2004; Bekkedal et al., 2011;

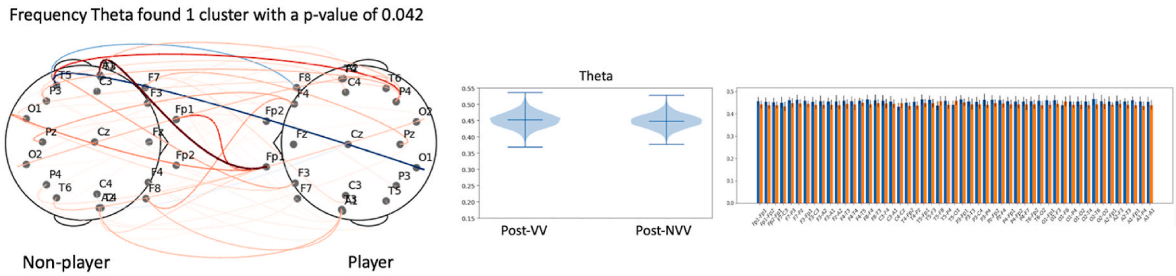

Fig. 2. Significant inter-brain synchrony differences in the significant theta band's cluster between Post-VV and Post-NVV.
Note. On the right, the specific electrodes' differences in the theta band's cluster between the direct gaze after the violent video game is plotted.
Blue lines represent negative t values; red lines represent positive t values. Post-VV: "Post-Violent Video game"; Post-NVV: "Post Not-Violent Video game". (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

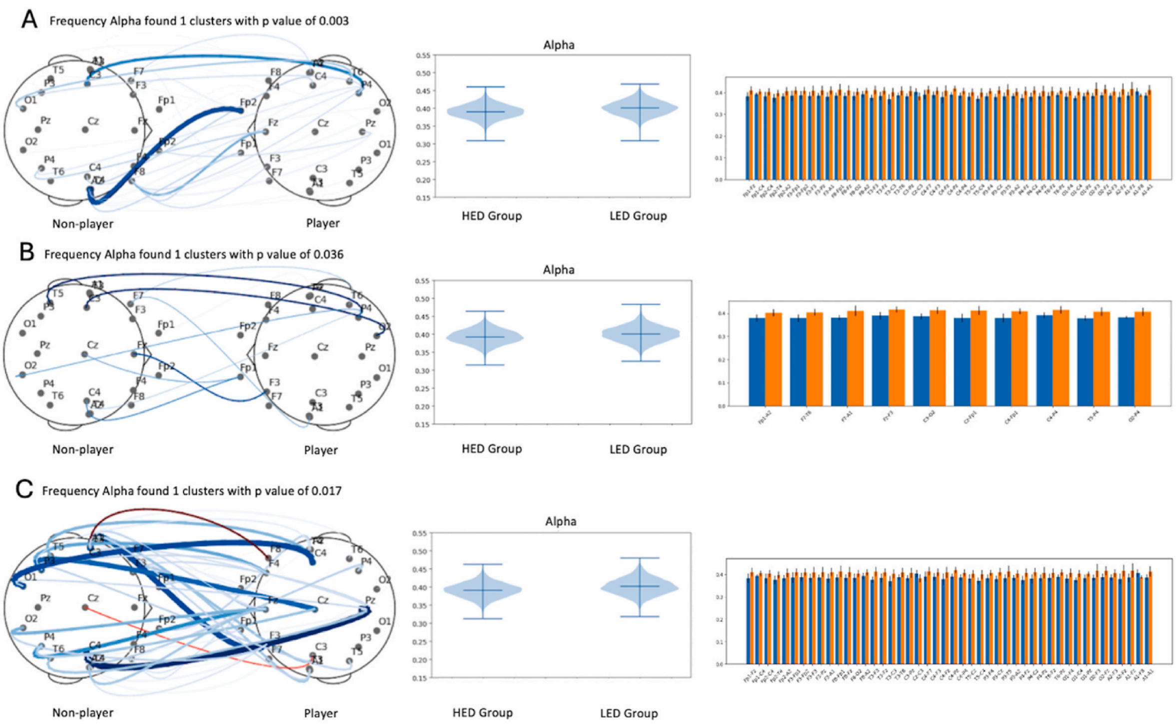

Fig. 3. Significant inter-brain synchrony differences in the significant alpha band's cluster between the high-emotionally dysregulated and low-emotionally dysregulated groups in First Direct Gaze (A), post-NVV (B), and post-VV (C).
Note. On the right are plotted the specific differences among electrodes related to the significant cluster in the alpha band, between the high emotionally dysregulated (in blue) and the low emotionally dysregulated (in orange) groups in First Direct Gaze (A), Post-NVV (B), and Post-VV (C).
Blue lines represent negative t values; red lines represent positive t values. Post-VV: "Post-Violent Video game"; Post-NVV: "Post Not-Violent Video game". (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Knyazev, 2007). This finding would confirm that violent video games predispose individuals to social interaction. Based on this empirical data, exposure to a violent video game may promote more heightened affective-cognitive processes than nonviolent video games, which can be detected at the inter-individual level.

A possible interpretation of this result is that violent video games could affect the perception of one's social rank, shifting it into greater dominance and control. Although triggered in virtual environments, such perceptions could play a regulatory role in real-life interactions, leading to a greater availability to engage in relationships with others, as previously hypothesized by behavioral studies (Villani et al., 2018). To verify this explanation, future studies should control for variables like the number of successes and failures players experience.

A recent study suggested that video games with interpersonal violence cues could elicit a pattern of emotional activation, arousal, or stress (Gentile et al., 2017). Accordingly, with this assumption, a further interpretation of the present study's results is that the increase in theta IBS after violent video games could represent an attempt to manage the stressful effects of a violent video game through an implicit process of co-regulation. Interestingly, higher theta IBS was mainly marked in the left frontotemporal areas, pivotal in comprehending and predicting others' intentions and behaviors (Barraza et al., 2020; Thornton, Weaverdyck, & Tamir, 2019). In this regard, several studies showed that frontal theta activity is associated with a response to socio-emotional information processing (Balconi & Caldiroli, 2011; Balconi & Cassioli, 2022; Rameson & Lieberman, 2009) in a social context (Billeke et al., 2013, 2014; Cristofori et al., 2013).

The present study also found the differences between a group with higher levels of emotional dysregulation (HED) and a group with lower levels of emotional dysregulation (LED) in a pre-video game session and in post-exposure IBS to the two types of video games. Interestingly, the results showed that the HED participants were less tuned at the level of alpha IBS in the pre-video game session, during the first direct gaze phase, and in both post-violent and nonviolent video game exposures. Scientific literature shows that higher levels of alpha IBS are associated with face-to-face interactions, synchronization, coordination, joint attention, and interpersonal body movement (Ahn et al., 2018; Dumas et al., 2010; Kawasaki et al., 2013; Mu et al., 2016; Tognoli et al., 2007; Toppi et al., 2016; Yun et al., 2012). Furthermore, alpha IBS has been associated with moments of high cooperativeness (Astolfi et al., 2011, 2012). In this context, it is possible to hypothesize that higher levels of emotional dysregulation affect attentional mechanisms, arousal, and implicit social interaction, associated with different alpha activities (Léger et al., 2014; Foxe & Snyder, 2011; van den Heuvel et al., 2018), thus reducing IBS in the HED group. Indeed, alpha activity has a fundamental role in emotion regulation ability (Goodman et al., 2013; Wang et al., 2018), where some studies have shown that the processing of emotionally salient stimuli was associated with activity in this band (Aftanas et al., 2004; Güntekin & Basar, 2007; Popov et al., 2012; Schneider et al., 2018; Uusberg et al., 2013). Also, alpha activity in the right frontal region has been associated with participants' flow state (Labonté-Lemoyne et al., 2016). The lower levels in alpha IBS of the HED group in the right frontal areas in the present study, particularly highlighted in the pre-video game session and in post-exposure to the violent video game might reflect lower top-down emotional regulation skills in face-to-face interactions.

Overall, the present findings highlight how playing violent video games can lead to a higher attunement expressed by higher theta IBS levels, especially in individuals' left frontal area. It remains to be clarified if this higher social attunement following a violent video game is due to stress relieving related to greater perceived control and dominance or due to an attempt of co-regulation after the exposure to stressful stimuli. The present study also highlighted the effect of intra-individual emotional regulation difficulties per IBS. In particular, higher levels of emotional dysregulation were associated with reduced IBS alpha, particularly among the right hemispheres, regardless of having played a video game.

Despite the present study providing new and interesting insight, several limitations must be underlined. Firstly, despite the recruited sample size being larger (N = 9 in Dumas et al., 2012; N = 12 in Hao et al., 2024; N = 13 in Rolison et al., 2020; N = 14 in Sciaraffa et al., 2021; N = 15 in Hu et al., 2018) or similar (N = 16 in, Dodel et al., 2020; N = 18 in Shiraishi & Shimada, 2021) to previous hyperscanning EEG studies, the number of participants, especially for the HED versus LED comparisons, limits the possibility to generalize the results of the present study. Notably, the detected effect sizes ranged between 0.49 and 0.95 for post-VV and post-NVV comparisons and between 1.08 and 2.55 for the HED versus LED comparisons, indicating a strong statistical power. Therefore, future studies with larger sample sizes are advocated to replicate the present study's findings. Moreover, the number of electrodes (N = 19) was small, leading to further caution about generalizing the present study's results. Regarding the experimental paradigm, it must be considered that the exposure duration of subjects to violent and nonviolent video games could have been too short. Finally, the present study did not consider the number of weekly hours spent playing video games, where averaging the EEG activity of diverse participants may have affected the outcome. Future paradigms might strengthen the present results by replicating them with larger samples and by using more electrodes. Also, future longitudinal studies could also evaluate participants' gaming history to assess whether prolonged use of video games may affect IBS. Finally, it is necessary to consider that some video games involve higher levels of violence than the games used in the present study. Thus, future studies could evaluate how the type of violence and levels of violence might affect participants' IBS differently.

CRediT authorship contribution statement

Giorgio Veneziani: Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Federica Luciani:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Marcello Miceli:** Methodology, Formal analysis. **Sara Spallaccini:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Federica Galli:** Writing – review & editing. **Lina Pezzuti:** Writing – review & editing. **Carlo Lai:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chbr.2024.100509.

Data availability

Data will be made available on request.

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