Lower Brain Volume and Poorer Emotional Regulation in Partner Coercive Men and Other Offenders

Marín-Morales, A., Pérez-García, M., Catena-Martínez, A., & Verdejo-Román, J. (2021)

Introduction

Intimate Partner Violence (IPV) is a global social problem (World Health Organization, 2017). According to the World Health Organization (WHO, 2017), IPV is one of the most common forms of violence against women and includes physical, sexual, and emotional abuse and controlling behaviors by an intimate male partner.

Characteristics of Partner Coercive Men

The literature suggests that partner coercive men differ from other offenders who have not been convicted of IPV (Fox et al., 2020). Although there are conflicting results in the literature (Mowat-Leger, 2003), the studies indicate that the two types of offenders differ in terms of demographic and childhood variables, finding that partner coercive men tend to be more educated and older than other types of offenders (Olson & Stalans, 2001). Moreover, partner coercive men appear to be more likely to have a history of child abuse and mental health treatment, higher levels of psychopathic traits and depression, and a greater severity of drug use than other violent offenders (Fox et al., 2020; Theobald et al., 2016). With respect to neuropsychological variables, partner coercive men show lower cognitive flexibility and better response inhibition than other offenders (Bueso-Izquierdo et al., 2016). In recent years, much research has focused on how emotional processing is related to batterer behavior (Bueso-Izquierdo et al., 2016; McKee et al., 2012; Nyline et al., 2018). However, while there is a growing literature on the neural correlates of emotional regulation (Buhle et al., 2014), the neuroanatomical basis of batterer behavior has largely been unexplored (Marín-Morales et al., 2021). Therefore, this study aimed to compare men incarcerated for misdemeanor level of crime of intimate partner violence (physical and/or psychological), men incarcerated for misdemeanor level of crimes other than intimate partner violence, and non-offenders men regarding the brain volumes of structures involved in emotional regulation in order to gain a deeper understanding of the neural mechanisms underlying the violent behavior of partner coercive men.

Concept and Neural Bases of Emotional Regulation

Emotional regulation involves consciously or unconsciously implementing a plan to start, stop or modulate the trajectory of an emotion (Ford & Gross, 2018). The most widely studied strategies include cognitive reappraisal, which involves changing one's interpretations or appraisals of affective stimuli (Buhle et al., 2014); expressive suppression, a strategy directed toward inhibiting behaviors associated with emotional responding (facial expressions, verbal utterances, and gestures) (Brockman et al., 2017); and distraction, an attention control strategy that allows the individual to shift their focus away from an emotional stimulus (Kanske et al, 2011). The neural bases of these strategies have been extensively studied (Buhle et al., 2014). According to the model developed by Etkin et al. (2015), there are two distinct types of emotional regulation: implicit emotional regulation and explicit emotional regulation. Implicit emotional regulation is characterized by the absence of explicit instruction, is automatically evoked by the stimulus itself, ends without conscious supervision, and can occur without consciousness (e.g., inhibition of fear). The brain areas associated with this process include the ventral Anterior Cingulate Cortex (vACC), and the ventromedial PFC (vmPFC). Explicit emotional regulation requires conscious effort and demands some level of active emotion regulation during implementation. The brain areas associated with this process are the dorsolateral Prefrontal Cortex (dlPFC), ventrolateral Prefrontal Cortex (vlPFC), Supplementary Motor Area (SMA), pre-SMA, and parietal cortex. Etkin's model also includes emotional reactivity, which is described as the emotion generated within a perceptionvaluation-action (PVA) sequence, in which an internal or external stimulus is perceived and valued ("this is good/bad for me"), which generates a set of multi-component actions (physiological, cognitive, motor, and subjective). Thus, an action is triggered that alters the external or internal world. The brain regions linked to emotional reactivity are the dorsal Anterior Cingulate Cortex (dACC), insula, amygdala, and periaqueductal gray (PAG).

Emotional Regulation in Partner Coercive Men

Partner coercive men appear to show difficulties in executing the various phases of emotional regulation. For instance, with regard to emotional expression, previous studies have demonstrated that partner coercive men exhibit increased levels of anger and hostility (Norlander & Eckhardt, 2005), and are unable to tolerate negative emotions expressed by others (Covell et al., 2007). Moreover, studies on emotional recognition have revealed that partner coercive men have difficulty in recognizing both their own emotions (Umberson et al., 2003) and those of others (Nyline et al., 2018) and make emotional misinterpretations (McKee et al., 2012). Regarding emotional modulation, the difficulties of partner coercive men regulating negative affect (McNulty & Hellmuth, 2008) and suppressing their emotions (Umberson et al., 2003) have been reported. Moreover, partner coercive men appear to have problems with managing their emotions and tend to hold the belief that men should not share their emotions or ask for help (Tager et al., 2010). Finally, a number of authors include empathy as a component of emotional regulation since these two constructs are directly related. In particular, empathy can be a strong promoter of extrinsic emotional regulation, the aim of which is to decrease or increase another person's negative or positive emotions (Nozaki & Mikolajczak, 2020). Previous studies have shown that partner coercive men have difficulties in empathizing with other people (Nyline et al., 2018), or their partners (Clements et al., 2007).

Brain Structures and Violent Behavior

There is an extensive body of literature that links violent behavior with certain brain structures (Raine, 2019). Numerous studies have analyzed the volume of gray matter in violent men, revealing that emotional and cognitive processing impairments are associated with structural deficits or abnormal brain function, particularly in the amygdala and orbitofrontal cortex (Gao et al., 2009). A meta-analysis conducted by Yang and Raine (2009) revealed that antisocial behavior is related to structural and functional deficits in the right orbito-prefrontal cortex, left dlPFC and right ACC. Gregory et al. (2012) reported differences in brain volume between violent people with and without psychopathy, finding that violent psychopaths showed a lower bilateral volume in the anterior prefrontal cortex and temporal lobes in comparison with violent and non-violent people (these latter two groups did not differ). Rosell and Siever (2015) found that brain structure and function — particularly in regions such as the amygdala and prefrontal areas — are key risk factors for violence. Rogers and De Brito's (2016) meta-analysis revealed that young people with behavioral problems showed a decreased volume of the insula, amygdala, frontal cortex, and temporal cortex. In their study of brain lesions in individuals with antisocial behavior, Darby (2018) found that the most common lesion location was the ventromedial prefrontal cortex. Among other neurobiological factors, Coccaro et al. (2018) found that a reduced volume of the medial and lateral regions of the prefrontal cortex was related to violent behavior. A recent study by Sajous-Turner et al. (2019) found that murderers differed from other offenders in relation to brain regions involved in emotional processing, behavior control, executive function, and social cognition (prefrontal regions, insula, cerebellum, cingulate, precuneus, and parietal cortex). In addition, they found that there were no structural differences between non-homicidal violent offenders and petty or non-violent offenders. In short, although the literature indicates an association between brain structure and violent behavior, this association differs according to the type of offender and the severity of the crime.

Brain Mechanisms in Partner Coercive Men

A number of functional and structural neuroimaging studies have been conducted in partner coercive men (Bueso-Izquierdo et al., 2016; Lee et al., 2008, 2009; Marín-Morales et al., 2020, Marín-Morales et al., 2021; Verdejo-Román et al., 2019; Zhang et al., 2013). The results of functional imaging studies suggest that partner coercive men show, in comparison with other offenders, different patterns of activation in brain areas related to emotional processing, specifically when responding to IPV-related images. In recent years, two structural studies using magnetic resonance imaging (MRI) have found that partner coercive men have reduced volumes and cortical thickness in regions involved in emotional processing (Zhang et al., 2013; Verdejo-Román et al., 2019). Zhang et al. (2013) found that alcohol-dependent partner coercive men had a lower volume of the right amygdala compared with controls and a group of non-violent alcohol-dependent individuals. Verdejo-Román et al. (2019) found that partner coercive men had reduced thickness of the prefrontal cortex (orbitofrontal) in the midline regions (anterior and posterior cingulate) and in limbic areas (insula and para-hippocampus) compared with a group of other offenders. In addition, they observed that the reduction in cortical thickness of the posterior cingulate cortex correlated positively with scores obtained on Ekman's emotional perception test.

Current Study

To the best of our knowledge, no studies of partner coercive men have yet analyzed the volume of the brain regions involved in the emotional regulation model proposed by Etkin et al. (2015) or have explored the possible link between these volumes and emotional regulation and empathy. Therefore, our main objective was to compare partner coercive men, other offenders and a control group of non-offenders in relation to the brain volumes of areas implied in emotion regulation. In addition, we analyzed whether brain differences are related to scores obtained on emotional regulation tests such as the Emotion Regulation Questionnaire (Cabello et al., 2013), the Cognitive Emotional Regulation Questionnaire (Domínguez-Sánchez et al., 2013), Difficulties in Emotion Regulation Scale (Hervás & Jódar, 2008), and on empathy tests (Interpersonal Reactivity Index test, Pérez-Albéniz et al., 2003). On the basis of the findings in the literature and the results of a preliminary study by Verdejo-Román et al. (2019), we hypothesized that: (1) partner coercive men would show lower regional brain volumes — specifically in the ventrolateral prefrontal area, anterior cingulate, insula, and amygdala — in comparison with other types of offenders and a group of non-offenders; (2) we also expected to find a positive correlation between the volumes in these areas and scores on emotional regulation and empathy. In particular, it was anticipated that brain volume would correlate positively with emotional regulation skills and the use of adaptive strategies, and negatively with the use of maladaptive emotional regulation strategies.

Methods

Participants

The participants of this study were 26 men convicted of intimate partner violence (Partner Coercive Group, PCG), 29 men convicted of crimes other than intimate partner violence (Other Offenders group, OOG) and 30 men without a criminal history (Non-Offenders group, NOG). All offenders were recruited from the Center for Social Insertion (CSI) (Centro de Inserción Social, CIS) "Matilde Cantos Fernández", in Granada (Spain). Participants in the NOG were recruited through internet advertisements, training academies and social networks. The groups did not differ in terms of age, years of education, use of medication, past trauma/childhood exposure to violence, or suffer a blow to the head (Table 1). However, the NOG and PCG differed in terms of severity of drug use ($p = .03$).

The inclusion criteria for all participants were: to be male and over 18 years of age; for the PCG, to be convicted of a crime of physical, psychological or sexual assault against a partner or former partner; for the OOG, to be convicted of other crimes such as drug trafficking, social security fraud, or any other crime (violent or non-violent) not involving the use of force or power against his partner or former partner. To improve understanding of our sample of men incarcerated, Spanish IPV Law and Penal Code can be found in Supplementary Material 1.

The exclusion criteria for the three groups included having a history of drug abuse or dependence according to DSM-IV criteria, illiteracy, any conditions that are incompatible with the MRI test (pacemaker, brackets, prosthesis), or a history of brain damage (loss of consciousness lasting more than one hour) (Cohen et al., 2003). For the NOG, the exclusion criterion was having being convicted of any crime. Following previous studies (Cohen et al., 2003), and in order to avoid the possible presence of IPV offenders in the two control groups, the participants of the OOG and NOG were required to obtain a score equal to or lower than 11 on the severity of physical violence of the Conflict Tactics Scale-2 (CTS2; Loinaz et al., 2012). This variable was calculated according to Straus (2001), first, assigning to each item of the physical violence scale a theoretical value, being higher according to the severity of the violent behavior (items 7, 9, 17, 45 and 53=1; items 27 and 73=3; items 33, 37, 43 and 61=5; item 21=8), and second, summing the theoretical value of each item. Mean scores for these groups were lower than 1 (Table 1). In addition, through Echeburúa's interview (Echeburúa et al., 2008), a risk assessment questionnaire for serious violence in a partner relationship, one participant from the NOG was excluded for having been accused of IPV. Additionally, three participants from the OOG were excluded due to excessive movement during acquisition of the brain images.

To control for levels of violence, we matched groups in terms of type of crime. We matched psychological IPV with convictions that do not include violence against people (Dangerous driving and fraud/scams), and physical IPV with violent convictions such as robbery and drug trafficking. These comparisons revealed that the groups were similar in terms of crime severity and violence (*p*= .267, Table 1).

Table 1

Characteristics of the sample

Variables (Mean (SD))		PCG (n=26)	OOG (n=26)	NOG (n=29)	P-value
Demographic variables					
Age		41.19 (9.71)	39.77 (10.79)	38.28 (8.24)	0.525
Years of education		9.19 (4.3)	9.5 (3.61)	9.86 (2.44)	0.778
Severity in use of drugs		17.23 (13.15)	15.38 (11.61)	9.59 (7.84)	0.030*
Medication (%/n)	Yes	38.5% (10)	26.9% (7)	17.2% (5)	0.210
	No	61.5% (16)	73.1% (19)	82.8% (24)	
Loss of consciousness (%/n)	Yes (<15 minutes)	23.1% (6)	12% (3)	20.6% (6)	0.576
	No (No blow to the head)	76.9% (20)	88% (22)	79.3% (23)	
Past Trauma (%/n)	Yes	23.1% (6)	23.1% (6)	37.9% (11)	0.364

	No	76.9% (20)	76.9% (20)	62.1% (18)	
Childhood exposure to violence (%/n)	Yes (psychological)	3.8% (1)	3.8% (1)	13.8% (4)	0.228
	Yes (physical)	19.2% (5)	11.5% (3)	27.6% (8)	
	No	76.9% (20)	84.6% (22)	58.6% (17)	
CTS2		4.27 (6.27)	0.27 (0.53)	0.31 (0.93)	0.000*
Type of crime [%(n)]					
		Psychological= 57.69%(15) Psychological and Physical=42.31%(11)	Dangerous driving 15.38% (4) Fraud/Scams 11.54% (3) Missing (unspecified minor crime/Non-violent) 11.54% (3) Drug trafficking 38.46% (10) Robbery 23.08% (6)		0.267

Note. SD= standard deviation; PCG= Partner Coercive Group; OOG= Other Offenders Group; NOG= Non-Offenders Group.

Measures

Sociodemographic variables were measured using a risk assessment questionnaire for serious violence in a partner relationship (Echeburúa et al., 2008). This instrument gathers information on sociodemographic variables of both the aggressor and the victim, the status of the couple's relationship, types of violence, profile of the aggressor, and vulnerability of the victim. In this interview, participants were also asked if they had suffered a blow to the head and, if they had lost consciousness, for how long. It was also recorded whether participants were taking any type of medication or if they had suffered from or witnessed any form of abuse during their childhood. The diagnostic subscale for substance dependence disorder (First, 1999) was included in the interview to calculate the severity of drug use according to the DSM-IV.

IPV severity. The CTS 2 Spanish version (Loinaz et al., 2012) of the original CTS2 Scales (Straus et al., 1996) was used to detect the existence of physical, psychological and/or sexual violence toward a partner in a relationship. This instrument measures the frequency and intensity of violence in the relationship. Cronbach 's α coefficient was 0.88.

Interpersonal Reactivity Index (IRI) (Davis, 1980; Spanish version Pérez-Albéniz et al., 2003). This scale measures empathy and is composed of four subscales: Fantasy Scale (FS), Perspective-Taking Scale (PT), Empathic Concern Scale (EC), and personal distress scale (PD). Cronbach 's α coefficients were α = .70 for Perspective taking; α = .71 for fantasy, α = .67 for Empathic concern; and α = .70 for Personal distress.

Emotion Regulation Questionnaire (ERQ; Gross & John, 2003; Spanish version Cabello et al., 2013). This 10-item scale is designed to measure respondents' tendency to regulate their emotions in two ways: 1) Cognitive reappraisal and 2) Expressive suppression. Cronbach 's α coefficients were α = .79 for Cognitive Reappraisal and α = .75 for Expressive Suppression.

Cognitive Emotional Regulation Questionnaire (CERQ; Garnefski et al., 2001; Spanish version, Domínguez-Sánchez et al, 2013). This questionnaire measures the following nine cognitive strategies of emotional regulation (adaptive strategies and less adaptive strategies): Self-blame, Acceptance, Rumination, Positive refocusing, Refocus on planning, Positive reappraisal, Putting into perspective, Catastrophizing and Blaming others. Cronbach 's α coefficients were α = .60 for Self-blame; α = .63 for Acceptance; α = .73 for Rumination; α = .89 for Positive refocusing; α = .79 for Refocus on planning; α = .86 for Positive reappraisal; α = for .82 Putting into perspective; α = for .71 Catastrophizing; and α = .78 for Blaming others.

Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004; Spanish version, Hervás & Jódar, 2008). This scale is a self-report designed to assess emotion regulation difficulties, including a) non-acceptance of emotional responses (non-acceptance), (b) difficulties in shifting to goal-directed behaviors when distressed (goals), (c) difficulties in controlling impulsive behaviors when distressed (impulse), (d) limited access to emotion regulation strategies perceived as effective (strategies), (e) lack of emotional awareness (awareness), and (f) lack of emotional clarity (clarity). Cronbach 's α coefficients were α = .93 for the total score; α = .80 for impulse; α =.88 for strategies; α =.87 for non-acceptance; α =.81 for goals; α =.68 for awareness; and α =.78 for clarity.

Magnetic resonance imaging

This information can be found in Supplementary Material 2.

Procedure

The evaluation was carried out in two separate sessions. In the first session, participants signed the informed consent and completed the socio-demographic interview and psychological tests at the "Matilde Cantos Fernández" Social Integration Centre (CIS) in Granada (Spain). The second session took place at the Mind Brain and Behavior Research Centre of the University of Granada (CIMCYC-UGR) where the brain images were acquired.

The total duration of the two sessions was approximately three hours. The participants who completed the two sessions received 50 euros for taking part in the study. Participants did not receive prison benefits for their participation.

The study was approved by the ethics committee at the University of Granada (number: 1000-CEIH-2019). Data confidentiality was guaranteed by Spanish data protection law (Spanish Organic Law 3/2018, of December 5). A similar description of the participants, instruments and procedure can be found in a previously published study that is part of the same research project (Marín-Morales et al., 2021).

Regions of interest

For the purposes of this study, the regions of interest were those proposed by the theoretical framework of Etkin et al. (2015) (Supplementary Material 3).

Data Analysis Plan

Prior to data collection, we determined the sample size using formal power analysis G*Power (Faul et al., 2007). Based on previous structural MRI data that revealed an effect size of 0.86 (Verdejo-Román et al., 2019), an expected power of 0.8, and an assumed alpha-level of 0.05, it was estimated that a minimum of 25 participants per group would be required. ANOVAs were conducted to compare the groups according to demographic, psychological, and type of crime variables. Student's t-tests were performed to analyze whether there were differences in IPV severity (CTS-2) according to the type of IPV (physical or psychological). Chi square tests were applied to compare the groups according to use of medication, loss of consciousness (and duration), past trauma/childhood exposure to violence, and suffer a blow to the head. A multivariate analysis of covariance (MANCOVA) was used to explore regional brain volume differences between partner coercive men and the rest of the groups. The dependent variable was the volume of the regions of interest, the independent variable was group (PCG, OOG, or NOG), and age, severity of drug consumption and Total Intracranial

Volume (TIV) were included as covariates. Analysis of Covariance (ANCOVAS) and Post Hoc (Bonferroni) analysis were carried out to determine the statistically significant group comparisons for those brain regions where significant differences were indicated in the MANCOVA model. Similarly, partial correlations were calculated to estimate the relationship between the volume of those brain regions for which group differences were found, and the scores on the tests of emotional regulation and empathy. These analyses were conducted for both the whole sample and for PCG, controlling for age, severity of drug consumption, and TIV. A more detailed description of the statistical analyses can be found in the Supplementary Material 4.

Results

Emotion regulation and empathy results

With regard to scores on the emotional regulation and empathy tests, statistically significant differences were found between the MGB and the rest of the groups. Similar results have been reported in a previous study (Marín-Morales et al., 2021). To summarize, the results for the total IRI test score indicate that the PCG showed less empathy than the NOG and OOG (all $p<0.03$). In addition, the PCG showed less empathy than the NOG on several subscales (i.e., Fantasy $p= .012$; Empathic concern $p= .043$). Further, the scores obtained on the CERQ test indicate that the PCG use more maladaptive strategies of emotional regulation compared with the NOG (Catastrophizing $p= .003$) and the OOG (Blaming others $p= .032$). Finally, the results indicate that both criminal groups, in comparison with the NOG, show a greater tendency to use maladaptive strategies ($p= .046$) along with the Self-blame strategy (all $p< .002$) (Supplementary Material 5).

Aim 1: Are brain volumes of areas implied in emotion regulation different between partner coercive men, other offenders and non-offenders?

The MANCOVA model was statistically significant (Roy's Greatest/largest Root, *F*

(20,57) =2.357, *p*= .006; *ηp²*= .453). ANCOVAs and Post Hoc analyses revealed that the PCG showed a lower volume in the right Accumbens (*p*= .003) and left Dorsal Anterior Cingulate Cortex (*p*= .022) in comparison with the NOG. The volume of the right Accumbens was also lower for the OOG compared with the NOG (*p*= .013) (Table 2, Figure 1). No differences in the volume of the studied brain regions were found between the PCG and OOG. However, after correcting for multiple comparisons with Holm-Bonferroni/Sequential Bonferroni, only the group differences in right Accumbens volume remained significant (*p*= .002). Additional between-group analyses were conducted based on effect size (Table 2, Supplementary Material 6).

Table 2

Mean volume (in mm³) of brain regions related to emotional regulation and statistical differences between groups

Region	Side	PCG (N=26) Mean (SD)	OOG (N=26) Mean (SD)	NOG (N=29) Mean (SD)	F	$\eta p.^2$	p value	p value with (correction Holm-Bonferroni)	post hoc (Bonferroni)
vACC	L	4424.19(457.15)	4351.42 (495.25)	4737.89 (657.09)	2.753	0.068	0.70	--	--
vACC	R	5814.30(613.28)	5634.76 (516.09)	5905 (817.81)	0.076	0.002	0.927	--	--
SMA/preSMA	L	2122.88(336.64)	2112.42 (386.85)	2172.37(376.40)	0.023	0.001	0.977	--	--
SMA/preSMA	R	2029.38(404.25)	1992.61 (321.02)	2141.89(382.46)	0.320	0.008	0.727	--	--
vlPFC	L	7543.65(667.00)	7788.19 (661.47)	7874.48(836.57)	2.020	0.051	0.140	--	--

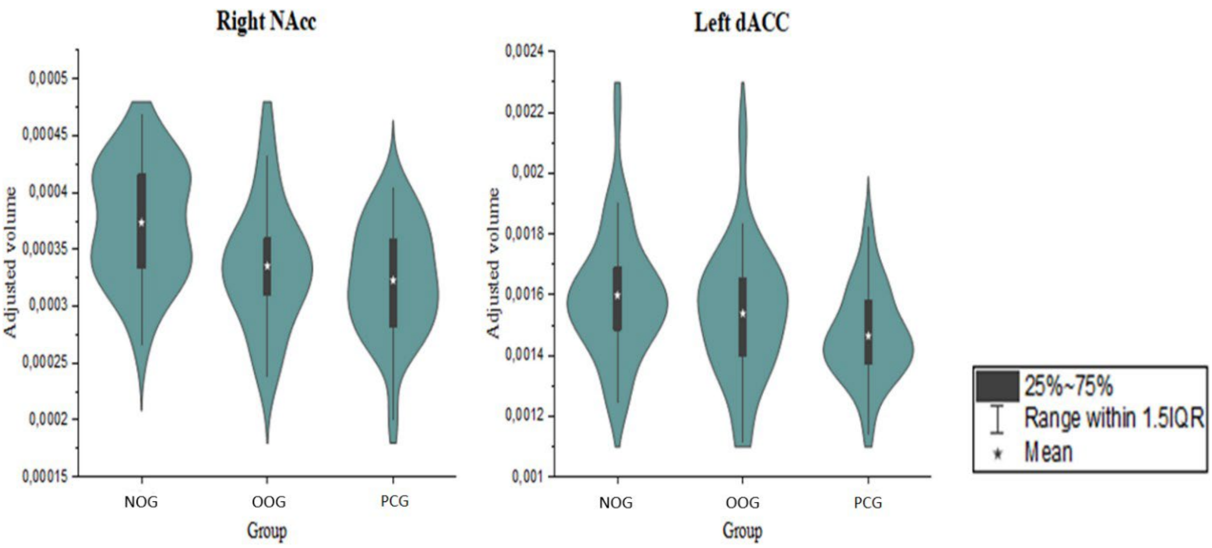
vlPFC	R	8471.53(859.74)	8369.11(621.74)	8558.20(942.85)	0.066	0.002	0.936	--	--
dlPFC	L	10184.57(1619.50)	10199.53(1551.66)	10772.93(1767.96)	0.271	0.007	0.763	--	--
dlPFC	R	8990.11(1418.90)	9107.03(1373.97)	9687.37(1520.66)	0.856	0.022	0.429	--	--
vmPFC	L	6738.00(646.95)	6596.46(668.12)	6832.62(785.35)	0.165	0.004	0.848	--	--
vmPFC	R	5597.38(551.49)	5370.76(513.23)	5693.10(649.87)	0.465	0.012	0.630	--	--
dACC	L	2355.34 (272.60)	2397.19(318.17)	2590 (434.10)	3.797	0.092	0.027*	--	NOG>PCG
dACC	R	2633.11(407.76)	2613.73(297.91)	2777.03(481.35)	0.524	0.014	0.594	--	--
Parietal	L	10643.84(1545.63)	10101.38(1219.96)	10248.27(1279.27)	2.540	0.063	0.086	--	--
Parietal	R	10387.69(1705.89)	9497.11(1544.57)	9972.72(1313.65)	2.095	0.053	0.130	--	--
Amygdala	L	1603.18(136.59)	1655.35(191.45)	1696.14(196.77)	1.393	0.036	0.255	--	--
Amygdala	R	1737.11(120.04)	1762.75(146.16)	1868.81(250.63)	2.567	0.064	0.084	--	--
Insula	L	3245.34(293.71)	3163.11(293.42)	3288.68(447.63)	0.030	0.001	0.971	--	--
Insula	R	3210.57(379.18)	3079.57(346.81)	3324.79(433.76)	1.057	0.027	0.353	--	--

NAcc	L	489.33(102.49)	504.92(76.50)	551.34(94.20)	2.412	0.06	0.097	--	--
NAcc	R	516.80(69.82)	522.55(80.24)	604.42(99.60)	6.792	0.153	0.002*	0.002*	NOG>PCG; NOG>OOG;

Note. PCG= Partner Coercive Group; OOG= Other Offenders Group; NOG= Non-Offenders Group; vACC= Ventral Anterior Cingulate Cortex; SMA= Supplementary Motor Area; vlPFC= ventrolateral Prefrontal Cortex; dlPFC= dorsolateral Prefrontal Cortex; vmPFC= ventromedial Prefrontal Cortex; dACC= dorsal Anterior Cingulate Cortex; NAcc= Accumbens Nucleus; ηp. 2= partial eta-squared.

Figure 1

Differences in brain volume between groups



Note. NOG= Non-Offenders Group; OOG= Other Offenders Group; PCG= Partner Coercive Group; NAcc= Nucleus Accumbens; dACC= dorsal Anterior Cingulate Cortex.

Aim 2: Are brain volumes differences related to scores on emotional regulation?

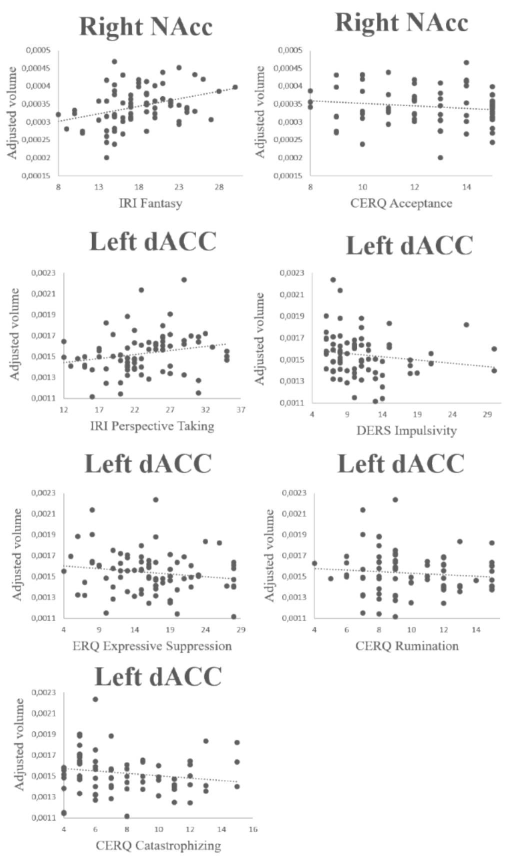
Correlations between behavioral measures and brain volumes for the whole sample are shown below.

Right Accumbens

Whole sample. The results indicate a positive correlation between the volume of the right Accumbens and scores on the *Fantasy* subscale (r= .271, p= .0021) of the IRI test, indicating that the lower the volume of the right Accumbens, the lower the tendency of the participants to identify themselves with fictional characters such as those found in books and movies (Figure 2). In addition, a negative correlation was found between right Accumbens volume and scores on the *Acceptance* subscale (r= -.270, p= .017) of the CERQ test, indicating that the greater the right Accumbens volume, the lower the tendency to accept experienced thoughts and to resign themselves to thinking about what has happened (Figure 2).

Figure 2

Correlations between volume of brain regions from entire sample and emotional regulation/empathy test



Note. dACC= dorsal Anterior Cingulate Cortex; NAcc= Nucleus Accumbens; IRI= Interpersonal Reactivity Index; CERQ= Cognitive Emotional Regulation Questionnaire; DERS= Difficulties in Emotion Regulation Scale; ERQ= Emotion Regulation Questionnaire.

Partner Coercive Group. In the PCG, a positive correlation was found between right Accumbens volume and scores on the *Fantasy* subscale (*r*= .436, *p*= .037) of the IRI test, indicating that the lower the volume of the right Accumbens, the lower the tendency of the participants to identify themselves with fictional characters such as those found in books and movies. A positive correlation was also found between right Accumbens volume and scores on the *Putting into perspective* subscale (*r*= .622, *p*= .013) of the CERQ test, indicating that the lower the volume of the right Accumbens, the lower use was made of the strategy of diminishing and relativizing the severity of the event by comparing it with other events.

Left Dorsal Anterior Cingulate Cortex

Whole sample. Positive correlations were found between left Dorsal Anterior Cingulate Cortex volume and scores obtained on the *Perspective Taking* subscale (*r*= .254, *p*= .031) of the IRI test, indicating that the lower the volume of the left Dorsal Anterior Cingulate Cortex, the lower the tendency or ability of the participants to adopt the perspective or point of view of other people. Negative correlations were also found between left Dorsal Anterior Cingulate Cortex volume and scores on the ERQ test, specifically the *Expressive suppression* subscale (*r*= -,238, *p*= .038), indicating that the greater the left Dorsal Anterior Cingulate Cortex volume, the lower the tendency of the individual to modify emotional expression in an attempt to conceal (but not alter) the experience. A negative correlation was also found between left Dorsal Anterior Cingulate Cortex volume and scores on the *Impulsivity* subscale (*r*= -.231, *p*= .045) of the DERS test, indicating that a greater left Dorsal Anterior Cingulate Cortex volume is related to fewer problems in controlling impulsive behaviors when distressed. A negative correlation was also found between left Dorsal Anterior Cingulate Cortex volume and the scores on the CERQ test, specifically the *Rumination* subscale (*r*= -.230, *p*=.047), indicating that the greater the left Dorsal Anterior Cingulate Cortex volume, the lower the use of the strategy of thinking excessively about the feelings and thoughts associated with the unpleasant event. Finally, left Dorsal Anterior Cingulate Cortex volume was also negatively correlated with scores on the *Catastrophizing* subscale (*r*= -,234, *p*= .039), indicating that the greater the left Dorsal Anterior Cingulate Cortex volume, the lower the use of the maladaptive strategy focused on excessive thinking that emphasizes experienced terror (Figure 2).

Partner Coercive Group. No significant correlations were found.

Discussion

To our knowledge, this is the first study that compares the volumes of brain areas related to emotional regulation between partner coercive men, other offenders, and non-offenders. The main objective of this study was to analyze if the brain volume of areas involved in emotional regulation differs between partner coercive men, and other offenders and non-offenders. Both groups of offenders were incarcerated for having committed misdemeanor crimes. Therefore, our results are focused on one type of partner coercive men, who have committed the misdemeanor level partner violence and have not perpetrated frequent or high levels of partner violence, according to their severity of violence scores. We hypothesized that partner coercive men would show lower regional brain volumes in regions implied in emotional regulation in comparison with other types of offenders and a group of non-offenders. We also hypothesized that brain volume would correlate positively with emotional regulation skills and the use of adaptive strategies, and negatively with the use of maladaptive emotional regulation strategies.

The results show that while partner coercive men have a lower volume in the right Accumbens and left dorsal Anterior Cingulate Cortex compared with non-offenders, no such differences were found between partner coercive men and other offenders. Furthermore, lower brain volume was found to be associated with the use of maladaptive emotional regulation strategies and low empathy. Therefore, these results partially confirm one of our hypotheses, that is, partner coercive men, in comparison with non-offenders, have lower volumes in emotion-related brain structures, as reported in previous studies (Verdejo-Román et al., 2019; Zhang et al., 2013). Our results indicate that no differences in brain volume were found between partner coercive men and other offenders. Several authors have reported that partner coercive men differ from other offenders at the functional level (Bueso-Izquierdo et al., 2016;Marín-Morales et al., 2020), but only when processing intimate partner violence-relatedstimuli, and only one preliminary structural study (Verdejo-Román et al., 2019) found differences in cortical thickness between partner coercive men and other offenders. However,the latter study used a different brain metric to the one used here. Previous studies in healthy populations have shown that regional brain volume and cortical thickness are weakly correlated(Winker et al., 2010). Additionally, there is only a partial overlap between the brain regions examined in our research and the study of Verdejo-Román et al. (2019). Thus, while previousresults could be taken to indicate that partner coercive men differ from other offenders when presented with intimate partner violence-related stimuli, when examining regional brainvolumes there are no differences between these groups of offenders.

The partner coercive men in our study showed a reduced volume of the right Accumbens. In addition, correlation analyses revealed that a reduced Accumbens volume is associated with lower empathy and poorer emotional regulation. The Accumbens is involved in motivation and reward, playing a role in the evaluation and selection of biologically relevant stimuli such as those linked to appetite, sex, and drugs (Lammel et al., 2014), along with the control of reactive aggression (Yamaguchi & Lin, 2018). Furthermore, this region plays a central role in the selection of actions when the action is motivated by an ambiguous and uncertain state (Floresco, 2015). Our findings could be relevant to the results of a study conducted by Chan et al. (Chan et al., 2010), which found that partner coercive men showed a bias toward negative affective stimuli along with a tendency to exhibit reactive violent behavior.

The group of partner coercive men in this study also showed reduced volumes in the left dorsal Anterior Cingulate Cortex, which correlated with low empathy and poorer emotional regulation. These results are in line with those reported by Verdejo-Román et al. (2019), who found a reduced thickness of the right Anterior Cingulate Cortex in partner coercive men. The Anterior Cingulate Cortex regulates emotional and cognitive processing through the integration of sensory (nociceptive and visuospatial), motor, cognitive and emotional information (Stevens et al., 2011) and is thus fundamental to emotional regulation (Giuliani et al., 2011), particularly anger management (Davidson et al., 2000), as well as empathy and theory of mind (Kanske et al., 2015). Kumari et al. (2014) found a lower Anterior Cingulate Cortex volume in aggressive men with antisocial personality disorders or schizophrenia but not in those without a history of violence, while Giuliani et al. (2011) found a positive correlation between Anterior Cingulate Cortex volume and emotional regulation (cognitive reevaluation strategy) in healthy subjects. Therefore, these results suggest that reduced Anterior Cingulate Cortex volume is related to poor emotional regulation and low empathy in partner coercive men and other offenders, as well as to violent behavior in general. With regard to the Anterior Cingulate Cortex, our results are compatible with the findings of a functional neuroimaging study conducted by Bueso-Izquierdo et al. (2016), which found that partner coercive men showed hyperactivation in the Posterior Cingulate Cortex in response to neutral and intimate partner violence-related images.

Finally, the observation that maladaptive emotional regulation strategies are used to a greater extent by partner coercive men could potentially explain the higher levels of reactive violence shown by these individuals (Morón & Biolik-Morón, 2021). Future studies should thus examine the relationship between emotional regulation and reactive violence in partner coercive men, since, according to the literature (Jiang et al., 2018), interventions should target specific emotional aspects depending on the type of aggression displayed (reactive/proactive). In summary, our findings suggest that both partner coercive men and other offenders have smaller brain volumes in regions involved in emotional regulation according to the model of Etkin et al. (2015). In addition, both groups of offenders show lower empathy and poorer emotional regulation in comparison with non-offenders. These results replicate those of previous structural neuroimaging studies demonstrating that reduced gray matter volumes in regions involved in emotional processes such as emotional regulation (Killgore et al., 2012) and moral decision-making (Hofhansel et al., 2020; Raine, 2019) are strongly linked to violent behavior (Rosell & Siever, 2015). Therefore, given that violent behavior arises from multiple interactions between the environment and emotional and cognitive processes, reduced volumes of the areas involved in the front-temporal-limbic circuit could serve as a biomarker of such behavior (Raine, 2019).

Limitations

This study has a number of limitations. First, we did not consider the heterogeneity of the sample of partner coercive men (Ali et al., 2016) and we have not classified them according to the various types of violence exercised (psychological, physical, or sexual). Second, our sample was composed by men who have committed the misdemeanor level of partner violence, not the more extreme level. For that reasons, generalization of our results is limited to a subset of partner coercive men. Third, in relation to major methodological, we have conducted a large number of statistical tests relative to the number of participants, which could increase the probability of making a Type I error or rejecting the null hypothesis when it is actually true. Fourth, the Partner Coercive Group was composed by men convicted for physical or psychological violence. According to Spanish Penal Code there are not differences between these types of intimate partner violence. Moreover, we did not find differences in CTS-2.

However, the large standard deviation in CTS-2 suggests that future studies should divide the groups according to the two forms of intimate partner violence and CTS-2 scores, since the type of conviction (physical or psychological violence) of these individuals might no necessarily reflect those violent acts that might have been committed in the past. Therefore, the generalizability to other partner coercive men and other contexts could be limited. For these reasons, replication of the exploratory findings of this study is necessary.

Future Research Directions

Future studies should replicate the results of this preliminary study with larger samples to analyze whether brain volume, emotional regulation, and empathy differ according to the type of partner coercive man (Carbajosa et al., 2017), the type of violence committed (for example, psychological or physical) as well as the severity of the violence. In addition, future studies with larger samples should explore whether the results found in relation to effect size are replicated.

Prevention, Clinical and Social Implications

Finally, our study has significant clinical and social implications. From a clinical standpoint, while this study shows that at a brain structural level, partner coercive men do not differ from other offenders, we found that the reduced volume of certain brain regions is associated with poorer emotional regulation strategies and low empathy. Therefore, these findings indicate the importance of working on empathy and adaptive emotional regulation strategies in order to reduce criminal behaviors in general. However, if the aim is to promote empathy and emotional regulation towards partners or ex-partners, it will be necessary to focus on partner coercive men. This is important, given the observation that partner coercive men show a distinct pattern of behavior in response to intimate partner violence-related images (Bueso-Izquierdo et al., 2016; Lee, 2009; Marín-Morales et al., 2020) and male norms of domination are associated with emotional deregulation in this group (Tager et al., 2010).

Consequently, advances in research on the behavior of partner coercive men will inform the development of effective, personalized, and targeted interventions for reducing the existing high rates of recidivism (Bowen, 2011). At the social level, our findings suggest the importance of implementing education programs aimed at developing emotional regulation and empathy skills from childhood in order to prevent both IPV and crime in general.

In conclusion, this preliminary study has demonstrated that partner coercive men and other offenders do not differ in terms of the brain structures associated with emotional regulation. Although previous studies have reported differences in brain functioning between partner coercive men and other offenders in response to images of intimate partner violence (Lee et al., 2009; Bueso-Izquierdo et al., 2016; Marín-Morales et al., 2020; Marín-Morales et al, 2021), no such differences were found in the present study. Therefore, our results provide further support for the notion that functional differences are not always associated with structural differences (Hofhansel et al., 2020). Moreover, our findings suggest that neuroscientific variables must continue to be studied in order to understand the complexity of intimate partner violence, while neuroscientific findings must be integrated into more general theories of batterer behavior. Finally, we provide evidence that is broadly consistent with the idea that both emotional regulation and empathy are important for predicting and understanding male violence towards partners or ex-partners and that such factors are critical to understanding violent behavior in general.

Supplementary Material

Supplementary Material 1

Spanish IPV Law and Penal Code

In Spain, IPV crimes are regulated by a specific law (Law 1/2004, “Comprehensive Protection Law against Intimate Partner Violence”). This law states that a man may be convicted by a judge for showing several types of aggressive behavior towards a woman, including insults, threats, slaps, beatings, sexual abuse, or murder. According to this law, first convictions for IPV without sexual or physical abuse are classified as a misdemeanor, which results in the perpetrator being sent to an open facility (CSI) of the Ministry of Justice for less than 2 years (but not to prison). In the CSI, perpetrators are required to attend IPV rehabilitation programs. In order to test whether perpetrators convicted by psychological or psychological and physical abuse differ on their Conflict Tactic Scale scores we conducted a Student's t-test. Results indicated no significant differences between groups (t=1,536; p=0.142).

Crime severity in Spanish law is regulated by a Penal Code (Article 33). According to this article, crimes carrying sentences between 3 months and 5 years are classified as “less serious.” Given that all the offenders were recruited from the CSI, they had the following characteristics: (a) this was the first time that the participants of both groups had been convicted, (b) they were serving a sentence of less than 2 years (“less serious”), and (c) they came from prison and were serving third-grade sentences. In sum, both groups of offenders were recruited from the same facility where misdemeanor offenders are incarcerated, or they were serving third-grade sentences.

Supplementary Material 2

Magnetic resonance imaging

The equipment used was a 3.0 T clinical MRI scanner with a thirty-two-channel phased array head coil (Siemens Magnetom Prisma Fit). A sagittal three-dimensional T1-weighted turbo-gradient-echo sequence was obtained with the following parameters: 208 slices, TR = 2.300 ms, TE = 3.1 ms, flip angle = 9, FOV = 256 x 256, 0.8 mm^3 voxels.

Volumetrics. All images were visually inspected for major artifacts and realigned to the AC-PC line. Image processing was carried out using the automated processing pipeline "recon-all" implemented in FreeSurfer (version 5.1.0, http://surfer.nmr.mgh.harvard.edu/), This pipeline involves intensity normalization, registration to Talairach space, skull stripping, segmentation of White Matter (WM) to separate it from grey matter (GM) and cerebrospinal fluid (CSF), tessellation of the WM boundary, and automatic correction of topological defects. Cortical volume parcellation was generated by combining adjacent labels from the Destrieux atlas (Destrieux et al., 2010) using weighted averaging based on the number of vertices in each label. Full technical details are described elsewhere (Fischl & Dale, 2000). Subcortical segmentation was performed based on an atlas containing probabilistic information on the location of structures (Fischl et al., 2002).

Supplementary Material 3

Regions of interest

For the purposes of this study, the regions of interest were those proposed by the theoretical framework of Etkin et al. (2015). With respect to the regions involved in emotional reactivity, we included the dorsal anterior cingulate cortex (dACC), insula, and amygdala. However, since the Destrieux atlas does not include the periaqueductal gray (PAG), we included the Nucleus Accumbens (NAcc), which plays a fundamental role in the integration of affective information (Floresco, 2015). Further, we included the dorsolateral prefrontal cortex, which is involved in "explicit" emotion regulation, and the vACC and vmPFC, both of which are involved in "implicit" emotion regulation. Correspondence between the Destrieux labels and the brain regions proposed by the model of Etkin et al. (2015) can be found in the Table.

Correspondence of the brain areas of the Etkin model and Destrieux atlas

Etkin Model (2015)	**Destrieux atlas (2010)**
Ventral Anterior Cingulate Cortex	Anterior part of the *cingulate gyrus and sulcus* (ACC)
Supplementary Motor Area (SMA/preSMA)	Superior part of the precentral sulcus
Ventral Lateral Prefrontal Cortex	Lateral orbital sulcus + Orbital part of the inferior frontal gyrus + Orbital Gyri
Dorsolateral Prefrontal Cortex	Middle frontal gyrus

Ventromedial Prefrontal Cortex	Medial orbital sulcus (olfactory sulcus) + straight gyrus/ Gyrus rectus + subcallosal area, subcallosal gyrus + Fronto-marginal gyrus (of Wernicke) and sulcus
Dorsal Anterior Cingulate Cortex	Middle-anterior part of the cingulate gyrus and sulcus (Amcc)
Parietal	Superior parietal lobule (lateral part of P1) + Intraparietal sulcus (interparietal sulcus) and transverse parietal sulci
Amygdala	Amygdala
Insula	Anterior segment of the circular sulcus of the insula + Short insular gyri
Accumbens	Accumbens

Supplementary Material 4

Data Analysis Plan

Data were analyzed using the Statistical Package for the Social Sciences, Version 22 (SPSS; Chicago, IL, USA). ANOVAs were conducted to compare the groups according to demographic, psychological, and type of crime variables. Student's t-tests were performed to analyze whether there were differences in IPV severity (CTS-2) according to the type of IPV (physical or psychological). Chi square tests were applied to compare the groups according to use of medication, loss of consciousness (and duration), past trauma/childhood exposure to violence, and suffer a blow to the head. Drug use severity was calculated by summing the DSM-IV criteria for alcohol consumption, including frequency and intensity (e.g., quantity, number of drugs,) and the DSM-IV criteria for the consumption of other drugs (e.g., cocaine, marijuana, heroin, and hashish). Since this variable was not normally distributed, it was normalized by applying the logarithm in base 10. Due to the statistical differences found between the NOG and PCG, the severity of drug use was introduced as a covariate in all analyses. Further, Total Intracranial Volume (TIV) was introduced as a covariate to control for variability in this measure. Age was also included as a covariate due to its correlation withGM Volume ($r = -.436$, $p = .000$). A multivariate analysis of covariance (MANCOVA) was usedto explore regional brain volume differences between partner coercive men and the rest of the groups. The dependent variable was the volume of the regions of interest, the independent variable was group (PCG, OOG, or NOG), and age, severity of drug consumption and TIV were included as covariates. We applied Roy's Greatest/Largest Root statistical test, which is the most appropriate statistical approach when the dependent variables are highly correlated (Haase & Ellis, 1987). Partial eta-squared ($\eta p2$) was used to estimate effect sizes. According to Cohen’s guidelines (1988), values from 0.01–0.06 are considered small, those ranging from 0.06–0.14 are considered medium, and values above 0.14 indicate large effect sizes.

In order to reduce Type I error, we corrected for multiple comparisons with Holm-Bonferroni Adjustment (Holm, 1979). Analysis of Covariance (ANCOVAS) and Post Hoc (Bonferroni) analysis were carried out to determine the statistically significant group comparisons for those brain regions where significant differences were indicated in the MANCOVA model. Similarly, partial correlations were calculated to estimate the relationship between the volume of those brain regions for which group differences were found, and the scores on the tests of emotional regulation and empathy. These analyses were conducted for both the whole sample and for PCG, controlling for age, severity of drug consumption, and TIV.

Supplementary Material 5

Emotion regulation and empathy test results

Test	PCG (n=26) Mean (SD)	OOG (n=26) Mean (SD)	NOG (n=29) Mean (SD)	p value
ERQ				
Cognitive reappraisal	30.79 (7.17)	30 (6.61)	29.34(7.45)	0.762
Expressive suppression	18.20 (6.57)	15.44 (6.54)	15.28 (5.09)	0.158
Total	49.04(12.30)	45.48(10.89)	44.62(10.18)	0.328
CERQ				
Self-blame	9.08 (3.96)	9.42 (2.59)	6.28 (2.13)	0.000*
Acceptance	11.77 (3.21)	12.88 (2.37)	11.24 (2.70)	0.092
Rumination	10.62(3.17)	10.16 (3.13)	9.19 (2.57)	0.206
Positive refocusing	9.54 (3.06)	8.96 (3.77)	8.86 (3.14)	0.738
Refocus on planning	11.96 (2.68)	12.19(3.07)	11.83(2.03)	0.873
Putting into perspective	12 (2.32)	12.69 (2.29)	11.38 (2.67)	0.147
Catastrophizing	8.54 (3.62)	7.50 (3.26)	5.72 (2.23)	0.004*
Blaming others	7.32 (4.11)	4.72 (2.29)	6.39 (2.42)	0.035
Positive reappraisal	11.92 (2.39)	12.85 (2.66)	11.86 (2.04)	0.244

Adaptive strategies	16 (4.27)	15.73(3.23)	14.17 (2.03)	0.086
Maladaptive strategies	14.04 (3.64)	14 (3.40)	12 (2.54)	0.036*
IRI				
Perspective taking	20.88 (5.44)	24.41 (4.963)	24.41(5.423)	0.028*
Fantasy	15.92(4.47)	18.41(4.32)	19.44(4.08)	0.012*
Empathic concern	23.27(4.4)	26.32(4.93)	26.26 (3.73)	0.021*
Personal distress	13.96(4.36)	14.55(4.58)	12.78(4.29)	0.357
Total	74.03(11.89)	83.68(10.31)	82.88(11.15)	0.005*
DERS				
No aceptación	12.88(6.54)	12.28(6.16)	11.64(5.18)	0.748
Metas	11.76(4.25)	10.96(4.58)	11.31(3.83)	0.796
Impulsividad	11.62(5.84)	11.65(5.98)	10.07(3.28)	0.448
Estrategias	14.04(6.47)	12.80(6.25)	12.52(5.56)	0.653
Consciencia	15(4.63)	12.80(4.74)	14.79(3.41)	0.135
Claridad	9.08(2.84)	8.46(3.65)	8.36(2.68)	0.66
Total	78.35(23.98)	65.23(23.43)	69.32(18)	0.15

Note. NOG= Non-Criminal Group; OOG= Other Offenders Group;

PCG= Partner CoerciveGroup; ERQ= Emotion Regulation

Questionnaire; CERQ= Cognitive Emotional RegulationQuestionnaire; DERS= Difficulties in Emotion Regulation Scale; IRI= Interpersonal Reactivity Index.

Supplementary Material 6

Results based on effect size

Additional between-group analyses were conducted based on effect size. In order to reduce the Type II error and to analyze the magnitude of the differences found in the study (Castro & Martini, 2014), we focused on analyzing the effect size or partial eta squared of dependent variables with medium or large effect sizes, as these are independent of sample size(Castro & Martini, 2014; Sullivan & Feinn, 2012). The results revealed a large effect size for the right Accumbens (NAcc) and a medium effect size for the left dorsal Anterior Cingulate Cortex (dACC), left ventral Anterior Cingulate Cortex (vACC), left Parietal, right Amygdala and left Accumbens (NAcc). In all these areas, the PCG showed a lower brain volume than theNOG, except in the left parietal, where the PCG showed a larger volume than the NOG.