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Reduced vagal tone in intimate partner violence perpetrators is partly explained by anger rumination

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Abstract

Polyvagal theory proposed that an autonomous nervous system imbalance might be characteristic of violent individuals, especially reduced parasympathetic or vagal tone. Accordingly, some studies concluded that when intimate partner violence (IPV) perpetrators deal with acute stress, they tend to present a sympathetic predominance over the parasympathetic nervous system once the stress has ended. However, less is known about cognitive mechanisms that explain this phenomenon. In fact, this functioning might be explained by inner speech and/or angry thoughts (anger rumination) in reactive aggressors. Nonetheless, there is a gap in the scientific literature assessing whether this psychophysiological functioning in IPV perpetrators is explained by anger rumination. For this reason, the first aim of this study was to assess the cardiorespiratory (heart rate (HR), pre-ejection period (PEP), and respiratory sinus arrhythmia (RSA)) and electrodermal (skin conductance level (SCL)) changes, as well as the anger state, when coping with an acute laboratory stressor, comparing a group of reactive IPV perpetrators ($n = 47$) and a group of non-violent men ($n = 36$). The second aim was two-fold. After checking whether the groups differed on their anger rumination and manifestation of aggression (reactive and/or proactive) scores, we studied whether these variables explained psychophysiological and psychological responses to a laboratory task (changes and levels during the recovery period) in each group. Our results demonstrated that, compared to the control group, IPV perpetrators presented lower RSA levels (vagal tone). Even though the groups did not differ on their anger rumination or manifestation of aggression scores (except for proactive aggression), only in the IPV perpetrators, high anger rumination and reactive aggression partly explained the lower vagal tone (RSA levels) and high levels of anger state at post-task. Consequently, this study contributes to understanding the psychobiological basis for violence proneness in IPV perpetrators, making it possible to explore new therapeutic strategies.

Keywords Manifestation of aggression · Anger rumination · Cardiorespiratory · Electrodermal · Intimate partner violence

Introduction

Intimate partner violence (IPV) against women is a worldwide problem with this kind of violence causing severe consequences for the victims' health (Martín-Fernández et al., 2019, 2020; World Health Organization, 2020). Subsequently, different lines of research have focused on reducing or preventing IPV. For example, a specialized field of studies has tried to understand the main reasons for IPV perpetration (Gracia et al., 2020, 2021; Heise, 2011; Herrero et al., 2020; Lila et al., 2019; Romero-Martínez et al., 2021a, 2021b, 2021c, 2022; Santirso et al., 2020). As the knowledge about this phenomenon grows, and specifically about the perpetrators, the ability to improve current psychotherapeutic interventions to reduce IPV recidivism also increases.

Most of the research on IPV perpetrators has been carried out from clinical and social perspectives. Although professionals in this field have made important advances in the comprehension of the IPV phenomenon, the relatively limited efficacy of current interventions in reducing IPV recidivism has been criticized (Arce et al., 2020; Babcock et al., 2004a, 2004b; Santirso et al., 2020; Wilson et al., 2021), which reinforces the need to add new and complementary perspectives to the current ones (Moya-Albiol et al., 2017; Pinto et al., 2010). In this regard, the

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neuroscientific perspective offers interesting tools, such as psychophysiological variables (e.g., cardiorespiratory, electrodermal…), which do not present the typical biases of self-reports (e.g., social desirability, inclination to give extreme or centered answers, etc.) (Moya-Albiol et al., 2017).

The assessment of the autonomic nervous system has been useful for establishing subcategories of violent individuals. In fact, polyvagal theory applied to violence proneness has pointed out the existence of an imbalance between the two branches of the autonomic nervous system (Porges, 2009), that is, the serious difficulties of the parasympathetic nervous system in maintaining a balance with the sympathetic nervous systems to regulate heart functioning. However, the polyvagal theory also stated that this imbalance might be explained, at least in part, by alterations in the brainstem areas (Porges, 2009). This alteration of the equilibrium underlies emotional and/or behavioral regulation. Anyway, one possible way to show this imbalance is to assess how individuals deal with acute stress, although this can sometimes be observed even during a resting (or basal) state (Gordis et al., 2010; Jennings et al., 2019; Lorber, 2004; Ortiz & Raine, 2004; Posthumus et al., 2009).

For more than three decades, a bimodal (reactive-proactive) categorical differentiation of aggressors was established (Cornell et al., 1996; Dodge & Coie, 1987) that seemed to correspond to different psychophysiological profiles (Pinto et al., 2010). Thus, on the one hand, Type I aggressors, in whom proactive or instrumental violence predominates, would show a hypoarousal of the autonomic nervous system when coping with acute stress. On the other hand, Type II aggressors would be characterized by a hyperarousal in which reactive, affective, or impulsive violence prevails (Hubbard et al., 2002; Scarpa & Raine, 1997; Scarpa et al., 2008, 2010; Schoorl et al., 2016; Zhang & Gao, 2015). In any case, it is important to highlight that these categories are not mutually exclusive because both types of violence can coexist in the same individual (Moya-Albiol & Romero-Martínez, 2020).

In the case of IPV perpetrators, Gottman et al. (1995) concluded that this categorization could be employed for men who perpetrate IPV. In fact, these authors submitted a group of IPV perpetrators to a marital conflict task (stress task). The IPV perpetrators whose heart rate (HR) decreased from resting period to stressor were classified as Type I (hyporeactivity), whereas those who were overexcited during the stressor received the categorization of type II (hyperreactivity). Nonetheless, later attempts to replicate these psychophysiological profiles were not successful (Babcock et al., 2004a, 2004b; Meehan et al., 2001). However, a later study with healthy young adults concluded that whereas reactive relational aggression was associated with high sympathetic reactivity to acute stress, the proactive profile was associated with high parasympathetic reactivity (Murray-Close et al., 2017).

Several studies have analyzed the relationship between IPV perpetration and reactive and proactive aggression based on criminal records or self-reported questionnaires (Ennis et al., 2017; Standford et al., 2008). Ennis et al. (2017) established differences between IPV perpetrators classified as reactive compared to those categorized in the proactive group, concluding that antisocial traits and hostile attitudes towards women, as well as risk of recidivism, were higher in the proactive group compared to the reactive group. However, IPV perpetrators classified as reactive presented higher psychopathological traits than proactive IPV perpetrators (Standford et al., 2008). Moreover, studies analyzing the psychophysiological profile of IPV perpetrators, predominantly classify them in the reactive profile based on their previous criminal records (Romero-Martínez et al., 2013a, 2013b, 2014, 2020, 2021b; Vitoria-Estruch et al., 2018a). These authors employed different psychosocial stressors (e.g., the Trier Social Stress Task related to IPV and a set of cognitive tasks), and they found a hyperreactivity of the sympathetic nervous system when these IPV perpetrators coped with both psychosocial stressors. Specifically, they concluded that reactive IPV perpetrators presented shorter total pre-ejection periods (PEP) than non-violent men (controls) when dealing with acute stress (Romero-Martínez et al., 2014). This predominance of the sympathetic nervous system was supported by later studies; specifically, reactive IPV perpetrators presented higher heart rates (HR), shorter PEP, higher skin conductance levels (SCL), and lower respiratory sinus arrhythmia (RSA) (reduced vagal tone) during the recovery period (after stress) in comparison with controls (Romero-Martínez et al., 2013a, 2013b, 2020, 2021b; Vitoria-Estruch et al., 2018a).

The hyperreactivity in the IPV perpetrators during the recovery period could be related to excessive vigilance maintenance, which lowers the threshold for reacting with violence when faced with certain stimuli (Dawson et al., 2000). In this way, these elevated arousal levels might reflect the inner speech; in other words, there appears to be an increase in the time spent continuously thinking the same thoughts, which has been defined as rumination (Moya-Albiol & Romero-Martínez, 2020). Moreover, this cognitive process has been related to negative affect, which includes a wide range of feelings, thoughts, verbalizations, and physical manifestation of aggression (Denson, 2009, 2012; Dodge & Coie, 1987; Li et al., 2019).

Anger rumination has been defined as the tendency to focus on experiences and moods related to anger (Anestis et al., 2009; Takebe et al., 2016; White & Turner, 2014). In fact, excessive anger rumination has been considered a problem of self-regulation or self-control of these thoughts, as well as disturbances in social information processing

(Denson, 2009, 2012; Dodge & Coie, 1987; Li et al., 2019). As can be inferred, these problems are broadly related to reactive aggression (Lee et al., 2018; Ross & Babcock, 2009; White et al., 2013; Wilkowski & Robinson, 2010), but there is also evidence of their association with proactive profiles (Wang et al., 2020). Regarding IPV perpetrators, rumination (measured with the Nolen-Hoeksema and Morrow paradigm) promoted an increase in sympathetic activation (Babcock & Potthoff, 2020). These results are consistent with those observed in Ray et al. (2008), who show a positive relationship between sympathetic activation and anger rumination. Therefore, anger rumination could be a maintenance factor of anger and sympathetic activity when coping with a stressor, which would promote the risk of aggression (Gerin et al., 2006). However, studies have not addressed whether anger rumination (self-reported) would explain autonomic nervous system imbalances in IPV perpetrators when coping with an acute stressor.

In summary, the objectives of the present study were three-fold. First, we assessed whether IPV perpetrators have different cardiorespiratory and electrodermal responses to a previously validated acute laboratory stressor in comparison with controls. Based on previous studies in this line of research (Gottman et al., 1995; Romero-Martínez et al., 2013a, 2013b, 2014; 2020, 2021b; Vitoria-Estruch et al., 2018a), we expected IPV perpetrators to show a sympathetic nervous system predominance (shorter PEP and higher SCL) over the parasympathetic nervous system (lower RSA or vagal tone) in response to a laboratory psychosocial stressor. Specifically, these differences would be more pronounced during the recovery period. Second, we analyzed whether the groups differed in terms of anger rumination and expression. Based on the conclusions of previous studies (Ray et al., 2008; White & Turner, 2014), we expected IPV perpetrators to exhibit greater anger rumination and manifestation of aggression (reactive and proactive), compared to controls. Lastly, we also assessed whether anger rumination and expression could explain the psychophysiological imbalance (total and during the recovery period) and anger state levels in both groups. As stated before (Babcock & Potthoff, 2020; Busch et al. 2017; Gerin et al., 2006; Ray et al., 2008), high anger rumination and reactive aggression would explain the psychophysiological imbalance (total and during the recovery period) and high anger states in both groups.

Method

Participants

From an initial sample of 94 healthy men recruited for the study, after screening, only 83 men were included in the study (4 of them refused to participate during the entire study, and 5 were eliminated from the statistical analyses because they presented values greater than 2.5 SD from the group mean on any of the psychophysiological variables). The experimental group consisted of 47 heterosexual men convicted of IPV, whereas the remaining 36 had no previous criminal records (involving IPV or any kind of violence) and formed the control group.

The IPV perpetrator group was recruited from the psychological and psychoeducational community treatment program "CONTEXTO", which operates in the Department of Social Psychology at the University of Valencia (Spain). This program is mandatory for men who receive a sentence of less than 2 years in prison for gender violence in their intimate partner relationships. They do not have other previous criminal records, and so they receive a suspended sentence on the condition that they complete this intervention program (Lila et al., 2018). Those who agreed to participate in the study had to score below the cutoff on the Alcohol Use Disorders Identification Test (AUDIT) (Contell-Guillamón et al., 1999; Saunders et al., 1993) and the Severity Dependence Scale for cocaine and/or cannabis (Miele et al., 2000; Vélez-Moreno et al., 2013). Moreover, they could not suffer from any physical (e.g., brain damage, chronic pain, cranioencephalic trauma, etc.) or mental (mood, personality, psychotic disorders, etc.) disorders. To determine this, all participants were interviewed by mental health professionals with considerable expertise with IPV perpetrators. Furthermore, the IPV perpetrators included were classified as reactive based on their previous criminal records, thus defining their acts as impulsive violence in reaction to marital conflicts.

The recruitment of the control group was based on advertisements published in the city of Valencia (Spain). As a result, those interested in participating in the study received an e-mail as a first contact. Subsequently, an initial interview was arranged for screening purposes. The inclusion criteria for this control group were not having a criminal record of violence against their partner or another individual, which was verified based on a criminal record certificate issued by a public institution; and scoring below 1 on the Conflict Tactics Scale-II (Muñoz-Rivas et al., 2007; Straus et al., 1996). In addition, they had to present similar anthropometric and sociodemographic characteristics to those of the IPV perpetrators included in our study.

Procedure

To carry out the study, each participant had to attend three one-hour sessions in the psychobiology laboratories of the Faculty of Psychology at the Universitat de València. Based on previous research (Vitoria-Estruch et al., 2018a, 2018b), all participants were asked to refrain from consuming food,

caffeine, alcohol, drugs, or medication and/or doing physical exercise two hours before each session.

Prior to the beginning of the first session, participants completed an informed consent form, and the necessary anthropometric data (weight and height) were collected. A semi-structured individual interview was then conducted with all participants to exclude those who did not meet the inclusion criteria and to collect the necessary sociodemographic data (see Fig. 1).

In the second session, the participants were taken to a noise-insulated room with a constant temperature of 22 ± 1 °C. This session always took place between 4 and 7 pm. Throughout the session, participants remained seated. Before starting, they were administered the State-Trait Anger Expression Inventory-2 (STAXI-2) in its Spanish version (Miguel-Tobal et al., 2001; Spielberger, 1999), which assesses anger state. Subsequently, participants were exposed to a cognitive and social laboratory stressor. While the participants were performing the laboratory tasks, cardiorespiratory and electrodermal measures were recorded. The recording was performed using the Vrije Universiteit Ambulatory Monitoring System (VU-AMS). The psychophysiological recording included the following periods: baseline/resting, anticipatory/preparatory, task/stressor, and recovery/post-task. The two initial periods lasted 5 min each, followed by the task/stressor, which lasted about 30 min, followed by a 10-min recovery period (Romero-Martínez et al., 2021b). After the stressor and the psychophysiological recording ended, anger state was reassessed (see Fig. 2).

In the third session, a battery of questionnaires was administered. First, we administered the Spanish version of the Reactive-Proactive Aggression Questionnaire (Andreu et al., 2009; Raine et al., 2006). In addition, the Anger Rumination Scale (Ortega-Andrade et al., 2017; Sukhodolsky et al., 2001) was also administered in its Spanish-validated version. After ending this session, all participants received 100€ to cover dietary and travel expenses.

It should be noted that this experiment was carried out in accordance with the ethical and legal guidelines of the Helsinki Declaration, and it was approved by the University of Valencia Ethics Committee, receiving the code: H1515749368278. Accordingly, all individuals participated voluntarily and gave their written informed consent before the study began.

Electrophysiological recording

As noted above, the Ambulatory Monitoring System (VU-DAMS) was used for recording. For the exploration of cardiorespiratory signals, seven pregelinized electrodes (EL503) were placed on the individual's chest and back. In addition, the Biopac TSD203 combined with isotonic gel (GEL101)

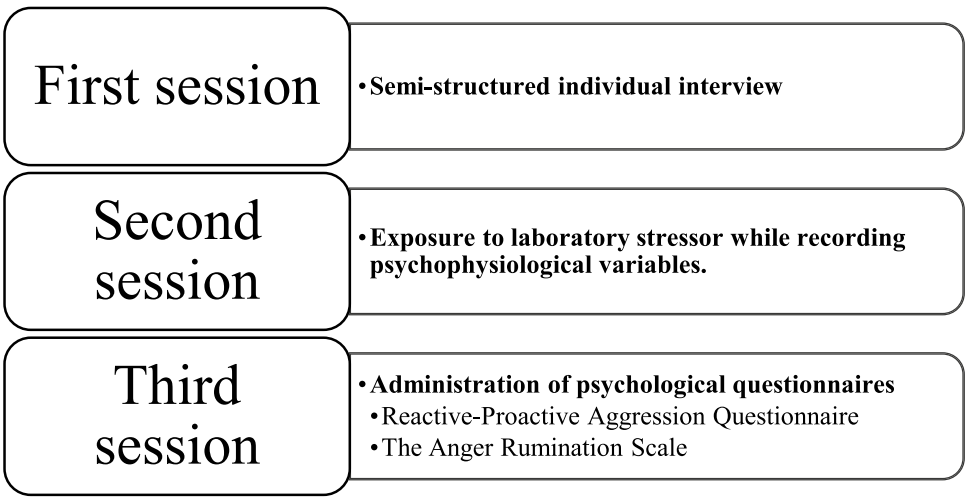

Fig. 1 Methodology of this quantitative case–control study

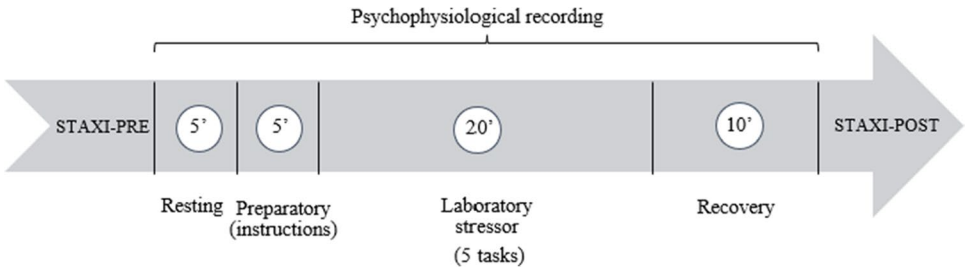

Fig. 2 Graphical representation of laboratory session

was used to record skin conductance, which was measured from the medial phalanges of the index, middle, or ring finger. The connection between the recording device (VU-DAMS) and the monitoring computer was established with an infrared interface cable.

Data management and analysis software (DAMS) (http://www.vu-ams.nl/vu-ams/software/) was used to process the data obtained from the recording. This program allowed automated scoring of each signal, including an improved artefact and R-peak detection that makes it possible to automatically remove artifacts. The quantitative data for the different signals studied (HR, PEP, RSA, and SCL) were extracted from it. Thus, HR was measured in beats per minute, whereas PEP was quantified from the contractility index in milliseconds (msec). RSA was computed following the peak-to-trough method. In fact, it was calculated as the difference between the longest inter-beat intervals during expiration and the shortest intervals during inspiration, expressed in msec. The SCL was measured in microSiemens (μSi). It should be kept in mind that HR was considered a general marker of the ANS, PEP and SCL were markers of sympathetic activity, and RSA was a parasympathetic marker.

Cognitive and social stressor

A previously validated laboratory stressor was used (Romero-Martínez & Moya-Albiol, 2017; Romero-Martínez et al., 2021a, 2021b; Vitoria-Estruch et al., 2018a), in other words, a psychosocial stressor that affected both groups equally and was not linked to any topic related to domestic violence. This was done to avoid emotional biases attributed to the stressor, as occurred in previous research conducted with batterers that included, for example, a marital conflict (Gottman et al., 1995; Meehan & Holtzworth-Munroe, 2001; Meehan et al., 2001; Murray-Close et al., 2012).

The stressor consists of a set of validated neuropsychological tests (five tasks) that assess different cognitive domains such as attention (Conners, 2015), memory (Pino et al., 2015), and executive functions (Del Ser Quijano et al., 2004; Heaton et al., 1993; Wilson et al., 1996) in front of a committee of experts. Therefore, it is both a cognitive stressor and a social stressor because these tasks have to be performed in front of two evaluators (committee) who are different from the interviewers or therapists. One evaluator of each sex was included to avoid gender bias. Additionally, to increase the socio-evaluative perception of the stressor, both evaluators alternatively gave negative feedback during the performance of each task and/or after ending each one. For example, evaluators made comments such as, "I recommend that you try harder" or "Is that all you can do?" Negative feedback was given to all participants at scheduled and specific times so that the stressor would be constant and controlled.

The state-trait anger expression inventory

As mentioned above, the State-Trait Anger Expression Inventory-II (STAXI-II), validated in Spanish (Miguel-Tobal et al., 2001) and created from its original version STAXI-2 by Spielberger (1999), was used for the assessment of the anger state. This inventory allows the complete assessment of anger, differentiating between the dimensions of experience, expression, and control of anger. It consists of 49 items organized in 6 scales and 5 subscales. Specifically, the three subscales that evaluate anger state, which include feelings and physical and verbal expression, were administered. Items were rated on a Likert scale ranging from 1 (not at all) to 4 (extremely). A total anger score was calculated by adding up the three scales. The reliability observed in this study after calculating Cronbach's alpha ranged between 0.72 (post) and 0.97 (pre).

The reactive and proactive aggression questionnaire (RPQ)

The violence expression profile was assessed with the Reactive Proactive Questionnaire. This is a self-report measure of physical and verbal aggression that analyzes the motives for the person's aggressive behavior in general, in other words, not in a restricted time. Thus, it makes it possible to understand the motivational processes in aggression and delve into the psychological processes involved in violent behavior (Andreu et al., 2009). It is composed of 23 items with a reactive dimension (11 items) versus a proactive dimension (12 items). Scores are rated on a Likert frequency scale as 0 (never), 1 (sometimes), and 2 (often).

Several studies have analyzed the reliability and validity of the questionnaire in its original version by Raine et al. (2006). These studies demonstrated good test–retest stability, convergent validity, criterion validity, and construct validity, and they supported the reliability of the two-factor (reactive-proactive) structure (Cima et al., 2013; Fossati et al., 2009). Additionally, Andreu et al. (2009) validated the psychometric properties of their Spanish version, demonstrating that the instrument reliably and validly discriminates between the two aggression profiles. Although it was originally developed for children and adolescents, its suitability for adults has also been demonstrated (Brugman et al., 2017). In this study, the reactive scale had a reliability of 0.82, whereas the proactive scale had reliability of 0.83.

Anger rumination scale (ARS)

The rumination tendency related to anger was assessed using the Spanish version of The Anger Rumination Scale (Ortega-Andrade et al., 2017) of the original version by Sukhodolsky et al. (2001). This scale analyzes the tendency to focus one's

attention on thoughts and memories about current and past anger experiences. Therefore, it evaluates anger rumination globally and not during a specific period. It consists of 19 Likert items rated on a scale ranging from 1 to 4, where 1 is "almost never" and 4 is "almost always". The items are grouped into four factors: memories of anger, understanding the causes of anger, post-anger thoughts, and thoughts of revenge. An overall score was obtained from the sum of these four factors.

In its initial version, it showed adequate reliability (Sukjodolsky et al., 2001). In addition, the Anger Rumination Scale has reported similar internal consistency values, as well as a 3-month test–retest reliability that supports the stability of the results over time (Ramos-Cejudo et al., 2017). In this study, Cronbach's alpha coefficient was 0.78.

Data analysis

After checking for normality regarding the sociodemographic, anthropometric, manifestation of aggression, and rumination differences, as well as the psychophysiological data and psychological variables (state and trait), we used t-tests for independent samples, Levenne's test for the analysis of equality of variances, and the Chi-square test for ordinal variables. Given that psychophysiological variables and proactive aggression did not meet the assumption of normality ($p \leq 0.05$), we employed the square root transformation. The effect size for significant differences between groups was calculated with *Cohen's d*, and effect sizes were interpreted as small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$) (Cohen, 1988).

To explore the psychological anger state, a repeated-measures ANOVA was performed with "time" (baseline and post-stressor) as the within-subject factor and "group" as the between-subject factor. Similarly, partial eta squared (η_p^2) was used to calculate the effect size, effect sizes being interpreted as small ($d = 0.01$), medium ($d = 0.06$), and large ($d = 0.14$) (Field, 2005). Change scores were measured as the differences between post-stressor minus baseline. Group differences were calculated by employing t-tests.

In the case of the cardiorespiratory and electrodermal variables, repeated-measures ANOVAs were performed with "time" (baseline and post) as the within-subject factor and 'group' as the between-subject factor. Greenhouse–Geisser corrections for degrees of freedom and Bonferroni corrections for multiple comparisons were applied where appropriate. For significant results, partial eta squared (η_p^2) is reported as a measure of effect size.

The magnitude of the stress responses was estimated from the area under the curve for increase (AUCi) and ground (AUCg). To quantify the magnitude of the response, the trapezoidal formula was used following the procedure established by Pruessner et al (2003). Whereas the AUCi allows us to know whether variables change with regard to the resting period, the AUCg measures the total levels. Thus, to test for potential group differences, t-tests were used for each AUC.

Statistical power for all analyses were provided, with the values being interpreted as small (power = 0.02), medium (power = 0.05), and large (power = 0.08) (Zhang et al., 2019).

After performing the correlation analysis to assess the association between anger rumination and manifestation of aggression (independent variables for regression analysis) (Supplementary Table), as well as the associations between the above mentioned variables with psychophysiological and psychological (anger state) variables, a hierarchical regression analysis was conducted with psychophysiological variables (AUC and during recovery) and psychological changes (change score and post-stressor) as the dependent variables and anger rumination and manifestation of aggression as predictors, introducing 'group' as a moderator variable. Accordingly, anger rumination or manifestation of aggression as predictors were entered in Step 1; group (dummy coded as 0 for IPV perpetrators and 1 for controls) was entered in Step 2; and the two-way interactions (e.g., anger rumination x group) in Step 3. When a significant two-way interaction (Step 3) was found, simple slopes were conducted for the interaction between independent and moderator variable.

Data analyses were performed using the Statistical Package for the Social-Sciences 28.0 (SPSS IBM) software. All $p \leq 0.05$ values were considered significant.

Results

Participant characteristics

There were no significant differences in age, BMI, demographic variables, reactive aggression, and anger rumination between the two groups (see Table 1). Furthermore, no significant differences were found in the resting values of the cardiorespiratory and electrodermal variables, the statistical power ranging from 0.05 to 0.46 Nonetheless, groups differed in proactive aggression ($t(81) = -2.13$, $p = 0.036$, $d = 0.48$), with IPV perpetrators scoring lower than controls, being the statistical power of this difference 0.61.

Groups differences in anger state

In eliciting state anger, the laboratory stressor was not effective. No significant differences were observed in the comparisons of the "time" effect in the total sample [$\varepsilon = 1.0$, $F(1, 82) = 0.90$, $p = 0.345$, $\eta_p^2 = .01$]. Similarly, neither a "time*group" effect [$\varepsilon = 1.0$, $F(1, 81) = 1.57$, $p = 0.214$, $\eta_p^2 = 0.02$] nor a "group" effect [$F(1, 81) = 0.581$, $p = 0.448$,

Table 1 Means (Standard Deviations), Percentages, and Means Comparisons for Anthropometric and Sociodemographic Data

Variables	IPV ($n=47$)	Controls ($n=36$)	t-test/Chi-square	*Cohen's d/ Kramer's V*
Age (M, SD)	42.30 (1.73)	37.34 (1.74)	1.92	.86
BMI (M, SD)	25.76 (.59)	26.30 (.89)	-.41	.72
Number of children (M, SD)	1.06 (.13)	.77 (.14)	1.68	.37
Level of education (%)				
Primary/lower secondary	64	39	5.1	.25
Upper secondary/vocational training	32	53	2	
University	4	8		
Marital status (%)				
Married	26	39	1.69	.14
Single	74	61		
Employment status (%)	51	53		
Employed	49	47	.024	.02
Unemployed				
Reactive-Proactive Questionnaire				
Reactive aggression	6.76 (4.16)	8.36 (3.67)	-1.82	0.07
Proactive aggression (square transformed)	.99 (1.01)	1.46 (0.95)	-.2.13*	.47
Anger rumination Scale (total score)	30.60 (9.12)	33.56 (9.48)	-1.44	.32

BMI Body mass index, *IPV* Intimate partner violence. *$p<.05$

$\eta_p^2=0.01$] was obtained. Furthermore, there were no differences in change scores (t(81) = -1.25, $p=0.214$) for IPV perpetrators and controls (-1.19 + 6.83 and 0.27 + 1.90, respectively). The calculation of statistical power revealed values below 0.22.

Group differences in psychophysiological variables

Regarding HR, a "time" effect was observed for the total sample [$\varepsilon=0.86$, F (2.57, 211.05) = 76.94, $p<0.001$, $\eta_p^2=0.49$]. No significant "time*group" effects [$\varepsilon=0.85$, F (2.55, 206.68) = 1.42, $p=0.240$, $\eta_p^2=0.02$] or "group" effects [F (1, 81) = 0.03, $p=0.861$, $\eta_p^2=0.00$] were observed (see Table 2). Similarly, no "group" differences were obtained for HR on AUCg (t(81) = 0.14, $p=0.888$) or AUCi (t(81) = -0.48, $p=0.635$). The statistical power was below 0.066.

With regard to PEP, a "time" effect was not observed in the complete sample [$\varepsilon=0.96$, F (2.89, 234.06) = 1.21, p = -307, $\eta_p^2=0.02$]. Similarly, neither a "time*group" effect [$\varepsilon=0.96$, F (2.89, 234.06) = 1.21, $p=0.307$, $\eta_p^2=0.02$] nor a "group" effect [F (1, 81) = 1.41, $p=0.239$, $\eta_p^2=0.02$] was obtained. Likewise, analyses of AUC reported no significant differences between groups for AUCg (t(81) = 1.24, $p=0.218$), or AUCi (t(81) = 0.25, $p=0.799$). After calculating the statistical power, the values were below 0.31.

A significant "time" effect was found in RSA for the whole sample [$\varepsilon=0.94$, F (2.82, 231.16) = 25.98, $p<0.001$, $\eta_p^2=0.24$]. Specifically, in both groups, the RSA value

Table 2 Means (standard error of the mean; square transformed) for psychophysiological variables in each group

	Groups M (SD)		Repeated measured ANOVA (Time x group)		
	IPV ($n=47$)	Controls ($n=36$)	F	Sig	η_p^2
HR (beats per minute)					
Resting	8.87 (.63)	8.83 (.71)	1.42	.24	.02
Preparatory	8.88 (.61)	8.85 (.71)			
Stress task	8.75 (.59)	8.78 (.68)			
Recovery	8.58 (.56)	8.52 (.63)			
PEP (milliseconds)					
Resting	9.81 (1.61)	9.32 (1.41)		.31	.02
Preparatory	9.39 (1.30)	9.52 (1.39)			
Stress task	9.66 (1.34)	9.47 (1.27)			
Recovery	10.06 (1.61)	9.57 (1.67)	1.21		
RSA (milliseconds)					
Resting	6.61 (1.93)	7.40 (1.97)	.55	.64	.01
Preparatory	6.84 (1.97)	7.87 (2.50)			
Stress task	7.42 (1.68)	8.45 (2.18)			
Recovery	7.32 (1.79)	8.19 (2.41)			
SCL (μSiemens)					
Resting	2.58 (.74)	2.78 (.68)	.02	.95	.00
Preparatory	2.66 (.78)	2.85 (.67)			
Stress task	2.77 (.78)	2.98 (.69)			
Recovery	2.66 (.70)	2.86 (.60)			

IPV intimate partner violence, *HR* heart rate, *PEP* pre-ejection period, *RSA* respiratory sinus arrhythmia, *SCL* Skin conductance level

followed a similar pattern. It was lower during baseline and increased until the task exposure period, and then it decreased again during recovery. A "time*group" effect was not observed [$\varepsilon = 0.94$, F (2.82, 228.12) = 0.55, $p = 0.638$, $\eta_p^2 = 0.01$]. However, a significant 'group' effect was found [F (1, 81) = 4.69, $p = 0.033$, $\eta_p^2 = 0.06$], with IPV perpetrators presenting lower total RSA values than controls. Similarly, significant differences between groups were obtained in AUCg (t(81) = -2.19, $p = 0.032$, $d = 0.48$), where IPV perpetrators showed lower RSA levels than controls, but not in AUCi (t(81) = 0.07, $p = 0.943$). Statistical power calculation for significant differences revealed that values were 0.57 and 0.61, respectively.

Finally, regarding SCL, significant differences in the 'time' effect were found in the total sample [$\varepsilon = 0.53$, F (1.59, 129.96) = 15.89, $p < 0.001$, $\eta_p^2 = 0.17$]. No "time*group" effect [$\varepsilon = 0.53$, F (1.58, 128.33) = 0.02, $p = 0.954$, $\eta_p^2 = 0.00$] or "group" effect [F (1, 81) = 1.66, $p = 0.201$, $\eta_p^2 = 0.02$] was found. The groups reported no significant differences in AUCg (t(81) = -1.29, $p = 0.199$) or AUCi (t(81) = 0.89, $p = 0.380$). Statistical power calculation revealed values below 0.11.

Bullet Anger rumination and manifestation of aggression (reactive and proactive) as predictors of psychophysiological (AUC and recovery period) and anger state (Change score and post-stressor) for IPV perpetrators and controls.

Cardiorespiratory and electrodermal

Regarding cardiorespiratory and electrodermal AUC and recovery periods, the interaction terms between 'anger rumination x group' were significant for the full sample in AUCg ($\beta = 0.266$, t = 2.28, $p = 0.025$; 95% CI = 0.022 to 0.332) and the recovery period of RSA ($\beta = 0.234$, t = 1.98, $p = 0.050$; 95% CI = 0.00 to 0.06). The analysis of simple slopes highlighted that the association between anger rumination and RSA was exclusive to IPV perpetrators. Specifically, anger rumination was associated with AUCg ($\beta = -0.412$, $t = -2.28$, $p = 0.027$; $r = -0.114$; collinearity (tolerance) = 0.61) and RSA recovery period ($\beta = = -0.417$, $t = -2.33$, $p = 0.025$; 95% CI = -0.15 to -0.01; $r = -0.118$; collinearity (tolerance) = 0.61).

Anger state

After evaluating the effect of anger rumination, reactive and proactive aggression, as well as the interaction between these variables with group for anger state (Change score and post-stressor), only a significant effect of anger rumination in anger state post-stressor was found ($\beta = 0.504$, $t = 5.25$, $p < 0.001$; 95% CI = 0.06 to 0.13). That is, the higher the anger rumination, the higher the anger state levels post-stressor in both groups.

Discussion

The results of our study showed that reactive IPV perpetrators presented a lower total RSA compared to the control group. However, no differences between groups were observed in the rest of the psychophysiological variables analyzed (HR, PEP, and SCL). Even though anger rumination and manifestation of aggression did not differ between groups (except for proactive aggression), only in IPV perpetrators, high anger rumination was associated with higher reactive and proactive aggression. Moreover, anger rumination partly explained lower vagal tone and high sympathetic activation, as well as high anger levels after the task in IPV perpetrators.

First, it should be kept in mind that the effectiveness of the laboratory stressor employed in our study to promote cardiorespiratory and electrodermal changes was congruent with previous studies (Romero-Martínez & Moya-Albiol, 2017; Romero-Martínez et al., 2021a, 2021b; Vitoria-Estruch et al., 2018a), but it was not effective for promoting changes in anger state. Because the psychophysiological variables were continuously registered during a sustained period, it was easy to detect changes in the response to this laboratory task. However, other variables such as salivary hormonal levels, which were measured at specific moments, did not seem to be affected by this laboratory procedure (Romero-Martínez et al., 2021a). This should be considered in future studies in order to adapt the procedures.

Regarding the first aim of the study, as expected, reactive IPV perpetrators presented a relatively different cardiorespiratory response, compared to the control group, when dealing with an acute stressor. However, the groups did not differ on their anger state responses to the task. In general terms, IPV perpetrators differed significantly from controls on their vagal tone (total RSA levels), but not during the resting period. Therefore, these results partly agree with previous results in this field and, especially, with the polyvagal theory, although it is necessary to clarify in which ways. Regarding IPV perpetrator studies, their results have pointed out that IPV perpetrators showed a sympathetic predominance during this laboratory task, based on PEP total values and, hence, a reduced vagal tone (Romero-Martínez et al., 2014). Contrary to our expectations, the groups did not differ on the psychophysiological variables during the recovery period, as pointed out by a previous study (Romero-Martínez et al., 2013a, 2013b, 2014, 2020; 2021b). In any case, the current data agree with the polyvagal theory by Porges et al. (2015) and the integrative neurovisceral model by Thayer and Lane (2009) in reactive aggressors. As previously stated

by Geisler et al. (2013), low RSA levels might be characteristic of individuals with high proneness to anger and/or aggressive behavior. Further investigation is necessary to discover whether differences between these individuals occur in the recovery period or are generalized to the entire procedure. However, to reinforce these theories, it is necessary to analyze the second aim of this study.

The second aim of the study was to explore whether the groups differed on anger rumination and manifestation of aggression (reactive and proactive). Our study did not support the existence of differences between groups. Curiously, the IPV group reported slightly lower scores on the proactive aggression scale. This could be attributed, at least in part, to social desirability bias in IPV perpetrators when answering self-reports assessing aggressive behavior (Sugarman et al., 1997). Nonetheless, the absence of differences in manifestation of aggression between groups was also highlighted in a previous study (Romero-Martínez et al., 2013a, 2013b). It could be hypothesized that IPV perpetrators conceived proactive aggression as more harmful than reactive aggression, explaining why they scored below the control group in proactive aggression. However, the pattern of associations between anger rumination and expression differed between groups. As expected, a positive relationship was observed between these variables only in IPV perpetrators.

The association between anger rumination and expression supports the conclusions of White and Turner (2014), who pointed out a detrimental mediating effect of lack of control or regulation, which is characteristic of a reactive profile. Linked to this is the relevance of anger rumination in the expression of violence, especially reactive violence. In fact, anger rumination was also associated with anger state levels after the study in both groups. Specifically, the higher the anger rumination in IPV perpetrators, the higher the post-stressor anger levels, whereas in controls anger rumination explained high anger changes. This, in turn, reinforces the relationship between negative affect and rumination processes, which is similar for both groups.

Regarding the association with the cardiorespiratory and electrodermal variables, the pattern of association was relatively different across groups. In IPV perpetrators, the higher the anger rumination score, the lower the total vagal tone, especially during the recovery period. Nonetheless, we also found that high anger rumination was related to low changes in RSA, which might be considered low variability in cardiorespiratory markers to cope with stress, whereas in controls, high levels of anger rumination were not related to RSA levels and levels during the recovery period. These results corroborate those obtained in the research by Ray et al. (2008) with a normative population, which suggest that psychophysiological variables have a different influence on anger rumination depending on the sample. Therefore, this possibility should be considered in future studies. In other words, low variability in cardiorespiratory and electrodermal markers might reveal the serious difficulties these individuals have in coping with their own emotions, which might affect emotional and behavioral regulation.

In conclusion, this study is based on the effort to improve our understanding of the biological bases that influence vulnerability to violence perpetrated by IPV. Despite the strengths of this experimental design and the collection of psychophysiological markers in combination with other psychological, it has considerable limitations that reduce the external validity of the results. The main limitation is the relatively small sample size. Perhaps this is the reason the results differ slightly from previous results in this field. Moreover, the participants come from the same demographic region, they are all heterosexual, and the results were obtained in a specific time interval. Additionally, we only focused on a specific profile of IPV perpetrators characterized by a reactive criminal profile and having been sentenced to less than 2 years, but we avoided other type of IPV perpetrators (e.g., perpetrating homicide, with neurological disorders, perpetrating violence against others and not only against their couples, etc.). For this reason, in order to generalize the results, there is a clear need to consider these results as preliminary and conduct further longitudinal research with a larger and more varied sample (e.g., including participants from other cultures, ethnicities, sexual orientations, who have committed more serious gender violence in their intimate partner relationships offenses and proactive violent acts, etc.). Additionally, it is important to note that the stressor did not elicit a change in anger state, and therefore the appropriateness of the stressor may be questionable. We also need to keep in mind that we employed the old version of the RPQ questionnaire (without updates of certain items, adolescent version…). Moreover, the inherent limitations of conducting a laboratory procedure (e.g., participants expectations, laboratory conditions, fictitious conditions to promote acute stress, among others) should be highlighted. Finally, it is necessary to highlight that the individual style of coping with a stressor can alter psychophysiological responses (Porges, 2009; Seery, 2013), and so it would be advisable to consider this variable in future research.

An additional limitation is that the type of expression profile presented by the IPV perpetrators was controlled by a self-reported questionnaire, which is conditioned by the participant's own perception and, probably, by social desirability. Likewise, this study evaluates the general tendency toward anger rumination; however, future studies should analyze the relationship between psychophysiological variables during the recovery period and the level of anger rumination at that moment, just after exposure to the stressor, that is, anger rumination related to the state of anger in stressful situations, as in the research by Borders and Lu (2017). Finally, future

research should include neuroimaging techniques that support the existence of anger rumination processes.

In summary, the results support the existence of a lower parasympathetic predominance or vagal tone in IPV perpetrators as a good indicator of anger rumination and, consequently, as a risk factor for violent aggression. Furthermore, the study corroborated that the integrative model of trait anger presented by Wilkowski and Robinson (2008), conducted with a normative population, also fits IPV perpetrators. In this study, the importance of automatic hostile interpretations, rumination, and self-control in the expression of aggression is pointed out. Thus, in relation to the implications outlined so far, the present study contributes to understanding the relationships between the autonomic nervous system and anger rumination that underpin violent behavior in IPV perpetrators. Therefore, it becomes clear that there is a need to focus on treating anger rumination in interventions, increasing self-regulation and self-control techniques that help to reduce ruminating on anger thoughts in stressful situations. In fact, the randomized controlled study by Hesser et al. (2017) demonstrated that the effectiveness of their treatment was partially mediated by changes in the emotional regulation ability in IPV perpetrators. Hence, these aspects should be integrated with techniques such as biofeedback, which allows individuals to regulate their cardiorespiratory and electrodermal states based on awareness of their levels. All these techniques would help to prevent vulnerability to anger and recidivism in all kinds of aggressions and facilitate the reintegration of IPV perpetrators into society.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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