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Meta-analysis

Amplitude modulation of the contingent negative variation in psychopathy: A systematic review and meta-analysis

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ABSTRACT

The CNV is analyzed in tasks related to EEG studies, often with participants presenting psychopathic personality traits. A systematic search of the literature was conducted, to solve some inconsistencies regarding CNV amplitude modulation by psychopathy. Nine studies ($N = 317$) were retrieved for analysis. Three meta-analyses were run – CNV, iCNV, tCNV. A qualitative analysis – reporting CNV amplitudes modulated by psychopathy dimensional features – was also featured. Overall effects for CNV and iCNV were not significant. Larger tCNV amplitudes were found in participants reporting higher psychopathy traits, $g = -0.58$, 95% CI [− 0.94, − 0.22]. These findings were surprising when confronted with previous assumptions in the literature, especially considering that no significant heterogeneity between studies was found. Neither of the studies' characteristics was a significant moderator. Findings require the need to discuss key differences between adaptive/(mal) adjustment patterns in participants presenting psychopathic traits. Future studies dissociating iCNV and tCNV modulation by psychopathy, especially in community samples and through a dimensional lens, could help to better understand the construct of psychopathy.

1. Introduction

1.1. Contingent negative variation and the modern era of ERP research

The contingent negative variation (CNV) component of the brain event-related potentials (ERP) is a broad negative deflection between a warning stimulus and a target stimulus. Described for the first time by Walter and colleagues (1964), it marks the beginning of the modern era of ERP research as the first cognitive ERP component reported in the scientific literature (Luck, 2014).

Even though the CNV is normally referred to as one component, classic studies already explored it as a merging of two negative waves (Connor and Lang, 1969): (a) the first is thought to reflect processing of warning stimuli and presents a frontally dominant activity, reaching its maximum during the first seconds of stimuli onset; (b) the second presents central activity related to response preparation, peaking just before or at target stimulus (Forth, 1982; Järviletho & Frühstorfer, 1970). These two waves are, respectively, named early/initial CNV (iCNV) and late/terminal CNV (tCNV; Birbaumer et al., 1990), and their amplitudes and topographical distribution are complex, depending upon task requirements (Brunia et al., 2012). The iCNV appears to be influenced by the: (a) relevance of the information provided by the warning stimuli (Kok, 1978); (b) amount of attention paid to warning stimuli (Squires et al., 1977); (c) orienting processes (Rohrbaugh and Gaillard, 1983); and (d) anticipation of affective stimulation (Forth, 1982). On the contrary, tCNV seems strongly related to motor preparation for optimal, effective responses (Gaillard, 1978). However, some studies have further suggested that tCNV is not just a motoric-related late wave (Donchin et al., 1972), and that a smaller iCNV is registered when the participant presents task habituation (Loveless, 1979).

Hence, although being an ERP component previously linked with associative learning (Walter et al., 1964), CNV has now been studied in different types of tasks and processes – preparatory cortical activity to task-related motor output, decision-making, and expected occurrence of task-related sensory input (Syndulko et al., 1975), as well as attentional processes and arousal (Tecce, 1972). More specifically, the Pavlovian

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approach based on the excitability/inhibition association process and the concept of expectancy, in which one learns that a preceding stimulus becomes a signal for a subsequent event (e.g., Flor et al., 2002; Paiva et al., 2020; Veit et al., 2013), is an interesting framework to understand CNV modulation in psychopathic and antisocial samples. For instance, aversive conditioning, a type of associative learning in which certain environmental stimuli predict aversive events (Bacigalupo and Luck, 2018; Flor et al., 2002; Paiva et al., 2020; Veit et al., 2013) is used to study the low-fear hypothesis (Lykken, 1957) in participants presenting psychopathic traits. This topic will be addressed in the next section.

1.2. Studies in psychopathy

According to Cleckley (1976), the concept of psychopathy relies on an absence of visible symptoms of mental illness, as well as on social poise, emotional stability, and persistent and severe behavioral deviancy. Primarily, this concept was operationalized as a taxon (i.e., a unitary construct relying on clinical cut-off scores) and framed within the antisocial spectrum, disregarding possible adaptive core-personality features (Patrick, 2006). This view was mostly expressed in Hare's (1980) Psychopathy Checklist (PCL), a measure that unveiled two independent but correlated factors, reflecting the affective/interpersonal features of psychopathy and features related to social deviance (factors 1 and 2, respectively; Hare et al., 1990). However, it is now widely accepted that psychopathy encompasses separable dimensions that, whilst exhibiting interrelations, are far from similar (Drislane and Patrick, 2017; Paiva et al., 2020; Patrick and Bernat, 2009; Patrick et al., 2009; Sellbom and Philips, 2013; Venables et al., 2014; Wall et al., 2015). A dimensional model created to address the complex structure of the psychopathic personality - the Triarchic Model of Psychopathy (TriPM; Patrick, 2010; Patrick et al., 2009) - proposes that it encompasses three distinct dimensions, namely boldness, disinhibition, and meanness, balancing the role of antisocial behavior and possible adaptive core-features of psychopathy (Patrick and Bernat, 2009; Patrick et al., 2009).

Importantly, psychopathy is associated with performance abnormalities in several affective and cognitive domains, although it remains unclear how these abnormalities directly reflect on patterns of (mal) adjustment. Psychopathic individuals were reported to fail to experience fear or anxiety, possibly due to a deficit on punishment-based learning (Lykken, 1957). Deficits related to fear conditioning would typically result in the disinhibition of antisocial and aggressive conducts but can also explain social dominance and tolerance to stressful situations (Patrick et al., 2009). Other studies suggest that psychopaths' diminished reactivity to threatening stimuli and emotional-related cues in general are linked to attention-related deficits, instead of a failure to experience fear or anxiety. The attention modulation hypothesis states that individuals high in psychopathy tend to over allocate attention to primary, goal-relevant stimuli, and exhibit deficits on the processing of peripheral information (Newman et al., 2010). Since the CNV component is featured in studies regarding expectancy and attentional processing, as well as arousal, decision-making and motor output, recent EEG studies focused on the modulation of CNV amplitude by psychopathy, in hopes to better understand both the CNV component's modulation and the psychopathy construct. Since both Newman et al. (2010) and Lykken (1957) theoretical models set forth psychopathic participants as the ones presenting deficits concerning either fear conditioning or allocation of attention, it could be hypothesized that psychopathic participants should present diminished CNV amplitudes. However, the research on this topic presents contradictory results.

Early studies reported that individuals presenting psychopathic traits are characterized by reduced CNV amplitudes in general (McCallum, 1975; Walter, 1964), but results have been hard to replicate, since more recent studies have either found no significant differences (Fenton et al., 1978; Paiva et al., 2020; Raine and Venables, 1987; Syndulko et al., 1975) or even a larger CNV amplitude in participants with psychopathic traits (Brouns, n.d.; Forth, 1982; Forth and Hare, 1989; Howard et al., 1984). Thus, the literature portrays an inconsistent relationship between CNV and psychopathic personality. The variability in results can be directly associated with the variety of measures used to assess the concept of psychopathy, as well as the different populations studied.

Taking this into account, the present study aims to address the inconsistencies regarding the modulation of CNV amplitude by psychopathy present in the literature. Bearing this goal in mind, we conducted a systematic review and three meta-analyses to aggregate the existing findings of CNV, iCNV and tCNV modulation in participants presenting psychopathic traits. A systematic search of the literature was conducted to find empirical studies analyzing CNV, iCNV and tCNV modulation in psychopathy, with the general expectation to find smaller CNV, iCNV and tCNV amplitudes in participants presenting psychopathic traits.

2. Method

This systematic review and meta-analysis were conducted following the PRISMA statement (Page et al., 2021, Fig. 1).

2.1. Search and study selection strategy

Selected studies were identified via PUBMED, Web of Knowledge, and EBSCOhost databases using the search expression: (Psychopath* OR Sociopath* OR antisocial OR anti-social OR callous OR unemotional OR "Conduct Disorder*" OR "Conduct Problem*" OR "Disruptive Behav*" OR "Oppositional Defiant" OR "oppositional behav*" OR "Defiant Behav*" OR "Behavior Problem*" OR Offen* OR criminal* OR inmate* OR prisoner* OR delinquen* OR violen* OR aggress*) AND ("event related potential" OR "erp" OR "cnv" OR "contingent negative variation") - limited to title, abstract or keywords. No time window was considered, and only articles written in English were screened.

2.2. Inclusion and exclusion criteria

To assess the eligibility of studies, the following inclusion criteria were used: (1) empirical study – the study had to report empirical findings; (2) CNV – the study had to include analysis of the CNV amplitude; (3) psychopathy – the study had to include participants assessed for psychopathic traits.

The included studies were analyzed for the following exclusion criteria: (4) missing information – studies not describing sample size or direction of results, and lacking replies from contacted authors; (5) methodological issues – studies that reported inconsistencies regarding presentation and interpretation of results.

2.3. Extracted Data

2.3.1. Sample characteristics

Psychopathy groups were coded considering the cut-off scores of the utilized measures (e.g., PCL). Group status (clinical/forensic) for the psychopathy group was coded depending on existent diagnostic or information of incarceration.

2.3.2. Task and study characteristics

Task coding is in accordance with the standardized nomenclature in the field (e.g., Forewarned Reaction Time, Aversive Conditioning Paradigm). Stimuli type (sound/image/text) and response required (passive/active) were also considered, as well as CNV type (CNV, iCNV or tCNV), type of sample (forensic, community and clinical) and type of study (between group analyses/correlations).

2.3.3. CNV

CNV, iCNV and tCNV amplitudes were computed considering each sample and condition. Missing information was requested from corresponding authors. A total of seven authors were contacted and five

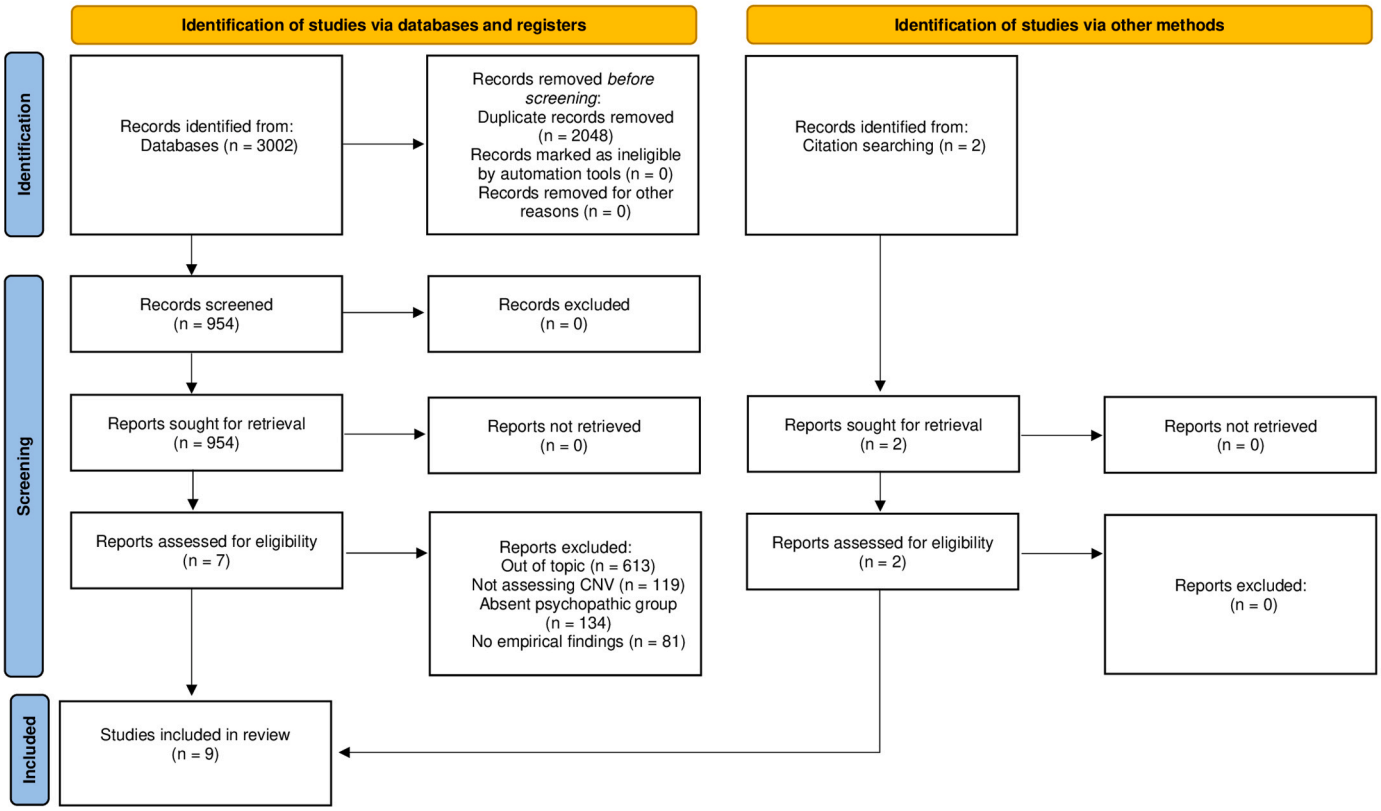

Fig. 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources.

provided the requested data.

2.4. Data Analysis

Effect sizes were computed as Hedges' *g* (Hedges, 1981). Effect sizes were coded as the difference in CNV, iCNV and tCNV amplitude for psychopathy minus for controls. As the CNV is a negative going ERP component, a more positive *g* indicates that the psychopathy group exhibited reduced (i.e., less negative) CNV amplitudes compared to the control group. When studies reported the correlation between CNV amplitudes and psychopathy, this measure was converted to Hedge's *g*. Some studies reported more than one effect size for the association between psychopathy and CNV amplitude in the same sample (e.g., by reporting effects for iCNV and tCNV and/or for CS+ and CS-) which leads to dependent comparisons. To correct for the inflation of the precision of effect sizes computed from the same sample, the weight attributed to each of these dependent effect sizes in the meta-analysis was divided by the total number of effect sizes being contributed by that sample, effectively bounding the contribution of this sample to the meta-analysis (Ferreira-Santos, 2018; Hedges et al., 2010). All meta-analytic procedures were conducted using the Metafor package (version 3.4, Viechtbauer, 2010) for the R software (version 4.2.0, R Core Team, 2022), through random effects models (restricted maximum likelihood). Publication bias was assessed using the Egger's test (Egger et al., 1997). The heterogeneity between studies was tested with the Cochrane's *Q* and quantified via the I^2 statistic (Higgins et al., 2003). Study characteristics of interest were analyzed as potential moderators of the effect sizes in heterogeneity analyses.

3. Results

3.1. Identification and screening

A total of 956 non-duplicated articles was found (Fig. 1). First, a screening by title and abstract was performed by two individual researchers (CP and RA), reaching an almost perfect agreement for study selection (Cohen's $k = .90$). Disagreements were solved by a third researcher (RP). Then, 954 articles identified through databases were assessed for inclusion criteria. Of those, 947 were excluded due to: being out of topic (613); not assessing CNV amplitude (119); absence of psychopathic group (134); no empirical findings (81). A grand total of 7 studies was retained for quantitative analysis, after a third researcher (FFS) solved remaining disagreements. Two additional studies were found through citation searching, fulfilling the total of 9 studies included in the meta-analysis (Fig. 1 and Table 1).

Since iCNV and tCNV are different components of the CNV wave, a better grasp on their modulation by psychopathy was held by running three separate meta-analyses: (a) CNV meta-analysis - four studies; (b) iCNV meta-analysis - five studies; (c) tCNV meta-analysis - five studies.

A qualitative analysis was also conducted for the nine included articles, to enrich previous quantitative data with qualitative data concerning psychopathy facets/dimensions. The only inclusion criterion was (a) presenting qualitative data regarding CNV modulation by factors/dimensions of psychopathy. Only four studies from nine total were considered.

3.2. CNV Meta-analysis: overall effect

The overall meta-analytic effect revealed non-significant differences between psychopathic groups and controls, in what regards CNV, $g = -0.26$, 95% CI [− 0.76, 0.24], $p = .31$. Studies are homogenous, $Q(3) = 6.68$, $p = .08$, $I^2 = 54.66$. There was also evidence for publication bias for the overall effect, $b = 1.29$, $p = .02$. The forest plot of this meta-analysis is presented in Fig. 2.

3.3. iCNV Meta-analysis: overall effect

The overall meta-analytic effect showed non-significant differences

Table 1
Summary of Studies.

Study	Type of Study	Compared Groups	Sample Number	Sample Type	Psychopathy Measures	Psychopathy Assessment	Total/ Facets	Cutoff Scores	M/ SD	Task	Type of Stimuli	Type of Response	CNV Type	Effect Sizes
Fenton 1978	Group	PP CG	14 14	Clinical	MMPI	Categorically	Total Scores	> 54 PP < 54 CG	- -	Click-flash	Sound	Active	CNV	$g = -0.21$, CI [− 0.93, 0.51]
Forth (1982)	Group	PP CG	12 12	Forensic	PCL-R	Categorically	Total Scores	> 32 PP < 32 CG		Forewarned Reaction Time	Sound	Active	iCNV & tCNV	iCNV: $g = -0.72$, CI [− 1.52, 0.08]; tCNV: $g = -0.53$, CI [− 1.32, 0.25]
Howard et al. (1984)	Group	PP CG	10 12	Clinical	MMPI	Categorically	Total Scores	> 54 PP < 54 CG		Click-flash	Sound	Active	CNV	$g = -1.09$, CI [− 1.96, − 0.22]
Raine and Venables (1987)	Group	PP CG	38 37	Community	Unsocialized-Psychopathy subscale of the Personal Opinion Study	Categorically	Total Scores	-		Forewarned Reaction Time	Sound	Active	CNV	$g = 0.18$, CI [− 0.27, 0.63]
Forth and Hare (1989)	Group	PP CG	12 11	Forensic	PCL	Categorically	Total Scores	≥ 32 PP < 32 CG	M = 35.5 M = 19.8	Forewarned Reaction Time	Sound	Active	iCNV & tCNV	iCNV: $g = -0.92$, CI [− 1.76, − 0.09]; tCNV: $g = -0.71$, CI [− 1.53, 0.11]
Flor et al. (2002)	Group	PP CG	9 12	Community	PCL-R-SV	Categorically	Total Scores	- -	M = 27.81 SD = 4.91 M = 3.40 SD = 2.66	Aversive Conditioning	Image	Passive	iCNV & tCNV	iCNV: $g = 0$, CI [− 0.83, 0.83]; tCNV: $g = -0.96$, CI [− 1.84, − 0.08]
Veit et al. (2013)	Correlation	N/A	13 PP	Forensic	PCL-R	Categorically	Total Scores	> 30	M = 30.14 SD = 2.77	Aversive Conditioning	Image	Passive	iCNV & tCNV	iCNV CS+ : $g = -0.38$, CI [− 1.91, 1.15]; iCNV CS-: $g = 0.25$, CI [− 1.26, 1.77] tCNV CS+ : $g = -0.94$, CI [− 2.63, 0.74] tCNV CS-: $g = -0.01$, CI [− 1.51, 1.49]

(*continued on next page*)

Table 1 (*continued*)

Study	Type of Study	Compared Groups	Sample Number	Sample Type	Psychopathy Measures	Psychopathy Assessment	Total/ Facets	Cutoff Scores	M/ SD	Task	Type of Stimuli	Type of Response	CNV Type	Effect Sizes
Paiva et al. (2020)	Correlation	N/A	43 PP	Community	TriPM	Continuously	Total Scores	N/A	N/A	Aversive Conditioning	Image	Passive	iCNV & tCNV	iCNV CS+: g = 0.30, CI [− 0.55, 1.15]; iCNV CS-: g = 0.05, CI [− 0.79, 0.89] tCNV CS+: g = −0.26, CI [− 1.11, 0.59] tCNV CS-: g = −0.54, CI [− 1.41, 0.33]
Brouns n.d	Correlation	PP CG	15 14	Clinical	PCL-R	Categorically	Total Scores	≥ 26 PP ≤ 17 CG	M = 28.6 SD = 2.8 M = 11.9 SD = 3.7	AX-continuous performance task	Text	Active	CNV	g = −0.26, CI [− 0.98, 0.45]

Note. MMPI – Minnesota Multiphasic Personality Inventory; PCL-R – Psychopathy Check-list Revised; PCL – Psychopathy Check-list; PCL-R-SV – Psychopathy Check-list Revised Short Version; TriPM – Triarchic Psychopathy Measure; CNV – Contingent Negative Variation; iCNV – Initial Contingent Negative Variation; tCNV – Terminal Contingent Negative Variation; PP – psychopathic participants; CG – control group; CI – Confidence Interval; g – Effect size.

for psychopathy groups and controls, in what regards iCNV, $g = -0.24$, 95% CI [− 0.65, 0.16], $p = .24$. Studies appear to be homogenous, $Q(6) = 6.77$, $p = .34$, $I^2 = 21.79$. No evidence for publication bias was found for the overall effect, $b = -0.59$, $p = .68$. The forest plot of the meta-analysis is presented in Fig. 3.

3.4. tCNV Meta-analysis: overall effect

The overall meta-analytic effect presented larger tCNV amplitudes for psychopathic groups, when compared to controls, $g = -0.58$, 95% CI [− 0.94, − 0.22], $p = .001$. Studies are homogenous, $Q(6) = 2.10$, $p = .91$, $I^2 = 0$. There was no evidence for publication bias for the overall effect, $b = -0.68$, $p = .89$. The forest plot of this meta-analysis can be consulted in Fig. 4.

3.4.1. tCNV Meta-analysis: subgroup characteristics

Despite the homogeneity of the selected studies, study characteristics of interest were analyzed as potential moderators for tCNV modulation by psychopathy. None of these characteristics were considered significant moderators, as seen on Table 2.

3.5. Qualitative analysis

Data related to the CNV modulation by psychopathy, specifically considering its different factors/dimensions, needs to be disentangled. Since quantitative data was not enough to gather information on this topic, each of the nine studies was inspected to retrieve qualitative data on the subject. Four studies (Brouns, n.d; Howard et al., 1984; Paiva et al., 2020; Veit et al., 2013) from the overall nine meta-analyzed studies were considered for this exploratory analysis and their results compiled on a table (Table 3).

According to the literature, we organized three main categories for the construct of psychopathy. Primary psychopaths – as categorized by Howard and colleagues – and participants scoring higher on factor 1 of the PCL-R (affective-interpersonal) – as categorized by Brouns (n.d) and Veit and colleagues (2013) were associated. Considering more recent dimensional approaches, such as the triarchic model of psychopathy (Patrick et al., 2009), and based on shared pathways portrayed in literature, meanness – linked to lack of empathy (Patrick and Bernat, 2009) – appears to integrate this category as well. On the contrary, disinhibition, a trait incorporated in the externalizing spectrum (Krueger et al., 2002) can be associated with factor 2 of the PCL-R (lifestyle-antisocial), sharing lack of inhibitory control, as well as lack of planning and foresight. Lastly, boldness – an adaptive phenotype (Lilienfeld et al., 2016) described as the capacity to remain calm under stressful situations and social efficacy (Patrick et al., 2009), was considered as its own category, since it presents fundamental differences from other psychopathy factors (Campos et al., 2022; Patrick et al., 2009; Patrick and Drislane, 2014; Skeem et al., 2011; Wall et al., 2015).

Results found were intriguing, since Howard and colleagues (1984) and Brouns (n.d) reported augmented CNV amplitudes for the affective-interpersonal factor of the PCL, with Brouns (n.d) describing diminished CNV amplitudes for the lifestyle-antisocial factor. Conflicting results are featured by Veit and colleagues (2013), in which participants scoring higher in the lifestyle-antisocial facet present both augmented iCNV and tCNV in the acquisition phase, versus diminished amplitudes for participants scoring higher in the affective-interpersonal facet. However, Veit and colleagues (2013) also report that this result changes for iCNV, since its amplitude decreases in the extinction phase, possibly due to the lack of warning stimuli. Boldness, however, was only considered in Paiva and colleagues' (2020) study, with no significant results found.

4. Discussion

The literature suggests that the CNV indexes preparatory cortical activity to task-related motor output, decision, expected occurrence of

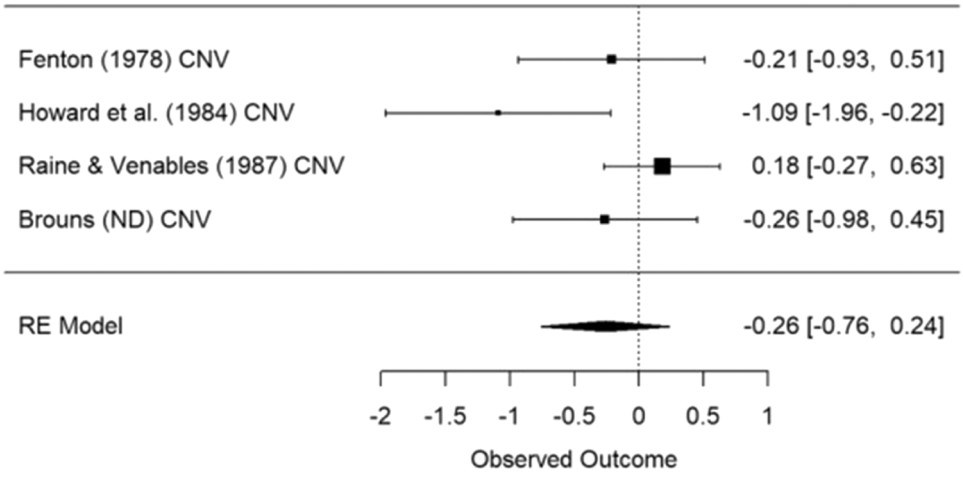

Fig. 2. CNV Forest plot.

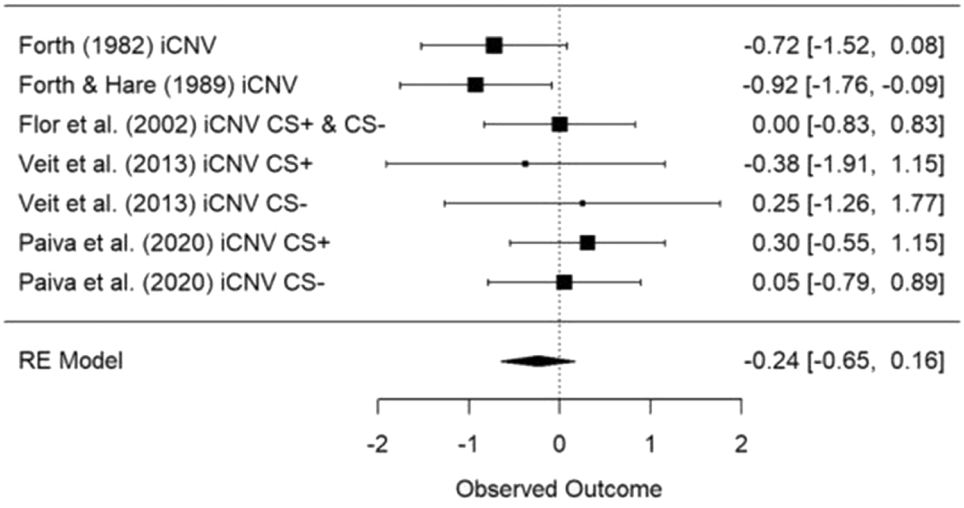

Fig. 3. iCNV Forest plot.

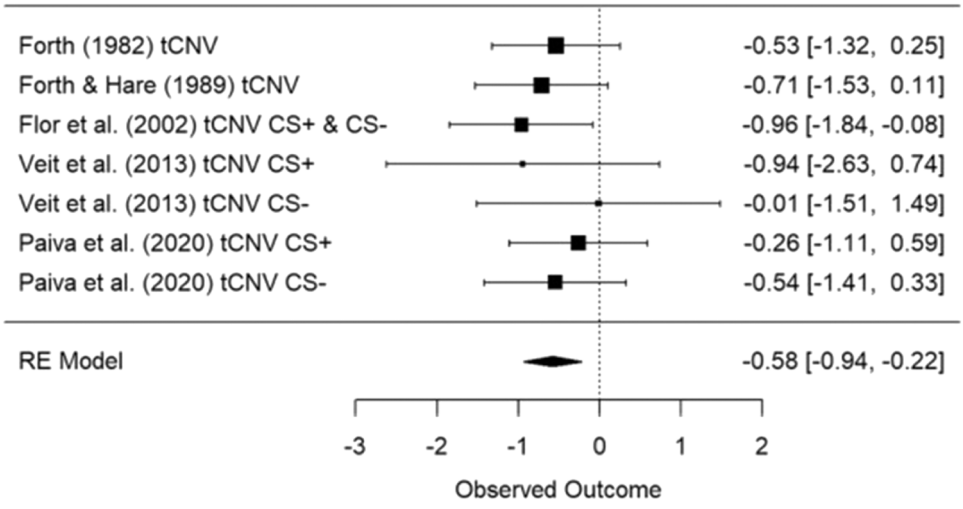

Fig. 4. tCNV Forest plot.

Table 2
tCNV: Heterogeneity analysis of discrete moderators.

Discrete moderator	Q_B	p_{QB}					
			Level	Q_{Level}	*K*	*G*	p_g
Study type	0.74	.389	Group	0.50	3	-0.72	.003
			Correlation	0.86	4	-0.40	.138
Sample type	0	.100	Community	1.27	3	-0.58	.023
			Forensic	0.84	4	-0.58	.025
Task type	0.03	.861	Aversive Conditioning	1.98	5	-0.55	.018
			Forewarned Reaction Time	0.09	2	-0.62	.033
Task stimulus type	0.03	.861	Sound	0.09	2	-0.62	.033
			Image	1.98	5	-0.55	.018
Task stimulus action	0.03	.861	Active	9.87	2	-0.62	.033
			Passive	3.29	5	-0.55	.018

Note: Q_B – between-samples component of *Q*; p_{QB} – significance of Q_B; Q_{Level} – Cochran's *Q* per level of the moderator; *k* – number of samples; *g* – effect size Hedge's *g*; p_g – significance of *g*. No significant moderators were found.

Table 3
CNV modulation by psychopathy: factors/ dimensions.

Study	Primary Factor 1 Meanness	Secondary Factor 2 Disinhibition	Boldness
Howard et al. (1984)	Primary psychopaths show highest CNV amplitudes	Non-significant	N/A
Veit et al. (2013)	Acquisition: Negative correlation with iCNV Negative correlation with tCNV	Acquisition: Positive correlation with iCNV Positive correlation with tCNV Extinction: Negative correlation with iCNV	N/A
Paiva et al. (2020)	N/A	N/A	Non-significant
Brouns n.d	Augmented CNV amplitudes for affective-interpersonal factor	Smaller CNV amplitudes for lifestyle-antisocial factor	N/A

Note. N/A – Not Applicable.

task-related sensory input (Syndulko et al., 1975), as well as attentional processes and arousal (Tecce, 1972). As such, an ERP component previously linked with associative learning (Walter et al., 1964), has now been studied in different types of tasks, and used to study participants with antisocial personality disorders and psychopathic traits (Brouns, n.d.; Fenton et al., 1978; Flor et al., 2002; Forth, 1982; Forth and Hare, 1989; Howard et al., 1984; Paiva et al., 2020; Raine and Venables, 1987; Veit et al., 2013).

Even though early studies refer diminished general CNV amplitudes in participants presenting psychopathic traits (McCallum, 1975; Walter, 1964), these results were not replicated, with other studies having found either no significant results (Fenton et al., 1978; Paiva et al., 2020; Raine and Venables, 1987; Syndulko et al., 1975) or larger CNV amplitudes in participants presenting psychopathic traits (Brouns, n.d.; Forth, 1982; Forth and Hare, 1989; Howard et al., 1984). Thus, the literature portrays an inconsistent relationship between CNV and psychopathic personality. The present meta-analyses aimed to address the inconsistencies present in the literature regarding the modulation of the CNV amplitude by psychopathy. We conducted a systematic review and three meta-analyses, as well as a qualitative analysis, to aggregate the existing findings of CNV, iCNV and tCNV modulation in participants presenting psychopathic traits, with the general expectation to find smaller CNV, iCNV and tCNV amplitudes in participants presenting higher levels of psychopathy.

4.1. Overall effect

The overall effect was non-significant for the CNV and the iCNV component, considering total scores of psychopathy. Even so, the overall effect for tCNV was statistically significant, showing larger tCNV amplitudes in psychopathic participants. This is unexpected, when examining previous statements made on this topic. Raine and Venables (1987) even stated that "it is commonly assumed that the CNV-antisociality relationship is a well-established fact". Nonetheless, results compiled for the tCNV meta-analysis were statistically homogenous in showing larger tCNV amplitudes in psychopathy. In fact, these results are even more surprising, since only two (Forth and Hare, 1989; Veit et al., 2013) out of the five articles included in the tCNV meta-analysis (Flor et al., 2002; Forth, 1982; Forth and Hare, 1989; Paiva et al., 2020; Veit et al., 2013) referred relevant tCNV modulation by psychopathy.

Indeed, three articles suggest that tCNV is not modulated by psychopathy, and explain the lack of significant results considering (a) only its relation to motor preparation for optimal, effective motor responses (Forth, 1982); (b) as consequence of a blunted emotional response to a cue, signalizing potential threat (Paiva et al., 2020); (c) or even simply stating an absence of differences found in psychopathic participants versus controls (Flor et al., 2002). For the remaining two, however, results appear to show larger tCNV in psychopathic participants, explaining these results in two different approaches: either (a) tCNV was larger for participants scoring higher in the antisocial facet of psychopathy (Veit et al., 2013); or (b) tCNV was larger for psychopathic participants but did not last, suggesting allocation of larger attentional resources at first, but then a difficulty to maintain such attention (Forth and Hare, 1989).

This last approach appears to reinforce Newman et al. (2010) theory that psychopaths show a tendency to over allocate attention to primary, goal-relevant stimuli, and reveal limitations on their processing of peripheral information. Importantly, both explanations bear resemblance to recent results regarding impaired sustained attention in forensic groups at high risk for antisocial personality disorder, in which the authors suggest a difficulty in the ability to maintain initial attention, resulting in a deficit in response preparation, which increases the likelihood of impulsive behaviors (Guan et al., 2022). This could help explain the importance of the qualitative results found, in which Veit and colleagues (2013) consider augmented tCNV in higher factor 2 scores (lifestyle and antisocial components) - or in the disinhibition phenotype, if interpreted in a dimensional perspective (Krueger et al., 2002; Patrick et al., 2009). Nonetheless, these results might be biased, since most of the included articles featured forensic psychopaths - except Paiva and colleagues (2020) - and results are precisely the opposite of the ones featured in Veit and colleagues' (2013), with Brouns (n.d) and Howard and colleagues (1984) even stating that psychopathic participants scoring high on factor 1 of the PCL (affective and interpersonal components) have augmented CNV amplitudes. In fact, the probability of finding participants scoring high in impulsivity traits in forensic contexts is elevated (Drugge, 1998), and these patterns may be different in community samples. It is also worth noticing that Guan and colleagues (2022) found lower CNV amplitudes for forensic antisocial participants, differing from Veit and colleagues (2013) conclusions.

The results from the included studies tend to focus more on the interpersonal facet of psychopathy, rather than the antisocial one. Howard and colleagues (1984) even mention in their study that larger CNV amplitudes displayed by psychopathic participants to be restricted to "primary psychopaths" (p.10) who are described as "sociable, non-anxious" (p.10), and distinguishable from secondary psychopaths, classified as "withdrawn, anxious" (p.10). In a dimensional perspective, both meanness – linked to lack of empathy – but also boldness, an adaptive phenotype (Lilienfeld et al., 2016) described as the capacity to remain calm under stressful situations and social efficacy (Patrick et al., 2009) – could relate to these participants. The modulation of CNV

amplitudes by psychopathy must, as such, contemplate different phenotypes, including adaptive ones, to better understand and interpret CNV modulation, as well as the construct of psychopathy. Still, it is unclear how these abnormalities directly reflect on patterns of (mal) adjustment, since higher boldness traits can also explain social dominance and tolerance to stress, in a more adaptive way.

Focusing more on iCNV results, even though they were not significant, the same inconsistences can be stated concerning sample type. Moreover, the diminished amplitude shown by Veit and colleagues (2013) during the extinction phase also presents another intriguing question, this time related with not only the type of task in general, but the type of stimuli used, since the lack of warning stimulus might be precisely what led to these results. Forth (1982) comments on this when stating that there is a possibility that their results for augmented amplitudes for iCNV relate to this component's sensitivity to anticipation of affective stimulation, categorizing psychopathic participants as failing to discriminate between neutral and affective events, and to attach appropriate motivational significance. Forth's (1982) interpretation of these results could be linked to Lykken's low-fear theory (1957), where psychopathic individuals were reported to fail, for instance, to experience fear or anxiety related to a deficit on punishment-based learning. On the contrary, both Forth's (1982) and Forth and Hare's (1989) studies not only present evidence for augmented iCNV in psychopathic participants, but both refer that psychopathic participants appear to be proficient at allocating their attentional resources to events that interest them. These results are corroborated by Brouns (n.d), who mentions enhanced attention-related processing in general in psychopathic participants, particularly in participants scoring high on factor 1, relating these results to heightened approach tendencies and deviating the discussion further away from impulsivity. These results could be interesting in light of Newman et al. (2010) theory, not only cementing the idea that a bigger discussion should be held regarding patterns of (mal)adjustment, but also regarding the type of tasks in which iCNV and tCNV are elicited and proposing the possibility of an augmented iCNV in psychopathic participants in attention related tasks. Future research could be done regarding this matter.

4.2. Limitations

This meta-analysis has some limitations. A larger number of studies, providing data from more samples, would have been desirable, to draw more robust conclusions and cement our findings. This is even more prominent when considering that three different meta-analyses were run, diminishing the number of studies included in each. Also, with more informative studies, characteristics that were not significant moderators, but in a subgroup analysis show dissociable effect sizes, could be significant, such as study type, sample type, type of stimuli presented and type of response required from the participant.

Another important limitation is the knowledge regarding the CNV itself. Whilst its functional significance appears to be associated with cognitive preparation, time estimation, and working memory (Banaschewski and Brandeis, 2007), there is still contradictory information regarding this topic, and a lack of consensus about the CNV component – namely whether it should be studied as an individual component or divided into two (iCNV and tCNV) – making it difficult to fully understand and study this brain potential.

Finally, many of the included studies are older than desirable, conceptualizing psychopathy as a taxon and not as a dimensional construct. This leads to a difficult conceptualization of the construct in a contemporary - multidimensional - view. Moreover, there were significant advances in data collection and preprocessing that may compromise comparability between studies.

4.3. Future directions

The present systematic review and meta-analysis aimed to solve contradictory findings regarding the modulation of the CNV component by psychopathy. Literature states that the CNV component modulation can be directly related to task demands and different brain processes iCNV is commonly associated with a warning stimulus, while tCNV can relate to motor responses. Larger tCNV amplitudes in participants scoring high in psychopathic traits pose the need to disentangle both iCNV and tCNV, focusing on what characteristics can influence each one. Therefore, there is still a need to design and test different tasks with warning stimuli or cues - either visual and auditory - and participant responses - either passive or active. Indeed, a need to test different paradigms and sample types, understanding its influence on iCNV and tCNV modulation is paramount for future research. One way to explore this could be through the application of an aversive conditioning paradigm, studying iCNV and tCNV modulation by psychopathic traits in youngsters.

Adding to this, the CNV modulation by psychopathy could potentially be influenced by different phenotypes of psychopathy. As such, it could be that applying tasks that will elicit iCNV and tCNV separately, but that are also related to each distinct phenotype of psychopathy, would potentially help to reach better conclusions regarding its modulation. Measuring both adaptive and maladaptive traits of psychopathy and integrating both perspectives is a way to achieve better comprehension regarding not only CNV modulation, but also the construct of psychopathy. In the future, other tasks could be tested, always bearing in mind the different phenotypes of psychopathy and the distinctions between iCNV and tCNV.

As previously stated, more information regarding specific characteristics that show dissociable effect sizes should also be searched for, especially considering that since forensic samples are overrepresented in the current study (and the most recent dimensional models were underrepresented). In fact, when we look at community samples, namely, in Paiva and colleagues' (2020) work, findings show no significant associations for either boldness or disinhibition for CNV amplitude. A bigger focus on understanding and mapping community samples is needed.

Our findings also suggest a bigger need to discuss patterns of (mal) adjustment in participants presenting psychopathic traits, since, when considering attention as simply focus on the task, there seems to be an agreement that participants with higher scores in psychopathy present an enhanced attentional-related processing (Brouns, n.d.; Forth, 1982; Forth and Hare, 1989). This attentional point also raises some questions, and possibly the need for a more systematic testing, using not only different types of paradigms - for instance, warning stimuli as not relevant for the task, versus relevant - but also different instructions, either deviating attention from the warning stimuli or focusing on said stimuli.

As such, these attempts could provide new approaches to the scientific community and more detailed information about this still understudied component, and its relevance in the study of psychopathy.

5. Conclusion

The current meta-analysis gives relevant information regarding the modulation of the CNV, iCNV and tCNV by psychopathy. In general, tCNV amplitudes are larger in participants scoring higher in psychopathic traits, with no significant moderators found. However, qualitative analysis shows that type of sample appears to be related to the CNV modulation - with mixed results for both factor 1 and factor 2 of the PCL - as well as a lack of results featuring boldness, that heightens a need for more dimensional approaches to the construct of psychopathy, as well as the study of the CNV. The possible influence of more adaptive psychopathy phenotypes, such as boldness, instead of the expected disinhibition phenotype, could account for a new need to discuss patterns of (mal)adjustment in participants presenting psychopathic traits. Another interesting discussion lies in the need to disentangle iCNV and tCNV components, instead of just analyzing CNV as just a single wave, since results found for this potential might be influenced by either iCNV or

tCNV.

Finally, questions regarding the importance of determined characteristics such as study type, sample type, task type, stimuli and response required from the participant were also raised. More informative studies and a stronger focus on the differences between iCNV and tCNV, as well as their modulation by psychopathy, especially in community samples, are needed. With this focus, it should be simpler to understand the influence of study and sample characteristics on iCNV and tCNV, as well as answering the questions raised and mapping the expression of the psychopathy phenotypes in community samples, to better understand cognitive, affective, and behavioral phenomena.

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Declaration of Competing Interest

The authors have no conflict of interest to disclose.

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