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ORIGINAL ARTICLE

Semantic emotional processing (N400) in violent individuals from a community sample

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KEYWORDS
Semantic processing;
Violent behavior;
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Abstract
Background: Several studies have suggested different brain abnormalities and cognitive impairment in violent individuals, all of them associated with brain areas like the prefrontal and temporal cortex and limbic regions involving executive functions, decision making, language and emotional regulation. However, most studies have focused on EEG quantitative analysis or other components like the P300; additionally, the majority have been performed on forensic samples.
Objective: To explore semantic/emotional processing using an N400 paradigm in a general population sample.
Material and methods: 60 adult males were recruited and divided into two groups: control group (healthy men from the general population; $n = 30$), violent group (violent men from the general population; $n = 30$). All subjects were assessed with an aggression questionnaire (RPQ; Raine et al.[17]) to be classified into one of the groups. Repeated-measures [Group (violent, control) × condition (congruent, incongruent)] ANOVA was used. Separate analyses were performed on the peak amplitude of the N400 difference wave and the original peaks from the incongruent and congruent conditions.

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Results: We found no significant differences in behavioral responses. However we found that the control group elicited different activity for each condition (congruent and incongruent); the violent group did not. We found significant differences in the N400 difference wave in medial and lateral lines between the groups. There were differences in the congruent condition in all the lines between groups; there were no differences in the incongruent wave between groups. In the brain mapping we observed that the control group elicited negative activity during the incongruent condition and positive activity during the congruent; meanwhile the violent group elicited similar activity in both conditions.
Conclusions: Semantic emotional processing is impaired in violent individuals, suggesting deficient processing in the integration of language elements in an emotional context. The biological risk of violence in these individuals is disputed.

PALABRAS CLAVE
Procesamiento semántico;
Conducta violenta;
Población general

Procesamiento semántico emocional (N400) en individuos violentos de la población general

Resumen
Antecedentes: Estudios sugieren anormalidades estructurales y cognitivas en individuos violentos, asociadas con la corteza pre frontal, temporal y la amígdala involucrando funciones ejecutivas, toma de decisiones, lenguaje y regulación emocional. Los estudios han realizado análisis cuantitativo (EEG) o análisis del P300; además, se han llevado a cabo en muestras forenses institucionalizadas.
Objetivo: Explorar el procesamiento emocional/semántico utilizando un paradigma de N400 en una muestra de la población general.
Material y método: Participaron 60 hombres adultos divididos en dos grupos: grupo control (n = 30), grupo violento (n = 30). Los sujetos fueron clasificados de acuerdo a la escala de agresión reactiva y proactiva (RPQ; Raine A, Dodge K, Loeber R. et al., 2006). Se utilizó una ANOVA de medidas repetidas [Grupo (violento, control) x condición (congruente, incongruente)]. Se realizaron análisis por separado para la diferencia de la amplitud N400, y para los picos originales (congruente e incongruente).
Resultados: No se encontraron diferencias significativas en las respuestas conductuales entre los grupos. Sin embargo, el grupo control genera actividad diferencial para cada condición, mientras que el grupo violento no. Se observaron diferencias en la diferencia de la amplitud del N400 derivaciones mediales y de la línea media. También se encontraron diferencias en las 3 líneas de electrodos en la condición congruente. No se encontraron diferencias entre los grupos en la condición incongruente. Con un mapeo cerebral se observó que el grupo control genera actividad negativa durante el procesamiento del estímulo incongruente y actividad positiva durante el congruente, mientras que el grupo control generó actividad similar ante ambas condiciones.
Conclusiones: El procesamiento semántico emocional se encuentra afectado en los individuos violentos, sugiriendo un procesamiento deficiente en la integración de los elementos del lenguaje en un contexto emocional. Se discute el posible riesgo biológico en estos individuos para la comisión de conductas violentas.

Introduction

The main results obtained in ERPs studies in violent psychopathic individuals have been made using P300, and they have shown reduced amplitudes. This result has been interpreted as a deficient frontal processing[1] and/or a diminished capacity for distributing attentional resources in a sustained way in time.[2–5]

Other studies in violent individuals with high psychopathic traits have reported that they elicit a negative component (N300), that is sensitive to the affective rather than the physical attributes of the stimulus.[6] Moreover, late negativities with large amplitudes located in frontal and central areas that appear after 300 ms have been previously reported in individuals with a criminal record in oddball tasks[7,8] where the target stimulus required attention,

orientation, and decision making processes. Studies using N400 are less common in this population, however, it has been suggested some difficulties with language and semantic processing in violent individuals.

Language and semantic processing in violent population

Williamson et al.[8] related psychopathy to a deficit in the emotional processing of language. The authors found that control subjects responded faster and more accurately to emotional words compared to neutral words, and showed a differentiation in ERPs according to the two types of words. Psychopaths responded equally accurate, but they showed no difference either in reaction times or ERPs for differentiating the two type of words.

Kiehl et al.[3] studied semantic processing of language in a psychopathic population. They assessed 29 male individuals divided into 3 groups: 8 psychopaths (score: 30 or above), 9 non-psychopaths (score: 20 or below) and 12 belonged to a mixed group (scores: between 21 and 29 points); classified according to the Hare's Psychopathy Check List (PCL-R), but they only included results from psychopaths and non-psychopaths. They wanted to determine if psychopaths would show the expected ERP differentiation between concrete and abstract words and between positive and negative (emotional) words. They assessed two different ERP time windows: (1) 300–400 ms, because they wanted to determine if psychopathy was associated with an abnormal late fronto-central ERP negativity when processing word stimuli (N350) and (2) 400–800 ms because it corresponded to the concrete/abstract differences seen in previous research. They found that psychopaths made more errors identifying abstract words than concrete words, and even though they responded faster to positive than negative words (as did the control group), but they did not show the expected event related potential differentiation between word stimuli. Additionally, in each task, the ERPs of the psychopaths included a large centrofrontal negative-going wave (N350), and this wave was absent or very small in the nonpsychopaths. They concluded psychopaths have difficulties in processing abstract information and a deficit in the emotional processing that is implicit in the psychopathy definition. This personality disorder is also associated to differences in the processing of semantic features of language, indicating that psychopaths might process semantic information in a different way compared to non-psychopaths.

N400 studies in violent individuals

N400 is a stimulus-related brain activity in the 200–600 ms post stimulus onset window, relative to a 100 ms pre-stimulus baseline. It is typically examined in cross-condition comparisons and routinely instantiated in a difference ERP created via a point-by-point subtraction of a congruent ERP from an incongruent one. This difference—or N400 effect—is a monophasic negativity over centro-parietal sites, with a slightly right hemisphere bias. At a physiological level, amplitude reductions might reflect smaller postsynaptic potentials in the same neurons, activation of fewer neurons in a population, and/or less temporal synchrony among the generating neurons. This component is altered by context and therefore it is related to language processing, representing a deficit in the integration of elements of language.[9] It has been proposed that it is a multimodal system, where a wave of activity begins in the medial posterior temporal gyri, distributing to ventral temporal regions; and later (370–500 ms) to the anterior temporal lobe and to both frontal lobes.[9] These processes which depend upon semantic memory are closely related to implicit associations.[10–12]

Kiehl et al.[5] studied semantic processing in psychopaths using N400 and P600 components. They assessed 50 male inmates in a security detention center. The inmates were divided into psychopaths ($n = 25$) and non-psychopaths ($n = 25$) using the PCL-R to classify them, they were both paired in age and years of education. To assess semantic processing, they used a typical N400 paradigm that was made up of one hundred sentences (eight to ten words in length); sentences ended with a word that was either semantically congruent (50% of trials) or semantically incongruent (50% of trials) with the previous sentence context. They did not find differences in the N400 amplitudes between groups. The authors concluded that the processes that underlie the elicitation of the N400 components during processing of sentences are relatively intact in psychopaths.

However, previous studies have suggested that abnormalities in language processes are most prevalent when psychopathic individuals are required to perform tasks involving semantic processing, and that they compartmentalize their speech into smaller, more discrete units than do others, differing from others in degree and extent of cognitive processes required to perform language tasks, especially when language processing is related to emotional stimuli.[13]

In summary, ERP's studies in violent psychopaths and individuals with criminal record have reported early latencies in brain stem potentials, an increased latency to increased middle latency ERP and larger visual EP amplitudes that has been linked to novelty seeking. Moreover, it has also been reported, enhanced P3 to task-relevant events, suggesting an excessive attention to this stimulating events.[14,15] It has been reported a negative component (N350) that non-psychopathic individuals did not elicit during semantic processing tasks, and it has been suggested a semantic/language deficit in this population; however, results are still scarce and inconclusive.

Currently most studies have been performed in criminal and psychopathic individuals, which are institutionalized in prisons or in mental security facilities whereas studies with violent people among the general population are less common, specially using EEG techniques.[16] Therefore, the aim of the present study was to study semantic processing in violent individuals from general population.

Material and methods

Participants

Sixty adult males from a community sample were recruited and divided into two groups: the violent group ($n = 30$) and the control group ($n = 30$). Nine individuals were excluded from the study; 6 participants of the control group and 3

from the violent due to excessive artifacts in the ERP recording (greater than 40% of trials). Thus, leaving a sample made up of 24 control individuals and 27 from the violent group.

The control group
The control group was comprised of 24 healthy individuals who did not reach the cutoff point in the RPQ (Reactive and Proactive Aggression Questionnaire[17]) scores above eight points in the reactive aggression subscale. In reference to violent behavior, individuals with a history of physical violence or a criminal record were excluded from this group; moreover, subjects with any psychiatric or neurological disorder were also excluded from this study.

The violent group
27 healthy individuals belonged to this group provided they scored above the cutoff point in the RPQ (scores under eight points in the reactive aggression subscale and/or three points in the proactive subscale). In reference to violent behavior, we considered point of the RPQ scale and the number of violent episodes and/or criminal, including criminal antecedents such as minor infractions, physical fights, being gang members, using weapons. Subjects with any psychiatric or neurological disorder were excluded from the study.

Materials

The Reactive and Proactive Aggression Questionnaire (RPQ) is a screening questionnaire that reflects physical or verbal aggression. It is made up by 23 items, 11 refer to reactive aggression and 12 to proactive aggression. We used the Spanish version of the Reactive and Proactive Aggression Questionnaire (RPQ).[18] Subjects scoring above eight points in the reactive aggression subscale were classified as violent, with a cutoff adjusted for Mexican population.

Stimuli

We used a semantic pairing task composed of one hundred sentences made up of one adjective (i.e. *nice*) and a transitive verb (i.e. *to help*). We included only transitive verbs because they express an action that the subject performs directly to another person or object. The sentences were presented one word at a time (450 ms stimulus duration and 1000 ms ISI) on a computer monitor. Sentences ended with a word that was either semantically congruent (50% of trials) or semantically incongruent (50% of trials) with the previous sentence context (adjective). The order of sentence presentation was random. All stimuli were presented in white on a black background, within a continuously displayed outline of a white rectangular box. A prompt (three X letters) was presented 1250 ms after the offset of the last word to indicate that the participant should make the sense/no sense discrimination. ERPs were analyzed only for correctly classified terminal words. Accuracy was stressed while response speed was de-emphasized.

Event related-potentials recording
Scalp potentials were recorded with tin electrodes (ElectroCap International) placed over 32 positions: FP1, FP2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, and O2 from10-20 system, besides FPz, FT7, FT8, FC3, FCz, FC4, TP7, TP8, CP3, CPz, CP4, and Oz electrode sites. All EEG electrodes were referenced to linked earlobes. Electrical impedances were maintained below 5 kΩ throughout the experiment. The EEG signals (NuAmp, Neuroscan) were amplified and filtered with a bandpass of 0.1–30 Hz, digitized at 1024 Hz sampling rate, and stored on a hard disk. The epoch length was 1024 ms with a 100 ms pre-stimulus baseline and 924 ms post stimulus. After exclusion of 9 participants due to excessive artifacts, there were no significant group differences in the number of trials averaged in any condition. Data was stored for further analysis using SCAN program in 4.3.1. version.

ERPs processing
Once the EEG activity was recorded, we conducted a visual inspection of the recording with the aim of eliminating artifacts. Afterwards, the epochs which amplitude exceeded the range $\pm 50\ \mu V$ were automatically eliminated. Then, we corrected the baseline of each epoch, taking into account the average of the pre-stimulus activity, and subtracting this average from each epoch.

Averaging
Finally, we averaged the 1024 points of each epoch, obtaining an average for each electrode and condition (congruent and incongruent). Every ERP was filtered off-line using a FIR (Finite Impulse Response) analogical filter with a broad band of 0.1 Hz and 12 Hz using a slope of 48 dB/octave, all with the purpose of highlighting the main components of the ERPs. Afterwards the grand averages were made for each condition and group.

Procedure

All subjects signed a written informed consent for this study and were guaranteed confidentiality of the information they provided. Ethics Committees of the participant institutions approved the study. Participants were assessed at the Laboratory of Neuropsychology and Psychophysiology in the Faculty of Psychology at the National Autonomous University of Mexico. Assessments were carried out by 5 psychologists previously trained and it consisted of three sessions of 2.5 h each. In the first session, a clinical history was applied to obtain details about the life history of the participant and/or to dismiss those with neurological and psychiatric conditions. In the second session, a neuropsychological evaluation was carried out, and in the third session, electrophysiological assessment was conducted using EEG and Event Related Potentials recording. For the aims of the present study, only the data from the first and the third session was analyzed.

Data analyses
We used a repeated-measures [Group (violent, control) $\times$ condition (congruent, incongruent)] ANOVA. The N400 is typically measured as the most negative peak amplitude in the 200–600 ms post-stimulus time window in the difference wave of incongruent minus congruent conditions.[9] However, several studies of the N400 component in psychopathologic populations have shown that relying solely on the difference wave can direct to mislead-

ing results.[19] Thus, separate analyses were performed on the peak amplitude of the N400 difference wave and the original peaks from the incongruent and congruent conditions. Separate ANOVAs were performed on midline (Fz, Fcz, Cz, Pz, and Oz), medial (Fp1, Fp2, F3, F4, Fc3, Fc4, C3, C4, P3, P4, O1 and O2) and lateral sites (F7, F8, Ft7, Ft8, T3, T4, Tp7, Tp8, T5 and T6). The first set of ANOVAs for the difference wave included factors of Group (violent and control), and Site (electrode derivations in each line).

For medial and lateral sites ANOVAs there was an additional factor of Hemisphere (right: even numbered channels and left: odd numbered channels). For the second set of ANOVAs for the peak amplitude analyses there was an additional factor of Condition (Congruent and Incongruent). The Geisser–Greenhouse correction was employed where appropriate[20] and a significance level of $p \leq 0.05$ was set, corrected for multiple comparisons using Bonferroni. Only the statistically significant results are presented in this study.

Table 1 Group differences in N400 wave.

Site (electrode)	Control group Mean (μv)	Violent group Mean (μv)
Medial sites		
Fp1-Fp2	−0.954*	−0.730
F3-F4	**−1.914**	**−0.368***
Fc3-Fc4	**−2.083**	**−0.760***
C3-C4	**−2.404**	**−0.519***
Cp3-Cp4	**−2.546**	**−0.385***
P3-P4	**−2.601**	**−0.470***
01-02	**−1.956**	**−0.240***
Lateral sites		
F7-F8	−0.810	−0.659
Ft7-Ft8	−1.083	−0.467
T3-T4	**−1.403***	**−0.222***
Tp7-Tp8	**−1.407***	**−0.360***
T5-T6	**−1.611***	**−0.118***

* $p \leq 0.05$.

Results

Behavioral data

There were no significant group differences in the number of errors committed (congruent: $F = 0.420$, $p = 0.52$; incongruent: $F = .015$, $p = 0.90$) or in the reaction time (congruent correct answers: $F = 0.1.22$, $p = 0.28$; incongruent answers: $F = 0.178$, $p = 0.67$; congruent errors: $F = 0.364$, $p = 0.55$; incongruent errors ($F = 0.896$, $p = 0.36$)).

Event-related potentials

Grand-mean ERPs for congruent terminal words, incongruent terminal words and for the incongruent-congruent difference waves are presented for violent and control groups (Fig. 1). We observed that the control group elicited differential activity for congruent and incongruent terminal words, particularly in centro-parietal areas and more accurate in the left hemisphere; meanwhile we found that the violent group hardly produced different activity for congruent and incongruent words, neither differences between both hemispheres.

N400 difference wave

Across all participants we found a main effect of site [$F(5, 250) = 2.869$, $p = 0.044$] in the midline, where the N400 was largest at centro-parietal sites. Between groups, we found differences in medial and lateral sites. In medial site we found differences in all electrodes except in the prefrontal derivations (Fp1-Fp2) [interaction site*group $F(6, 282) = 4.007$; $p = 0.020$], and in lateral site we found differences in temporal derivations (anterior and posterior), as well as in temporal–parietal derivations [interaction site * group $F(4, 212) = 5.108$, $p = 0.009$] (see Table 1); there were no differences between groups in midline. Within groups we found that, in medial site, prefrontal derivations were different from the rest in the control group and there were no differences in the violent group.

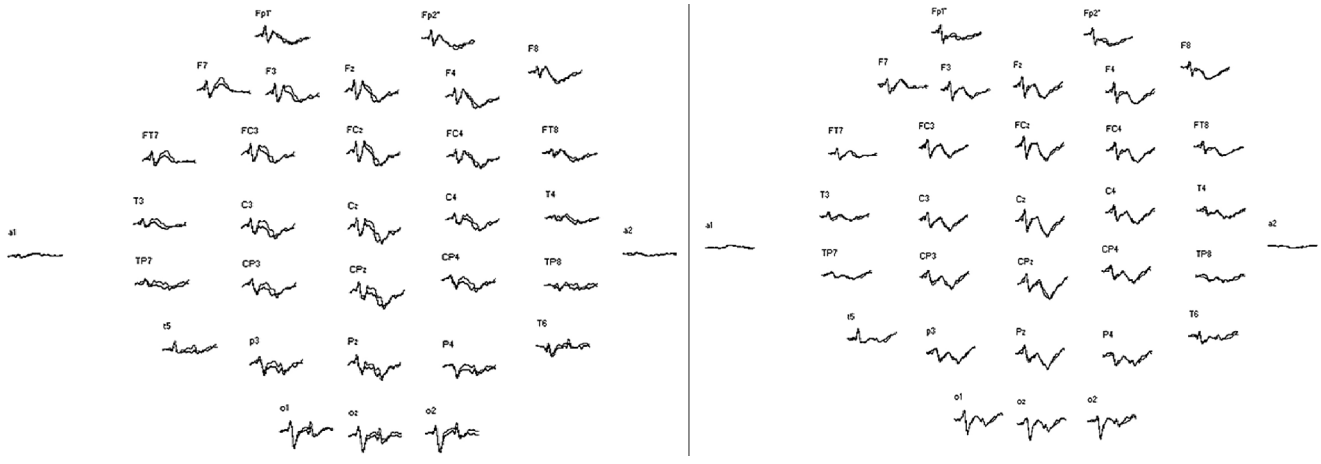

Figure 1 On the left we showed the grand-mean ERPs of the control group, and to the right the violent group. In gray is the wave activity for congruent terminal words, and in black we show the wave activity for incongruent terminal words.

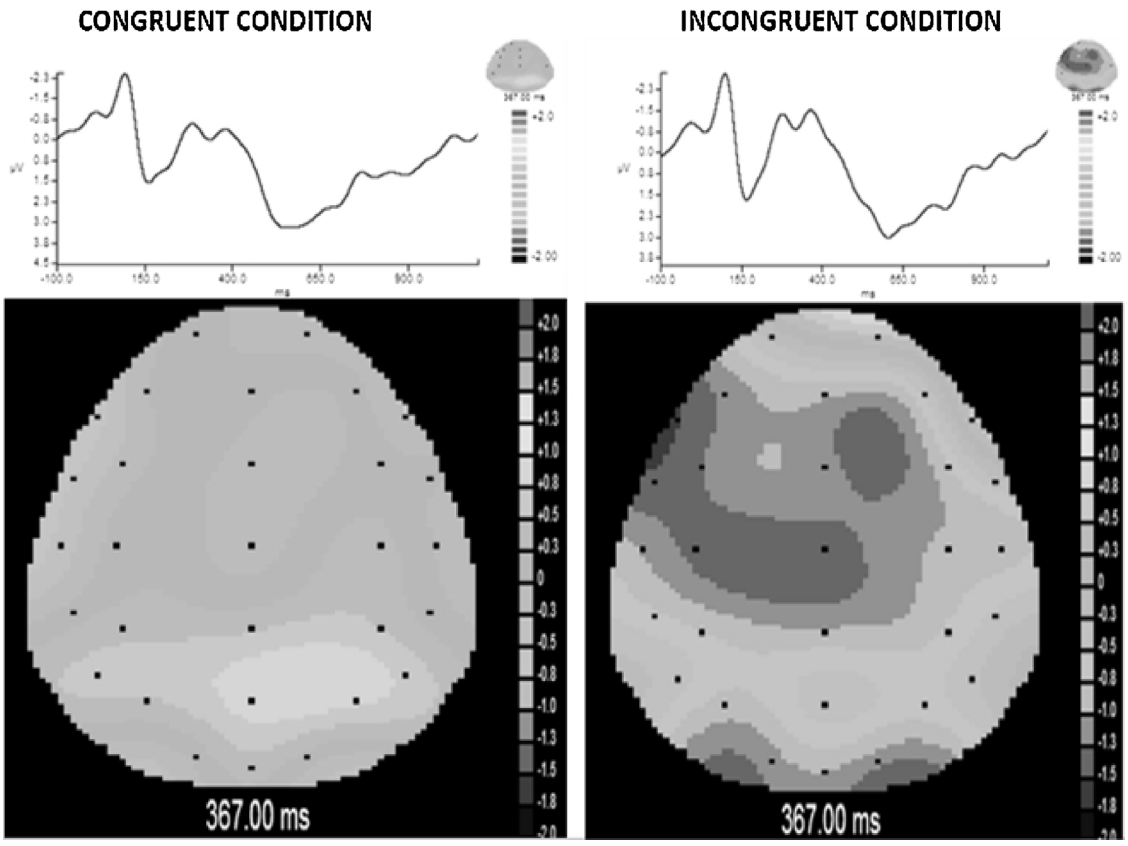

Figure 2 Brain mapping in the control group.

N400 peak analyses

We found differences between groups in all three line sites to congruent terminal words: midline [interaction condition * group $F(1, 50) = 27.163$, $p \leq 0.000$]; medial [interaction condition * group $F(1, 47) = 17.148$, $p \leq 0.000$]; and lateral [interaction condition * group $F(1, 53) = 9.235$, $p = 0.004$] (see Table 2). We created a brain mapping of the activity from the two conditions in each group, and we observed (as it was expected) negative activity to the incongruent condition and more positive activity to the congruent condition in the control group; conversely, in the violent group we observed negative activity produced to the congruent condition and less positive activity to the incongruent condition; exhibiting a very similar activity on both conditions (see Figs. 2 and 3).

Within groups we found that the control group differentiated the congruent from the incongruent condition in all line sites. There were differences to the congruent condition in the centro-parietal electrodes (in medial site). In the violent group we found that they differentiated between conditions only in the midline site, and in the congruent condition, we found differences in prefrontal, frontal, and fronto-central derivations; in the incongruent condition we found differences between frontal and fronto-central derivations [interaction site * condition * group $F(6, 282) = 4.007$, $p = 0.020$].

Table 2 Differences between groups in the conditions.

Condition	Control group Mean (μv)	Violent group Mean (μv)
Midline		
Congruent	**0.984***	**−0.837***
Incongruent	−1.780	−1.452
Medial		
Congruent	**0.763***	**−1.303***
Incongruent	−0.285	−0.781
Lateral		
Congruent	**0.411***	**−0.228***
Incongruent	−0.852	−0.593

* $p \leq 0.05$.

Discussion

The aim of this study was to explore semantic processing in violent individuals from general population. In accordance with previous studies, we found a main effect of hemisphere, with a larger effect over the right hemisphere.[5,21]

When we analyzed the N400 effect, we found differences between groups in medial and lateral sites, specifically in temporal and parietal derivations. Within groups, we found that in the control group, the prefrontal derivations were different from the rest, whereas in the violent group there were no differences between electrodes. This results are not in accordance to Kiehl et al.[5]; however, they used a

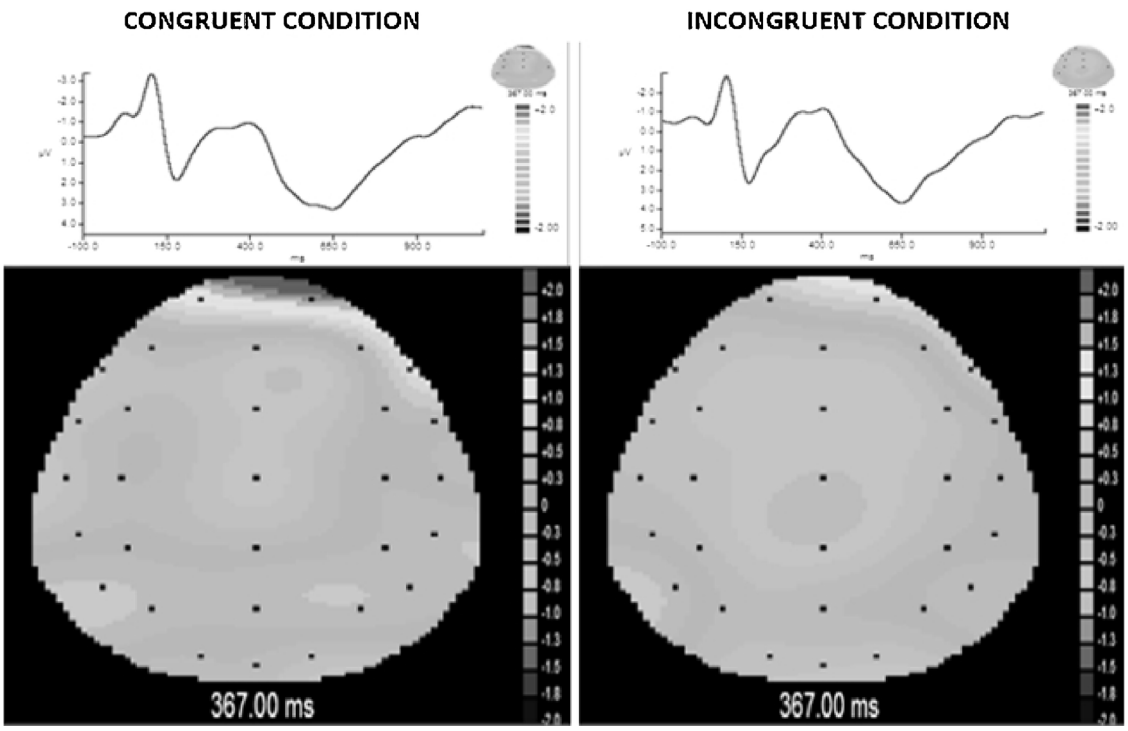

Figure 3 Brain mapping in the violent group.

different N400 paradigm (a classical N400 paradigm) using sentences with no emotional content. Therefore, our data could be related to the negative component reported previously in individuals with a criminal record N300[2,4,7,8] and to the negative fronto-central component (N350) found in psychopaths, using an emotional content paradigm.[3]

When we analyzed the N400 conditions (congruent and incongruent) between groups, we found differences in the congruent condition in all three sites (midline, medial, and lateral). Both groups differentiated the conditions in midline, but in the lateral and in the medial site the violent group showed no differences between conditions. Within groups, in the control group we found the expected event-related potential differentiation between conditions in centro-parietal, frontal, and temporal derivations. Meanwhile, in the violent group these differences were found in temporal and frontal regions, not showing the expected ERP differentiation between conditions in all sites. Moreover, there were no statistical differences in the behavioral responses or in the reaction times between groups. Regarding these results, we believe that control group is using cognitive resources that have been previously associated with the processing of semantic memory, like centro-parietal regions[9] and successfully integrate the information to a context, leading to differentiate between conditions. Meanwhile, the violent group appeals to frontal areas, suggesting probably a stronger cognitive demand for them,[22,23] and not fully succeed at the differentiation task, since they can behaviorally discriminate between conditions but they do not show the expected ERP differentiation. These results have been previously reported in psychopathic individuals.[3]

Additionally, we observed that the violent group generated negative activity during the congruent condition, and a lesser negativity under the incongruent. Previous studies in schizophrenic individuals with N400 have reported the same negative activity during congruent stimuli.[20,24] They have proposed that this excessive negativity under congruent conditions is the reason why the N400 difference wave has a lesser amplitude, suggesting that the greater amplitudes found in both conditions (congruent and incongruent) might reflect a deficient processing in the contextual integration that's language related, representing a disturbance in the integration of elements in language.

It has been previously suggested that violent behavior is the result of an interaction of several biological, cognitive and social factors.[25] According to our results, we could be in line with the idea of a different, less efficient processing in violent individuals. This deficiency starts in early stages of cognitive processing (milliseconds), previous to the behavioral response, and even though they can respond behaviorally accurate, this may be leading them toward a less efficient way of cognitive functioning, affecting other cognitive processes like decision making, integration of lexical elements into a context (language), and the emotional processing, that has been previously reported in this population.[11,12,15]

In conclusion, our results do support the hypothesis that processes underlying the elicitation of the N400 components during a semantic task with emotional content are impaired in violent individuals. It is probable that the deficiency we found in our violent sample may not be strong enough to lead them to violate social rules, but they are definitely in a higher risk to commit a violent act where the use of their cognitive resources (such as semantic processing) may be less effective than in non-violent individuals. Also, it is of great importance to consider that they can behaviorally respond correctly, but they can't show different ERP activity between conditions; this may

be the highlight of a neurobiological marker. This treats highly correlate to the neuropsychological deficits consistently reported in these groups, such as impulsivity, planning problems, mental flexibility, inhibition, abstraction and self-emotional regulation.[5,17,26–31]

Studies concerning this topic using N400 are still scarce and more complementing imaging techniques research are required for a better understanding of the neurobiological basis of violent behavior.

Limitations and further research

The present study showed semantic and emotional processing in violent individuals, however our design can be interpreted methodologically as biased because is not a randomized sample since we recruited violent man from the community sample. Therefore we recommend to take this results carefully for generalize this data. Regarded to this issue we propose to make future research in a group of violent inmates and a bigger sample to minimize the biased effect of the sample and so the results become widespread. As well, we believe this work should be complemented with neuroimage data and neuropsychological assessment.

Conflict of interest

The authors declare that they have no conflict of interests.

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