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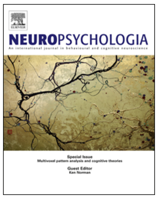

Cognitive and affective control in a flanker word task: Common and dissociable brain mechanisms

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ABSTRACT

In the present study we compared the nature of cognitive and affective conflict modulations at different stages of information processing using electroencephalographic recordings. Participants performed a *flanker task* in which they had to focus on a central word target and indicate its semantic category (cognitive version) or its valence (affective version). Targets were flanked by congruent or incongruent words in both versions. Although tasks were equivalent at the behavioral level, event-related potentials (ERPs) showed common and dissociable cognitive and emotional conflict modulations. At early stages of information processing, both tasks generated parallel sequential conflict effects in the P1 and N170 potentials. Later, the N2 and the first part of the P3 wave were exclusively modulated by cognitive conflict, whereas the last section of the P3 deflection/Late Positive Component (LPC) was only involved in affective current conflict processing. Therefore, the whole data set suggests the existence of early common mechanisms that are equivalent for cognitive and affective materials and later task-specific conflict processing.

1. Introduction

When performing a task, humans often have to focus their attention on stimuli that are relevant to the task at hand and overcome the influence of distracting, irrelevant information. These situations require the implementation of control processes, given that relevant and irrelevant stimuli often trigger opposite action tendencies (see Norman & Shallice, 1986; Posner & Fan, 2004). How we exert control and solve such conflicts is a key research question that has been studied for many years using stimulus-response compatibility (SRC) tasks (Kornblum, Hasbroucq, & Osman, 1990). In this type of settings, goal-relevant targets are surrounded by irrelevant stimuli that are associated with the same (congruent) or opposite (incongruent) action tendencies. The typical *conflict effect* (Eriksen & Eriksen, 1974) arises, as responses are faster and more accurate in congruent than in incongruent trials. On the other hand, the *conflict adaptation effect* (Gratton, Coles, & Donchin, 1992) is evaluated based on the interaction between the previous and current congruency in consecutive trials. Responses on trials following an incongruent trial show decreased conflict. This finding is supposed to reflect the heightened activation of control mechanisms, which seem to be more available for the resolution of new incongruences (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Egner, Etkin, Gale, & Hirsch, 2008). This effect seems to be domain-specific, as it does not transfer across different SRC tasks that are performed sequentially (Egner, 2008; Egner et al., 2008; Funes, Lupiáñez, & Humphreys, 2010).

In neural terms, according to the conflict-monitoring hypothesis, the anterior cingulate (ACC) and dorsolateral prefrontal (dlPFC) cortices are involved in monitoring conflictive situations and implementing control mechanisms, respectively, when required (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Cohen, Botvinick, & Carter, 2000; MacDonald, Cohen, Stenger, & Carter, 2000). This hypothesis posits that the ACC monitors the occurrence of conflict online and the dlPFC holds task-relevant representations and amplifies cortical responses to reduce conflict. After that, the ACC is thought to provide feedback (Botvinick et al., 2001, 1999; Cohen et al., 2000; Egner & Hirsch, 2005).

Initially, research on emotional conflict used SRC paradigms such as the emotional counting Stroop task (Whalen et al., 1998) and other related tasks (Bush, Luu, & Posner, 2000) in which emotional information was a distractor but not a target, as targets were always cognitive. However, further developments were aimed at equating cognitive and affective types of conflict within a single task (Egner et al., 2008; Kanske & Kotz, 2010a) and using the same type of stimuli across conditions (Ochsner, Hughes, Robertson, Cooper, & Gabrieli, 2008).

For example, Egner et al. (2008) modified the classic Stroop task (Stroop, 1935) by displaying overlapping male and female faces (expressing fear or happiness) and words (referring to the

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gender or the emotional expression of the faces). Participants had to respond to the gender of the faces in the cognitive version of the task and to the emotional expression of the faces in the affective version of the task. In both cases, participants had to ignore irrelevant superimposed verbal information. Thus, faces and words could be either congruent or incongruent in both cognitive and emotional tasks. Similarly, Ochsner et al. (2008) used a task in which a word (target) was presented at the center of the screen, flanked by another two words displayed above and below. Participants had to indicate the semantic category (fruits vs. metals) of the target in the cognitive version of the task and respond to the valence of the words (positive vs. negative) in the emotional version.

To date, several reports have jointly explored the neural substrate of cognitive and affective conflict. Results converge on the finding of common areas of activation for both types of tasks in the dorsal ACC. However, differences have also been found between cognitive and affective versions. Cognitive conflict seems to involve activity in the dorsolateral prefrontal cortex, whereas affective conflict seems to recruit the rostral medial prefrontal and ventral anterior cingulate cortices (Bush et al., 2000; Egner et al., 2008; Kanske & Kotz, 2010a; Ochsner et al., 2008). These results are mainly derived from functional magnetic resonance imaging (fMRI). This technique, however, is not appropriate to conduct analyses on how different types of conflict affect the various rapid stages of information processing that take place from stimulus onset to response execution. By contrast, electroencephalography (EEG) provides excellent temporal resolution that helps understand whether cognitive and emotional conflicts generate common or dissociable effects along the various stages of stimulus processing.

Several event-related potentials (ERPs) are sensitive to conflict modulation across different stages of information processing. First, the P1 and N170 are early potentials that reflect perceptual processing in visual cortices (Hillyard, 2009; Luck, Woodman, & Vogel, 2000). The amplitude of the P1 is also heightened by selective attention to spatial positions and stimulus features (Hillyard, 2009; Luck, 2005), and seems to reflect the amplification of relevant information (Hillyard, Vogel, & Luck, 1998). According to research conducted by Meeren, Van Heijnsbergen, and Gelder (2005), the P1 displays larger amplitudes for congruent than for incongruent face-body emotional expressions. Similarly, Scerif, Worden, Davidson, Seiger, and Casey (2006) used a classic flanker paradigm and found conflict adaptation effects in the P1 potential. At that stage, incongruent trials preceded by trials of the same type had larger amplitude than the other combinations of previous and current congruency in a sequence of trials. Together, these results suggest that conflict and its previous congruency context can influence the processing of perceptual information at a very early stage.

The N170 potential is associated with perceptual discrimination and object categorization processes (Hillyard, 2009; Luck et al., 2000) and can be modulated by attention (see Aranda, Madrid, Tudela, & Ruz, 2010; Ruz & Nobre, 2008a). In two recent parallel experiments, Zhu, Zhang, Wu, Luo, and Luo (2010) used a Stroop face-word manipulation in which participants had to indicate the emotional category of the target stimulus (the *face* in Experiment 1 and the *word* in the Experiment 2) while ignoring the distractor element (similar to Egner et al., 2008). In Experiment 1 (in which participants responded to the face), the N170 potential had larger amplitude in the incongruent condition than in the congruent condition. In Experiment 2 (in which the word was the target), the amplitude pattern was reversed. Thus, the amplitude of this potential was enhanced by task-relevant information during emotional conflict processing (Zhu et al., 2010). Altogether, this evidence from the P1 and N170 potentials shows that cognitive and emotional conflict can modulate the perceptual processes reflected in these potentials and — at least in the P1 potential — reflects the control of cognitive conflict according to its previous congruency context.

The term 'N2' includes several waves that have generally been related to the allocation of attention to target stimuli and the suppression of irrelevant stimuli (Luck, 2005). The N2 that is most strongly associated with cognitive control is a negative deflection that takes place around 200 ms after stimulus onset with a fronto-central topography (Heil, Osman, Wiegelmann, Rolke, & Hennighausen, 2000; Kopp, Rist, & Mattler, 1996). Using a classic flanker task, Kopp et al. (1996) found that the amplitude of the N2 was larger in incongruent trials than in congruent trials (Kopp et al., 1996; Van Veen & Carter, 2002). This result, which seems to reflect the implementation of control mechanisms (Folstein & Van Petten, 2008), has since been replicated several times (Folstein & Van Petten, 2008; Van Veen & Carter, 2002). With the help of computer simulations, Yeung et al. (Yeung, Botvinick, & Cohen, 2004) proposed that the N2 potential reflects conflict monitoring in correct responses prior to response execution. In fact, the N2 potential seems to reflect a process of detection of potential future errors that takes place before response execution (Yeung et al., 2004).

Regarding emotions, Kanske and Kotz (2010b, 2011a,b) have used various paradigms to study the influence of emotional and neutral materials during the resolution of cognitive conflict. In their tasks (Kanske & Kotz, 2010b, 2011a,b), however, the valence of the stimuli is not relevant for performance, and therefore the response never concerns this dimension. In two of their studies, for example, Kanske and Kotz (2010b, 2011b) used a flanker task composed of affective and neutral words. In each trial, three stimuli (a target word flanked by two additional words) were displayed in the same (congruent condition) or different colors (incongruent condition). Participants were required to indicate the color of the target but the meaning of the words was irrelevant. The presence of irrelevant affective material generated an N2 of larger amplitude compared to irrelevant words with neutral meaning. This effect was accompanied by a decrease of the conflict effect for affective materials. The authors therefore concluded that the emotional nature of irrelevant stimuli speeds up conflict resolution.

Finally, the P3 potential has been associated with stimulus selection and categorization and with the implementation of the required response (Luck, 2005). Polich (2006) posited that the P3 would be modulated by inhibitory processes involved in avoiding 'extraneous' information and in focusing attentional resources on the relevant elements of the task. Thus, the harder it was to inhibit 'extraneous' elements, the lower the amplitude of the P3. In addition, studies using SRC paradigms have reported larger amplitudes of this potential for congruent than for incongruent conditions (Neuhaus et al., 2010; Valle-Inclán, 1996a). Although few experiments have explored the susceptibility of the P3 to emotional conflict, a study using words in a modified Go/NoGo task found larger P3 amplitudes in NoGo trials but only for affective and non-neutral words (Chiu, Holmes, & Pizzagalli, 2008).

In summary, previous studies comparing cognitive and emotional conflict resolution have mainly used fMRI methods, and those recording EEG have not compared both types of material using the same type of stimuli and equating task demands. Therefore, in this study we explored the temporal dynamics of cognitive and emotional conflict resolution using the same kind of materials and task settings across conditions. To this end, we adapted the paradigm developed by Ochsner et al. (2008) and recorded EEG while participants assessed the semantic category or affective valence of words flanked by congruent or incongruent stimuli in different blocks. We focused on the P1, N170, N2 and P3 potentials as markers of different stages of information processing and studied how current and previous trial congruency factors affected such stages. Based on previous fMRI studies, we predicted that both tasks would show both similarities and differences in the neural stages modulated by cognitive and emotional conflict. More specifically, we expected conflict to be reflected in larger P1 and N170 amplitudes for incongruent than for congruent trials. In addition, we expected to find a congruency effect in the N2 potential, with more negative amplitude for incongruent than for congruent trials. Finally, we hypothesized a conflict effect for both types of tasks at later P3 stages.

2. Methods

2.1. Participants

The sample was composed of 26 healthy volunteers (1 left-handed participant, 11 men, mean age: 22 years) with normal or corrected-to-normal vision and Spanish as their native language. Participants were recruited from the University of Granada in exchange for course credit. All participants signed a consent form approved by the local Ethics Committee.

2.2. Stimuli, apparatus and procedure

Participants performed a modified version of the classic flanker task (Eriksen & Eriksen, 1974), previously adapted by Ochsner et al. (2008). The cognitive and affective versions of this task were presented in different blocks. A group of 20 words was selected from the Spanish version of the Affective Norms for English Words (ANEW; Redondo, Fraga, Padrón, & Comesaña, 2007) to serve as stimuli; these were divided in two 10-words sets. The cognitive task included 5 words of each semantic category (5 *animals*, 5 *pieces of furniture and fittings*) and the affective task included 5 words of high *positive* valence and 5 words of high *negative* valence. Their combination yielded 72[1] target—flanker sets, 36 for each task. Every possible target—flanker combination appeared only once in each block to avoid immediate stimulus repetitions. No further constraints were applied on stimuli, response repetitions or trial sequences. Words were matched across tasks in mean frequency of use ($Mn_{Freq}=14$; $SD=2.13$), number of letters ($Mn_{NLett}=6.4$; $SD=0.16$) and mean concreteness ($Mn_{Con}=5.82$; $SD=0.53$), all p's > 0.05. The average valence was equal for words used in the cognitive ($Mn_{ValCog}=5.42$; $SD=1.09$) and affective tasks ($Mn_{ValAffe}=4.76$; $SD=2.97$), $F<1$. Affective words had extreme negative ($Mn_{ValNeg}=1.96$; $DT=1.49$) and positive ($Mn_{ValPos}=7.55$; $SD=1.52$) values; $F(1,8)=368.88$, $p<0.001$.

The task was created and displayed using E-Prime 2.0 Professional software (Schneider, Eschman, & Zuccolotto, 2002). All stimuli were composed of white uppercase letters displayed on a black background. Each trial comprised the following sequence (see Fig. 1): after a fixation point (0.43°) of 2500 ms duration on average (random 2000—3000 ms range), target and flanker words (2.57°/3.42° on average) were displayed vertically aligned on the center of the screen for 1500 ms. From target onset, participants had 1500 ms to respond by pressing one of two buttons with their left and right index fingers. The association between hand and response was counterbalanced across tasks and participants.

Participants were asked to respond to the semantic category of the words in the cognitive version (*animals* vs. *furniture*) and to their valence in the affective task (*positive* vs. *negative*). In every trial, three words were displayed in the center of the screen (see Fig. 1). The central word was the target and was surrounded above and below by two other words (flankers). Participants were asked to focus on the target word and to ignore the flankers. Trials were congruent if the semantic category (cognitive task) or the valence indexes (affective task) were the same for target and flankers and incongruent if they were different.

At the beginning of the session, participants performed a training block of 30 trials (15 for each task) to familiarize themselves with the procedure. During this practice, they received feedback of their performance. The experiment was composed of 10 blocks (5 for each task) of 72 trials each (720 trials in total; 360 trials per task, each composed of 180 congruent and 180 incongruent trials), separated by short breaks. The order of presentation of each group of blocks (cognitive or affective) was counterbalanced across participants.

2.3. EEG recording and data analyses

Subjects were seated in front of the computer monitor in an electrically shielded room and were instructed to avoid eye blinks and movements during stimulus presentation and responses. EEG was recorded with a high-density 128-channel EEG system Geodesic Sensor Net (Tucker, 1994), referenced to the vertex channel. The head coverage included sensors lateral to and below both eyes to monitor horizontal and vertical eye movements (HEOG and VEOG). The EEG net was connected to an AC-coupled, high-input impedance amplifier (200 MΩ). At the beginning of the recording session, impedance was measured for each channel and was set below 50 kΩ, as recommended for Electrical Geodesics high-input impedance amplifiers. Amplified analog voltages (0.1—100-Hz band pass) were digitized at 250 Hz (12 bits A/D converter and 0.02 μV minimum resolvable voltage).

The continuous EEG was filtered offline using a 40 Hz low-pass filter. After that, the EEG was segmented 200 ms before and 800 ms after target onset. Subsequently, segments were submitted to software processing for identification of artifacts. Trials containing eye blinks or eye movements (electro-oculogram channel differences greater than 70 μV) or more than 20% of bad channels were not included in the ERPs. Data from consistent bad channels were later replaced using a spherical interpolation algorithm (Perrin, Bertrand, & Echallier, 1989). ERPs were re-referenced offline to the average. The 200 ms pre-stimulus epoch served as the baseline. A minimum criterion of 30 artifact-free trials per subject and condition (cognitive and affective CC, CI, IC, and II) was established to maintain an acceptable signal-to-noise ratio. A final grand-average was obtained per condition by pooling the subject's averages in each experimental condition. Eight group-average ERP waveforms were constructed according to task (*cognitive* vs. *affective*), current congruency (*congruent* vs. *incongruent*) and previous congruency (*congruent* vs. *incongruent*) factors. Conditions were equated in number of trials, $F<1$.

To facilitate the selection of spatio-temporal windows for amplitude analyses, the ERPs were submitted to a segmentation analysis performed with Cartool software (D. Brunet, Geneva, Switzerland; http://sites.google.com/site/fbmlab/cartool). This analysis shows the voltage distribution (topographies) over the scalp for each experimental condition as a function of time. These topographic maps represent stable periods of electrical field patterns that correspond to dissociable functional states of the brain (Murray, Brunet, & Michel, 2008; Pascual-Marqui, Michel, & Lehmann, 1995; Ruz & Nobre, 2008b), which normally match identifiable ERPs on the grand-averaged waveforms (Pascual-Marqui et al., 1995).

The topographic analysis was conducted with some limitations: the maps had to remain stable for 20 ms and the correlation between different maps could not be higher than 92% (see Aranda et al., 2010; Baines, Ruz, Rao, Denison, & Nobre, 2011; Cojan, Archimi, Cheseaux, Waber, & Vuilleumier, 2013; Correa, Rao, & Nobre, 2009; Foxe, Murray, & Javitt, 2005; Morand, Harvey, & Grosbras, in press; Nobre, Griffin, & Rao, 2008; Ruz & Nobre, 2008b, for similar constraints). This procedure was used to obtain a common sequence of topographies, which served to select the spatio-temporal windows in the ERPs for data analyses.

The optimal sequence of topographies and number of maps (restricted by the constraints mentioned above) that best explained the entire data set were defined by a researcher-independent cross-validation (CV) criterion (Pascual-Marqui et al., 1995). This criterion is used to assess the validity of regression models (Snee, 1977). The topographic solution with the minimum CV value is chosen, as it is the one in which the smallest number of maps explains the greatest variance in the data. After that, the temporal ranges of the cluster maps or topographies are used to delimit the temporal windows for the ERP analyses.

Voltage analyses were performed on the spatio-temporal windows that captured the grand-average peaks of the potentials of interest. The selected electrodes were those where the components were maximally distributed (see Figs. 4 and 5). The temporal windows were centered on the peak of the potentials in the grand-averaged waveforms and always fell within the time intervals of the corresponding topographic maps.

Only correct responses were considered; errors, post-error trials and the first trials of each block were removed from the set. Data from three participants were rejected because they had too many bad channels or excessive artifacts during recording (they were also excluded from the behavioral analyses). Mean amplitude voltages averaged over the selected channels and time windows were submitted to repeated-measures ANOVAs with the same factors as those included in the group-average ERP. Analyses were carried out for the P1, N170, N2 and P3 potentials ($P3_1$, $P3_2$ and $P3_3$ included topographic constraints). The hemisphere was included as a factor (right, left) for the P1 and the N170. The same ANOVA was used with participants' mean errors and RT.

3. Results

3.1. Behavioral results

Only correct responses were considered in the RT and the ERP analyses. Errors and post-error trials (6.42%) were eliminated from the data. RT shorter than 300 ms (0.82%) were excluded. In addition, trials at the beginning of each block (1.38%) were also discarded.

Overall accuracy was 96%. Performance was more accurate in the congruent ($Mn_{AccCon}=97.9\%$; $SD=1.5$) than in the incongruent

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[1] Six combinations from each set were removed to avoid the simultaneous presence of the same word as target and flanker.

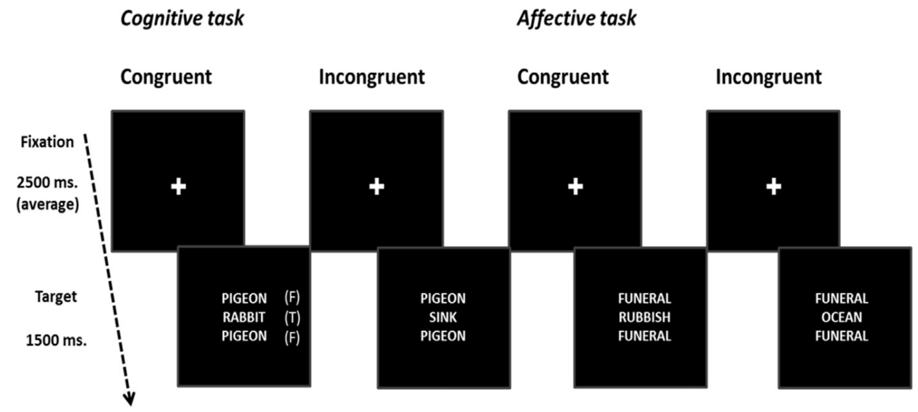

Fig. 1. Experimental conditions and sequence of events in a trial. F=Flanker; T=Target. Target and flanker words have been translated into English.

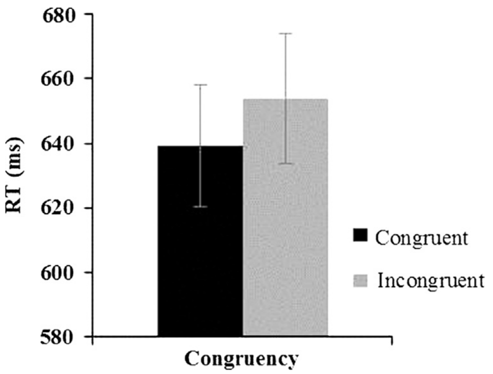

Fig. 2. Congruency effects on RT.

condition ($Mn_{AccIn}=96.9\%$; SD=1.8), $F(1,25)=22.681$, $p<0.001$. The interaction between current and previous congruency only reached marginal significance levels, $F(1,25)=3.411$, $p=0.077$.[2] All other comparisons were not significant, p's > 0.05.

RT analyses showed a main effect of congruency, $F(1,25)=33.627$, $p<0.001$, as responses were faster in the congruent ($Mn_{RTCon}=639.05$; SD=96.60) than in the incongruent condition ($Mn_{RTInc}=653.84$; SD=102.98; see Fig. 2). The previous congruency factor was close to significance levels, $F(1,25)=3.343$, $p=0.079$ ($Mn_{RTPrevCon}=644.87$; SD=98.11 vs. $Mn_{RTPrevInc}=647.97$; SD=101.39). There were no other significant effects, all Fs < 1. The mean and standard deviation of behavioral data in all conditions are shown in Table 1.

3.2. Electrophysiological results

The topographic analysis showed that ERP data was best explained by 7 sequential maps, which are displayed in Fig. 3.

The first map showed negative polarity in frontal regions and positive polarity in posterior regions, corresponding to the P1 potential. The second map showed positive voltages at anterior-central sites and negative voltages at posterior sites, and corresponded to the N170. The fourth map had negative values in frontal regions and positive voltages in central ones, corresponding to the N2 potential. The seventh, eighth and ninth maps showed positive polarity at central sites. These last three maps corresponded to first ($P3_1$), second ($P3_2$) and third sections ($P3_3$) of the P3 potential, respectively. Each topography is thought to represent a different processing stage and dissimilarities in the underlying brain sources (Lehmann, 1987). Hence, each segment of the P3 wave seems to correspond to a different brain microstate (Michel, Henggeler, & Lehmann, 1992; Pascual-Marqui et al., 1995). As a result, the segments were analyzed separately. Similar strategies and map labeling can be found in Baines et al. (2011) and in Nobre et al. (2008).

3.2.1. Early processing stages

The P1 potential peaked approximately at 138 ms and was analyzed from 106 ms to 170 ms over posterior bilateral electrodes (see Fig. 4). The analysis of the averaged amplitudes showed a significant hemisphere effect, $F(1,25)=13.013$, $p<0.05$, with larger positive voltages in right electrodes ($Mn_{AmpRH}=1.90$; SD=2.03) than in left electrodes ($Mn_{AmpLH}=0.89$; SD=1.52). In addition, the interaction between current and previous congruency factors was significant, $F(1,25)=5.377$, $p<0.05$. Subsequent comparisons showed an effect of previous congruency only for current incongruent trials, $F(1,25)=4.228$, $p=0.05$. In other words, incongruent trials following congruent trials showed larger positive amplitudes ($Mn_{AmpCI}=1.48$; SD=1.67) than incongruent trials preceded by incongruent trials ($Mn_{AmpII}=1.29$; SD=1.60). This difference was not significant for current congruent trials, $p=0.347$ (see Fig. 4). The cognitive vs. affective nature of the task did not show an effect or interact with any other factor, all Fs < 1.

The N170 potential peaked approximately at 215 ms and was analyzed from 175 ms to 255 ms over posterior bilateral electrodes (see Fig. 4). The analysis of the averaged amplitude for the N170 showed an effect of hemisphere, $F(1,25)=26.379$, $p<0.001$, as more negative amplitudes were found in left ($Mn_{AmpLH}=-2.07$; SD=1.80) than right locations ($Mn_{AmpRH}=-0.83$; SD=1.79). In addition, the interaction between current and previous congruency factors was again significant, $F(1,25)=13.792$, $p=0.001$. Planned comparisons showed an effect of the previous congruency factor only for current incongruent trials, $F(1,25)=9.402$, $p<0.01$; the voltage values were more negative for incongruent trials following identical trials ($Mn_{AmpII}=-1.56$; SD=1.65) than for those following congruent ones ($Mn_{AmpCI}=-1.40$; SD=1.67). This difference was not significant for current congruent trials, $F<1$ (see Fig. 4). Again, neither the cognitive vs. affective nature of the task nor its interactions with other factors were significant, all p's > 0.05.

3.2.2. Intermediate processing stages

The N2 potential peaked approximately at 330 ms and was analyzed from 318 ms to 342 ms over central electrodes. The ANOVA with the averaged amplitude values showed an effect of previous congruency, $F(1,25)=8.808$, $p<0.01$, as trials following an incongruent trial showed a more negative-going deflection

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[2] Subsequent comparisons did not show significant effects of the previous congruency factor for either congruent or incongruent current trials, all p's > 0.26.

($Mn_{AmpPrevInc}=0.52$; $SD=1.67$) than those preceded by a congruent trial ($Mn_{AmpPrevCon}=0.79$; $SD=1.54$). Two significant interactions were also found: task × current congruency, $F(1,25)=5.606$, $p<0.05$, and task × previous congruency, $F(1,25)=5.970$, $p<0.05$. Subsequent analyses showed that there was an effect of current congruency in the cognitive task, $F(1,25)=6.151$, $p<0.05$, as the N2 amplitude in the incongruent condition was more negative-going ($Mn_{AmpInc}=0.60$; $SD=1.80$) than in the congruent condition ($Mn_{AmpCon}=0.92$; $SD=1.70$; see Fig. 5). Moreover, there was an effect of previous congruency again only in the cognitive task, $F(1,25)=21.103$, $p<0.001$; this was because trials following an incongruent trial showed a more negative-going deflection ($Mn_{AmpPrevInc}=0.47$; $SD=1.80$) than those following a congruent trial ($Mn_{AmpPrevCon}=1.04$; $SD=1.69$). There were no effects of current or previous congruency in the affective task, all F's <1.

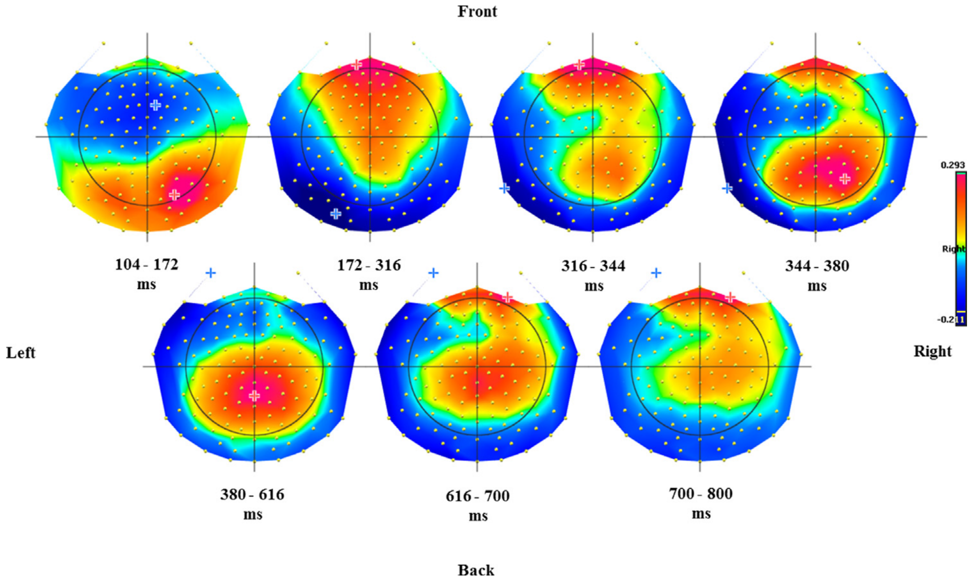

Fig. 3. Sequence of topographies associated with the task.

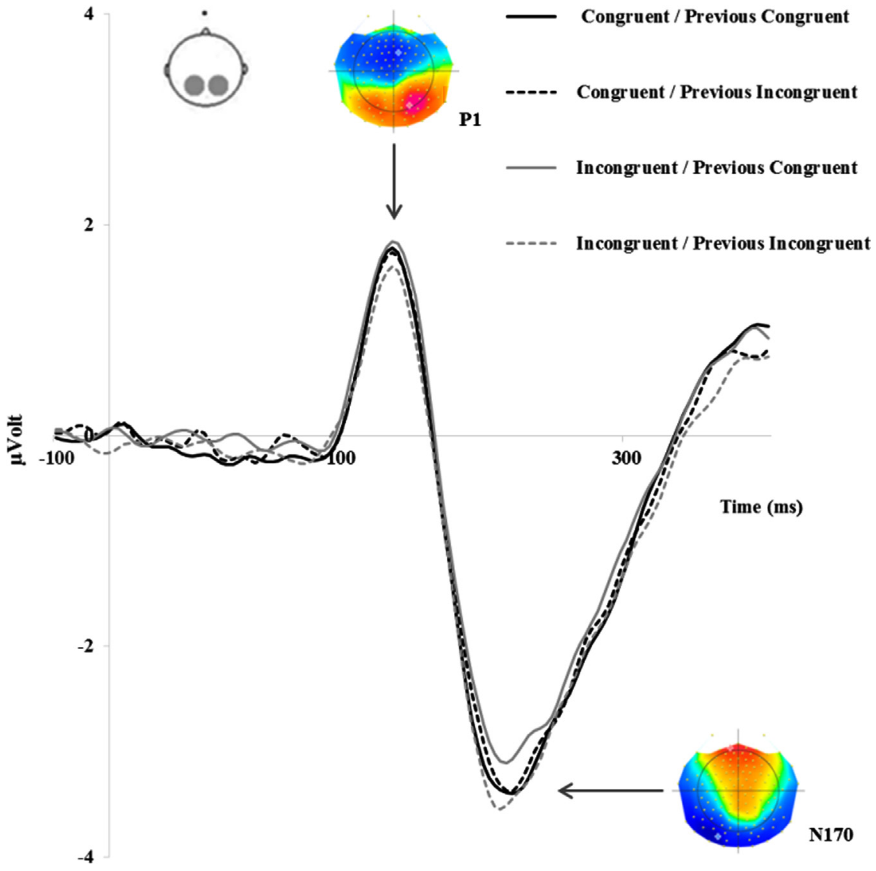

Fig. 4. Topographies during the P1 (top) and N170 time windows (bottom), location of the selected channels (next to T5 and P3) and the ERP of a representative posterior electrode. Positivity is plotted upwards in all figures.

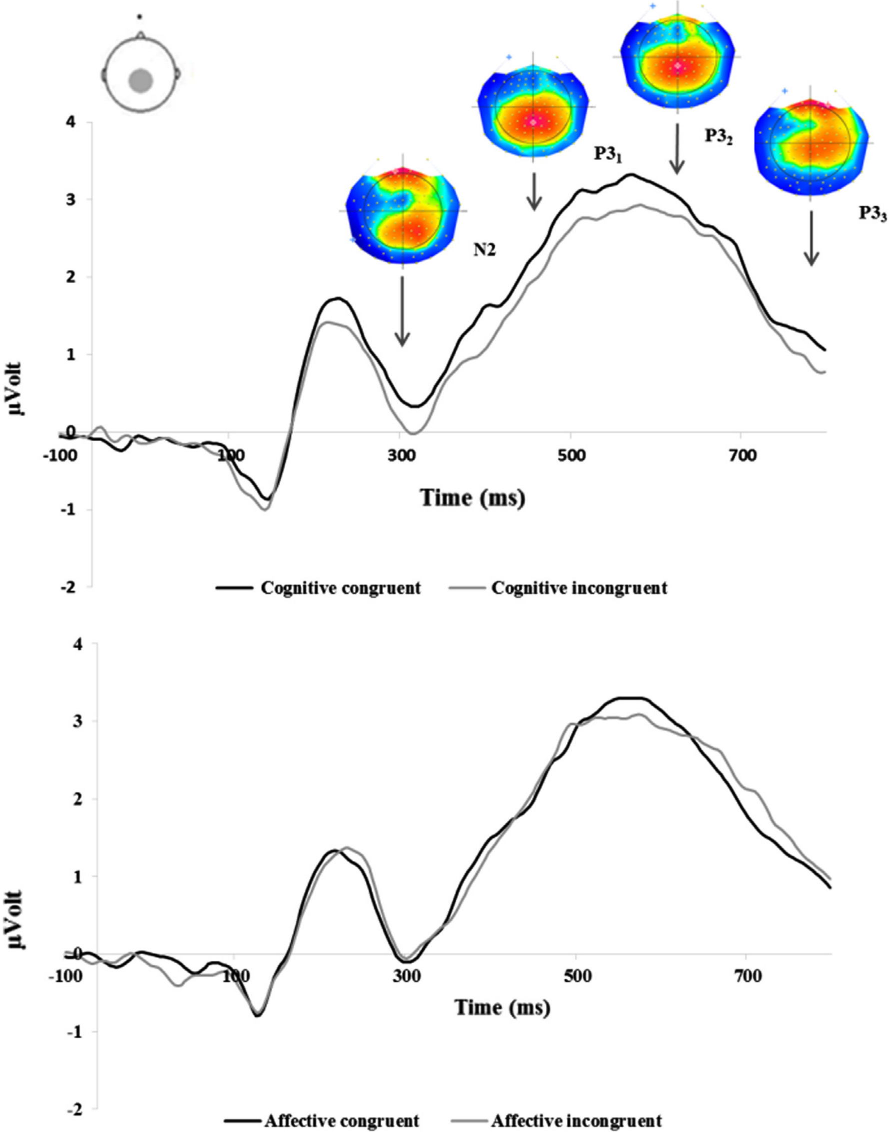

Fig. 5. The display shows the topography (top panel) of the experimental tasks during the N2 and P3 (P3$_1$, P3$_2$ and P3$_3$) time windows (upper panel: cognitive task; bottom panel: affective task), the location of the selected channels and the ERP of a representative central electrode (below Cz) for the current congruency effect in these potentials.

Table 1
Descriptive statistics of behavioral data.

	Cognitive task		**Affective task**	
	Mean ACC (SD)[a]	**Mean RT (SD)**	**Mean ACC (SD)**	**Mean RT (SD)**
Previous congruent				
Current congruent (**CC**)	0.98 (0.14)	638.92 (177.22)	0.98 (0.13)	636.12 (170.89)
Current incongruent (**CI**)	0.97 (0.18)	651.55 (187.57)	0.97 (0.17)	652.87 (179.85)
Previous incongruent				
Current congruent (**IC**)	0.98 (0.15)	643.71 (184.43)	0.98 (0.15)	637.51 (172.99)
Current incongruent (**II**)	0.97 (0.17)	658.02 (187.63)	0.97 (0.16)	652.98 (177.62)

[a] *SD*=Standard deviation.

3.2.3. *Late processing stages*

Following the topographic maps associated with the P3 wave (see Fig. 5), this potential was analyzed in three separate time windows (P3$_1$, from 382 to 614 ms; P3$_2$, from 616 to 700 ms; and P3$_3$, from 700 to 800 ms) over the same central channels.

The P3$_1$ reflected an effect of previous congruency, $F(1,25)=12.054$, $p<0.01$, as the amplitude of trials following congruent trials was larger ($\text{Mn}_{\text{AmpPrevCon}}=2.53$; SD=2.11) than that of those following incongruent trials ($\text{Mn}_{\text{AmpPrevInc}}=2.25$; SD=2.13). There was also a marginal interaction between task and current congruency, $F(1,25)=4.075$, $p=0.05$. A current congruency effect was found only in the cognitive task, $F(1,25)=4.515$, $p<0.05$, as the amplitude of P3$_1$ was larger in the congruent condition ($\text{Mn}_{\text{AmpCon}}=2.49$; SD=2.20) than in the incongruent one ($\text{Mn}_{\text{AmpInc}}=2.25$; SD=2.18). This effect was absent in the affective task, $F<1$ (see Fig. 5).

The analysis of the second time window ($P3_2$) yielded a main effect of previous congruency, $F(1,25)=6.228$, $p<0.05$, as trials following a congruent trial showed a more positive amplitude ($Mn_{AmpPrevCon}=2.32$; $SD=1.98$) than those following an incongruent trial ($Mn_{AmpPrevInc}=2.10$; $SD=2.02$). There were no other significant effects; neither the task factor nor its possible interactions reached significant values, all p's >0.05.

The ANOVA of the averaged amplitudes in the $P3_3$ showed, as in the $P3_1$ analysis, an interaction between task and current congruency, $F(1,25)=4.724$, $p<0.01$. The analysis of the affective task showed an effect of current congruency, $F(1,25)=8.469$, $p<0.01$. This was because the $P3_3$ had a more positive amplitude in the incongruent ($Mn_{AmpInc}=1.39$; $SD=1.91$) than in the congruent condition ($Mn_{AmpCon}=1.06$; $SD=1.74$). The effect of current congruency was absent in the cognitive task, $F<1$. There was an effect of previous congruency, $F(1,25)=5.711$, $p<0.05$, which was better explained by its interaction with the task factor, $F(1, 25)=4.350$, $p<0.05$. Planned comparisons for each task showed an effect of previous congruency only for the cognitive task, $F(1,25)=10.101$, $p<0.01$, which showed larger amplitudes in trials preceded by a congruent one ($Mn_{AmpPrevCon}=1.33$; $SD=1.62$) than in those preceded by an incongruent trial ($Mn_{AmpPrevInc}=0.93$; $SD=1.72$). The effect of previous congruency was absent in the affective task, $p>0.05$. There were no other effects of interest, all p's >0.05 (see Fig. 5).

4. Discussion

The aim of the present study was to extend our knowledge of the differences and similarities in the modulations generated by cognitive and emotional conflict processing and their contextual effects in stimulus processing stages. Our behavioral results showed a higher rate of errors and slower responses in incongruent trials. This slowing down of responses seemed to persist in consecutive trials, as indicated by an effect of previous congruency, although this effect did not reach significance levels in the behavioral data. The set of results of previous and current congruency factors seemed to be equivalent in cognitive and affective tasks. In addition, electrophysiological data suggest the existence of parallel conflict modulations for both kinds of stimuli at initial stages of processing and later dissociations according to the cognitive or affective nature of the task.

Our behavioral results are consistent with previous studies using SRC paradigms with cognitive and affective materials. We replicated the typical conflict effect (Botvinick et al., 2001; Eriksen & Eriksen, 1974). However, we did not observe conflict adaptation effects in the interaction between current and previous congruencies. The reasons for this lack of replication at the behavioral level are unclear. One potential explanation may lie in the differences between the current paradigm and previous SCR tasks. In classic tasks, participants are asked to judge simple features of stimuli, such as their spatial orientation. In the current task, however, participants had to evaluate the meaning of the words. Thus, the heightened cognitive control recruited by incongruent conditions may have not facilitated further conflict resolution but rather set the system in a 'more careful' mode, which would slow down subsequent responses regardless of trial type. This is reminiscent of some observations in the literature about the slowing down of responses owing to control mechanisms: the *post-error slowing effect* and the *bivalence effect*, also known as *post-conflict slowing effect*. The post-error slowing effect happens when participant responses slow down after an error (Botvinick et al., 2001). In the *bivalence effect*, responses to univalent stimuli slow down if they are presented in blocks also containing incongruent bivalent stimuli (Grundy et al., 2011; Woodward, Meier, Tipper, & Graf, 2003; Woodward, Metzak, Meier, & Holroyd, 2008) or if they occur immediately after an incongruent bivalent trial (Verguts, Notebaert, Kunde, & Wühr, 2011). Thus, as Verguts et al. (2011) noted, task difficulties or interruptions such as incongruencies seem to lead to slower task performance in both current congruent and incongruent trials, as is the case in our results.

The P1 and N170 potentials showed conflict adaptation effects for both tasks, although these effects were absent in behavioral indices. Conflict adaptation effects had been previously reported for the P1 (Scerif et al., 2006), in an experiment in which arrow targets were preceded by three consecutive congruent or incongruent trials. Scerif et al. (2006) found that incompatible trials preceded by an incompatible context generated a P1 of larger amplitude than the rest of possible combinations of previous context and current conflict. In their explanation, the sequence in the incongruent context helped attention focus on the location of the target, thus reducing flanker interference in the following incongruent trial (Scerif et al., 2006). We found conflict adaptation effects at early processing stages too, which mimicked the results obtained by Scerif et al. (2006) in the N170 potential but showed the reverse pattern for the P1. In both cases, conflict only modulated the amplitude of the visual potentials in current incongruent trials. However, whereas the amplitude of the P1 was larger for incongruent trials preceded by congruent ones, the N170 was largest for a sequence of two incongruent trials. In contrast to the arrows used by Scerif et al. (2006), participants in our study had to judge the semantic nature of the target words, which calls for a more elaborated processing. While responding to the spatial orientation of arrows depends heavily on the allocation of attention and the spatial arrangement of the flanker and targets, these elements seemed less important for the correct performance of our task or may be more relevant at later stages of processing (e.g. Ruz & Nobre, 2008a).

If heightened amplitude is taken as an index of deeper or more attentive processing (Hillyard et al., 1998; Luck, Fan, & Hillyard, 1993), our results suggest the following: initially, the perception of incongruent targets is boosted when they follow a congruent context (P1 potential) but a few milliseconds later incompatible trials following identical ones are subject to heightened processing (N170 potential); this facilitates the discriminative processing of the stimuli (Hillyard, 2009; Luck et al., 2000). In conflict terms, these sequential patterns could be interpreted as the detection of conflict (P1) and the subsequent implementation of control (N170), respectively. According to the conflict monitoring theory (Botvinick et al., 1999; Egner, 2007; Gratton et al., 1992), current incongruent trials preceded by congruent ones are supposed to reflect a situation low in control (as the previous trial was congruent) but high in conflict (as the current situation is conflictive). The fact that the P1 potential had the largest amplitude in this situation for the cognitive and emotional versions of the task suggests that in both cases the P1 reflected the detection or monitoring of conflict. By contrast, current incongruent trials preceded by others of the same type are thought to reflect a situation of high control and low conflict. As the amplitude of the N170 potential was heightened in this trial sequence, it could be argued that this modulation reflected the implementation of control processes for cognitive and emotional conflicts alike (Botvinick et al., 1999; Egner, 2007).

The lack of sequential effects at the behavioral level argues for caution in the interpretation of the ERP results. It should be noted that Ochsner et al. (2008) used the same paradigm but did not show conflict adaptation (either in behavioral or in neuroimaging data). This suggests that the present paradigm is not best suited to obtain behavioral adaptation effects. However, the electrophysiological findings strongly suggest that these processes take place for both types of conflict at *early* processing stages, which makes them even more intriguing. Electrophysiological data also indicate that response execution stages were no longer affected by adaptation effects (as there were no interactions between current and previous congruency for either task in the P3), which could help explain the lack of adaptation effects in behavioral indexes. In any case, the P1 and N170 results cannot be explained by spurious stimuli repetitions affecting congruent and incongruent trials in a differential manner, as the two conditions were equivalent at the perceptual level and every possible target—flanker combination in our experiment appeared only once in each block. Moreover, as mentioned by Egner (2007), the repetition account is less plausible when a large set of stimuli is used, as is the case in our experiment.

Another relevant outcome from the P1 and N170 potentials was the absence of main or interactive effects of the cognitive vs. affective nature of the task. Although the words used in the two conditions were different, they were equated in average levels of item length, frequency, concreteness and valence, which could help explain the lack of main task effects. Moreover, as suggested by Olofsson, Nordin, Sequeira, and Polich (2008), the processing of affective materials at early stages seems to be more sensitive to negative or unpleasant items when they are confronted with positive or neutral ones. In our manipulation, however, these materials only appeared separately in congruent trials but not in the incongruent ones; hence, we cannot evaluate the conflict effects independently for each valence category. Nevertheless, the outcome of equivalent conflict adaptation effects across the cognitive and affective versions strongly suggests that these early mechanisms are general and common to different task requirements.

The N2 potential, which has been associated with cognitive control using several kinds of paradigms (for a review, see Folstein & Van Petten, 2008), displayed larger negative amplitudes for incongruent than congruent trials during the cognitive task. This pattern is consistent with previous evidence of N2 modulations by focusing attention on targets and filtering out irrelevant stimuli (Luck, 2005). More specifically, an extensive body of literature has reported similar results, using mostly cognitive materials (Folstein & Van Petten, 2008; Kanske & Kotz, 2010b, 2011a; Kopp et al., 1996). N2 modulations seem to be related to the response. Therefore, they are thought to reflect the monitoring of inappropriate planned responses during conflictive situations mediated by the ACC (Van Veen & Carter, 2002) that take place before response execution (Folstein & Van Petten, 2008; Yeung et al., 2004). We also found that the amplitude of the N2 was largest for trials following incongruent ones, which parallels the results obtained at the behavioral level and is consistent with an explanation in terms of conflict monitoring (Yeung et al., 2004). As mentioned above, a close relationship has been suggested between behavioral conflict data and amplitude modulations in the N2 potential (Folstein & Van Petten, 2008; Yeung et al., 2004). It is therefore reasonable to assume that the 'more careful' mode promoted by the resolution of previous incongruences remains in the current trial; this seems to lead to a deeper evaluation of online responses based on those already executed regardless of the current trial type.

By contrast, we did not observe any N2 modulation in the affective task. Although surprising, this result agrees with those recently obtained by Ruz, Madrid, and Tudela (in press). These authors employed a novel paradigm to study the effect of conflictive emotions during interpersonal interactions, in which participants had to judge the emotions displayed by their partners in an economic game. Although emotional conflict was found at the behavioral level, this effect did not modulate the amplitude of the N2 potential. On the other hand, other previous studies have argued that the emotional nature of the materials modulates the N2 (Kanske & Kotz, 2010b, 2011a). These authors used SRC tasks in which participants had to respond according to the cognitive nature of target stimuli displayed upon an affective background. Their results showed larger amplitudes for the affective than for the neutral background along with a conflict effect only for affective materials (Kanske & Kotz, 2010b, 2011a). As these authors themselves explain, their tasks evaluated the influence of affective materials over the resolution of 'cognitive' conflict and not affective conflict resolution per se (Kanske & Kotz, 2011a). Thus, whereas in the current experiment and also in Ruz et al. (in press) participants performed explicit affective evaluations, the results obtained by Kanske and Kotz (2010b, 2011a,b; see also Gootjes, Coppens, Zwaan, Franken, & Van Strien, 2011; Ma, Wang, Wang, Wang, & Wang, 2010; Van Hooff, Dietz, Sharma, & Bowman, 2008) may reflect the influence of the mood induced by the emotional material over cognitive conflict resolution, rather than emotional task-conflict. Further experiments directly comparing explicit and implicit affective evaluations could help clarify this issue.

The last potential explored in our study was the P3 wave, which was divided into three sections ($P3_1$, $P3_2$ and $P3_3$) according to the maps revealed by the topographic analysis. Interestingly, the decision and response processes associated to the P3 (Luck, 2005; Polich, 2006) interacted with the cognitive or affective nature of the task in different epochs, whereas the nature of the previous trial modulated the potential for both tasks. The first part of the P3 displayed larger amplitudes for current congruent trials than for incongruent trials, but only in the cognitive task. This result has been previously obtained in similar studies on cognitive conflict (Neuhaus et al., 2010; Valle-Inclán, 1996a). It has been established that stimuli that are most difficult to resolve usually show lower amplitudes in the P300 than easier ones (Johnson, 1986; Valle-Inclán, 1996b). This evidence is consistent with the inhibition hypothesis proposed by Polich (2006), who postulated the existence of mechanisms involved in the inhibition of 'extraneous' task events underlying P3 modulations. Thus, a correct or higher inhibition would allow a greater available amount of attentional resources for target processing. Hence, incongruent trials that are more difficult to resolve also leave less cognitive resources available and, as a consequence, the incongruent condition generates smaller amplitudes in the P3.

By contrast, this potential was modulated by the current emotional conflict in the last part of the P300. Previous research suggests a special sensitivity of the P3 to the affective nature of the stimuli (Cano, Class, & Polich, 2009; Gootjes et al., 2011; Olofsson et al., 2008; Polich, 2006; Wu & Zhou, 2009). This modulation also resembles the late positive complex/potential (LPC/LPP; Olofsson et al., 2008) commonly studied in emotion paradigms (see Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp, Junghöfer, Weike, & Hamm, 2004). In this epoch, incongruent trials displayed a P3 of larger amplitude than congruent ones, which reverses the pattern observed for the cognitive task in the first P3 section. Chiu et al. (2008) obtained amplitude results that were similar to our findings using an emotional Go/NoGo task. These amplitude variations may reflect a special discriminability of the emotional materials due to their motivational salience (Chiu et al., 2008; Polich, 2006). In a similar way, Zhang, Kong, and Jiang (2012), found a valence congruency effect reflected in larger amplitudes for the incongruent condition in the LPC/LPP. Zhang et al. (2012) explained their results as reflecting a special modulation of the affective stimuli at later processing stages due to the influence of valence over semantic categorization operations.

Finally, in the first two sections of the P3, trials following a congruent trial had a larger amplitude regardless of the type of task, whereas the same modulation was restricted to the cognitive version in the third part of the P3 potential. Thus, it is reasonable to argue that when the previous trial demanded fewer cognitive resources, as was the case in the congruent situation, there were more resources available for the following trials. This could have generated an enhancement of all types of subsequent trials, reflected in larger P3 amplitudes. The absence of this effect in the third part of the wave for the emotional task may be explained by a greater engagement of resources owing to the special salience of affective stimuli, as mentioned above.

Despite all this evidence, one intriguing result is the temporal mismatch between the average speed of responses and the latency of the emotional conflict effect in the third section of the P3 potential. Note that this modulation occurs in a temporal window in which the average response has already taken place, which could be interpreted to mean that the behavioral emotional conflict has no reflection in the ERP data. An explanation for this could be that the modulation observed in the P3 was partly a cortical reflection of conflict-related computations that took place earlier in time (before response execution) in brain regions (i.e. subcortical structures) that are not well-captured by electrophysiological scalp measurements, such as the amygdala (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006; Sabatinelli, Keil, Franka, & Lang, 2013). This subcortical structure, which belongs to the limbic system, seems to have a reciprocal communication with the ACC during affective conflict processing (Etkin et al., 2006). In line with this evidence, similar subcortical areas seem to be engaged in emotion evaluation and their activity may be reflected in the P3 potential (Linden, 2005) and/or the LPC/LPP (Sabatinelli et al., 2013). Therefore, there may exist earlier conflict detection and/or control adjustments for emotional conflict that we are not able to observe with our current methodology and paradigm. On the other hand, the P1 and N170 potentials already track emotional conflict in interaction with the previous context. Similarly, the first two parts of the P3 potential were modulated by the previous context regardless of the type of task. In short, these effects suggest that both types of information processing already respond to the conflictive nature of the materials at early stages and even at the beginning of the P3.

To our knowledge, the current study is the first to conduct a direct comparison of the time course of cognitive and affective conflict processing using EEG recordings in a task including an explicit evaluation of both kinds of materials. Although we found a common conflict effect on behavioral data, the ERP analysis showed both shared and dissociable effects for both tasks. This suggests that the first levels of information processing, mainly perceptual analyses, deal with conflict through the same mechanisms. By contrast, later stages involved in cognitive control and response planning diverge according to the nature of the task requirements generating the conflict. Further studies could be aimed at exploring these commonalities and divergences with different types of materials and probing whether similar effects are found in different settings, such as the social realm.

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