Emotional context modulates response inhibition: Neural and behavioral data

Jacobo Albert *, Sara López-Martín, Luis Carretié

Facultad de Psicología, Universidad Autónoma de Madrid, 28049 Madrid, Spain

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Although recent hemodynamic studies indicate that neural activity related to emotion and that associated with response inhibition constitute closely interrelated and mutually dependent processes, the nature of this relationship is still unclear. In order to explore the temporo-spatial characteristics of the interaction between emotion and inhibition, event-related potentials (ERPs) were measured as participants (N = 30) performed a modified version of the Go/Nogo task that required the inhibition of prepotent responses to neutral cues during three different emotional contexts: negative, neutral, and positive. Temporal and spatial principal component analyses were employed to detect and quantify, in a reliable manner, those ERP components related to response inhibition (i.e., Nogo-N2 and Nogo-P3), and a source-localization technique (sLORETA) provided information on their neural origin. Behavioral analyses revealed that reaction times (RTs) to Go cues were shorter during the positive context than during neutral and negative contexts. ERP analyses showed that suppressing responses to Nogo cues within the positive context elicited larger frontocentral Nogo-P3 amplitudes and enhanced anterior cingulate cortex (ACC) activation than within the negative context. Regression analyses revealed that Nogo-P3 (i) was inversely related to RTs, supporting its association with the inhibition of a prepotent response, and (ii) was associated with contextual valence (amplitude increased as context valence was more positive), but not with contextual arousal. These results suggest that withholding a prepotent response within positively valenced contexts is more difficult and requires more inhibitory control than within negatively valenced contexts.

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Introduction

Response inhibition, defined as the ability to suppress inappropriate thoughts and actions, is an important component of human behavior. Indeed, deficits in response inhibition are prominent in several neurological and psychiatric disorders, including Huntington’s disease (Beste et al., 2008), obsessive-compulsive disorder (Bannon et al., 2000; Herrmann et al., 2003), bipolar disorder (Altshuler et al., 2005; Elliott et al., 2004), and especially attention-deficit/hyperactivity disorder (Pliszka et al., 2000; Rubia et al., 1999; Schulz et al., 2004; Smith et al., 2004). Interestingly, some recent studies on hemodynamic brain responses indicate that neural activity related to emotion and that associated with response inhibition constitute closely interrelated and mutually dependent processes (Elliott et al., 2000; Goldstein et al., 2007; Shafritz et al., 2006). This interaction is well reflected in several prefrontal regions, including the orbitofrontal cortex (OFC) and the anterior cingulate cortex (ACC). However, it remains unclear whether the role of these regions in emotion-modulated response inhibition is related to valence (negative–positive) or to arousal (calming–arousing), two affective dimensions widely considered to explain the principal variance of the emotional meaning (Lang et al., 1993; Osgood et al., 1957; Smith and Ellsworth, 1985). Thus, on the one hand, data exist showing that OFC and ACC increase their activity when subjects inhibit motor responses to arousing stimuli, both negative and positive (Elliott et al., 2000; Goldstein et al., 2007; Shafritz et al., 2006). On the other hand, it has been shown also that valence influences both OFC and ACC inhibition-related activity to a greater extent than arousal, negative stimuli eliciting the highest activation (Goldstein et al., 2007; Shafritz et al., 2006). Taking both affective dimensions into account is therefore necessary to examine whether OFC and ACC interact with valence (negative vs. positive), with arousal (high = both negative and positive vs. low arousal = neutral) or with both.

The studies mentioned above examine emotion-modulated response inhibition using brief presentations of emotional stimuli such as affective words (Elliott et al., 2000; Goldstein et al., 2007) and emotional facial expressions (Goldstein et al., 2007; Hare et al., 2005; Schulz et al., 2009; Shafritz et al., 2006). In natural conditions, however, controlling behavior within long-duration affective situations or contexts is often needed. Emotion- or motivation-related behavioral and neural reactions elicited by short-duration stimuli are obviously not as intense or as complete as those elicited by longer-lasting emotional situations (Bradley et al., 1996; Carretié et al., 2006; Cuthbert et al., 2000; Schupp et al., 2000; Sutton et al., 1997). Thus, using affective contexts may help to evoke clearer affective trends, both approach- and withdrawal-related. On the other hand, the use of...
contexts facilitates the design of indirect tasks (i.e., unrelated to the emotional content of stimulation), which have been recently recommended for the study of emotion-modulated response inhibition (Goldstein et al., 2007). Moreover, brain responses elicited by emotional stimuli in direct or explicit tasks (e.g., tasks in which participants are asked to direct their controlled resources to the affective content of stimulation) are different from those elicited in indirect or implicit tasks (Carretié et al., 2006; Hariri et al., 2003; Taylor et al., 2003).

Due to their high temporal resolution and their capability for providing information on the origin of the recorded activity through source-localization algorithms, event-related potentials (ERPs) are particularly well suited to study emotion-modulated response inhibition. Both emotion and response inhibition are characterized by involving rapid (short latency) and brief (short duration) subprocesses, some of the most important occurring within the first 600 ms after stimulus onset (e.g., Bokura et al., 2001; Carretié et al., 2001; Kiefer et al., 1998; Olofsson et al., 2008). Data currently available indicate that the P3 component of the ERPs is a robust index of inhibition. This component is usually obtained through the Go/Nogo paradigm, which involves both execution (Go trials) and inhibition (Nogo trials) of motor responses. This paradigm typically elicits two components, maximal over frontocentral areas, whose amplitudes are larger in Nogo than in Go trials: N2 (200–400 ms) and P3 (300–500 ms) (Bokura et al., 2001; Eimer, 1993; Kiefer et al., 1998; Pfefferbaum et al., 1985). The Nogo-N2 and Nogo-P3 components reflect different aspects of response inhibition, Nogo-N2 mirroring a wide range of cognitive control processes that are not strictly circumscribed to the inhibitory process itself. For example, it has also been linked to effortless attention, detection of response conflict, and action monitoring (Donkers and van Boxtel, 2004; Nieuwenhuis et al., 2003; van Veen and Carter, 2002; Yeung et al., 2004). By contrast, Nogo-P3 has been primarily related to the inhibitory process itself (Briuñ et al., 2001; Smith et al., 2006, 2008) and, less commonly, to the evaluation of the outcome of inhibition (Briuñ et al., 2001; Roche et al., 2005). Source-localization algorithms applied to scalp ERP recordings suggest that several prerfrontal areas, including the OFC and especially the ACC, are involved in the generation of Nogo-N2 and Nogo-P3 (Beste et al., 2008; Bokura et al., 2001; Fallgatter et al., 2002; Kiefer et al., 1998).

The present study aimed to examine the influence of emotional context on response inhibition using ERPs in conjunction with a source-localization technique. To this end, we used a modified version of the Go/Nogo task that required the inhibition of prepotent responses to neutral cues during three different emotional contexts generated by pictorial backgrounds: negative, neutral, and positive. The use of pictorial material may potentiate affect-related neural processes in Go/Nogo tasks (Chiu et al., 2008), due to its greater arousing power (Hinojosa et al., 2009; Keil, 2006). As mentioned above, Nogo-N2 and Nogo-P3 have been associated with different aspects of response inhibition, so analyses focused on these components. Moreover, participants provided subjective ratings of each emotional context so discrimination of valence from arousal effects on neural and behavioral data was facilitated.

Methods

Participants

Thirty students (16 women) from the Universidad Autónoma de Madrid, with an age range of 20–38 years (mean = 22.83 years; standard deviation = 3.07) took part in this experiment. Participants reported normal or corrected-to-normal visual acuity. All students provided informed consent and received course credit for their participation. The study was approved by the Research Ethics Committee of the Universidad Autónoma de Madrid.

Stimuli and procedure

Stimuli consisted of two capital letters (‘M’ and ‘W’; ‘Arial’ font) and 9 pictures used as background contexts (3 positive, 3 neutral, and 3 negative). Angles of vision were 5.16° (height) for letters and 75.17° for background images. Letters were coloured in yellow and outlined in solid black so they are clearly highlighted from the background, on which they were superimposed. Pictures used as background contexts were taken from the International Affective Picture System (IAPS; Lang et al., 2005). These images were selected on the basis of their scores in arousal and valence taking into account our previous experience with Spanish samples. Moreover, each participant filled out a bidimensional scaling test for each picture after the recording sessions, assessing each picture valence and its arousal level. Table 1 shows the means and standard deviations on both dimensions for each type of emotional context (negative, neutral, and positive). As explained later (Results section), regression analyses revealed that valence but not arousal explained the observed experimental effects. Furthermore, images of each emotional context were matched in mean luminance and spatial frequency (information on spatial frequency of IAPS pictures is provided in Delplanque et al., 2007).

Subjects were placed in an electrically shielded, sound-attenuated room. They were instructed to press a button with the thumb of their right hand, as fast and accurate as possible, whenever the letter “M” (Go) was presented, and to withhold pressing when the letter presented was “W” (Nogo). They were asked to look continuously at the center of the screen and to refrain from blinking during block runs, in order to control eye–movement interference. Between each experimental block (1 minute), they were allowed to rest. Participants performed the task during three different emotional contexts generated by pictorial backgrounds: negative, neutral, and positive. The order in which they were presented was counterbalanced across subjects in a Latin-square design. Each emotional context contained 133 letters (93 Go and 40 Nogo) presented in three blocks. Thus, percentage of Nogo trials in each emotional context was 30%. Each block within each emotional context had a different picture as background. Go and Nogo trials were presented in semi-random order (i.e., avoiding the consecutive presentation of two Nogo trials) within each block. Nogo trials could be preceded by one to four Go trials. Each trial began with the presentation of the letter M or W (200 ms), followed by a fixation cross (800 ms); 500 ms later, the next letter appeared. Both letter and fixation cross were superimposed on the center of the background picture (Fig. 1). An animation reproducing several Go and Nogo trials within negative, neutral, and positive context blocks as well as their temporal characteristics can be seen at http://www.uam.es/carretie/grupo/EmotionalGoNogotask.htm.

Before the beginning of the experiment, subjects completed a practice block of 12 trials (8 Go and 4 Nogo) with a neutral picture as a background, to ensure task instruction understanding. The experimental task was programmed using Inquisit Millisecond software (Millisecond Software, 2006) and presented through an RGB projector on a backprojection screen.

Table 1

<table>
<thead>
<tr>
<th>Emotion Context</th>
<th>Valence (Mean ± SD)</th>
<th>Arousal (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative</td>
<td>1.54 (0.54)</td>
<td>1.13 (0.21)</td>
</tr>
<tr>
<td>Neutral</td>
<td>3.13 (0.21)</td>
<td>2.9 (0.44)</td>
</tr>
<tr>
<td>Positive</td>
<td>4.39 (0.35)</td>
<td>3.71 (0.72)</td>
</tr>
</tbody>
</table>

Means and standard deviations (in parentheses) of valence and arousal assessments given by the 30 participants to the three types of emotional context (Negative, Neutral, and Positive).

After asterisks, the IAPS code of employed pictures is provided.

* 1301, 6410, 9330.
** 7006, 2190, 7185.
*** 8210, 7400, 2352.


df
ERPs, components explaining most of the ERP variance in the ERP analysis performed using Emotional context (three levels: Negative, Neutral, and Positive).

With regard to RTs, a univariate repeated-measures ANOVA was carried out for the relevant temporal factors (those corresponding to N2 and P3). Also in this case, the decision on the number of factors to select was based on the scree test, and extracted factors were submitted to promax rotation.

**Recording**

Electroencephalographic (EEG) activity was recorded using an electrode cap (ElectroCap International) with tin electrodes. Thirty electrodes were placed at the scalp following a homogeneous distribution. All scalp electrodes were referenced to the nose tip. Electrooculographic (EOG) data were recorded supra- and infraorbitally (vertical EOG), as well as from the left versus right orbital rim (horizontal EOG). A band-pass filter of 0.3 to 40 Hz was applied. Recordings were continuously digitized at a sampling rate of 210 Hz throughout the recording session. The continuous recording was divided into 1000-ms epochs for each trial, beginning 200 ms before stimulus onset. Trials in which subjects responded outside the inter-trial interval (1500 ms) or erroneously were eliminated. Epochs containing eye movements or blinks over 100 μV in amplitude were deleted. For the rest of the epochs, the EEG artifact removal procedure described by Gratton et al. (1983) was applied whenever EOG activity was observed. Behavioral performance was recorded through a two-button keypad whose electrical output was continuously digitized at a sampling rate of 840 Hz.

**Data analysis**

All statistical analyses described below were carried out using the SPSS software package (Version 15.0; SPSS Inc, Chicago, USA). In all statistical contrasts involving analyses of variance (ANOVAs), the Greenhouse–Geisser (GG) epsilon correction was applied to adjust the degrees of freedom of the F-ratios, and post hoc comparisons to determine the significance of pairwise contrasts were made using the Bonferroni procedure (\(\alpha<0.05\)).

**Behavioral analysis**

Omission and commission error rates (i.e., no responses in Go trials and button presses in Nogo trials, respectively, divided by the number of trials; these measures range from 0 to 1) and reaction times (RTs) to Go stimuli were analyzed. In the case of RTs, outliers, defined as responses above 1500 ms or below 150 ms, were omitted in the analyses. Repeated-measures ANOVAs on error rates were carried out with respect to Trial type (two levels: Go and Nogo) and Emotional context (three levels: Negative, Neutral, and Positive). With regard to RTs, a univariate repeated-measures ANOVA was performed using Emotional context (three levels: Negative, Neutral, and Positive) as a factor.

**ERP analysis**

With the aim of testing whether N2 and P3 were present in the ERPs, components explaining most of the ERP variance in the temporal domain were detected and quantified through covariance-matrix-based temporal principal component analysis (tPCA). This technique has been repeatedly recommended since the exclusive use of traditional visual inspection of grand averages and voltage computation may lead to several types of misinterpretation (Chapman and McCreary, 1995; Coles et al., 1986; Donchin and Heffley, 1978; Fabiani et al., 1987). The main advantage of tPCA over traditional procedures based on visual inspection of recordings and on ‘temporal windows of interest’ is that it presents each ERP component separately and with its ‘clean’ shape, extracting and quantifying it free of the influences of adjacent or subjacent components. Indeed, the waveform recorded at a site on the head over a period of several hundreds of milliseconds represents a complex superposition of different overlapping electrical potentials. Such recordings can stymie visual inspection. In brief, tPCA computes the covariance between all ERP time points, which tends to be high between those time points involved in the same component and low between those belonging to different components. The solution is therefore a set of independent factors made up of highly covarying time points, which ideally correspond to ERP components. Temporal factor score, the tPCA-derived parameter in which extracted temporal factors may be quantified, is linearly related to amplitude. In the present study, the decision on the number of components to select was based on the scree test (Cliff, 1987). Extracted components were submitted to promax rotation, as recently recommended (Dien et al., 2005). As explained in detail later, the presence of N2 and P3 was confirmed.

Signal overlapping may also occur at the space domain. At any given time point, several neural processes (and hence, several electrical signals) may concur, and the recording at any scalp location at that moment is the electrical balance of these different neural processes. While temporal PCA “separates” ERP components along time, spatial PCA (sPCA) separates ERP components along space, each spatial factor ideally reflecting one of the concurrent neural processes underlying each temporal factor. Additionally, sPCA provides a reliable division of scalp into different recording regions, an advisable strategy prior to statistical contrasts, since ERP components frequently behave differently in some scalp areas than in others (e.g., they present opposite polarity or react differently to experimental manipulations). Basically, each region or spatial factor is formed with the scalp points where recordings tend to covary. As a result, the shape of the sPCA-configured regions is functionally based and scarcely resembles the shape of the geometrically configured regions defined by traditional procedures. Moreover, each spatial factor can be quantified through the spatial factor score, a single parameter that reflects the amplitude of the whole spatial factor. Therefore, sPCAs were carried out for the relevant temporal factors (those corresponding to N2 and P3). Also in this case, the decision on the number of factors to select was based on the scree test, and extracted factors were submitted to promax rotation.
Finally, repeated-measures ANOVAs on N2 and P3 spatial factor scores were carried out with respect to Trial type (two levels: Go and Nogo) and Emotional context (three levels: Negative, Neutral, and Positive). First, the main effect of Trial type was analyzed to confirm that both N2 and P3 were associated with response inhibition (i.e., they showed larger amplitudes in Nogo than in Go trials). Subsequently, the Trial type × Emotional context interaction was also contrasted to examine the modulatory influence of emotional context specifically on Nogo-N2 and Nogo-P3.

Source-localization analysis

In order to three-dimensionally locate the cortical regions that were sensitive to the experimental effects, standardized low-resolution brain electromagnetic tomography (sLORETA; Pascual-Marqui, 2002) was applied to relevant temporal factor scores. sLORETA is a 3D discrete linear solution for the EEG inverse problem. Although, in general, solutions provided by EEG-based source-location algorithms should be interpreted with caution due to their potential error margins, LORETA solutions have shown significant correspondence with those provided by hemodynamic procedures in the same tasks (Dierks et al., 2000; Mulert et al., 2004; Vitacco et al., 2002), including the Go/Nogo paradigm (Chiu et al., 2008). Moreover, the use of tPCA-derived factor scores instead of direct voltages (which leads to more accurate source-localization analyses: Carretié et al., 2004b) and the relatively large sample size employed in the present study (N = 30), contribute to reducing this error margin. In its current version, sLORETA computes the standardized current density at each of 6239 voxels in the cortical gray matter and the hippocampus of the digitized Montreal Neurological Institute (MNI) standard brain. Specifically, a two-step analysis was carried out for the relevant temporal factors to identify the neural mechanisms underlying emotion-modulated response inhibition. Firstly, brain regions involved in response inhibition (not taking into account emotional categories) were located. To that aim, the voxel-based whole-brain sLORETA-images were compared between Nogo and Go conditions using the sLORETA built-in voxelwise randomization tests (5000 permutations) based on statistical non-parametric mapping (SnPM) methodology (for details, see Nichols and Holmes, 2001). Secondly, a region-of-interest (ROI) approach was performed in order to explore the modulatory influences of emotional context on those regions detected in the first step as response inhibition-related. ROIs (radius = 5 mm) were defined across subjects and Nogo conditions by sLORETA according to the coordinates found in the previous step. Subsequently, current densities were computed for these ROIs and submitted to univariate repeated-measures ANOVAs using Emotional context (three levels: Negative, Neutral, and Positive) as a factor.

Results

Behavioral data

Table 2 shows mean RTs, omission, and commission error rates in the task for the three types of emotional contexts. Repeated-measures ANOVAs on error rates with respect to Trial type and Emotional context were carried out, as previously described. As expected, a significant main effect of Trial type was observed: error rates were higher for Nogo (i.e., commission errors) than for Go trials ( omission errors) ( F(1,29) = 62.66, p < 0.05). However, the Trial type × Emotional context interaction did not yield significant differences: neither omission nor commission errors were modulated by the emotional context. By contrast, univariate repeated-measures ANOVA on RTs to Go stimuli showed significant differences between emotional contexts ( F(2,58) = 4.12, GG epsilon = 0.993, p < 0.05). Bonferroni post hoc tests showed that RTs to Go cues were shorter in the positive context than in the negative and neutral contexts.

ERP data

Fig. 2 shows a selection of grand averages once the baseline value (prestimulus recording) had been subtracted from each ERP. These grand averages correspond to the frontocentral scalp area, where experimental effects (described later) were most prominent. As a
consequence of the application of the tPCA, five components were extracted from the ERPs (Fig. 3). Factor peak latency and topography characteristics associate Factor 4 (peaking at 319.04 ms) with the wave labeled N2 in grand averages and Factor 2 (peaking at 457.14 ms) with that labeled P3. These labels will be employed hereafter to make the results easier to understand. As shown in Table 3, the sPCAs subsequently applied to temporal factor scores extracted three spatial factors for both N2 and P3.

Repeated-measures ANOVAs on N2 and P3 spatial factor scores (directly related to amplitudes, as previously indicated) were carried out for Trial type and Emotional context factors. First, the effect of Trial type alone helped to confirm that N2 and P3 amplitudes were associated with response inhibition: as expected, they were larger in Nogo relative to Go trials at frontocentral regions but also at posterior areas (Table 3a). The second objective of the analyses was to examine whether Nogo-N2 and Nogo-P3 amplitudes were modulated by the emotional context. In this case, the Trial type × Emotional context interaction was the relevant contrast. This interaction was significant in frontocentral P3 (Table 3b): post hoc comparisons indicated that whereas P3 amplitude at this region differed as a function of the emotional charge of the context in Nogo trials, no differences were observed in Go trials. Specifically, Nogo-P3 amplitude was larger in the Positive context than in the Negative context.

**Relationship between emotional assessments, behavior, and ERP**

An important question was to estimate the emotional dimension explaining the experimental effects on ERPs described above. Although it is reasonable to deduce from previous analyses that valence more than arousal explains results concerning the Nogo-P3 component, since differences between Positive context and Negative context are clear (see Fig. 2), this trend must be statistically confirmed. Therefore, the association between frontocentral Nogo-P3 amplitudes and valence and arousal ratings given by subjects to background pictures in the questionnaire was analyzed via multiple regression using the stepwise method. Nogo-P3 amplitude was the predictor variable, and predictor variables were RTs and commission error rates. RTs associated significantly with Nogo-P3 amplitude ($\beta=-0.398$, $p<0.001$), while commission errors did not. Specifically, the linear association pattern between frontocentral Nogo-P3 amplitudes and RTs showed a negative slope: the greater the former, the shorter the latter.

**Source-localization data**

The last analytic step consisted of three-dimensionally localizing the cortical regions that were responsible for the experimental effects described above. To this end, P3 temporal factor scores of each subject, electrode and condition were submitted to sLORETA. First, the voxel-based whole-brain sLORETA images were compared between Nogo and Go conditions using non-parametric randomization tests in order to identify the cortical regions involved in response inhibition. As illustrate in Fig. 4, ACC ($x=5, y=25, z=20$; BA 24/33) showed significantly greater activation during response inhibition (Nogo conditions) than during response execution (Go conditions). Second, an ROI approach was used to examine whether inhibition-related ACC activation was modulated by the emotional context. The ACC ROI was defined (radius = 5 mm) according to the coordinates found in the previous non-parametric tests and was computed specifically for Nogo conditions. Univariate repeated-measures ANOVA revealed that inhibition-related ACC activation was sensitive to the emotional context ($F(2,58)=3.432$, GG epsilon = 0.947, $p<0.05$), specifically, post hoc comparisons showed greater activation during the Positive context than during the Negative context.

**Discussion**

The present study aimed to examine the influence of emotional contexts on response inhibition at the neural and behavioral levels. Results have shown that the inhibition of prepotent responses to neutral cues during the positively valenced context elicited larger frontocentral Nogo-P3 amplitudes and stronger ACC activation than during the negatively valenced context. These data suggest that positive situations require, to a greater extent than negative ones, the mobilization of inhibitory resources. This conclusion is also supported by regression analyses between ERPs and emotional assessments. Concretely, these analyses showed that valence (but not arousal) was associated with Nogo-P3: its amplitude increased as context valence was more positive. Taking into account all these data, it is quite reasonable to propose that withholding a prepared response within positively valenced contexts is more difficult and consumes greater inhibitory resources than within negatively valenced contexts.

Approach and withdrawal constitute two basic behavioral patterns mediating different forms of motivation and emotion. It is well

![Fig. 3](image_url)

Fig. 3. tPCA: factor loadings after promax rotation. Temporal factors 4 (N2) and 2 (P3) are drawn in black.
established that negative emotions elicit withdrawal-related behaviors, whereas positive emotions facilitate approach-related behaviors and continued action (Cacioppo and Gardner, 1999; Lang et al., 1997). Thus, it is not surprising that subjects responded faster to Go cues within the positively valenced context and then they had greater difficulty overriding prepotent responses to Nogo cues within this emotional context. Previous experiments have shown that facial expressions of happiness elicit faster behavioral and neural responses (Batty and Taylor, 2003; Kirita and Endo, 1995; Leppänen et al., 2003; Leppänen and Hietanen, 2004; Schulz et al., 2007) and, further, that these responses are more difficult to inhibit than those to sad or fearful faces (Hare et al., 2005; Schulz et al., 2007). In this regard, some recent behavioral data suggest that, in contrast with the narrowing of attentional focus during negative affective states, positive affect enhances the scope of attention by reducing the functionality of inhibitory control mechanisms (Rowe et al., 2007). These findings have been interpreted within the “broaden-and-build” theory (Fredrickson, 2004), which proposes that positive emotions broaden people’s momentary thought–action repertoires due to a reduction or absence of inhibitory functioning.

Another important question to be discussed is the nature of the neural mechanisms underlying Nogo-P3. Research indicates that Nogo-N2 and Nogo-P3 may represent different aspects of response inhibition. The former has been associated with pre-motor inhibition (Falkenstein et al., 1999), response activation (Bruin et al., 2001), and especially conflict monitoring (Donkers and van Boxtel, 2004; Nieuwenhuis et al., 2003; Yeung et al., 2004). The latter has been primarily related to the inhibitory process itself (Bruin et al., 2001; Smith et al., 2006, 2008) and, less commonly, to the evaluation of the outcome of inhibition (Roche et al., 2005). The fact that Nogo-P3, but not Nogo-N2, was modulated by the emotional context may suggest that emotion interacts specifically with the inhibitory process itself. In this same sense, the regression analyses between Nogo-P3 amplitudes and RTs support the role of this component in the inhibition of a prepotent response, since faster responses to Go cues were associated with larger Nogo-P3 amplitudes to Nogo cues. In other words, these data may be interpreted as showing that a greater mobilization of inhibitory resources (i.e., Nogo-P3 amplitudes) is necessary to suppress faster responses. Similar results were obtained in a previous experiment using the stop signal task (Dimoska et al., 2006), another behavioral task to address inhibitory control, which, in this case, so the ACC activity may be the outcome of multiple cognitive and affective processes involved in Go/Nogo tasks. Indeed, the ACC has been shown to play a role in attentional control, conflict monitoring, inhibition itself, and error processing (Devinsky et al., 1995; Garavan et al., 2001; Canli et al., 1998, 2001; Garavan et al., 2001; Kim and Hamann, 2007).

In the present study, however, regression analyses suggest that inhibition-related neural activity was associated with valence rather than with arousal. Second, hemodynamic procedures record an accumulation of activity over relatively long periods (several seconds) so the ACC activity may be the outcome of multiple cognitive and affective processes involved in Go/Nogo tasks. Indeed, the ACC has been shown to play a role in attentional control, conflict monitoring, inhibition itself, and error processing (Devinsky et al., 1995; Garavan et al., 2002; Menon et al., 2001), which may intervene in these tasks. Third, previous hemodynamic investigations examined brain activity associated with the inhibition of responses to emotional stimuli, whereas the present research explored neural activity related to the inhibition of responses to neutral stimuli within emotional back-ground contexts. Future studies are required to clarify the role of ACC in the interaction of response inhibition and emotional valence and arousal.

In summary, the present results indicate that emotional context has a modulatory effect on response execution and response inhibition at the behavioral and neural levels, respectively. On the one hand, behavioral data showed that RTs to neutral Go cues were shorter during the positive context than during the neutral and negative contexts. On the other hand, electrophysiological data revealed that suppressing prepotent responses to neutral Nogo cues within the positive context elicited larger Nogo-P3 amplitudes and stronger ACC activation than within the negative context. Moreover, regression analyses showed that Nogo-P3 interacts with valence rather than with arousal-related contextual information. This study shows that contextual inhibitory paradigms may be a useful approach to examine the interaction of emotion and response inhibition, since they may help to elicit clearer affective tendencies (both approach- and withdrawal-related) during the Go/ Nogo task, and therefore may be more capable of eliciting stronger activation of inhibition-related neural mechanisms. Further research employing a wide range of experimental tasks and designs, as well as recording methodologies that may improve the spatial resolution of EEG data, is needed to substantiate and extend these findings.
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