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Sex differences in emotional contexts modulation on response inhibition

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ABSTRACT

The aim of the present study was to explore sex differences in the effects that emotional contexts exert on the temporal course of response inhibition using event-related potentials (ERP). Participants performed a Go-NoGo response inhibition task under 3 context conditions: with 1) neutral background stimuli, and 2) pleasant, and 3) unpleasant emotional contexts. No sex differences were found in relation to accuracy. Women showed higher N2NoGo amplitudes than men in both emotional contexts; whereas during inhibition men tended to show higher P3NoGo amplitudes than women in the unpleasant context. Both groups experienced a relevant effect of the presence of the unpleasant context during inhibition processing, as shown by the enhancement of the N2NoGo amplitudes in frontal regions compared to results from the neutral and pleasant conditions. In addition, women showed differences between the pleasant and unpleasant contexts, with the latter inducing higher amplitude values. Only in men did inhibition accuracy correlate with higher N2NoGo and lower P3NoGo amplitudes in the emotional context conditions. These findings suggest that when an inhibition task is performed in an emotionally-neutral background context no sex differences are observed in either accuracy or ERP components. However, when the emotional context was introduced –especially the unpleasant one– some gender differences did become evident. The higher N2NoGo amplitude at the presence of the unpleasant context may reflect an effect on attention and conflict monitoring. In addition, results suggest that during earlier processing stages, women invested more resources to process inhibition than men. Furthermore, men who invested more neural resources during earlier stages showed better response inhibition than those who did it during later processing stages, more closely-related to cognitive and motor inhibition processes.

1. Introduction

In recent decades, considerable evidence has emerged in relation to sex differences in diverse cognitive processes (see Pletzer (2014) for a review). In particular, we are interested in studying differences between women and men in inhibitory control processing, as this is a core component in behavioral and emotional regulation, prepotent response withholding, interference control in selective attention, and generating adaptive responses in the presence of emotional contexts. The few neuroimaging studies that have addressed sex differences in response inhibition found no differences in inhibition accuracy, but did observe such differences in brain structure activation during inhibition tasks, including higher activation of the anterior cingulate in men (Liu et al., 2012), and enhanced activity in the middle frontal gyrus, the inferior parietal lobule, the right superior, middle and inferior temporal gyri, and the thalamus, lentiform and cerebellum in women during a Go/NoGo task (Garavan et al., 2006).

Those studies probed sex differences in brain functioning during response inhibition in the absence of emotional stimuli, but such stimuli are common in daily life situations and so exert an influence on cognitive processing and decision-making. Therefore, the study of sex-differentiated, emotion-related influences is highly-relevant. Indeed, several studies have described sex differences in emotional perception, experience, expression and regulation, in the strategies employed by women and men during emotional processing, and in the underlying neural mechanisms that may contribute to such differences (for reviews, see Whittle

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et al. (2011) and Kret and De Gelder (2012)).

One neuroimaging study that did explore sex differences in inhibition processing in the presence of emotional stimuli found that women and men activate different neuronal networks while performing inhibitory tasks (Li et al., 2006). Those authors observed that despite the absence of sex differences in behavioral performance in a stop-signal paradigm, variations were detected in neural areas and the breadth of their activation, as well as in hemispheric participation. Li et al. (2006) described that men showed a higher activation than women in cortical and subcortical regions, perhaps indicating that the latter employ fewer neural resources during inhibition processing because they apply more efficient strategies.

One of the most common strategies used to evaluate inhibitory processes is based on inhibiting prepotent responses using a Go/NoGo paradigm. A high rate of presentation of a frequent stimuli (Go) to which the subject must respond to, induces the establishment of a prepotent response, while a low rate of an infrequent stimuli (NoGo), where subjects must withhold their responses, makes it possible to evaluate inhibitory abilities (Aron et al., 2004). Temporal activation of the neural substrates involved in prepotent response inhibition during Go/NoGo tasks has been studied using the event-related brain potential (ERP) technique due to its high temporal resolution. The main ERP components associated with inhibition seem to be N2 and P3. N2 is a negative frontocentral deflection that peaks between 200 and 400 ms after stimulus, with higher amplitude in NoGo than Go trials. It has been suggested that N2 reflects responses to novelty, attentional control, conflict resolution, and inhibition processes associated with frontal cortex functioning (Bokura et al., 2001; Folstein and Van Petten, 2008; Zhang and Lu, 2012). P3 component is a positive deflection with a maximum peak between 300 and 600 ms after stimulus. This component also shows higher amplitudes on NoGo than Go trials in fronto-central regions, while a reverse pattern occurs in central-parietal areas. It has been suggested that this NoGo component also reflects cognitive and motor inhibition processes as well as the evaluation of inhibitory performance (Bokura et al., 2001; Bruin et al., 2001; Smith et al., 2008).

Several studies have provided evidence of the effects of emotion on cognitive processes based on ERP. Affective stimuli can modulate ERP across several processing stages (see Olofsson et al. (2008) for a review). Regarding response inhibition, Verbruggen and De Houwer (2007) mentioned an interference effect of high-arousal emotional stimuli, suggesting that affective stimuli exert an influence on cognitive processes because they divert attentional resources due to their adaptive importance. Zhang and Lu (2012) proposed that N2Go is modulated by emotions and reflects top-down attention, while GoP3 reflects motivational relevance. Regarding the inhibition process, they point out that while N2NoGo is related primarily to attentional monitoring of conflict, P3NoGo modulation by valence overlapped with the automatic response inhibition of emotion. In their work, Ramos-Loyo et al. (2013) have observed that face emotional valence interferes with response inhibition, as evidenced by higher P3 amplitudes and longer N2 and P3 latencies, while Albert et al. (2010) reported that suppressing responses to NoGo cues in a positive context elicited larger frontocentral P3 amplitudes. Thus, it is clear that dealing with highly-salient stimuli has an important effect on inhibition processing. However, we are not aware of any ERP study regarding sex differences in the influence of emotional contexts on inhibition processing.

In support of studies which have found that women react more to negative stimuli, while men react more strongly to positive ones –particularly erotic pictures– (Bradley et al., 2001; Lithari et al., 2010; Gardener et al., 2013), sex differences in ERP have been observed when subjects view pictures with emotional content. While observing negative pictures, more robust P3 effects are elicited in the left hemisphere in women than men, but in the right hemisphere in men compared to women (Gasbarri et al., 2007). Due to the greater effect of negative emotional stimuli observed in women compared to men, we assumed that it would be more difficult for the former to disentangle attention from this kind of stimuli, and that this would affect response inhibition, whereas men would find it more difficult to inhibit positive stimuli. We hypothesized that these differences would be reflected in ERP components. In addition, we expected that emotional contexts, particularly unpleasant ones, would hinder inhibition processing, since they attract more attention and so create a distraction from the main task. To our knowledge, only one neuroimaging study has explored sex differences in inhibition processing while emotional stimuli were present in a stop-signal paradigm (Li et al., 2006), while one other evaluated the effect of emotional contexts on response inhibition by means of ERPs in a Go/NoGo task (Albert et al., 2010), but without considering sex differences.

Based on these antecedents, the objective of the present study was to explore sex differences in the effects that emotional contexts exert on the temporal course of response inhibition using ERP in a Go/NoGo paradigm.

2. Method

2.1. Participants

Thirty healthy, right-handed volunteers participated in the study: 15 men (X=27, SD=2.10 years old) and 15 women (X=28.45, SD=2.7 years old). All had graduate studies, and none reported neurological or psychiatric antecedents, or were under medical treatment. Any potential subject who was taking a drug or substance known to affect nervous system functions was not included. Due to there are several studies that have demonstrated an effect of sex steroid hormones in cognition (Hamson et al., 2016) and brain activity (Goldstein et al., 2010; Solís-Ortiz et al., 1994; Zhang et al., 2013), data from women' cycles were obtained regarding cycle regularity and the first day of their last menstruation. Thereafter, the approximate cycle phase was calculated for each woman: follicular phase was defined as days 1–14 (n=7) and luteal phase as days 15–28 (n=8). Participants gave their written informed consent after the experimental procedures were fully explained. The study was previously approved by the Ethics Board of the Institute of Neuroscience.

2.2. Stimuli and experimental procedures

Subjects were seated comfortably in front of a computer screen at a distance of 60 cm, where the Go/NoGo response inhibition task was presented under 3 conditions: neutral context (NC), and pleasant (PC) and unpleasant (UC) emotional contexts. They were instructed to press a key when an arrow located in the middle of the screen coincided in both direction (left or right) and color (green, red or blue) with a bar presented on the left or right edge (Go), but withhold the response when it did not match (NoGo).

Emotional stimuli from the International Affective Picture System (IAPS, Lang et al., 1997) were used. A total of 60 images, 30 with pleasant and 30 with unpleasant contents, were presented. All subjects were shown the same neutral, pleasant (adventures, couples) and unpleasant (disgust, fear, violence) images, though some (5 images) of the pleasant stimuli showing opposite sex models differed for women and men. The neutral context consisted of scrambled versions of the same pleasant and unpleasant images. The pleasant and unpleasant images that obtained the highest emotional scores in similar groups of women and men