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Electrophysiological and behavioral evidence of gender differences in the modulation of distraction by the emotional context

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ABSTRACT

Gender differences in brain activity while processing emotional stimuli have been demonstrated by neuroimaging and electrophysiological studies. However, the possible differential effects of emotion on attentional mechanisms between women and men are less understood. The present study aims to elucidate any gender differences in the modulation of unexpected auditory stimulus processing using an emotional context elicited by aversive images. Fourteen men and fourteen women performed a well-established auditory–visual distraction paradigm in which distraction was elicited by novel stimuli within a neutral or negative emotional context induced by images from the IAPS. Response time increased after unexpected novel sounds as a behavioral effect of distraction, and this increase was larger for women, but not for men, within the negative emotional context. Novelty-P3 was also modulated by the emotional context for women but not for men. These results reveal stronger novelty processing in women than in men during a threatening situation.

1. Introduction

Emotional disorders bring great distress to human life and are known to have an asymmetrical prevalence among men and women. For example, the prevalence of major depressive disorder in women is 5–9%, while in men it is only 2–3%. Similarly, anxiety disorders are much more frequently diagnosed in women than in men (DSM-IV-R, 1997). Consequently, gender differences in emotional processing have been the object of recent research due to their importance for understanding the unequal prevalence of anxiety and emotion-related disorders in women and men.

Previous studies have demonstrated that men and women process emotional stimuli differently. For instance, Kemp et al. (2004) recorded steady-state, visually evoked potentials elicited to pictures from the International Affective Picture System (IAPS; Lang et al., 2005). They found widespread frontal latency reduction associated with the processing of unpleasant pictures in women as compared to men, suggesting that women were more responsive to emotionally loaded stimuli. In an event-related potential (ERP) study, Orozco and Ehlers (1998) found significantly enhanced amplitudes in frontal regions in response to sad faces as compared to neutral ones in both men and women; however, the amplitude was larger for women in comparison to men on the P450, an ERP component related to the "intensity" of response to emotional stimuli, thus suggesting that women may be more "sensitive" to emotional stimuli. Moreover, neuroimaging studies exploring the neural correlates of emotional processing have shown stronger right amygdala activation in women as compared to men (Wrase et al., 2003; Hofer et al., 2006), and stronger activation of its related cerebral network (Canli et al., 2002). The amygdala, a subcortical structure located in the anterior medial temporal lobe, has a crucial role in the processing of emotions (LeDoux, 2000), and it has been shown to differ in men and women not only functionally but also in terms of structure and in several aspects of its ontogenesis (Goldstein et al., 2001).

On the other hand, research has also shown that negative emotions interact with the processing of concomitant stimuli, either facilitating or competing with them; this occurs not only within (Mogg and Bradley, 1999; Anderson, 2005) but also across sensory modalities. For instance, stimuli with an affective load have been shown to elicit stronger and faster attention capture than do non-emotional stimuli (Hansen and Hansen, 1988; Öhman et al., 2001). Emotional stimuli capture attention at very early stages of information processing in the human brain, circa 100–200 ms from stimulus onset (Smith et al., 2003; Carretié et al., 2004; Krolak-Salmon et al., 2004) or earlier, around 50–100 ms from stimulus onset (Sugase et al., 1999), even when the emotional

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stimuli occur outside the attentional focus, that is, automatically (Vuilleumier et al., 2001; Pessoa et al., 2002; Schupp et al., 2003; Carretié et al., 2005; Williams et al., 2004). A visually induced negative emotion interacts with the processing of concomitant auditory inputs, as indexed by startle reflex potentiation via picture arousal (Amrhein et al., 2004; Stanley and Knight, 2004) and P3 attenuation through the valence of the image (Schupp et al., 1997; Cuthbert et al., 1998). Moreover, a recent fMRI study has reported that areas involved in auditory novelty processing (bilateral superior temporal gyri) are significantly more activated in a negative emotional context as compared with a neutral one (Domínguez-Borràs et al., 2008b), thus demonstrating how an emotional context can modulate the orientation of attention towards salient stimuli, analogous to other top-down mechanisms of attentional control (SanMiguel et al., 2008). In a similar ERP study the electrophysiological results revealed an enhancement of novelty-P3 when novel sounds were processed during the performance of a task involving emotionally negative pictures (Domínguez-Borràs et al., 2008a). The study of gender differences for such emotional modulation of involuntary attention mechanisms may help to elucidate the different impact that an emotional environment exerts on women and men.

In order to examine the possible differential modulatory effects of emotion on involuntary attention we used a modified version of a well-characterized "distraction paradigm" (see reviews in Escera et al., 2000; Escera and Corral, 2003, 2007), derived from an adaptation of the so-called "oddball" paradigm, in which a high-probability standard stimulus is replaced randomly by a rare or "odd" stimulus. In the auditory–visual distraction paradigm a sequence of task-irrelevant frequent standard sounds (e.g. 80%) and infrequent deviant or novel sounds (e.g. 20%) is delivered. Task-relevant targets were digits presented 300 ms after the to-be-ignored auditory stimuli, and participants were instructed to classify them (e.g. as odd or even). This timing is optimal for eliciting distraction and accurately measuring behavioral and brain responses related to involuntary auditory attention (Escera et al., 2000; Escera and Corral, 2003, 2007); it was chosen on the basis of a previous study that showed distracting effects of deviant sounds when they occurred 200 ms before the target but not when they occurred 560 ms in advance (Schröger, 1996). Behavioral distraction has been shown through delayed response times obtained in a range of experiments using both auditory–auditory (Schröger and Wolff, 1998; Bert and Schröger, 2001; Roeber et al., 2003) and auditory–visual paradigms (Alho et al., 1997; Escera et al., 1998, 2000, 2001, 2002, 2003; Yago et al., 2001a, 2001b, 2003). Concomitant recordings of ERPs show the "distraction potential", a well-defined electrophysiological response which begins with a negative deflection combining an enhancement of the auditory N1 component and the *mismatch negativity* (MMN). This early negativity indexes the mechanisms for stimulus change detection, leading to attention capture (Escera et al., 1998; Alho et al., 1998). The auditory N1 component is elicited by the onset of any abruptly commencing sound (Näätänen and Picton, 1987), and the subsequent MMN is an ERP component elicited by any discriminable change in the otherwise repetitive auditory stimulation, reflecting automatic change detection (Näätänen, 1989; Näätänen et al., 2007). N1-enhancement/MMN is followed by a prominent positivity, the so-called novelty-P3 or P3a, which is associated with the evaluation of these novel events for subsequent behavioral action (Friedman et al., 2001) and reflects an effective orienting of attention toward the detected change (Friedman et al., 2001; Escera et al., 1998). P3a is an ERP component of the "P300 family", which discloses the early and frontocentral P3a elicited by unexpected stimuli from the later centro-parietal P3b elicited to task-relevant target stimuli (see Polich, 2007). The P3a or novelty-P3 component has been described to have two subcomponents, the early and late ones, which are clearly distinguished on the basis of their respective latency, scalp distribution and psychological concomitants (Escera et al., 1998, 2000; Polo et al., 2003; Yago et al., 2003; SanMiguel et al., 2008; Cortiñas et al., 2008). After the novelty-P3, another negative response may be observed: this is the 'reorienting negativity' (RON), reflecting processes in the context of reorienting attention towards task-relevant aspects of stimulation following distraction (Schröger and Wolff, 1998). These typical waveforms index three main stages of exogenous attentional control: acoustic change detection, effective orienting of attention towards the detected change, and reorienting of attention towards the current task (Escera et al., 2000; Escera and Corral, 2003).

It has been suggested that the processing of novel sounds may be modulated if the amount of attentional resources available is modified by the task conditions (Berti and Schröger, 2003; SanMiguel et al., 2008; Lavie, 2005), for instance, by increasing working memory load. The auditory–visual distraction paradigm has been demonstrated to be a useful tool for examining these effects of task conditions on the mechanisms of auditory novelty processing and distraction (SanMiguel et al., 2008; Domínguez-Borràs et al., 2008a,b), and it may therefore be suitable for investigating the impact of emotions on attentional processing and the potential gender differences of this impact.

Unexpected novel stimuli in an emotionally negative situation, such as a threatening or fear environment, acquire a vital importance as they may be potentially harmful; therefore, stronger processing becomes crucial and has an obvious adaptive value. The present study aimed to elucidate by means of ERPs any gender differences in the modulatory effect of an aversive emotional context on the brain response to task-irrelevant novel sounds. As previous studies have demonstrated that women have a more intensive response to affective stimuli, we hypothesised that a negative emotional context would have a larger modulatory effect on auditory novelty processing in female compared to male participants.

2. Materials and methods

2.1. Participants

Fourteen female subjects (right handed, mean age 22 ± 4.2 years, range 18–29 years) and fourteen male subjects (one left-handed, mean age 23 ± 3.5 years, range 18–29 years) participated in the present study. All subjects reported a history with no neurological or psychiatric illness, phobias, drug consumption or hearing problems, and they each gave informed consent according to both the Declaration of Helsinki and to procedures established by the local ethical committees. They all had normal or corrected-to-normal vision and were within the normal range of anxiety levels (assessed with the State-Trait Anxiety Inventory (STAI); Spielberger et al., 1983). Male and female subjects did not differ significantly in either state or trait anxiety scores.

2.2. Procedure

Participants performed a modified version of a well-characterized auditory–visual distraction paradigm (Escera et al., 1998, 2000, 2001, 2003). In this paradigm participants classify visual stimuli that appear 300 ms after task-irrelevant auditory stimuli. Auditory stimuli were a 700 Hz standard tone and 100 unique environmental complex novel sounds, generated as in Escera et al. (1998) and chosen from amongst those most highly rated by a sample of 30 subjects on a scale of familiarity (Escera et al., 2003). Over the sequence the probability of occurrence of the standard tone was 0.8, while novel sounds occurred with a probability of 0.2; thus, each novel sound was delivered only once within each emotional condition. The duration of all auditory stimuli was 200 ms, delivered binaurally through Sennheiser® HD202 headphones. All stimuli were presented with the stimulation program Presentation® (Neurobehavioral Systems Inc.).

In the version of the auditory–visual distraction paradigm used here the visual targets were complex pictures with emotional content instead of numbers. The