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Sex differences in memory of emotional images: A behavioral and electrophysiological investigation

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ABSTRACT

Current research suggests that emotional responses differ between men and women. Sex differences regarding emotional effects on memory have been recently studied through brain imaging techniques. However, the majority of investigations have often neglected to balance the variable of emotional intensity (arousal) across pleasant and unpleasant pictures. Additionally, men and women were often mixed or studied separately. The current study aims at comparing men and women's electrophysiological responses related to emotional memory of photographic material. These responses were measured using Event Related brain Potentials (ERP) in response to a task of episodic memory of emotional images. The frontal N200, the parietal P300 and the central LPC were compared in 17 men and 17 women matched for age, social economic status, education and intelligence. Behavioral results showed that, in men, reaction times were modulated by valence, whereas for women, reaction times were mainly modulated by arousal. Accuracy was affected by both emotional valence and arousal, but only in women. ERP analyses revealed that emotional valence influenced earlier time components (frontal N200 and parietal P300), whereas arousal influenced memory in the later time component (central LPC). Moreover, sex differences, mediated by valence and arousal, were found in ERP responses at different times in the processing stream.

1. Introduction

Memories, the very basic foundation for the narratives of our lives, are colored by our emotional responses to every day events. Does the brain encode memories differentially depending on their emotional content? Do men and women encode events differently depending on their subjective experience? Cognitive and affective neuroscience is grappling with these fundamental issues by trying to understand what was once thought to be an inaccessible aspect of cognition. Emotional memory is one of the most important ways we define our identity and understanding its brain correlates is an important contemporary issue.

Dimensions of emotional arousal and valence have often been operationalized in studies that have investigated the recall of photographic images depicting complex scenes (landscapes, animals, crime scenes, erotica, mutilations, car accident, etc.). (Lang et al., 1990a). Behaviorally, it has been observed that pleasant stimuli are recognized more quickly (Kissler and Hauswald, 2008; Smith et al., 2004; Van Strien et al., 2009) and more accurately than neutral or negative stimuli (Bradley et al., 1992; Lang et al., 1990b). Studies have generally found that emotional stimuli elicit greater ERP amplitudes than do neutral stimuli (Diedrich et al., 1997; Dolcos and Cabeza, 2002; Johnston et al., 1986; Lang et al., 1990b; McNeely et al., 2004; Schupp et al., 2000). This effect has specifically been observed in the P300 component (Johnston et al., 1986; Lang et al., 1990b) and in the Late Positive Potential (LPP) (McNeely et al., 2004; Schupp et al., 2000). Despite consensus in the literature regarding this emotional effect—larger amplitudes for emotional compared with neutral stimuli—very little agreement has been reached when comparing pleasant and unpleasant stimuli. Some studies have previously found that unpleasant images elicit larger P200 (Carretie et al., 2001), as well as larger P300 and late positive potential (Ito et al., 1998; Lang et al., 1990b), whereas others have found that pleasant images elicit larger amplitudes in the N200/P300 range (Conroy, 2007; Delplanque et al., 2004; Van Strien et al., 2009). Interestingly, others have found larger positivity in response to pleasant stimuli and larger N100/N200 in response to unpleasant stimuli (Lithari et al., 2009).

The discrepancies in the ERP data described above are likely explained by several factors. In a review of affective picture processing, Olofsson et al. (2008) suggest that valence is affecting earlier attentional processes such as the P100 and the early posterior negativity components, whereas arousal is responsible for later time components starting at around 300 ms. Furthermore, much of the earlier literature has not controlled for arousal. Olofsson et al. (2008) insist on the importance

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of controlling for arousal using both the normative International Affective Picture System (IAPS: Lang et al., 2008) ratings as well as subjective ratings.

Studies that have examined arousal consistently showed that highly arousing images elicit larger ERP amplitudes than do low arousing images (Cuthbert et al., 2000; Rozenkrants et al., 2008; Van Strien et al., 2009). Dolcos and Cabeza (2002) have suggested that arousal elicits an emotion effect in parietal areas in later time components, whereas valence influences earlier processes in the prefrontal cortex. In sum, both arousal and valence contribute to an emotion effect, seen behaviorally and in electro-cortical activity. However, the processes of these two dimensions are different, which is why it is important to examine them independently.

The orthogonal investigation of arousal and valence effects is further delineated with a consideration of sex differences. In a comprehensive review of literature, Olofsson et al. (2008), noted that very few studies have controlled for sex, but those that have, typically observed important differences between men and women. Few studies have systematically investigated arousal and valence as independent factors as well as investigating sex differences. Some have found sex differences with respect to valence, especially in unpleasant images (Bradley et al., 1992; Kemp et al., 2004; Lithari et al., 2010). Although there is still not a wealth of literature on the precise sex differences in arousal and valence, the results are consistent enough to further investigate another dimension of cognitive processing: memory.

In the current study, we seek to investigate the behavioral and electro-cortical consequences of arousal and valence in a memory context. We have chosen to investigate the N200, the P300 and the LPC given the large amount of study that documented these typical memory ERP components. In a non-emotional context of recognition memory, it has been consistently shown that items previously presented (old) elicit a larger parietal ERP amplitude than the items not previously presented (new), generating topographically distinct "old/new" effects (Allan et al., 1998; Rugg et al., 1995; Van Petten and Senkfor, 1996). First, an early (300–500 ms) bilateral frontal effect (N200) occurs when the access to perceptual and conceptual information related to test items is facilitated (Curran, 1999; Rugg et al., 1998a; Ullsperger et al., 2000). Secondly, a left parietal old–new effect (500–1000 ms) shows larger amplitude for deeply than to superficially encoded items. This parietal deflection, also called the Late Positive Component (LPC), reflects conscious recollection (Curran and Cleary, 2003; Paller et al., 1999; Rugg et al., 1998b; Smith and Guster, 1993; Wilding and Rugg, 1996).

In general, the literature has found that emotional stimuli are better recalled than neutral stimuli (Bradley et al., 1992; Smith et al., 2004). Accordingly, some studies have found larger old–new effects for emotional stimuli (Dietrich et al., 2000; Dolcos and Cabeza, 2002; Schupp et al., 2000). However, when examining lateralization of emotional memory effects, cognitive processes appear to be more complex.

Once again, sex differences may be a mediator with regards to the complexity of emotional memory effects. A handful of neuroimaging studies using fMRI, glucose PET, and blood flow PET have found sex differences in emotional memory. They have mainly observed that men activated more cortical and sub-cortical regions in the right hemisphere, whereas women activated more regions in the left hemisphere (Cahill, 2003; Canli et al., 2002). However, arousal levels were often not equated across emotional valence categories and furthermore, many of these studies compared solely unpleasant stimuli with neutral ones.

With ERP techniques, other research has also found interesting sex differences. For instance, Guillem and Mograss (2005) have observed that in the context of memory recognition, without emotion, women have a higher hit rate than men do. Furthermore, the ERP old–new effect is much larger for women than it is for men, who seem to show hardly any amplitude difference between old and new stimuli. In an emotional memory paradigm using ERPs, sex differences were also found and, consistent with brain imaging, unpleasant images elicited larger amplitudes in the left hemisphere in women and in the right hemisphere in men (Gasbarri et al., 2007). Unpleasant images were reported to be "mutilations, wounded people" while pleasant images were reported as "puppies, happy babies". All of these studies have reported better recall for intense low valence-unpleasant images, especially for women (Cahill, 2003; Canli et al., 2002; Gasbarri et al., 2007). However, as in previous neuroimaging studies, arousal was not controlled.

The goal of the current study was twofold. First, we examined whether recognition performance would be affected by emotional images controlled for both valence and arousal level ratings. Second, we investigated sex differences in emotional memory, while valence and arousal remained independent. To our knowledge, this has not been systematically performed at both the behavioral and electrophysiological level. Based on prior research and existing literature, we hypothesized that there will be an ERP interaction between memory, valence and arousal. Moreover, we predict sex differences in the old/new effect for the treatment of the various categories of valence and arousal images.

2. Method

2.1. Participants

Thirty-four subjects (17 men, 17 women) with normal or corrected-to-normal vision were selected. The mean age of the group was 28 years (range = 18–45 years old) with an average schooling of 17 years. Ninety-six percent of our participants were right handed ($n=2$ male left handed). Participants were administered the Raven test of intelligence (Raven and Court, 1989) and the partial Weschler Adult Intelligence Scale (WAIS-III) including vocabulary, similarities and blocks subtest (Wechsler, 1997) in order to ensure normal functioning in general intelligence and verbal memory. All participants scored within the normal range according to published norms and there were no significant differences between men and women for intelligence, neuropsychological testing, education level and age (Table 1). They also completed the Edinburgh Handedness Inventory (Oldfield, 1971), the Bem Sex Role Inventory (Bem, 1981) and the PDQ 4+ personality questionnaire (Hyler, 1994). Participants were recruited by advertisements and were screened for absence of psychiatric, medical (head trauma, allergies, surgery) and family history hospitalization (psychiatric or any other medical illness). None of the participants were taking psychiatric medications. All participants signed a consent form approved by the local ethic committee (*comité mixte de l'éthique de la recherche du Réseau Neuroimagerie Québec*—CMER-RNQ) and were told that they could ask questions at any time to further their understanding.

Table 1
Demographic information of the participants.

Characteristics	Men ($n=17$)	Women ($n=17$)	*P*
Age	28	27	ns
Education years	17	17	ns
Edinburgh Handedness Inventory	64	71	ns
Socioeconomic status	2.17	1.86	ns
Raven	85	80	ns
WAIS block	13	12	.05
WAIS similitude	12	11	ns
WAIS vocabulary	11	12	ns
Bem sex role masculinity	5	5	ns
Bem sex role feminity	4	5	ns
Bem sex neutral	4	5	ns
Personality Disorder Questionnaire (PDQ-IV)	20	19	ns

WAIS: Weschler Adult Intelligence Scale.
ns: non-significant.