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Working memory for emotional facial expressions: Role of the estrogen in young women

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Summary Physiological hormonal fluctuations during the menstrual cycle, postpartum, and menopause have been implicated in the modulation of mood, cognition, and affective disorders. Taking into account that women's performance in memory tasks can also fluctuate with circulating hormones levels across the menstrual cycle, the cognitive performance in a working memory task for emotional facial expressions, using the six basic emotions as stimuli in the delayed matching-to-sample, was evaluated in young women in different phases of the menstrual cycle. Our findings suggest that high levels of estradiol in the follicular phase could have a negative effect on delayed matching-to-sample working memory task, using stimuli with emotional valence. Moreover, in the follicular phase, compared to the menstrual phase, the percent of errors was significantly higher for the emotional facial expressions of sadness and disgust. The evaluation of the response times (time employed to answer) for each facial expression with emotional valence showed a significant difference between follicular and luteal in reference to the emotional facial expression of sadness. Our results show that high levels of estradiol in the follicular phase could impair the performance of working memory. However, this effect is specific to selective facial expressions suggesting that, across the phases of the menstrual cycle, in which conception risk is high, women could give less importance to the recognition of the emotional facial expressions of sadness and disgust. This study is in agreement with research conducted on non-human primates, showing that fluctuations of ovarian hormones across the menstrual cycle influence a variety of social and cognitive behaviors. Moreover, our data could also represent a useful tool for investigating emotional disturbances linked to menstrual cycle phases and menopause in women.

1. Introduction

The sex steroid hormone estrogen affects the nervous system in many different ways extending beyond the role it plays in controlling the reproductive function. Recent studies have

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underlined several important issues regarding its hormonal influence on cognitive functions such as learning and memory processes (Stevens et al., 2005; Lacreuse, 2006; Luine, 2007; Markou et al., 2005). This effect can be explained by the modulator role of estrogens on several neurotransmitter systems, acetylcholine in particular (Dumas et al., 2006; Norbury et al., 2007), but also catecholamines (Leranth et al., 2000), serotonin (Bethea et al., 2002; Amin et al., 2006a), and GABA, both in animals and in humans (McEwen, 2002; Sherwin, 2003; Amin et al., 2006b). Another reason may lie in the widespread presence of estrogen receptors detected in many limbic regions involved in learning and memory, including the hippocampal formation and amygdala, and the cerebral cortex (Shughrue and Merchenthaler, 2000; Sherwin, 2003, 2006; Markou et al., 2005). Due to the fact that estrogen acts across a broad range of neural systems, it is likely that it exerts its actions on cognition by altering the relative participation of specific memory systems, thus acting as a conductor, orchestrating the dynamics, timing and coordination of multiple cognitive strategies during learning (Korol, 2004; Zurkovsky et al., 2007). In particular, the results of many studies suggest that estrogen enhances performance in working memory tasks, including face-tasks and the delayed matching-to-sample task (DMTS) (Lacreuse et al., 2000, 2002, 2007; Lacreuse and Herndon, 2003).

Taking into account that estrogen modulates cognitive processes, menstrual-cycle-related changes in estrogen levels can have different effects on various cognitive tests. In fact, in the late follicular and midluteal phases, compared to menses, improved performance on tests of articulatory and fine motor skills were reported while impaired performance on tests of spatial ability were revealed, indicating that variations in estradiol levels may, at least in part, be responsible for these effects (Hampson, 1990a,b; Hausmann et al., 2000; Sandstrom and Williams, 2004).

Numerous studies assessing performance across the estrous and menstrual cycles evidenced that ovarian hormones influence cognition and neural substrates subserving learning and memory, including working memory, in both rodents (Warren and Juraska, 1997; Daniel et al., 2006; Kritzer et al., 2007) and humans (Hampson, 1990a,b; Janowski et al., 2000). The decline of estrogen levels after ovariectomy or menopause enhances the risk of diseases like osteoporosis and vasomotor dysfunction (Timins, 2004; Warren and Halpert, 2004), but could also be involved in cognitive impairments (Sherwin, 2003; Markou et al., 2005). Estrogen replacement therapy relieves various menopausal symptoms, but whether its benefits include comprised protection of cognitive functions is still controversial (Norbury et al., 2004; Resnick et al., 2004; Prelevic et al., 2005; LeBlanc et al., 2007). The most consistent results are related to the positive cognitive effects of estrogen replacement therapy on verbal memory (Sherwin and Tulandi, 1996; Amin et al., 2006a; Stephens et al., 2006). Physiological fluctuations in sex hormones across the menstrual cycle allow for non-invasive studies of the cognitive effects of estrogen in young women and underlie a reliable pattern of cognitive modification across the menstrual cycle (Penton-Voak and Perrett, 2000; Lacreuse et al., 2001; Maki et al., 2002).

In order to point out possible differences related to the physiological hormonal fluctuations, in the present study the cognitive performance in a working memory task for emotional facial expressions, using six basic emotions (Ekman and Friesen, 1971) as stimuli in (DMTS), was evaluated in young women in the different phases across the menstrual cycle.

2. Methods

2.1. Participants

The subjects included in this study were 56 female volunteers, aged 19—31 (mean age 22.9 $\pm$ 3.6), all students at the University of L'Aquila.

All the subjects were initially submitted to a screening interview, to evaluate the regularity of their menstrual cycle (from 25 to 35 days in length). The screening also established certain exclusion criteria: any form of oral contraceptive within the last 3 months, medication for chronic illness, neurological or psychiatric disorders, and substance abuse. Moreover, subjects were all right-handed and had normal vision.

During the screening interview, data regarding last menstrual period were collected and subjects were subdivided into three groups, corresponding to menstrual, luteal or follicular phases.

Women in the menstrual group were in their first or second day of the menstrual cycle (n = 14). Subjects in their 4th—13th day were placed in the follicular group (n = 21) while the luteal group included subjects in their 14th—32nd day of the cycle (n = 21).

To assess ovarian function and verify the cycle phase, salivary measures of estradiol and progesterone were used being a non-invasive method.

All experiments were conducted in accordance with the Declaration of Helsinki, and all the procedures were carried out with the adequate understanding of the subjects, who read and signed an informed consent before taking part in this research.

2.2. Materials

2.2.1. Stimuli

The stimuli consisted in 110 grayscale pictures of facial expressions, from Ekman and Friesen (1976) pictures of facial affect series. The pictures selected were multiple examples of six facial expressions (happiness, sadness, surprise, anger, fear and disgust), made by male and female actors, the majority of which are shown posing at least one example of each of the six expressions.

Pictures were 256 grayscale (eight-bit) computer files, 5 cm $\times$ 5 cm in size.

The test consisted in the presentation of 26 stimuli: 5 facial expressions of happiness, 4 of surprise, 5 of sadness, 4 of fear, 4 of anger and 4 of disgust.

2.2.2. Software

The experiment was conducted using Pentium IV PC, with a windows XP operative system. The stimuli were presented on 350 mm SVGA type monitors. The computer arranged the experimental events and recorded the participants' responses using the SysMem programme, written for this purpose in Delphi language.