



Fluctuations of estradiol during women's menstrual cycle: Influences on reactivity towards erotic stimuli in the late positive potential



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ABSTRACT

Background: While several studies examined the reactivity towards negative emotional stimuli across women's menstrual cycle, only few investigated responses to positive emotional cues in association with sexual hormones on a neural level. Therefore, the aim of the current EEG-experiment was to study the differential reactivity towards positive (erotic) words during the menstrual cycle (i.e. with fluctuations in the steroids estradiol and progesterone) in the late positive potential (LPP). Regarding reactivity towards erotic stimuli, the LPP is seen as the most relevant ERP-component, as more positive amplitudes in the LPP reflect larger incentive salience and higher arousal. The LPP towards erotic words was expected to be more pronounced during fertile phases of the menstrual cycle (around ovulation). Furthermore, associations with hormonal concentrations of estradiol and progesterone were investigated.

Method: 19 young, free cycling women were tested in an Erotic Stroop paradigm during the follicular phase, ovulation, and the luteal phase in a balanced cross-over design, while electroencephalogram (EEG) was recorded.

Results: LPPs in reaction to erotic compared to neutral words were larger in every phase. During the follicular phase and ovulation, higher estradiol-concentrations were associated with more positive LPP-amplitudes towards erotic- than to neutral words. No effects of progesterone, as well as no effects of cycle phase, were evident. Results are being discussed regarding implications for further research.

1. Introduction

Modulation of emotional processing by the menstrual cycle has gained more attention during last decades, as it affects women's behavior as well as their mental health. In spite of the importance of this topic – in which way especially positive emotional cues interact with sex hormones during menstrual cycle – it still remains a research field, where effects have only sparsely been reported (Toffoletto et al., 2014). In an evolutionary sense, it seems likely for the reactivity towards positive cues – and especially – those with erotic content – to vary during menstrual-cycle (Krug et al., 2000; Little, 2013). According to the ovulatory shift hypothesis (Gangestad et al., 2005), naturally cycling women's evaluation of male-attractiveness varies throughout the cycle. Therefore, characteristics that reflect 'genetic quality ancestrally', such as symmetry (van Dongen and Gangestad, 2011), facial- and vocal masculinity (Little et al., 2011), are seen as more attractive around ovulation (i.e. high fertility). At the same time, this is supposed to be evident especially regarding short-time desirability. A recent meta-analysis has shown that the cycle shift regarding the evaluation of

male's attractiveness is indeed stable, especially regarding body masculinity (Gildersleeve et al., 2014). Relevant brain areas regarding sexual behavior- and desire, involve the hypothalamus (regulating sexual behavior) as well as the amygdala and the mesolimbic reward circuit regarding motivational aspects of sexual behavior (Micevych and Meisel, 2017; Salamone et al., 2015). However, how the neural reactivity towards erotic cues is associated with cycle phase and hormonal concentrations in humans, still mainly remains unclear. Especially regarding event-related-potentials (ERPs), most studies concentrate on effects of negative stimuli on early ERPs (Avitabile et al., 2007; Wu et al., 2014), or on progesterone and ERPs (Brötznner et al., 2015; Mačiukaitė et al., 2017; Zhang et al., 2015; Zhang et al., 2013), while most of the possible associations regarding hormonal fluctuations with reactivity towards positive emotional stimuli in ERPs have not been reported so far.

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1.1. Menstrual cycle phases and emotional reactivity: the roles of estradiol and progesterone

Estrogen- and progesterone-receptors are localized in various regions of the brain – all being involved in stress reactivity, emotion- and cognitive regulation (Andreano and Cahill, 2010; Ossewaarde et al., 2010; Poromaa and Gingnell, 2014; Toffoletto et al., 2014; van Wingen et al., 2007). In spite of the effort to study different influences of hormonal variations on emotion and cognition, results are far from being clear. This might also be due to different assessment methods (between-subject vs. within-subject design), but also to the fact that only very few studies validate the cycle phases with hormonal analyses, relying on the information given by the subjects, which are firstly often unreliable (Jukic et al., 2007; Small et al., 2007; Wideman et al., 2013), and secondly cycle phases are of variable length (Farland et al., 2017; Harris et al., 2017; van Anders and Watson, 2006). Therefore, it seems most promising to analyze both progesterone and estradiol in subjects over several measuring times (i.e. in a within-subjects-design), while measuring their reactivity towards emotional stimuli in ERPs.

1.1.1. Progesterone

In contrast to reported associations of progesterone with increased sensitivity to threat-associated facial expressions (Conway et al., 2007; Derntl et al., 2013; Pearson and Lewis, 2005), as well as increased amygdala reactivity and emotional memory performance in the luteal phase (LU) (Andreano and Cahill, 2010; Bayer et al., 2014; Poromaa and Gingnell, 2014), associations with reactivity towards positive emotional or erotic cues have not often been described.

1.1.2. Estradiol

In an ERP study, Wang and Johnston (1993) showed associations with higher pleasantness-ratings to emotional stimuli during phases with high estradiol levels, while observing the ERP-component “P3” being larger in response to baby-faces during LU. Regarding stimuli associated with reproduction, Abler et al. (2013) investigated differences between free cycling women and those taking hormonal contraceptives (HC). While no differences between the groups regarding explicit sexual material (videos, pictures) were reported, free cycling women showed elevated activation in the precentral gyrus during FO in comparison to those with HC in response to more subtle stimuli (moderately erotic and positive emotional pictures). Similar results were reported in a fMRI study by Rupp et al. (2009), with increased activity in the orbitofrontal-cortex in response to male faces during FO, and correlations with estradiol/progesterone-ratios.

1.1.3. Estradiol, progesterone, and synaptic plasticity

Estradiol is, however, not only relevant regarding the regulation of women’s menstrual cycle, but also regarding long term potentiation and learning (Azcoitia et al., 2017). Animal studies have shown that estradiol regulates functional and morphological synaptic plasticity (Di Mauro et al., 2015; Grassi et al., 2011; Zhou et al., 2010), especially in females (Fester et al., 2011; Vierk et al., 2012). Furthermore, estradiol modulates learning by influencing dopamine signaling in the mesolimbic system: While estradiol leads to an increase of spine density in the arcuate nucleus, experience in sexual activity leads to an increase of spines in the nucleus accumbens (Micevych and Meisel, 2017).

While it has been shown that estradiol is needed to initiate lordosis-behavior in rats, neither progesterone, nor progesterone receptors are essential for its initiation, but rather ends lordosis behavior (Micevych and Meisel, 2017). Insights from those studies shed more light on the associations of cycling ovarian hormones in human women with sexual behavior and especially stress the importance of estradiol and sexual motivation in association with dopaminergic neurotransmission.

1.2. LPP

Regarding ERPs in context of emotional processing, one of the most promising component to investigate is the LPP. It is a wide positive potential over centro parietal scalp areas with onset at approximately 400–500 ms post stimulus, which can last for several hundred milliseconds (Hajcak et al., 2010). Whereas the localization of the LPP’s origin is not clear, it is postulated that it is associated with activity in the limbic system and the mesolimbic dopamine system, as LPP-amplitudes increase after presentation of emotional- and reward-related stimuli (Cuthbert et al., 2000; Munk et al., 2016; Schacht and Sommer, 2009; Schupp et al., 2000) and as emotional impact on the LPP is related to the emotional intensity- and salience of the stimulus (Hajcak et al., 2009). Therefore, associations with variations of hormonal concentrations and reactivity of relevant brain regions towards emotional/erotic stimuli as measured with fMRI, might as well be found in the LPP: fMRI studies have shown that relevant brain areas activated during observation of erotic stimuli are predominantly areas belonging to the limbic system, whereas results according to associations with menstrual cycle revealed heterogeneous results (Gizewski et al., 2006; Zhu et al., 2010). In contrast to the reactivity towards negative stimuli, reward-related areas belonging to the mesolimbic dopamine system, also play a role regarding viewing of sexual stimuli (Micevych and Meisel, 2017), in line with the idea of “wanting” (anticipation of reward) postulated by Berridge and Robinson (1998).

1.2.1. LPP and menstrual cycle

Studies regarding associations of the LPP and sexual hormones are sparse. However, in a recent study (between-subject-design) 23 women were asked to rate emotional stimuli in terms of valence and arousal, while recording the EEG (Mačiukaitė et al., 2017), however, no significant associations between LPP and sexual hormones could be found. Another study by Krug et al. (2000) reported larger LPPs towards sexual stimuli during ovulation (OV) in a visual attention task (within-subject design), implying associations with estradiol. The authors concluded that stimuli with reproductive significance would elicit higher LPPs during fertile phases, however, hormonal concentrations had not directly been assessed, but estimated out of subjects’ self-reported cycle phase.

Main weaknesses of former psychological cycle studies are, therefore, that either hormonal concentrations were not assessed (but estimated by cycle phase), as well as a lack of neural studies regarding the reactivity towards positive emotional and erotic cues, with a stronger focus on behavioral measures (see Gildersleeve et al., 2014).

Therefore, the following study was conducted in order to further elucidate associations of estradiol and progesterone with LPP-amplitudes – especially towards sexual stimuli in a within-subject-design – as it was expected for those hormones to be influencing the LPP. To our knowledge, no study has directly investigated the effects of sex hormones in reaction to erotic stimuli during menstrual cycle phase in an emotional-Stroop-paradigm before. This paradigm was chosen because erotic words were expected to be more implicit than for example images, and, therefore, not leading to ceiling-effects with which possible associations could be occluded.

1.3. Hypotheses

1.3.1. First hypothesis: LPP towards erotic stimuli

Serving as manipulation check, the general reactivity towards erotic words in the LPP is expected to be higher than towards neutral ones, independent of cycle phase

1.3.2. Second hypothesis: differences in regard to cycle phases

As concluded from above, LPP-amplitude in response to erotic stimuli is postulated to be higher during fertile phases of the menstrual cycle (i.e. FO & OV)

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