VILNIUS UNIVERSITY

LIFE SCIENCES CENTER

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The Relationship Between Menstrual Cycle Phases and Metacognition: A Study on Emotion Recognition

Master Thesis

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Abbreviations

ANOVA: Analysis of Variance

AUROC2: Area Under the Type 2 Receiver Operating Characteristic Curve

EF: Early Follicular

FSH: Follicle Stimulating Hormone

GnRH: gonadotropin-releasing hormone

HPO: Hypothalamus - Pituitary- Ovarian

LH: Luteinizing Hormone

LMM: Linear Mixed-Effects Model

ML: Mid-Luteal

NA: Negative Affect

O: Ovulation

PA: Positive Affect

PANAS: Positive and Negative Affect Schedule

ROC: Receiver Operating Characteristics

SDT: Signal Detection Theory

SRP: Self-Reported Performance

TAS-20: Toronto Alexithymia Scale

Introduction

Fluctuations in self-perception, emotional states, and cognitive performance are commonly observed across the menstrual cycle (Nillni et al., 2021; Röder et al., 2009; Sundström Poromaa & Gingnell, 2014). These changes are linked to variations in sex hormone levels, particularly estrogen and progesterone, during different phases of the menstrual cycle, such as the follicular and the mid-luteal phases (Abo et al., 2022). Although many women report changes in how they think and feel throughout the cycle (Krohmer et al., 2019), the cognitive mechanisms underlying these experiences are not fully understood.

One such mechanism is metacognition, defined as the awareness and ability to monitor and evaluate one's cognitive processes (Fleming & Dolan, 2012). Metacognition plays an important role in decision making (Benwell et al., 2022), emotional regulation (Davis et al., 2010), and self-awareness (Mazancieux et al., 2019). Despite its importance, metacognition has rarely been studied in the context of the menstrual cycle. However, research suggests a link between hormonal fluctuations across the different phases of the cycle and self-perception. For instance, Röder et al. (2009) found that women reported feeling more attractive and desirable during the fertile phases, compared to the non-fertile phases of the menstrual cycle, particularly the luteal phase. These self-perceptions involve metacognitive processes like self-evaluation of internal states. To investigate the relationship between metacognition and different phases of the menstrual cycle, this study employed a facial emotion recognition task.

Facial emotion recognition, which is interpreting other's emotional expressions (Nejati et al., 2022, Review Article), is fundamental to social interactions (Mehta et al., 2018). Although this task primarily assesses emotion perception, it can also be adapted to measure metacognitive processes by having participants evaluate their confidence in their responses after the task (Rouault et al., 2018). Previous research (Pearson & Lewis, 2005; Röder et al., 2009) suggests that both emotion recognition and metacognitive judgments may be linked to hormonal fluctuations. For instance, the luteal phase, characterized by elevated progesterone levels, has been associated with increased emotional variability and reduced confidence in cognitive judgments (Schnall et al., 2002). However, few studies have directly examined how metacognitive evaluations, such as confidence in emotional judgments, change across the menstrual cycle.

The present thesis aimed to investigate the association between different phases of the menstrual cycle and metacognitive performance during emotion recognition task, with consideration of individual psychological and self-reported factors. The objectives of this study:

1. Evaluate the association between metacognitive performance parameters and psychological characteristics and self-reported evaluations, across different phases of the menstrual cycle.

2. Investigate confidence ratings across different phases of the menstrual cycle during a facial emotion recognition task.
3. Assess performance sensitivity (d'), in different phases of the menstrual cycle during a facial emotion recognition task.
4. Examine metacognitive sensitivity (AUROC2) across different phases of the menstrual cycle during a facial emotion recognition task.

1. Literature Review

The menstrual cycle is a complex physiological process that is mainly related to reproduction, but is also linked to cognitive functioning (Owen, 1975). Previous research has investigated the link between the menstrual cycle and cognition, with a specific emphasis on memory, attention, and executive processes (Hatta & Nagaya, 2009; Souza et al., 2012, Review Article). One aspect of cognition that has received less attention about the menstrual cycle is metacognition, which refers to an individual's ability to evaluate and monitor their own cognitive processes (Sundström Poromaa & Gingnell, 2014). Metacognition is crucial for cognitive tasks including decision-making (Benwell et al., 2022), and facial emotion perception (Pletzer et al., 2019) which is the capacity to identify and analyze the emotions displayed on other people's faces (Farage et al., 2008, Review Article). Therefore, understanding how the menstrual cycle may relate to metacognition during facial emotion recognition tasks is vital; it could provide insights into potential differences in social cognition and emotional processing during the menstrual cycle.

1.1. Menstrual Cycle

The menstrual cycle can be divided into two main phases: follicular and luteal (Abo et al., 2022). The cycle is regulated by the hypothalamus-pituitary-ovarian (HPO) axis, a complex system involving hormonal communication between the hypothalamus, pituitary gland and the ovaries. The hypothalamus secretes gonadotropin-releasing hormone (GnRH), which stimulates the anterior pituitary to release follicle stimulating hormone (FSH) and luteinizing hormone (LH). These gonadotropins play several central roles in coordinating the menstrual cycle: they regulate the production of estrogen and progesterone by the ovaries, trigger ovulation, and support the formation and function of the corpus luteum (*Figure 1.A.*) (Laisk et al., 2018; Reilly, 2000, Review Article).

The follicular phase begins on the first day of the menstruation and continues until ovulation. It is characterized by low levels of estrogen and progesterone at the start. During this phase, FSH promotes the development of ovarian follicles. As the follicles mature, they secrete estradiol (Thiyagarajan et al., 2024). Rising estrogen levels exert negative feedback on the hypothalamus and pituitary, reducing FSH release and ensuring that only one follicle continues to develop (Drummond et al., 2006).

Mid-cycle, rising estrogen levels stimulate a surge in LH, which then triggers ovulation. This LH surge induces the release of a mature oocyte from the follicle into the fallopian tube, marking the transition from the follicular to the luteal phase (Erickson, 1996; Reed & Carr, 2000). In the luteal phase, the remaining cells of the follicle transforms into the corpus luteum, a temporary endocrine structure that secretes large amounts of progesterone and moderate levels of estrogen (Reed & Carr, 2000). These hormones prepare the endometrium for potential implantation. High levels of progesterone and estrogen exert negative feedback on GnRH, FSH, and LH, preventing the maturation of new follicles (McCracken et al., 1999). If fertilization does not occur, the corpus luteum degenerates leading to a drop in hormone levels and the start of a new cycle (*Figure 1.B.*) (Channing et al., 1978; Mihm et al., 2011; Niswender et al., 2000).

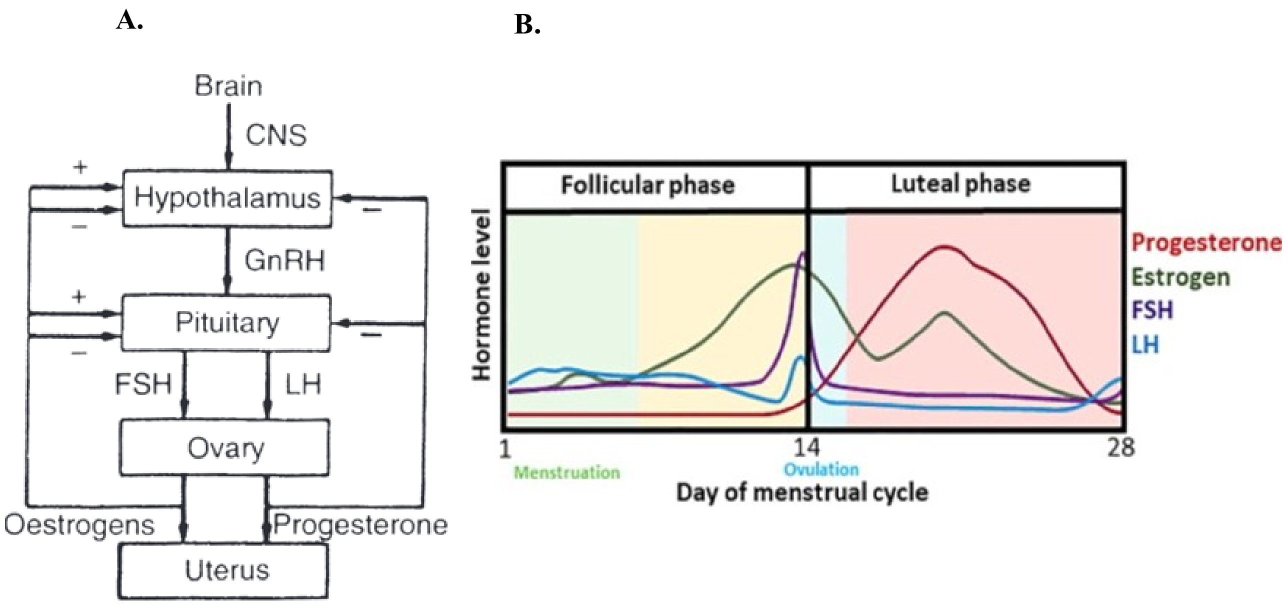

Figure 1. Overview of hormonal regulation during the menstrual cycle. (**A.**) The feedback loop between the hypothalamus, pituitary, and ovaries, with the roles of GnRH, LH, estrogen and progesterone (Reilly, 2000, Review Article). (**B.**) Hormonal fluctuations across the menstrual cycle with key phases including the follicular phase (green) and luteal phase (red). Progesterone (red line) peaks during the luteal phase, while estrogen (green line), LH (blue line) and FSH (purple line) show distinct patterns in response to each phase (Abo et al., 2022).

1.2. Metacognition

Metacognition refers to one's capacity to reflect on one's own performance and abilities (Kelly & Metcalfe, 2011). Accurate metacognition enables individuals to assess the reliability of their knowledge, either by proceeding with confidence or seeking more information when unsure. This awareness helps in avoiding incorrect assumptions that may negatively affect social connections and increases learning by devoting attention and time appropriately (Kelly & Metcalfe, 2011). It also helps individuals to better understand their weaknesses and strengths, allowing them to make more informed decisions about their learning and problem-solving strategies (Baird, 1986). In addition, research suggests that metacognitive deficits are linked to various psychological disorders, like depression (Ådnøy et al., 2023) and schizophrenia (Lungu et al., 2023; Seow et al., 2021).

Metacognition can be categorized into local and global metacognition (Händel et al., 2020). Local metacognition refers to the ability to assess and regulate one's performance on a specific task or trial-by-trial basis. It is usually assessed by confidence ratings in cognitive tasks, where participants indicate their certainty regarding individual responses. Meanwhile, global metacognition refers to an overall assessment of one's cognitive abilities and self-awareness across different domains or over time. It consists of a broader evaluation of one's strengths and weaknesses in cognition, this allows for long-term self-improvement (McWilliams et al., 2023; Sadnicka et al., 2024, Review Article). Interestingly, as people age, they tend to have lower confidence in their overall performance (global metacognition) and show decline in how well they assess individual decisions (local metacognition), however, their ability to accurately judge their local metacognitive efficacy remains stable. This means that different mechanisms govern local and global metacognition, with local efficacy being more resistant to age-related decline (McWilliams et al., 2023).

Within both local and global metacognition, metacognition bias and sensitivity are two key dimensions (Fleming & Lau, 2014). Metacognitive bias reflects one's overall confidence level, independent of how accurate their judgments are. For example, someone with a positive bias tends to be overconfident, while negative bias reflects under confidence. Metacognitive bias can occur at both the local (specific trials) and global (overall self-assessment) levels. On the other hand, metacognitive sensitivity measures how accurately confidence aligns with one's actual performance. High metacognitive sensitivity means confidence is closely aligned with accuracy, while low sensitivity means poor alignment between confidence and accuracy (Fleming & Lau, 2014).

One can assess metacognition using subjective and objective measures (Fleming & Lau, 2014). Subjective measures rely on self-report questionnaires that assess how well individuals believe they can monitor and evaluate their own cognitive performance. Examples include the metacognitive awareness inventory (MAI) and the Self-Regulation Questionnaire (SRQ). These tools evaluate skills such as planning, monitoring, and evaluating one's learning processes (Schraw & Dennison, 1994). Objective measures use experimental tasks to evaluate how accurately a person's confidence aligns with their actual performance. For instance, Signal Detection Theory (SDT), which categorizes responses as hits (correctly identifying signal), misses (failing to detect signal), false alarms (incorrectly identifying signal when none is present), and correct rejections (correctly identifying the absence of a signal). The outcomes are used to compute sensitivity indices and used to derive measures such as meta-d' and d'. d' is a measure of first-order task sensitivity, which reflects how well a participant can distinguish between signal and noise, like recognizing an emotional face from a neutral one. It depends on the task objective task performance, regardless of the participant's confidence. Meta-d' reflects second-order sensitivity, or metacognitive sensitivity, which refers to how well a participant's confidence judgments aligns with their correct and incorrect responses. Another metric is AUROC2 (Area Under the Type 2 Receiver Operating Characteristic Curve), which quantifies the probability that a participant will assign higher confidence to correct that to incorrect decisions. AUROC2 values range from 0.5 (no metacognitive sensitivity) to 1 (perfect discrimination), and like meta-d’, it provides a model-free estimate of metacognitive accuracy (Fleming & Lau, 2014). These metacognitive measures are relevant in domains such as emotion recognition, where individuals both identify emotional expressions accurately, and assess their own certainty in doing so (Kelly & Metcalfe, 2011).

1.3. Emotions and Emotion Recognition

Emotions are crucial components of human lives, playing a key role in social interaction and survival in times of danger. Primary emotions such as anger, happiness, sadness, fear, and disgust are universally recognized (Šimić et al., 2021). They are linked to distinct neural activity in the brain. For instance, happiness has been associated with the ventromedial prefrontal cortex, insula and the basal ganglia, while fear is primarily associated with the amygdala (Nakajima et al., 2022). Emotions are expressed through specific facial expressions. For instance, a frown can suggest confusion, while a smile can convey happiness or satisfaction. This type of non-verbal communication is important for professional settings as well, where understanding emotions could enhance teamwork and academic performances (Rehman et al., 2021) and overall well-being (Guerra-Bustamante et al., 2019).

Emotion recognition is the ability to recognize and interpret the emotional states of individuals and oneself accurately (Mehta et al., 2018). Accurately reading others’ emotions is a key part of emotional intelligence, which is the ability to regulate, recognize, understand, and express emotions effectively (Davronbek Rakhmatullaev, 2023).

1.3.1. Metacognition on Emotion Recognition

Kelly & Metcalfe (2011) investigated metacognitive awareness in facial emotion recognition, using both global and relative measures. Participants were Colombia University students (38 males; 60 females; two unknowns) who were asked to identify emotional expressions (anger, fear, happiness, sadness, and disgust). The task involved 90 faces, three female actors and three male actors. Participants were then asked to provide confidence ratings about their performance before (prospective) and after (retrospective) each response.

The results of this study showed that retrospective judgments were significantly higher than prospective judgments, but the difference was small. Both retrospective and prospective judgments were significantly greater than zero, which means that the participants could accurately predict and evaluate their performance to task difficulty. However, self-reported measures of empathy and global metacognition were not related to actual performance.

These findings suggested that metacognition in emotion recognition is best captured through trial-level confidence judgments rather than general self-perceptions. This highlights the need to evaluate not just how accurately individuals identify emotions, but also how well they monitor and evaluate their own performance. Although the study did not report significant sex differences and did not examine the hormonal link, its approach is highly relevant to the current thesis.

1.3.2. Menstrual Cycle and Emotion Recognition

Hormonal fluctuations across the menstrual cycle are related to differences in how emotional expressions are perceived and interpreted (Derntl et al., 2008). However, when it comes to emotion recognition performance, findings remain inconclusive. The following study by Pearson & Lewis (2005) hypothesized that fear recognition would vary from one menstrual phase to another, with stronger recognition at high estrogen stages of the menstrual cycle. The results revealed a significant interaction between menstrual phase and emotion displayed in predicting women's emotion recognition accuracy. Specifically, at the pre-ovulatory, where estrogen is at its highest, women recognized fear expression significantly more accurately than at menstruation as shown in *Figure 2*.

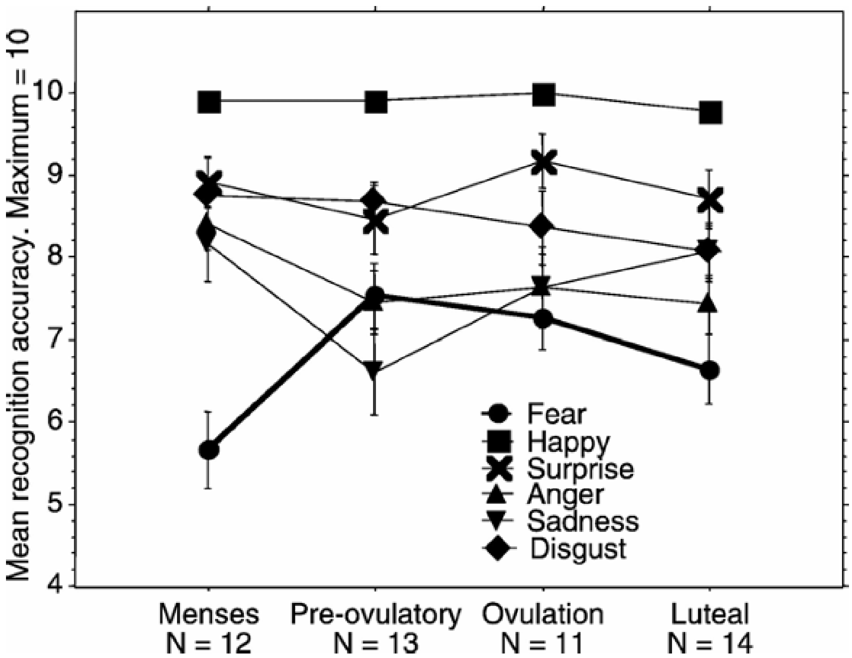

Figure 2. Mean recognition accuracy (maximum=10) for different emotions across menstrual phases (Menses, Pre-ovulatory, Ovulation and Luteal). Emotions categories include fear, happiness, surprise, anger, sadness and disgust. The results show significant interaction between menstrual phase and emotion, with fear recognition being lowest during menses and improving in the pre-ovulatory phase with higher estrogen levels (Pearson & Lewis, 2005).

Another study by Rafiee et al. (2023) investigated the relationship between hormonal fluctuations across the menstrual cycle and facial emotion recognition. This research focused on the late follicular and mid-luteal phases and examined how estradiol and progesterone are connected to women's ability to recognize emotions, while also considering the role of personality traits like openness, extraversion, and neuroticism. Contrary to previous literature suggesting improved emotion recognition during the late follicular phase and reduced performance in the mid-luteal phase (Lobmaier et al., 2019; Mesen & Young, 2015; Sundström Poromaa & Gingnell, 2014), Rafiee et al. (2023) found no significant differences in overall facial emotion recognition accuracy across menstrual phases.

In contrast, a study by Derntl et al. (2008) found a significant relationship between menstrual cycle phases and emotion recognition accuracy in women. Women in their follicular phase exhibited higher emotion recognition accuracy than those in the luteal phase. Specifically, the follicular group outperformed the luteal group in recognizing anger and disgust, while participants in their luteal phase were more likely to misclassify sad or fearful faces as angry or disgusted. Furthermore, the study found a negative correlation between progesterone levels and overall emotion recognition accuracy, meaning that higher progesterone was associated with lower performance across all participants. Additional analysis showed that higher progesterone levels were also associated with greater confusion in recognizing anger, and less confusion in identifying neutral expressions.

Overall, research on the relationship between menstrual cycle phases and emotion recognition remains inconclusive, with some studies supporting hormonal-driven fluctuations while others do not. Despite the mixed findings, the increasing evidence shows the complexity of hormonal fluctuations on cognitive and emotional processing, highlighting the need for further research with refined methodologies to better understand these interactions.

1.4. Metacognition During Menstrual Phases on Facial Emotion Recognition

Although studies examining the relationship between metacognition and facial emotion recognition across menstrual phases are limited, research on related topics provides a basis for exploration. For instance, a study by Röder et al. (2009) investigated women's self-perception across different phases of the menstrual cycle. The study included 25 heterosexual women aged 19-32 who were not taking any hormonal contraceptives. Self-questionnaires were included, and the participants completed the daily questionnaires before going to bed, which included 20 questions about their behavior and self-perception. Menstrual cycle was divided into fertile days "near ovulation", and low fertile days which were the rest of the cycle. Questions addressed four points: attractiveness, sexual interest, styling, and shopping. For identifying fertile days, researchers used backward calculation from the expected next period to when ovulation occurred. This method relies on the assumption that ovulation occurred approximately 14 days before the next menstrual period starts. Findings about self-perception indicated that women felt more attractive and desirable during fertile phase compared to the low fertile phase. Additionally, there was an increase in styling efforts and sexual interests during the fertile phase. The desire to go shopping also increased during the fertile phase but was not statistically significant. Although this study didn't directly measure metacognition, findings implied that the fertile phases of the menstrual cycle may have a relationship with increased self-perception. This supports the idea that hormonal fluctuations potentially shape metacognitive processes.

Schnall et al. (2002) explored the relationship between hormonal fluctuations and self-perception premenstrual syndrome. The study consisted of two separate experiments, where participants tracked their mood changes daily for 60 days. Findings suggested that women who were highly responsive to bodily cues, like internal sensations, posture, and emotional reactions, exhibited significant fluctuations in mood throughout their cycle. In contrast, women who relied more on situational cues, like culturally shaped expectations about appropriate emotional responses, showed no significant mood alterations across cycle. This suggests that heightened body awareness makes individuals more susceptible to emotional variability. Furthermore, women who based their mood evaluations on bodily cues reported more negative mood during the premenstrual phase. Interestingly, when women were reminded that they were in the premenstrual phase of their cycle, they reported fewer symptoms related to premenstrual syndrome. This suggests that simply being aware of their hormonal status helped them better manage their emotional responses. These findings highlight a link between hormonal fluctuations and metacognitive processes, like self-awareness and emotion evaluation. Women who were more responsive to internal cues may possess higher emotional insights, but also more vulnerable to cycle-related mood variability. Taken together with the study by Röder et al. (2009), which demonstrated shifts in self-perception during the fertile phase, the findings from Schnall et al. (2002) suggests that women's metacognitive processes, particularly self-monitoring and emotional self-evaluation, may fluctuate across the menstrual cycle. While previous studies have not directly linked these metacognitive shifts to facial emotion recognition, it's possible that the way women assess their own internal states could be linked to how they interpret other's emotional expressions. This is relevant to the current thesis, which examines whether hormonal phase-related differences in self-awareness are associated with metacognitive judgments in emotion recognition.

2. Materials and Methods

The study design was approved by The Vilnius Regional Biomedical Research Ethics Committee (2023-09-12, nr. 2023/9-1536-999).

2.1. Participants

The study included forty-one naturally cycling female participants, aged between 19-35 years old (21.95 ± 3.02). Participants self-reported that they had no psychiatric, endocrinal, or neurological diseases. All participants did not use hormonal contraceptives for three months before the experiment and during the experiment. In addition, participants self-reported that they had normal or corrected to normal vision.

Participants attended three sessions within a month during different phases of their menstrual cycle: early-follicular (EF), ovulation (O), and mid-luteal (ML). The average cycle day for each phase was as follows: EF: 3.46 ± 1.45; O: 14.93 ± 2.24, ML: 22.78 ± 2.59. Visit times were determined based on the individual cycle length (mean ± SD of cycle length: 28.29 ± 2.71), which was used as a reference to calculate the exact days of each phase, as shown in *Table 1.* Twenty participants completed their first visit during the EF phase, nine during the O phase and twelve during the ML phase.

Table 1. Menstrual cycle phase classification based on cycle length: Categorization of the EF, O, and ML phases based on the total duration of the menstrual cycle.

Duration of the cycle (Days)	EF	O	ML
24	2-3	9-11	17-19
25	2-3	10-12	18-20
26	2-3	11-13	19-21
27	2-4	12-14	20-22
28	2-4	13-15	21-23
29	2-5	13-15	21-24
30	2-5	14-16	22-25
31	2-6	15-17	23-26
32	2-6	16-18	24-27
33	2-7	17-19	25-28
34	2-7	19-21	26-29
35	2-7	20-22	27-31

Note: EF - early follicular phase of the menstrual cycle, O - ovulation, and ML – mid-luteal phase of the menstrual cycle.

2.2. LH Tests

To monitor the timing of ovulation, participants were provided with Easy@Home Ovulation Test Strips. Each participant received a set of five test strips and was instructed to begin testing five days prior to their expected ovulation day, based on their reported cycle length. Participants received written instructions on how to perform the test at home. They were asked to notify the research team once they observed a deep purple line (*see example Figure 3*) suggesting a surge in LH. Participants photographed the test result and sent it to the research team, who then confirmed whether the results showed a reliable LH surge based on the visibility and intensity of the test line.

Figure 3. Example of a positive LH test results using the Easy@Home Ovulation Test Strip. A surge in LH is indicated by the appearance of two distinct purple lines of similar intensity, signaling the onset of ovulation.

2.3. Questionnaires

At the beginning of each visit, participants completed demographic and self-report questionnaires. Questionnaires differed between the visits. During the first visit, participants provided informed consent before proceeding with the experiment. The demographic questionnaire included items on age, relationship status, and relationship satisfaction on a scale from 1 to 10 (mean ± SD of relationship satisfaction level: 8.39 ± 1.64). Participants also reported their stress level over the past two weeks using a five-point Likert scale (1 = very low, 2 = low, 3 = medium, 4 = high, 5 = very high) (3.14 ± 0.84).

Additionally, smoking habits were assessed by inquiring whether participants smoke and, if so, how many hours had passed since their last cigarette (13.05 ± 22.42). The number of hours slept the previous night was also indicated (7.27 ± 1.15).

Cycle-related questions included whether participants' menstrual cycles were regular, and whether they used hormonal contraceptives within the past three months. Participants indicate the current cycle day and their typical cycle length. In addition to these measures, participants completed the Positive (PA) and Negative Affect (NA) Schedule (PANAS), and the Toronto Alexithymia Scale (TAS-20) (see *Table 2* for mean ± SD values). See Appendix A for the full psychological and biographical assessment questionnaires.

During the second and third visit, participants completed a similar questionnaire which included current relationship status and satisfaction level, number of hours slept the previous night, and smoking habits, specifically how many hours ago they last smoked. Cycle-related questions remained consistent, including the regularity of their cycle, the current day and the length of their cycle. Emotional states were assessed using PANAS.

Before beginning the emotion recognition task, participants rated their emotional arousal level on a paper-based scale ranged from 1 (not aroused at all) to 10 (very aroused). After completing the task, participants repeated the arousal rating, emotional arousal levels difference was calculated (emotional arousal change = post-task arousal rating - pre-task arousal rating) then grouped to three groups: less aroused (post-task arousal was lower than pre-task arousal), no change (no difference between pre-/post-task arousal), and more aroused (post-task arousal was higher than pre-task arousal). Participants then rated how well they believed they had performed on the emotion recognition task performance using a paper-based self-reported performance (SRP) scale of 1 to 10 (*Table 2*). See Appendix B for the full self-report rating scales.

Table 2. Summary of psychological and subjective measures. Values are presented as mean ± SD.

Measure	**mean ± SD**	**EF (M ± SD)**	**O (M ± SD)**	**ML (M ± SD)**
TAS-20	45.22 ± 10.67	45.22 ± 10.67	45.22 ± 10.67	45.22 ± 10.67
PANAS-PA	33.08 ± 7.06	30.32 ± 6.14	36.32 ± 6.57	32.61 ± 7.09
PANAS-NA	18.59 ± 6.37	19.83 ± 6.45	17.54 ± 5.99	18.39 ± 6.45
Pre-Task Arousal	4.78 ± 1.91	4.84 ± 1.8	5.18 ± 1.91	4.31 ± 1.93
Post-Task Arousal	5.24 ± 1.82	5.42 ± 1.75	5.41 ± 1.9	4.9 ± 1.76
Emotional Arousal Change	0.47 ± 1.89	0.58 ± 1.44	0.24 ± 2.05	0.59 ± 2.08
SRP	5.66 ± 1.73	5.61 ± 1.77	6.02 ± 1.57	5.34 ± 1.78

Note: EF - early follicular phase of the menstrual cycle; O – ovulation; and ML – mid-luteal phase of the menstrual cycle; TAS-20 – Toronto Alexithymia Scale; PANAS – Positive and Negative Affect Schedule; PA – Positive affect; NA - Negative Affect; SRP – Self-Reported Performance.

2.4. Emotion Recognition Task

2.4.1. Stimuli

Facial stimuli were presented using E-Prime 3.0 (version 3.03.80). All facial images were selected from the FACES database, a validated collection of facial expressions that includes young individuals (Ebner et al., 2010). Each visit included eighty-nine stimuli: five presented during the practice session, and eighty-four stimuli during the main session.

The stimuli featured six actors (three male, three female), each displaying one of five emotions: anger, fear, happiness, sadness, or neutral. Emotional expressions were presented in three intensity levels: 25%, 50% and 100% (*see example Figure 4*), while neutral expression was shown only at 100% intensity.

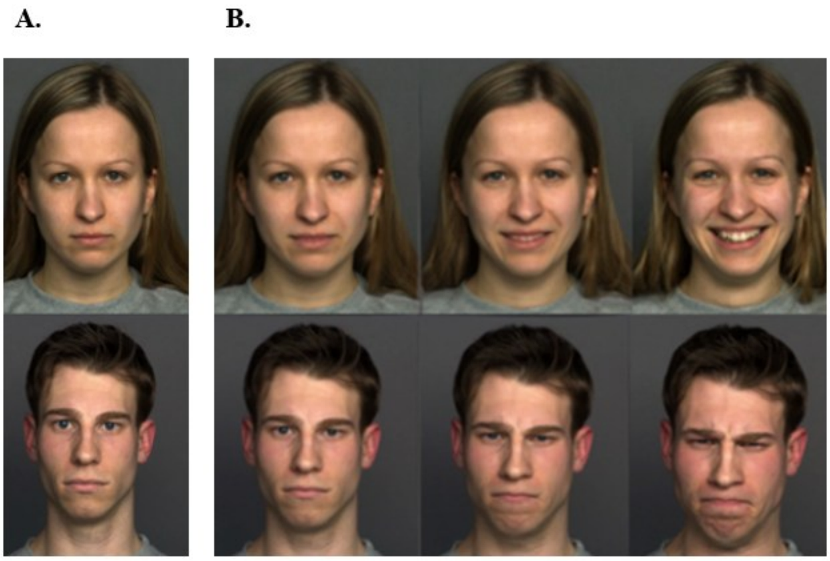

Figure 4. Example of emotional facial expressions at 25%, 50% and 100% intensity levels used in the experiment from the FACES database (Ebner et al., 2010). (**A.**) The images show female (top) and male (bottom) actors expressing neutral expressions at 100% intensity (**B**.) The images show female showing happiness expressions at three different intensity levels (top) and male showing anger expressions at three different intensity levels (bottom) actors expressing happiness. These stimuli were used to represent graduations in emotional intensity during the emotion recognition task.

2.4.2. Task Procedure

Each trail began with a central fixation cross (500-800ms), followed by a facial expression (1500ms) (*Figure 5*). All stimuli were presented in a random order. After viewing the face, participants selected the perceived emotion from multiple-choice options displayed on the screen. Participants then rated their confidence using a computerized Likert scale from 1 (not at all confident) to 4 (very confident).

2.5.Saliva Samples

Saliva samples were collected twice during each visit, once before and once after the experiment. Prior to collection, participants were instructed to rinse their mouths thoroughly with water using a cup. They were provided with sterile saliva collection tubes (IBL Salicaps, Germany) and, if preferred, with disposable straws to facilitate saliva transfer.

Participants deposited saliva directly into the tubes until an adequate volume was reached. The samples were immediately stored at -70C in an ultra-low temperature freezer for later analysis. Due to technical reasons, saliva samples were not analyzed but will be in the future.

2.6. General Procedure

Participants began with completing a series of questionnaires. After the questionnaires, participants rated their arousal level and then provided their first saliva sample. Next, participants completed the practice session of the emotion recognition task, followed by the main task. They were then asked to rate their confidence in their response. The task took approximately ten minutes. Eye movements were recorded during the task but not analyzed in the present study, as they are planned for analysis in future work. After finishing the task, participants rated their emotional arousal again and assessed their task-performance. Finally, participants provided their second saliva sample *(Figure 5*).

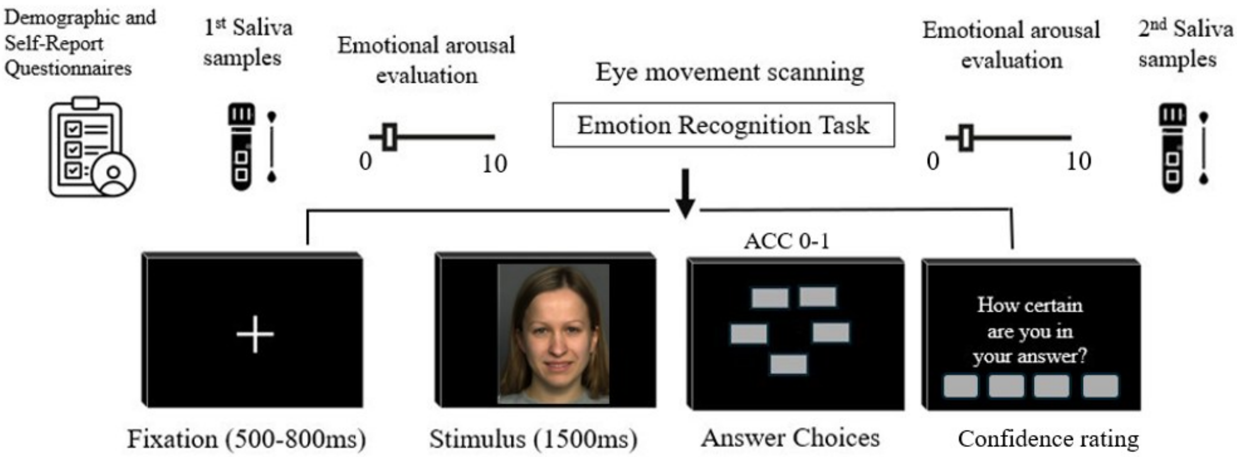

Figure 5. Overview of the experimental procedure.

2.7. Statistical Analysis

All analysis was conducted using RStudio (version 2023.12.1 Build 402). A variety of R packages were used, including: haven for importing Excel data, dplyr and tidyverse facilitated data wrangling and transformation. Statistical modeling was performed using lme4 with lmerTest package. The emmeans package was used for estimating marginal means and performing post hoc comparisons. For ROC analysis and metacognitive sensitivity estimation, the pROC package was used. All data visualizations were created using ggplot2.

The dataset was organized in a long format. Categorical variables, including, menstrual phase, emotion, intensity, and visit number were coded as factors. The dependent variables included confidence ratings, performance sensitivity (d'), and metacognitive sensitivity (AUROC2). Linear mixed-effects models (LMM) were employed to account for the repeated-measures structure of the data, Type III ANOVA (with Satterthwaite method) to find main effects, and Estimated Marginal Means (EMM) with Holm corrections to find pairwise comparisons. Across all models, participant ID was included as random intercept to control for between-subject variability. Fixed effects varied depending on the outcome but typically included menstrual phase, emotion, intensity, and visit number, the latter was treated as a covariant.

To assess the effect of psychological parameters on confidence ratings, models examining psychological and subjective measures were separated into two categories: one focused on TAS-20 scores, modeled independently with phase as a fixed effect and participant as a random intercept, while the other included PANAS (PA and NA), arousal change, and self-reported performance (SRP), in a single model with phase and visit number as fixed effect, the latter served as a covariate. This separation was necessary because TAS-20 was given only during the first visit, whereas PA, NA, pre-/post-task arousal, and SRP, were collected at every visit. Arousal change scores were grouped to “less aroused” (arousal change < -0.5), “no change” (arousal change = 0), and “more aroused” (arousal change > 0.5). SRP scores were also grouped into three levels: low (0 to 3.9), medium (4 to 6.9) and high (7 to 10). These thresholds were selected based on data distribution and were intended to improve visualization and facilitate clearer interpretation. Additional analysis included the psychological (except alexithymia) parameters and self-reported performance evaluation as dependent variables to analyze menstrual phase effect on these variables.

Participants’ ability to distinguish emotional (signal) from neutral (noise) stimuli – d’, was assessed using SDT measures. Hits (correct identification of emotional stimuli, Miss (emotional stimuli identified as neutral), False Alarm (neutral stimuli incorrectly identified as emotional), and Correct rejections (correct identification of neutral stimuli) were grouped by phase, visit number, emotion and intensity. Sensitivity (d’) scores were then calculated as the difference between the z-transformed HR and FAR, followed by linear mixed-effects model and type III ANOVA analysis.

Metacognitive sensitivity was estimated using ROC analysis, where Area Under the Type 2 ROC Curve (AUROC2) served as the index for metacognitive sensitivity. AUROC2 was calculated to quantify the relationship between the participants’ accuracy and their confidence ratings, providing a measure of how well participants’ confidence aligned with their recognition performance. AUROC2 was calculated with the roc() function from the pROC package. The inputs included the participants’ trial by trial binary accuracy (0 = incorrect, 1 = correct), raw confidence ratings, fixed factors such as phase, emotion, and intensity. Fixed-effect covariate is visit number and random intercept is subject. Since the ROC method requires both correct and incorrect responses, a custom helper function (safe_auc()) was implemented to skip trials or condition where this assumption is violated, thereby avoiding calculation errors, with binary accuracy scores as the response and raw confidence ratings as predictor. Additionally, to conduct ROC curves, two key rates: True Positive Rate (TPR) and False Positive Rate (FPR) were used, with the logic: TPR = correct trials that had high confidence / total correct trials, FPR = incorrect trials that had high confidence / total incorrect trials. The resulting AUROC2 values were modeled using linear mixed-effects model with metacognitive sensitivity as the dependent variable. As with other models, subject was treated as a random intercept, and phase, emotion, intensity and visit number were entered as fixed effects.

Misclassified responses, particularly those identified as neutral across varying intensities, were also analyzed separately using frequency analysis (see Appendix C.).

3. Results

3.1. Psychological Parameters and Self-Reported Scales

Analysis revealed main effects of menstrual phases on PANAS (PA: $F(2, 2) = 821.0$, $p = 0.001$, $\eta^2 = 0.195$; NA: $F(2, 8) = 22.1$, $p = 0.001$, $\eta^2 = 0.850$). Participants had higher PA in O compared to the EF, and the ML phases (both $p < 0.001$). Participants also had higher PA in ML compared to EF phase ($p < 0.001$). Whereas NA scores were higher in the EF phase than in O ($p < 0.001$), and higher in the ML phase compared to O ($p < 0.001$), while no significant difference was observed between the EF and ML phases ($p = 0.331$) (*Table 3*).

Menstrual phases had no significant main effect on arousal change ($F(2, 118) = 0.749$, $p = 0.475$, $\eta 2 = 0.010$). Furthermore, there was significant effect of menstrual phases on SRP ($F(2, 20.5) = 515.3$, $p < 0.001$, $\eta 2 = 0.980$). SRP scores were higher in O than in EF and ML phases (both $p < 0.001$). Participants also rated higher SRP in ML compared to EF phase ($p < 0.001$) (*Table 3*).

Table 3. Psychological Parameters and Self-Reported Scales Across Phases.

Measure	F-value	p-value	Effect Size η^2	Comparisons EMM
PANAS-PA	821	0.001	0.195	EF < O, ML (both p < 0.001) O > ML (p < 0.001)
PANAS-NA	22.05	0.001	0.850	EF > O, ML (both p < 0.001)
Emotional Arousal Change	0.749	0.475	0.010	ns
SRP	515.26	< 0.001	0.980	EF < O, ML (both p < 0.001) O > ML (p < 0.001)

Note: TAS-20 – Toronto Alexithymia Scale; PANAS – Positive and Negative Affect Schedule; PA – Positive affect; NA - Negative Affect; SRP – Self-reported Performance.

3.1.1 Confidence Ratings and Self-Reported Evaluations

Analysis revealed no effect of TAS-20 ($F(1, 121) = 0.806$, $p = 0.371$), PA ($F(1, 102.8) = 0.279$, $p = 0.598$), NA ($F(1, 102.9) = 0.132$, $p = 0.717$), and arousal change ($F(2, 103.9) = 0.053$, $p = 0.948$) on confidence ratings. SRP had a significant main effect on confidence ratings ($F(1, 102.8) = 9.90$, $p = 0.002$, $\eta^2 = 0.090$). Post hoc comparisons revealed that confidence was significantly higher when participants reported high than low SRP ($p = 0.001$), and medium than low SRP ($p = 0.005$). There was no significant difference in confidence between high and medium SRP groups ($p = 0.434$) (*Figure 6*).

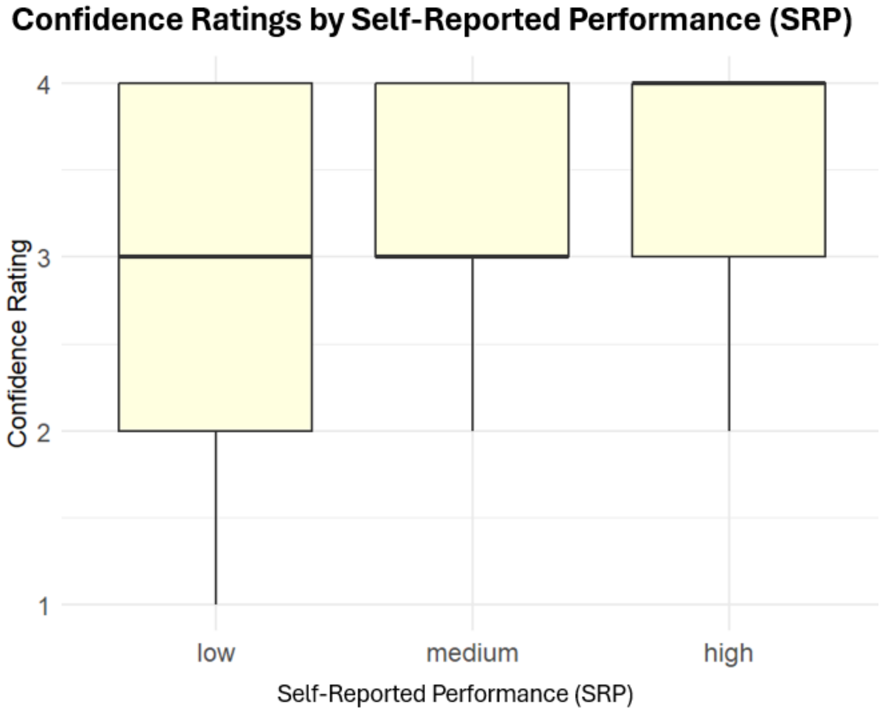

Figure 6. Boxplot of confidence ratings by SRP. Participants with higher SRP reported significantly higher confidence than those with lower scores. The box represents the interquartile range (IQR), and the line inside the box shows the median. Whiskers represent variability outside the upper and lower quartiles.

In addition, no significant interactions were found between phase and: PANAS (PA ($F(2, 102.8) = 0.197$, $p = 0.821$); NA ($F(2, 102.7) = 0.208$, $p = 0.812$)), arousal change ($F(4, 103.9) = 0.735$, $p = 0.569$), and SRP ($F(2, 102.8) = 0.280$, $p = 0.756$) on confidence ratings.

3.1.2 Performance Sensitivity (d') and Self-Reported Evaluations

There were no significant main effects of TAS-20 ($F(1, 39) = 1.15$, $p = 0.290$), PANAS (PA: ($F(1, 167.7) = 0.057$, $p = 0.81$); NA ($F(1, 73.3) = 0.174$, $p = 0.678$)), arousal change ($F(2, 206.3) = 0.229$, $p = 0.795$), or SRP scores ($F(1, 79.7) = 0.59$, $p = 0.442$) on performance sensitivity.

Additionally, no significant interactions were found between phase and: PA ($F(2, 468.1) = 0.243$, $p = 0.784$), NA ($F(2, 1013.6) = 0.511$, $p = 0.599$), arousal change ($F(4, 376.4) = 0.234$, $p = 0.919$), and SRP ($F(2, 855.4) = 1.560$, $p = 0.784$) on performance sensitivity.

3.1.3 Metacognitive Sensitivity (AUROC2) and Self-Reported Evaluations

Analysis revealed no significant main effect of TAS-20 on AUROC2 ($F(1, 43.3) = 0.244$, $p = 0.624$). Similarly, PANAS scores did not have an effect on metacognitive sensitivity (PA: $F(1, 241.7) = 2.236$, $p = 0.136$; NA: $F(1, 90.9) = 0.047$, $p = 0.829$), nor did arousal change ($F(2, 274.7) = 2.249$, $p = 0.107$), and SRP scores ($F(1, 98.8) = 2.76$, $p = 0.099$).

The interaction between menstrual phases and emotional arousal had a significant main effect on AUROC2 ($F(4, 438.2) = 3.02$, $p = 0.018$, $\eta^2 = 0.030$). Pairwise comparisons revealed a trend towards higher awareness of performance when participants were less aroused after the task in O than in EF phase ($p = 0.087$), and in ML than in EF phase ($p = 0.087$) (*Figure 7*). No other differences were found between menstrual phases and emotional arousal (all $p \geq 0.117$).

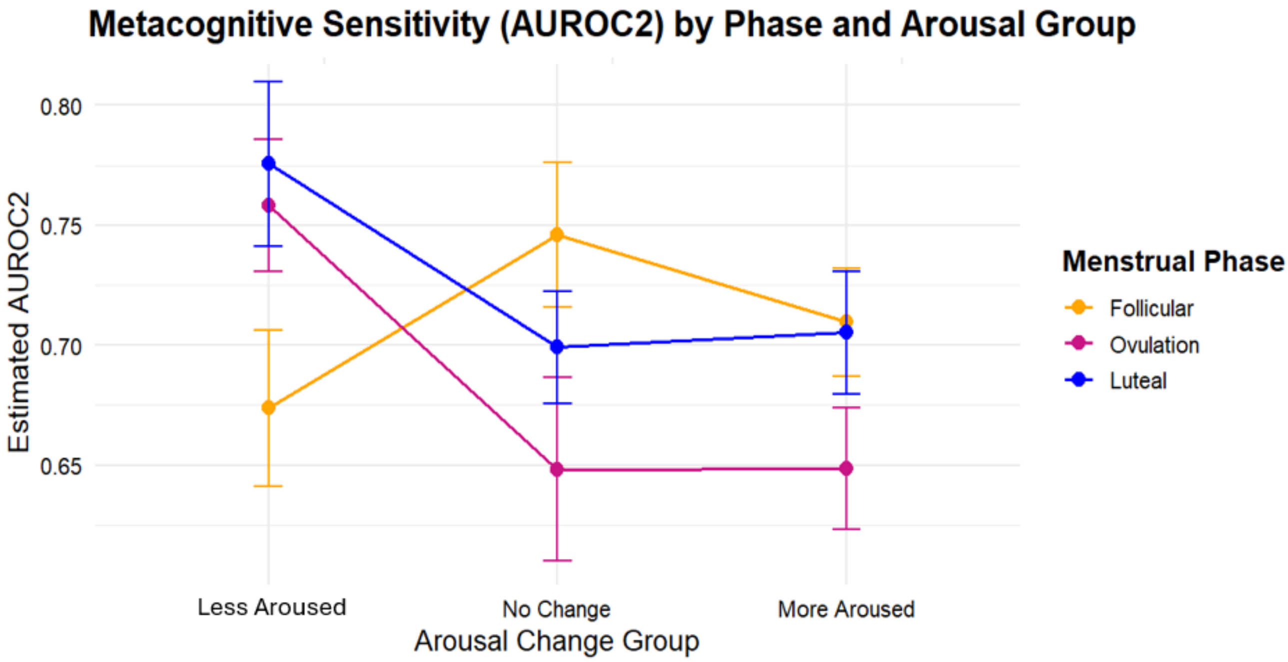

Figure 7. Estimated AUROC2 menstrual phase and arousal group. A trend towards higher AUROC2 was observed when participants were less aroused after the task in O than in EF phase, and ML than in EF phases. Whiskers represent ± standard error of the mean.

No significant interactions were found between phase and: SRP ($F(2, 639.5) = 1.07$, $p = 0.343$), PANAS scores (PA: $F(2, 508) = 1.71$, $p = 0.182$; NA: $F(2, 667.6) = 0.99$, $p = 0.373$), on metacognitive sensitivity.

3.2. Confidence Ratings

Analysis revealed no significant main effect of menstrual phases ($F(2, 118.4) = 0.725$, $p = 0.487$) on confidence ratings. Emotions had a significant main effect on confidence rating ($F(4, 9435) = 891.23$, $p < 0.001$, $\eta^2 = 0.270$). Participants reported significantly higher confidence when viewing angry ($p = 0.002$), fearful ($p = 0.006$), and happy ($p = 0.003$) faces compared to sad faces. Moreover, confidence ratings were significantly higher for all emotional expressions compared to neutral stimuli (all $p < 0.001$). There were no other differences (all $p > 0.05$).

The interaction between phase and emotion ($F(8, 9435) = 1.32$, $p = 0.227$) had no significant main effect on confidence ratings. The interaction between phase and intensity showed a significant main effect on confidence ratings ($F(4, 9435) = 4.66$, $p < 0.001$, $\eta^2 = 0.001$). Specifically, when viewing 25% intensity emotional expressions, women in EF phase reported lower confidence compared to O ($p < 0.001$) and the ML ($p = 0.024$) phase. Additionally, the O reported higher confidence than the ML ($p = 0.002$) group. At 50% intensity, no significant differences observed between phases (all $p \geq 0.767$). When participants viewed 100% intensity expressions, they had higher confidence in O compared to ML phase ($p = 0.023$) (*Figure 8*). No other differences were found between the phases (all $p \geq 0.538$).

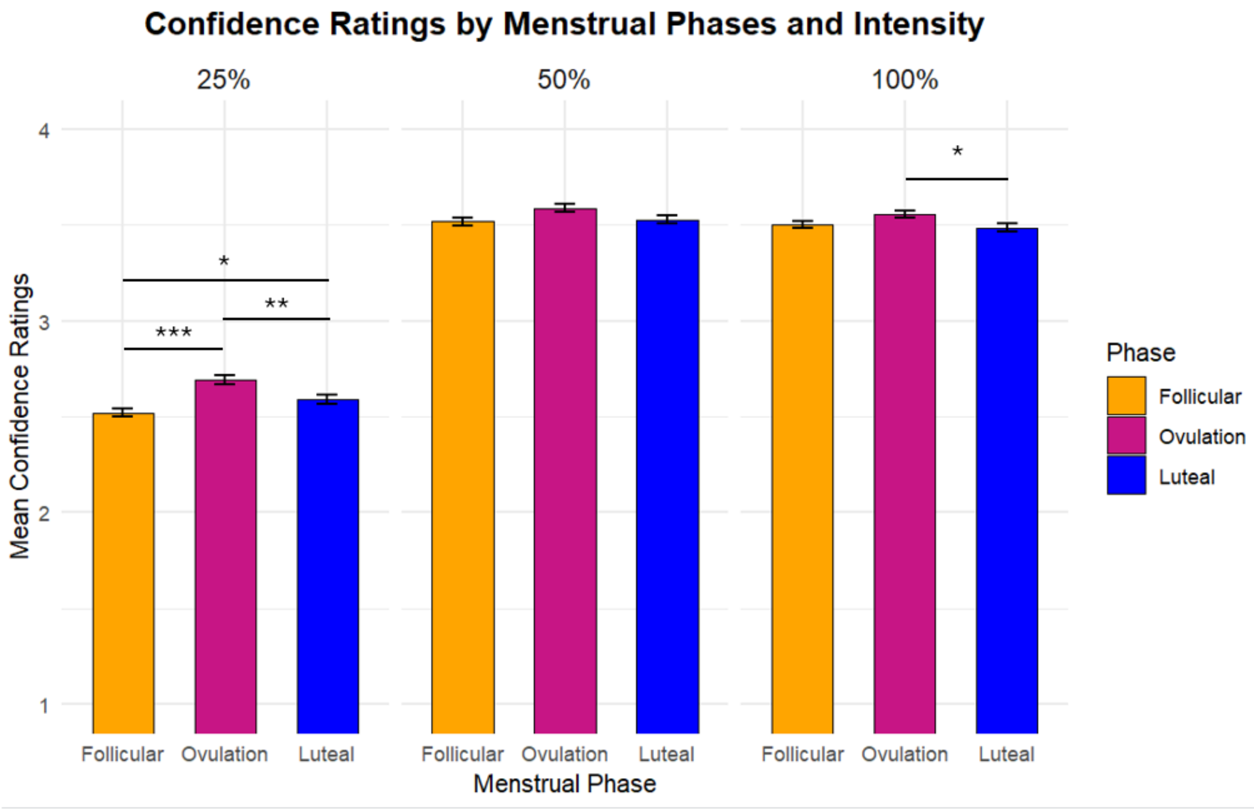

Figure 8. Mean confidence ratings across menstrual phases: early follicular, ovulation, mid luteal, at each intensity level: 25%, 50% and 100%. Significant differences between phases are indicated with airstrikes (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$). Whiskers represent ± standard error of the mean.

Furthermore, the interaction between phase, emotion and intensity had a significant main effect on confidence rating ($F(12, 9435) = 2.53$, $p = 0.002$, $\eta^2 = 0.003$). Specifically, at the lowest intensity (25%), participants in O reported higher confidence ratings, compared to the EF and ML phases (both $p < 0.001$) when they viewed fearful facial expressions (*Figure 9*). Similarly, confidence ratings were reported significantly higher in O during trials showing anger expressions compared to both EF ($p = 0.003$) and ML phases ($p = 0.016$), at 25% intensity. The O group had higher confidence ratings when viewing sadness at 25% than the EF group ($p = 0.024$), and sadness at 100% than ML group ($p = 0.024$) (*Figure 9*).

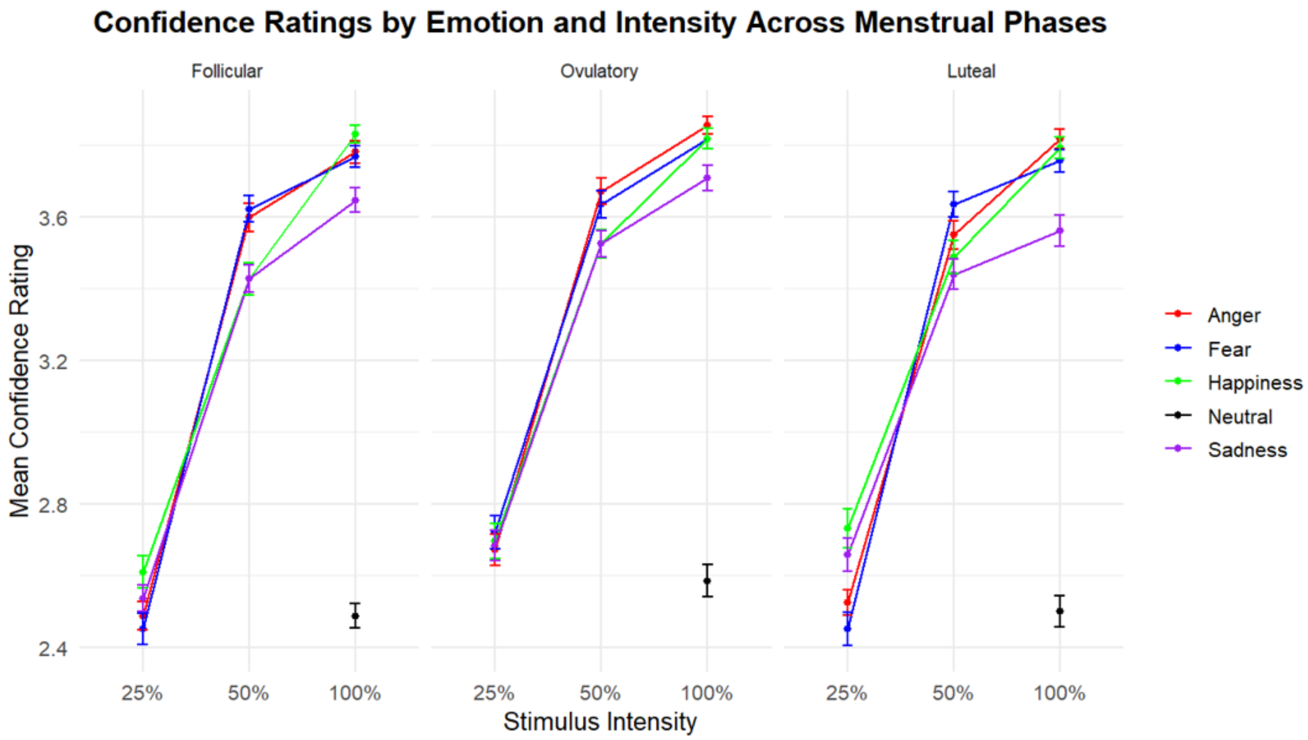

Figure 9. Confidence ratings by emotion and stimulus intensity across menstrual phases. Confidence increased with intensity for all emotions. In O, confidence was higher for 25% intensity anger (red line), fear (blue line), and sadness (purple line), as well as for sadness at 100% intensity, compared to the EF and ML phases. Whiskers represent ± standard error of the mean.

3.3. Performance Sensitivity (d')

There was no significant main effect of menstrual phases on d' ($F(2, 1518) = 0.353$, $p = 0.703$). Emotion had a significant main effect on d' ($F(4, 1518) = 96.8$, $p < 0.001$, $\eta^2 = 0.200$). All emotional stimuli were more distinguishable than neutral ($p < 0.001$). As the d' reflects sensitivity to emotional expressions versus neutral, no differences in sensitivity between the emotional stimuli can be analyzed.

The interaction between phase and emotion ($F(8, 1518) = 0.417$, $p = 0.912$), between phase and intensity ($F(4, 1518) = 0.190$, $p = 0.943$), and between phase, emotion and intensity ($F(12, 1518) = 0.098$, $p = 0.999$) did not have an effect on d'. Emotion and intensity interaction had a significant main effect on d' ($F(6, 1518) = 4.61$, $p < 0.001$, $\eta^2 = 0.020$). When stimuli were at the highest intensity (100%), participants perceived emotional expressions more distinguishable than neutral (all $p < 0.001$) (*Figure 10*).

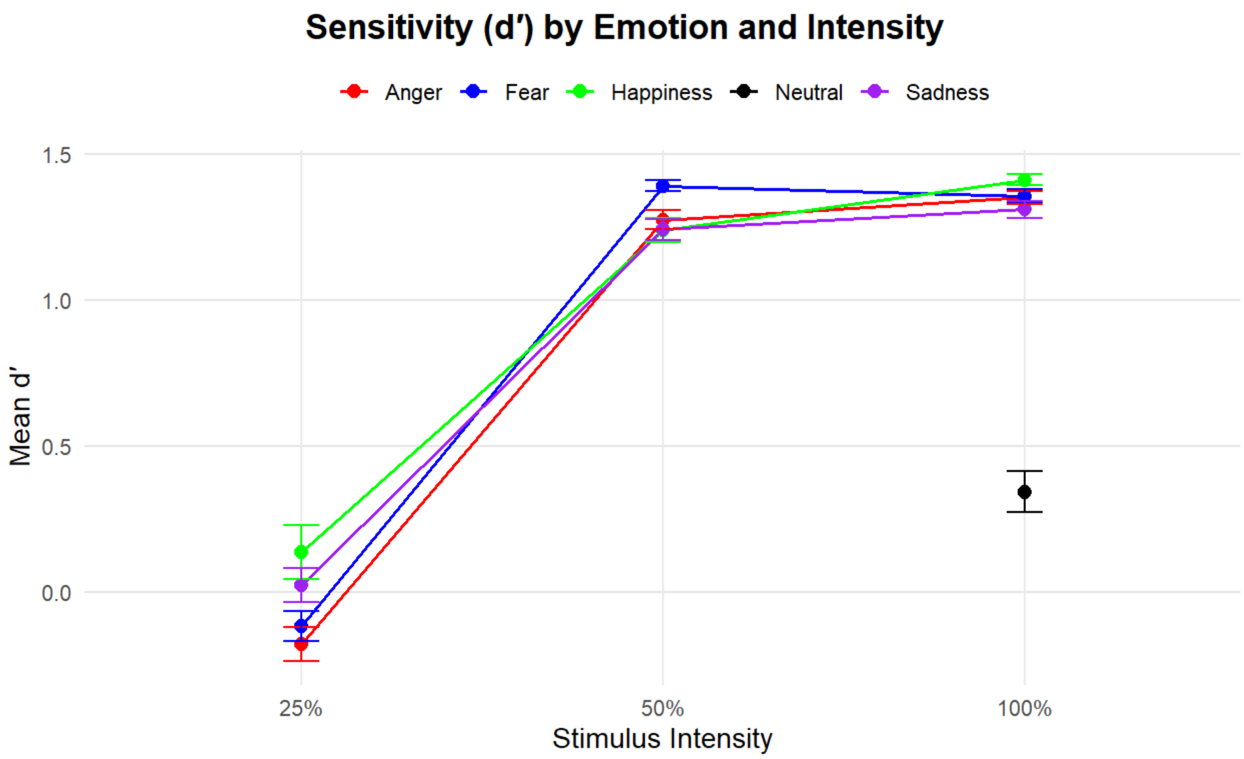

Figure 10. Mean performance sensitivity by emotion and stimulus intensity. Sensitivity increased with stimulus intensity. Neutral expressions (black line) consistently showed the lowest sensitivity compared to emotional expressions (colorful lines). Whiskers represent ± standard error of the mean.

3.4. Metacognitive Sensitivity (AUROC2)

Although analysis revealed no significant main effect of menstrual phases on AUROC2 ($F(2, 636.8) = 1.78$, $p = 0.169$), the ROC curves (*Figure 11*) provided an illustration of phase-related patterns. The AUROC2 values were descriptively highest in the EF phase (AUROC2 = 0.769), followed by the ML phase (AUROC2 = 0.762), and lowest in O (AUROC2 = 0.756), but differences were not statistically significant.

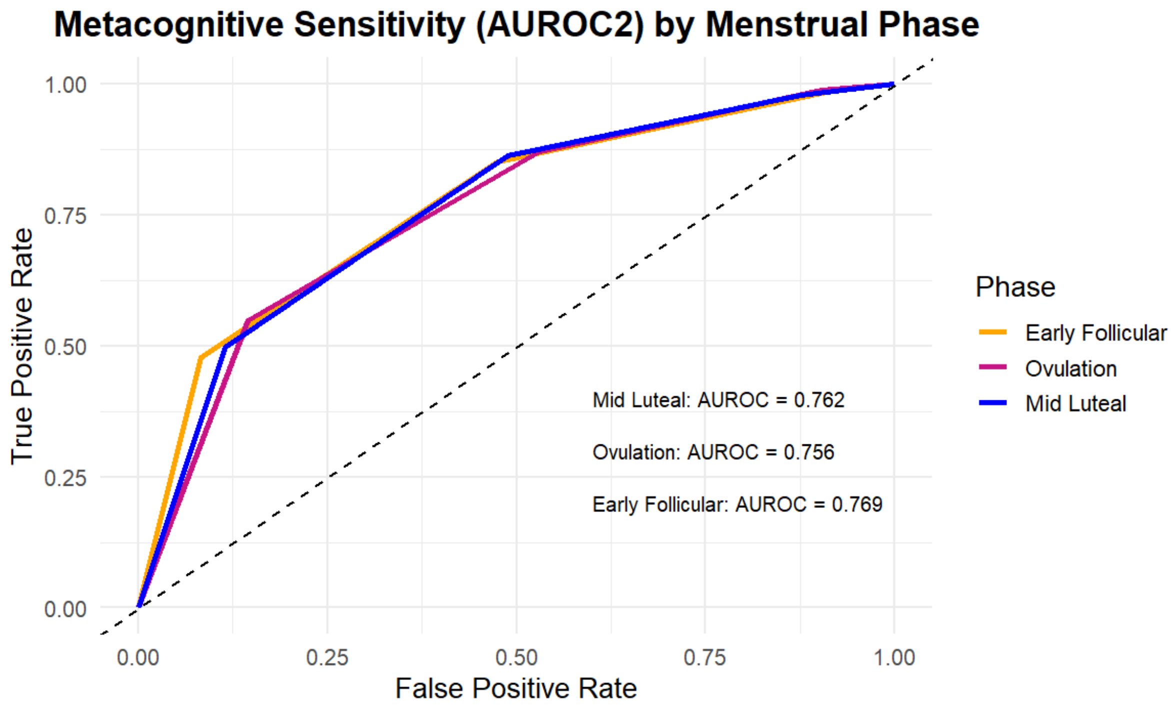

Figure 11. ROC curves showing AUROC2 by menstrual phase. EF (orange curve), O (purple curve), and ML (blue curve) phases showed comparable overall AUROC2 values, suggesting no significant main effect of menstrual phase on metacognitive sensitivity.

Emotions had a significant effect on AUROC2 ($F (4, 655.3) = 9.18$, $p < 0.001$, $\eta^2 = 0.050$). Participants were more accurately aware of their performance when viewing anger ($p < 0.001$), happiness ($p < 0.001$), fear ($p = 0.016$), and sadness ($p = 0.009$) compared to neutral expressions. No other differences were found between the emotions (all $p > 0.05$) (*Figure 12*).

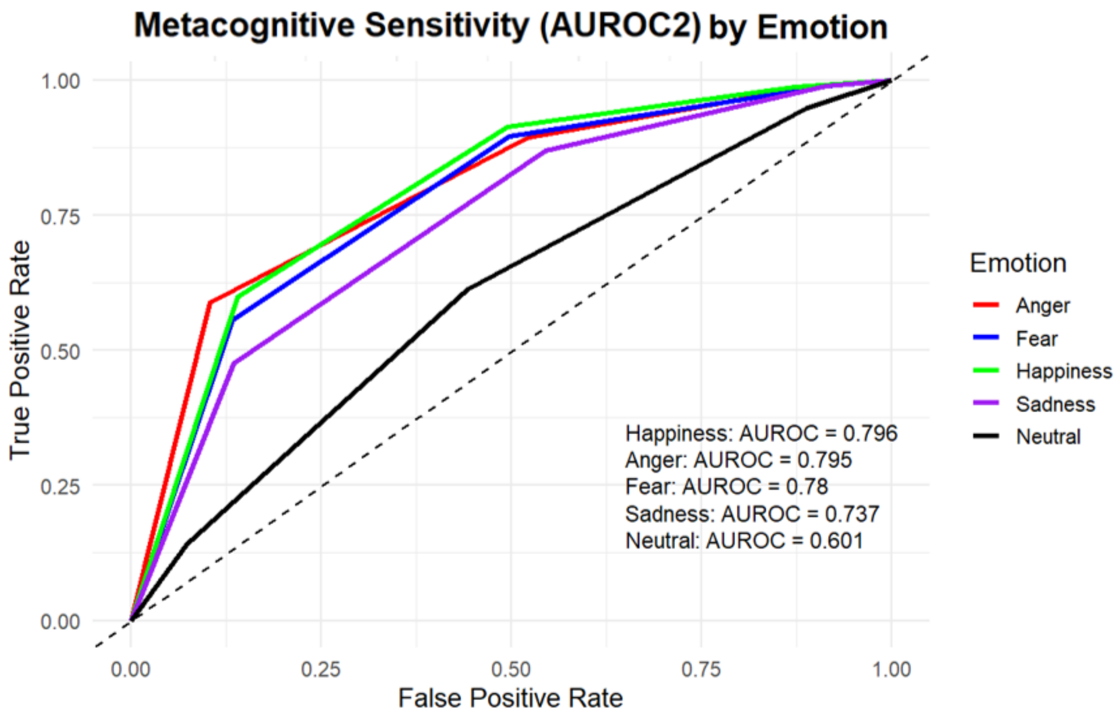

Figure 12. ROC curves showing metacognitive sensitivity (AUROC2) by emotion. Emotional stimuli (happiness (green curve), anger (red curve), fear (blue curve), and sadness (purple curve)) showed higher AUROC2 compared to neutral expressions (black curve), with happiness achieving the highest sensitivity and neutral the lowest.

Furthermore, the analysis revealed no significant main effect of the interaction between phase and intensity on AUROC2 ($F(4, 640.24) = 0.43$, $p = 0.789$). There was a significant main effect of the interaction between phase, emotion and intensity on AUROC2 ($F(12, 637.4) = 2.30$, $p = 0.007$, $\eta^2 = 0.040$) on AUROC2. Pairwise comparisons indicated higher awareness in participants' performance when they viewed angry facial expressions at 100% intensity in the EF phase compared to the ML phase ($p = 0.043$). Similarly, there was significant reduction in AUROC2 observed for fearful facial expressions in O relative to the EF phase ($p = 0.037$) at 100% intensity (*Figure 13*).

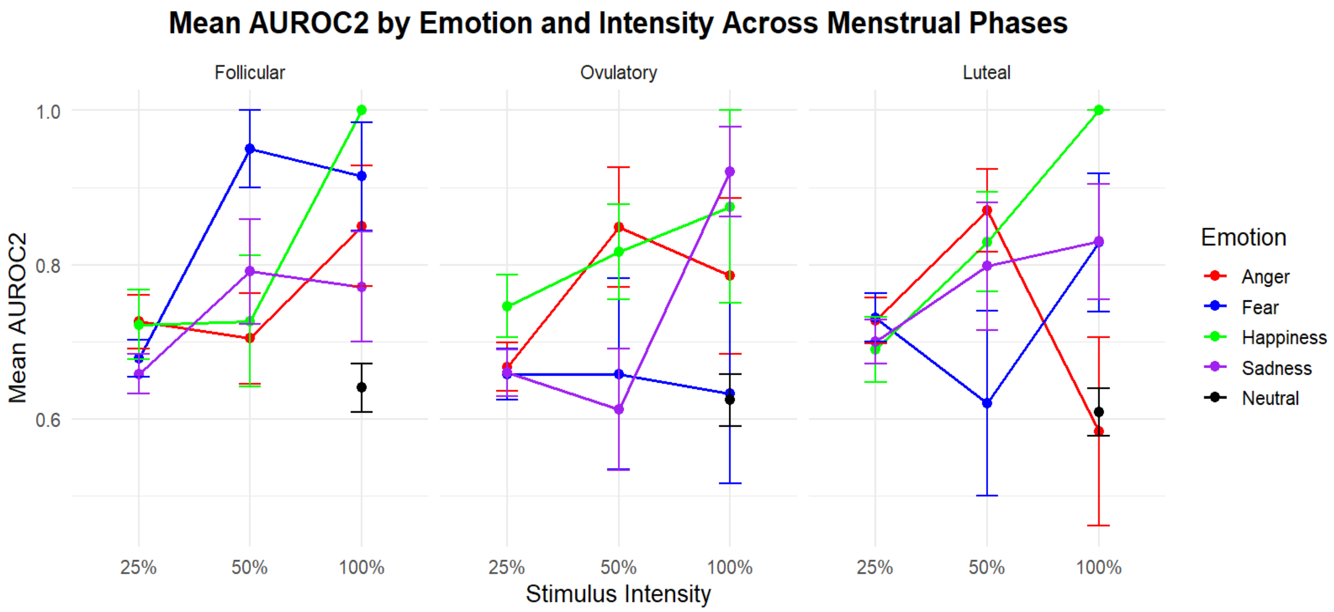

Figure 13. Mean AUROC2 scores by emotion and intensity across menstrual phases. Metacogntive sensitivity varied by both emotion and intensity across the EF, O and ML phases. Whiskers represent ± standard error of the mean.

4. Discussion

The study examined the relationship between different phases of the menstrual cycle: early follicular phase (EF), ovulation (O) and the mid-luteal phase (ML), and metacognition during an emotion recognition task, with consideration of individual psychological and subjective factors.

Analysis revealed main effects of menstrual phases on positive affect (PA), negative effect (NA) and self-reported performance (SRP). Participants reported a significantly higher PA in O than in EF and ML phases, and in the ML phase than in the EF phase. Conversely, NA was higher in the EF phase than in the ML phase, and higher in the ML phase than in O. These findings align with evidence that emotional well-being improves during O, likely due to high estradiol levels in O and low progesterone (Derntl et al., 2008). The findings are also consistent with Rafiee et al. (2023) who acknowledged mood variability and its potential hormonal bias. Specifically, increased estradiol during the late follicular phase (around ovulation) is linked to more positive mood, while elevated progesterone in the ML phase is associated with more negative affect. Furthermore, participants rated higher SRP in O than in both the EF and ML phases, and higher in the ML phase than the EF phase. This aligns indirectly with Röder et al. (2009), who found that women reported felling more attractive and engaged more in self-enhancing behaviors (e.g., styling) during O. Although their study did not assess task-related self-evaluation, their findings suggest heightened self-perception during this phase, which corresponds with our study's result of higher SRP in O.

Psychological variables, including alexithymia, PA, NA, and emotional arousal change, did not significantly affect confidence, performance sensitivity, or metacognitive sensitivity. This finding contrasts with previous research suggesting links between emotional awareness and metacognitive performance (Ådnøy et al., 2023; Seow et al., 2021). Ådnøy et al. (2023) reported that metacognition and mindfulness, measured by the Metacognition Questionnaires (MCQ-30), the Five Facet Mindfulness Questionnaire (FFMQ), and the Acceptance and Action Questionnaire (AAQ-II), were strongly related to symptoms of anxiety and depression. These measures reflected a common ability to flexibly manage thoughts and emotions. This flexibility supports better metacognitive functioning, including the ability to evaluate one's own performance. Seow et al. (2021) using interceptive and physiological indices (e.g., heart rate and skin conductance), found that both local metacognition (the ability to judge the accuracy of one's decisions during an ongoing task) and global metacognition (general beliefs about one's abilities across time) are important for mental health: lower confidence and more negative self-beliefs were associated with higher levels of depressions and anxiety. Compared to Ådnøy et al., (2023) and Seow et al. (2021), our study employed direct self-report scales focused on affective traits and states (TAS-20, PANAS, emotional arousal rating scale). These tools may not have captured the more complex or long-term patterns of emotional and cognitive regulation, which could explain the lack of significant associations. Furthermore, fluctuations in affective states measured by PANAS, which might be expected to correspond with menstrual-related mood changes (Sundström Poromaa & Gingnell, 2014), did not translate into differences in performance sensitivity in our study. While Sundström Poromaa & Gingnell (2014) reviewed studies reporting menstrual cycle effects on emotional processing, these were generally based on accuracy or reaction time measures. This suggests that traditional behavioral measures may be more sensitive to cycle-related changes than signal detection indices like d'.

This one exception was SRP, which significantly affected confidence ratings, suggesting that participants who perceived themselves as better in the task tended to feel more confident in their answers. This finding highlights the role of self-reported evaluation in shaping confidence. However, SRP did not differ across the menstrual cycle, indicating that its effect may be more trait-like than hormonally modulated. This contrasts with Schnall et al. (2002) findings, who showed that bodily awareness affects self-perception across the menstrual cycle. While subjective and psychological states appear to shape confidence to some degree, they do not affect performance or metacognitive sensitivity.

Results showed a significant effect of the interaction between menstrual phase and facial expression intensity on confidence ratings, while no main effect was observed for phase alone. Specifically, participants expressed higher confidence in O than EF and ML phases when viewing low-intensity (25%) emotional expressions. This supports findings from Röder et al. (2009) indirectly, where women reported increased attractiveness and self-perception during fertile periods, suggesting a better self-evaluation around ovulation.

Additionally, confidence was affected by the interaction of phase, emotion and intensity. In O, participants reported greater confidence when viewing anger, fear and sadness expressions at 25% intensity and sadness at 100%, compared to EF and ML phases. In contrast, confidence in recognizing happy expressions did not differ across the phases. These confidence differences emerged only for the negative emotions such as fear, anger and sadness. This may be because negative emotions signal potential threats or social conflict. Being able to detect these cues, especially at low intensity, may have evolutionary advantages by helping individuals respond to danger. In contrast, happy expressions are less critical for immediate survival and usually easier to identify, which may explain why confidence did not differ across phases for happiness. It is possible that higher confidence during O reflects increased awareness of social and emotional cues at a time when fertility is highest.

These results are similar to findings by Schnall et al. (2002), who showed that self-evaluations differed across the menstrual cycle, particularly among women with high emotional awareness. Their study suggested heightened emotional sensitivity in the pre-menstrual phase, which may parallel the increased confidence observed in O in recognizing subtle emotional cues. Taken together, these findings suggest that confidence in emotion recognition is sensitive to both menstrual phases and the emotional factors, especially under low intensity. The differences observed at low intensity may be due to the increased difficulty of recognizing emotions when cues are less clear. In O, elevated estradiol levels may enhance emotional processing and self-monitoring (Albert et al., 2015), supporting higher confidence under uncertain conditions. In contrast, when facial expressions are more intense and easier to identify, hormones may be less relevant, resulting in fewer differences across phases.

d’ from signal detection theory was used to evaluate perceptual sensitivity by isolating true recognition ability from bias. This allows for more objective assessment than raw accuracy alone, especially in a task that includes different intensity levels. While d’ does not measure accuracy per say, it reflects a participant’s ability to discriminate between emotional and neutral stimuli. Results showed no menstrual phase influence on participant’s ability to distinguish between emotional and neutral stimuli. This is inconsistent with studies such as Pearson & Lewis (2005) and Derntl et al. (2008), which reported phase-specific enhancement in fear and anger recognition. These studies relied primarily on raw accuracy scores without accounting for potential response bias. Pearson & Lewis (2005) analyzed correct recognition rates and reaction times across cycle phases, while Derntl et al. (2008) used percent accuracy and confusion metrics, with supplementary sensitivity/specificity measures based on hit and false alarm rates but without full SDT modeling. By analyzing varying intensities and controlling visit effects using mixed-effects models, our analysis may have filtered out subtle biases mistaken for sensitivity in prior work. In contrast, Rafiee et al. (2023) relied on accuracy rates and found no significant effect of menstrual cycle phases on emotion recognition. Thus, despite methodological differences, our findings align with Rafiee et al. (2023) general conclusion that menstrual phases do not appear to substantially affect emotion recognition performance. Furthermore, despite the lack of phase effects, participants demonstrated better sensitivity to emotional expressions over neutral ones.

AUROC2 metric was selected to assess metacognitive sensitivity as it reflects how well confidence ratings align with actual performance, independent of response bias. AUROC2 was not significantly influenced by menstrual phase alone. However, the interaction between phase, emotion and intensity revealed significant effects. For instance, participants demonstrated higher metacognitive sensitivity for 100% anger stimuli in the EF phase compared to the ML phase, and lower sensitivity for fear in O relative to EF. These findings build on prior work by Kelly & Metcalfe (2011), who demonstrated that metacognitive awareness is best measured on a trial-by-trial basis, especially in emotion recognition tasks. They also extend earlier research (Röder et al., 2009) by showing that differences across menstrual phases may affect how accurately participants monitor their own performance, not just how they view themselves.

Interestingly, the interaction between phase and arousal change affected AUROC2. A trend emerged suggesting that participants who felt calmer after the task (i.e., experienced a decrease in emotional arousal), were more aware of their performance in O and the ML phase than in the

EF phase. These findings partially aligned with Schnall et al. (2002), who showed that women who were more attuned to bodily cues (such as arousal), exhibited stronger emotional responses across the menstrual cycle. In our contact, reduced emotional arousal may have made it easier for participants to evaluate their performance. In O and ML phase, the elevated estradiol may be the reason of the higher metacognitive sensitivity, since it has been associated with better cognitive and emotional performances (Albert et al., 2015), In contrast, during the EF phase, when both progesterone and estradiol hormones are low, the cognitive resources required for accurate self-evaluation may be less accessible, even when arousal is reduced.

Several limitations should be acknowledged in this study, such as the moderate sample size, and the uneven distribution of participants' first sessions across menstrual phases with more participants beginning in the follicular phase than luteal phase or ovulation. This imbalance may have introduced order or learning effects, where differences in performance or confidence could reflect task familiarity over time rather than true effects of hormonal fluctuations.

Due to technical and logistic constraints, we were unable to assess sex steroid concentrations in the present study. Incorporating biochemical verifications of hormone levels, such as analyzing salivary estradiol and progesterone, would enhance the validity of future research. Furthermore, expanding sample size and minimizing phase-related imbalances in study design would strengthen future findings.

Conclusions

1. Although psychological characteristics and self-reported performance fluctuated across the menstrual cycle, with higher positive affect and self-reported performance in ovulation than in both early follicular and mid-luteal phases, and higher negative affect in early follicular compared to ovulation and mid-luteal phase, these fluctuations had no significant effect on metacognitive performance.
2. Menstrual phases were related to confidence ratings only in interaction with emotion type and facial expression intensity, with higher confidence in ovulation than in early follicular and mid-luteal phases when presented by low-intensity emotional stimuli.
3. Performance sensitivity was stable throughout the menstrual cycle.
4. Emotional facial expressions at full intensity were related to metacognitive sensitivity: it was higher in the early follicular than in the mid-luteal phase for angry faces, and higher in ovulation than in the early follicular phase for fearful faces.

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Finally, I would like to acknowledge Vilnius University for providing the resources and academic environemnt that made this work possible.

VILNIUS UNIVERSITY

LIFE SCIENCES CENTER

Ghina Hafez

Master's thesis

The Relationship Between Menstrual Cycle Phases and Metacognition: A Study on Emotion Recognition

ABSTRACT

This thesis aimed to investigate the relationship between metacognition and different phases of the menstrual cycle during a facial emotion recognition task, while accounting for psychological and subjective variables. Key objectives included evaluating changes in psychological metrics, confidence ratings, performance sensitivity (d') and metacognitive sensitivity (AUROC2) across the phases.

Forty-one naturally cycling women completed a facial emotion recognition task during three different phases of the menstrual cycle: early follicular (EF), ovulation (O), and mid-luteal (ML). Participants chose the perceived emotional facial expressions (anger, fear, happiness, sadness, and neutral) at varying intensities (25%, 50% and 100%), and provided confidence ratings after each response. Psychological assessments included alexithymia (TAS-20), positive (PA) and negative (NA) affects (PANAS), emotional arousal (pre-/post-task), and self-reported performance (SRP).

Menstrual phase had a significant effect on psychological parameters: PA and SRP were higher in O than in EF and ML phases, and ML than EF. While NA was higher in EF than O, and ML than O. Alexithymia, affect and arousal, had no effect on confidence, d', or AUROC2. SRP had an effect on confidence, where higher confidence was observed for higher SRP scores than lower. Furthermore, confidence was stable across phases overall but was significantly higher in O when recognizing 25% intensity negative emotions than in EF and ML phases. d' was stable across the menstrual phases but increased for emotional than neutral expressions. While AUROC2 showed no overall phase effect, interactions with emotion and intensity revealed higher AUROC2 for 100% anger expressions in EF than ML phase, and reduced AUROC2 for fear in O than EF phase.

In summary, while metacognitive performance remained stable across menstrual phases, fluctuations emerged in relation to emotion, facial expression intensity and phase, with minimal effect of the psychological and self-reported evaluations on metacognitive performance.

VILNIAUS UNIVERSITETAS

GYVYBĖS MOKSLŲ CENTRAS

Ghina Hafez

Magistro baigiamasis darbas

Ryšys tarp menstruacinio ciklo fazių ir metakognicijos: emocijų atpažinimo tyrima

SANTRAUKA

Šio darbo tikslas - ištirti ryšį tarp metakognicijos ir menstruacinio ciklo fazių atliekant emocijų atpažinimo užduotį, atsižvelgiant į psichologinius ir subjektyvius parametrus. Pagrindiniai uždaviniai buvo įvertinti psichologinių rodiklių, pasitikėjimo vertinimų, atlikimo jautrumo (d') ir metakognityvinio jautrumo (AUROC2) pokyčius skirtingose menstruacinio ciklo fazėse.

Keturiasdešimt viena natūralų menstruacinį ciklą turinti moteris atliko emocijų atpažinimo užduotį trijose skirtingose menstruacinio ciklo fazėse: ankstyvojoje folikulinėje (EF), ovuliacijoje (O) ir vidurinėje geltonkūnio (ML). Dalyvės turėjo pasirinkti, kokią emocinę veido išraišką (pyktį, baimę, džiaugsmą, liūdesį ar neutralią) atpažįsta, esant skirtingam išraiškos intensyvumui (25 %, 50 % ir 100 %), ir po kiekvieno atsakymo pateikti pasitikėjimo savo sprendimu įvertį. Psichologiniai vertinimai apėmė aleksitimiją (TAS-20), teigiamą (PA) ir neigiamą (NA) afektą (PANAS), emocinį sužadinamumą (prieš ir po užduoties) ir užduoties atlikimo vertinimą (SRP).

Psichologiniai parametrai menstruacinio ciklo metu kito: PA ir SRP buvo didesni O nei EF ir ML fazėse, bei ML nei EF fazėje. Tuo tarpu NA buvo mažesnis O lyginant su EF ir ML fazėmis. Aleksitimija, afektas ir emocinis sužadinamumas nebuvo susiję su atlikimo pasitikėjimu, d' ar AUROC2. Tačiau SRP buvo susiję s su atlikimo pasitikėjimu: didesnis pasitikėjimas buvo stebimas esant aukštesniems SRP įverčiams nei žemesniems. Nors pasitikėjimas savo atlikimu nekito ciklo metu, tačiau O buvo gerokai didesnis atpažįstant 25 % intensyvumo neigiamas emocijas nei EF ir ML fazėse. d' išliko stabilus menstruacinio ciklo eigoje, tačiau buvo didesnis atpažįstant emocines nei neutralias išraiškas. Nors menstruacinio ciklo fazių poveikio AUROC2 nenustatyta, sąveikos su emocija ir jos intensyvumu atskleidė aukštesnį AUROC2 100 % pykčio išraiškoms EF nei ML fazėje, bei sumažėjusį AUROC2 baimei O lyginant su EF faze.

Apibendrinant, metakognicija išliko stabili menstruacinio ciklo eigoje, tačiau buvo stebimi svyravimai, priklausantys nuo emocijos, veido išraiškos intensyvumo ir ciklo fazės sąveikos, o psichologiniai bei savistabos įverčiai turėjo tik minimalų poveikį metakognicijos parametrams.

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Appendices

Appendix A. Psychological and Biographical Assessment Questionnaire

Data__________ Tiriamosios nr.___________

Bendros informacijos klausimynas

1. Amžius (nurodykite, kiek Jums šiuo metu yra metų): ____

2. Turimas arba šiuo metu siekiamas įgyti išsilavinimas (pažymėkite tinkamą):

□ Vidurinis; □ Profesinis; □ Bakalauras: baigtas kursas: ___ □ Magistras: baigtas kursas:___

□ Doktorantūra: baigti metai: ___

3. Įrašykite, kokiai profesijai save priskiriate (pvz.: istorikė, psichologė ir t.t.)________________________

4. Kokia yra Jūsų biologinė lytis (nustatyta gimus):

□ Moteriška □ Vyriška

5. Kokia yra Jūsų lyties tapatybė (socialinė lytis):

□ Moteris □ Vyras □ Kita____________________

6. Santykių statusas: ar šiuo metu esate susituokusi/turite pastovų partnerį/ę?

□ Ne □ Taip

7. Kiek esate patenkinta šiais santykiais, įvertinkite skalėje:

Visiškai nepatenkinta Labai patenkinta

8. Kokia yra Jūsų lytinė orientacija:

□ Heteroseksuali □ Biseksuali □ Homoseksuali □ Kita____

9. Ar nešiojate akinius ar kontaktinius lęšius (pažymėkite tinkamą)?

□ Ne □ Taip

Jei atsakėte teigiamai, prašome nurodyti, ką dėvite eksperimento metu: ______________________________

10. Ar turite kitų problemų susijusių su akimis/ regėjimu (pažymėkite tinkamą)?

□ Ne □ Taip

Jei atsakėte teigiamai, prašome nurodyti ar dėl jų Jums gali kilti sunkumų aiškiai matyti ekeperimento metu pateikiamą informaciją monitoriaus ekrane (vidutinio dydžio raidės ir vaizdai, 80-100 cm atstumu:

□ Ne □ Taip

11. Ar turite problemų susijusių su klausa (pažymėkite tinkamą)?

□ Ne □ Taip

12. Jeigu rūkote, prašome parašyti, prieš kiek valandų paskutinį kartą rūkėte?__________________________

13. Kiek valandų šią naktį išmiegojote?____

14. Ar per pastarąjį mėnesį turėjote žymių savo mitybos pakitimų?

□ Ne □ Taip

Jei taip, kaip tai galėjo paveikti Jūsų svorį (padidinti/sumažinti/kita)

____

15. Įvertinkite pastarųjų dviejų savaičių streso/įtampos lygį savo gyvenime:

□ Labai žemas □ Žemas □ Vidutinis □ Aukštas □ Labai aukštas

16. Ar Jūsų ciklas reguliarus (reguliariu laikomas pastovios trukmės, 21-35 dienų ciklas)?

□ Taip □ Ne

Jei ne, trumpai apibūdinkite____

17. Jei Jūsų ciklas reguliarus, kelinta šiandien yra ciklo diena (pvz.: 4-ta)? ___________________________

18. Kokia yra Jūsų ciklo trukmė (pvz. 26)? ____

19. Ar esate anksčiau vartojusi hormoninę kontracepciją?

□ Ne □ Taip

Jei taip, prieš kiek laiko (mėn/m) ___________, kaip ilgai (mėn/m)__________, kokią (tabletės, hormoninė spiralė, pleistras, kita)__________________________________?

20. Ar vartojate hormoninę kontracepciją (pažymėkite tinkamą)?

□ Ne □ Taip

Jei vartojate hormoninę kontracepciją, įrašykite kelinta tabletės vartojimo diena yra šiandien dalyvaujant eksperimente? ____

Naudojamo preparato pavadinimas? ____

21. Ar pajutote pokyčius pradėjusi vartoti hormoninę kontracepciją? Atsakykite į kiekvieną punktą, jei atsakėte teigiamai, paaiškinkite kaip stipriai, kokio pobūdžio pokyčiai:

-seksualinio potraukio (libido) pokyčiai: □ Ne □ Taip _________________________________

____

-emocijų pokyčiai (jutimas, išreiškimas ir kt.): □ Ne □ Taip ____________________________

____

-nuotaikos pokyčiai: □ Ne □ Taip____

____

-kiti pokyčiai (pvz. fiziologiniai, socialinio pobūdžio ar pan.): □ Ne □ Taip ________________

____

RANKIŠKUMO TESTAS

Edinburgo rankiškumo klausimynas

Prašome nurodyti, kuriai rankai teikiate pirmenybę atliekant žemiau nurodytas veiklas. Įrašykite + ženklą atitinkamame stulpelyje. Jei pirmenybės teikimas vienai rankai toks stiprus, kad kitą ranką naudotumėte tik esant būtinybei, nurodykite tai ++ ženklu. Jei naudojate abi rankas vienodai, nurodykite + ženklą kiekviename stulpelyje. Prašome atsakyti į kiekvieną klausimą.

Nr.	Veikla	Kaire	Dešine
1	Rašymas		
2	Piešimas		
3	Siuvimas (ranka laikanti adatą)		
4	Žirklių laikymas		
5	Dantų valymas		
6	Peilio laikymas		
7	Šaukšto laikymas		
8	Šluotos naudojimas (viršutinė ranka)		
9	Degtuko uždegimas (ranka laikanti degtuką)		
10	Dėžės atidarymas (ranka laikanti dangtį)		

Data__________ Tiriamosios nr.___________

PANAS

Šiame puslapyje surašyti žodžiai apibūdina skirtingus jausmus ir emocijas. Perskaitykite kiekvieną žodį ir pažymėkite, kaip Jūs šiandien jaučiatės.

	Visiškai ne arba labai mažai	Nelabai	Vidutiniškai	Gana daug	Labai daug
1. Besidomintis (-i)	□1	□2	□3	□4	□5
2. Kenčiantis (-i)	□1	□2	□3	□4	□5
3. Sužadintas (-a), jaudrus (-i)	□1	□2	□3	□4	□5
4. Prislėgtas (-a)	□1	□2	□3	□4	□5
5. Stiprus (-i)	□1	□2	□3	□4	□5
6. Kaltas (-a)	□1	□2	□3	□4	□5
7. Išsigandęs (-usi)	□1	□2	□3	□4	□5
8. Priešiškas (-a)	□1	□2	□3	□4	□5
9. Entuziastingas (-a)	□1	□2	□3	□4	□5
10. Išdidus (-i)	□1	□2	□3	□4	□5
11. Irzlus (-i)	□1	□2	□3	□4	□5
12. Budrus (-i), pasirengęs (-us)	□1	□2	□3	□4	□5
13. Susigėdęs (-usi)	□1	□2	□3	□4	□5
14. Pilnas (-a) įkvėpimo	□1	□2	□3	□4	□5
15. Laimingas (-a)	□1	□2	□3	□4	□5
16. Ryžtingas (-a)	□1	□2	□3	□4	□5
17. Dėmesingas (-a)	□1	□2	□3	□4	□5
18. Neramus (-i)	□1	□2	□3	□4	□5
19. Nervingas (-a)	□1	□2	□3	□4	□5

Data__________ Tiriamosios nr.___________

20. Veiklus (-i)	□1	□2	□3	□4	□5
21. Bijantis (-i)	□1	□2	□3	□4	□5

TAS - 20

Nustatykite, ar Jums tinka, ar netinka kiekvienas teiginys. Atsakydami pasirinkite tik vieną variantą: apibraukite „1“, jei šis teiginys Jums visiškai netinka; apibraukite „2“, jei šis teiginys Jums iš dalies netinka; apibraukite „3“, jei nežinote, ar Jums tai tinka; apibraukite „4“, jei šis teiginys Jums iš dalies tinka; apibraukite „5“, jei šis teiginys Jums labai tinka.

	Balų skaičius				
1. Man dažnai sunku suprasti savo išgyvenamus jausmus.	1	2	3	4	5
2. Man sunku surasti žodžius, kuriais galėčiau tiksliai išreikšti savo jausmus.	1	2	3	4	5
3. Kartais kreipiuosi į gydytojus atsiradus kokiems nors simptomams, bet gydytojai nenustato jų priežasties.	1	2	3	4	5
4. Man lengva papasakoti, ką aš jaučiu.	1	2	3	4	5
5. Aš mėgstu giliai išanalizuoti problemą, o ne tik paviršutiniškai su ja susipažinti.	1	2	3	4	5
6. Aš nesuprantu, ką jaučiu susierzinęs (-usi) - pyktį, baimę ar liūdesį.	1	2	3	4	5
7. Aš dažnai jaučiu fizinius pojūčius, kurie mane nustebina.	1	2	3	4	5
8. Aš įpratęs (-usi) stebėti įvykių eigą, negalvojant apie jų priežastis.	1	2	3	4	5
9. Kartais man būna neaišku, ką jaučiu.	1	2	3	4	5
10. Manau, kad visda reikia stebėti ir suprasti savo jausmus.	1	2	3	4	5
11. Man sunku suprasti, ką aš jaučiu kitiems žmonėms, taip pat sunku rasti tikslius žodžius, kuriais juos galėčiau išreikšti.	1	2	3	4	5
12. Artimi žmonės man sako, kad aš turėčiau dažniau kalbėti apie tai, ką jaučiu.	1	2	3	4	5
13. Nesuprantu, kas darosi mano sieloje	1	2	3	4	5
14. Dažnai supykstu be jokios priežasties.	1	2	3	4	5
15. Mėgstu kalbėtis apie kasdienius dalykus, o ne apie pašnekovų vidinius išgyvenimus.	1	2	3	4	5
16. Man patinka pramoginės laidos, dramatinių laidų nemėgstu.	1	2	3	4	5
17. Slapčiausius jausmus man sunku atskleisti net ir artimiausiems žmonėms.	1	2	3	4	5
18. Su kai kuriais žmonėmis jaučiuosi artimas(-a) net ir tyledamas (-a).	1	2	3	4	5
19. Jausmų analizė man padeda išspręsti asmenines problemas.	1	2	3	4	5
20. Nebejaučiu malonumo, jei žiūrėdamas (-a) filmą ar spektaklį pradedu svarstyti, kokia prasmė glūdi tame kūrinyje.	1	2	3	4	5

Appendix B. Self-Reported Rating Scales

Emocijų atpažinimo užduoties atlikimo vertinimo skalė **EA ________**

Kaip manote, kaip Jums pavyko atlikti užduotį? Įvertinkite, uždėdami brūkšnelį atkarpoje:

Labai blogai atlikta užduotis — Labai gerai atlikta užduotis

Emocinio sužadinamumo vertinimo skalė **Prieš ________**

Kaip stipriai emociškai sužadinta/susijaudinusi jaučiatės? Įvertinkite, uždėdami brūkšnelį atkarpoje:

Visiškai emociškai nesužadinta — Maksimaliai emociškai sužadinta

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Emocinio sužadinamumo vertinimo skalė **Po ________**

Kaip stipriai emociškai sužadinta/susijaudinusi jaučiatės? Įvertinkite, uždėdami brūkšnelį atkarpoje:

Visiškai emociškai nesužadinta — Maksimaliai emociškai sužadinta

Appendix C. Emotions Misclassification

A frequency analysis was conducted to better understand how often emotional expressions were misclassified as neutral across different intensity levels. This analysis focused on incorrect responses to stimuli presented at low (25%), moderate (50%) and full (100%) intensities, excluding neutral stimuli (e.g., filter(`intensity` == 2, ACC == 0, emotion != 5).

Analysis revealed that at 25% intensity, sadness was most frequently misclassified as neutral (n= 278), followed by anger (n = 267) , happiness (n = 261), and fear (n = 226). At 50% intensity, happiness was the most misclassified emotion as neutral (n = 13). At 100% intensity, misclassifications were minimal and observed only for anger and sadness (n = 1 each).