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Original Article

Physiology Section

Simple and Discriminatory Reaction Times in Preovulatory and Postovulatory Phases of Menstrual Cycle in Healthy Young Females: A Cross-sectional Study

HEMALATHA MANJESHWARA[1], V SUGANTHI[2], AMUDHARAJ DHARMALINGAM[3], MILIND V BHUTKAR[4], GOPINATH MANAVAZHAGAN[5]

ABSTRACT

Introduction: The menstrual cycle plays a significant role in the functioning of the cardiovascular and central nervous systems. Cognitive processing is affected differently during the various phases of the menstrual cycle, in addition to emotional processing. Cognitive domains such as attention, awareness, and memory show variations across the phases of the menstrual cycle. However, considerable conflicts exist in the scientific literature regarding the changes in these parameters during the menstrual cycle. Reaction times have been established as an objective measurement of cognitive processing in humans.

Aim: To observe and compare simple and discriminatory visual and auditory reaction times in healthy adult females in the pre and postovulatory phases of their menstrual cycles.

Materials and Methods: This cross-sectional observational study was conducted in the southern part of India during the years 2018-2024. Interested volunteers were questioned regarding their menstrual history to rule out any abnormalities. Healthy young adult females were included in the study after obtaining their informed consent in writing. Preovulatory reaction times were measured on the 10^{th} or 11^{th} day, while postovulatory reaction times were measured on the 20^{th} or 21^{st} day of the menstrual cycle. Simple and discriminatory visual and auditory reaction times were measured in triplicate at a resolution of one millisecond, with the minimum value included for analysis. The Kolmogorov-Smirnov test was used to analyse the normality of the distribution, and the Wilcoxon signed-rank sum test was used to test the significance of the difference in medians of the paired samples. Statistical Package for Social Sciences (SPSS) version 16.0 was employed for the analysis.

Results: Simple Visual Reaction Times (SVRT) significantly differed between the pre and postovulatory phases (p-value 0.048). Simple Auditory Reaction Times (SART) also significantly differed between the pre and postovulatory phases (p-value 0.003). Discriminatory Visual Reaction Times (DVRT) and Discriminatory Auditory Reaction Times (DART) did not statistically differ between the pre and postovulatory phases (p-value=0.938, p-value=0.076, respectively).

Conclusion: Simple visual and auditory reaction times were significantly prolonged in the postovulatory phases.

Keywords: Attention, Cognition, Simple auditory reaction times, Simple visual reaction times

INTRODUCTION

Ovarian steroid hormones, in addition to their primary role in the reproductive system, exert a significant influence on the human nervous system. Studies have demonstrated their effects on many aspects of nervous system functioning, including the affective, cognitive and psychomotor domains [1-3]. The literature indicates that a differential action exists between the ovarian hormones oestrogen and progesterone in relation to nervous system function. Moreover, as the levels of these hormones change in a cyclical manner throughout the menstrual cycle, their effects also change, cognition and psychomotor functioning in human females. It has been observed that serum levels of both estradiol and progesterone are low during the bleeding phase, with high estradiol levels in the follicular phase and elevated oestrogen and progesterone levels in the luteal phase [4]. Cognitive processing is affected differently during the various phases of the menstrual cycle, in addition to emotional processing. Cognitive domains such as attention, awareness and memory show variations across these phases [5]. However, considerable conflicts exist in the scientific literature regarding the nature of these changes during the menstrual cycle phases, including disagreements about whether these phases are significant determinants, differences in cognitive performance across phases and the magnitude of these changes. Therefore, it is important to study the functioning of the nervous system throughout the menstrual cycle. Various attempts have been made in the past to elucidate this, yet studies differ in their methodologies, sample sizes and suffer from limitations such as unmeasured hormone levels, inconsistent time points within the same menstrual phases and varying inclusion and exclusion criteria [6-8].

In this context, the current study aimed to observe neural functioning in healthy menstruating adult females during the menstrual cycle, drawing relevant insights from previous research. Reaction times have been established as an objective measure of cognitive processing in humans, encompassing several factors, including the time taken for perceptual processing, cognitive processing and final motor execution [9]. Various reaction times have been investigated, including auditory, visual and tactile [10]. In the present study, the visual and auditory reaction times, which are salient for many aspects of executive functioning in daily life, were included. Therefore, this study aimed to observe the reaction times during the preovulatory and postovulatory phases of the menstrual cycle in young healthy adult females. The objectives of the study were to analyse and compare SVRT, DVRT, SART and DART in healthy young adult females during the pre and postovulatory phases. The data presented here is part of a larger study.

MATERIALS AND METHODS

The cross-sectional observational study was conducted in the Department of Physiology at Aarupadai Veedu Medical College and Hospital, Puducherry, India, during the period from July 2018 to June 2024. Prior to the commencement of the study, approval from the Institutional Research Committee (IRC) (AVIRC2018026) and the ethics committee (AV/IEC/2018/042) was obtained.

Inclusion criteria: Interested menstruating female volunteers were assessed for inclusion based on their menstrual history. Menstrual cycle history for the last six months was evaluated. Healthy female subjects aged 18-22 years, with a cycle length of 26-35 days, were included in the study.

Exclusion criteria: Female subjects with any acute or chronic illness who were on medications or had premenstrual syndrome. Subjects with a history of excessive physical activity, such as athletes and those experiencing sleep deprivation were also excluded from the study.

Sample size calculation: The minimum sample size required to reject the null hypothesis using a paired t-test, with a type I error of 5% and a type II error of 20%, was calculated based on an expected mean difference in reaction times between menstrual phases from previous studies and was found to be 65 pairs [9]. However, 105 samples were taken and a convenient sampling method was followed.

Methodology and parameters: Conflicting studies have both refuted and supported cognitive changes postprandial; however, in the present study, reaction times were measured in all subjects only after three hours postprandial [11,12]. All recordings were conducted in the evening, after 5:00 pm. The subjects were instructed to avoid caffeine and nicotine atleast 12 hours prior to the study [13]. Ovulation dates were estimated based on the data of previous menstrual histories by subtracting 14 days from the cycle length. Preovulatory reaction times (SVRT, SART, DVRT, DART) were measured on the 10th or 11th day of the menstrual cycle, while postovulatory reaction times (SVRT, SART, DVRT, DART) were measured on the 20th or 21st day of a typical 28-day menstrual cycle using a reaction time apparatus (Make: Anand Agencies, Pune) with a resolution of 0.001 seconds, accuracy of ±1 digit, and two different lights (red and green), along with two different sounds, tone and click sounds. The subsequent menstruation in the next cycle acted as confirmation.

The subjects were instructed about the procedure, and after adequate practice, the tests were performed. For simple reaction times, the subjects were instructed to hold the key using the index finger of their dominant arm and to release it reflexively when they saw or heard the desired stimuli. This approach was designed to ensure the objectivity of the reaction times with minimal influence from psychomotor coordination. In the assessment of SVRT, the desired colour of the visual stimuli was chosen randomly, as significant disagreement exists regarding the effect of colour on visual reaction time [14,15]. However, one study pointed out that there is no significant difference between red and green colours [7].

The inbuilt electronic stopwatch is triggered to start and count only in an AND gate configuration, meaning both the subject's and examiner's keys must be in the pressed/ON position; if either key is released, the stopwatch ceases counting. In this method, the simple reaction time values are read directly from the seven-segment LED display of the apparatus, which is positioned on the examiner's side, to a resolution of one millisecond. The procedure is repeated three times for both visual and auditory stimuli for each subject, with a one-minute rest interval given between trials. The lowest of the three values was included for analysis.

For the measurement of DVRT, the subject was instructed to hold the key and to release it only when they see or hear the desired visual or auditory stimuli. During this test, non desired signals are presented multiple times before the desired signal is introduced at random intervals. The subject was instructed not to release the key for any non desired stimuli and to release the key only in response to the desired signal, whether visual or auditory. The DVRT values are read directly from the digital display of the apparatus. As with simple reaction times, discriminatory reaction times are also performed in triplicate, with a one-minute rest interval between trials, and the lowest of the values is used for analysis [10]. In the present study, for simple auditory reaction times, tone and click sounds were used randomly as the desired auditory stimuli, while red and green colours were used randomly as desired visual stimuli.

STATISTICAL ANALYSIS

The Kolmogorov-Smirnov test was used to analyse the normality of the distribution, and the Wilcoxon signed-rank sum test was employed to test the significance of the difference in medians of the paired samples. SPSS version 16.0 was used to analyse the data. The null hypothesis is rejected at a p-value of 0.05.

RESULTS

The mean age of the participants was 19.22±0.823 years. The mean menstrual cycle length was 30.60±2.77 days.

[Table/Fig-1] shows the median and range values for various reaction times in seconds. Auditory reaction times were longer than visual reaction times, and postovulatory reaction times were longer than preovulatory reaction times.

Variable	Sample size	Distribution	Median (seconds)	Range
SVRT- pre	105	Non normal	0.143	0.069-0.261
SART- pre	105	Non normal	0.153	0.105-0.319
DVRT- pre	105	Non normal	0.153	0.014-0.314
DART- pre	105	Non normal	0.152	0.109-0.323
SVRT- post	105	Non normal	0.146	0.1-0.305
SART- post	105	Non normal	0.162	0.102-0.333
DVRT- post	105	Non normal	0.156	0.099-0.328
DART- post	105	Non normal	0.157	0.101-0.303

[Table/Fig-1]: Reaction time during pre-ovulatory and postovulatory period.
*SVRT: Simple visual reaction time; * DRT: Discriminatory reaction time;
*SART: Simple auditory reaction time; * DART: Discriminatory auditory reaction time.

Significant differences were observed between simple visual and auditory reaction times across the preovulatory and postovulatory phases (p-value <0.05). However, such significant differences were not observed between discriminatory visual and auditory phases (p-value>0.05) [Table/Fig-2].

Sample size	Variable during postovulatory and pre-ovulatory phase	p-value
105	SVRT post - SVRT pre	0.048*
105	SART post - SART pre	0.003**
105	DVRT post - DVRT pre	0.938
105	DART post - DART pre	0.076

[Table/Fig-2]: Wilcoxon signed rank sum test- for testing significance.
(p<0.05*, p<0.1**); SVRT: Simple visual reaction time; SART: Simple auditory reaction time;
DVRT: Discriminatory visual reaction time; DART: Discriminatory auditory reaction time.

DISCUSSION

The present study observed that the SVRT significantly differed between the preovulatory and postovulatory phases, with SVRTs being shorter in the preovulatory phase compared to the postovulatory phase. This finding was in concordance with other studies [9,16], which indicate a prolonged visual reaction time in the luteal phase compared to the follicular phase. This difference could be attributed to the fluctuating levels of sex hormones.

Similarly, SART also significantly differed between the preovulatory and postovulatory phases. Like the SVRTs, SARTs were shorter in the preovulatory phase compared to the postovulatory phase, which aligns with findings of prolonged auditory reaction times in the luteal phase [4]. In contrast, a study by Afshan A et al., observed shorter reaction times during the luteal phase [8].

The DVRT did not significantly differ between the preovulatory and postovulatory phases, nor did DART, which had a p-value of 0.076. The reasons for these observations could be attributed to the smaller sample size; additionally, since discriminatory reaction times involve longer and multiple Central Nervous System (CNS) loops, the effects of hormones might be reduced due to complex interactions [17]. Other studies have concluded that fluctuating levels of oestrogen and progesterone during the normal menstrual cycle affect reaction times [6,9].

The literature indicates that progesterone levels have been inversely correlated with neuroprocessing speed, as measured through performance in cognitive tests during the luteal phase [2,17]. At the same time, studies have demonstrated conflicting or differentiated performance in cognitive domains during this phase [18,19]. One possible explanation is that progesterone levels may allocate neuro-processing resources specifically to emotionally salient information that aids in survival, rather than to process emotionally neutral or less significant information [6]. Furthermore, progesterone levels have been associated with memory for more negative images or semantics, and observations of depression during pregnancy in clinical practice reinforce this assertion [6]. This may offer a survival advantage in wildlife, where the behavioural modification influenced by progesterone results in lower initiative and less inclination toward novel instincts, leading to a preference for routine and safer environments during pregnancy.

Conversely, during the follicular phase, where progesterone levels are lower and oestrogen levels are higher, neuroprocessing speeds are faster for emotionally neutral information. Subjects in this phase report more positive moods and memory retention is greater for positive images and semantics. Oestrogen has been shown to enhance cognitive ability in humans in several studies [20-22]. The follicular phase, with rising plasma levels of oestrogen, demonstrates increased neuroprocessing, cognitive ability, positive mood and retention of memory for emotionally neutral or positive images and semantics [23].

The aforementioned observations can be applied to our understanding of cyclical changes in neuroprocessing and mood states, highlighting the importance of complementing activities that may enhance optimal performance and quality of life.

Limitation(s)

The study was conducted within a narrow age group distribution; hence, its findings cannot be generalised. Multiple age groups must be included to enable the generalisation of the observations from this study.

CONCLUSION(S)

The SVRT and SART were significantly prolonged in the postovulatory phase compared to the preovulatory phase. However, significant differences were not observed in the discriminatory visual and auditory reaction times. In the future, more studies should be conducted that include various age groups of healthy menstruating women to enable generalisation.

Declaration: The data has been presented in the international conference “BMSeCON 2023” in December 2023 and well received but however authors declare that there is no publication of their presentation including the abstract in any journals.

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PARTICULARS OF CONTRIBUTORS:

1. Assistant Professor, Department of Physiology, Aarupadai Veedu Medical College and Hospital, Pondicherry affliated to Vinayaka Missions Research Foundation (DU), Salem, Tamil Nadu, India.
2. Professor, Department of Physiology, VMKVMC, Vinayaka Missions Research Foundation (DU), Salem, Tamil Nadu, India.
3. Additional Professor, Department of Physiology, All India Institute of Medical Sciences, Mangalagiri, Andhra Pradesh, India.
4. Professor, Department of Physiology, Swami Vivekananda Medical College Hospital and Research Institute, Tiruchengode, Tamil Nadu, India.
5. Professor, Department of Physiology, Aarupadai Veedu Medical College and Hospital, Pondicherry affliated to Vinayaka Missions Research Foundation (DU), Salem, Tamil Nadu, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Amudharaj Dharmalingam,
Additional Professor, Department of Physiology, AIIMS Mangalagiri,
Mangalagiri-522503, Andhra Pradesh, India.
E-mail: rajraj19831@gmail.com

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