

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

**CHANGES IN PERFORMANCE ON COGNITIVE ABILITIES AND  
MANUAL DEXTERITY TASKS ACROSS DIFFERENT PHASES OF  
THE MENSTRUAL CYCLE.**

*Project submitted for partial fulfillment of the degree of*

MASTERS OF ARTS

IN

PSYCHOLOGY



**THAPAR INSTITUTE**  
OF ENGINEERING & TECHNOLOGY  
(Deemed to be University)

SUBMITTED BY:

Tavleen Kaur

UNDER THE SUPERVISION AND GUIDANCE OF:

Professor (Dr.) Santha Kumari

School of Liberal Arts & Sciences

Thapar Institute of Engineering and Technology, Patiala.

CERTIFICATION

This is to certify that the thesis entitled, 'Changes In Performance On Cognitive Abilities And Manual Dexterity Tasks Across Different Phases Of The Menstrual Cycle' is being submitted in partial fulfillment of requirements for the award of the degree of Master of Arts in Psychology, presented in the Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala is a bonafide work carried out under the supervision of Dr. Santha Kumari, Professor & Program Chair, Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala and that no part of this project has been submitted for the award of any other degree.



(TAVLEEN KAUR)

This is to certify that the above statement by the student concerned is correct and true to the best of my knowledge.



(Dr. SANTHA KUMARI)

Professor & Program Chair, TSLAS

Thapar Institute of Engineering and Technology, Patiala

CANDIDATE'S DECLARATION

I hereby declare that the work presented in this thesis entitled, 'Changes In Performance On Cognitive Abilities And Manual Dexterity Tasks Across Different Phases Of The Menstrual Cycle' submitted in partial fulfillment of requirements for the award of the degree of Master of Arts in Psychology, presented in the Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala, is an authentic record of my work carried out under the supervision and guidance of Dr. Santha Kumari, Professor & Program Chair, Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala and refers other researchers' work which is duly listed in the reference section.

The matter embodied in this thesis has not formed the basis for awarding any other degree at this or any other university.

Date- 26.05.2023

Place- Patiala, Punjab



(TAVLEEN KAUR)

This is to certify that the above statement by the student concerned is correct, valid, and accurate to the best of my knowledge.



(Dr. SANTHA KUMARI)

Professor & Program Chair, TSLAS

Thapar Institute of Engineering and Technology, Patiala

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

## DECLARATION

I, Tavleen Kaur (862102040), a student of M.A. Psychology (2021-2023), Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala, have completed the project entitled, 'Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks Across Different Phases of The Menstrual Cycle.'

DATE: 26.05.2023

M. A. Psychology (2021-2023)

Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology,

Patiala, Punjab.

### ACKNOWLEDGEMENT

Only one person never crafts a noteworthy task, but the commitment of various individuals in their distinctive ways makes it achievable. I want to thank my guide, Dr. Santha Kumari, Professor & Program Chair, Thapar School of Liberal Arts & Sciences, Thapar Institute of Engineering and Technology, Patiala, for her profitable supervision and predictable support all through the project work. She made it a point to be accessible to clear up our questions, notwithstanding her bustling calendars. I considered it an extraordinary chance to do my examination program under her direction and learn the systems of research skills.

I might likewise want to thank the members of this investigation for taking as much time as needed as sincerely as they did as they made the exploration achievable. Lastly, I would like to express thanks to our families for their help all through and for giving us incredible support.

Tavleen Kaur

862102040

TABLE OF CONTENT

S.No.	Contents	Page No.
1	Abstract	9
2	Introduction	10
3	Review of Literature	19
4	Objectives and Hypotheses	24
5	Methodology	27
6	Results	31
7	Discussion	39
8	Conclusion, Limitations, Scope for Future Research, and Implications	43
9	References	45
10	Appendix A	55
11	Appendix B	56

LISTS OF TABLES

Table	List of Tables	Page No.
1	Descriptive Statistics for Spatial Ability Task for Both Phases	31
2	Descriptive Statistics and Paired T-Test for errors of Executive Functioning task for Both Phases	32
3	Descriptive Statistics and Paired T-Test for perseverative responses of Executive Functioning task for Both Phases	34
4	Descriptive Statistics and Paired T-Test for perseverative errors of Executive Functioning task for Both Phases	35
5	Descriptive Statistics and Paired T-Test for categories completed of Executive Functioning task for Both Phases	36
6	Descriptive Statistics and Paired T-Test for Working Memory Task for Both Phases	37
7	Descriptive Statistics and Paired T-Test for Manual Dexterity Task for Both Phases	38

LIST OF FIGURES

Figure	List of Figures	Page No.
1	Mean Performance on Spatial Ability Task	32
2	Mean Errors on Executive Functioning Task	33
3	Mean Perseverative Responses on Executive Functioning Task	34
4	Mean Perseverative Errors on Executive Functioning Task	35
5	Mean Categories Completed on Executive Functioning Task	36
6	Mean Performance on Working Memory Task	37
7	Mean Performance on Manual Dexterity Task	38

### ABSTRACT

Variations in Performance on various cognitive abilities, verbal memory, perceptual motor skills, etc., owing to different phases of the Menstrual Cycle, have produced mainly conflicting results in the past. Although performances of both genders overlap to a large degree (McKeever, 1995), women tend to outperform men in specific aspects of verbal ability (Halpern, 1986; McGlone, 1980), whereas men achieve higher scores in spatial tasks (Halpern, 1996; Hyde, 1981; McGee, 1979; Voyer, Voyer, & Bryden, 1995; Witkin, Dyk, Faterson, Goodenough, & Karpis, 1962). The present experiment investigated Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks Across Different Menstrual Cycle Phases. The data was collected from 35 female participants aged 18 to 28 years. The tools used for the purpose described above were the 3-Dimensional Space Task for Spatial Ability (a subscale in GATB), O'Connor Finger Dexterity Test, the Letter-Number Sequencing Task (a subscale of WAIS-IV), and the Wisconsin Card Sorting Test. Descriptive Statistics and Paired T-Test was computed to calculate the results for the obtained data. The results revealed that women perform better on Spatial Ability Task, Executive Functioning Task, and Working Memory Task when menstruating compared to when in the Luteal phase. In contrast, the results of Manual Dexterity were quite promising in the Luteal Phase compared to the Menstrual Phase.

**Keywords-** Spatial Ability, Working Memory, Automated Tasks, Menstrual Phase, and Luteal Phase.

## **CHAPTER-1**

### **INTRODUCTION**

#### **1.1 THE MENSTRUAL CYCLE**

The menstrual cycle is the physiological process by which sex hormone changes affect the uterine lining and stimulate ovarian egg production, allowing reproduction. The hypothalamus-pituitary-gonadal (HPG) axis regulates the menstrual cycle's hormonal variations. Gonadotropin-releasing hormone (GnRH) is secreted by the hypothalamus, which stimulates the anterior pituitary to create luteinizing hormone (LH) and follicle-stimulating hormone (FSH). LH and FSH both stimulate female ovaries to produce estrogen and progesterone. Hormone levels then give negative feedback to the brain and pituitary, causing GnRH, LH, and FSH secretion to decrease. The average cycle length is typically between 24-35 days for women of reproductive age who have regular cycles. The menstrual cycle contains four distinct phases.

##### **1. The Menstruation**

Menstruation is generally referred to as a period. When a woman menstruates, the uterine lining sheds and runs through her vagina. The period comprises blood, mucus, and cells from the uterine lining. Menstruation lasts three to seven days on average.

##### **2. The Follicular Phase**

The follicular phase starts on the first day of an individual's menstruation and lasts 13 to 14 days, culminating in ovulation. The pituitary gland in the brain releases a hormone to stimulate the formation of follicles on the surface of an ovary. Typically, only one follicle matures into an egg. In preparation for pregnancy, the uterine lining thickens during this stage.

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

### 3. Ovulation

Ovulation occurs when a mature egg leaves the ovary and travels down the fallopian tube to the uterus. Ovulation happens roughly two weeks before your next period once a month. Ovulation can last anywhere between 16 to 32 hours. It is plausible to become pregnant during the five days preceding and on the day of ovulation, but it is more likely during the three days preceding and including ovulation. Once discharged, the egg can live for up to 24 hours. If sperm reaches the egg during this period, one may become pregnant.

### 4. The Luteal Phase

Cells in the ovary (the corpus luteum) release progesterone and a trace of estrogen after ovulation. This causes the uterine lining to thicken to prepare for pregnancy. When a fertilized egg implants in the uterine lining, the corpus luteum generates progesterone, which thickens the uterine lining. If no pregnancy occurs, the corpus luteum dies, progesterone levels fall, the uterine lining sheds, and the period resumes.

## **Role Of Hormones in The Menstrual Cycle**

Female hormones, estrogen, progesterone, FSH, and LH, influence each menstrual cycle phase. The change in the levels of each hormone determines the stage a female goes through. The anterior pituitary gland secretes luteinizing hormone (LH) and follicle-stimulating hormone (FSH). FSH promotes the development of ovarian follicles, which releases estrogen. The corpus luteum secretes progesterone. During the follicular phase, FSH and LH output gradually increase. They promote follicle growth and the release of estrogen from them. Estrogen increases endometrial proliferation. LH and FSH levels peak in the middle of the cycle. LH stimulates ovulation. Just before ovulation, there is a sudden increase in LH levels. Following

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

ovulation, the burst follicle develops into the corpus luteum, which secretes progesterone, incrementing progesterone levels during the luteal phase. Progesterone is essential for endometrial maintenance in preparation for implantation. Without fertilization, the corpus luteum shrinks, and the progesterone level falls. It causes the endometrium to disintegrate, resulting in menstrual flow.

Sex hormones, including estrogen, progesterone, and testosterone, significantly impact the brain, behavior, and cognitive ability. The menstrual cycle has proven to help investigate how minor changes in these hormones might affect emotional and mental performance.

### **1.2 SPATIAL ABILITY**

The ability to reason flexibly about matter and its spatial features is an essential aspect of everyday cognition and has adaptive implications. Spatial skills may also be crucial for high-level cognitive skills, and we utilize spatial analogies and models to think about complicated systems or processes in many science disciplines (National Research Council, 2012; Newcombe, 2010). According to Lohman (1979), spatial ability is developing, retaining, and altering abstract visual pictures. There is substantial evidence that spatial ability is not a single construct but a collection of discrete talents (see Hegarty & Waller, 2005, for a review of factor-analytic techniques). It is the mental feat accomplished by architects and engineers when designing buildings. This ability allows a chemist to consider a molecule's three-dimensional structure or a surgeon to navigate the human body. There are two forms of spatial ability or abilities related to visual and mental perception and manipulating objects in space. The first is known as spatial orientation, and it refers to a firm grasp of one's location concerning other items in the environment or the ability to picture the look of objects from various orientations. The second spatial skill is visualization, which is imagining how different things will look when put together in a specific way. There can be simple spatial skills and complex spatial

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

skills. In comparison to the ability to mentally spin a complex figure, the ability to match line orientations is often seen as a straightforward task. Spatial skills are simply one part of a person's overall intellect. Still, a large body of research demonstrates that spatial thinking is necessary for success in STEM (science, technology, engineering, and mathematics). For example:

- Pre-schoolers who are better at visualizing spatial relationships perform better in primary school. (Zhang et al 2014; Gilligan et al 2017; Verdine et al 2014; Verdine et al 2017).
- Middle school pupils adept in mental rotation perform better in science subjects (Ganley et al. 2014).
- Teens with strong spatial skills are more likely to work in the visual arts or business. (Wai et al. 2009).

Males are generally more proficient than females in spatial activities (the mental rotation test, which uses 3-dimensional cube figures devised by Shepard and Metzler (1971), provided the most reliable gender differences of all spatial tests). (For reviews, see Gaulin and Hoffman, 1988; Maccoby and Jacklin, 1974; Linn and Peterson, 1985.) Earlier attempts to account for these differences focused primarily on socialization practices (Maccoby and Jacklin, 1974). Still, the phenomenon's generality across populations and situations and its observation in non-human species shifted the emphasis to biological and, in particular, hormonal factors.

(See Gaulin and Hoffman 1988; Harris 1978; Kimura and Hampson 1990; Linn and Peterson 1985; McGee 1979; Reinisch, Ziemba-Davis, and Saunders 1991; Williams and Meek 1991; for reviews.). In this regard, Hampson and Kimura (1988) established explicit predictions about the cyclic effects of circulating hormones like estrogen on women's cognitive performance during the menstrual cycle.

### **1.3 EXECUTIVE FUNCTIONING**

An increasing body of research has identified that executive functions, the set of processes that control and guide our thoughts and behavior, have played an essential role in mathematics achievement and learning over the last two decades (e.g., review papers by Bull & Lee, 2014; Cragg & Gilmore, 2014; Raghubar, Barnes, & Hecht, 2010).

Executive functions (EFs) are an umbrella name for the collection of higher-order cognitive abilities required to pursue and attain a goal. These functions allow us to comprehend complex or abstract concepts, solve previously unknown problems, plan our next trip, and manage relationships. Working memory, inhibitory control, cognitive flexibility, planning, reasoning, and problem-solving are mental qualities that make up EFs. (Cicerone et al., 2000; Kennedy et al., 2008)

The executive system controls other cognitive capacities (e.g., attention and memory). Individuals can change their overlearned behavioral patterns when unsatisfactory (Van der Linden et al., 2000). It also allows adaptation to unfamiliar and difficult daily living conditions (Collette et al., 2006). As a result, EF deficiencies have profound effects on everyday life, including poor goal-directed behavior and reduced social functioning (Hanks et al., 1999; Busch et al., 2005). Frontal cortical injury is now thought to be sufficient to cause executive dysfunction.

The first EFs model was proposed by Luria (1973). He viewed problem-solving behavior as dependent on overarching talents, or EFs, which rely on proper frontal brain function. He defined the EFs system's significant components as anticipation (establishing realistic

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

expectations, comprehending consequences), planning (organization), execution (flexibility, maintaining set), and self-monitoring (emotional control, mistake recognition).

Executive functions are the systems that optimize performance in situations demanding the activation of several cognitive processes (Baddley, 1986). Among these functions, planning and decision-making are essential. Decision-making is a process that begins with the subject analyzing a situation and ends with the subject selecting one solution among multiple available options. Executive functioning is essential throughout this period when effective new action plans must be developed, and appropriate sequences of responses must be selected and organized. Executive functions also include components linked to withholding temporarily available knowledge or "online" (Goldman-Rakic's, 1987), or working memory, the marshaling of attentional resources (Shallice and Burgess, 1993), and monitoring behavior in relation to context and affective or motivational factors. (Damasio, 1994; Petrides, 1996).

Executive function is a significant element of learning across all academic courses; therefore, we would expect executive function skills to play a role in academic progress and school success in general. Evidence for the role of executive function abilities in mathematics, reading, writing, and science results exists (Best, Miller, & Naglieri, 2011; Nunes, Bryant, Barros, & Sylva, 2012; St Clair-Thompson & Gathercole, 2006). Hatta, Nagaya, and Onishi (2005b) investigated sex-related developmental changes in cognitive abilities related to prefrontal brain function in depth.

### **1.4 WORKING MEMORY**

Understanding working memory is critical to many high-level cognitive processes, and it has long been a focus of cognitive psychology and neuroscience research. Understanding working

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

memory is essential for discussing cognitive function since it contributes significantly to overall intellectual capacity and predicts school accomplishment. Working memory is the temporary storage of knowledge that is no longer available in the environment for ongoing cognition. It is both an attentional and a memory function. Working memory varies from short-term memory (STM) in that it stores and manipulates information and emphasizes its functional role in complex cognition. Working memory deficits are so frequently connected with executive function disorders that some neuropsychologists define them as executive functions. Working memory is tested through tasks that include reversed operations, such as repeating a set of digits or spelling a word backward. Many working memory assessments demand that the participant maintain information and conduct a cognitive activity. Daneman and Carpenter developed the Reading Span Test in 1980, which requires subjects to read sentences aloud and retain the last word of each phrase for later recall. Working memory varies significantly between individuals and is influenced by various illness states, psychiatric problems, and aging. Working Memory occurs neurally through an interaction between caudal frontal systems engaged in information selection and posterior systems involved in information representation. Working memory (WM) integrates cognitive and motivational processes, allowing us to retain and manage information and make decisions (Baddeley and Hitch, 1974; Postle, 2006). Baddeley's traditional working memory model proposes domain-specific storage modules and a central executive. The prefrontal cortex is vital for working memory, but how it is organized to facilitate working memory is unknown. Extensive animal research and multiple human studies suggest that estrogen or progestogen treatment alone can improve cognitive function in learning and memory processes, but when combined, they degrade them. (Frick, 2015; Maki 2012).

## 1.5 MANUAL DEXTERITY

Manual dexterity is the ability to grip and manipulate items using coordinated hand and finger movements. Manual dexterity is the ability to produce small, precise movements using muscular, bone, and neurological capabilities. These abilities develop over time, mainly during childhood. Developing manual dexterity necessitates the capacity to organize and execute a task mentally. These abilities are required for an individual to experience and learn about their surroundings. The development of manual dexterity follows a sequence of developmental milestones, beginning with gross motor body movements and advancing to fine motor movements, indicating that manual dexterity is roughly divided into two types: gross motor movements and fine motor movements. Manual dexterity development typically culminates in the capacity to use a pencil, stack blocks, pick up small items, and cut using scissors to perform other tasks that require precise movements.

The manual praxis system is a motor programming system in the left hemisphere that selects hand and arm movements. It is especially crucial for regulating actions performed with minimal external sensory guidance. Few researchers have looked at the criteria surrounding normal praxis function, but preliminary findings suggest that men may rely less on praxis control than women.

Furthermore, tasks requiring small-amplitude motor skills, such as inserting pegs into holes (Hall & Kimura, 1995) and sequencing motor motions, including verbal articulation (Nicholson & Kimura, 1996), are often performed better by women. These duties are carried out within arm's reach of the body, i.e., in intrapersonal space. Throwing a missile at an external target, for example, is often performed better by men (Hall & Kimura, 1995; Jardine & Martin, 1983; Peters, 1990; Watson & Kimura, 1989, 1991), as is intercepting a

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

projectile (Watson & Kimura, 1989, 1991).

## **CHAPTER-2**

### **REVIEW OF LITERATURE**

The literature review found that several Research Scholars have investigated the variables under consideration in this research study to varying degrees in the past. A few examples are provided below: -

#### **2.1 MENSTRUATION AND SPATIAL ABILITY**

A Research study conducted by Hampson and Korman (2014) aimed to investigate the essential characteristics of the MRT which might be responsible for its link to estradiol level with 44 women aged 20 to 38 years, has shown change in women's performance on mental rotation tasks in relation to estrogen levels throughout the menstrual cycle. Compared to other phases of the cycle, when estrogen levels were high, performance was better during menstruation.

Menstrual cycle effects on reaction latencies (but not accuracy) were observed in an experiment done by Ho, Cilger, and Brink (1986) utilizing a two-dimensional mental rotations task. The Space Relations test yielded no results. The study examined menstrual cycle effects on the performance of spatial information processing and consisted of 20 women with fairly regular menstrual cycles.

Hampson conducted a study in 1990b to examine the notion that estrogen, rather than estrogen with progesterone, was responsible for improving female-superior talents. The subjects were assessed during the menstrual cycle and the preovulatory phase. The results were favorable when compared to the menstrual/luteal comparison. Male-superior tests performed better during menstruation, while female-superior tests performed better during the preovulatory phase. It was determined that the change in cognitive performance was caused solely by estrogen.

Gordon and Lee 1993 wanted to sample women's performance on verbo-sequential and

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

visuospatial neuropsychological tests during the different menstrual cycle phases in regularly menstruating women and at comparable time points among women taking oral contraceptives and among those who had amenorrhea. The study found no evidence for a link between hormone levels, or changes in hormone levels, and sex-biased visuospatial or verbo-sequential ability.

The available literature depicts quite contradicting nature of results. One can't say whether the spatial ability is varied owing to the menstrual cycle effect. More research must occur in this direction to establish such a claim.

### **2.2 MENSTRUATION AND EXECUTIVE FUNCTIONING**

Lord and Taylor (1991) tested 50 university women with consistent and rhythmic menstrual cycles to report monthly fluctuation in task concentration in female college students. They found that during the premenstrual phase, an enhanced interference effect on Stroop's color-word naming task (Stroop, 1935) indicated that the women's concentration was at the lowest level during the latter part of the monthly cycle.

Fourteen women with PMS and ten without PMS were tested on a collection of neuropsychological tests during the follicular and late luteal phases of two consecutive menstrual cycles by Kennan et al. (1992). The results have shown that the performance on Trail Making Test, Trail B (Reitan, 1983), was better during the follicular phase than during the luteal phase of the menstrual cycle.

An EEG study done by Ortiz et al. (2004) on the performance of a task demanding prefrontal functions for nine healthy women revealed that during the late luteal (LL) phase, performance was at its worst when hormone levels were at their lowest and was associated with a decrease in beta1 and beta2 power together with a significant attenuation of alpha1 and alpha2 power whereas during the menstrual (MEN) phase when hormone levels were at its lowest and (performance at its highest) was associated with a significant decrease of

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

alpha1 and alpha2 power and no changes in beta power were observed.

Research Studies with the RFT (Rod and Frame Test) have examined the effect of gonadal hormone levels at different menstrual phases in adult non-menopausal females (Hampson & Kimura, 1988). Poorer accuracy (more visual dependency) was found during the late cycle when estrogen levels are high relative to menses (Days 3–5), which indicated that females' weight visual, gravity, and body orientation cues differently at different phases of the menstrual cycle.

A careful literature study shows that various tools have been used to document sex hormones-related differences in executive functioning. However, the most prominent of all tests and tasks, the Wisconsin Card Sorting Test, doesn't have much literature to its name.

### **2.3 MENSTRUATION AND WORKING MEMORY**

The literature review highlights that little research has been done on working memory as a variable. However, the difference in performance on memory tasks due to varying levels of hormones has been well documented. The following studies provide insight into the same: -

The impact of 33 healthy women's menstrual cycles on an implicit memory test was reported by Hampson et al. in 2005. Compared to the mid-luteal phase, they found that menstruating women could distinguish between primed and unprimed stimuli at a more degraded level of fragmented objects.

Phillips and Sherwin (1992) evaluated the hormone, memory, and mood levels of 25 women during their cycles' luteal and menstrual phases. The visual memory (delayed recall) scores were significantly poorer during the menstrual phase than the luteal phase. Other memory tests, such as digit span, paired-associate learning, immediate recall of visual information, and immediate or delayed paragraph recall, did not reveal any phase

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

differences.

Simic and Santini (2012) aimed to investigate changes in masculinity and femininity in the various phases of the menstrual cycle for 17 females with a regular menstrual cycle, as well as changes in verbal fluency and mental rotation efficiency. Based on prior studies, they reported that verbal fluency task performance would be better during sex hormone peak periods. On the other hand, when sex hormone levels are at their lowest, mental rotations may be performed with the most incredible efficiency.

Dadín (2009) wanted to examine how sex hormone cycles naturally affect memory and how gender differences are affected. Memory tests were administered twice to 20 men and 19 women, timed to coincide with the testosterone cycle in males and the menstrual cycle in women. Women have been found to perform better than men in delayed verbal memory, immediate and delayed object recall, and digit span. Additionally, it was discovered that the hormone cycles considerably impacted verbal working memory and the spatial aspect of visuo-constructive memory.

### **2.4 MENSTRUATION AND MANUAL DEXTERITY**

Hampson (1990) studied 50 females between 20 and 43 years. As expected, the articulatory and manual speed composites showed a significant improvement during the preovulatory phase, when performance on some tests favored by women tended to be better, and performance on some tests favored by men tended to be worse than during menses, when estrogen and progesterone levels are low.

While spatial ability is more robust in the low-estrogen phase (menstrual), verbal articulatory speed and small-amplitude manual capabilities in personal space are often improved during the high-estrogen stages of the menstrual cycle (mid-luteal and preovulatory). These findings were made by Saucier and Kimura (1998) after testing 33 women on an intrapersonal motor task (the Manual Sequence Box) during both the mid-

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

luteal and menstrual periods as well as an extra-personal space-focused spatial-motor task (Targeting).

A relatively recent study by Işık, Soygun, Kahraman, & Koçak (2022) sought to compare the effects of the menstrual cycle on students in the dental faculty's grip strength, fingertip touch, and manual dexterity (70 female participants). The menstrual and ovulation phase measures of the BDI, PSQI, Semmes-Weinstein monofilament test (right), O'Connor tweezers skill test, Purdue pegboard test (right + left), and the Purdue Pegboard test (total and assembly) were found to differ statistically.

Epting & Overman (1998) explored the performance of sex-sensitive tasks with a sample size of 20 men and 27 women. They found surprising results for the finger-tap task. Though the task described above is often regarded as a female-favoring task, Epting and Overman's results were in the opposite direction, meaning males outperformed females on the finger-tap task.

The difference in results by various scholars over a singular phenomenon measured by different apparatus or tools calls forth deeper and careful investigation of the said variable to establish concrete directional results.

In conclusion, it is clear from the literature review that: - there have been opposing outcomes on Spatial Ability Tasks, the paucity of the most prominent tool of executive functioning, paucity of research studies on working memory, and finally, insufficient literature on Menstrual Cycle Effect and Gross Motor Speed.

## **CHAPTER-3**

### **RESEARCH GAP**

#### **3.1 Research Gap**

From the above literature review, it is evident that the nature of the results is quite conflicting; some studies support the notion of the Menstrual Cycle Effect on various variables, while others have reported the phenomenon to be insignificant. Secondly, Verbal Memory is a profoundly studied parameter, whereas the allied phenomenon of working memory hasn't been much explored. Another significant gap in research is the absence of literature addressing the Menstrual Cycle Effect on executive functioning using one of the most prominent tasks of the Wisconsin Card Sorting Test (a clear and widely used indicator of prefrontal functioning). Lastly, the effect of the menstrual cycle on manual dexterity has been measured using complex tasks requiring fine motor skills. In contrast, few reports have indicated the Menstrual Cycle Effect on manual dexterity concerning gross motor skills. The present research aimed to investigate Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across the Menstrual (low hormone phase) and Luteal (high hormone phase) phases of the Menstrual Cycle. Therefore, the present investigation aims to fill the gaps mentioned above.

#### **3.2 Theoretical Framework**

A concept given by Kimura explains the differences in cognitive capacity between the sexes. The key features of Kimura's hypothesis, commonly called the "Sex-Related Hormone Theory," are that estrogen is crucial in verbal ability and perceptual quickness. At the same time, the amount of hormonal release substantially influences other sexually differentiated functions.

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

According to studies from numerous researchers interested in brain functional asymmetry, the variation of sex-related hormone levels during the menstrual cycle appears to impact women's cognitive ability.

### **3.3 Objectives**

1. To investigate variations in performance on Spatial Ability Tasks across different phases of the Menstrual Cycle.
2. To study variations in performance on Executive Functioning Tasks across different phases of the Menstrual Cycle.
3. To examine variations in performance on Working Memory Tasks across different phases of the Menstrual Cycle.
4. To study variations in performance on Manual Dexterity Tasks across different phases of the Menstrual Cycle.

### **3.4 Rationale & Hypotheses**

The existing literature shows that Menstrual Cycle Effect has been examined variably. But it's the nature of results has always been conflicting. Thus, this study aims to investigate variation in performance on various tasks with respect to the Menstrual Cycle Effect. Since the Menstrual Cycle Effect and the related hormonal changes direct our behavior, it would be interesting to find out how various cognitive activities and manual dexterity is affected. Thus, the following hypotheses have been formulated.

H<sub>1</sub> - There will be a difference in Spatial Ability Task performance in the Menstrual and Luteal Phases.

H<sub>2</sub> - There will be a difference in Executive Functioning Task performance in the Menstrual and Luteal Phases.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

H<sub>3</sub> - There will be a difference in performance on Working Memory tasks in the Menstrual and Luteal Phases.

H<sub>4</sub> - There will be a difference in performance on Manual Dexterity Task in the Menstrual and Luteal Phases.

## **CHAPTER-4**

### **METHODOLOGY**

#### **4.1 Sample**

The inclusion criteria for the present research were females aged 18 to 28 years who had "fairly regular" menstrual cycles averaging 25 to 35 days and had "not" taken any oral contraceptives within six months before testing. It was ensured that the subjects did not suffer any hormonal issues like PCOS, PCOD, etc. The Present investigation comprised 35 female participants with a mean age of 21.26 years (S.D. = 1.804). The data was collected using a snowball sampling method. The sample was collected from Patiala, Punjabi.

#### **4.2 Design**

Within-Subject Design was used for the study.

Independent Variable: Phases of Menstrual Cycle, i.e., Luteal and Menstrual Phases.

Dependent Variable: Spatial Ability, Executive Functioning, Working Memory, and Manual Dexterity.

#### **4.3 Tools Used**

As per the objective of the investigation, four measures were used to assess spatial ability, executive functioning, working memory, and manual dexterity. The following tools were used for the study: -

##### **1. Menstrual Status Questionnaire**

A form to enquire about the accurate stage of the Menstrual Cycle was used. It included questions like the average length of the menstrual cycle (in days), the number of days since the beginning of the previous/last Menstrual Period or Date of the previous/last Menstrual Period, and the use of oral contraceptives in the last six months.

## 2. 3-Dimensional Space Perception Subtest of GATB (General Aptitude Test Battery)

The Indian adaptation of this test developed by Dolke (1976) was used to measure spatial ability. 40-line drawings of flat metal strips that can be folded, rolled, or bent along the dotted lines make up the test's 40 items. The task required the subject to choose, from a list of choices, the form that, when folded, rolled, or bent, would most closely resemble the supplied object. The ability to successfully visualize and rotate via mental imagery the effects of folding, rolling, and bending a two-dimensional image into three dimensions is required for performance on this test. The number of problems correctly solved throughout the allotted six minutes was used to calculate the score. The maximum score of the test was 40, i.e., one score for each correct item.

## 3. Wisconsin Card Sorting Test (WCST)

The WCST was developed by David A. Grant and Esta A. Berg in 1948. The WCST can be viewed as a test of executive function, which requires the capacity to establish and maintain a suitable problem-solving approach despite shifting stimuli to accomplish a future objective. The subject must match the response cards to one of the four key cards (the matching rule isn't disclosed). Various parameters in WCST are to be scored (number of trials administered, the total number of correct responses, total number of errors, perseverative responses, and errors, non-perseverative errors, etc.). The interscorer reliability coefficients for the 11 WCST scores varied from .895 to 1.000, except for the Learning to Learn score ( $r=.658$ ). WCST has adequate construct validity (Axelrod et al.,1992). Cronbach's alpha coefficient, used to measure reliability, was outstanding for the entire instrument ( $\alpha = 0.930$ ) (Miranda et al., 2020)

## 4. Letter Number Sequencing (subscale of WAIS)

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

The WAIS-IV test battery includes the Letter-Number Sequencing task as a WMC measure (Wechsler, 1997). The task requires the subject to hear a string of letters and digits and then report the stimuli with the numbers in ascending numerical order and the letters in ascending alphabetical order. Consequently, the stimuli get harder. There was a total of 21 elements, 3 for each string length. Each item contains no letters or numbers repeated elsewhere (each character in the string is unique). A single or 1 point was awarded for a correct response, with a maximum score of 21 possible.

### 5. O'Connor Finger Dexterity Task

Hines M. & O'Connor J. (1926) developed the O'Connor Finger Dexterity Task. Wherever quick item manipulation, particularly the picking up and placing small pieces, is crucial, the O'Connor Finger Dexterity Test has been utilized successfully as a predictor. Using only one hand, the subject had to pick up three pins at a time and insert them into the holes drilled in the board. It was advised that all examinees have their fingernails freshly and consistently cut because the quality of the fingernails affects how quickly the pins could be changed. The time taken to fill all the 100 holes was noted using a stopwatch.

### **4.4 Procedure**

The experiment was conducted in comfortable and well-lit settings. Informed consent was obtained from the subjects before conducting the experiment. The present investigation examined variations in the performance of various tasks owing to the Menstrual Cycle Effect. The subjects were then given the Menstrual Status Questionnaire. The experiment was once conducted in the menstrual phase (2 to 4 days following onset) and then in the luteal phase (16 to 20 days following the beginning of the last menstrual period). The phases were counterbalanced to avoid any practice effect. All the tasks were conducted one after the other in the first phase, and the same procedure was repeated in the second phase for each subject.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

Instructions on how to perform each task were stated out loud to the subjects each time before the beginning of each task in both phases. The information collected from the subjects was kept strictly confidential.

#### **4.5 Statistical Analyses**

Statistical Package for Social Science (SPSS) version 20.1 and Microsoft Excel were used to analyze the data. Descriptive statistics were computed to find out the mean and standard deviation. Paired T-Test was performed to calculate the results of the obtained data.

## CHAPTER-5

### RESULTS

To meet the objectives of the present investigation, the obtained data were subjected to various statistical analyses. Descriptive Statistics and Paired T-Test was done. The tables below clearly show the descriptive statistics and Paired T-Test for the variables under study.

Table: -1 shows Descriptive Statistics and Paired T-Test for the Spatial Ability task for Both Phases. The mean and standard deviation of the Menstrual and Luteal Phase for Spatial Ability is  $18.69 \pm 7.17$  and  $15.03 \pm 6.38$ , respectively. Paired T-Test was performed to compare the means of different phases on spatial ability. There was a significant difference between the means of different phases on spatial ability ( $t(34) = 8.01, p \leq 0.001$ ).

The effect size was large, with a Cohen's  $d$  of 1.35, indicating a statistically significant difference between the mean scores of the Menstrual and Luteal Phases.

TABLE: - 1 Descriptive Statistics and Paired T-Test for Spatial Ability task for Both Phases

	N	Mean	Std. deviation	t	Significance (2-tailed)	Cohen's d
Menstrual Phase	35	18.69	7.17	8.01	.001	1.35
Luteal Phase	35	15.03	6.38			

Table: -1 and Figure: -1 depict that the subjects' mean performance was higher in the Menstrual Phase than in the Luteal Phase when computing differences for the Spatial Ability Task.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

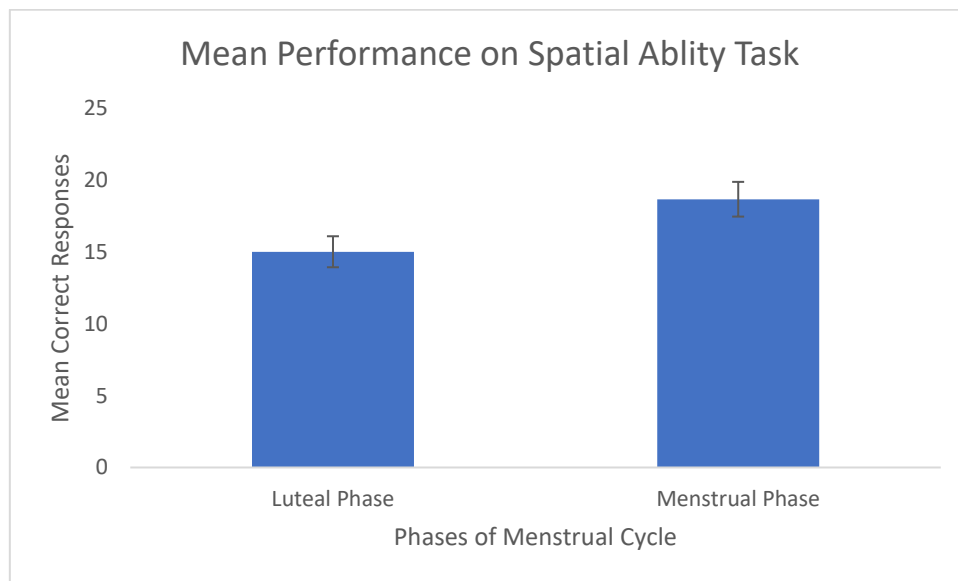


Figure: -1 Mean Performance on Spatial Ability Task

Table: – 2 shows Descriptive Statistics and Paired T-Test for errors on the Executive Functioning task for Both Phases. The mean and standard deviation of errors of the Menstrual and Luteal phases were  $18.60 \pm 16.40$  and  $29.46 \pm 19.40$ , respectively.

A paired T-Test was performed to compare the means of different phases on the number of errors. There was a significant difference between the means of different phases on the number of errors ( $t(34) = 5.37, p \leq 0.001$ ).

The effect size was large, with a Cohen’s  $d$  of 0.91, indicating a statistically significant difference between the mean scores of the Menstrual and Luteal Phases.

TABLE: – 2 Descriptive Statistics and Paired T-Test for errors on Executive Functioning task for Both Phases

	N	Mean	Std. deviation	t	Significance (2-tailed)	Cohen’s d
Menstrual Phase	35	18.60	16.40	5.37	.001	0.91
Luteal Phase	35	29.46	19.40			

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

Table: -2 and Figure: -2 depict that the subjects' mean errors were more in the Luteal Phase than the Menstrual Phase when computing differences for the Executive Functioning Task.

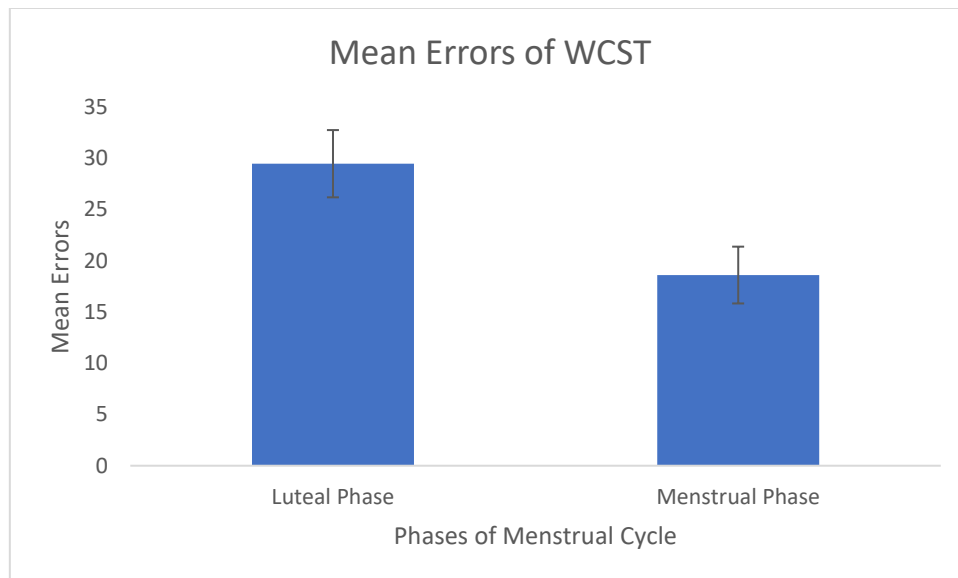


Figure: -2 Mean errors of WCST

Table: – 3 shows Descriptive Statistics and Paired T-Test for perseverative responses on the Executive Functioning task for Both Phases. The mean and standard deviation of perseverative responses of the Menstrual and Luteal phases were  $4.34 \pm 6.92$  and  $9.31 \pm 12.67$ , respectively. A paired T-Test was performed to compare the means of different phases on perseverative responses (PR). There was a significant difference between the means of different phases on perseverative responses (PR) ( $t(34) = 3.27, p < 0.01$ ).

The effect size was medium, with a Cohen's  $d$  of 0.55, indicating a statistically significant difference between the mean scores of the Menstrual and Luteal Phases.

TABLE: – 3 Descriptive Statistics and Paired T-Test for perseverative responses on Executive Functioning task for Both Phases

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

	N	Mean	Std. deviation	t	Significance (2-tailed)	Cohen's d
Menstrual Phase	35	4.34	6.92	3.27	.002	0.55
Luteal Phase	35	9.31	12.67			

Table: -3 and Figure: -3 depict that the mean Perseverative Responses of the subjects were more in the Luteal Phase than the Menstrual Phase when computing differences for the Executive Functioning Task.

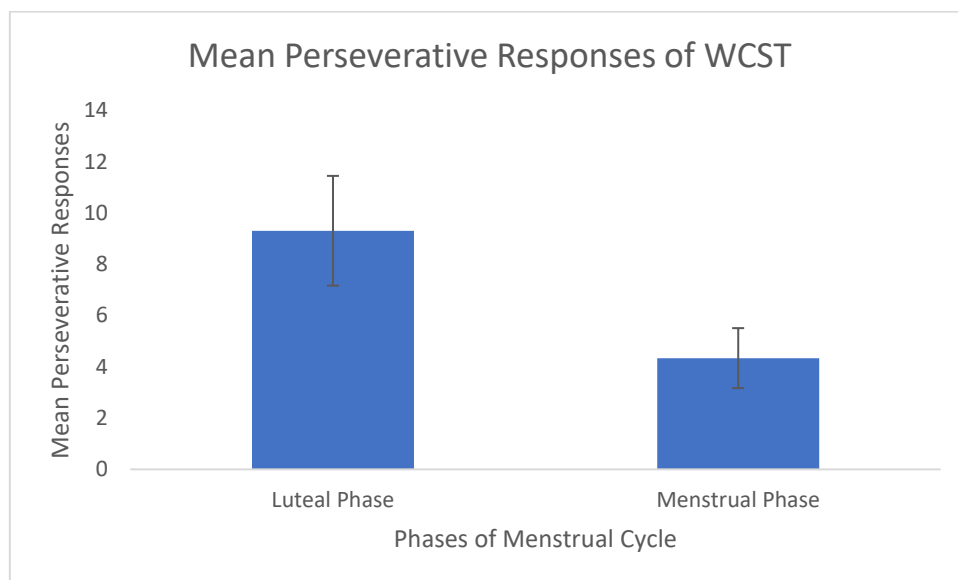


Figure: -3 Mean Perseverative Responses of WCST

Table: – 4 shows Descriptive Statistics and Paired T-Test for perseverative errors on the Executive Functioning task for Both Phases. The mean and standard deviation of perseverative errors of the Menstrual Phase and Luteal Phase came out to be  $3.31 \pm 5.29$  and  $7.11 \pm 9.85$ , respectively;

Paired T-Test was performed to compare the means of different phases on perseverative errors (PE). There was a significant difference between the means of different phases on perseverative errors (PE) ( $t(34) = 3.18, p < 0.01$ ).

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

The effect size was medium, with a Cohen’s d of 0.54, indicating a statistically significant difference between the mean scores of the Menstrual and Luteal Phases.

TABLE: – 4 Descriptive Statistics and Paired T-Test for perseverative errors on Executive Functioning task for Both Phases

	N	Mean	Std. deviation	t	Significance (2-tailed)	Cohen’s d
Menstrual Phase	35	3.31	5.29	-3.18	.003	0.54
Luteal Phase	35	7.11	9.85			

Table: -4 and Figure: -4 depict that the subjects' mean Perseverative Errors were more in the Luteal Phase than the Menstrual Phase when computing differences for the Executive Functioning Task.

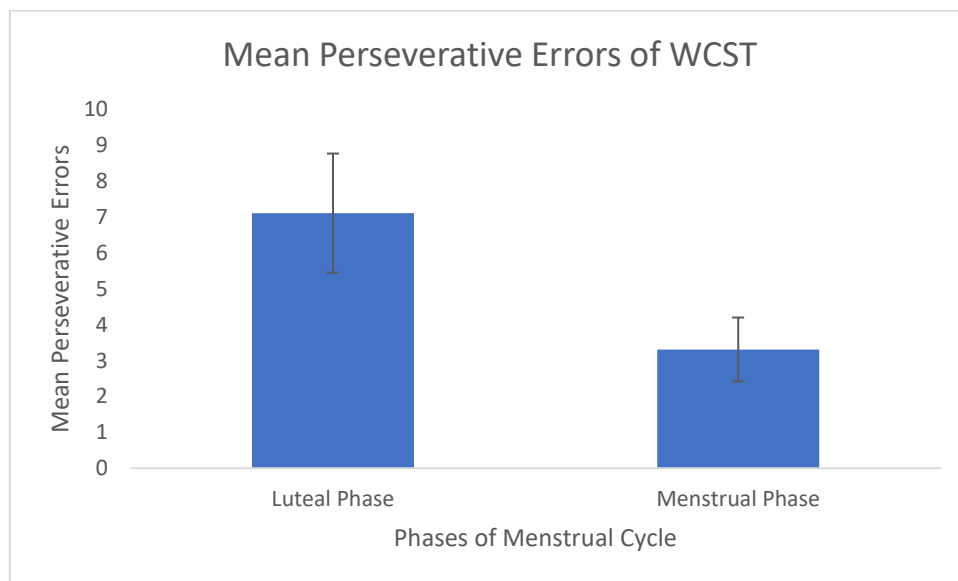


Figure: -4 Mean Perseverative Errors of WCST

Table: – 5 shows Descriptive Statistics and Paired T-Test for categories completed on the Executive Functioning task for Both Phases. The mean and standard deviation of the number of categories completed in the Menstrual Phase and Luteal Phase were  $5.29 \pm 1.53$  and  $4.83 \pm$

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

1.95, respectively. A paired T-Test was performed to compare the means of different phases on the number of categories completed (CC). There was a significant difference between the means of different phases on the number of categories completed (CC) ( $t(34) = 2.76, p < 0.01$ ). The effect size was small, with a Cohen's  $d$  of 0.47, indicating a statistically significant difference between the mean scores of the Menstrual and Luteal Phases.

TABLE: – 5 Descriptive Statistics and Paired T-Test for categories completed on Executive Functioning task for Both Phases

	N	Mean	Std. deviation	t	Significance (2-tailed)	Cohen's d
Menstrual Phase	35	5.29	1.53	2.76	.009	0.47
Luteal Phase	35	4.83	1.95			

Table: -5 and Figure: -5 show that the mean number of categories completed by the subjects was more in the Menstrual Phase than the Luteal Phase when computing differences for the Executive Functioning Task.

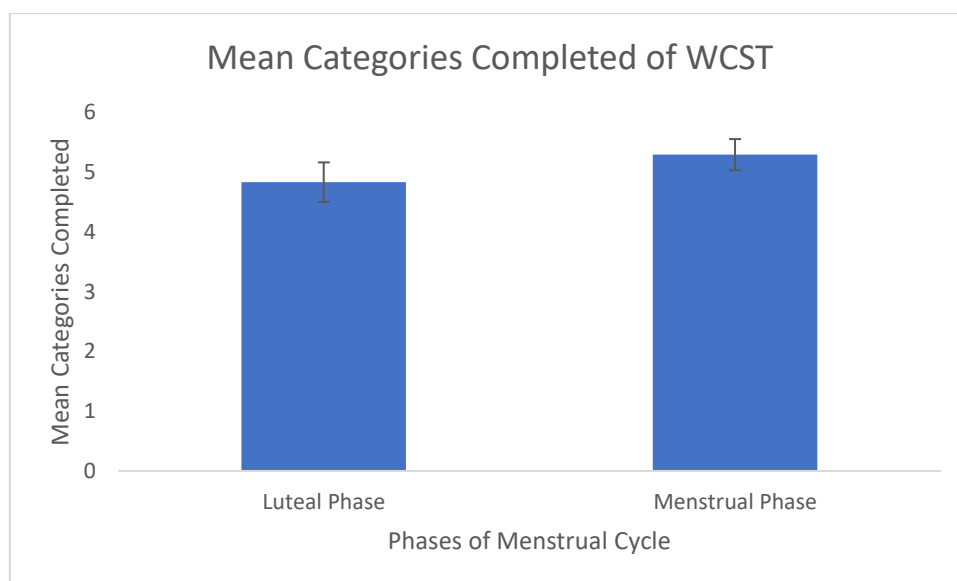


Figure: -5 Mean Categories Completed of WCST

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

Table: – 6 shows Descriptive Statistics and Paired T-Test for the Working Memory task in Both Phases. The mean and standard deviation of the Menstrual and Luteal phases for working memory were computed to be  $12.17 \pm 2.68$  and  $10.31 \pm 2.13$ , respectively. Paired T-Test was performed to compare the means of different phases on working memory. There was a significant difference between the means of different phases on working memory ( $t(34) = 9.03, p \leq 0.001$ ).

The effect size was large, with a Cohen’s d of 1.53, indicating a statistically significant difference between the mean scores of the Menstrual and Luteal Phases.

TABLE: – 6 Descriptive Statistics and Paired T-Test for Working Memory task in Both Phases

	N	Mean	Std. deviation	t	Significance (2-tailed)	Cohen’s d
Menstrual Phase	35	12.17	2.68	9.03	.001	1.53
Luteal Phase	35	10.31	2.13			

Table: -6 and Figure: -6 depict that the subjects' mean performance was higher in the Menstrual Phase than in the Luteal Phase when computing differences for the Working Memory Task.

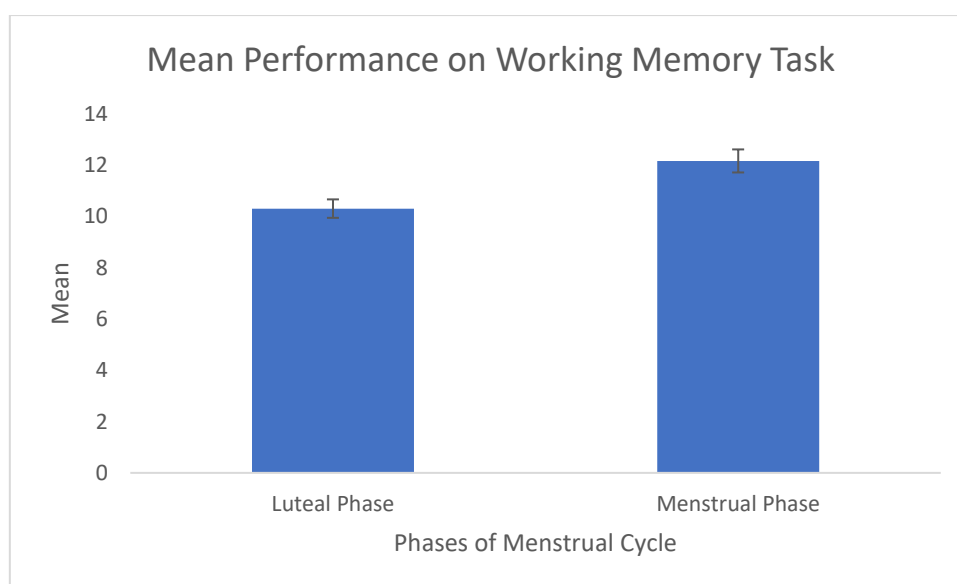


Figure-6 Mean Performance on Working Memory Task

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

Finally, Table: – 7 shows Descriptive Statistics and Paired T-Test for the Manual Dexterity task in Both Phases. The mean and standard deviation of the Menstrual and Luteal phases for manual dexterity were obtained to be 527.23±65.59 and 499.89±55.85, respectively. Paired T-Test was performed to compare the means of different phases on Manual Dexterity. There was a significant difference between the means of different phases on (t (34) = 5.07,  $p \leq 0.001$ ).

The effect size was large, with a Cohen’s d of 0.86, indicating a statistically significant difference between the mean scores of the Menstrual and Luteal Phases.

TABLE: – 7 Descriptive Statistics and Paired T-Test for Manual Dexterity task in Both Phases

	N	Mean	Std. deviation	t	Significance (2-tailed)	Cohen’s d
Menstrual Phase	35	527.23	65.59	5.07	.001	0.86
Luteal Phase	35	499.89	55.85			

Table: -7 and Figure: -7 depict that the subjects' mean performance was higher in the Luteal Phase than in the Menstrual Phase when computing differences for the Manual Dexterity Task.

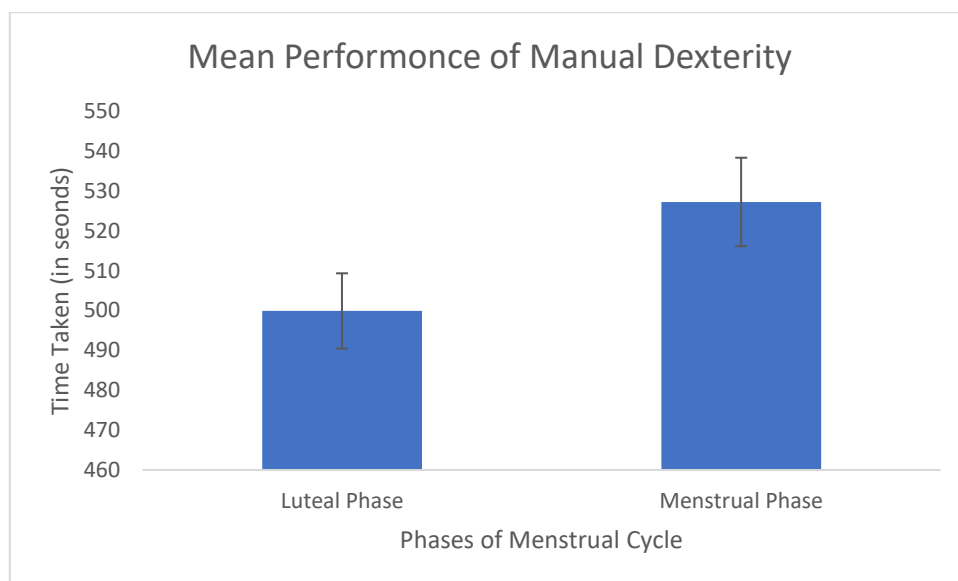


Figure: -7 Mean Performance on Manual Dexterity Task

## **CHAPTER-6**

### **DISCUSSION**

Although men and women have the same level of general intelligence (IQ), women outperform men in many areas, including verbal ability, perceptual speed and accuracy, rote memory, and fine motor skills, while men outperform women in spatial ability and mathematical reasoning (for reviews, see Maccoby & Jacklin, 1974; Linn & Petersen, 1985).

The first objective of the present study was to investigate variations in performance on Spatial Ability Tasks across different phases of the Menstrual Cycle. It was hypothesized that there would be a difference in Spatial Ability Task performance in the Menstrual and Luteal Phases. The results revealed that the subjects' mean performance was higher in the Menstrual Phase than in the Luteal Phase when computing differences for the Spatial Ability Task. A Research study by Hampson and Korman (2014) supports the results computed by the present study. The researchers have shown a change in women's performance on mental rotation tasks in relation to estrogen levels throughout the menstrual cycle. Compared to other phases of the cycle, when estrogen levels were high, performance was better during menstruation. The results are consistent with an early theory by Petersen (1976), based on the observation that more physically androgynous individuals of both sexes tend to do best on spatial tests.

Researchers Hampson and Kimura (1992) have also confirmed that human spatial abilities are classified into numerous kinds and exhibit some sexual differentiation. Other prominent investigations of estrogen and spatial ability that employed both menstrual cycle phase salivary or blood assays to determine estrogen level are Hampson, 1990b; Komnenich, Lane, Dickey, & Stone, 1978; all of which yielded comparable results to the current study.

To study variations in performance on Executive Functioning Tasks across different

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

phases of the Menstrual Cycle, the Wisconsin Card Sorting Test was employed. It was hypothesized that there would be a difference in Executive Functioning Task performance in the Menstrual and Luteal Phases. The results revealed that subjects made fewer errors, perseverative responses, and perseverative errors in the Menstrual phase compared to the Luteal phase. Furthermore, the subjects could complete more categories in the Menstrual phase than the Luteal phase. These results were in line with the findings of Ortiz et al. (2004), who did an EEG study to investigate the performance of tasks requiring prefrontal function. They reported that performance in the Late Luteal phase was poorer than in the Menstrual Phase. Many other researchers have also reported that frontal lobe functions are performed better in the low-hormone phase (Lord and Taylor, 1991 & Kennan et al., 1992).

The Letter-Number Sequencing Task was used to examine variations in performance on Working Memory Tasks across different phases of the Menstrual Cycle. It was hypothesized that there would be a difference in Working Memory Task performance in the Menstrual and Luteal Phases. The results revealed that subjects performed better on the letter-number sequencing task during their menstrual phase than the luteal phase. Some researchers believe that working memory is a component of executive functioning. Therefore, it can be readily said that the performance on this task was poor in the Luteal phase due to high estrogen levels. The results align with the research conducted by Dadín (2009).

Lastly, the present investigation aimed to study variations in performance on Manual Dexterity Tasks across different phases of the Menstrual Cycle and found that the performance of females was better in the luteal phase than in the menstrual phase. Supporting studies are that of Hampson (1990), who studied 50 females between 20 and 43 years. As expected, the articulatory and manual speed composites showed a significant improvement during the preovulatory phase, when performance on some tests favored by women tended to be better, and performance on some tests favored by men tended to be

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

worse than during menses, when estrogen and progesterone levels are low. These findings did not appear to be explained by mood changes.

While spatial ability is more robust in the low-estrogen phase (menstrual), verbal articulatory speed and small-amplitude manual capabilities in personal space are often improved during the high-estrogen stages of the menstrual cycle (mid-luteal and preovulatory). These findings were made by Saucier and Kimura (1998) after testing 33 women on an intrapersonal motor task (the Manual Sequence Box) during both the mid-luteal and menstrual periods as well as an extra-personal space-focused spatial-motor task (Targeting).

Now, the question arises of why or what causes the performance of spatial ability, executive functioning, and working memory to improve in the Menstrual Phase. On the other hand, why or what causes poor performance in manual dexterity in the Menstrual Phase? The following research studies have tried to explain the Menstrual Cycle Effect somewhat.

If increased levels of estrogen and progesterone cause undervalued spatial performance, it would be interesting to learn how these hormones affect spatial ability. The animal literature reveals one possibility. Variations in sex hormone levels during the estrous cycle generate substantial alterations in dendritic arborization in the hippocampus, a structure critical for spatial cognition (Woolley, Gould, Frankfurt, and McEwen, 1990).

During the proestrus phase, an increased number of spines on the dendrites of neurons in the CA1 region of the hippocampus has been observed in the female rat brain. The density of dendrites decreases during the estrus phase (McEwen and Woolley, 1994).

Therefore, based on animal literature, one can form conjectures that a similar phenomenon may lead to the Menstrual Cycle Effect in humans.

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

Silverman and Philips (1993) discovered that both organizational and activational investigations often reveal declines in spatial ability with increased estrogen levels, consistent with reported sex differences. Increases in spatial performance with increased testosterone levels are more common in females than males. Furthermore, testosterone alone had a significant and favorable effect on MRT (Mental Rotation Test) performance, as did testosterone paired with the negative influence of estrogen.

Indeed, considerable research (e.g., Kampen and Sherwin, 1996) shows that testosterone improves spatial performance in laboratory animals (e.g., Isgor and Sengelaub, 1998; Roof and Havens, 1992).

Many other research investigations have supported the current study's findings for other frontal brain skills, such as executive functioning and working memory.

Many research scholars have evaluated how some frontal lobe functions relate to gonadal steroids. During the premenstrual phase, there are deficits in various cognitive functions, such as perceptual interference (Lord and Taylor, 1991), concentration (Kennan et al., 1992), and counting bias in sequences formed (Brugger et al., 1993). All these processes are necessary prerequisites for performing frontal lobe functions. Deficits in the various cognitive processes explain the subjects' poor performance on the frontal lobe tasks in the present study.

Regarding the better performance of the subjects in the Luteal Phase on the Manual Dexterity Task, insight by Kimura (1977) seem fitting.

Kimura (1977) found that performance on the Box task requires the participation of left-hemisphere praxis systems. He concluded that a significant function of the left hemisphere is the control of changes in the limbs or articulatory posture and that its complex verbal and praxis functions are derived from such control. Estrogen can influence activity in the hypothalamic regions like the striatum and cerebellum, which are responsible for motor coordination and control (Becker & Beer, 1986; Becker & Cha, 1989; Smith, 1989).

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

Verbal Memory and Perceptual Motor Skills are Estrogen-favoring tasks that explain better performance in the Luteal phase (high hormone phase) than in the Menstrual phase (low hormone phase).

## **CHAPTER-7**

### **CONCLUSION, IMPLICATION, LIMITATIONS, AND SCOPE FOR FUTURE**

#### **RESEARCH**

##### **7.1 Conclusion**

We can safely conclude that spatial performance, Executive Functioning, working memory, and Manual Dexterity are sensitive to hormonal fluctuations over the menstrual cycle or the Menstrual Cycle Effect.

The performance on spatial ability tasks, executive functioning tasks, and working memory tasks improve in the Menstrual Phase. On the other hand, the performance on manual dexterity tasks was better in the Luteal Phase.

Finally, it is evident from the present investigation that sex hormones significantly affect cognition and other frontal lobe functions. The help of the technologies like fMRI, EEG, etc., will provide direct evidence for the neural basis of hormone effects on cognition.

##### **7.2 Implication**

Extensive literature has established that males and females don't differ much in IQ. But research on sex-hormones-related differences has shown contradictory nature of results. Understanding the influence of sex hormones on cognitions and other frontal functions can foster knowledge essential for bridging the gap between the performance of both sexes. Understanding the impact of sex hormones on cognitive functioning can help women optimize their performance in various settings, such as in the workplace or academic settings.

It can prove to be helpful in the rehabilitation of patients suffering from sex-hormones-related conditions. While the theory has been criticized for oversimplifying complex issues, it provides a valuable framework for understanding the biological basis of gender differences.

### **7.3 Limitations**

There are some limitations of the present study. The snowball technique used to collect the data is a non-randomized sampling method that can be a limitation source. The small sample size restricted to only Patiala, Punjab, can be another study limitation. A significant limitation of the present study could be the inability to collect blood or saliva assays to determine hormonal levels.

### **7.4 Scope for future research**

The random sampling method would be a better way to collect the data. The sample size could be increased to provide more generalizability of results. Better generalizability of results can also be attained by collecting data from a wider geographical area. Collection of blood/saliva assays is crucial to know the levels of hormonal fluctuations in different phases. Elaborate research on working memory task performance and different phases of the menstrual cycle is required.

## REFERENCES

- Axelrod, B. N., Goldman, R. D., & Woodard, J. L. (1992). Interrater reliability in scoring the Wisconsin card sorting test. *Clinical Neuropsychologist*, 6(2), 143–155.
- Baddeley, A. D. (2010). Working memory. *Scholarpedia*, 5(2), 3015.
- Baddeley, A.D., & Hitch, G. (1974). Working memory. *Psychol. Learn. Motiv*, 8, 47–89
- Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and Individual Differences*, 21(4), 327–336.
- Bowler, R. M., & Lezak, M. D. (2015). Neuropsychologic evaluation and exposure to neurotoxicants. In *Handbook of Clinical Neurology*, 23–45.
- Brugger, P., Milicevic, A., Regard, M., Cook, N.D. (1993). Radom-number generation and the premenstrual cycle: Preliminary evidence for a premenstrual alteration of frontal lobe functioning. *Percept. Mot. Skills*, 77, 915–921.
- Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives*, 8(1), 36–41.
- Busch, R.M., Curtiss, G., & McBride, A. (2005). The components of executive functioning in traumatic brain injury. *J Clin Exp Neuropsychol*, 27 (8), 1022–1032.
- Case A.M., Reid R.L. (1998) Effects of the Menstrual Cycle on Medical Disorders. *Arch. Intern. Med.*, 1405–1412.

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

- Chipman, K., Hampson, E., & Kimura, D. (2002). A sex difference in reliance on vision during manual sequencing tasks. *Neuropsychologia*, *40*(7), 910–916.
- Cicerone, K.D., Dahlberg, C., & Kalmar, K. (2000). Evidence-based cognitive rehabilitation: recommendations for clinical practice. *Arch Phys Med Rehabil*, *81* (12), 1596-1615
- Collette, F., Hogge, M., & Salmon, E. (2006). Exploration of the neural substrates of executive functioning by functional neuroimaging. *Neuroscience*, *139* (1): 209–221.
- Cragg, L., & Gilmore, C. (2014). Skills underlying mathematics: The role of executive function in the development of mathematics proficiency. *Trends in Neuroscience and Education*, *3*(2), 63–68.
- Dadín, C.O., Salgado, D.R., & Fernández, E.A. (2009). Ciclos naturales de las hormonas sexuales y diferencias entre sexos en memoria. *EBSCOhost*, *37*(1), 18–24.
- Damasio, A.R. (1994). *Descartes' Error: Emotion, Reason and the Human Brain*. Putnam Press, New York.
- Epting, L. K., & Overman, W. H. (1998). Sex-sensitive tasks in men and women: A search for performance fluctuations across the menstrual cycle. *Behavioral Neuroscience*, *112*(6), 1304–1317.
- Frick, K.M. (2015). Molecular mechanisms underlying the memory-enhancing effects of estradiol. *Horm. Behav.* *74*, 4–18.
- Ganley, C.M., Vasilyeva, M., & Dulaney, A. (2014). Spatial ability mediates the gender difference in middle school students' science performance. *Child Dev.* ,*85*(4),1419-32.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

- Gaulin, S. J. C., & Hoffman, H. A. (1988). Evolution and development of sex differences in spatial ability. In L. Betzig, M. B. Mulder, & P. Turke (Eds.), *Human Reproductive Behavior: A Darwinian Perspective*. Cambridge Univ. Press, Cambridge
- Gilligan, K.A., Flouri, E., & Farran, E.K. (2017). The contribution of spatial ability to mathematics achievement in middle childhood. *J Exp Child Psychol.*,163,107-125.
- Goldman, R.P.S. (1987). Circuitry of primate prefrontal cortex and regulation of the behavior by representational memory. *Handbook of Physiology*, 5, 373–417.
- Gordon, H. W., & Lee, P. D. (1993). No difference in cognitive performance between phases of the menstrual cycle. *Psychoneuroendocrinology*, 18(7), 521–531.
- Hall, J. A. Y., & Kimura, D. (1995). Sexual orientation and performance on sexually dimorphic motor tasks. *Archives of Sexual Behavior*, 24, 395-407.
- Hampson E, Kimura D. (1992). Sex differences and hormonal influences on cognitive function in humans. *Behavioral Endocrinology*, 357-398.
- Hampson, E, Levy C.N.A., & Korman, J.M. (2014) Estradiol and mental rotation: relation to dimensionality, difficulty, or angular disparity? *Horm Behav*, 65(3), 238-248.
- Hampson, E. (1990). Estrogen-related variations in human spatial and articulatory-motor skills. *Psychoneuroendocrinology*, 15(2), 97–111.
- Hampson, E. (1990b). Variations in sex-related cognitive abilities across the menstrual cycle. *Brain Cognition* 14, 26–43.
- Hampson, E., & Kimura, D. (1988). Reciprocal effects of hormonal fluctuations on human motor and perceptual skills. *Behavioral Neuroscience*, 102, 456– 459.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

- Hanks, R.A., Rapport, L.J., & Millis, S.R. (1999). Measures of executive functioning as predictors of functional ability and social integration in a rehabilitation sample. *Arch Phys Med Rehabil*, 80 (9): 1030–1037.
- Hatta, T., & Nagaya, K. (2009). Menstrual Cycle Phase Effects on Memory and Stroop Task Performance. *Archives of Sexual Behavior*, 38(5), 821–827.
- Hatta, T., Nagaya, K., & Onishi, M. (2005). Age-related sex difference in higher cognitive abilities in healthy elderly people. *International Behavioural Development Symposium*, Minot State University, Minot, ND.
- Hausmann, M., Slabbekoorn, D., & Van Goozen, S.H.M. (2000) Sex hormones affect spatial abilities during the menstrual cycle. *Behav Neurosci*, 114(6):1245-1250.
- Hegarty, M., & Waller, D. (2005). Individual differences in spatial abilities. In P. Shah & A. Miyake (Eds.), *The Cambridge Handbook of visuospatial thinking*, 121–169.
- Ho, H., Gilger, J.W., & Brink, T.M. (1986). Effects of menstrual cycle on spatial information processes. *Perceptual and Motor Skills*. 63: 743-751.
- Isgor, C., & Sengelaub, D. R. (1998). Prenatal gonadal steroids affect adult spatial behavior, CA1 and CA3 yta-midal cell morphology in rats. *Hormones and Behavior*, 34. 183-198.
- Işık, E., Soygun, K., Kahraman, Ö. C., & Koçak, E. F. (2022). The effect of the menstrual cycle on the sense of touch, grip strength, and manual dexterity of dental students. *International Journal of Occupational Safety and Ergonomics*, 28(2), 1167–1175.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

- Jardine, R., & Martin, N. G. (1983). Spatial ability and throwing accuracy. *Behavior Genetics*, 13, 331-340.
- Kampen, D. L., & Sherwin, B. B. (1996). Estradiol is related to visual memory in healthy young men. *Behavioral Neuroscience*, 110, 613-617.
- Kennan, P.A., Stern, R.A., Janowsky, D.S., Pedersen, C.A., (1992). Psychological aspects of premenstrual syndrome. I: Cognition and Memory. *Psychoneuroendocrinology* 17, 179–187.
- Kennedy, M.R.T., Coelho, C., Turkstra, L. (2008). Intervention for executive functions after traumatic brain injury: a systematic review, meta-analysis, and clinical recommendations. *Neuropsychol Rehabil* 18 (3): 257–299.
- Kimura, D. (1977). Acquisition of a Motor Skill After Left-Hemisphere Damage. *Brain*, 100(3), 527–542.
- Kommenich, P., Lane, D. M., Dickey, R. P., & Stone, S. C. (1978). Gonadal hormones and cognitive performance. *Physiol. Psychol.* 6, 115-120.
- Kunjayi, S. K. (2003). Comparing Adolescent and Middle-Age Groups on Spatial Task Performance: A Developmental-Differentiation Approach. *Psychologia*, 46, 174-181.
- Lenton E.A., Landgren B.M., Sexton, L., & Harper R. (1984). Normal variation in the length of the follicular phase of the menstrual cycle: Effect of chronological age. *BJOG Int. J. Obstet. Gynaecol.* 91,681–684.
- Linn, M. C., & Peterson, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Dev.* 56, 1479–1498.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

- Lohman, D. F. (1979). Spatial ability: A review and reanalysis of the correlational literature. *Aptitude Research Project*, 8.
- Lord, T., Taylor, K., (1991). Monthly fluctuations in task concentration in female students. *Percept. Mot. Skills* 72, 435–439.
- Luria, A. (1973). *The working brain: an introduction to neuropsychology*, New York, NY.
- Maccoby, E. E., & Jacklin, C. N. (1974). *Psychology of Sex Differences*. Stanford Univ. Press, Palo Alto, CA.
- Maki, P.M., (2012). Minireview: effects of different HT formulations on cognition. *Endocrinology* 153, 3564–3570.
- Makofske, B. (2011). Manual Dexterity. *Encyclopedia of Clinical Neuropsychology*. Springer, New York, NY.
- Mäntylä, T. (2013). Gender differences in multitasking reflect spatial ability. *Psychol Sci.*, 24(4), 514-520.
- McEwen, B. S., & Woolley, C. S. (1994). Estradiol and progesterone regulate neuronal structure and synaptic connectivity in adults and developing brains. *Experimental Gerontology*, 29(3–4), 431–436.
- Mielicki, M. K., Koppel, R. H., Valencia, G. N., & Wiley, J. (2018). Measuring working memory capacity with the letter-number sequencing task: Advantages of visual administration. *Applied Cognitive Psychology*, 32(6), 805–814.
- Miranda, A. R., Sierra, J. F., Roulet, A. M., Rivadero, L., Serra, S. V., & Soria, E. A. (2020). Age, education and gender effects on Wisconsin card sorting test: standardization,

## Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

reliability, and validity in healthy Argentinian adults. *Aging Neuropsychology and Cognition*, 27(6), 807–825.

National Research Council (2012). A framework for K-12 science education: practices, crosscutting concepts, and core ideas. *Board on Science Education, Division of Behavioural and Social Sciences and Education*. , The National Academies Press.

Nee, D. E., & D'Esposito, M. (2015). Working Memory. In *Elsevier eBooks*, 589–595.

Newcombe, N. S. (2010). Picture this: Increasing math and science learning by improving spatial thinking. *American Educator*, 34, 29–43.

Nicholson, K. G., & Kimura, D. (1996). Sex differences for speech and manual skill. *Perceptual and Motor Skills*, 82, 3-13.

Nunes, T., Bryant, P., Barros, R., & Sylva, K. (2012). The relative importance of two different mathematical abilities to mathematical achievement. *British Journal of Educational Psychology*, 82(1), 136–156.

Peters, M. (1990). Subclassification of non-pathological left-handers poses problems for theories of handedness. *Neuropsychologia*, 28, 279-289.

Petrides, M.P., 1996. Lateral frontal cortical contribution to memory. *Seminars Neurosci*, 8, 57–63.

Phillips, S. M., & Sherwin, B. B. (1992). Variations in memory function and sex steroid hormones across the menstrual cycle. *Psychoneuroendocrinology*, 17(5), 497–506.

Possin, K. L. (2014). Memory, Working. In *Elsevier eBooks* (pp. 1051–1054). Elsevier BV.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

Postle, B.R., 2006. Working memory as an emergent property of the mind and brain.

*Neuroscience*, 139, 23–38

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics:

A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences*, 20(2), 110–122.

Razzak, R. A., Bagust, J., Docherty, S., Hasan, Z. A., Irshad, Y., & Rabiah, A. S. M.

(2015). Menstrual phase influences gender differences in visual dependence: A study with a computerized Rod and Frame Test. *Journal of Cognitive Psychology*, 27(1), 80–88.

Reitan, R.M., (1983). Validity of the trail-making test as an indication of organic brain

damage. *Percept. Mot. Skills*, 8, 271– 276.

Roof R.L., & Havens M.D. (1992). Testosterone improves maze performance and induces

the development of a male hippocampus in females. *Brain Res* 572, 310-313.

Saucier, D. M., & Kimura, D. (1998). Intrapersonal motor but not extrapersonal targeting

skill is enhanced during the mid-luteal phase of the menstrual cycle. *Developmental Neuropsychology*, 14(2–3), 385–398.

Shallice, T., & Burgess, P., (1993). Supervisory control of action and thought selection.

Attention: selection, awareness, and control, 171–187.

Shepard, R.N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*,

171, 701-703.

Šimić, N., & Santini, M. (2014). Verbal and spatial functions during different phases of

the menstrual cycle. *Psychiatr Danub.*, 24(1),73-79.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

- Solís-Ortiz, S., Guevara, M. A., & Corsi-Cabrera, M. (2004). Performance in a test demanding prefrontal function is favored by early luteal phase progesterone: an electroencephalographic study. *Psychoneuroendocrinology*, 29(8), 1047–1057.
- St Clair-Thompson, H. L. S., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology*, 59(4), 745–759.
- Stroop, J.R., (1935). Studies of interference in serial verbal reactions. *J. Exp. Psychol.*, 18, 643–660.
- Van der Linden, M., Meulemans, T., & Marczewski, P. (2000). The relationships between episodic memory, working memory, and executive functions: the contribution of the prefrontal cortex. *Psychol Belg* 40 (4): 275–297.
- Vandenberg, S.G., Kuse, A.R. (1978). Mental rotations, a group test of three-dimensional spatial visualization. *Perceptual & Motor Skills*, 47,599–601.
- Verdine, B.N., Golinkoff, R.M., Hirsh-Pasek, K., & Newcombe, N.S. (2017). I. Spatial skills, their development, and their links to mathematics. *Monogr Soc Res Child Dev.* 82(1):7-30.
- Verdine, B.N., Irwin, C.M., Golinkoff, R.M., & Hirsh-Pasek, K. (2014). Contributions of executive function and spatial skills to preschool mathematics achievement. *J Exp Child Psychol*, 126:37-51.
- Wai, J., Lubinski, D., & Bendow, C.P. (2009). Spatial ability for STEM domains: aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, 101, 817-835.

Changes in Performance on Cognitive Abilities and Manual Dexterity Tasks across Different Phases of the Menstrual Cycle

Watson, N. V., & Kimura, D. (1989). Right-hand superiority for throwing but not for intercepting. *Neuropsychologia*, 27, 1399-1414.

Zhang, X., Koponen, T., Räsänen, P., Aunola, K., Lerkkanen, M.K., & Nurmi, J.E. (2014). Linguistic and spatial skills predict early arithmetic development via counting sequence knowledge. *Child Dev.* 85(3),1091-107.

## APPENDIX A

# CONSENT FORM

---

Greetings,

I am Tavleen Kaur, a Master's student at Thapar Institute of Engineering and Technology, Patiala. I am approaching you regarding my Master's Dissertation in Psychology. My study pertains to variations in human performance on specific tasks due to the effects of hormones. Your participation will not be associated with any physical or psychological risk or harm.

The experiment would only require 15 to 20 minutes of your precious time.

All information you provide will remain confidential and not be associated with your name. If for any reason, during the experiment, you do not feel comfortable, you may leave the laboratory, and your information will be discarded.

The results of this experiment may be presented at professional meetings or published in the scientific literature. Your name will not be used in the reporting of results. Only group data will be used; however, your scores and name will be coded for a possible follow-up study or reanalysis of the data. All personal details will be kept confidential.

If you wish to withdraw from the experiment, you may do so at any time without penalty.

Following the experiment, I will discuss the results of the investigation with you if needed.

If you have any questions, please feel free to connect with me at [tkaur\\_ma21@thapar.edu](mailto:tkaur_ma21@thapar.edu)

Thank you for participating in the experiment.

I, \_\_\_\_\_ (First Name) \_\_\_\_\_ (Last Name),  
understand that my participation in this experiment is voluntary and that I may refuse to participate or withdraw from the experiment at any point of time without penalty.

\_\_\_\_\_ Signature of Participant

\_\_\_\_\_ Date (DD/MM/YYYY)

**APPENDIX B**

**Menstrual Status Questionnaire**

1. Your Full Name: \_\_\_\_\_
2. Your Age (in years): \_\_\_\_\_
3. Average Length of your Menstrual Cycle (in days): \_\_\_\_\_
4. Are you currently Menstruating? \_\_\_\_\_
5. Number of days since the beginning of your pervious/last Menstrual Period or Date of  
your pervious/last Menstrual Period \_\_\_\_\_
6. Are you currently using any oral contraceptives? \_\_\_\_\_