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The Effect of the Menstrual Cycle on Cognitive Performance: Spatial Reasoning, Visual & Numerical Memory

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Abstract

The menstrual cycle has been a topic of interest in relation to behavior and cognition for many years, with historical beliefs associating it with cognitive impairment. However, recent research has challenged these beliefs and suggested potential positive effects of the menstrual cycle on cognitive performance. Despite these emerging findings, there is still a lack of consensus regarding the impact of the menstrual cycle on cognition, particularly in domains such as spatial reasoning, visual memory, and numerical memory. Hence, this study aimed to explore the relationship between the menstrual cycle and cognitive performance in these specific domains. Previous studies have reported mixed findings, with some suggesting no significant association and others indicating potential differences across the menstrual cycle. To contribute to this body of knowledge, we explored the research question of whether the menstrual cycles have a significant effect on cognition, particularly in the domains of spatial reasoning, visual and numerical memory in a regionally diverse sample of menstruating females. A total of 30 menstruating females from mixed geographical backgrounds participated in the study, and a repeated measures design was used to assess their cognitive performance in two phases of the menstrual cycle: follicular and luteal. The results of the study revealed that while spatial reasoning was not significantly related to the menstrual cycle ($p = 0.256$), both visual and numerical memory had significant positive associations ($p < 0.001$) with the luteal phase. However, since the effect sizes were very small, the importance of this relationship might be commonly overestimated. Future studies could thus entail designs with larger sample sizes, including neuro-biological measures of menstrual stages, and consequently inform competent interventions and support systems.

Keywords

Menstrual Health, Menstrual Cycle, Menstruation, Mental Health, Cognition, Spatial Reasoning, Visual Memory, Numerical Memory

1. Introduction

There has been a great deal of interest in analyzing the menstrual cycle's impact on behavior and cognition since as early as the 1930s. In one of the first instances, a study done by Frank (1931) [1] founded the notion of 'premenstrual tension', linking the menstrual cycle and cognitive impairment in his female patients who showed 'foolish and ill-considered' actions. Historically, this link has been weaponized to restrict the entry of women into certain spaces and careers. Sommer (1992) [2] criticized studies linking the menstrual cycle and various aspects of cognition, such as attention, memory and spatial skills, for using subjective measures. She attributed this to widespread popular belief in the notion of "paramenstrual cognitive debilitation". An idea that was often cited as a justification for dated social norms, such as women being deemed incapable of flying commercial aircraft or taking college entrance exams due to "cyclic disadvantages". Richardson (1991) [3] found no evidence for the idea of para-menstrual debilitation but discovered that women's processing capability appears to be highest in the luteal phase.

Rippon (2019) [4] has brought to light the heavy emphasis on negative events in studies on the menstrual cycle and cognition. She points out that 'Moos Menstrual Distress Questionnaire' [5], one of the most frequently used questionnaires to gather data on this topic, contains such connotations in its very title. Along with this, it mentions a majority of negative effects such as "forgetfulness" and "confusion", with only a minority of effects being positive or neutral.

However, there has been an emerging scientific consensus on the association of the ovulatory and luteal phases with improved cognitive processing, opposing the historical link between female hormones and cognitive deficits [6].

While the menstrual cycle is often described in terms of two broad phases—the follicular and luteal phases—this is an oversimplification of the complex hormonal and physiological changes that occur. The cycle begins with the follicular phase on the first day of menstruation and continues until ovulation, followed by the luteal phase, which lasts until the start of the next menstrual period. Despite the more intricate hormonal fluctuations throughout the cycle, for the purposes of this study, we focused specifically on these two phases (luteal and follicular) to simplify our analysis of cognitive performance in relation to menstrual cycle stages.

The relationship between the menstrual cycle and cognitive functioning has been extensively studied. Notably, this research includes one of the few studies to focus on women and girls residing in Middle Eastern countries, who represent a

significant portion of our participants. This inclusion enhances the scientific literature by broadening the understanding of how the menstrual cycle affects cognition, especially in a region that has been relatively underrepresented in prior research.

Currently, there doesn't appear to be a clear consensus on how menstruation affects cognition, or whether it even does at all. Consequently, a study done by Leeners *et al*. [7] looked for associations between female hormone levels and certain aspects of cognition across two menstrual cycles. The findings of this study revealed that there were no significant associations between female hormone levels and cognition. Similarly, a 2014 review done by Poromaa & Gingnell on the impact of the menstrual cycle on cognitive function found that differences in sexually dimorphic tasks are small and difficult to replicate. Their study also demonstrated that emotion-related changes are more often found and better associated with progesterone than with estradiol. Moreover, in terms of spatial reasoning, most studies [8]-[11] were unable to find any difference across the menstrual cycle. However, some studies [12]-[14] found substantial evidence of variations in cognitive performance across the different phases of the menstrual cycle. It has also been discovered that performance gain in motor learning is lower in the luteal phase and higher in the follicular phase [15].

Recently, there has been renewed cultural interest in this relationship between the menstrual cycle and cognition. There's a growing idea in the online sphere that not only is there a highly significant relationship between these variables, but it can be utilized to achieve maximum productivity [16]-[18]. This has created a market for courses that teach women to "work with their hormones" [19]. However, unlike previous cultural narratives, the trend frames the perceived link between the menstrual cycle and cognitive processes as a way to boost one's pursuits, and not necessarily as an impairment.

This study aims to explore the impact of the menstrual cycle on cognition, specifically on spatial reasoning, visual memory, and numerical memory. These domains were selected due to their relevance in academic and professional settings, where tasks such as problem-solving, data interpretation, and mental calculations are often required. Spatial reasoning is especially crucial in fields like engineering, architecture, and STEM disciplines, while memory functions are integral to everyday learning and productivity. By investigating these cognitive domains, we seek to understand whether menstrual cycle-related variations could have practical implications in these areas.

2. Methods

2.1. Design

This study adopted a repeated measurement design and a prospective observational research method. There were four dependent variables (visual memory score, numerical memory score, spatial reasoning score and overall cognitive score) and one independent variable (menstrual cycle phase). The purpose of this

study was to investigate the correlation between an overall score, which was determined based on the performance on three variables (visual memory score, numerical memory score, and spatial reasoning score), and the menstrual cycle stage of the participants. Therefore, we looked at the correlation between one independent variable (menstrual cycle phase) and four dependent variables (overall cognitive performance score and the individual scores of spatial reasoning, visual memory and verbal memory).

2.2. Ethics

Prior to the commencement of this study, the research design and objectives were discussed with the Girl Up Program Coordinator in charge of Girl Up's STEM for Social Good programming, who provided approval for the study to proceed. As Girl Up United Nations programs do not currently have an ethics committee and a Girl Up club-led study was a novel initiative by us, we were unable to obtain consent from such an entity. Nevertheless, the study solely relied on non-interventional surveys, ensuring the privacy and confidentiality of participants' data, which was anonymized and only viewed by the authors of this study. All participants provided informed consent through the registration form and were given the opportunity to withdraw from the study at any point.

2.3. Participants

A total of 30 menstruating females took part in this study in two phases of the menstrual cycle: follicular and luteal, of which 26 did not report any endocrine disorders while 4 reported being diagnosed with Polycystic Ovary Syndrome (PCOS). The ages of the participants ranged from 18-49 and the mean age of the participants was 21 (SD = 8). Our sample size consisted of mixed geographical backgrounds to approach this question from a larger sociocultural context. Majority of the participants were based in the Middle East (53%; n = 16), with others residing in Africa (13%; n = 4), Europe/North America (17%; n = 5) and other Asian countries (17%; n = 5). In terms of education, a greater part of the participants were either currently in high school or high school graduates (43%; n = 13) and undergraduate students (33%; n = 10). The highest level of education held by a participant was a doctorate (3%; n = 1), followed by a master's degree (3%; n = 1) and a bachelor's degree (10%; n = 3). The participants in this study were recruited by convenience sampling. Survey links regarding this study were posted on social media, primarily Instagram and the community website of the United Nations' Girl Up campaign. Finally, informed consent was obtained from all participants.

2.4. Measures

2.4.1. Menstrual Cycle Stages

The participants self-reported the stages of their cycle in both of the questionnaires used in this study. This information was also included in the prior sign up

and interest forms. They were guided to use menstruation as the reference to identify their cycle stage. Participants who were menstruating, or in the first nine days after menstruation, reported themselves to be in the follicular phase while those who had exceeded nine days since their last menstrual period reported themselves to be in the luteal phase. These were based on women's average days spent in the follicular phase, ranging from 10 to 16 and the 14 days of the luteal phase [20].

Since the uterine shedding from the first day of the menstrual period initiates the beginning of the follicular phase (a process lasting an average of 4 to 10 days), it was estimated that the next nine days after this would complete the course of the follicular phase. In order to account for individual differences, participants were also asked to report the number of days they menstruate typically.

2.4.2. Spatial Reasoning

The questions to assess spatial reasoning were adapted from free tests by AssesmentDay and 123test. These websites provide psychometric reasoning tests for large userbases of employers, employees and schools.

2 items on each of the 2 questionnaires assessed the participants' spatial awareness and abilities. They were asked to organize 2D shapes, and transform 2D nets into 3D shapes, along with mentally rotating and reflecting 3D shapes. This evaluated the ability of the participants to think about 2D and 3D objects, mentally manipulate those objects into new forms, and spot patterns between shapes [21].

2.4.3. Numerical Memory

A digit span test [22] was initially considered to assess numerical memory but to exclude its aspect of verbal memory and stick with shorter tasks to suit the format of the digital questionnaire, this study opted for a simpler short term numerical memory test instead. This assessed the numerical memory of the participants in the recall condition [23].

The participants viewed 2 videos per questionnaire. They watched each video containing a unique numerical sequence for 17 seconds and then typed out the numbers they were able to recall. The first sequence consisted of 10 digits, followed by a shorter one of 9 digits. Participants were scored on their ability to recall the numbers, as well as the order in which they were displayed.

2.4.4. Visual Memory

A simple test was adapted from the University of Washington's picture-based short-term memory test to measure visual memory. This was an application of the short-term recall test from Visual Memory Test based on Snodgrass Pictures (VMT-SP).

Two 22-second clips were attached separately to both of the questionnaires, containing images of everyday objects. Participants were asked to observe the objects attentively within the time limit and then type out the names of everything they were able to recall. The first video displayed 20 objects, while the second video showed 14 different ones. This pattern was followed in both questionnaires.

Participants were scored solely on their ability to recall the objects; therefore, misspellings were ignored and synonyms still received equal points.

2.5. Procedure

The participants in this study were recruited through convenience sampling, and their participation was incentivized by being set to receive their own scores on cognitive tests during their different menstrual phases, which helped them learn more about the personal impact of their own menstrual cycle. As advertised, the individual scores were later sent to them with an inconclusive descriptive analysis. The participants submitted a registration form to sign up for participation, where they gave consent, demographic information and their menstrual cycle phase at the time. A second batch of participants (included in the total of 30 participants), were also entered in a raffle to win a virtual or physical edition of a free book of their choice. Like the first batch of participants, they participated across the three groups.

To assess and compare their cognitive performance in the two phases of the cycle, participants were assessed twice through two questionnaires. All participants did Questionnaire 1 first, followed by Questionnaire 2. They were split into two groups and a third control group. Group 1 (n = 9) included those who were in the follicular phase during the first questionnaire but in the luteal phase during the second one. Group 2 (n = 11) consisted of those who responded to the first questionnaire in their luteal phase and the second questionnaire in their follicular phase. This swapped order in the two groups was done to rule out practice effect and the effects of any minor differences between the two questionnaires.

Participants who responded to both questionnaires during the same phase of their cycle were assigned to the control group, Group 3 (n = 10). The phases of the cycle were self-reported using menstruation for reference. Participants who were menstruating or in the first nine days after menstruation, reported themselves to be in the follicular phase while those who had surpassed nine days after their last menstrual period reported themselves to be in the luteal phase. Due to the participants in each group doing the questionnaire a second time in their second phase, we received a total of 60 responses. It should be noted that using these time-period windows to estimate menstrual cycle phases without the support of neurobiological measures like hormonal or urinary measures is a substantial limitation, which future research replicating our design can overcome by incorporating such measures.

2.6. Statistical Analysis

The statistical analysis was carried out in Google Colab. We performed Linear Mixed Effect Models (LMEs) to compare the spatial reasoning, numerical memory, visual memory and overall score of the participants across the multiple stages of the menstrual cycle (see Table 1). This was done using the mixed function from the statsmodels package, with overall score being the primary focus.

All of the variables were score values, except for the stages that were either follicular (denoted by '5') or luteal (denoted by '6').

The first model looked at the interaction between the overall score and stage to assess the relationship. Next, a model was run to separately analyze the interaction of each variable with stage.

Results are reported with standardized regression coefficients (β) and their respective standard errors (SE). The dataset and scripts can be viewed here (https://colab.research.google.com/drive/1JUArw5BmAyQSGreRVgvxLWwK8C8bgK_E?usp=sharing).

3. Results

Distributions of the overall scores and their median values were visualized in the form of violin plots (see Figure 1).

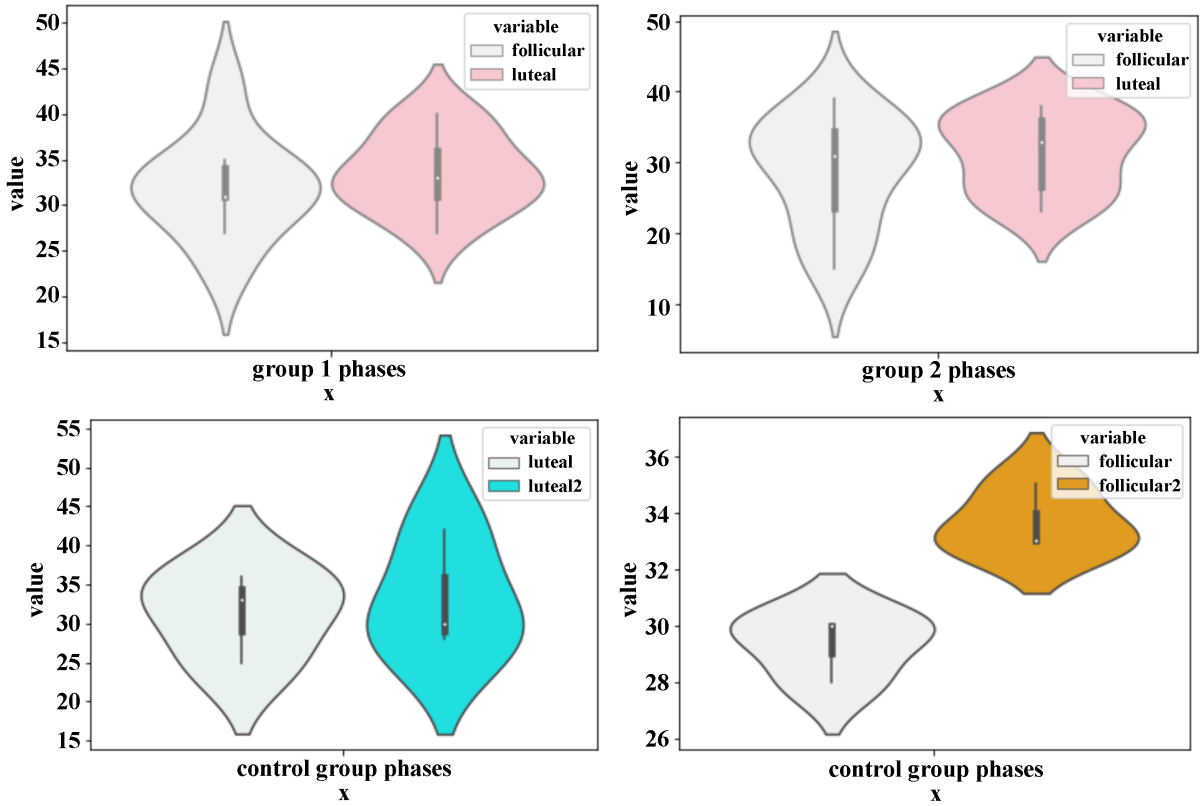

Figure 1. Distribution and kernel probability density of overall cognitive performance scores in the menstrual cycle phases of the groups.

For Group 1 (top left plot), which included participants who were in the follicular phase during the first questionnaire and in the luteal phase during the second questionnaire, the scores in the follicular phase show greater variability with a wider spread around the median of 31. In contrast, the luteal phase scores are more tightly clustered around the higher median of 33. Similarly, Group 2 (top right plot), consisting of participants who took the first questionnaire in the luteal

phase and the second in the follicular phase, shows a similar pattern. The follicular phase scores have more variation with the median of 31, whereas the luteal phase scores are more concentrated around the similarly higher median of 33.

The control group, represented in the bottom plots, included participants who completed both questionnaires in the same phase of their cycle. For the subgroup in the luteal phase for both questionnaires (bottom left), the luteal phase scores show less variation around medians of 33 and 30, compared to the follicular phase scores in the other two groups (bottom right), with greater variation around medians of 29 and 33.

Across both Group 1 and Group 2, the overall score values show greater variation during the follicular phase and a more clustered distribution around a higher median during the luteal phase. The control group further supports this observation, showing the pattern of greater variability in the follicular phase and higher scores in the luteal phase, as seen in the other groups.

The validity of this pattern was put to the test through linear mixed effects models.

In order to make the dataset homoscedastic, the variable of spatial reasoning was transformed using the cube root transformation. This was preferred over the log transformation since this variable contained a few zero values.

The Breusch-Pagan test was used to verify the absence of heteroscedasticity. It proved that the dataset didn't contain any heteroscedasticity, confirming the null hypothesis of homoscedasticity ($p = 0.02$).

Further, the Kolmogorov-Smirnov test was used to prove normality. It confirmed the null hypothesis of the test ($p < 0.001$), showing a normal distribution was being followed.

Finally, the dataset was fit into the linear mixed effects models (LMM) (results shown in Table 1 While ANOVA is commonly used for comparing group means across conditions, we selected LMM as it offers several advantages given the structure of our data. Specifically, the LMM approach allowed us to handle repeated measurements from the same individuals across different menstrual cycle stages. This method accounts for the non-independence of these repeated measures, where each participant contributes multiple data points at different phases of the menstrual cycle. Unlike ANOVA, which assumes independent observations, LMM is better suited to account for this dependence, ensuring more accurate estimates of the relationships between menstrual cycle stages and cognitive performance.

The first model was run to assess the interaction between the stages of the menstrual cycle and the overall score, along with the effect of this interaction on the overall score itself.

This revealed a positive relationship that held up to statistical significance ($\beta = 0.142$, $SE = 0.009$, $p < 0.001$).

Next, we specifically analyzed the cognitive measures making up the overall score in terms of their relationship to the menstrual cycle.

No significant interaction was found between spatial reasoning and the stages of the menstrual cycle ($\beta = -0.226$, SE = 0.256, p = 0.378).

The interaction between the numerical memory and stage was significant, showing a positive relationship ($\beta = 0.232$, SE = 0.025, $p < 0.001$). This suggests a positive association of numerical memory with the luteal phase since the follicular and luteal phases were numbered as 5 and 6.

Similarly, visual memory and stage had a significant positive association ($\beta = 0.215$, SE = 0.020, $p < 0.001$).

After calculating Pearson's coefficients, we found that the effect sizes for numerical memory and visual memory relationship to the stage of the cycle were very small (both r = 0.1). As for spatial memory, which the model found to not be significantly related to the menstrual cycle, the effect size showed a small correlation (r = 0.1).

Table 1. Associations of cognitive performance scores with the menstrual cycle.

	P-value	β coefficient	Standard error	R (Pearson's coefficient)
Spatial reasoning	0.378	−0.226	0.256	0.1
Visual memory	<0.001	0.215	0.020	0.1
Numeric memory	<0.001	0.232	0.025	0.1

4. Discussion

The menstrual cycle has been studied extensively in relation to cognitive domains. However, this is one of the first few studies to include women and girls residing in Middle Eastern countries in this analysis, with these members making up a numeric majority of our participants. This adds to scientific literature by expanding the understanding of the cognitive impact of the menstrual cycle with inclusion of a region that has been relatively underrepresented in previous research.

Although there is mixed evidence on the relationship between the menstrual cycle and memory, our finding of a positive correlation between these two variables is consistent with previous literature [24]-[26]. The effect size (r = 0.1) suggests that females may perform better on visual and verbal memory tasks during the luteal phase of the cycle.

The hormonal changes during this phase could be one of the possible reasons for the correlation. Progesterone and estrogen levels (both associated with enhanced memory) are at peak levels during the luteal phase.

Progesterone has been associated with positive effects on certain aspects of memory [27] [28] such as working memory. This study analyzed working memory through two cognitive domains, namely visual and numerical memory.

Estrogen also has similar associations with a positive effect on working memory [29] and visual memory [30]. The interaction between these two hormones could be a possible explanation for the increase in working memory performance during the luteal phase.

However, the low effect size of this relationship in the present study also suggests that other variables, such as socio-cultural factors, may potentially influence the pattern instead of the menstrual cycle phase. The impact of individual differences on cognitive performance may also be influencing this pattern, but the likelihood of that appears to be low due to the repeated measures used by the study. There are several examples of prior research having found no relationship between memory and the menstrual cycle [31]-[33].

This study also found no significant relationship between spatial reasoning and the stage of the menstrual cycle, indicating that it is likely due to chance. This is inconsistent with previous literature, which suggests that spatial reasoning is impacted significantly by the menstrual cycle [34]-[36]. While we observed a weak positive, statistically insignificant association between spatial reasoning and the luteal phase, Ronca *et al*. [37] found improved spatial performance during menstruation in visuospatial tasks, suggesting a complex relationship that could vary across populations or task types. These contradictory findings underscore the need for further research to understand how hormonal changes influence spatial cognition, as well as how socio-cultural or environmental factors may mediate these effects.

It is also possible that these hormonal fluctuations don't directly impact spatial reasoning. Instead, they might be influencing attentional processes, such as reducing focus or increasing attention to detail, which can impact performance in certain spatial reasoning tasks. Prior research has established a positive relationship between attention span and the luteal phase of the cycle [38].

The empirical evidence regarding this relationship remains inconclusive, with some studies finding it in the inverse direction or no correlation at all [39]. This aligns with the findings of this study. Furthermore, spatial reasoning is influenced by multiple factors beyond hormonal fluctuations, such as previous experience and socio-cultural influences. Other cognitive processes, such as attention and working memory, may play a more determining role in spatial reasoning abilities than the stage of the menstrual cycle.

Our study possesses several notable strengths which contribute to its validity. The geographically diverse sample size makes the findings more generalizable, as it reduces the potential influence of regional biases in our findings. Despite the participation of individuals from North America, Africa and other Asian countries, the majority of participants were based in the Middle Eastern region. By focusing on women and girls residing in Middle Eastern countries, our study contributes to the diversity and inclusivity of the literature, allowing for a more comprehensive understanding of the interplay between menstrual cycle and cognition across different populations.

Additionally, our findings have the potential to inform and enhance the development of culturally sensitive interventions and support systems that cater to the specific needs of women and girls in these regions, promoting their overall well-being and academic success. Particularly because most of these participants were

high-school or college-aged students. This is particularly important because understanding cognitive performance variations during different menstrual phases can help women better navigate their academic and workplace responsibilities, leading to improved outcomes.

Circling back to the online cultural interest in the menstrual cycle, it does appear that the menstrual cycle affects cognitive processes to a significant extent. However, due to the small effect sizes, it is inconclusive whether these effects may be impactful enough to plan academic and professional routines around.

This is among the first few studies which analyze the menstrual cycle and cognition through digital questionnaires distributed online. Participants were allowed to respond at times of their own convenience in their natural settings, without the responses being timed. This reduces social desirability and increases the ecological validity of the study, making the findings more reliable in everyday, real-world situations. The questionnaires were also kept brief to prevent fatigue and maintain the attention of participants. The low variance in scores across the questionnaires demonstrated that fatigue or practice effect is unlikely to have occurred.

Despite these strengths, there are also limitations to be taken into consideration. This study had a relatively small size, reducing the generalizability of the findings. The results may not accurately represent the larger population. Consequently, caution should be exercised when extrapolating these findings to other contexts or populations. However, it is worth noting that the study's focus on a specific group (women and girls residing in Middle Eastern countries) allows for exploration within this particular context. Future research with larger and more diverse samples could broaden our findings to a wider population.

Another limitation of our study is that the menstrual cycle stages were self-reported by the participants, which introduces a potential source of measurement error and decreases the reliability of the reported cycle phases. Factors such as individual interpretation, memory biases, misconceptions regarding the menstrual cycle phases could influence the accuracy of the reported information. The interpretation of our findings could also be complicated by the inclusion of two participants with PCOS, experiencing anovulatory cycles or by any participants on birth control who may have had a suppressed or diminished luteal phase. Replicating our study with the inclusion of neurobiological measures would address this limitation.

The virtual nature of this study, while providing convenience and accessibility, limited our ability to control other confounding variables, such as the environment of the participants while attempting the questionnaire, potentially decreasing the internal validity of the findings. Further research could incorporate more interactive study designs, with the potential use of virtual video calls and so on, to counter the aforementioned limitations.

Furthermore, while the short nature of the questionnaires helped prevent mental fatigue, it is important to acknowledge that these measures may not fully capture

the complexity and nuances of participants' cognitive performance. To enhance the validity of our findings, future studies could consider incorporating complementary measures, such as objective cognitive assessments or neurobiological measures, to provide a more comprehensive evaluation of cognitive performance during different menstrual cycle phases.

To enhance this study's reliability, it could be replicated with a control group consisting of males or individuals who do not menstruate. This inclusion would validate the association of any observed patterns specifically to the menstrual cycle, ruling out potential unrelated variations. Similar approaches have been employed in previous studies, where individuals who have never experienced menstruation produced identical profiles to women when completing the Menstrual Moos Distress Questionnaire, thereby disproving its exclusive link to female-specific hormones [40].

5. Conclusions

The aim of our study was to measure the impact of menstruation on cognition. Consistent with prior studies, we found a positive correlation between the menstrual cycle and visual and numerical memory, but no significant relationship between spatial reasoning and the menstrual cycle, suggesting that chance may be a contributing factor.

It is important to acknowledge that the effect sizes of these relationships were small, indicating that factors beyond the menstrual cycle phase may also contribute to cognitive performance.

Socio-cultural factors, individual differences, and other cognitive processes, such as attention and working memory, could play significant roles. The variability in findings across previous research on memory and the menstrual cycle aligns with our results.

Therefore, this study has met our goal of generation insights into the significance of the impact of menstruation on cognition, as well as the interplay of various other confounding variables previously mentioned, suggesting that cognition is a multi-dimensional element comprising several socio-cultural as well as neurobiological factors that are yet to be explored.

This study contributes to the literature on the relationship between the menstrual cycle and cognitive performance by examining primarily women and girls residing in Middle Eastern countries, with its regionally diverse sample and use of ecologically valid questionnaires. It expands our understanding of the cognitive impact of the menstrual cycle within this specific geographic context, which has been relatively underrepresented in previous research.

Nonetheless, limitations such as small sample size and use of self-report measures for identification of menstrual phase must be acknowledged. Replication studies with larger and more diverse samples, along with the inclusion of neurobiological measures, would enhance the reliability and validity of future investigations, while informing the development of culturally sensitive interventions and support systems

tailoring to the specific needs of women, girls and the assigned-female-at-birth populations, promoting their academic and overall well-being.

Author Contributions

I.A. (Isra Allana) conceived the study design and edited the manuscript. A.S. (Areej Shahid) and F.Y. (Fatima Yousaf) collected the data. I.K. (Ishika Khandelwal), Z.S (Zahra Sultan), F.Y. (Fatima Yousaf) and A.S. (Areej Shahid) were responsible for data management. A.A. (Anusha Asim) conducted the statistical analysis, and wrote the initial manuscript. R.M. (Rifah Maryam) participated in writing and editing the manuscript. All authors are members of Girl Up Emirates, a chapter of the United Nations' Girl Up Campaign, and have read and approved the final manuscript.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors report there are no competing interests to declare.

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Appendices

Appendix A

Demographic questions:

*** Indicates that the question is required**

Name that you have used in previous forms

*

Email ID

*

Age

*

Menstrual Questionnaire 1

Help us study cognition and the menstrual cycle! This questionnaire will test your memory and spatial reasoning during your current phase in the menstrual cycle. There are no right or wrong answers within this questionnaire, so remember to adhere to the guidelines and answer the questions stress-free. We rely on your honesty to ensure the validity of our research.

*** Indicates that the question is required**

What part of the menstrual cycle are you currently in? (Within this month)

*

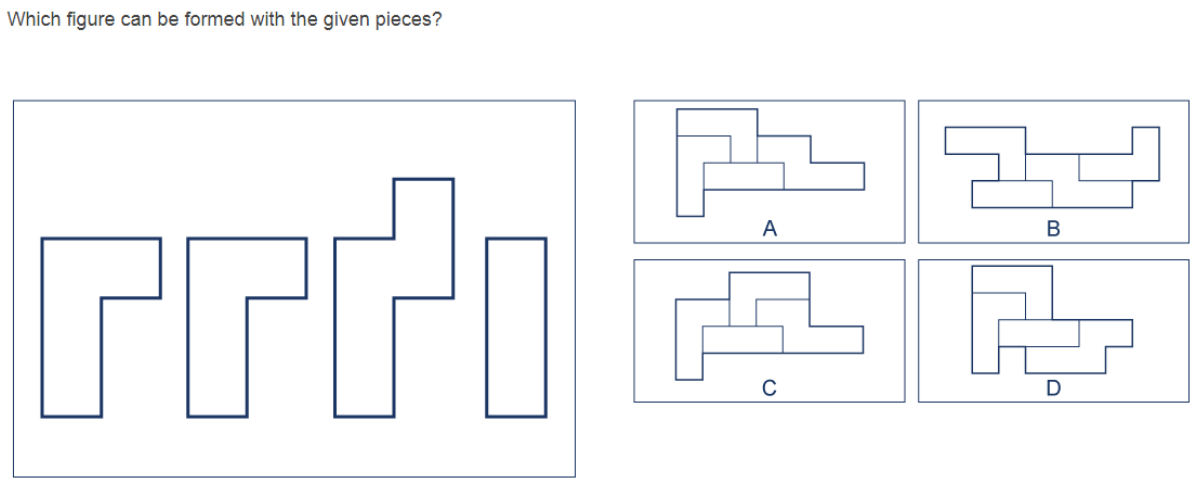
Haven't menstruated this month yet (luteal phase)
Currently Menstruating (follicular phase)
It's been 9 days since you menstruated (follicular phase)
It's been more than 9 days since you menstruated (either ovulatory or luteal phase)
It's been less than 9 days since you menstruated (follicular phase)

How do you feel right now?

*

Neutral
Tired
Upset
Happy
Other:

Observe the image 2



Pick the correct figure which can be formed with the given pieces in the image *

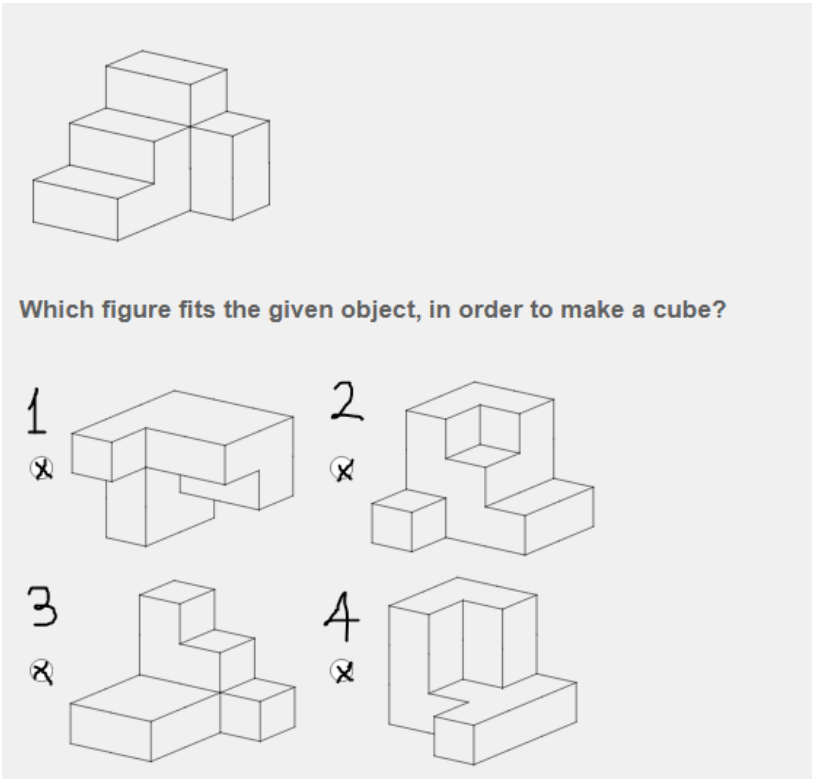
Figure A

Figure B

Figure C

Figure D

Observe the image 3



Pick the correct figure which can fit the given object to make it a cube
*

Figure 1
Figure 2
Figure 3
Figure 4

Please view this 17-second clip and try to remember the given number. If you are unable to open the video, please copy paste this link into your browser: https://youtu.be/wvuIDefOjiI

Type here all of the digits that you can remember from the video
*

Please view the next 17-second clip clip and try to remember the given number. If you are unable to open the video, please copy paste this link into your browser: https://youtu.be/zB6OxbA2NrQ

Type here all of the digits that you can remember from the second video
*

Please observe the objects in this 22-second clip. If you are unable to open the video, copy paste this link into your browser: https://youtu.be/h8s715Nv-wU

Please type out the objects that you remember from the image displayed in the clip. (You can list them and separate them with commas. The order and spellings don't matter)
*

Observe the image objects in the next 22-second clip. If you're unable to open the video, please copy paste this link into your browser: https://youtu.be/cmmEgGU9kjQ

Please type out the objects that you remember from the image displayed in the clip. (You can list them and separate them with commas. The order and spellings don't matter)
*

Answer this question to help us estimate a better date for questionnaire 2.

How many days do you menstruate usually?
*

How many days have it been since you finished menstruating? (Skip this question if you are currently menstruating)

If you are currently menstruating, what day of your period are you in? (Skip this question if you are not menstruating at the moment)

Appendix B

Demographic questions:

*** Indicates that the question is required**

Name that you have used in previous forms
*

Email ID
*

Menstrual Questionnaire 2

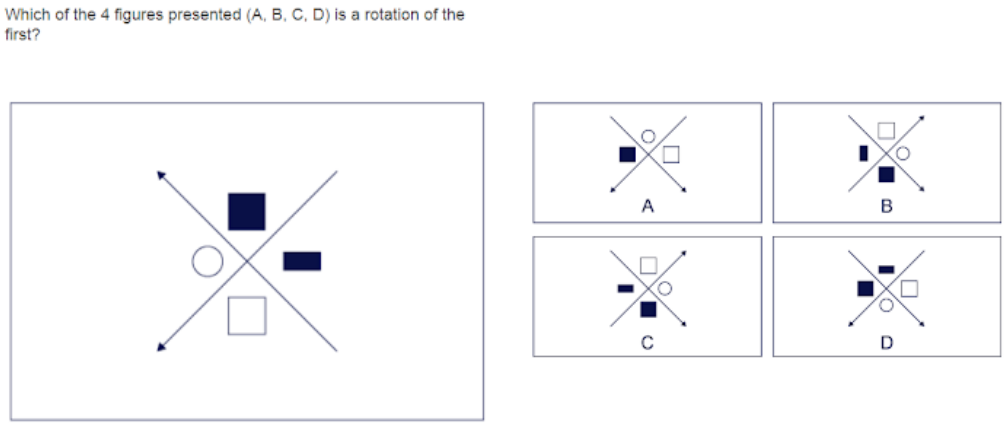
Help us study cognition and the menstrual cycle! There are no right or wrong answers within this questionnaire, so remember to adhere to the guidelines and answer the questions stress-free. We rely on your honesty to ensure the validity of our research.

*** Indicates that the question is required**

What part of the menstrual cycle are you currently in? (Within this month)
*
Haven't menstruated this month yet (luteal or ovulatory phase)
Currently Menstruating (follicular phase)
It's been less than 9 days since you menstruated (follicular phase)
It's been 9 days since you menstruated (follicular phase)
It's been more than 9 days since you menstruated (either ovulatory or luteal phase)

How do you feel right now?
*
Happy
Neutral
Upset
Tired
Other:

Observe the image4



Which of the given figures is a rotation of the image?

*

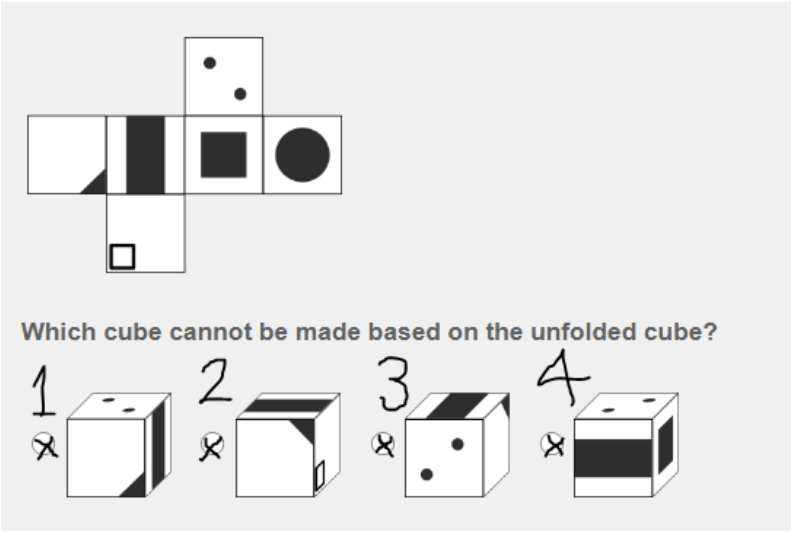
Figure A

Figure B

Figure C

Figure D

Observe the image5



Pick the correct cube from above (numbered left to right)

*

Cube 1

Cube 2

Cube 3

Cube 4

Please view this 17-second clip and try to remember the given number. If you are unable to open the video, please copy paste this link into your browser: https://youtu.be/EstaaHVWju8

Type here all of the digits that you can remember from the video
*

Please view the next 17-second clip clip and try to remember the given number. If you are unable to open the video, please copy paste this link into your browser: https://youtu.be/WzX0-sCPtAM

Type here all of the digits that you can remember from the second video
*

Please observe the objects in this 22-second clip. If you are unable to open the video, copy paste this link into your browser: https://youtu.be/vqzxpjNiPmg

Please type out the objects that you remember from the image displayed in the clip. (You can list them and separate them with commas. The order and spellings don't matter)
*

Observe the image objects in the next 22-second clip. If you're unable to open the video, please copy paste this link into your browser: https://youtu.be/Ev2aMoZYA8U

Please type out the objects that you remember from the image displayed in the clip. (You can list them and separate them with commas. The order and spellings don't matter)
*