Effects of the Menstrual Cycle on Verbal Working Memory in Young Women

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This paper presents verbal working memory test results towards establishing the effects of menstrual cycle on working memory of women. The study comprised of a subject-set of twenty healthy young women with a regular 28 – 32 day menstrual cycles. Subjects were tested twice, once during their menstrual phase and second during their ovulation phase (on approximately day 12). Working memory tests were performed in a random sequence i.e. for some subjects during the menstrual phase (low estrogen level) working memory test occurred before their ovulation phase (high estrogen level) memory test and vice versa for other subjects. Study revealed that the test scores in the ovulatory phase were significantly higher than those in the menstrual phase. These findings suggest that higher levels of estrogen may improve working memory. Moreover, effects of estrogen on mood were also considered during both phases of menstruation. The fluctuation in estrogen levels seems to have an effect on women’s mood during menstrual and ovulation phases.

**Keywords:** Menstrual cycle, Estrogen, Ovulation, Verbal working memory and Mood.

**Aim**
The aim of this paper is to see whether high or low levels of estrogen can effect verbal working memory and mood in fertile women.

**Introduction**
Recently a number of researchers have tried to study the effects of estrogen on human cognition – especially towards working memory. Working memory is referred to a limited capacity system that temporarilly stores and processes information (Baddeley, 2002). In other words, working memory is a mental workspace which not only stores and manipulates information but also supports cognitive functions such as problem solving and planning.

It has been observed that people tend to hold from five to nine meaningful items in their working memory, and most people are not capable of remembering a series of irrelevant words or random numbers without a focused training. According to George Miller (Passer & Smith, 2007) the capacity limit is “the magical number seven, plus or minus two”.

Relationship between working memory and estrogen has been studied by a number of
researchers, and a general consensus exists among researchers that a higher level of estrogen can lead to an improved working memory. Such a conjecture finds its roots in Estrogen Replacement Therapy (ERT) on post-menopausal women. Women in post-menopausal phase are observed to have a declining working memory because of their low levels of estrogen and their treatment with ERT showed improvement of their working memory.

Before proceeding to method of study and results obtained, levels of estrogen during a normal menstrual cycle, earlier research studies on the effects of estrogen on working memory and effects of estrogen on mood are discussed in section 1.1 – 1.3 respectively.

Estrogen and the menstrual cycle
Menstrual cycle of healthy women can be categorized into five phases, (Riley, 1999), which are as follows:

1. Menstrual phase (Day 1-5)
2. Follicular Phase (Day 6- 11)
3. Ovulation Phase (Day 12- 16)
4. Luteal Phase (Day 17- 23)
5. Premenstrual Phase (Day 23-28)

Another way to divide the menstrual cycle is as follows: follicular phase generally extends from Day 1 (the first day of menstruation) to Day 12. During this phase, the level of estrogen is low however it peaks prior to ovulation phase. At this time, the follicular phase ends and ovulation phase is started (around Day 12 - 16). Estrogen levels are on peak during day 12 - 16 and remain high in the luteal phase. The luteal phase starts from day 16 to 28 and it is characterized by high levels of estrogen and progesterone (Maki et al., 2001). However, estrogen levels start declining gradually in the late luteal phase.

Therefore there is a natural fluctuation in estrogen across a typical menstrual cycle that permits the study of the relationship between levels of estrogen and various cognitive functions, such as working memory.

Estrogen and working memory

The natural fluctuations in level of estrogen across the menstrual cycle seem to have an impact on human cognition – especially memory. In order to understand the impact of estrogen levels on human cognition, one should consider the functions of estrogen in brain. Namely, estrogen plays role in maintenance of neural functions in brain and protection against neural damage. That’s why a decline in one or both of these functions due to small or declining levels of estrogen directly impacts working memory function. Evidence for the involvement of estrogen in the maintenance of neural functions comes mostly from studies on what happens to the brain as estrogen levels in conjunction with the menopausal period in women. As estrogen levels decline over the menopause, the cognitive and other behavioral processes that depend on them also decline in their functional capacities (McEwen et al., 1999). In addition, it has been shown that estrogen has a profound influence on the morphological and electrophysiological properties of the hippocampus, a brain region implicated in certain forms of learning and memory.
The second function of estrogen is to protect the nerve cells against damage. While low levels of estrogen may increase the vulnerability of brain cells to insults and to the effects of other age related changes in neural function (Bruce et al., 1999), these threats can often be controlled by estrogen replacement therapy (ERT). For example, it has also been noted that the absence or decline of estrogen may contribute to Alzheimer - a disease known for its devastating impact on memory. In principle, estrogen effects in the hippocampal formation and basal forebrain. These structures are prominent in learning and memory, and serve as sites of neural degeneration in Alzheimer (McEwen et al., 1999). However estrogen replacement therapy can help to improve some cognitive functions especially those that involve memory such as spatial working memory, verbal memory test and fine motor skills (Hampson, 1990; Kimura, 1992; Sherwin, 1994 & Sherwin et al., 1996). There are even some reports that suggest that ERT may lower the risk of Alzheimer's disease and may improve age related memory decline. For instance, a number of studies report that postmenopausal women with Alzheimer's disease treated with high dose of estrogen exhibited enhanced attention and memory (Asthana et al., 2001).

In contrast to postmenopausal women, young women who have a naturally occurring increase in estrogen levels are thought to have improved forms of learning such as verbal memory. For instance, studies in women have found that increased estrogen during normal hormonal fluctuation enhances verbal memory (Hausmann et al., 2000). The effects of fluctuating estrogen levels on mood during menstrual phase will be discussed in next section. In place of taking blood test of subjects, a checklist of physical and psychological symptoms was created to have a proxy estimate of how women generally find themselves during menstrual and ovulation phase.

**Estrogen and Mood**

Estrogen and progesterone have been shown to influence and interact with a multitude of brain regions, compounds and processes that are associated with the regulation of mood and behavior. For instance, animal studies suggest that the amygdala, a structure involved in emotion and memory has one of the highest densities of estrogen in the brain (Merchanthaler et al., 2004., Mitra et al., 2003., Shughrue et al., 1997., Shughrue & Merchanthaler, 2001). When it comes to women, they normally complain about feeling aggressive and more negative when they are expecting a menstrual phase within a span of a week or so, which can be associated with phases of declining hormones across the menstrual cycle. Symptoms that are observed and interpreted as negative are feelings of anxiety, irritability, tension and depression (Collins et al., 1985).

The hormonal effects on mood are apparent across the normal menstrual cycle. As mentioned earlier, low estrogen and negative mood continues with increasing levels of estrogen, peaking just before ovulation, followed by an increase in progesterone and still high estrogen levels (resulting in gradual elevation in mood) through most of luteal phase. In the late luteal phase, just before menstruation, there are low levels of both ovarian hormones which results in negative mood (irritability, anxiety and tension). In general, mood is more negative during the premenstrual and menstrual phases than the periovulatory phase (e.g. Collins et al., 1985.). When estrogen levels are high, more
mood elevating chemicals are available to circulate (Douma et al., 2005). That is why; high levels of plasma estrogen have also been shown to have a positive mood in postmenopausal women (Klaiber et al., 1979, Sherwin, 1991, Shleifer et al., 2002).

With the help of studies that are carried out on postmenopausal women, this paper will try to find if estrogen effects working memory in young women who experience fluctuation of estrogen during their fertility span. Thus memory and mood in relation to estrogen were measured in fertile women during their menstrual and ovulation phases.

Method

Participants
Twenty female participants aged 20 - 40 years, voluntarily took part in this study. Participants were randomly recruited by announcements from different areas of Stockholm city. Only women with regular menstrual cycles who kept record of their cycles were selected. All participants reported having a regular menstrual cycle between 28 - 32 days. It was further confirmed that the subjects had not taken hormones or oral contraceptive.

Material
Because the working memory of the subjects was tested twice, two lists of words in English were created. List A was used to test working memory during menstrual cycle (Day 1 - 4) whereas list B was used while subjects were going through their ovulation phase (Day 12 - 16). Both lists were comprised of same words. However, list B had the same words in reverse. The words were randomly selected from English TV programs and from the glossary of different articles from PsychInfo. The words were printed in Times New Roman (with font size 12) on small pieces of paper. The words are as follow:

|-------------|---------|-----------|-------------|--------------|-------------|

In order to note down mood swings during both phases, psychological and physiological symptoms were provided on a piece of paper with options such as negative or normal mood. Negative mood was defined as irritability, feeling of anxiety, tension, stress and depression. Where as physical symptoms included pain in lower back and abdomen, and tenderness in the breasts. On the other hand, the normal mood category was defined as absence of physical pain and negative mood.

Procedure
Participants were told that the purpose of the study was to examine the relationship between estrogen and working memory. The subjects were tested randomly, according to their menstrual and ovulation phases. Those subjects who reported to be in the first four days of their menstrual cycle were tested first in the low estrogen condition and those who reported to be in the ovulation phase were tested first in the high estrogen condition. The estimate of menstrual cycle was made by counting from the first day of last menstrual period (Day 1) to the present day of the menstrual phase.
In order to test effects of estrogen on working women, a verbal working memory task was performed. All subjects were informed about their rights as a research subject and that they had the right to quit at any time without giving a reason. The testing was conducted in the morning on both testing occasions in order to control for time of day.

The words were presented one at a time on a piece of paper which remained in front of the participant for 5 seconds. After 5 seconds, the next word was presented until all – 12 words had been presented. This phase took one minute (5 seconds per word). Next, the subject was asked if she was experiencing mood swings or any physical discomfort. The information was noted down in 2-3 minutes which was followed by the recall session of the test. The subject was then given one minute to recall the words, disregarding word order. While the subject was recalling words, the experimenter recorded correct answers. A stopwatch was used in both sessions of verbal working memory test. The results from both tests were noted down in a register where the name, age and ethnicity of subjects were recorded along with the self reported mood and physical symptoms.

Data reduction and analysis
In order to calculate the difference between verbal working memory during menstrual and ovulation phases, a paired samples t-test was used. The level of significance was set at 0.5 in all statistical analysis.

Results
The subjects in their menstrual phase recalled an average of 6.70 words (i.e. \( \text{mean}_{\text{menstrual\_phase}} = 6.70 \)) as compared to their ovulation phase where the average number of words recalled were 7.45, i.e. \( \text{mean}_{\text{ovulation\_phase}} = 7.45 \).

The standard deviation for scores in the menstrual phase was 1.26 and for the ovulation phase it was 1.88 with 19 df (degrees of freedom). A significant effect for verbal working memory between menstrual and ovulation phases was found \( t_{(19)} = -2.45, p<0.05 \).

Table 1: Menstruation Score

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Valid</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>50.0</td>
<td>60.0</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>15.0</td>
<td>75.0</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>10.0</td>
<td>85.0</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>15.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Table 3 presents the reported psychological and physiological symptoms by subjects in Ovulation phase. All the subjects reported normal psychological and physiological symptoms as shown in Table 3. Table 4, on the other hand, presents the reported psychological and physiological symptoms by subjects during menstrual phase. Abnormality in psychological symptoms is classified into irritability, anxiety and stress experienced by subjects during menstrual phase. Similarly, physiological abnormality is classified into pain in lower back/abdomen, increased appetite and breast tenderness. Please see Table 4 for complete results. Results are further discussed in the discussion section.

Table 3: Mood in Ovulation Phase (Reported Psychological and Physiological Symptoms)

<table>
<thead>
<tr>
<th>Ovulation Phase</th>
<th>Normal Psychological Symptoms</th>
<th>Normal Physiological Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/20</td>
<td></td>
<td>20/20</td>
</tr>
</tbody>
</table>

Table 4: Mood in Menstrual Phase (Reported Psychological and Physiological Symptoms)

<table>
<thead>
<tr>
<th>Menstrual Phase</th>
<th>Abnormal Psychological Symptoms</th>
<th>Abnormal Physiological Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irritability</td>
<td>18/20</td>
<td>13/20</td>
</tr>
<tr>
<td>Anxiety</td>
<td>18/20</td>
<td>Increased Appetite</td>
</tr>
<tr>
<td>Stress</td>
<td>6/20</td>
<td>3/20</td>
</tr>
<tr>
<td>Breast Tenderness</td>
<td>3/20</td>
<td>3/20</td>
</tr>
</tbody>
</table>
Discussion

The aim of this paper was to examine the effect of hormonal fluctuation on verbal working memory in women during the menstrual and ovulation phases of a regular menstrual cycle. The verbal working memory scores were different during the menstrual and ovulation phases of same subjects. Women have higher estrogen levels during ovulation phase than that in the beginning of the cycle. This finding supports the hypothesis that increased estrogen levels are associated with improved working memory. The steroid hormone’s ability to change across the menstrual cycle may influence perception, cognition, arousal, pain and other neural mechanisms (Hellström, 2003).

According to the menstrual frequency table, the minimum score was 5 and the maximum was 9 words recalled. Whereas the ovulation frequency table indicated a slightly more symmetrical score pattern although a higher range of scores, from a minimum of 5 to a maximum of 11. The majority of the participants did score between 5 and 9 points on this verbal working memory test which is supported by George Miller’s concept of magical number seven, plus or minus two” (Passer & Smith, 2007). The effect of estrogen levels on subjects during menstrual and ovulation is as follows:

As previously discussed, negative mood has been associated with phases of declining or low ovarian hormones across the menstrual cycle (Collins et al., 1985, Hendrick et al., 1996). This study has also clearly demonstrated that the normal menstrual cycle is characterized by a number of mood changes and symptoms such as irritability, anxiety and stress that are already referred as negative mood in this paper. Eighteen subjects reported experiencing mood swings in late luteal phase and in early (first two days) menstrual phase which is further supported by an epidemiologic study of a large population in Gothenberg by Andersch (1980). According to that study, a large percentage of normal women experience mild to moderate mood changes during the menstrual cycle. However, the intensity of psychological and physical (pain) symptoms varies according to their routine and lifestyle. Almost every third subject reported stress and workload as major factors behind negative mood swings and physical pain.

When it comes to experiencing physical pain in late luteal or early follicular phase, subjects with stress or workload complained having physical pain along with negative mood. As many as thirteen subjects reported experiencing pain in lower back and abdomen on the first day of menstruation when they are going through any kind of psychological stress.

Another interesting finding was related to appetite and estrogen levels. Three out of twenty subjects reported feeling extremely hungry before having menstruation which is supported by Laura et al. (2007) according to which, irritability is the most frequent mood symptom and craving carbohydrate-rich foods is a common specific appetite change. However, all of the subjects reported to have a normal psychological and physical state during ovulation phase and therefore could be classified as having no negative mood or symptoms as defined by this study (see also section 2.2).

Despite the significant findings of this study, there are caveats. This study did not perform hormone assays to verify the actual hormone levels and henceforth, claiming
that verbal working memory is associated with estrogen levels as demonstrated through the description of experienced mood and physical symptoms, might not be sufficient enough to draw any final conclusions. Although there are evidence supporting estrogen's role in improving working memory in postmenopausal women (Asthana et al., 2001), a number of factors should be taken into consideration while drawing further conclusions. Factors such as good long term memory could have affected verbal working memory results in this study. For instance, a few students seemed to have remembered at least two words from the list when they were tested for the second time. This might have affected the score they received on their second testing occasion.

Another interesting finding was related to subject’s personal interest. Eleven subjects thought that the list contained a few words closely related to their fields of interest and therefore they could have had an easier time to remember and recall these words, giving them an advantage over other participants. Five subjects kept on talking while they were being tested (during 1 minute recall session). In this way, they lost 10-15 seconds and ran out of time. Four subjects reported that they were not familiar with the words presented in the list when they were tested for the first time. However, they did not complain when they were being tested again. Although those particular subjects were highly educated, (PhD students) they thought that words like Gucci, Mascara and Amethyst were quite unusual for them. As a result, the scores of these students were below average during their first testing as compared to the rest.

In conclusion, there is substantial evidence for estrogen interactions in brain regions involved in mood and cognition. It appears to improve working memory in women who are in menopause period with the help of ERT at the same time as it affects positively working memory of women during ovulation phase. Similarity between postmenopausal and pre menopausal women during follicular phase are low levels of estrogen. Moreover, fluctuating estrogen and sustained deficit in women are correlated with significant mood disturbance. This study may lend further insight into the effects of estrogen on working memory and mood from pre to postmenopausal women in future.

References


