

VERBAL AND SPATIAL FUNCTIONS DURING DIFFERENT PHASES OF THE MENSTRUAL CYCLE

Nataša Šimić & Maria Santini

Department of Psychology, University of Zadar, Zadar, Croatia

received: 5.10.2010;

revised: 30.11.2010;

accepted: 5.12.2011

SUMMARY

Background: It has been reported that high levels of sex hormones improve the efficiency in tasks which are usually better performed by females. In contrast, in tasks which are usually better performed by males, the best efficiency corresponds to low levels of sex hormones. The aim of this study was to examine changes of efficiency in tasks of verbal fluency and mental rotations, as well as changes in masculinity and femininity during the menstrual cycle.

Subjects and methods: Seventeen female subjects with a regular menstrual cycle took part in the study. For assessments of masculinity and femininity, the subjects filled the Bem's Sex Roles Inventory. Endler's Anxiety Scale was used for determining the autonomic-emotional and cognitive-worry components of anxiety. Subjects performed the verbal fluency task and mental rotations tasks during the menstrual and the early follicular phase, as well as during the pre-ovulation and the midluteal phase.

Results: The results showed the best performance in mental rotation tasks which included rotations of three-dimensional objects along x and y axis during the phases of menstrual cycle, which are characterized by a low level of sex hormones. The most pronounced during these phases was also the masculinity. Furthermore, the best performance in verbal fluency task occurred during the menstrual and midluteal phase. Anxiety and femininity did not change across the menstrual cycle.

Conclusion: Low levels of sex hormones potentiated the typical male cognitive profile.

Key words: femininity – masculinity - menstrual cycle - spatial abilities - verbal abilities

* * * * *

INTRODUCTION

Many cognitive functions are influenced by variations in the levels of sex hormones in the body. These influences are called activational, because it is believed that hormones activate specific neural circuits, whose organization has been defined and determined during prenatal development (Sherwin 2003). In the cognitive abilities that are developed in an unequal degree in men and women can be observed activational effects of sex hormones. Previous studies have shown that women on average achieve better results in tasks of verbal fluency, perceptual speed, memory location of objects, fine motor skills and facial recognition (Maylor et al. 2007, Silverman et al. 2007). Unlike women, men generally show an advantage in spatial relations, in tasks of mental rotation, target shooting and monitoring, and mathematical reasoning (Maylor et al. 2007).

Changes in cognitive functions during different phases of the menstrual cycle could also be due to activational effects of sex hormones. Previous studies have included testing the effects of fluctuations in the levels of estrogen and progesterone during the menstrual cycle on different cognitive functions. Most often compared the performances between two phases, one of which is menstrual phase when estrogen and progesterone levels in the body are low. However, second measurement conducted during the late follicular phase (pre-ovulation phase), characterized by high levels estrogen only, or during the midluteal phase,

when the levels both estrogen and progesterone in the body are high. Some researchers prefer to measure in the late follicular phase, when performance in cognitive tasks is certainly attributable to the high levels of estrogen. The advantage however midluteal phase is longer duration (Phillips & Silverman 1997), and the stability of its duration (Fehring et al. 2005).

Previous investigations have shown the positive effect of sex hormones in tasks which are usually better performed by women (Hampson & Kimura 1988, Maki et al. 2002). Thus, in verbal fluency tasks, and those that require fine motor skills, the highest efficiency was found in the late follicular or midluteal phase (Maki et al. 2002, Rosenberg & Park 2002).

High levels of sex hormones could have a negative impact on performance in tasks which are usually better performed by males. Previous investigations, which included changes of efficiency in tasks of mental rotation during the menstrual cycle, are not given quite consistent results. Some studies report improved performance in the menstrual phase in comparison with the midluteal phase (Phillips & Silverman 1997, Hausmann et al. 2000). It was found reduced the performance in the luteal phase in comparison with early follicular phase (Maki et al. 2002), while there was no difference between the pre-ovulation and the menstrual phase (Hromatko 2001).

Several studies reported no differences in affective states across the menstrual cycle (Phillips & Silverman 1997, Maki et al. 2002, Hausmann et al. 2006), while

others reported higher rating anxiety and negative moods during the menstrual and/or luteal phase (Symonds et al. 2004, Šimić & Manenica 1998). These changes can also influence on cognitive performance during different phases of the menstrual cycle.

The aim of this study was to examine changes of efficiency in tasks of verbal fluency and mental rotations, as well as changes in masculinity and femininity in the different phases of menstrual cycle. On the basis of previous investigations we assumed better efficiency in verbal fluency task during the phases when the levels of sex hormones are high. On the other hand, the best efficiency in task of mental rotations, could be occurs, when the levels of sex hormones are the lowest. Furthermore, the previous studies did not include comparison of efficiency in these cognitive tasks between the midluteal phase, when the levels of both sex hormones are high, and late follicular phase, when only levels of estrogen are high. Although the menstrual and early follicular phase are characterized by low levels of both sex hormones, due to the presence of various psychosomatic symptoms and negative emotional states during the menstrual phase, the differences in performance between these two phases can also be expected. Changes in efficiency in these tasks could be related to changes in masculinity and femininity during the menstrual cycle.

SUBJECTS AND METHODS

Subjects

Nineteen female healthy subjects, aged 18-22 years, University students, with regular menstrual cycles lasting 28 +/- 2 days, and duration of the phase of the menstrual bleeding 5 +/- 2 days took part in this study. They did not use oral contraceptives, or other type of hormonal therapy at the time of testing, as well as the last six months. All subjects were right handed.

Methods

The Bem Sex Roles Inventory (BSRI) provides independent assessments of masculinity and femininity in terms of the subject's self-reported possession of socially desirable, stereotypically masculine and feminine personality characteristics. It consists of 60 items, 20 of items are stereotypically masculine (e.g. ambitious, independent, assertive), 20 feminine (e.g. affectionate, understanding, sensitive) and 20 neutral (happy, conceited). For the purpose of this study, the BSRI was modified. Instead of the instruction "How often do you behave like that", the subjects had to answer the question "How often have you behaved like that in the last 3 days". The subjects answers ranged from 1 (meaning "do not describe me") to 7 (meaning "completely describes me"). Separate scores for masculinity and femininity scales were expressed and the mean score for each scale was computed.

For determining the state anxiety, we used Endler's Multidimensional Anxiety Scale (EMAS-S) (Sorić 2002), which consists of two subscales: autonomic-emotional and cognitive-worry components of anxiety. The subjects' task were that for each of 20 items on a scale of 5 degrees, where 1 meant not at all, 3 somewhat, and 5 is very, marked as it is currently being felt. The mean score for each components of anxiety was calculated.

Two-factor structure of the EMAS-S scale was confirmed by the Croatian student sample. Internal consistency (Cronbach alpha) for subscale cognitive-worry was 0.87, while for the autonomic-emotional component of state anxiety was 0.83. The internal reliability of the whole scale was 0.90 (Sorić 2002).

Verbal fluency task was constructed for the purpose of this study. This task examines the ability of producing words by default rules during a specific time interval. In this study, we used the phonemic fluency task, which of the subjects were required to produce the words with given letter, without the possibility of using repetition of words, proper names, numbers or variations of the same word. Production time was limited to a period of one minute for each letter.

Four letters were selected (K, N, O and Z). According to the Dictionary of Croatian Language (Anić 2003), the total number of words in Croatian language for given letters ranged from 2200 to 2700 words. In a preliminary study with 10 subjects who did not participate in this main study, we found no statistically significant differences in the number of produced words for four default letters ($F=1.81$, $df=3$, $p=0.16$). The average number of produced words was 12 for the letter K, 10.76 for the N, 10.71 for the O and 12.12 for the Z.

Testing of verbal fluency in the main study conducted in a way that the subjects in each of four phases of menstrual cycle had different default letter (K, N, O or Z). The order of letters was rotated amongst the subjects and different phases of menstrual cycle according to the Latin square principle. The subject's task was to produce too many words with the given letter. During testing, subjects were comfortably sitting. The microphone for recording produced words was on the table. In the analysis of results as the dependent variable is used the sum of produced words during a limited period of time (one minute) for each default letter.

For the purpose of the study, computerized mental rotation task was constructed. We used the three-dimensional objects developed by Shepard & Metzler (1971). These objects were employed because it is suggested that three-dimensional tasks represent the most ecologically valid representations of the spatial world (Phillips & Silverman 1997). These objects are more sensitive to sex differences than two-dimensional task. Furthermore, significant menstrual cycle's effects were observed only on three-dimensional objects (Phillips & Silverman 1997). The tasks of mental

rotations consist of pairs of three-dimensional objects, which are rotated along x, y or z axis, and simultaneously presented on the computer screen. The subjects' task were to determine, as rapidly as possible, whether the presented object on the right side of the computer screen, is rotated version of the object presented to the left. The subjects responded to the numeric keyboard of computer, press the marked button "Yes", when they thought that it was a rotated version of the same object. If they thought that the different objects are presented, they responded by pressing the marked button "No", on the computer keyboard. There were 60 items, ie. pairs of presented objects (20 objects for each of the three axis), which were presented randomly during different phases of the menstrual cycle. Subjects solved the task their right hand. Total time for solving each item, as well as a number of correctly solved items were registered. Since more than 80% of items were correctly solved, we decided to use task time for correctly answers as the dependent variable in the tasks of mental rotations. Previous investigations have also shown that this measure is highly reliable (Kozaki & Yasukouchi 2008) and sensitive to the effects of menstrual cycle (Kozaki & Yasukouchi 2009, Šimić et al. 2010). The reaction time also indicate a strong positive relation with the degree of angular disparity between the three-dimensional objects (Kozaki & Yasukouchi 2009, Neely & Heath 2010).

Procedure

The subjects performed the tasks of verbal fluency and mental rotations during four phases of the menstrual cycle: menstrual (day 2, levels of estrogen and progesterone are low), early follicular (day 7, levels of estrogen and progesterone are low), pre-ovulation phase (day 12; high level of estrogen and low level of progesterone), midluteal phase (22 day, levels of estrogen and progesterone are high). As in previous studies, testing was not conducted first day of the menstrual cycle, due to the uncertain time of the occurrence of menstrual bleeding, as well as any physical discomfort, and/or possible use of medication. Each phase was determined by counting forward from first day of last menstrual bleeding. These phases were also confirmed by counting backward from the onset of the next menstrual phase. Before solving tasks, subjects completed BSRI Inventory and EMAS-S Scale. The sequence of completing these questionnaires and solving tasks is rotated by the principle of ABBA, among subjects, as well as between the different phases of the menstrual cycle. For to avoid the effects of time of day, subjects were tested at the same time, between 10 and 12 hours a.m., in the Psychophysiological Laboratory at the Department of Psychology of University of Zadar. The study was conducted during non-exam period. Subjects started this investigation during different phases of cycle. They had not taken medication, caffeine and alcohol within 24 h of the experiment.

Statistical analyses

The results of two subjects are removed from the analyses because they were tested at a wrong time-window within the menstrual cycle. Therefore, all analyses were performed on the results of 17 subjects. For testing the significance of the differences of examined variables during different phases of the menstrual cycle, we used one-way analyses of variance for repeated measurements on one factor. After analyses of variance, we used post hoc analyses (Scheffe's test) for testing differences between the various phases of the menstrual cycle. For calculation the correlations, Pearson's correlation coefficients were used. As the criterion for significance of changes, $p < 0.05$ was used. The results are analysed in the statistical package *Statistica 7.0*.

RESULTS

Means of all variables are presented in Table 1. Analysis of variance showed no significant changes in the autonomic-emotional and cognitive-worry components of anxiety during the various phases of the menstrual cycle (Table 2). Changes of femininity during different phases of the menstrual cycle did not also show significant (Table 2). However, analysis of variance showed a significant change of masculinity during the menstrual cycle (Table 2). An increase of masculinity is found during phases with low levels of sex hormones (Table 1). Post-hoc analysis showed no significant differences in masculinity between phases when the levels of sex hormones in the body are low (menstrual and early follicular phase) ($p=0.53$). Also, differences in masculinity between phases of elevated level of estrogen (pre-ovulation phase) and both hormones (midluteal phase) were not significant ($p=0.14$). However, post-hoc analysis showed significant differences between phases of low (menstrual and early follicular phase, separately) and high levels (pre-ovulation and middle luteal phase, separately) of sex hormones ($p<0.04$).

Effects of menstrual cycle's phases on efficiency in the verbal fluency task were significant (Table 2). Contrary to expectations, subjects produced the most words in the menstrual and midluteal phase (Table 1). Post-hoc analysis showed no differences in the number of produced words between these two phase ($p=0.61$), as well as between the early follicular and the pre-ovulation phase ($p=0.68$), the pre-ovulation and the midluteal phase ($p=0.12$). However, we found differences between the following phases: the menstrual and the early follicular phase ($p=0.02$), the pre-ovulation and the menstrual phase ($p=0.04$), and the early follicular and the midluteal phase ($p=0.05$).

As shown in Table 2, there are significant effects of cycle's phases on efficiency in the tasks which included the rotation of three-dimensional objects along the x and y axis. In the task which included the rotation of objects along the x axis, shorter times were found in the phases

Table 1. The mean scores for examined variables during four phases of the menstrual cycle

Variable	Menstrual phase	Early follicular phase	Pre-ovulation phase	Midluteal phase
Autonomic-emotional component of anxiety	1.94	1.82	1.74	1.70
Cognitive-worry component of anxiety	2.04	1.98	1.89	1.71
Femininity	4.52	4.84	4.57	4.70
Masculinity	4.42	4.50	3.95	4.15
Number of produced words (verbal fluency task)	13.12	10.24	10.71	12.53
Task time (in mins) (mental rotation, x axis)	2.40	2.19	2.87	3.21
Task time (in mins) (mental rotation, y axis)	2.50	2.22	3.11	2.83
Task time (in mins) (mental rotation, z axis)	2.74	2.40	2.83	3.15

Table 2. ANOVA changes of examined variables during four phases of the menstrual cycle

Variable	df	F	p
Autonomic-emotional component of anxiety	3	0.52	0.67
Cognitive-worry component of anxiety	3	0.94	0.43
Femininity	3	2.02	0.12
Masculinity	3	7.66	0.0003
Number of produced words (verbal fluency task)	3	2.98	0.04
Task time (mental rotation, x axis)	3	5.06	0.004
Task time (mental rotation, y axis)	3	4.00	0.01
Task time (mental rotation, z axis)	3	1.68	0.18

which are characterized by low levels of sex hormones (menstrual and early follicular phase). As expected, longer times were found in the phases when hormone levels are high (pre-ovulation and middle luteal phase) (Table 1). In this task, post hoc analysis showed no differences in performance between the menstrual and early follicular phase ($p=0.47$). As expected, the differences were not significant between pre-ovulation and midluteal phase ($p=0.25$). However, significant differences were found between the phases of low and high levels of sex hormones ($p<0.05$). Similar results were obtained in mental rotations task which included the rotations of objects along the y axis. As predicted, shorter times have been obtained in the menstrual and early follicular phase, while longer times were during pre-ovulation and midluteal phase (Table 1). Post-hoc analysis showed no significant differences in the times between the phases of low levels of sex hormones ($p=0.31$), as well as between the phases of elevated levels of sex hormones ($p=0.31$). Contrary, significant differences were observed between phases of low and high levels of sex hormones, separately ($p<0.05$). In task which included the rotations of three-dimensional objects along z axis, no significant changes of efficiency during different phases of the menstrual cycle were found (Table 2).

The analysis of results included calculations of Pearson's correlation coefficients between the variables in the different phases of the menstrual cycle, separately. Performance in both tasks were not associated with state anxiety in different phases of the cycle ($r=0.05-0.42$; $p>0.05$). Masculinity were not associated with task times in mental rotation tasks, too ($r=0.13-0.36$; $p>0.05$). Likewise, there were not significant correlations between femininity and efficiency in verbal fluency task in different phases of menstrual cycle ($r=0.05-0.15$; $p>0.05$).

DISCUSSION

Experimental studies of activational effects of sex hormones on various aspects of cognitive functioning typically included measuring the efficiency in the sexually dimorphic tasks during different phases of the menstrual cycle. Studies of this type usually included investigations of different emotional states and moods. In the present study, no significant changes in both components of state anxiety (autonomic-emotional and cognitive-worry) during different phases of the menstrual cycle were found. These obtained results are consistent with previous studies which included the application of different scales or questionnaires of mood

(Phillips & Silverman 1997, Maki et al. 2002, Hausmann et al. 2006). Taking into account the results of previous studies which have shown that around ovulation women change their behavior in a manner that enhances the chances of attracting a possible mate (Roberts et al. 2004), in this study could be expected an increase of femininity during pre-ovulation phase. However, significant changes of femininity during different phases of the menstrual cycle were not found. At the same time, significant changes of masculinity were found. The results showed that masculinity becomes more expressed during phases of low levels of sex hormones (the menstrual and early follicular phase). Since low levels of sex hormones potentiate the typical male cognitive profile, these results could be expected. Specifically, differences in masculinity between phases of low and high levels of sex hormones are shown. However, comparisons of masculinity between phases when levels of sex hormones are low showed no significant differences. Similar results were obtained between phases of high levels of sex hormones. On the basis of previous investigations, lower masculinity in pre-ovulation time could be expected. For example, it has been shown that women near the most fertile point of their cycle are more attractive to males, as manifest through more attractive body scent (Havliček et al. 2006) and greater facial attractiveness (Roberts et al. 2004). When conception is likely, they also dress more impressive showing more skin (Haselton et al. 2007). It is possible that less expressed masculinity during the pre-ovulation phase make possible an active pursuit for an available mate. In addition, pattern of changes in masculinity in this study could also reflect more general changes across the cycle, such as changes in mood. However, we found no significant correlations between anxiety levels and the assessments of masculinity.

Regarding the changes of efficiency in verbal fluency task, the effects of cycle's phase were significantly. Previous studies have not included a comparison of performance in this type of task between the menstrual and early follicular phase. The lowest performance in this task in the early follicular phase could be expected, taking into account the results of previous studies (Maki et al. 2002, Rosenberg & Park 2002). However, our results showed significant differences in verbal production between phases with low levels of sex hormones. Contrary to expectations, the subjects produced the most words in the menstrual, as well as midluteal phase. Some functional magnetic resonance imaging studies (Weis et al. 2008, for example) have been shown that during performance of verbal task, the inhibitory influence of left-hemispheric language areas on homotopic areas of the right hemisphere is strongest in the menstrual phase (cycle day 1-3), resulting in a pronounced cerebral lateralization. However, during the follicular phase (cycle day 9-11), due to rising estrogen levels, inhibition and thus functional cerebral asymmetries are reduced. These results point to estradiol is one of the key factors for the

modulation of interhemispheric inhibition and thereby for changes of functional cerebral asymmetries between the menstrual and follicular phase. Further, significantly greater number of produced words were also found in the midluteal phase, when levels of both sex hormones in the body increased. This research also revealed no differences in verbal production between pre-ovulation and midluteal phase. These results are consistent with previous studies, which are also shown greater success in verbal tasks in phases of high levels of sex hormones (Maki et al. 2002, Rosenberg & Park 2002, Symonds et al. 2004). Greater efficiency in verbal fluency task during the pre-ovulation and midluteal phase in comparison to the early follicular phase is also consistent with the hypothesis of facilitatory influence of estrogen on the functions of the left hemisphere. It is well known that language functions control the left hemisphere. Mead and Hampson (1996) found that right ear performance on the nonverbal dichotic test was significantly reduced at the midluteal phase. These results suggest suppression of right hemisphere processing areas and possible reduction in callosal transfer when higher levels of sex hormones occurred. Although positive relationship between estrogen levels and the efficiency in verbal task were found (Maki et al. 2002, Jennings et al. 1998), our results have not shown significant correlations between the assessments of femininity and the efficiency in this type of task

Moreover, the results have shown that high levels of sex hormones had a negative impact on performance in mental rotation tasks. Specifically, during the menstrual and early follicular phase, subjects solved quickly mental rotation tasks, which included the rotations of objects along x and y axis. The obtained results also showed differences in task times between the phases of low and high levels of sex hormones. As expected on the basis of previous studies (Phillips & Silverman 1997, Hausmann et al. 2000, Kozaki & Yasukouchi 2009), performance was reduced during the pre-ovulation and midluteal phase. The obtained results also showed that the task times were longer during pre-ovulation phase when conception is possible. One possible explanation of the above, proposed the theory of fertility and parental care by Sherry and Hampson (1997), as cited in Tadinac (2004). This theory assumes the lowest ability processing of spatial information at time of high estrogen level. This theory postulates an adaptive evolutionary mechanism which reduces female's spatial abilities and mobility, as a consequence of the fertile period. Furthermore, regarding the relationship between the degree of masculinity and performance in mental rotation task, the obtained results did not show that a greater degree of masculinity was significantly associated with higher efficiency in this type of task. The results also showed no significant effects of phase on performance in more difficult task which included the rotations of objects along the z axis. This result suggests that efficiency in more complex task of mental rotations might be affected by other

variables in addition to sex hormones. Cherney (2008) has shown that high mathematical ability improved mental rotation scores, while only 4 hours of computer game practice produced an improvement in performance. It is also possible that our subjects used different strategies in solving this task. While males preferred to use a holistic strategy, females used an analytic-verbal strategies (Hirnstein et al. 2009). Although this is supported by functional imaging study (Jordan et al. 2002), further explanations for no changes in the speed of mental rotations along z axis during different phases of menstrual cycle are need.

In the present study we were not able to check the subjects' hormonal status by radioimmunoassay analysis of blood or saliva. Although ovulation took place in every cycle in 62% of the women aged 20-24 years (Hampson & Young 2008), this study is not included the application of method for identifying the time of ovulation (measurements of basal body temperature, vaginal mucus or using luteinizing hormone test, etc.). However, a number of investigations in this area are used the method of counting days in regular menstrual cycles. Our sample was also small and restricted to college population. The results of this study provide insight into activational effects of sex hormones on cognitive functions in healthy women. These results can also serve as a starting point for investigations of women with psychiatric disorders. Namely, schizophrenic women showed exacerbation of psychotic symptoms during phases with reduced levels of estrogen (Hallonquist et al. 1993, Gattaz et al. 1994). Although some early studies (for example, Harris 1997) showed no exacerbation of psychotic symptoms during the menstrual phase, their results indicated that the symptoms which were exacerbated in schizophrenic women were mostly somatic and affective in nature, and thus similar to those symptoms that have been found to be characteristic of the menstrual symptomatology in healthy and depressed women. However, previous studies did not provide insight in cognitive function in women with various psychiatric disorders during the phases characterized by elevated and reduced levels of sex hormones. Therefore, the results obtained in this study could serve as guidelines for future studies.

CONCLUSION

The results obtained in this study showed no significant change in anxiety and femininity during different phases of menstrual cycle. However, the greatest number of produced words is found during the menstrual and midluteal phase. Contrary to results of previous studies, no differences in verbal production between these phases are found. As expected, the results also showed no significant differences in verbal production between the pre-ovulation and midluteal phase, when the level of sex hormones is high. In accordance with previous studies, low levels of estrogen and progesterone in the menstrual and the early

follicular phase potentiated the typical male cognitive profile, which included increased masculinity, as well as greater efficiency in mental tasks which included the rotation of three-dimensional objects along x and y, but not z axis. It is possible that other variables are more involved as mental rotation tasks become more complex.

Acknowledgements: None.

Conflict of interest : None to declare.

REFERENCES

1. Anić V: *Dictionary of Croatian language [In Croatian]*. 4th ed. Novi Liber, Zagreb, 2003.
2. Cherney ID: *Mom, let me play more computer games: they improve my mental rotation skills*. *Sex Roles* 2008; 59:776-786.
3. Fehring RJ, Schneider M, Raviele K: *Variability in the phases of the menstrual cycle*. *JOGNN* 2005; 35:376-84.
4. Gattaz WF, Vogel P, Riecher-Rossler A, Soddu G: *Influence of the menstrual cycle phase on the therapeutic response in schizophrenia*. *Biol Psychiatry* 1994; 36:137-139.
5. Hallonquist JD, Seeman MV, Lang M, Rector NA: *Variation in symptom severity over the menstrual cycle of schizophrenics*. *Biol Psychiatry* 1993; 33:207-209.
6. Hampson, E, Young EA: *Methodological issues in the study of hormone-behavior relations in humans: Understanding and monitoring the menstrual cycle*. In Becker JB, Berkley KJ, Geary N, Hampson E, Herman JP, Young E (eds): *Sex differences in the brain: from genes to behavior*, 63-78. Oxford University Press, 2008.
7. Harris AH: *Menstrually related symptom changes in women with schizophrenia*. *Shizophr Res* 1997; 27:93-99.
8. Haselton MG, Mortezaie M, Pillsworth EG, Bleske-Rechek A, Frederick DA: *Ovulatory shifts in human female ornamentation near ovulation, women dress to impress*. *Horm Behav* 2007; 51:40-5.
9. Hausmann M, Slabbekoorn D, Van Goozen SHM, Cohen-Kettenis PT, Gunturkun O: *Sex hormones affect spatial abilities during the menstrual cycle*. *Behav Neurosci* 2000; 114:1245-50.
10. Hausmann M, Tegenthoff M, Sanger J, Janssen F, Gunturkun O, Schwenkreis P: *Transcallosal inhibition across the menstrual cycle: a TMS study*. *Clin Neurophysiol* 2006; 117:26-32.
11. Havliček J, Dvorakova R, Bartoš L, Flegr J: *Non-advertized does not mean concealed: Body odour changes across the human menstrual cycle*. *Ethology* 2006; 112:81-90.
12. Hirnstein M, Bayer U, Hausmann M: *Sex-specific response strategies in mental rotation*. *Learn Individ Differ* 2009; 19:225-228.
13. Hromatko I: *The influence of estrogen on spatial ability, perceptual speed and fine motor abilities [In Croatian]*. *Suvremena psihologija* 2001; 4:61-71.
14. Jennings PJ, Janowsky JS, Orwoll E: *Estrogen and Sequential Movement*. *Behav Neurosci* 1998; 112:154-9.
15. Jordan K, Wustenberg T, Heinze HJ, Peters M, Jancke L: *Women and men exhibit different activation patterns during*

- mental rotation tasks. *Neuropsychologia* 2002; 40:2397-2408.
16. Kozaki T, Yasukouchi A: Relationships between salivary estradiol and components of mental rotation in young men. *J Physiol Antropol* 2008; 27:19-24.
 17. Kozaki T, Yasukouchi A: Sex differences on components of mental rotation at different menstrual phases. *Intern J Neurosci* 2009; 119:59.67.
 18. Maki PM, Rich JB, Rosenbaum RS: Implicit memory varies across the menstrual cycle: estrogen effects in young women. *Neuropsychologia* 2002; 40:518-29.
 19. Maylor EA, Reimers S, Choi J, collaer ML, Peters M, Silverman I: Gender and sexual orientation differences in cognition across adulthood: age is kinder to women than to men regardless of sexual orientation. *Arch Sex Behav* 2007; 36:235-49.
 20. Mead LA, Hampson E: Asymmetric effects of ovarian hormones on hemispheric activity: evidence from dichotic and tachistopic tests. *Neuropsychology* 1996; 4:578-87.
 21. Neely KA, Heath M: Visuomotor mental rotation: reaction time is determined by the complexity of the sensorimotor transformations mediating the response. *Brain Res* 2010; 1366:129-140.
 22. Phillips K, Silverman I: Differences in the relationship of menstrual cycle phase to spatial performance on two- and three-dimensional tasks. *Horm Behav* 1997; 32:167-75.
 23. Roberts SC, Havliček J, Flegr J, Hruskova M, Little AC, Jones BC, et al.: Female facial attractiveness increases during the fertile phase of the menstrual cycle. *Proc R Soc Lond B* 2004; 271 (S5):S270-S272.
 24. Rosenberg L, Park S: Verbal and spatial functions across the menstrual cycle in healthy young women. *Psychoneuroendocrinology* 2002; 27:835-41.
 25. Shepard RN, Metzler J: Mental rotation of three dimensional objects. *Science* 1971; 71:701-3.
 26. Sherwin BB: Estrogen and cognitive functioning in women. *Endocr Rev* 2003; 24:133-51.
 27. Silverman I, Choi J, Peters M: The Hunter-Gatherer theory of sex differences in spatial abilities: Data from 40 countries. *Arch Sex Behav* 2007; 36:261-8.
 28. Sorić I: Ender's multidimensional scales of anxiety [In Croatian]. In Lacković-Grgin K, Proroković A, Čubela V & Penezić Z (eds): *Collection of Psychological Scales and Questionnaire*, 115-123. Faculty of Philosophy, 2002.
 29. Symonds CS, Gallagher P, Thompson JM, Young AH: Effects of the menstrual cycle on mood, neurocognitive and neuroendocrine function in healthy premenopausal women. *Psychol Med* 2004; 34:93-102.
 30. Šimić N, Manenica I: Changes of psychophysiological variables during the menstrual cycle [In Croatian]. *Radovi Filozofskog fakulteta u Zadru* 1998; 36:79-90.
 31. Šimić N, Tokić A, Peričić M: Performance of fine motor and spatial tasks during the menstrual cycle. *Arh Hig Rada Toksikol* 2010; 61:407-414.
 32. Tadinac M, Hromatko I: Evolution psychology and gender differences [In Croatian]. In Hrgović J & Polšek D (eds): *Evolution of sociality*, 175-91. Naklada Jesenski & Turk, 2004.
 33. Weis S, Hausmann M, Stoffers B, Vohn R, Kallermann T, Sturm W: Estradiol modulates functional brain organization during the menstrual cycle: an analysis of inter-hemispheric inhibition. *J Neurosci* 2008; 28:13401-10.

Correspondence:

Nataša Šimić, Ph.D, Assistant professor
Department of Psychology, University of Zadar
Krešimirova obala 2, 23000 Zadar, Croatia
E-mail: nsimic@unizd.hr