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Menstrual cycle effects on perceptual closure mediate changes in performance on a fragmented objects test of implicit memory

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Abstract

Healthy premenopausal women with regular menstrual cycles were assessed on a fragmented objects test of implicit memory. Testing took place at either the low estrogen ($n = 17$) or the high estrogen ($n = 16$) stages of the menstrual cycle. Concentrations of ovarian hormones were confirmed by saliva assays. Both groups of women exhibited a priming effect, in that primed objects were identified faster and at greater fragmentation than unprimed objects. There was no evidence that high estrogen inhibits perceptual object priming. However, women at the menstrual phase were able to identify both primed and unprimed objects at a more degraded level of fragmentation. Changes in perceptual closure over the menstrual cycle may be the basis for the changes in performance on the fragmented objects test observed in previous studies.

1. Introduction

There is increasing evidence that estrogen modulates neuropsychological functioning in women. Naturalistic studies of cognitive performance across the menstrual cycle and studies of postmenopausal women taking estrogen replacement therapy are two methods used to investigate estrogen effects. Observational studies and randomized controlled trials have shown a favorable effect of estrogen on tests of explicit and implicit memory (e.g., Maki, Rich, & Rosenbaum, 2002; Sherwin & Tulandi, 1996). In contrast, more than a dozen studies have shown that performance on tests of mental rotation and other spatial abilities is decreased at phases of the menstrual cycle characterized by high estrogen and improved at phases of low estrogen (Hampson, 1990; Maki et al., 2002). Thus estrogen's effects on cognition are complex and multi-faceted.

In a recent report, Maki et al. (2002) argued that high levels of ovarian hormones might inhibit perceptual object priming. Women tested in the early follicular phase of the menstrual cycle, when estrogen is low, performed better on a fragmented object identification (FOI) task than did women tested at the midluteal phase, when estrogen is high. This paradoxical finding does not fit with the emerging picture of estrogen's favorable effects on a variety of memory tasks, nor with performance on a test of conceptual implicit memory reported in the same study (Maki et al., 2002), and suggests that there may be another explanation for the findings.

In the present report, we show that changes in performance across the menstrual cycle on a test of implicit memory, the FOI task, may be explained by cycle-related changes in the ability to synthesize visual-perceptual information, i.e., by changes in perceptual closure.

2. Method

2.1. Participants

The participants were 33 healthy female undergraduates with regular menstrual cycles averaging between 25

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(minimum) and 35 (maximum) days in length ($M = 28.31$, $SD = 2.34$). The age range was 20–38 years with a mean of 23.58 years ($SD = 4.62$). All participants were non-smokers and had not used oral contraceptives for at least 6 months. Thirty-one participants were right-handed and two were mixed or left-handed.

2.2. Procedure

All prospective volunteers filled out a confidential demographic and reproductive health questionnaire. Women meeting the above criteria were recalled for testing at a later date. The timing of each test session was individually targeted to coincide with either the menstrual phase of the cycle ($n = 17$) when estrogen levels are lowest (Days +3 to +5), or the midluteal phase of the cycle ($n = 16$) when estrogen levels reach a sustained peak (Days −6 or −7). Assignment of women to the two test groups was random. Because the menstrual cycle is not perfectly reliable, each woman's menstrual stage at testing was confirmed retrospectively. Testing was considered successful if radioimmunoassays of saliva collected during the test session provided independent confirmation of estrogen levels. In the group of 33 women reported here, the mean level of 17β-estradiol, the major estrogen in women of reproductive age, was 3.14 pg/mL ($SD = 0.96$) during the menstrual phase and 6.38 pg/mL ($SD = 1.72$) during the midluteal phase. Associated levels of progesterone were 12.32 pg/mL ($SD = 3.72$) and 68.44 pg/mL ($SD = 95.43$), respectively.

Each woman was tested individually. The session began and ended with the collection of a saliva specimen for hormonal analysis. All specimens were frozen at −20 °C until the end of the study then analyzed in a single assay. The cognitive testing took approximately 1 h and 15 min during which a battery of cognitive and perceptual tests was administered. Included in the test battery were the FOI and perceptual closure tests described below.

2.3. Tests

2.3.1. Fragmented object identification test

The fragmented object identification (FOI) test was used to measure perceptual priming. Items consisted of line drawings of common objects selected from the Snodgrass and Vanderwart stimulus set.

The test was presented in two parts. In the first part, the Study Phase, 16 whole objects were presented individually on 4″ × 6″ file cards. The stimuli were presented in the guise of an object-naming task; participants were allowed 5 s to view and name each object aloud. The experimenter recorded verbatim the object names generated.

Later in the test session, without warning, the Test Phase was administered. In the Test Phase, participants were asked to identify fragmented versions of objects shown at progressively increasing levels of completeness (Snodgrass, Smith, Feenan, & Corwin, 1987). Sixteen objects were displayed: 8 randomly chosen objects from the Study Phase (primed objects) and 8 new objects (unprimed objects), not presented earlier. There were 8 levels of fragmentation for each object, arranged on separate cards from most to least fragmented. The final level showed the object in its entirety. Participants were asked to identify each object, starting at Level 1, the most fragmented level. A maximum of 10 s was allowed at each level. If the participant did not identify the object within 10 s the test proceeded to the next level, until a correct identification was made. Priming was defined as earlier identification (i.e., at a more degraded level of the visual stimulus) of previously studied objects compared with new objects. Two dependent measures were recorded for each object: the total number of seconds to correct identification (max = 80); and the level of fragmentation (1–8) at which object identification was made. Priming was therefore evident as a shorter mean identification time and/or an earlier level of fragmentation for the previously studied items compared to non-studied ones.

Following Maki et al. (2002), we also computed a priming index for each participant. Specifically, a ratio was calculated using the formula (UIDT-PIDT)/(UIDT), where UIDT and PIDT represent, respectively, the mean identification times for unprimed and primed objects. This ratio reflected the relative size of an individual's improvement in identification threshold for primed as compared to unprimed items.

2.3.2. Mooney–Harshman Closure Test

A modification of the original Mooney Closure Test (Mooney & Ferguson, 1951), incorporating a broader selection of objects, was administered in booklet form to each participant. The test has been validated in clinical assessments of patients with brain lesions. Each item depicts a common object with parts of the picture missing and the participant is allowed 20 s to identify the item. Responses were recorded verbatim by the experimenter. The measures taken were the time in seconds to correctly identify the picture and the number of correct responses (max = 20).

2.3.3. Profile of Mood States

The Profile of Mood States (POMS) is a self-report mood inventory in which the participant was asked to rate how accurately her current mood was described by each of 65 mood descriptors (e.g., "grouchy"). Responses were made on a 5-point scale ranging from "Not at all" to "Extremely." Items were totaled to provide six subscale scores (Tension, Depression, Anxiety, Vigour, Fatigue, and Confusion). The POMS was administered to be sure any changes in cognition were