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Research report

Attentional validity effect across the human menstrual cycle varies with basal temperature changes

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Abstract

This study examined the correlation between covert attention and basal temperature change during menstrual cycle phase in 22 adult females. Previous work showing beneficial effects of estrogen on working memory led us to hypothesize that attentional function would be facilitated at the apparent time of ovulation. Menstrual phase was determined through questionnaires and objective measurements of basal body temperature (BBT) spikes over a 1 month period. The cued target detection (CTD) task was used to assess visuospatial attentional performance at three times during the menstrual cycle. The mean reaction times (RTs) to visual targets were measured as a function of menstrual cycle phase, cue type and target location. As predicted, the onset of ovulation showed decreased reaction times and a significant increase in the cue validity effect on the days immediately preceding and following ovulation. The magnitude of the attention validity effect was negatively correlated with the basal temperature rise. Women lacking basal temperature shifts failed to show these changes. Results support the conclusion that the natural fluctuations of body temperature, and possibly reproductive hormones, during the menstrual cycle may enhance the attentional component of cognitive performance.

Keywords: Menstrual cycle; Reflexive attention; Covert attention; Reaction time

1. Introduction

The effects of menstrual cycle phase on some cognitive function in human female subjects without psychopathology are controversial. Studies of sustained attention [22,25,34], executive function [26,27], perceptual sensitivity, and response criterion [21] in women during different menstrual phases have not found significant, phase-dependent, response differences. Studies of performance on cognitive tasks during sleep deprivation [42], nonspatial reflexive attention [35], spatial working memory [33], reaction times (RTs) on perceptual detection tasks [21] and perceptual restructuring tasks [6] have documented declines in performance around the time of menstruation. There is evidence that visuospatial information processing tasks are improved during the menstrual phase, including faster reaction times accompanied by decreases in accuracy [17]. In contrast to these results, others report increased accuracy during the menstrual phase [15,18] and reaction times that were faster during the pre-ovulatory phase than during the menstrual phase [17].

Results from tests of mnemonic function have proven equally conflicting. Tests of implicit verbal and spatial memory, but not explicit verbal memory showed deficits during the follicular phase but not the midluteal phase [21]. In rhesus monkeys, performance on a spatial, delayed recognition span test was significantly better during the follicular and luteal phase than during the periovulatory phase [19]. Similar results were reported for human females for a mental rotation task [16]. In other studies, spatial working memory is said to be enhanced in women during the nonmenstruating phases of the cycle [15,35]. Still others report no differences in spatial working memory tasks [13]. As is often the case, methodological differences may have influenced the outcomes of some of these studies.

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In female animals, estrogen levels fluctuate during the oestrus cycle to induce and suppress specific behaviors, including lordosis and copulation (see [29] for a review). In human females estrogen level variation during the menstrual cycle is also measurable but specific behavioral changes, if any, are covert [28]. Variations in estrogen activity can be measured during pre-ovulatory, ovulatory and post-ovulatory phases of the cycle. During the pre-ovulatory phase, the production of follicle stimulating hormones (FSH) promotes follicle maturation, which secretes estrogen. LH promotes the synthesis of androgens, which are then converted to estrogens by aromatase. Ovulation occurs around days 10–14 in the menstrual cycle, when estrogen levels are high. This is the time when basal body temperature (BBT) may be high also [7]. After ovulation, estrogen levels fall while progesterone levels rise and then fall until menstruation. Progesterone remains low for 11–14 days prior to the end of the cycle, and declines further if the egg has not been fertilized (see [29]). During this time, body temperature usually decreases gradually.

The fluctuations in estrogen and other hormones can modulate neuronal function, either directly through estrogen receptors or indirectly by altering serotonergic and cholinergic neuronal activity [11,12,23–25,42]. Many of these receptors are located in the telencephalic brain region, including the hippocampus and neocortex [38]. This may help explain both the mnemonic deficits found in patients with Alzheimer's disease and the general cognitive benefits of hormone replacement in this population [20]. However, it is not clear whether the hormonal facilitation occurs only in elderly women or whether it may act more generally to facilitate spatial working memory in younger women as well. In contrast, progesterone seems to play a minor role in cognition (see [14] for a review).

An important component of spatial working memory is attentional allocation (see [3] for a review). Attention is necessary to transform information held in working memory into a more permanent form and is essential for recall of that information from long term storage [2]. Several lines of evidence suggest that attention deficits may be the earliest and most reliable symptoms of mnemonic decay, including Alzheimer's disease [30,31]. Animal studies suggest that drugs that inhibit cholinergic neurotransmission impair attentional function at lower doses than they impair spatial working memory [1,4,40]. Taken together, these studies suggest the hypothesis that at least part of estrogen's improvement of spatial working memory may be mediated through attentional facilitation. Some of the conflicting evidence from studies of cognitive performance in different menstrual phases may be due to the lack of attentional controls in the cognitive tests.

To test the hypothesis that spatial attention is affected by the menstrual cycle, the present study assessed the effect of the natural variation of sex hormone level on visuospatial attention in a modified cued target detection task (CTD) [31,37,39]. In this task, reflexive attention is measured by a manual reaction time to a precued visual target in the right or left visual field. Cues and targets were presented at the same locations (valid cues) or in different locations (invalid cues). The validity effect was the mean difference between invalid and valid cue reaction times and represents the range of benefits provided by the spatial allocation of attention e.g., [33,39,41]. We also examined nonspatial cues and defined the alerting effect as the difference between no cues and double cues. This metric independently assesses the benefits of abrupt cues that lack a spatial component. BBT was used to approximate the time of ovulation. While this method is not absolutely reliable for detecting the exact time of ovulation, it is reasonably well correlated with LH and FSH increases and elevated estrogen levels [10]. We specifically hypothesized that subjects in the ovulatory phase of the menstrual cycle will show improved performance, as measured by the attentional validity effect.

2. Methods

2.1. Subjects

Female students were recruited from the university's human subject pool to participate in this experiment. Twenty-two subjects included for testing had an average age of 21.5 years (range = 18–25 years) and were ethnically representative of the local student population (20 Caucasian, 1 Asian-American, one Afro-American). Potential subjects were prescreened with a questionnaire that assessed whether birth control was used and, if so, its type. In addition, subjects were screened for use of attention modifying substances, including tobacco, and psychotropic medications, e.g., antidepressants or methylphenidate. Other medications listed by subjects that did not influence the central nervous system were allowed. General alcohol and caffeine use were not assessed, although no subject had consumed alcohol during the morning prior to attention testing. Recent work suggests that caffeine does not have specific effects on the orienting of attention [5]. Lastly, subjects diagnosed with attention deficit disorder before age 8 with or without hyperactivity (self report), were excluded from the study. For the experimental group, subjects not on any oral contraceptives or hormones for any other reason for at least 3 months prior to pretesting, not ingesting attention modifying substances, and free from known attention disorders were accepted for the study and received credits toward class requirements as compensation. Informed consent was obtained from each subject tested prior to any data collection. All aspects of this study were reviewed and approved by the university Institutional Review Board.

2.2. Task

A laboratory computer was programmed to present the stimuli of the CTD task, detect manual responses, and compute reaction times and response accuracy. The manual response was a key release. The spatial arrangement, stimulus size, and timing of the trial events have been described in