Pergamon

Neuropsychologia, Vol. 33, No. 1, pp. 131–138, 1995
Elsevier Science Ltd
Printed in Great Britain
0028–3932/95 $9.50+0.00

0028–3932(94)00103–0

NOTE

FLUCTUATIONS OF PERCEPTUAL ASYMMETRY ACROSS TIME IN WOMEN AND MEN: EFFECTS RELATED TO THE MENSTRUAL CYCLE

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(*Received* 27 *January* 1994; *accepted* 20 *August* 1994)

Abstract—Women and men performed the same tachistoscopic chair identification task and free-vision face processing task during each of three test sessions. For women, the first and third sessions were performed during two successive periods of menstruation and the second session was performed during the intervening midluteal phase of the menstrual cycle. For men, the three test sessions were presented at 2-week intervals. For the chair identification task, there was no visual field (hemispheric) asymmetry for men during any of the three test sessions. For women, there was a right visual field (left-hemisphere) advantage during the second (midluteal) test session, but not during the first and third (menstrual) sessions. For the free-vision face processing task, there was a robust left-side (right-hemisphere) bias during all test sessions for both women and men and no effect of test session for either gender. Results for the nonlateralized chair identification task are consistent with the hypothesis that, in women, the left hemisphere is more activated during the midluteal phase of the menstrual cycle relative to the menstrual phase. Results for the lateralized face processing task suggest that hemispheric dominance for specific aspects of information processing are less likely to show such phase-related effects.

Key Words: perceptual asymmetry; laterality; menstrual cycle.

INTRODUCTION

There is growing evidence that sex hormones influence cognition and brain function, both at certain critical stages of ontogenetic development [11] and in adulthood as various hormone levels fluctuate over time [4, 21]. Among the most dramatic and predictable hormonal fluctuations in adults are the changes that take place over phases of the menstrual cycle in women. In view of this, it is interesting that performance of certain perceptual and cognitive tasks has been shown to change in a complementary way across the phases of women's menstrual cycles. For example, women tend to do better on various verbal tasks and on tasks requiring fine motor coordination when tested during the midluteal phase of the menstrual cycle (when levels of estrogen and progesterone are at their highest) than when tested during the menstrual phase (when levels of estrogen and progesterone are at their lowest) [10, 15, 16, 21]. By way of contrast, women tend to do better on various nonverbal, spatial tasks such as rod-and-frame when tested during the menstrual phase than when tested during the midluteal phase [16, 21]. It is interesting that those tasks associated with superior performance during the midluteal phase are generally thought to involve processing for which the left cerebral hemisphere is superior whereas those tasks associated with superior performance during the menstrual phase are generally thought to involve processing for which the right cerebral hemisphere is superior. With this in mind, Kimura and Hampson have suggested that relative hemispheric activation may fluctuate with phases of the menstrual cycle such that the left hemisphere is more activated during the midluteal phase relative to the menstrual phase [21]. The present experiment provides a preliminary investigation of this hypothesis by examining visual half-field asymmetry during midluteal and menstrual phases of women's menstrual cycles and comparing the results to those obtained from men tested at comparable time intervals. The specific tasks used in the

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experiment were chosen because they have been hypothesized previously to be sensitive to individual differences in the relative level of left- vs right-hemisphere activation.

Although previous studies have shown that overall cortical activation or arousal is higher intermenstrually than premenstrually [1, 3, 4, 5, 7], these studies have not been concerned with possible differences in the *relative* activation of the left vs right cerebral hemispheres. Nevertheless, individuals have been hypothesized to differ in their characteristic patterns of asymmetric hemispheric activation which serves to influence the direction and magnitude of certain perceptual asymmetries [20, 22, 23]. Levy *et al.* [23] argue that this type of asymmetric hemispheric activation can be measured in a variety of physiological and behavioral ways, including the use of electrophysiological measures, measures of regional cerebral blood flow, lateral eye movements and as a "characteristic perceptual asymmetry" which would favor the sensory half-field contralateral to the more activated hemisphere. The present experiment used a chair identification task that was first developed by Levine and colleagues to measure the characteristic perceptual asymmetry that results from asymmetric hemispheric activation [22]. This task is particularly useful as a measure of asymmetric hemispheric activation because there is no evidence that one hemisphere or the other is inherently more specialized for identifying chairs. Thus, any asymmetry that is obtained for an individual is free to reflect whatever perceptual bias might arise from asymmetric activation of the two hemispheres.

On each trial of the chair identification task, pictures of two chairs are flashed briefly on a screen, one to the right visual field/left hemisphere (RVF/LH) and one to the left visual field/right hemisphere (LVF/RH). This is followed by an array containing pictures of these two chairs plus 10 additional chairs and subjects attempt to identify the two chairs that have just been presented. Previous studies indicate that, for subjects as a group, there is no visual field asymmetry for this task. That is, averaged across subjects, the number of chairs recognized from the RVF/LH location is equal to the number of chairs recognized from the LVF/RH location [9, 20, 22]. This suggests that neither hemisphere is superior to the other for chair recognition at the group level. However, individuals differ reliably from each other in terms of their visual field asymmetry on this task. That is, some individuals consistently show a RVF/LH advantage, others consistently show a LVF/RH advantage and others consistently identify approximately the same number of chairs from both locations. In fact, both split-half and test–retest reliabilities of visual field difference scores are in the range of 0.50–0.60 [9]. Furthermore, visual field asymmetry on the chair identification task is correlated with visual field asymmetry for a variety of other tasks that present different stimuli simultaneously to the two visual fields [20, 22]. Thus, the chair identification task measures the type of characteristic perceptual asymmetry that would be expected to result from asymmetric activation of the two hemispheres [for additional discussion of this point, see 20, 22]. According to the hypothesis outlined earlier, women should tend to show a RVF/LH superiority for this task during the midluteal phase relative to the menstrual phase whereas men who are tested at approximately the same time intervals should remain unbiased across test session.

Subjects in the present experiment also performed a free-vision face task that requires subjects to make judgements about the emotions shown on faces [24]. Unlike the chair identification task, performance on the face task shows an asymmetry in the mean performance. Specifically, subjects are more influenced by the side of the face toward the viewer's left—a result that has been attributed to right-hemisphere dominance for processing faces and emotions [24]. This task was included for the following reasons. Individuals differ reliably in the extent of bias on this face processing task; e.g. split-half and test–retest reliabilities of left–right difference scores are in the range of 0.70–0.90 [9]. Although it has been suggested that some of this individual variation is related to differences in the asymmetric activation of the two hemispheres, a good deal of the variation is also likely related to individual differences in the extent of right-hemisphere dominance for the task [23, 24]. This being the case, the face task was included to determine whether any phase-related changes in asymmetry for the non-lateralized chair recognition task would extend to a strongly lateralized task.

METHOD

Subjects

Thirty-one undergraduate volunteers (16 men, 15 women) from introductory psychology courses participated in the present experiment. All subjects were right-handed, free of any known neurological disease or impairment and were native speakers of English. None of the women had taken oral contraceptives or any other medication that would influence hormonal fluctuation for a period of at least 3 months prior to the experiment and none had been pregnant for at least a year prior to being tested. All of the women reported that their last several menstrual cycles were regular (within three days) and all reported a cycle length of between 28 and 31 days. During the time they were being tested, two of the women had a cycle length that fell outside of this range and their data were excluded. Thus, the results are reported for the 13 women whose cycles fell within the range that had been used to predict their midluteal phase.

Design, stimulus materials and procedures

Each subject performed the same two experimental tasks three times. For women, the first and third experimental sessions took place during the third through fifth days of two successive periods of menstruation. The second session took place approximately 2 weeks after the time of the first session, with the specific time of the second session determined separately for each woman based on the expected length of her cycle. The phase-length estimates provided by Asso [2] were used to time the second session so that it would fall in the midluteal phase (e.g. days 17–20 of a 28-day cycle). The onset of the subsequent menstruation provided a check on the actual cycle length during the time of the experiment. For 13 of the 15 women, the actual cycle length was as predicted. As noted earlier, the data from the other two women were excluded. For men, the three test sessions were scheduled at successive 2-week intervals.

During each experimental session, subjects performed each of two tasks: a chair-identification task [20, 22] and a free-vision face processing task [24]. The order of these two tasks was counterbalanced across subjects. In addition, each subject completed a handedness questionnaire prior to the beginning of the first session.

The stimuli for the chair-identification task were 24 black and white, front-view photographs of chairs, which were divided into two arrays of 12 chairs each. On each trial, two chairs were chosen from one of the arrays and flashed simultaneously, one to each visual field. The task of the subject was to identify both chairs from the appropriate 12-chair array. The chair-identification task was administered using a Macintosh IIci computer system and the MacProbe software package. Subjects sat in front of the computer screen with their heads placed in a chinrest apparatus located at a distance of 60 cm from the screen. At the beginning of each trial, a black "+" sign appeared in the center of the screen and served as a fixation point. After 1 sec, the "+" sign disappeared and a pair of chair pictures was flashed on the screen. Each chair picture subtended approximately 2.5° of visual angle horizontally and 3.0° of visual angle vertically and was located approximately 2.3° of visual angle from the center of the screen. Exposure duration was titrated from trial to trial in the following manner. The initial exposure duration was 195 msec. If both chairs on a trial were identified correctly, the duration was reduced by 15 msec for the subsequent trial. If neither chair on a trial was identified correctly, the duration was increased by 15 msec for the subsequent trial (but the duration was never increased beyond 210 msec). If one chair was identified correctly and the other was not, then exposure duration remained the same for the subsequent trial. Immediately after the pair of chairs was flashed on the screen, the appropriate array of 12 chairs appeared on the screen and remained until the subject chose two chairs as their best guesses about which two chairs had been presented on that trial. In each array, chairs were numbered 1 through 12. Subjects responded by reporting out loud and in either order two numbers corresponding to their two choices of chairs. The experimenter then entered their responses on computer. During each session, each subject received eight unscored practice trials and 20 experimental trials.

The stimulus materials for the second task were identical to those developed by Levy and her colleagues [24]. Each of nine males was photographed once with an emotionally neutral expression and once with a happy expression. From these, 36 pairs of chimeric faces were constructed in the following manner. The two halves of each chimeric face came from the same individual, but each half displayed a different expression. That is, one side of each chimeric face showed a neutral expression and the other side showed a happy expression. The two chimeric faces in each pair were photographic mirror images of each other and were presented one above the other on 21.5 × 35 cm cards. That is, the two faces on each card were identical except for the side on which the happy expression was presented. Photographs of each of the nine individuals were used to generate four such cards. On two of the cards the happy expression came from the left side of the individual's face and on two cards the happy expression came from the right side of the individual's face (with the neutral expression coming from the opposite side). Orthogonal to this, on two cards the normal photographic print was presented at the top of the card and the mirror image at the bottom and on the other two cards this was reversed. The experimenter presented one card at a time in front of the subject's midline. For each card, subjects indicated, by circling their choice on a response sheet, whether the top face looked happier, the bottom face looked happier or the two faces looked equally happy.

RESULTS

Chair identification

The mean stimulus durations were subjected to an ANOVA with Gender as a between-subjects variable and with Session as a within-subjects variable. The only effect to approach statistical significance in this analysis was the main effect of session [$F(2, 54) = 14.66$, $P < 0.001$], as the mean exposure duration decreased across sessions (Session 1: $M = 140$ msec; Session 2: $M = 119$ msec; Session 3: $M = 105$ msec).

Figure 1 shows the mean number of correct identifications of chairs presented to LVF/RH and RVF/LH locations for each of the three test sessions. The results for men and women are shown in the upper and lower panels, respectively. The number of correct identifications was subjected to an ANOVA with Gender as a between-subjects variable and with Session and Visual Field as within-subjects variables. As suggested by Fig. 1, there was a significant main effect of session [$F(2, 54) = 5.01$, $P < 0.01$], with overall performance improving across sessions. However, this is qualified by a significant Session by Visual Field interaction [$F(2, 54) = 3.17$, $P < 0.05$], and by a significant Gender by Session by Visual Field interaction [$F(2, 54) = 3.28$, $P < 0.05$]. In order to shed additional light on the nature of these interactions, separate Session by Visual Field analyses were conducted on the data from men vs women. For men, the only effect to approach statistical significance was the main effect of session [$F(2, 30) = 8.27$, $P < 0.002$]. For women, the only effect to approach statistical significance was the Session by

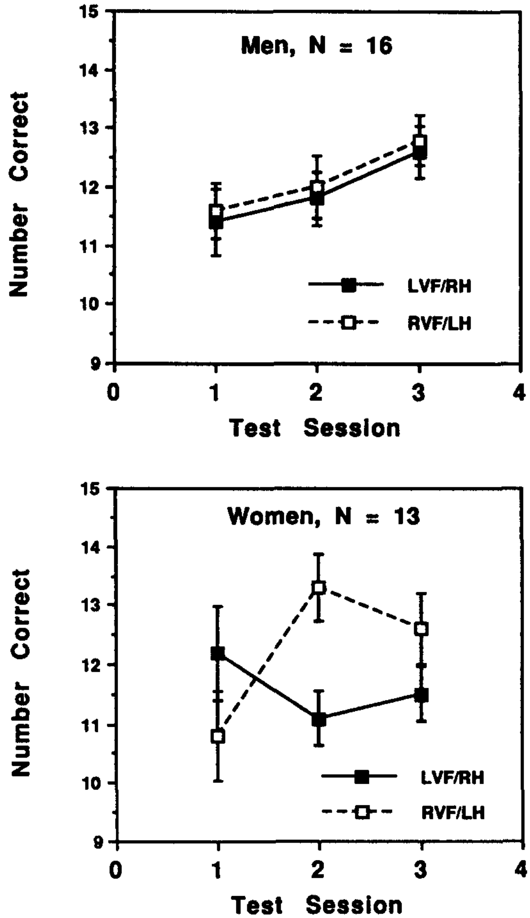

Fig. 1. Number of correct chair recognitions for the three test sessions. The parameter in each panel is the visual field to which the stimuli were presented (LVF/RH, RVF/LH). The results for men and women are shown in the upper and lower panels, respectively. For women, test Sessions 1 and 3 were conducted during the menstrual phase and test Session 2 was conducted during the midluteal phase. (Error bars represent the standard error of the mean.)

Visual Field interaction [$F(2, 24) = 5.24$, $P < 0.02$]. This interaction can be accounted for by the fact that there was no significant visual field difference for either Session 1 [$F = 1.45$], or Session 3 [$F = 1.20$] (both taking place during the menstrual phase). For Session 2 (taking place during the midluteal phase), however, there was a significant RVF/LH advantage [$F(1, 12) = 7.12$, $P < 0.025$]. These phase-related changes in visual field asymmetry came about because the effect of session was significant for RVF/LH trials [$F(2, 24) = 4.61$, $P < 0.025$] but not for LVF/RH trials, consistent with previous research suggesting that the left hemisphere is more sensitive than the right hemisphere to hormonal fluctuation [10, 26].

In order to provide a clearer indication of whether perceptual asymmetry for the chair identification task varied with phases of the menstrual cycle in females, the following analysis was performed. A laterality score (number of RVF/LH chairs correct minus number of LVF/RH chairs correct) was computed for each subject for each of the three test sessions. Note that a positive laterality score indicates an RVF/LH advantage and a negative laterality score indicates an LVF/RH advantage. For women, the mean laterality score was computed for the menstrual phase (combining test Sessions 1 and 3) and compared with the laterality score obtained during the midluteal phase (Session 2). To provide a comparison and control for practice effects, the mean laterality score for men was also computed for test Sessions 1 and 3 combined and the result compared with the laterality score obtained during Session 2. Figure 2 shows these laterality scores for men and women.

As shown in Fig. 2, for men the laterality score is virtually zero for both Sessions 1 and 3 combined and for Session

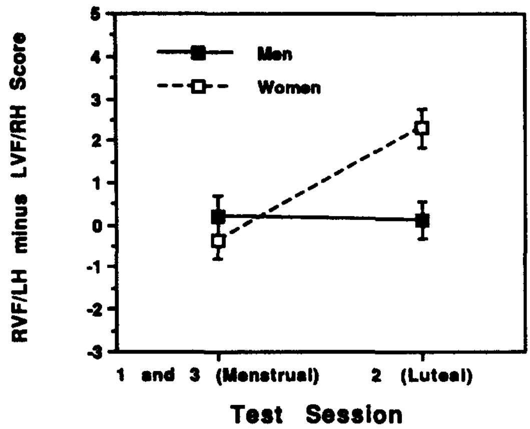

Fig. 2. Visual field difference in chair recognition (RVF–LVF) for test Sessions 1 and 3 combined vs test Session 2. The parameter is subjects' gender (men vs women). For women, test Sessions 1 and 3 were conducted during the menstrual phase and test Session 2 was conducted during the midluteal phase. (Error bars represent the standard error of the mean.)

2. As a result, there is no significant effect of session for males. For females, the laterality score is also virtually zero when they are tested during the menstrual phase (Sessions 1 and 3 combined). However, when women are tested during the midluteal phase (Session 2), the laterality score is significantly positive [$F(1, 12) = 7.12$, $P < 0.025$]. As a result of this, there is a significant effect of session for women [$F(1, 12) = 7.33$, $P < 0.025$], and a significant Gender by Session interaction [$F(1, 27) = 4.33$, $P < 0.05$].

Face processing task

For each subject during each of the three test sessions, a bias score was obtained from each subject for the face processing task, using the formula (R–L), where R is the number of trials on which the face with the smile on the viewer's right was judged to look happier and L is the number of trials on which the face with the smile on the viewer's left was judged to look happier. Thus, a positive score indicates a bias toward the right side of space and a negative score indicates a bias toward the left side of space. Figure 3 shows these bias scores for men and women during each of the three test sessions. The mean bias scores were uniformly negative, with each of the points shown in Fig. 3 being significantly less than zero. This left-side bias replicates the results of several previous experiments that have used similar free-vision tasks that require judgements of emotion shown on faces [9, 18, 20, 24]. In an ANOVA that included Gender as a between-subjects variable and Session as a within-subjects variable, no effects approached statistical significance. Thus, there is no indication that performance asymmetry for this task is related to phases of the menstrual cycle in women or to repeated testing for either gender.

DISCUSSION

The present study was designed to test the hypothesis that asymmetric hemispheric activation in women fluctuates over the menstrual cycle such that the left hemisphere is more activated during the midluteal phase relative to the menstrual phase. The results of the chair identification task are consistent with this hypothesis, showing the predicted phase-related shift in women but no similar practice-related shift in men. That is, women correctly identified more chairs in the RVF/LH vs LVF/RH during the midluteal phase, whereas during the menstrual phase chair identification was essentially equal for both visual fields. Chair identification was also approximately equal for both visual fields for men across all three test sessions. In the present study, the phase-related asymmetry shift in women was attributable to phase-related changes in RVF/LH but not LVF/RH performance. This is consistent with results from other behavioral and psychophysiological studies which have shown the left hemisphere to be more sensitive than the right hemisphere to hormonal fluctuation [10, 15, 26].

The results of the face processing task do not show similar phase-related fluctuations in perceptual asymmetry. One possibility considered in the introduction is that this task is so strongly lateralized in favor of the right hemisphere that it does not provide a sufficiently pure measure of individual variation in hemispheric activation. At the very least, such a task would also be sensitive to individual variation in the extent of right-hemisphere dominance for processing the emotions shown on faces. On logical grounds, it seems unlikely that fundamental aspects of hemispheric dominance, superiority or "specialization" for a strongly lateralized task shift over the menstrual cycle.

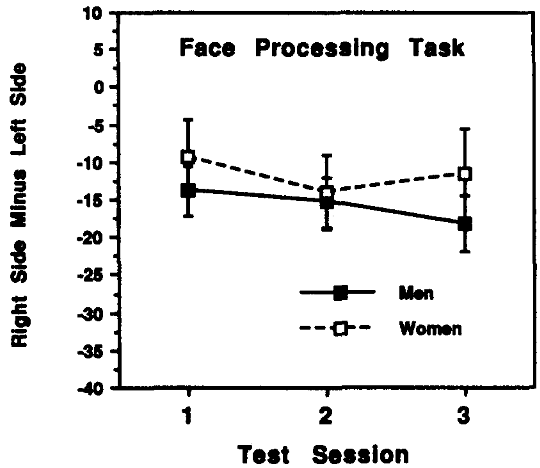

Fig. 3. Side preference in the face processing task (Right Side–Left Side) for the three test sessions. The parameter is subjects' gender (men vs women). For women, test Sessions 1 and 3 were conducted during the menstrual phase and test Session 2 was conducted during the midluteal phase. (Error bars represent the standard error of the mean.)

If there are shifts in aspects of asymmetry, it seems more likely that they will show up for those tasks or measures that are more likely to reflect asymmetric activation as opposed to specialization of function. This includes non-lateralized tasks such as the one used in the present study, but may also include other measures. For example, both Gruzelier and Venables [14] and Braier and Asso [7] suggest that changes in state of arousal are likely to influence response bias [also see 10, 19]. With this in mind, it is interesting that at least one study has reported a phase-related shift of asymmetry in response bias [10]. Specifically, Chiarello and associates [10] found no shifts in visual field asymmetry over the menstrual cycle for a lexical decision task for *d′* (a sensitivity measure of signal detection theory) or reaction time for correct responses (see also [17]), but did find a shift in asymmetry for response bias (as assessed by the *log beta* measure of signal detection theory). That is, the criterion to report the stimulus as a word was more relaxed on RVF/LH trials than on LVF/RH trials during the midluteal phase, when women have been reported to do better on various verbal tasks, and also during the follicular phase. By way of contrast, this visual field difference was reversed during the menstrual phase, when women have been reported to do more poorly on various verbal tasks. Moreover, Chiarello *et al.* found that this shift in asymmetry occurred because response bias on RVF/LH trials changed over the cycle, whereas response bias on LVF/RH trials did not. Note that on RVF/LH trials the criterion to report the stimulus as a word was more relaxed during the midluteal phase (when the present study suggests relatively greater activation of the left hemisphere) than during the menstrual phase. This is especially interesting in view of the suggestion made by Gruzelier and Venables [14] that impulsivity increases with the level of activation or arousal.

Although the present results are straightforward, additional research is needed to determine their generality and to determine the specific hormonal correlates of the phase-related shift in asymmetry. For example, participation was restricted to women with a history of regular menstrual cycles spanning a small range of average cycle length (28–31 days). While this suggests that the timing of the midluteal phase estimates did, in fact, capture a period of high estrogen and progesterone (e.g. [2, 25] but also see [8]), the results may not generalize to women with less regular cycles or to regular cycles that fall too far outside of this limited range. In addition, the present experiment tested women only during the menstrual and midluteal phases of their cycle. While this aspect of procedure is similar to what has been done in much of the cognitive research that motivated the present study [10, 15, 16], it does not permit a separation of the effects of estrogen and progesterone (because both are at low levels during the menstrual phase and at high levels during the midluteal phase). In view of the present findings, it would be instructive to test women during the follicular (preovulatory) phase of the menstrual cycle when estrogen levels are high but progesterone levels remain low and compare the results to those found during menstrual and midluteal phases. For example, Chiarello *et al.* [10] report a visual field shift in response bias for follicular vs menstrual phases as well as for midluteal vs menstrual phases.

Results of the present experiment are consistent with the hypothesis that asymmetries in hemispheric activation may be one mechanism that contributes to fluctuations in cognitive performance over the menstrual cycle [21]. This is not to say, however, that asymmetric hemispheric activation is the only mechanism that effects cognitive performance. For example, there are also phase-related shifts in general arousal levels [1, 3–5, 7, 28] and in sensory thresholds (see [6] for review) and further studies are needed to determine how these may also be related to the many variations that have been found in cognitive and perceptual motor performance [8, 10, 15–17, 19, 21, 27, 29, but see 12, 13].

Finally, the fact that certain aspects of perceptual asymmetry change over the menstrual cycle in women is relevant for investigations of sex-related differences in hemispheric asymmetry. That is, some of the inconsistencies found in studies of sex differences in cognition and sex differences in laterality may be attributed to the failure to take into account the menstrual cycle phase of the women. This possibility can be investigated further in additional experiments that utilize a wider range of behavioral tasks that make appropriate information processing demands.

Acknowledgement—The research reported in this manuscript was supported in part by a research grant awarded to Joseph B. Hellige from the National Science Foundation (SBR-9209534).

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