Effects of Trimester and Fetal Sex on Face Recognition Memory and Hemispheric Asymmetry in Pregnancy

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Date of acceptance: 16 January 2017
Date of receipt: 03 November 2016

ABSTRACT

Background: Although hemispheric asymmetries (HA) in face perception during menstrual cycle have been studied, there is no study about HA in face perception during pregnancy. The aim of this study was to find out if face perception changes during pregnancy and to test the effects of trimester and fetal sex on HA and face recognition memory.

Methods: In the first experiment, we investigated HA of pregnant women (n=31) in a face-discrimination task by using visual half-field technique and compared their performance with non-pregnant (n=34) women who were in menstruation phase. Additionally, face recognition memory was tested. In the second experiment, we tested the effects of trimester and fetus sex on face perception of pregnant women (n=49).

Results: Pregnant and non-pregnant participants showed right hemispheric dominance (RHD) in face discrimination F(1, 63) = 8.17, p = .006, n² = .11; however, pregnant women (n = 31, M = 6.16, SD = 1.43) recognized more facial stimuli than non-pregnant women (n = 34, M = 5.24, SD = 1.77) F(1, 63) = 22.78, p = .001, n² = .27. A RHD was observed in all trimesters F(1, 43) = 9.81, p = .003, n² = .19. However, we found a trimester-fetus sex interaction in LVF/RH (left visual field/right hemisphere) performance F (2, 43) = 5.07, p = .01, n² = .19. The performance in LVF/RH condition improved from the first trimester to the second trimester in pregnant women who had male fetus (p = .02) while it remained steady in pregnant women who had female fetus. Subjects in the third trimester recognized more stimuli than the subjects in the first trimester (p = .02).

Conclusions: Right hemispheric pattern for face-discrimination is stable while the performance is affected by the trimester and fetal sex in pregnancy. Face recognition memory seems to be increased from the first trimester to the third trimester. The findings were discussed in the context of the cognitive effects of increasing hormone levels during pregnancy.

Keywords: Pregnancy, hemispheric asymmetry, face discrimination, face recognition memory, visual-half field.

ÖZET

Hamilelikte Trimesterin ve Fetal Cinsiyetin Yük Tanıma Belleği ve Hemisferik Asimetri Üzerindeki Etkisi


Yöntem: İlk deneyde bir yüz ayr etme görevinde görsel yarı-alan teknigi kullanarak hamile kadınlardaki (n=31) HA araştırılmış ve bu katılımcıların performanslarıyla, hamile olmayan ve menstruasyon döneminde bulunan kadınlarla (n=34) karşılaştırılmıştır. Ayrıca, yüz tanıma belleği test edilmisti. İkinci deneyde hamile kadınlardaki (n=49) yüz algısında trimester ve fetus cinsiyetinin etkileri test edilmiştir.

Bulgular: Hamile olan ve olmayan kadınlar yüz ayr etmede bir sağ hemisfer baskını (SAHB) göstermiş (F(1,63) = 8.17, p = .006, n² = .11); bununla birlikte, hamile kadınlar (n = 31, M = 6.16, SD = 1.43), yüz ayr etme görevinde görmüş olduklari yüz uyanıklarını hamile olmayan kadınlara (n = 34, M = 5.24, SD = 1.77) kıyasla daha yüksek oranda doğru olarak hatırlamıştır (p = .001, n² = .27). Tüm trimesterlerde sağ hemisfer performansının daha yüksek olduğu gözlenmiştir (F(1, 43) = 9.81, p = .003, n² = .19). Ayrıca, SOGA/SAH (sol görsel alan/sağ hemisfer) performansında trimester-fetus cinsiyeti etkileşimi gözlenmiştir F (2, 43) = 5.07, p = .01, n² = .19. Erkek fetüsü sahip olan kadınlarda SOGA/SAH koşulundaki performans birinci trimesterden ikinci trimestere doğru artış göstermiştir; kız fetüsü olanlardaki performans sabit kalmıştır. Genel olarak, üçüncü trimesterdeki katılımcıların, birinci trimesterden kelime hatırlamlarında daha fazla uyanı hatta daha az hatırlamıştır (p = .02).

Sonuçlar: Hamilelik boyunca yüz ayr etmede sağ hemisfer örtüntüsü sabit kalmakla birlikte, trimesterler ve fetus cinsiyeti tarafından etkilenmektedir. Yüz tanıma belleği ilk trimesterden üçüncü trimestre doğru artış göstermektedir. Bulgular hamilelikte artan hormon düzeylerinin bilisel etkileri bağlamında tartışılmalıdır.

Anahtar sözcükler: Hamilelik, hemisferik asimetri, yüz ayr etme, yüz tanıma belleği, görsel yarı-alan
INTRODUCTION

It has been known for literally hundreds of years that the two sides of the human brain are different in their processing abilities and preferences. The structural and functional differences between the two hemispheres are called hemispheric asymmetry. Although left hemisphere is specialized for language function and right hemisphere is specialized for spatial processing and face recognition, sex differences have been observed in some of those lateralized cognitive functions. Although not all lateralization studies have shown gender effect, “the pattern of a more symmetrical lateralization in females, but a more pronounced asymmetry in males pervades in many studies”. Thus, hormonal differences may be one of the possible factors affecting hemispheric asymmetries. There are some studies focusing on the link of hemispheric asymmetry and hormonal levels. By using half-visual field presentation techniques, Hausmann and Güntürkün have shown that performance of young women in the right (face discrimination, figural comparison) and the left hemisphere tasks (lexical decision) had changed during the menstrual cycle whereas, the lateralization patterns for post-menopausal women were identical to those of young men. Young women showed less hemispheric asymmetry in their performance when they were tested in midluteal phase (when progesterone level was relatively high) and showed more asymmetrical performance in menstrual phase (when progesterone level was low). According to progesterone-mediated interhemispheric decoupling hypothesis progesterone reduces cortico-cortical transmission resulting functional hemispheric decoupling and a temporal reduction in functional asymmetry. Hausmann and his colleagues have also found a strong relationship among the levels of progesterone and functional cerebral asymmetries (FCAs) by using visual half field technique in various cognitive tasks. On the other hand, Compton and his colleagues found no significant correlation between progesterone levels and interhemispheric communication. Recent studies have shown that estradiol had also influence on functional cerebral asymmetries. Dietrich and colleagues showed that the estrogen level increases the size, but not the pattern of cortical activation during the performance of cognitive tasks such as verbal and mental rotation.

Being one of the lateralized cognitive functions, face perception has been studied by means of a number of imaging techniques and right hemisphere dominance was observed even if a complex bilaterally distributed network is responsible for such perception. Other behavioral studies such as chimeric face studies and half-visual field experiments have supported this right hemisphere specialization in face perception.

Lateralization in face perception is also thought to be affected by hormonal fluctuations. Hausman and colleagues observed that estrogen, but not progesterone was correlated to the performance of both hemispheres in face discrimination task. In another study it has been shown that asymmetry pattern in face perception decreased linearly from a large right hemisphere superiority during menstruation to a small left hemisphere superiority during the premenstrual phase. However, Bibawi and colleagues found that face processing is less likely to show phase-related effects indicating a right hemispheric dominance.

Interestingly, right hemisphere lateralization is more apparent in men than it is in women. On the other hand, face perception studies indicate that women especially in emotion perception tasks, have superior face recognition ability than men. Women’s advantage over men in memory for faces is particularly marked for female faces and is typically smaller for male faces. In an fMRI study it was found that women recognized more female than male faces and they showed higher activity to female than male faces in individually defined regions of fusiform face area (FFA) and inferior occipital gyrus. Infant faces elicit sex differences in behavior and brain responses that appear dependent on sex hormones. Some studies have shown that babies’ faces took the attention more than adult faces did. For infant faces, Kringlebach and colleagues found a peak in activity first in medial orbitofrontal cortex and then in the right FFA.

Hormones also affect the recognition of emotions: it changes cyclically in women and negative correlation was found between recognition of negative emotions and both estrogen and progesterone levels. Mareckova and colleagues found stronger neural responses to faces in the right FFA in women taking oral contraceptives (vs freely cycling women) and during mid-cycle (vs menstruation) in both groups. It seems that neural responses to faces in the right FFA get higher when the levels of progesterone and estrogen increase. Consistently, it was suggested that increases in progesterone levels during the luteal phase of menstrual cycle were associated with increased accuracy in decoding facial expressions and increased attention to social stimuli. Conway and colleagues found that non-pregnant women were more sensitive to facial cues signaling nearby contagion and physical threat when progesterone level was raised concluding that elevating progesterone prepares the body for pregnancy.

Pregnancy is a special period of a woman’s life during which various hormonal changes (estradiol, progesterone, 17-hydroxyprogesterone, and 11-deoxycortisol, cortisol and androstenedione) peak. These hormonal changes do not only prepare the woman to share her body with a developing embryo, but also prepare the body including brain towards being a mother. It was shown that brain plasticity occurs during pregnancy. The neurological effects of pregnancy also include areas that regulate learning, memory and areas involved the control of fear and anxiety. A large amount of data shows that pregnancy affects memory and attention in women. Anderson and Rutherford pointed out the pregnancy-induced advantage in recognition memory and social cognition. They interpreted the pregnancy-induced memory decline in some cognitive tasks and enhanced social cognition as a protective function of pregnancy.

There are also pregnancy studies focusing on face perception. The comparison of early and late pregnancy shows that participants had higher accuracy scores to encode negative emotions such as sadness during late pregnancy. Similarly, Roos and colleagues found that pregnant women showed altered attentional responses to fearful faces, in comparison to controls and attention to fear was significantly associated with increased levels of estrogen and progesterone at trimester 2, and decreased levels of cortisol at trimester 3 of pregnancy. In another study, Roos and colleagues measured neural activity of prefrontal cortex (PFC) of pregnant women for fearful faces by using near-infrared spectroscopy (NIRS). They found that the activation was most pronounced at trimester 2, compared to the other trimesters. PFC activation was significantly associated with increased levels of cortisol and testosterone in pregnancy.

The sex of the fetus may have an additional hormonal effect on pregnant women’s cognition. It has been shown that maternal serum hCG (MShCG) is higher when the fetus is a female than when it is a male as early as week 3 post-fertilization. Additionally, the concentration of anti-Müllerian hormone (AMH) changes according to the sex of the fetus. AMH is known to be one of the two classic hormones determining sex differentiation in the developing fetus. Immediately after the testis becomes morphologically recognizable (at around day 40 after conception in humans) it starts to secrete AMH, which, in concert with testosterone, ensures male development of the secondary sex.
characteristics. In contrast, the female fetus does not secrete these two hormones and develops femaleness according to the classical paradigm.[31] Consistently, a recent study showed that pregnant women with male fetuses performed better than mothers with female fetuses on the Computation Span (arithmetic working memory), Listening Span (verbal working memory) and the Shephard Metzler Mental Rotation Task (spatial visualization/spatial working memory).[32]

In the light of the presented literature, we conducted two experiments: In the first experiment, we aimed to examine face perception in pregnancy where we can indirectly observe the effects of hormones such as progesterone and estradiol by comparing pregnant women in the third trimester and non-pregnant women. We investigated hemispheric asymmetries in pregnant women in a face discrimination task which is known as a typical right hemisphere task[30] and compared their performance with young women who were not pregnant and in menstruation phase of their cycle when the progesterone and estrogen levels were expected to be low. Our hypothesis was that hemispheric specialization pattern of face processing in pregnant and non-pregnant women would be different due to the hormonal changes occurring in pregnancy. Additionally, we hypothesized that face recognition performance of pregnant women would be higher due to the increasing hormone levels. In the second experiment, we aimed to test the effects of trimester and sex of fetus on hemispheric asymmetry pattern in face discrimination and face recognition performance. Our hypothesis was that hemispheric specialization pattern in face processing and face recognition performance of pregnant women would be affected by the trimester and fetus sex due to being exposed to different hormone levels.

METHODS

Participants

Sixty-five women subjects participated the study, 31 of whom visited the Gynecology and Obstetrics Polyclinic of Akdeniz University Medical Faculty Hospital. All pregnant subjects were in the third trimester of their pregnancy. The other 34 women were undergraduate students in Akdeniz University who had regular menstrual cycle. Women who had 28-32 days menstrual cycle were assumed to have regular cycle. Non-pregnant women did not use any oral contraceptives and none of the subjects had any hormonal, neurological and psychiatric treatment. None of the subjects had any head injury, neurological or psychiatric diagnosis. The age of pregnant women ranged 19-39 (M = 27.48, SD = 4.78 years) and the age of non-pregnant women ranged 19-25 (M = 20.8, SD = 1.8 years). Prior to the experimental sessions, subjects were informed about the general procedure and a questionnaire about their general health (psychological, neurological symptoms etc.) was filled. Pregnant women filled an additional questionnaire about their pregnancy-related symptoms. The gestation weeks of the pregnant women ranged 24-38 (M = 30.16, SD = 4.82 weeks). Non-pregnant women were tested during their menstruation phase between the 1st and the 5th days of their cycle. Edinburgh Handedness Inventory was used to determine participants’ hand use. The asymmetry-index (LQ) was calculated as (R-L / R+L) / 100. The subjects whose asymmetry index were +60 and above included in the experiment as right hand users. The subjects had normal or corrected visual acuity. All participants completed and signed an informed consent form while their anonymity was strictly guaranteed. Experimental procedure was approved by the Ethical Committee of Akdeniz University Faculty of Medicine.

Materials and Procedures

Facial Stimuli. Nine facial photographs (2 men’s, 3 women’s and 3 babies’ faces) were used. The photographs were black and white and only facial features and hair were included. In half of the trials, one element of the face (the eye, nose, or mouth) was erased.

Procedure

Subjects were seated in an adjustable chair and their heads were fixed by a chin rest approximately 40 cm from the screen in order to maintain viewing distance.

Face discrimination task

E-Prime 2 software was used for stimulus presentation and data acquisition. Subjects were instructed to fix their heads in the chin rest and focus on the fixation point on the computer screen. After presenting the fixation point for 2 seconds, a face stimulus was shown in one of the visual fields for 120 msec. After the first stimulus disappeared, the second stimulus was presented in the same visual field for 120 msec. The stimuli subtended a visual angle of 10.13° horizontal by 12.17° vertical and each stimulus positioned 13.40° from the fixation point.

After the presentation of the two stimuli, subjects were asked if the two photographs were identical or not. In half of the trials (36), the photographs were identical; whereas, in the other half of the trials (36) the photographs were changed by erasing one element of the facial regions such as eye, nose or mouth. Participants were told to press “1” on the keyboard if the faces were identical and to press “2” if any part of the face was erased. Participants’ evaluation time and responses were recorded. Figure 1 shows a left visual field/right hemisphere stimulus presentation as an example to the procedure. The stimuli were presented in a randomized order and the order of the stimulus position (left-visual half field (LVF)/right visual half field (RVF)) was also randomized. Participants were tested by using both the left and the right hands. The order of the hand use was counterbalanced between subjects. One session consisted of 72 trials.

Figure 1. Face discrimination task procedure. A LVF/RH presentation is represented. In half of the trials (a), the photographs were identical; in the other half of the trials (b) the photographs were changed by erasing one element of the facial regions such as eye, nose or mouth.
original faces which were presented in the experiment. The other nine photographs were new faces. The original and the new faces were presented in a mixed fashion. The subjects were required to choose the faces that they had seen in the experimental session. The numbers of the correct and incorrect answers were recorded in order to measure the face recognition memory of the subjects. We calculated the “facial recognition memory score” by subtracting the number of incorrect stimuli from the number of the correct stimuli.

RESULTS
Facial Discrimination Task: Correct Response Ratio
We calculated the ratio of correct responses to total responses. In order to determine the effects of the subject type and visual half field/hemisphere on subjects’ correct response ratio, 2 x 2 (Subject type [menstruation, pregnant] × Visual half field/hemisphere [RVF/LH and LVF/RH]) repeated measures ANOVA was conducted. Data analyses were carried out with subject type as between subject factor and visual half field/hemisphere as a within subject factor. Within subject factor results indicated a significant main effect of visual half field/hemisphere, $F(1, 63) = 8.17, p = .006, \eta^2 = .11$ (Figure 2); but no significant interaction effect of subject type and VHF/hemisphere was found (Table 1a).

Figure 2. Means of correct response ratios in RVF/LH and LVF/RH conditions of pregnant women and women at menstrual phase. Both groups showed right hemisphere dominance in face discrimination task.

Table 1a. Results of Repeated Measures ANOVA for Correct Response Ratio in Face Discrimination Task

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between (Subject type)</td>
<td>.015</td>
<td>1</td>
<td>.015</td>
<td>673</td>
<td>.415</td>
<td>.011</td>
</tr>
<tr>
<td>Error</td>
<td>1.409</td>
<td>63</td>
<td>.022</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within (VHF/H)</td>
<td>.084</td>
<td>1</td>
<td>.084</td>
<td>8.17</td>
<td>.006</td>
<td>.115</td>
</tr>
<tr>
<td>Subject type X VHF/H</td>
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<td>1</td>
<td>.003</td>
<td>285</td>
<td>.596</td>
<td>.04</td>
</tr>
<tr>
<td>Error</td>
<td>.645</td>
<td>63</td>
<td>.01</td>
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<td></td>
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</table>

Table 1b. Means and Standard Deviations for Correct Response Ratio in Face Discrimination Task

<table>
<thead>
<tr>
<th>Subject Type</th>
<th>RVF/Left Hemisphere M</th>
<th>SD</th>
<th>LVF/Right Hemisphere M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pregnant</td>
<td>.77</td>
<td>.13</td>
<td>.81</td>
<td>.07</td>
</tr>
<tr>
<td>Menstruation</td>
<td>.74</td>
<td>.16</td>
<td>.80</td>
<td>.13</td>
</tr>
</tbody>
</table>

Face Recognition Memory
We presented 18 facial photographs at the end of the experimental session and calculated the “facial recognition memory score” by subtracting the number of incorrectly recognized stimuli from the number of correct stimuli. We conducted one-way ANOVA in order to compare the memory score of each group. The one-way ANOVA showed that the difference in memory scores of menstruation group (n = 34, M = 5.24, SD = 1.77) and pregnant group (n = 31, M = 6.16, SD = 1.43) was statistically significant $F(1, 63) = 22.78, p = .001, \eta^2 = .27$ (Table 2a). Pregnant women recognized more facial stimuli than non-pregnant women. Descriptive statistics are presented in Table 2b, Figure 4.

Figure 3. Facial recognition memory score (means of correct - incorrect facial stimuli) of pregnant women and women at menstrual phase. Pregnant women recognized more facial stimuli than women at menstrual phase.

EXPERIMENT II
METHODS
Participants
Forty-nine pregnant women participated the study who visited the Gynecology and Obstetrics Polyclinic of Akdeniz University Medical Faculty Hospital. Of those 16 were in the first trimester
(M = 10.06, SD = .58 weeks), 16 were in the second trimester (M = 19, SD = .59 weeks) and other 17 were in the third trimester (M = 31.4, SD = 1.09 weeks) of their pregnancy. The age of pregnant women ranged 19-38 (the first trimester (M = 27.6, SD = 1.55 years), the second trimester (M = 28.63, SD = 1.32 years), the third trimester (M = 26.76, SD = 1.31 years)). Education levels (p > .05) and age of the subjects (p > .05) did not differ among three groups. Twenty-five of the subjects had male fetuses and 24 of the subjects had female fetuses. Education levels (p > .05) and age of the subjects (p > .05) did not differ between these two groups. Prior to the experimental sessions, subjects were informed about the general procedure and a questionnaire about their general health (psychological, neurological symptoms etc.) and an additional questionnaire about their pregnancy-related symptoms were filled. Edinburgh Handedness Inventory was used to determine participants’ hand use. The asymmetry-index (LQ) was calculated as (R-L / R+L) / 100. The subjects whose asymmetry index were +60 and above included in the experiment as right hand users. The subjects had normal or corrected visual acuity. All participants gave written informed consent. Experimental procedure was approved by the Ethical Committee of Akdeniz University’s Faculty of Medicine. Materials and Procedures

The same stimuli and experimental procedure in the first experiment were used. An additional information, the sex of the fetus, was recorded. It was determined by ultrasound imaging techniques. The sex of the fetus was confirmed after the delivery.

RESULTS

Hemispheric Asymmetry in Facial Discrimination Task: Correct Response Ratio

We calculated the ratio of correct responses to total responses. In order to determine the effects of trimester, fetus sex and visual half field/hemisphere on subjects’ correct response ratio, 3 × 2 × 2 (Trimester [1, 2, 3] × Fetus sex [male, female] ×Visual half field/hemisphere [RVF/LH and LHF/RH]) repeated measures ANOVA was conducted. Data analyses were carried out with trimester and fetus sex as between subject factor and visual half field/hemisphere as a within subject factor. Within subject factor results indicated a significant main effect of visual half field/hemisphere, F(1, 43) = 9.81, p = .003, $\eta^2_p = .19$ (Table 3a, Figure 5); but no significant interaction effect of trimester and VHF/hemisphere was found. We found neither interaction effect of fetus sex and VHF/hemisphere nor interaction effect of trimester, fetus sex and VHF/hemisphere.

We observed that, correct response ratio in LHF/RH condition is higher than the correct response ratio in RVF/LH conditions (Table 3b). Therefore, subjects in all trimester groups and both subject groups having female and male fetuses showed the same right hemispheric pattern in face discrimination.

Hemispheric Asymmetry in Facial Discrimination Task: Response Time

In order to determine the effects of trimester and fetus sex and visual half field/hemisphere on subjects’ response time (the medians of the reaction times), 3 × 2 × 2 (Trimester [1, 2, 3] × Fetus sex [male, female] ×Visual half field/hemisphere [RVF/LH and LHF/RH]) repeated measures ANOVA was conducted. Data analyses were carried out with trimester and fetus sex as between subject factor and visual half field/hemisphere as a within subject factor. Within subject factor results indicated no significant main effect of visual half field/hemisphere, and no significant interaction effect of trimester and VHF/hemisphere. The effects of trimester and sex of fetus on each hemispheric condition (RVF/LH and LHF/RH)

We aimed to find out if trimester and fetus sex have any effect

Table 2a. One-Way ANOVA Results for Facial Recognition According to Subject Type

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>60.15</td>
<td>1</td>
<td>60.15</td>
<td>22.78</td>
<td>.001</td>
</tr>
<tr>
<td>Within</td>
<td>166.31</td>
<td>63</td>
<td>2.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>226.46</td>
<td></td>
<td></td>
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</table>

Table 2b. Means and Standard Deviations of Facial Recognition Memory

<table>
<thead>
<tr>
<th>Subject Type</th>
<th>Baby Faces</th>
<th>Female Faces</th>
<th>Male Faces</th>
<th>Total</th>
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<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Pregnant</td>
<td>2.63</td>
<td>.55</td>
<td>2.38</td>
<td>.66</td>
</tr>
<tr>
<td>Menstruation</td>
<td>2.32</td>
<td>.77</td>
<td>1.44</td>
<td>.89</td>
</tr>
</tbody>
</table>

Figure 4. Number of stimuli (baby faces, female and male faces) those are correctly recognized by pregnant women and women at menstrual phase.

Figure 5. A LVF/RH superiority pattern was observed in face discrimination task in all trimester groups.

We observed that, correct response ratio in LHF/RH condition is higher than the correct response ratio in RVF/LH conditions (Table 3b). Therefore, subjects in all trimester groups and both subject groups having female and male fetuses showed the same right hemispheric pattern in face discrimination.

Materials and Procedures

The same stimuli and experimental procedure in the first experiment were used. An additional information, the sex of the fetus, was recorded. It was determined by ultrasound imaging techniques. The sex of the fetus was confirmed after the delivery.

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Hemispheric Asymmetry in Facial Discrimination Task: Correct Response Ratio

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In order to determine the effects of trimester and fetus sex and visual half field/hemisphere on subjects’ response time (the medians of the reaction times), 3 × 2 × 2 (Trimester [1, 2, 3] × Fetus sex [male, female] ×Visual half field/hemisphere [RVF/LH and LHF/RH]) repeated measures ANOVA was conducted. Data analyses were carried out with trimester and fetus sex as between subject factor and visual half field/hemisphere as a within subject factor. Within subject factor results indicated no significant main effect of visual half field/hemisphere, and no significant interaction effect of trimester and VHF/hemisphere. The effects of trimester and sex of fetus on each hemispheric condition (RVF/LH and LHF/RH)

We aimed to find out if trimester and fetus sex have any effect

Figure 5. A LVF/RH superiority pattern was observed in face discrimination task in all trimester groups.
on the performance of RVF/LH and LVF/RH conditions. Therefore, we conducted multivariate ANOVA in order to see the effects of independent variables (trimester and fetus) on dependent variables separately (correct response ratio of RVF/LH and LVF/RH conditions, response time of RVF/LH and LVF/RH conditions). MANOVA results indicated that the multivariate main effect of trimester and fetus sex on dependent variables were not significant. However, the results from this MANOVA demonstrated a significant multivariate effect for the interaction of fetus sex and trimester, $F(8, 78) = 2.09$, $p < .05$; Hotelling’s $T^2 = .43$, partial $n^2 = .18$.

**Table 3a. Results of Repeated Measures ANOVA for Correct Response Ratio in Face Discrimination Task**

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>p</th>
<th>$n^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between (Trimester)</td>
<td>.020</td>
<td>1</td>
<td>.010</td>
<td>.24</td>
<td>.792</td>
<td>.011</td>
</tr>
<tr>
<td>(Fetus)</td>
<td>.000</td>
<td>2</td>
<td>.001</td>
<td>.23</td>
<td>.935</td>
<td>.000</td>
</tr>
<tr>
<td>(Trim X Fetus)</td>
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<td>7</td>
<td>.001</td>
<td>.007</td>
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<td>1.799</td>
<td>43</td>
<td>.042</td>
<td>1.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within (VHF/H)</td>
<td>.072</td>
<td>2</td>
<td>.072</td>
<td>9.81</td>
<td>.003</td>
<td>.19</td>
</tr>
<tr>
<td>Fetus X VHF/H</td>
<td>.001</td>
<td>2</td>
<td>.001</td>
<td>.004</td>
<td>.82</td>
<td>.001</td>
</tr>
<tr>
<td>Trim X VHF/H</td>
<td>.012</td>
<td>2</td>
<td>.012</td>
<td>.812</td>
<td>.036</td>
<td></td>
</tr>
<tr>
<td>Trim X Fetus X VHF/H</td>
<td>.017</td>
<td>2</td>
<td>.017</td>
<td>.009</td>
<td>.17</td>
<td>.052</td>
</tr>
<tr>
<td>Error</td>
<td>.316</td>
<td>43</td>
<td>.007</td>
<td></td>
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</tr>
</tbody>
</table>

**Table 3b. Means and Standard Deviations for Correct Response Ratio in Face Discrimination Task**

<table>
<thead>
<tr>
<th>Subject Type</th>
<th>RVF/Left Hemisphere</th>
<th>LVF/Right Hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>Trimester 1</td>
<td>16</td>
<td>.75</td>
</tr>
<tr>
<td>Trimester 2</td>
<td>16</td>
<td>.73</td>
</tr>
<tr>
<td>Trimester 3</td>
<td>17</td>
<td>.76</td>
</tr>
</tbody>
</table>

Univariate results demonstrated a significant interaction effect of fetus sex and trimester for correct response ratio of LVF/RH, $F(2, 43) = 5.07$, $p = .01$, $n^2 = .19$ and response time of LVF/RH, $F(2, 43) = 3.78$, $p = .03$, $n^2 = .15$. Additionally, univariate results demonstrated a significant interaction effect of fetus sex and trimester for response time of RVF/LH, $F(2, 43) = 3.92$, $p = .03$, $n^2 = .15$. The results for correct response ratio of RVF/LH was not significant.

Following the significant fetus sex x trimester interaction effect, we conducted two separate MANOVA for each fetus group in order to see the trimester effect on correct response ratio of LVF/RH, response time of LVF/RH and RVH/LH. Results from this MANOVA demonstrated a significant multivariate effect for the trimester in male fetus group, $F(8, 36) = 2.31$, $p = .01$; Hotelling’s $T = 3.07$, partial $n^2 = .41$, but not in female fetus group. The univariate results for women who had male fetus indicated a significant trimester effect on correct response ratio of LVF/RH, $F(2, 22) = 5.02$, $p = .02$, $n^2 = .31$ (Figure 6). No significant effect was found for the response time of LVF/RH and RVH/LH. Post hoc Tukey HSD tests for correct response ratio of LVF/RH showed that the difference between the performance of subjects in trimester 1 ($n = 9$, $M = .69$, $SD = .19$) and trimester 2 ($n = 7$, $M = .88$, $SD = .05$) was statistically significant however no significant difference was found between the trimester 1 and trimester 3 ($n = 9$, $M = .83$, $SD = .08$) and also trimester 2 and 3.

**Face Recognition Memory**

We presented 18 facial photographs at the end of the experimental session and calculated “facial recognition memory score” by subtracting the number of incorrectly recognized stimuli from the number of correct stimuli as we did in the first experiment. We conducted one-way ANOVA in order to compare the memory scores of each group. The one-way ANOVA showed that the difference among memory scores of subjects in trimester 1 ($n = 16$, $M = 6.56$, $SD = 1.15$), trimester 2 ($n = 16$, $M = 6.81$, $SD = 1.17$) and trimester 3 ($n = 17$, $M = 7.72$, $SD = 1.66$) was statistically significant $F(2, 43) = 4.35$, $p = .02$, $n^2 = .17$ (Table 4a, 4b, Figure 7). Tukey Post-hoc comparison tests indicated that the memory scores of subjects in trimester 1 and the subjects in trimester 3 were different, $p = .02$. However, neither the difference between trimester 1 and trimester 2 nor the difference between trimester 2 and 3 was statistically significant. Pregnant women in trimester 3 recognized more facial stimuli than the pregnant women in trimester 1. The main effect of fetus sex and the interaction effect of trimester and fetus sex were not significant.

**DISCUSSION**

In the first experiment, we compared the hemispheric asymmetry pattern of pregnant and non-pregnant women in a face discrimination task. We observed that both pregnant women and the women at menstrual phase showed a right hemispheric advantage for correct response ratio data. Our findings for women in menstruation is consistent with the other studies\(^{11,12,13}\) indicating right hemispheric dominance in face perception during menstrual phase when the levels of estrogen and progesterone are relatively low. On the other hand, parallel with the progesterone-mediated interhemispheric decoupling hypothesis we were expecting that pregnant women might show less hemispheric asymmetry due to elevating levels of progesterone. However, we observed that pregnant women had also right hemispheric bias in face discrimination. Our response ratio findings are consistent with the findings of Bibawi et al. showing that face processing is less likely to show phase-related effects indicating a right hemispheric dominance.\(^{14}\) Consistently, some emotional face perception studies\(^{47,48}\) in pregnancy indicated that levels of estrogen and progesterone
were associated with higher performance in attention and encoding tasks. It seems that elevating levels of estrogen and progesterone in pregnancy do not change the hemispheric asymmetry pattern rather it may steam up the typical hemispheric dominancy pattern for face discrimination.

We observed from the descriptive statistics that both pregnant and non-pregnant women recognized more baby faces than female and male adult faces. Studies about infant face perception indicated that baby faces took the attention more than adult faces did. This may be due to the anatomic structures that baby faces have such as large eyes, small chin and short face. These physical features may have stronger effects in memory and they may be easier to be recalled. Even if the baby faces activated the same brain regions as adult stimuli did, Kringelbach and colleagues showed that infant faces elicited early activity in OFC that adult faces could not. It seems that the infant face is processed in a somewhat specific way. Thus, one may expect that delay and potential baby, pregnant women might be more sensitive to baby faces when comparing non-pregnant women. However, we observed that both groups recognized baby faces better than the other faces. Because all of the young women have a potential to have a baby, their brain may be hard-wired for being a mother before they have this experience. We found that pregnant women significantly recognized more faces than women in menstruation did. In pregnancy, recognizing a man or a woman who is not trustworthy may be critical for both the survival of mother and her offspring. Additionally, recent findings indicated that gray matter volume in brain regions related to social cognition changes during pregnancy and 2 years post-pregnancy. Probably these changes improve woman’s ability to understand her baby’s needs.

In the second experiment, we compared hemispheric asymmetry pattern in face perception and face recognition memory among trimesters and additionally we tested the effect of fetus sex. We observed the same left visual field/right hemispheric bias for correct response ratio in all trimesters. Additionally we found a significant fetus sex and trimester interaction effect on correct response ratio of LVF/RH. The correct response ratio of LVF/RH in women who had male fetus changed among trimesters while correct response ratio of LVF/RH in women who had female fetus remained steady. Correct response ratio of LVF/RH increased from trimester 1 to trimester 2 for mothers who had male fetus. Second trimester is a critical time point for sexual differentiation in genitals of fetus. Immediately after the testis becomes morphologically recognizable (at around day 40 after conception in humans) it starts to secrete AMH, which, in concert with testosterone, ensures male development of the secondary sex characteristics. Increasing levels of AMH and testosterone might be responsible for the improvement of right hemispheric performance of mothers with male fetus in the face discrimination task. Consistently, another study indicated that pregnant women with male fetus performed better than mothers with female fetus did on the Shephard Metzler task. Neural responses to faces in the right FFA got higher when the levels of progesterone and estrogen increased. Similarly, PFC NIRS activation for faces was most pronounced at trimester 2 compared to other trimesters and it was associated with increased levels of cortisol and testosterone. Additionally, attention to faces was significantly associated with increased levels of estrogen and progesterone at trimester 2. Overall, increasing hormone levels in trimester 2 seem to improve right hemisphere’s performance on face processing.

Another result of the second experiment was that, pregnant women in trimester 3 recognized more faces than pregnant women in trimester 1 did. It seems that face recognition memory got better with...
the increasing hormone levels in pregnancy. Second trimester is a crit-
tical period of pregnancy for hormonal fluctuations: Cortisol increa-
sed up to the second trimester and androstenedione increased by 80%
per cent by gestation week 12 then remained steady. 31 AMH in con-
cert with testosterone goes on to be secreted in the second trimester
from male fetuses. Therefore, additional hormonal effects from fetus
occur since trimester 2. Other hormones such as cortisol, androstene-
dione, DHEA-S may also mediate the functional asymmetries of face
perception in pregnancy. Therefore, more detailed hormone measures
should be taken into account in order to clarify the hormonal effects
on hemispheric asymmetry pattern and face recognition memory
in pregnancy.

One of the limitations of our study is, hormone levels were not
measured in pregnant and non-pregnant women. We collected data
according to the term of menstrual cycle and pregnancy. However, it
seems that it is crucial to show the link between hormone levels and
the performance. The second limitation is we did not have direct me-
asurement of hemispheric activity. We measured the behavioral as-
pects of hemispheric asymmetry such as the reaction time and the cor-
rect response ratio by using visual half field presentation technique.
It would be supportive to use a direct brain imaging technique for
showing the hemispheric asymmetry pattern in face perception.

Overall, our evidence studied that the term of pregnancy is a
specific timeframe for face perception in women. Progesterone and
estrone are thought to be the most probable hormones associated
with the improvement in face perception. Additionally, AMH and tes-
tosterone may be responsible hormones for the improvement of right
hemispheric performance of mothers with male fetuses in the second
trimester. It seems that all these hormones have influence on face per-
ception during pregnancy; however, there is strong need for further
research with hormonal measures to clearly understand how the
hormones effect hemispheric asymmetries and face recognition memory
in pregnancy.

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