Pregnancy Does Not Affect Human Olfactory Detection Thresholds

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Abstract

Hyperosmia is suspected in pregnancy; however, no empirical study using validated measures of olfactory function has clearly confirmed the anecdotal reports of this phenomenon. The goal of the current study is to compare the olfactory sensitivity of pregnant women to that of nonpregnant women and men. All participants rated their sense of smell and pregnant women listed the odors to which they were most sensitive. Detection thresholds were measured using a well-validated protocol. A group of pregnant and nonpregnant women was studied longitudinally using a signal detection procedure designed to detect small differences in sensitivity. Pregnant women, particularly in the 1st trimester, rated their sense of smell to be higher than nonpregnant women and men and indicated many (primarily unpleasant) odors to which they were more sensitive. Women rated their sense of smell higher than men. However, there was no sex difference in thresholds and neither thresholds nor signal detection measures of sensitivity were significantly affected by either sex or pregnancy status. The implications of the lack of relationship between self-report and measures of olfactory sensitivity, particularly in pregnancy, are discussed.

Key words: odor thresholds, olfaction, pregnancy, self-rating, sensitivity

Introduction

Sense of smell is important for detecting danger, enjoying food, and for overall quality of life (Deems et al. 1991; Miwa et al. 2001; Hummel and Nordin 2005). Although much research has focused on the impact of loss of sense of smell, relatively little research has explored heightened sense of smell or hyperosmia. This is important because, even if relatively rare, hyperosmia is thought to be disruptive to normal functioning (Erick 1995; Heinrichs 2002; Nordin et al. 2005).

Hyperosmia refers to the condition in which there is an increase in sensitivity or decrease in detection threshold (minimum concentration required for detection) of a particular odor or set of odors. Hyperosmia is suspected in pregnancy and it has been proposed to serve a protective function by decreasing the likelihood that pregnant women ingest teratogens, particularly in the 1st trimester when the fetus is vulnerable, and that there is, thus, an evolutionary advantage (Profet 1992).

Support for hyperosmia in pregnancy comes primarily from measures of self-report. Approximately two-thirds of women in the early stages of pregnancy rate their sense of smell to be higher than normal (Cameron 2007) or report abnormal smell sensitivity (Nordin et al. 2004). Cameron (2007) found that 85% of women identified at least 1 odor to which they were more sensitive while pregnant and Nordin et al. (2004) reported that significantly more pregnant than nonpregnant women identified particular odors to which they were sensitive (Nordin et al. 2004). In a third study, pregnant women rated their sense of smell as more sensitive compared with controls (Ochsenbein-Kölble et al. 2007).

It should be noted, however, that not all studies have found increased self-reported olfactory sensitivity in pregnancy (Gilbert and Wysocki 1991). Given the evidence that self-reported olfactory function is often unreliable (Landis et al. 2003; Nordin et al. 1995), olfactory sensitivity should be verified empirically when hyperosmia is suspected. Surprisingly few studies have made such measurements, and none have provided evidence for hyperosmia in early pregnancy. Köble et al. (2001) found no difference in detection thresholds of nonpregnant women and women in the 1st trimester of pregnancy. Laska et al. (1996) measured such thresholds longitudinally across all 3 trimesters and found no significant changes across the trimesters nor between the pregnant and nonpregnant women, although there was a slight rise in sensitivity in the 3rd trimester. This
finding is consistent with Good et al. (1976) who, in a case study, found d’ (a measure of sensitivity derived from signal detection theory, Green and Swets 1966) was higher in the 3rd than the 2nd trimesters and a more recent report of decreased olfactory thresholds in the 3rd trimester (Ochslein-Kölble et al. 2007). This finding, however, is inconsistent with earlier reports that recognition thresholds are higher in late pregnancy (Hanssen and Glass 1936; Noferi and Giudizi 1946; Luvara and Murizi 1961). Thus far, there is no evidence for general hyperosmia during pregnancy.

In sum, studies suggest that women rate their sense of smell to be higher while pregnant, but do not generally exhibit enhanced sensitivity to odors. The purpose of the current study is to reexamine detection thresholds in pregnant women and to make explicit comparisons between their self-reports of olfactory sensitivity and empirically determined measures of olfactory sensitivity, as measured both by threshold and signal detection paradigms, the latter being a particularly sensitive measure of such sensitivity, as well as response bias (see Doty et al. 1981). In the first experiment, olfactory detection thresholds were measured in early pregnancy, and in nonpregnant women and men. Given that no differences in thresholds were observed, in the second experiment pregnant and nonpregnant women were tested using a sensitive signal detection measure that can detect small differences in sensitivity as well as response bias.

Materials and methods

Participants

A total of 136 nonsmokers (32 males) participated in this study. In the first experiment, 17 pregnant women (12 in their 1st trimester; mean: 25 years), 32 nonpregnant women (mean: 20 years), and 32 men (21 years) completed a standard olfactory detection threshold task (see below). In the second experiment, 30 pregnant women (mean: 31 years) and 25 nonpregnant women (mean: 26 years), who had not participated in the first experiment, were studied longitudinally and were tested on both the threshold and signal detection tasks (see Olfactory detection threshold task and Signal detection trials). Thirteen participants (10 pregnant) were lost to attrition. Participants were compensated with small gift baskets at each test session.

Self-rating of sense of smell and sensitivity to odors

On a scale of 1 (poor) to 9 (exceptional) participants responded to the prompt “Please rate your sense of smell as you think it compares to the average. (If pregnant, also indicate your pre-pregnancy sense of smell.)” The pregnant women also responded to the question: “Now that you are pregnant, are there odors to which you are more sensitive? If yes, please list and indicate if they are more or less pleasant.” Women who were tested longitudinally (experiment 2) were asked to rate their sense of smell as well as to indicate odors to which they were more sensitive during each trimester of testing. Thus, each participant participated in 3 test sessions corresponding to the 3 trimesters of pregnancy, or to equivalent times for the nonpregnant women.

Olfactory detection threshold task

Olfactory detection thresholds of all participants were measured using a standard protocol (see Doty 2000; Doty and Laing 2003). Thirty milliliters of solution (phenyl ethyl alcohol [PEA; a pleasant smelling rose odor at high concentration]) diluted in propylene glycol) was presented in 120-mL glass jars. On each trial, 2 jars were presented to the participant. One jar contained diluent only and the other contained the diluent plus some PEA. Half-log dilution steps ranging from −10 to −2 (log vol/vol) were used. The initial concentration was always −6 (log vol/vol). The task was a 2-alternative forced choice one in which the participant was required to say which of the 2 sequentially presented jars smelled stronger. Concentration of PEA was decreased by a half-log step following 2 sequential correct trials (5 for the first concentration) and increased by a half-log step following a single incorrect trial (a reversal), except full-log step increases were used until the first decrease in concentration. A single staircase procedure was used and threshold was determined by taking the geometric mean of the last 4 of 7 “reversals.” No feedback was given. Jars were placed under the participant’s nose for about a second. The interstimulus interval was about 6 s (time to replace 1 cap, chose the next jar, remove that cap, and place the jar under the participant’s nose). Intertrial interval was slightly longer (approximately 10 s, giving time to record the participant’s response). Testing lasted about 30 min.

Signal detection trials

In order to assess sensitivity more precisely, each of the participants who were tested longitudinally (experiment 2) completed an additional 75 signal detection trials (see Doty et al. 1981) at each of the 3 test sessions. The participant’s own threshold for PEA determined the concentration of the PEA “signal” trials. On each trial, 2 jars were presented—on half of the trials one of the jars contained the weak PEA odorant (“signal + noise”) and the other the diluent alone (“noise”) and on the other half of the trials both jars contained the diluent alone (“noise”). The task of the participant was to indicate whether or not the odor was present. Thus, it was possible to ascertain rates of “hits” (signal present and participant indicated that it was present) and “false alarms” (signal was not present but the participant indicated that it was) to calculate d’ (sensitivity) and criterion (c; response bias). Feedback was given. It took approximately 40 min to complete the signal detection trials.

This study was approved by the Institutional Review Boards of both Carthage College and the Medical College of Wisconsin and was conducted in accordance with the guidelines for the ethical treatment of human participants. All participants provided written consent prior to participation.
Results

Self-ratings of olfaction

Figure 1 shows mean self-rating for participants in experiment 1. In accord with previous data, a Student’s t-test indicated there was a significant difference between the mean self-rating of pregnant women and their prepregnancy self ($P = 0.02$). A 1-way ANOVA revealed a significant main effect of group when comparing pregnant women’s ratings with men and nonpregnant women ($F(2,78) = 9.75$, $P = 0.0002$). Student–Newman–Keuls multiple comparisons demonstrated a significant difference between pregnant women’s ratings and those of nonpregnant women ($P = 0.03$) and men ($P = 0.0001$). Nonpregnant women rated their sense of smell higher than did men ($P = 0.01$).

Figure 2 shows the mean self-rating for the women who were tested longitudinally (experiment 2). A 1-way repeated measures ANOVA indicated a main effect of pregnancy status ($F(3,57) = 9.91$, $P < 0.0001$). Student–Newman–Keuls multiple comparisons revealed a significant difference between preterm ratings and 1st trimester ratings ($P < 0.0001$) and 2nd trimester ratings ($P = 0.02$) but not 3rd trimester ratings ($P = 0.50$). There was a significant difference between 2nd and 3rd trimester ratings ($P < 0.05$). A Student’s t-test demonstrated no significant difference between the ratings of women prepregnancy and women who had never been pregnant ($P = 0.14$). The longitudinal data show that pregnant women rated their sense of smell higher than both their prepregnancy self and nonpregnant women. Three quarters of pregnant women’s ratings were higher during pregnancy compared with their prepregnancy rating.

Most pregnant women (about two-thirds of the sample in experiment 1 and three-fourth in the sample in experiment 2) identified particular odors to which they were more sensitive (see Table 1). The vast majority (90%) of those odors were identified as unpleasant. The number of women who reported odors to which they were more sensitive dropped to about a half later in pregnancy, although the vast majority (over 90%) of odors were still identified as unpleasant.

There was a large range of odors identified by women as ones to which they were more sensitive across pregnancy (see Table 2). The odors tended to cluster into odor categories (food, social odors, and noxious odors) and there was some overlap in odors reported across pregnancy. Food odors were the most commonly reported odor category. The number of items identified decreased across trimester of pregnancy (see Table 1). These results are in accord with previous data (Cameron 2007; Nordin et al. 2004).

Psychophysical measures of olfactory sensitivity

Despite pregnant women’s self-reported heightened sense of smell, there was no difference in thresholds between pregnant and nonpregnant women or men. A 1-way ANOVA showed no significant differences in detection thresholds for PEA between pregnant women and nonpregnant women or men ($F(2,79) = 0.64$; $P = 0.53$). These results are shown in Figure 3.

There were no differences in thresholds among pregnant women in experiment 2, nor in comparison with

Figure 1 Mean self-rating ± standard error of the mean for participants in experiment 1. Pregnant women provided 2 ratings—1 for their prepregnancy sense of smell and 1 for their current, pregnant, sense of smell. Differences significant at *$P < 0.05$; **$P < 0.001$ (for t-test and ANOVA with multiple comparisons, see text for details).

Figure 2 Mean self-rating ± standard error of the mean for experiment 2. There were 22 nonpregnant women and 20 pregnant women who participated in all 3 test sessions. The pregnant women provided 4 ratings—1 for their prepregnancy sense of smell and 1 for their current, pregnant, sense of smell in each of 3 test sessions (1 in each trimester). Differences significant at *$P < 0.05$; **$P < 0.001$ (for t-test and ANOVA with multiple comparisons, see text for details).
nonpregnant women as revealed by a 2-way repeated measures ANOVA. There was no main effect of test session/trimester ($F(2,80) = 2.09; P = 0.13$) nor pregnancy status ($F(2,40) = 0.01; P = 0.91$), and no interaction ($P = 0.28$). There was some evidence of a ceiling effect (some women were able to detect the very lowest concentration of PEA). A reanalysis without those data revealed no change in statistical results. These results are shown in Figure 4.

Figure 5 shows the analysis of signal detection trials. Figure 5a plots sensitivity, as measured by $d'$. Figure 5b plots response bias as measured by criterion ($c$): $d' = z[p(\text{hit})] - z[p(\text{false alarm})]; c = -0.5 \times \{z[\text{hit}] + z[\text{false alarm}]\}$. A 2-way repeated measures ANOVA indicated that there was no significant difference between sensitivity as measured by $d'$ across test session ($F(2,80) = 1.702; P = 0.19$) nor between pregnant and nonpregnant women ($F(1,40) = 1.01; P = 0.32$). There was no significant interaction between pregnancy status and test session/trimester of pregnancy ($P = 0.95$). However, there were consistently higher, though nonsignificant, $d'$ scores in pregnant women. A 2-way repeated measures ANOVA indicated that criterion ($c$) varied across session ($F(2,80) = 5.981, P = 0.004$) but that there was no effect of pregnancy status ($F(1,40) = 0.009, P = 0.82$). There was a significant interaction ($P = 0.03$), which suggests that criterion moved closer to zero as pregnancy progressed. The more negative values of $c$ early in pregnancy indicate a relatively more “liberal” criterion—participants responded “yes” both when the target was present and when it was not.

There was no significant correlation between self-ratings and thresholds. None of the correlations (Pearson’s $r$) between self-rated sense of smell and thresholds for men ($r = 0.11$), nonpregnant women ($r = 0.15$), and pregnant women ($r = 0.24$) were significant ($1$-tailed $P$’s = 0.28, 0.22, and 0.18, respectively). For nonpregnant participants, the correlation between their self-rating and the average of their thresholds from the $3$ test sessions was $0.14$ (Pearson’s $r$ was not significant, $P = 0.11$). For pregnant participants, the correlation between their self-rating and their threshold for each trimester was $0.07$ (Pearson’s $r$ was not significant, $P = 0.30$).

### Discussion

The results of this study are in accord with most of the literature on women’s sense of smell during pregnancy. Although the majority of women reported that their sense of smell was heightened, particularly in early pregnancy, in this study there was no systematic increase in sensitivity to PEA, as measured by either detection threshold or signal detection procedures. That being said, there was a trend in the signal detection data suggesting that there may be a small increase in $d’$, particularly early in pregnancy and the evidently more liberal criterion in pregnancy demonstrates a willingness of these women to indicate that an odor is present. These results are consistent with the finding that self-report is not positively correlated with empirical measures of smell function (Landis et al. 2003; Nordin et al. 1995).

There are, however, limitations to the current study. First, the tests may not be sensitive enough and may require more participants and/or more trials. Although this is possible, it would indicate that the changes during pregnancy are very small, and certainly smaller than suggested by self-report. Moreover, these same methods have been used to detect differences between the sexes and across ages (Deems and Doty 1987), and in a variety of neurodegenerative diseases such as Alzheimer’s and Parkinson’s (Doty 2003).

Second, the current study measured threshold for a single odorant. Performance depends on the specific odor presented in odor identification (Cameron 2007; Gilbert and Wysocki 1991; Laska et al. 1996), intensity ratings (Cameron 2007; Gilbert and Wysocki 1991; Laska et al. 1996); and in judgments of hedonic tone (Cameron 2007; Gilbert and Wysocki 1991; Laska et al. 1996; Ochsenbein-Kölble et al. 2007; Köble et al. 2001). Thus, perhaps it is not surprising that pregnant women were not more sensitive to the rose odor used in this study, particularly given that none of them reported rose as an odor to which they were more sensitive.

Although there are individual differences, there is some consistency in the odors identified by pregnant women as ones to which they are more sensitive (Cameron 2007; Nordin et al. 2004).
Table 2. Specific odors identified by pregnant women as ones to which they were particularly sensitive

<table>
<thead>
<tr>
<th>Experiment 1</th>
<th>Experiment 2 (1st trimester)</th>
<th>Experiment 2 (2nd trimester)</th>
<th>Experiment 2 (3rd trimester)</th>
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</thead>
<tbody>
<tr>
<td><strong>Food</strong></td>
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<tr>
<td>All food</td>
<td>Garlic (3)</td>
<td>Garlic</td>
<td>Garlic (2)</td>
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<tr>
<td></td>
<td>Onion</td>
<td>Onion</td>
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<tr>
<td></td>
<td>Coffee (2)</td>
<td>Coffee (3)</td>
<td>Coffee</td>
</tr>
<tr>
<td></td>
<td>Alcohol (3)</td>
<td>Alcohol</td>
<td>Alcohol</td>
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<tr>
<td></td>
<td>Bacon</td>
<td>Bacon</td>
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<td></td>
<td>Fish</td>
<td>Fish</td>
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</tr>
<tr>
<td></td>
<td>Grease; oil</td>
<td>Frying/baking food (2)</td>
<td>Frying/baking food (3)</td>
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<td></td>
<td>Grilled chicken</td>
<td>Hamburger</td>
<td>Meat</td>
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<td></td>
<td></td>
<td></td>
<td>Rotten food</td>
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<td></td>
<td></td>
<td></td>
<td>Burnt food</td>
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<tr>
<td>Egg</td>
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<td>Egg</td>
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<tr>
<td>Mexican food</td>
<td>Chinese food</td>
<td>Italian food</td>
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<tr>
<td>Fruit (2)</td>
<td>Citrus</td>
<td>Fruit</td>
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<tr>
<td>Artichokes</td>
<td>Pickles</td>
<td>Seasonings</td>
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<tr>
<td>Dressing</td>
<td>Subway sandwiches</td>
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<td></td>
<td>Vitamins</td>
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<td></td>
<td>Toast</td>
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<td></td>
<td>Soup</td>
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<td></td>
<td>Sweets</td>
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<td></td>
<td>Dog food (2)</td>
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<tr>
<td><strong>Social odors</strong></td>
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<tr>
<td>Perfume (2)</td>
<td>Perfume/cologne (5)</td>
<td>Perfume/cologne</td>
<td>Perfume (2)</td>
</tr>
<tr>
<td>Body odor</td>
<td>Body odor (5); urine (2)</td>
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<td>Breath</td>
</tr>
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<td>Dirty clothes/diapers (2)</td>
<td>Bathroom odors</td>
<td>Bathroom odors</td>
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<tr>
<td>Home deodorizer</td>
<td>Body wash/lotion/hair oil/sanitizers (4)</td>
<td>Vomit</td>
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<tr>
<td>Dogs and cats (2)</td>
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<tr>
<td><strong>Noxious odors</strong></td>
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<tr>
<td>Smoke</td>
<td>Cigarettes (2) smoke (2)</td>
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<td>Cigarettes</td>
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<td>Cleaning products (2)</td>
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<td>Garbage (2)</td>
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<tr>
<td>Gas</td>
<td>Car fumes (3)</td>
<td>City odors</td>
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<td>all odors</td>
<td>All odors (4)</td>
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<td>Hospital</td>
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<td>Hospital smells</td>
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<td>Basement</td>
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<td>Musty basement</td>
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<tr>
<td>Cucumber lotion</td>
<td>Toothpaste</td>
<td>Carpet</td>
<td>Rubber floor samples</td>
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<td>Candles</td>
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<td></td>
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<td>Strong odors (2)</td>
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</tbody>
</table>

Each item mentioned once, unless noted in parentheses.
to conjure up names of odors to which they felt more sensitive. Future research might consider a checklist that would help identify odors commonly found by pregnant women to be ones to which they are sensitive. Such an enterprise could inform future studies in which those odors could be targeted for other measures of olfactory sensitivity. A third limitation of the current study is that pregnant women were not asked to report odors to which they were less sensitive. This should be taken up in future studies.

Sex differences

Smell function is sometimes reported to be better in females than males, but these effects are generally small, depend on the odor tested, and are more pronounced when there is a verbal component to the task (such as odor identification) and in the elderly population (for a review, see Doty and Cameron 2009). It is likely that age accounts for the lack of sex difference in thresholds reported in this study as the participants were young adults, a cohort in which sex differences are particularly small (Doty et al. 1984). The lack of a verbal component in this detection threshold task further decreased the likelihood of observing a sex difference. It is noteworthy that women rated their sense of smell higher than men did.
Effect of pregnancy on sensitivity in other sensory modalities

Limited data exist on the effect of pregnancy on perceptual sensitivity in other modalities. Two studies of taste perception have shown an increase in threshold (i.e., lower sensitivity) during pregnancy as measured by electrogustometry and filter paper discs (Kuga et al. 2002) and by a “threshold-like” taste tablet test using 4 basic tastes (Ochesenbein-Köble et al. 2005). Bhatia and Puri (1991) also found an increase in thresholds for both phenylthiocarbamide and glucose, although thresholds decreased as pregnancy progressed. Sennaroglu and Belgin (2001) measured hearing levels in pregnant women with normal hearing and found that they decreased across pregnancy for stimuli below 500 Hz (though not to “pathological” levels) and returned to normal postpartum. Tsunoda et al. (1999) reported normal hearing (as measured with pure tone and impedance audiometry) in pregnant women who complained of ear problems. In visual perception, Orbán and Dastur (2012) reported an improvement in color perception in pregnant women (but note that this was a hue discrimination, not detection task), and Akar et al. (2005) found enhanced sensitivity in visual fields measured with perimetry in late pregnancy, but Ebeigbe et al. (2012) reported no changes in visual acuity in pregnant women. Corneal tactile thresholds are increased during pregnancy (Millodot 1977; Riss and Riss 1981). Overall, there appears to be little to no evidence for an increase in sensitivity in any sensory system during pregnancy.

Managing the effect of altered sense of smell during pregnancy

The argument has been advanced that hyperosmia leads to nausea and vomiting in pregnancy. This is a commonplace connection described in the popular press and in the medical literature (Heinrichs 2002; Erick 1995; Lee 2001, 2002). As mentioned in the introduction, it has been proposed that hyperosmia could provide a protective function by decreasing the likelihood that pregnant women ingest teratogens, particularly in the 1st trimester when the fetus is vulnerable, and that there is, thus, an evolutionary advantage (Profet 1992). Although controversial (Brown et al. 1997), careful analyses have provided evidence for the hypothesis that “morning sickness” provides a protective function (Flaxman and Sherman 2000; Fessler et al. 2005). In the context of olfaction, the relevant outstanding question remains whether there is a link between hyperosmia and nausea and vomiting in pregnancy.

The case made here is that there is no evidence for hyperosmia in pregnancy. Moreover, there is apparently no link between hyperosmia and nausea and vomiting (Hummel 2002) nor is there evidence that hyperosmia during pregnancy provides an adaptive function (Swallow et al. 2005). Notwithstanding these negative findings, there are perceived changes to olfaction during pregnancy that may be linked to nausea and vomiting. For example, there is evidence that women rate suprathreshold odors to be more intense during pregnancy (Cameron 2007; Gilbert and Wysocki 1991; Nordin et al. 2004). In addition, pregnant women find most odors to be less pleasant during pregnancy (Cameron 2007; Gilbert and Wysocki 1991; Köble et al. 2001; Laska et al. 1996; Swallow et al. 2005) and exhibit intolerance to ambient odors (Nordin et al. 2007). This is consistent with the correlation between self-rating of olfactory function and self-rating of odor annoyance in a very large sample (Knaapila et al. 2008). Thus, pregnancy changes the “valence” of odors, which may lead to a heightened awareness or attention to odors. That heightened attention may change the perceived quality of odors, which leads to a perception of heightened sensitivity. Thus, the change may be taking place at a more cognitive/conscious level and not at a sensory level (Olofsson et al. 2005), which is consistent with the apparently more liberal criterion of pregnant women in the current study. A better understanding of the mechanisms underlying perceived changes in olfaction during pregnancy is important in order for physicians to provide treatment to pregnant women who are either simply irritated by odors or afflicted with debilitating nausea and vomiting.

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