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Measures of Human Olfactory Perception During Pregnancy

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Abstract

Although considerable anecdotal evidence suggests that pregnancy affects olfactory sensitivity, scientific evidence is limited and inconclusive. Whereas hedonic ratings are affected by pregnancy, odor identification is not. The aim of the current study was to examine odor perception in women across pregnancy and in the postpartum period. One hundred nonsmoking women who were pregnant, postpartum, or had never been pregnant were tested on the University of Pennsylvania Smell Identification Test (UPSIT). Intensity ratings and scratch patterns were collected as potential indicators of sensitivity, and participants rated the odors' pleasantness. Participants also rated their own sense of smell. Mean UPSIT scores did not differ significantly across groups indicating no difference in odor identification. Trends in planned comparisons suggested that in the first trimester, odors were rated as more intense and less pleasant. In the first trimester, women scratched the odor strips significantly fewer times. Consistent with previous reports, 90% of pregnant women reported that specific odors smelled less pleasant and 60% reported that some odors smelled more pleasant. Although nearly two-thirds of pregnant women rated their olfactory sensitivity to be enhanced during pregnancy and overall pregnant women's self-rated olfactory sensitivity was higher than controls', self-ratings were not correlated with UPSIT scores nor odor intensity ratings. These results suggest that these and previous findings may reflect the fact that the effect of pregnancy on olfaction is small and inconsistent.

Key words: hedonics, intensity rating, odor identification, olfaction, self-rating, UPSIT

Introduction

Considerable anecdotal evidence suggests that pregnant women are more sensitive to odors than nonpregnant women, although the scientific evidence is limited and inconclusive. Enhanced olfactory sensitivity has been cited as a mechanism that could provide an evolutionary advantage, discouraging pregnant women from ingesting substances that could be dangerous to the developing fetus (Profet 1992). Although empirical evidence has not universally supported this hypothesis (Swallow et al. 2005), 2 recent studies that relied on self-report have lent some support. One study found that women reported heightened levels of disgust in the first trimester of pregnancy, which correlates with a period of immunosuppression (Fessler et al. 2005), and another demonstrated a heightened sensitivity to noxious substances that may provide a threat to the fetus (Nordin et al. 2005).

Whereas some studies have found evidence for hyperosmia during pregnancy (e.g., Dastur 2001; Broman et al. 2003), or increased responsiveness (Cantoni et al. 1999; Nordin et al. 2004) particularly early in pregnancy, others have not (e.g., Gilbert and Wysocki 1991; Laska et al. 1996; Kölble et al. 2001; Swallow et al. 2005). In fact, some have found a hyposmia in late pregnancy (Hanssen and Glass 1936; Noferi and Giudizi 1946; Luvara and Murizi 1961), and some have even reported anosmia during pregnancy (Schmidt 1925). Moreover, some have reported that pregnant women experience distortions in the perception of particular odors (e.g., Nordin et al. 2004). Finally, many studies have reported the ubiquitous change in ratings of pleasantness among pregnant women (e.g., Gilbert and Wysocki 1991; Laska et al. 1996; Cantoni et al. 1999). This effect could be due to a hormonally modulated strengthened connection between the olfactory system and the limbic system (known to be connected to the olfactory system) during pregnancy or, as Kölble et al. (2001) suggest, it could be the result of changes in cognitive odor information processing.

In summary, with the exception of hedonics, the literature is suggestive but inconclusive about the effects of pregnancy on olfactory perception. The present study was designed to examine several factors that may be important in characterizing the effect of pregnancy on olfaction.

First, it is likely that olfactory perception is not constant across trimesters and in the postpartum period given that hormone levels, which appear to impact the sense of smell, change dramatically throughout this period. A limitation of

some previous studies is that not all trimesters were examined or necessarily distinguished. Thus, the current cross-sectional study examines olfactory perception in pregnant women in all 3 trimesters of pregnancy and postpartum.

Second, pregnancy may affect the perception of some but not all odors, and most studies have employed a limited number of odors. Thus, the current study examines performance on a battery of 40 odors as a starting point to examine the effect of odor, per se, on olfactory function during pregnancy.

Third, it is clear that the hedonic value of odors is an important aspect of olfaction during pregnancy. The current study examines hedonic ratings of 40 odors across all phases of pregnancy and postpartum.

This is the first published report of the effect of pregnancy on performance on the University of Pennsylvania Smell Identification Test (UPSIT). In addition, participants also rated each odor on intensity and pleasantness and they rated their own sense of smell so that the relationship between self-report and behavioral measures could be explored.

Methods

Participants

One hundred women participated in this experiment—20 in each trimester of pregnancy, 20 postpartum, and 20 controls who were not and had never been pregnant. The average age of each group was 29.4 years (first trimester), 29.5 years (second trimester), 30.3 years (third trimester), 29.9 years (postpartum), and 25.9 years (not pregnant). Average number of weeks pregnant for each group was 11.1 (first trimester), 18.0 (second trimester), and 31.7 weeks (third trimester). Postpartum women were tested within 3 months of delivery, and 60% were tested at their 6-week obstetrics follow-up visit.

About three-quarters of the participants (mostly pregnant and postpartum) were recruited from Froedtert Hospital Obstetrics and Gynecology Clinic, associated with the Medical College of Wisconsin in Milwaukee, WI, and thus ethnicity, socio-economic status, and occupation were diverse. The remainder of the participants was recruited via word-of-mouth in a smaller town in Wisconsin (Kenosha), with a predominantly Caucasian population. Many of the nonpregnant women were college students and a few were college professors. All participants were nonsmokers, and none were suffering from colds or allergy symptoms. Phase of the menstrual cycle of nonpregnant participants was not controlled, and 4 of the nonpregnant participants were taking birth control pills. (I did not control for menstrual cycle for logistical reasons. Moreover, although there appears to be a peak in olfactory sensitivity during ovulation [Doty 1976], more than one peak in sensitivity has been detected and there are individual differences [LeMagnen 1952]. Therefore, it seems unclear which would be the best period during the cycle to serve as a control, and thus I chose to let the phase of the menstrual cycle vary.)

Materials

Participants completed the 40-item UPSIT (Doty et al. 1984), scratching the odor strip with a Sensonics pencil and making a 4-alternative forced-choice identification response. In addition, women verbally rated the perceived intensity and pleasantness of each of the odors on a 7-point Likert scale (1 being the least intense/pleasant and 7 being the most intense/pleasant). Participants verbally reported their rating for the experimenter to record. The experimenter watched and counted the number of times that the participants scratched and sniffed the odor strips as potential indicators of their sensitivity (i.e., fewer scratches/sniffs suggesting increased sensitivity).

Procedure

Prior to completing the UPSIT, participants completed a demographic questionnaire (on the back of booklet #1 of the UPSIT), which ensured that they did not have any major medical problems (including those of the ear and nose) and were not taking any medications that are known to influence the olfactory system. Participants also rated their own sense of smell (sensitivity). Specifically, prior to completing the UPSIT, participants were asked "On a scale of 1 to 7 (with 1 being very poor and 7 being excellent, how would you rate your sense of smell (your sensitivity), in general?" Pregnant women were then asked "On that same scale, how would you rate your sense of smell since becoming pregnant?"

Each participant was instructed to make a large "Z" on the odor strip (as demonstrated by the experimenter) to ensure standard scratch patterns. Participants were told that they could "scratch and sniff" as many times as they needed in order to identify the odor and that the experimenter would record this information.

Once testing began, participants made the 4-alternative forced-choice response of the UPSIT for each odor and then rated the intensity and pleasantness of the odor. Upon completion of the UPSIT, all participants were asked to rate their sense of smell again. Pregnant women were additionally asked "Are there any odors that you are particularly sensitive to now that you are pregnant?" They were also asked, for each odor they reported, whether it was more or less pleasant than prior to pregnancy.

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.

Results

Self-ratings

Consistent with anecdotal reports, nearly two-thirds (61%) of pregnant women indicated that their sense of smell was

higher during pregnancy. About a third (39%) indicated no change in their sense of smell during pregnancy, and only one woman (0.02%) indicated that her sense of smell had gotten worse during pregnancy. A 2-way analysis of variance (ANOVA) was conducted on the ratings from the pregnant participants, which revealed a main effect of pregnancy (women rated their sense of smell higher when they were pregnant, $P < 0.0001$) and trimester ($P = 0.01$), but no interaction. Figure 1a shows these results. Although the interaction was not significant ($P = 0.28$), such an interaction would support what appears to be a decrease in sensitivity rating as pregnancy progresses and no difference in nonpregnant ratings. A 1-way ANOVA comparing nonpregnant, postpartum, and pregnant women (prepregnancy ratings) yielded no significant effect, confirming that the 5 groups did not vary in their baseline self-rating.

Odor identification

Although pregnant women rated their sense of smell to be significantly higher than control participants, they were not better at identifying odors. These results are shown in Figure 2a. The average UPSIT score for each group was approximately 35. Neither the 1-way ANOVA nor any of the planned comparisons (Student–Newman–Keuls) were statistically significant.

Some odors were identified more accurately than others. Item #14 (cheddar cheese) was odorless in the batch of UPSITs used, thus that odor was removed from all subsequent analyses. Therefore, UPSIT scores in this study were based on 39 odors but were calculated to reflect a score out of 40 for ease of comparison with data in the literature. Seven items were poorly identified (i.e., identified by less than 75% of participants)—items #3 (menthol), #12 (fruit punch), #15 (cinnamon), #22 (turpentine), #27 (lime), #32 (grass), and #36 (lemon). In some cases, this reflects the fact that some of the odor strips in our batch of UPSITs were fading (e.g., #32, grass, was very faint), and in others it reflected participants' unfamiliarity with the odor (e.g., #22, turpentine).

The mean scores for all groups were lower than published norms (see Doty 1995), and some odors were particularly poorly identified. Therefore, the data were reanalyzed with those items removed. The reanalysis resulted in an increase in the UPSIT scores by about 4% (data not shown), bringing the scores into the normal range. This analysis had no impact on the relative performance of the 5 groups.

Odor intensity ratings and scratch patterns

Pregnant women, in the first trimester, appear to rate odors as more intense than nonpregnant controls (see Figure 1b). A Wilcoxon–Mann–Whitney rank sum test comparing intensity ratings from women in the first trimester and controls revealed a trend ($P = 0.06$) indicating that the mean intensity rating was marginally higher in women in their first trimester.

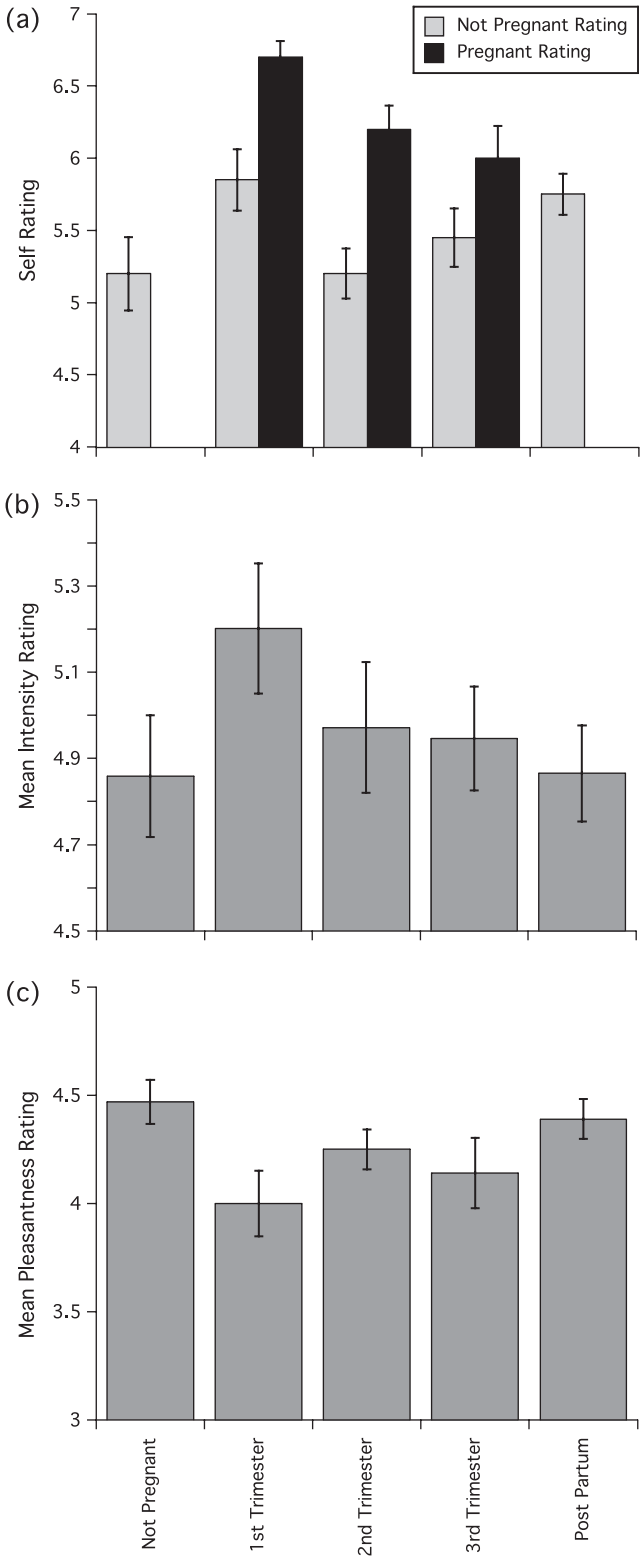

Figure 1 **(a)** Mean self-rating of sense of smell with standard error of the mean (SEM) is plotted as a function of group. Black bars represent ratings of pregnant women; grey bars represent ratings of nonpregnant women or pregnant women's "in general" self-rating. **(b)** Mean intensity ratings with SEM as a function of group. **(c)** Mean pleasantness ratings with SEM plotted as a function of group. The range of all Likert scales was 1–7.

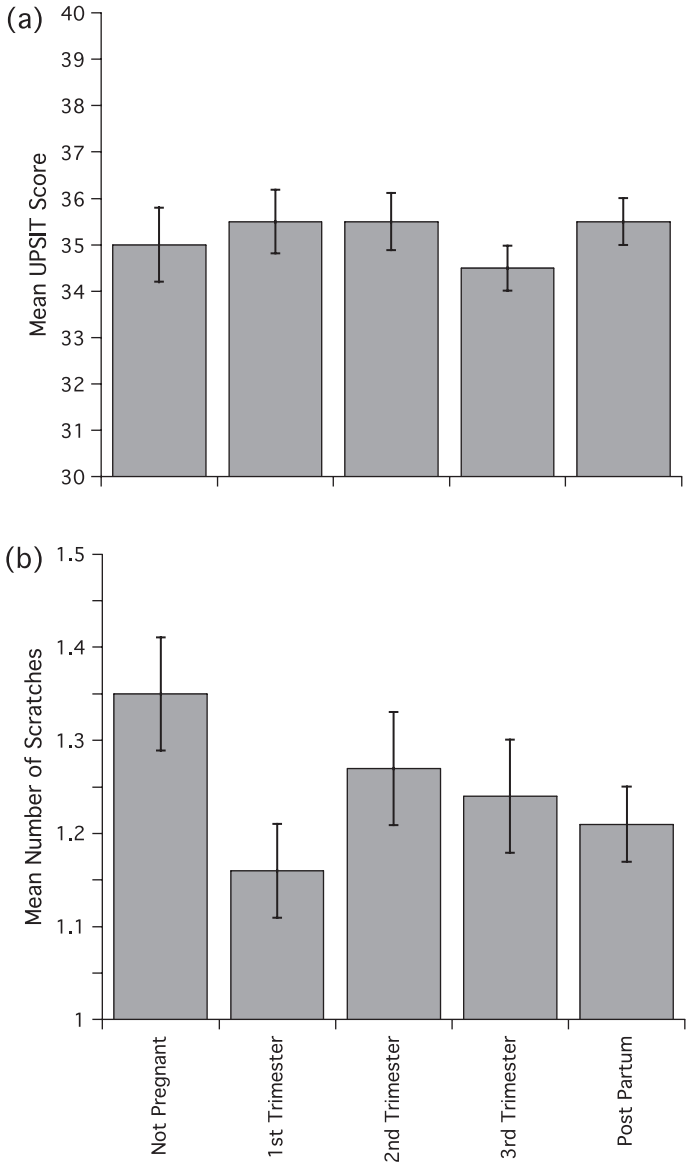

Figure 2 **(a)** Mean UPSIT score with SEM as a function of group. **(b)** Mean number of scratches with SEM as a function of group.

It should be noted that a 1-way ANOVA revealed no main effect of group and planned comparisons (Student–Newman–Keuls) were not significant. Planned comparisons between pregnancy trimesters were not significant, although there appears to be trend toward a return to baseline in intensity ratings for women in the later stages of pregnancy and postpartum.

As a corollary to intensity ratings, women in the first trimester scratched the microencapsulated odor stimuli fewer times than nonpregnant controls (Figure 2b). A Wilcoxon–Mann–Whitney rank sum test demonstrated that women in their first trimester scratched the odor strips significantly less often than nonpregnant controls ($P = 0.02$). As with intensity ratings, no main effect of group was observed in a 1-way ANOVA, and none of the planned comparisons were significant.

Hedonic ratings

Pregnant women, in the first trimester, appeared to rate odors as less pleasant than nonpregnant controls (see Figure 1c). A Wilcoxon–Mann–Whitney rank sum test revealed a trend ($P = 0.08$) in the difference between first trimester women and nonpregnant controls, indicating that the mean pleasantness rating was marginally lower in women in their first trimester. In this case, the 1-way ANOVA revealed a trend in the main effect of group ($P = 0.06$) and a trend ($P = 0.06$) in the planned comparison between first trimester and nonpregnant controls (lower pleasantness ratings in women in their first trimester).

Odor dependence in effect of pregnancy on olfaction

In order to determine whether specific odors were identified or rated as more intense or more/less pleasant by pregnant women, particularly in the first trimester, an item-by-item analysis using chi-squares was performed. In the case of identification, there was no significant effect of pregnancy on any odor except watermelon ($P = 0.008$), which was identified more accurately by pregnant women.

Although women in the first trimester of pregnancy rated 29 of 39 odors (about 75%) as more intense than controls, a chi-square analysis comparing the intensity ratings of women in the first trimester to nonpregnant controls revealed that only 3 odors (leather, lemon, and natural gas) were rated significantly more intense by pregnant women ($P < 0.05$). Three others were rated marginally more intense (fruit punch, watermelon, and smoke; $0.05 < P < 0.15$).

Finally, although women in the first trimester of pregnancy rated 32 of 39 odors (about 82%) as less pleasant than controls, a chi-square analysis revealed that only 3 odors (orange, grape, and natural gas) were rated as significantly less pleasant by pregnant women ($P < 0.05$). Ten others were rated as marginally different in pleasantness (motor oil, onion, fruit punch, licorice, cedar, peach, dill pickle, grass, rose, and peanut; $0.05 < P < 0.15$). Only fruit punch was rated as marginally "more" pleasant.

Self-report

Across trimester, the majority of women (85%) reported that there were odors to which they were more sensitive when pregnant (see Table 1). Most pregnant women (90%) reported that there were odors that they found less pleasant (e.g., meat and smoke), including 95% of the women in the first trimester. Although, on average, fewer pregnant women (60%) reported that there were items that were more pleasant (e.g., fruit), this proportion increased later in pregnancy. These differences across trimester in self-reports as well as the intensity and pleasantness ratings indicate that effects

Table 1 Percentage of women who reported that they were more sensitive to odors during pregnancy, for each trimester, and percentage who found odors to be either less or more pleasant

Trimester	More sensitive (%)	Less pleasant (%)	More pleasant (%)
First	85	95	55
Second	90	90	55
Third	80	85	70
Total	85	90	60

of pregnancy on olfaction are more pronounced early in the pregnancy.

In addition, pregnant women spontaneously named twice as many unpleasant as pleasant odors. Those identified as "*less*" pleasant during pregnancy were roughly divided into 3 major categories—social (e.g., body odors [husband's and baby's], pets, perfumes), food-related (e.g., meat, fish, eggs), and noxious (e.g., gasoline, oil, fuels, smoke) odors. Those identified as "*more*" pleasant during pregnancy were also roughly divided into 3 categories, although food, particularly fruit or fruity foods, contributed to the bulk of the odors that were identified as more pleasant during pregnancy. Figure 3 shows these results for (a) less pleasant odors and (b) more pleasant odors.

Finally, even though nearly two-thirds of pregnant women reported that their sense of smell had changed during pregnancy, there was no clear relationship between self-report and behavioral measures. In an analysis of odor identification, intensity, and pleasantness judgments, there was no systematic, statistically significant difference in performance between the pregnant women who reported a change in perception and those who did not (data not shown).

Discussion

The results of this study are consistent with other reports in the literature in several ways. First, they confirm the finding that overall odor identification, in this case with the 40-item UPSIT, is not improved in pregnancy (e.g., Gilbert and Wysocki 1991; Laska et al. 1996; Dastur 2001; Kölble et al. 2001), although an odor dependence appears to exist in this and other studies—some odors are identified better by pregnant women. Although the UPSIT is an identification test, UPSIT scores are highly correlated with detection thresholds for phenyl ethyl alcohol (Doty et al. 1984), and thus the UPSIT was employed in this study. It is important to note that the lack of difference in UPSIT scores between pregnant women and controls does not rule out the possibility that olfactory sensitivity may increase in pregnancy, as only threshold measurements directly test sensitivity. Indeed, a second finding that is consistent with some of the literature is that women in their first trimester of pregnancy rated odors as marginally more intense as suggested by a trend and they scratched odor strips significantly fewer times than nonpregnant women perhaps indicating enhanced sensitivity (e.g., Luvara and Murizi 1961; Dastur 2001; Broman et al. 2003; Fessler et al. 2005). The differences in intensity ratings between women in their first trimester and controls were statistically significant for particular odors, again suggesting an odor specificity. The differences in inferred olfactory sensitivity appear to occur early in pregnancy, consistent with several (e.g., Luvara and Murizi 1961; Cantoni et al. 1999; Dastur 2001; Nordin et al. 2004; Fessler et al. 2005) but not all (e.g., Laska et al. 1996; Kölble et al. 2001) reports in the literature and anecdotal reports.

Third, these data are consistent with many reports that hedonic ratings of odors are altered by pregnancy (e.g., Gilbert and Wysocki 1991; Laska et al. 1996; Cantoni et al. 1999; Kölble et al. 2001); primarily, in this case, a trend suggests a decrease in perceived pleasantness in the first trimester. Significant differences were observed for a subset of odors. Moreover, in terms of self-report, when asked the question "Are there specific odors to which you are more sensitive now that you are pregnant?", the vast majority of pregnant women reported odors that smelled strong to them and then, interestingly, immediately commented on the pleasantness (usually unpleasantness) of the odors. Most pregnant women could specify particular odors that they found more or less pleasant.

Finally, although odor identification and intensity and pleasantness ratings do not suggest a profound impact of pregnancy on olfaction, overall, pregnant women rated their sense of smell to be significantly higher than controls. A majority of pregnant women reported this enhancement in their sense of smell, and most identified odors to which they were more sensitive, consistent with Cantoni et al. (1999), Nordin et al. (2004), and anecdotal reports but not with Gilbert and Wysocki (1991).

Factors involved in alterations of olfactory perception during pregnancy

The fact that some of the comparisons made in the current study were not statistically significant might lead one to conclude that there is little or no effect of pregnancy on olfaction. Indeed, some studies in the literature have failed to demonstrate a significant impact of pregnancy on olfactory perception (e.g., Laska et al. 1996; Kölble et al. 2001) although many studies support the conclusion that pregnancy does affects olfaction on a variety of measures in at least subtle ways (e.g., Hanssen and Glass 1936; Noferi and Giudizi 1946; Luvara and Murizi 1961; Gilbert and Wysocki 1991; Cantoni et al. 1999; Dastur 2001; Broman 2003; Nordin et al. 2004, 2005). Limitations of some previous studies include small sample sizes, lack of a control group, no verification of subjective reports with objective tests, and inattention to trimester. The current study used a sample size comparable to studies that have found effects of pregnancy on

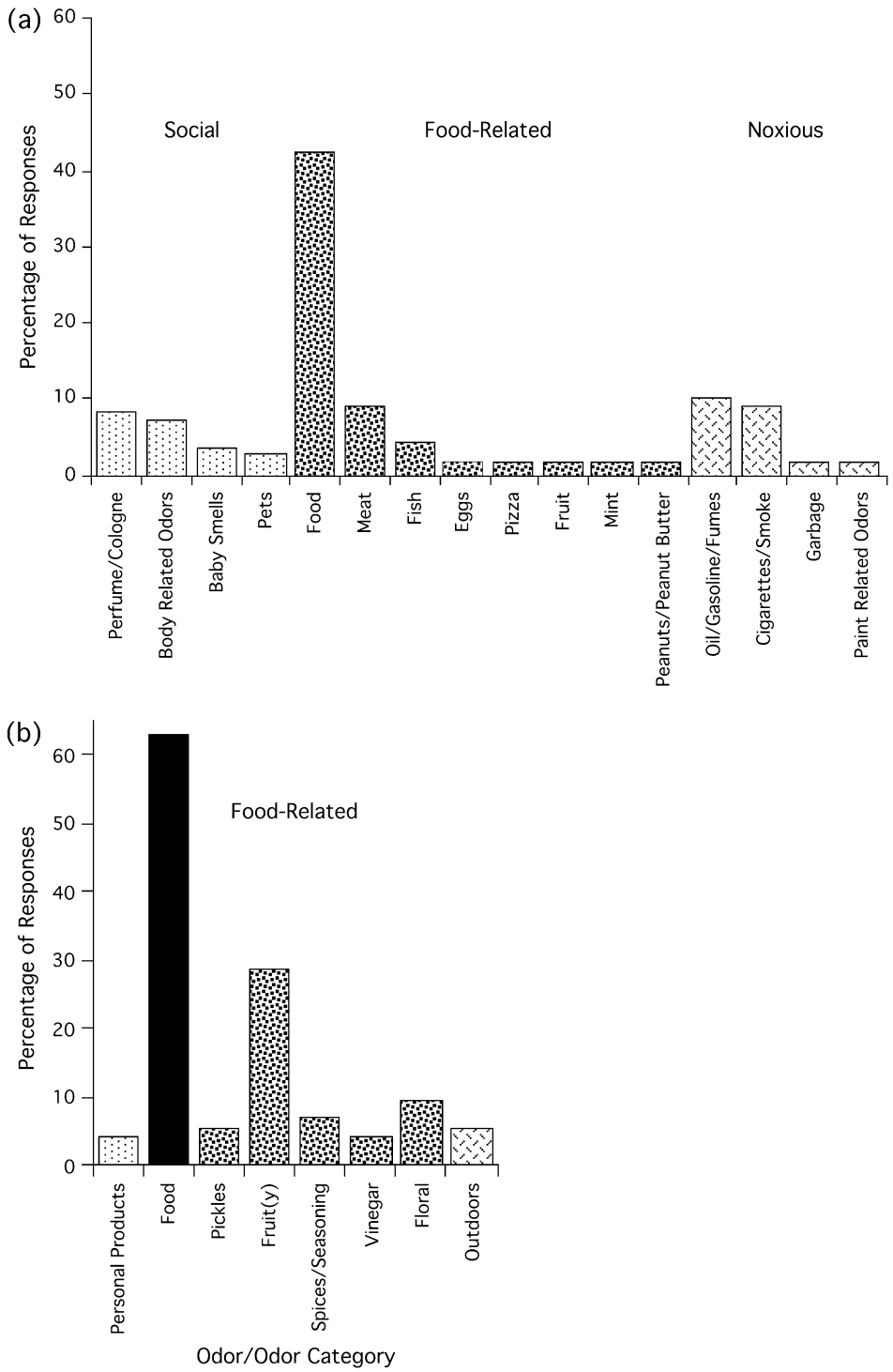

Figure 3 **(a)** Percentages of responses identifying an odor as particularly "*unpleasant*" during pregnancy. Total number of responses = 168; total number of participants = 60; 90% of participants contributed at least one odor. **(b)** Percentages of participants who identified an odor as particularly "*pleasant*" during pregnancy. Total number of responses = 73; total number of participants = 60; 60% of participants contributed at least one odor.

olfaction (e.g., Dastur 2001; Broman et al. 2003). Moreover, it improved upon previous studies by including a control group and concomitantly employing subjective and objective measures of olfaction. Finally, the current study differentiated among trimesters of pregnancy, although it should be noted that a cross-sectional design was used. It is possible that intrasubject measurements would be more appropriate, although given that the primary dependent variable in this

study was odor identification (UPSIT), the repeated testing on the same odors in a longitudinal design was deemed undesirable.

What other factors could explain why many of the differences between pregnant and nonpregnant women were not more pronounced?

First, the primary measure in this study was UPSIT score, and most (e.g., Gilbert and Wysocki 1991; Laska et al. 1996; Dastur 2001; Kölble et al. 2001) studies have reported no significant change in overall odor identification in pregnancy. Thus, no difference was predicted. Second, ratings of intensity and pleasantness were made using a 7-point linear scale. Perhaps, other scales (e.g., Green et al. 1996) would have picked up more subtle differences. It is possible that the effect of pregnancy on olfaction is small and that more sensitive measures of olfactory perception are required to reveal these differences. Third, the effect of pregnancy may vary with individuals. For example, in the current study, many but not all women reported an enhanced sense of smell during pregnancy. Moreover, no odors were identified as ones to which "*all*" pregnant women reported being more sensitive. Further, some odors (e.g., fruity) were not universally identified as more pleasant. These results suggest that the phenomenon may be further complicated by individual differences.

Finally, and perhaps most importantly, an odor specificity, similar to that described in sex difference in olfactory perception (see Bailey and Nichols 1884; Bailey and Powell 1885; LeMagnen 1952; Doty 1976; Cain 1982; Brand and Millot 2001), may obscure some effects of pregnancy on olfaction. For example, Gilbert and Wysocki (1991) reported that pregnant women correctly identified eugenol, but not several other odors, more often than nonpregnant women. They also reported that pregnant women rated some odors as more intense (isoamyl acetate and mercaptans) but other odors as less intense (androstenone and galaxolide). Likewise, Laska et al. (1996) reported a variety of odor-dependent results, including the finding that pregnant women in some phases of pregnancy found musk and androstenone more intense than controls. In the current study, compared with controls, pregnant women in their first trimester rated 3 odors (leather, lemon, and natural gas) as significantly more intense and 75% of odors as slightly more intense (not statistically significant). In addition, pregnant women in the first trimester of pregnancy rated 3 odors (orange, grape, and natural gas) as significantly less pleasant than controls and over 80% of odors as slightly less pleasant (not statistically significant). Such an odor dependence may have obscured the effect of pregnancy on olfaction in this and other studies.

Why is there a discrepancy between women's self-rating/report and psychophysical measures of olfactory perception?

There appears to be no clear correlation between self-rating or self-report and psychophysical measures of olfactory perception (odor identification, and intensity and hedonic ratings, in the case of the present study). This may be explained by several factors. First, the underlying psychometric function for odor detection may be steeper in pregnant women. Thus, a small change in concentration may lead to a large change in perception. Such a change would not necessarily be reflected in simple measures of threshold or the measures used in this study but would result in a change in odor perception. Second, self-rating and self-report result from cognitive processing, which may reflect different mechanisms than those involved in basic odor perception. Note that Kölble et al. (2001) argue that the change in olfaction during pregnancy may reflect a change in cognitive function. Finally, the discrepancy may be due, in part, to the fact that self-rating and self-report may reflect changes in hedonics rather than sensitivity. Indeed, many women spontaneously answered questions about olfactory sensitivity in terms of pleasantness (or usually the unpleasantness) of odors. The discrepancy between self-rating, self-report, or anecdotal evidence and psychophysical measures of olfactory perception clearly needs further study.

Evolutionary advantage

An important question is whether the confirmed differences in hedonic ratings and possible differences in olfactory sensitivity, particularly in early pregnancy, occur for odors that have particular relevance for pregnant women (e.g., ones that cause nausea and vomiting and may cause harm to the fetus). Although such conjecture is commonplace and has been cited as a mechanism that could provide an evolutionary advantage, discouraging pregnant women from ingesting substances that could be dangerous to the developing fetus (Profet 1992), few studies have examined this question directly and those that have do not uniformly support the connection. In the case of nausea and vomiting, Heinrichs (2002) reported a substantial decrease in reports of nausea and vomiting in pregnant women with congenital anosmia, but Hummel et al. (2002) found no correlation between heightened olfactory sensitivity and increases in nausea. Swallow et al. (2005) found no support for an adaptive olfactory mechanism that would protect the fetus, whereas Nordin et al. (2005) and Lundström et al. (2006) tentatively support such a conclusion. The current study does not support this sort of odor specificity as there was no clear enhancement of odor perception for all noxious or unpleasant odors in the UPSIT (e.g., motor oil, smoke, paint thinner, or gasoline), although there was for one (natural gas). It does, however, support the notion that olfaction is affected more in early pregnancy.

The effect of pregnancy on olfaction is an important issue in women's health as an understanding of basic olfactory perception may lead to a better understanding of maternal nutritional status that has a significant impact on fetal well-being and nausea and vomiting (morning sickness),

which afflicts about three-quarters of pregnant women (e.g., Lacroix et al. 2000), and may be related to a heightened sense of smell (e.g., Heinrichs 2002).

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