

## Attitudes toward Olfaction: A Cross-regional Study

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### Abstract

This study aimed to determine whether there are regional influences on attitudes toward olfaction. A total of 1082 participants aged 21–50 years from 4 different regions (Mexican, Korean, Czech, and German) were asked to rate general attitudes toward olfaction in everyday life. To examine affective attitudes to odors (i.e., pleasantness), participants were also asked to list 3 odors as being the most pleasant or unpleasant, respectively. Next, the mentioned odor names were attributed to 1 of 4 main categories: "Food & Drink," "Social relationship," "Nature," and "Civilization" and the distribution of these categories was compared across regions. Mexicans were significantly different to the other regions in their general attitudes toward olfaction. In addition, in all regions, in comparison with men, women indicated a higher interest in the sense of smell. Moreover, a significant positive correlation was present between individuals' self-rating of olfactory sensitivity and general attitudes toward olfaction. Finally, there were significant cross-regional differences in affective attitudes toward specific categories of odors. In conclusion, our findings support and extend the notion that regions affect attitudes toward the olfactory world.

**Key words:** attitude, cross-region, gender, olfaction, preference, self-rating of olfactory function

### Introduction

Olfaction appears to be significant in everyday life, although it is much less important for humans than vision or audition. Indeed, olfaction plays an important role in a wide range of functions. Specifically, in his recent systematic review, Stevenson (2010) classified olfactory function into 3 main categories: 1) functions relating to ingestion behavior, 2) avoidance of environmental hazards, and 3) social communication. For example, the human sense of smell can detect (Porter et al. 2007) and identify foods suitable for eating (Fallon and Rozin 1983). Also, smelling can modulate appetite, dietary behaviors, or nutrition status (Duffy et al. 1995; Aschenbrenner et al. 2008; Seo and Hummel 2009; but see also a critical review on this issue by Mattes 2002). Moreover, olfaction warns against possible microbial threats (e.g., feces, vomit, or organic decay) evoking disgust (Stevenson et al.

2010) and nonmicrobial hazards including gas leak, smoke, and toxic materials accompanied by fear (Cain and Turk 1985; Cain et al. 1987; Miwa et al. 2001; Santos et al. 2004). Finally, research demonstrated that humans have a potential to communicate information related to reproduction, for example, inbreeding avoidance and fitness detection (Herz and Cahill 1997; Ober et al. 1997; Havlicek et al. 2008) and to emotion (e.g., fear and anxiety) via body odors (Prehn-Kristensen et al. 2009; Zhou and Chen 2009).

Nevertheless, although it seems that people have different attitudes toward olfaction, surprisingly little is known about this issue. The term "attitude" can be characterized as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor" (Eagly and Chaiken 1993), as "object-evaluation associations in

memory" (Fazio et al. 1982), or as "summary evaluations" (Fazio 2007), even though there has been no universally agreed definition. In fact, several studies have demonstrated variations in human attitudes toward olfaction. Specifically, the sense of smell appears to be more important to females than males (Frasnelli and Hummel 2005; Croy et al. 2010; but see also Wrzesniewski et al. 1999). For example, Frasnelli and Hummel (2005) reported that female patients with olfactory dysfunction complained about decrements of quality of life more seriously compared with male patients. This is in agreement with the results of a survey conducted by Croy et al. (2010) showing that female respondents judged the sense of smell as being more important in their lives than male respondents. In addition, females are more interested and attentive toward olfactory cues than males (Ferdenzi et al. 2008; Havlicek et al. 2008). For example, Schleidt et al. (1981) observed that female participants classified their own body odor more frequently as being pleasant, whereas male participants rated their body odor more frequently as being unpleasant. With regard to age, Croy et al. (2010) reported that olfaction is important across the life span. Furthermore, the significance of the sense of smell was more or less constant throughout life, with no correlation of age with ratings for subjective olfactory importance, although olfactory performance generally decreases with age (Doty et al. 1984; Wysocki and Gilbert 1989; Hummel et al. 2007; Shu et al. 2009).

In addition to demographic factors, we wanted to investigate in this study regional effects on attitudes toward olfaction. Indeed, many studies have shown that human social attitudes are partly determined by genetic factors (Olson et al. 2001) and attitudes are also represented in memory and vary with the strength of the object-evaluation association based on past experiences with the object (Allport 1935; Fazio et al. 1986; Fazio 2007). In a similar vein, several studies have revealed cross-regional differences in attitudes toward olfaction (Schleidt et al. 1981; Schaal et al. 1997; Ferdenzi et al. 2008). For instance, Schleidt et al. (1981) showed that Japanese respondents, irrespective of gender, judged odors more frequently as being unpleasant than German and Italian respondents. Moreover, Schaal et al. (1997) demonstrated that Sudanese and Indonesian children were more tolerant of unpleasant odors than French Canadian and Syrian children. Additionally, Ferdenzi et al. (2008) found that Finnish children tended to have more attentive and reactive attitudes toward odors than French children.

Moreover, regional factors appear to modulate olfactory performances including odor memory (Schleidt et al. 1988; Wysocki et al. 1991) and odor pleasantness (Schleidt et al. 1981; Pangborn et al. 1988; Wysocki et al. 1991; Schaal et al. 1997; Ayabe-Kanamura et al. 1998; Distel et al. 1999). Specifically, from the largest international smell survey, the so-called "National Geographic Smell Survey," based on 1.42 million participants from 76 countries of 9 regions: Africa, Americas, Asia, Australia, British Isles, Canada, Caribbean, Europe, and United States (Gilbert and Wysocki 1987),

Wysocki et al. (1991) demonstrated that olfactory performances in response to the 6 odorants tested varied depending on geographic, regional, and individual differences. Additionally, in another cross-regional study using Japanese and German participants, Ayabe-Kanamura et al. (1998) demonstrated that international odorants common in both regions, for example, odors of peanuts, chocolate, coffee were overall rated as pleasant by both regions, whereas Japanese-specific odorants, for example, odors of soy sauce, dried fish, and Japanese tea were generally judged as unpleasant by German participants. Given these reports, environmental factors such as learning and experience have, apart from genetic variation, been assumed to play an important role in the modulation of olfactory performance across regions (for review, see Hudson 1999).

In the current study, we aimed to determine whether regional factors affect attitudes toward olfaction by a comparison of 4 regions: Mexican, Korean, Czech, and German. Because these regions are different in terms of geographic location (Latin America, Asia, and Europe), their language and food habits (i.e., each region has its own typical cuisine), participants should carry a background that is not shared between regions, even though Germany is geographically adjacent to the Czech Republic. Thus, we hypothesized that attitudes (in this study, we call it "general attitude") toward olfaction are different across regions due to nonshared backgrounds across regions.

In addition, on the basis of the findings that attitude is thought to consist of 3 distinguishable components (affective, cognitive, and behavioral consequences; Olson and Zanna 1993), we wanted to compare affective attitudes (i.e., pleasantness) toward odors based on memory across regions. To do this, we examined the frequency distribution of main categories of odors recalled as being pleasant or unpleasant across regions (in this study, we call it "affective attitude"). To date, most studies reporting regional effects on odor preference have investigated differences in the hedonic rating of odorants, although little is known about the cross-regional variation of everyday odors when judged as being pleasant or unpleasant based on the participants' free recall (i.e., without presenting odorants). One study by Schleidt et al. (1988) is, however, closely related to this issue. In their study, German and Japanese participants were asked to name individual pleasant and unpleasant odors from their own memory, and the mentioned odors were subsequently allocated to 5 main categories. They found that the frequency distribution of the 5 main categories, "Civilization," "Food and Drink," "Nature," "Man," and "Remainder," was very similar in both regions. However, regional dissimilarities were observed in the distributions of subcategories. For example, German participants named odors of high-protein diet, such as meat and fish, more often than Japanese did. To extend this issue, the current study has the aim to compare more specifically the category distribution of odors recalled as being pleasant or unpleasant among 4 regions.

## Materials and methods

### Participants

A total of 1128 volunteers aged 21–50 years were recruited from 4 different countries: Mexico ( $N = 756$ , from throughout Mexico), South Korea ( $N = 132$ , from Daejeon), the Czech Republic ( $N = 139$ , from Pardubice), and Germany ( $N = 101$ , from Dresden). Clinical patients with olfactory loss or major olfactory diseases were excluded from this study. Among the participants, those who were not native (46 of Mexican) were excluded from data analyses. Thus, data from a total of 1082 respondents were used for analyses. Table 1 presents demographic details (gender ratio and mean age) of the respondents from 4 regions.

### Questionnaire

We used a questionnaire consisting of 3 sections: 1) attitudes toward olfaction, 2) lists of pleasant or unpleasant odors from individuals' free recall, and 3) participants' demographics. For the first section, we employed the "importance of olfaction questionnaire" (IOQ), previously designed by our group (Croy et al. 2010). The IOQ is composed of 3 subscales: "association," "application," and "consequence," with 6 questions per subscale. The association subscale was designed to indicate emotions, memories, and values evoked by the sense of smell. Next, the application subscale reflects to what extent participants employ the olfactory sense in their daily lives. Finally, the consequence subscale represents to what extent they rely on the olfactory sense in daily decision making. Answers to the questionnaire were assessed on a 4-point category scale 1) I totally disagree, 2) I mostly disagree, 3) I mostly agree, and 4) I totally agree. Because participants

in this study were not clinical patients, we did not use the additional subscale of "aggravation," designed to detect patients' overestimation of olfactory function (Croy et al. 2010). As a measure of each subscale, the mean score was used. Finally, we considered the mean score of the IOQ as an indicator of "general attitudes toward olfaction."

Next, to compare odor preferences across regions, the participants were asked to list 3 odors which they liked the most and 3 odors which they disliked the most. The data collected from 4 regions were allocated to 1 of 4 main categories: "Food & Drink," "Social relationship," "Nature," "Civilization," either according to odor source or odor character or to usage in everyday life (see lists of subcategories belonging to each main category in Table 2). The classification of odors was performed by each experimenter after agreeing on the classification via discussions among experimenters of the 4 regions. Although the participants were instructed to name 3 pleasant odors and 3 unpleasant odors, many participants only listed 1 or 2 pleasant or unpleasant odors, respectively. That is, different contributions were present between participants. Therefore, to control the different weights between them, we assigned 6 points (3 points for pleasant or unpleasant odors, respectively) to all participants. If the participant listed 3 odor names for pleasant odors, 1 point was given to each odor. However, if the participant provided only 1 or 2 names for pleasant odors, 3 or 1 and half points were allocated to each odor. For statistical analyses, we divided the points by 6 in pleasant or unpleasant odors, respectively.

Finally, we asked 5 questions relating to gender, age, education level, self-ratings of olfactory sensitivity, and health status.

**Table 1** Demographic profiles of participants from four regions

	Mexican	Korean	Czech	German	Total
Total					
Frequency	710 (100.0) <sup>a</sup>	132 (100.0)	139 (100.0)	101 (100.0)	1082 (100.0)
Age	29.5 (7.2) <sup>b</sup>	31.7 (9.1)	32.5 (8.0)	32.6 (10.1)	30.4 (8.0)
Females					
Frequency	431 (60.7%)	61 (46.2%)	96 (69.1%)	63 (62.4%)	651 (60.2%)
Mean age	29.5 (7.1)	32.7 (9.7)	32.2 (8.2)	32.5 (10.4)	30.5 (8.0)
Males					
Frequency	279 (39.3%)	71 (53.8%)	43 (30.9%)	38 (37.6%)	431 (39.8%)
Mean age	29.4 (7.3)	30.9 (8.5)	33.1 (7.7)	32.7 (9.7)	30.3 (7.9)

<sup>a</sup>Frequency (%).

<sup>b</sup>Mean  $\pm$  standard deviation.

**Table 2** Main categories and their subcategories of odors recalled as being pleasant or unpleasant

Main categories	Subcategories
Food & Drink	Foods and drinks Food wastes
Social relationship	Human body Human excrements
Nature	Perfume and cosmetics Clothing Cigarette Nature
Civilization	Plants Animals Daily products Traffic and industry Buildings and places Aroma compounds and detergents Wastes and toxic compounds

The self-ratings of olfactory sensitivity and health status were evaluated on a 5-point Likert scale (1: very insensitive/very unhealthy to 5: very sensitive/very healthy), respectively.

This questionnaire was translated to the native language of each country and checked by preliminary sample tests to reduce misunderstanding. Data were collected via personal interview, with the exception of Mexico. In Mexico, data were obtained via an internet-based system. To prevent replication of data from the same person, only 1 completed questionnaire was allowed per Internet Protocol address. Moreover, based on answers to additional 3 questions regarding nationality, city of origin, and city of residence, only Mexicans living in Mexico were considered for the analyses. As mentioned earlier, those who were not native ( $N = 46$ ) were excluded from the data analyses. In all regions, there was no limitation on the time allowed to fill the questionnaire, and all data were recorded anonymously.

### Statistical analysis

Data analyses were performed using SPSS 12.0 for Windows (SPSS Inc.) and XLSTAT (Addinsoft). To examine differences in general attitudes toward olfaction between regions, the nonparametric Kruskal–Wallis and Mann–Whitney tests were employed because the null hypothesis that the data came from a normally distributed population (Shapiro and Wilk 1965) was rejected (Shapiro–Wilk  $W = 0.994$ , degrees of freedom [df] = 1, 027,  $P < 0.001$ ).

To check for the possible influence of uneven group size on the statistical results, first, from the 710 Mexican respondents 30 random samples of 100 respondents each were taken and compared with the respondents from the other 3 regions ( $N = 101$ –139; cf. Table 1) and second, all data ( $N = 1082$ ) were mixed, and using a random integer generator (<http://www.random.org>), 1 group of 700 and 3 groups of 100 respondents were randomly formed and then compared statistically.

Moreover, multidimensional scaling (MDS; Kruskal and Wish 1978) was used to examine similarities or dissimilarities in the general attitudes toward olfaction across regions by mapping the data on biplot graphs. Also, to identify correlations between ratings of the IOQ and demographic variables, Spearman coefficients were used. In addition, chi-square tests and correspondence analyses (CA; Greenacre and Belsius 1994) were employed to reveal region-dependent distribution patterns of odor categories (i.e., affective attitudes) when reported either as pleasant or as unpleasant. The level of significance was set at  $P < 0.05$ .

## Results

### General attitudes toward olfaction

#### Regional differences

We examined the effect of “region” on mean scores of the IOQ using Kruskal–Wallis tests. Significant effects of region

were not only obtained in general attitudes toward olfaction (Kruskal–Wallis  $\chi^2 = 82.4$ , df = 3,  $P < 0.001$ ) but also in 3 subscales (association:  $\chi^2 = 105.7$ , df = 3,  $P < 0.001$ ; application:  $\chi^2 = 63.3$ , df = 3,  $P < 0.001$ ; consequence:  $\chi^2 = 21.7$ , df = 3,  $P < 0.001$ ) as seen in Table 3. Post hoc Mann–Whitney *U*-tests revealed that Mexican participants rated the IOQ significantly higher than participants from the other regions ( $P < 0.001$ ). In addition, no significant difference was found in the mean score of the IOQ between Koreans, Czechs, and Germans ( $P > 0.05$ ).

Moreover, Mann–Whitney *U*-tests found that Mexican participants rated each subscale significantly higher than participants from the other regions ( $P < 0.001$ ); however, no significant difference was present in the ratings of the consequence subscale between Mexican and German participants ( $P > 0.05$ ). In addition, German participants judged the consequence subscale significantly higher than Korean and Czech participants ( $P < 0.05$ ).

In addition, to be certain that the regional differences in general attitudes toward olfaction were not simply due to differences in group size, 2 more analyses were performed. First, we compared the data of 100 respondents randomly selected from the Mexican group ( $N = 710$ ) with the other regions’ data. As before, significant effects of region were found in the general attitudes toward olfaction (Kruskal–Wallis  $\chi^2 = 46.0$ , df = 3,  $P < 0.001$ ) and also in 3 subscales (association:  $\chi^2 = 50.0$ , df = 3,  $P < 0.001$ ; application:

**Table 3** General attitudes toward olfaction across regions

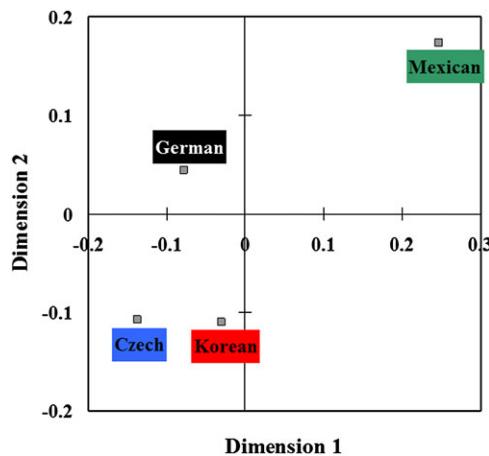
Regions	Means of the 3 subscales	Subscales		
		Association	Application	Consequence
Total				
Mexican	$3.11 \pm 0.35^a$	$3.41 \pm 0.41$	$3.05 \pm 0.46$	$2.86 \pm 0.40$
Korean	$2.88 \pm 0.36$	$3.10 \pm 0.43$	$2.85 \pm 0.44$	$2.72 \pm 0.45$
Czech	$2.85 \pm 0.42$	$3.09 \pm 0.47$	$2.74 \pm 0.57$	$2.72 \pm 0.53$
German	$2.94 \pm 0.38$	$3.17 \pm 0.44$	$2.80 \pm 0.51$	$2.85 \pm 0.42$
Females				
Mexican	$3.16 \pm 0.34$	$3.44 \pm 0.41$	$3.09 \pm 0.44$	$2.92 \pm 0.39$
Korean	$2.99 \pm 0.36$	$3.16 \pm 0.41$	$2.97 \pm 0.47$	$2.83 \pm 0.44$
Czech	$2.94 \pm 0.40$	$3.16 \pm 0.45$	$2.82 \pm 0.58$	$2.82 \pm 0.53$
German	$3.04 \pm 0.35$	$3.23 \pm 0.44$	$2.89 \pm 0.46$	$2.97 \pm 0.39$
Males				
Mexican	$3.05 \pm 0.35$	$3.37 \pm 0.39$	$2.99 \pm 0.49$	$2.77 \pm 0.41$
Korean	$2.79 \pm 0.34$	$3.04 \pm 0.44$	$2.75 \pm 0.40$	$2.63 \pm 0.44$
Czech	$2.66 \pm 0.42$	$2.92 \pm 0.48$	$2.56 \pm 0.53$	$2.50 \pm 0.47$
German	$2.76 \pm 0.37$	$3.05 \pm 0.43$	$2.65 \pm 0.56$	$2.63 \pm 0.40$

<sup>a</sup>Mean  $\pm$  standard deviation.

$\chi^2 = 27.0$ , df = 3,  $P < 0.001$ ; consequence:  $\chi^2 = 16.8$ , df = 3,  $P = 0.001$ ), as shown in Supplementary Figure 1. In addition, post hoc Mann–Whitney *U*-tests showed that the Mexican participants rated the IOQ significantly higher than the participants from the other regions ( $P < 0.001$ ). This significant difference was consistently obtained with all randomly generated groups of 100 Mexican respondents ( $N = 30$ ). Second, after mixing all data ( $N = 1,082$ ), we randomly selected 1 group of 700 respondents and 3 groups of 100 respondents. As shown in Supplementary Figure 2, significant effects were found neither in general attitudes toward olfaction (Kruskal–Wallis  $\chi^2 = 1.65$ , df = 3,  $P = 0.65$ ) nor in any of the 3 subscales (results not shown). Taken together, these analyses indicate that the above reported significant differences in the IOQ ratings were not due to group size.

This finding was supported by the MDS analyses (Kruskal's stress = 0.01) using mean scores of the 3 subscales as shown by the biplot in Figure 1. Specifically, there were 2 separate partitions (i.e., Mexican vs. the other regions) according to the *x* axis (Dimension 1). In addition, 3 separate partitions (i.e., Mexican vs. German vs. Korean and Czech) were shown on the biplot.

Furthermore, we compared the mean scores of the IOQ across regions in relation to gender separately to reduce a possible gender effect on the general attitudes toward olfaction (see below). Table 3 presents mean scores of the IOQ ratings from the 4 regions according to gender. For female participants, there were significant differences in the IOQ ratings across regions (Kruskal–Wallis  $\chi^2 = 33.5$ , df = 3,  $P < 0.001$ ). Post hoc Mann–Whitney *U*-tests revealed that Mexican female participants rated the IOQ significantly higher compared with participants from the other regions ( $P < 0.05$ , respectively). Significant regional differences in the IOQ ratings were also seen in male participants (Kruskal–Wallis



**Figure 1** Distribution of the 4 regions on a biplot yielded from MDS using ratings from the IOQ. Dimension 1 is related to differences in the subscale application, whereas dimension 2 is related to differences in the subscale association (cf. Table 3). Mexican participants differed from Korean, Czech, and German participants in general attitudes toward olfaction. This figure appears in color in the online version of *Chemical Senses*.

$\chi^2 = 59.5$ , df = 3,  $P < 0.001$ ). Post hoc Mann–Whitney *U*-tests revealed that Mexican male participants assessed the IOQ significantly higher compared with Korean, Czech, and German males ( $P < 0.05$ , respectively).

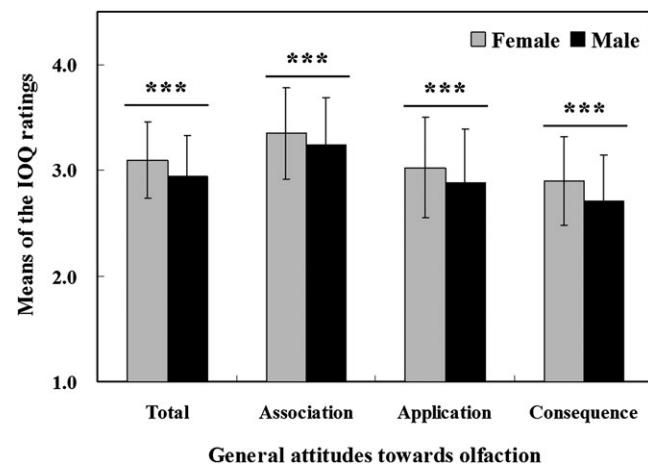
#### Gender differences

As shown in Figure 2, the Mann–Whitney *U*-tests reported that female participants rated the IOQ significantly higher than male participants ( $P < 0.001$ ), and this result was also seen for each of the 3 subscales ( $P < 0.001$ , respectively). Moreover, Mann–Whitney *U*-tests showed gender-related differences in the ratings of the IOQ (i.e., female > male) in all regions ( $P < 0.01$ , respectively).

#### Correlation of self-rating of olfactory sensitivity

There was a significant difference in terms of self-rating of olfactory sensitivity across regions (Kruskal–Wallis  $\chi^2 = 23.2$ , df = 3,  $P < 0.001$ ). Post hoc Mann–Whitney *U*-tests found that Czech (mean  $\pm$  standard deviation:  $4.01 \pm 0.70$ ) and German ( $3.99 \pm 0.67$ ) participants rated their olfactory function as being more sensitive than Mexican ( $3.69 \pm 0.97$ ) and Korean ( $3.63 \pm 0.80$ ) participants ( $P < 0.01$ , respectively).

To examine associations of self-ratings of olfactory sensitivity with ratings of the IOQ, we performed correlation analyses between them. Spearman's correlation coefficient ( $\rho$ ) showed a positive correlation between mean scores of the IOQ and self-ratings on participants' olfactory sensitivity (Spearman  $\rho_{1027} = 0.32$ ,  $P < 0.001$ ). That is, as participants judged their olfactory function as being more sensitive, they also rated their general attitudes toward olfaction as being more positive. This result was present in each region (Mexican:  $\rho_{672} = 0.35$ ,  $P < 0.001$ ; Czech:  $\rho_{136} = 0.22$ ,  $P < 0.01$ ; Korean:  $\rho_{125} = 0.39$ ,  $P < 0.001$ ; and German:  $\rho_{94} = 0.40$ ,  $P < 0.001$ ).



**Figure 2** Gender-related differences in general attitudes toward olfaction. The Mann–Whitney *U*-tests revealed that female participants rated the IOQ significantly higher than male participants. \*\*\* indicates a significance at  $P < 0.001$ . Error bars represent standard deviations.

There was no significant relationship between the ratings of the IOQ and the other demographic variables such as education level and self-rating of health status ( $P > 0.05$ ).

### Affective attitudes toward olfaction

#### Regional differences

**Pleasant odors.** On the basis of the frequency ratios of main categories across regions, odors mentioned as pleasant were most often from the “Food & Drink” category (37.3%), followed by “Nature” (29.2%), “Social relationship” (27.0%), and “Civilization” (6.5%).

The frequency ratios of the main categories were significantly different across regions ( $\chi^2 = 23.4$ ,  $df = 9$ ,  $P < 0.01$ ). Specifically, as shown in Table 4, each region had different orders in the frequency ratios of the main categories.

Furthermore, the CA explaining 99.7% of total variance supports this regional difference more obviously (Figure 3). For example, Mexican participants recalled the “Social relationship” odors as being pleasant more often compared with the other regions. See Table 4 for an overview of these results.

**Unpleasant odors.** In contrast to pleasant odors, the odors mentioned by participants most frequently as unpleasant were from the “Social relationship” category (43.6%), followed by “Civilization” (36.9%), “Food & Drink” (15.1%), and “Nature” (4.4%).

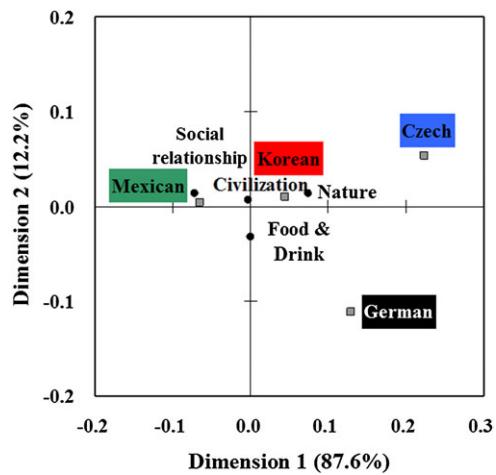
The frequency ratios of the main categories were significantly different across regions ( $\chi^2 = 28.1$ ,  $df = 9$ ,  $P < 0.001$ ). Specifically, half of Mexican participants recalled the “Civilization” odors as being unpleasant the most frequently, whereas participants from the other regions reported

**Table 4** Frequency ratios (%) of the main categories of odors recalled as being pleasant or unpleasant odors across regions

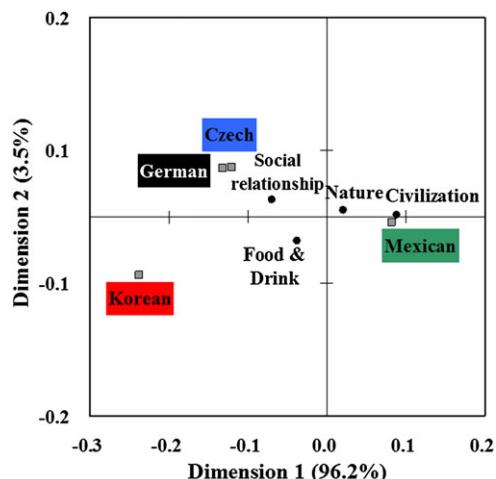
Pleasant odors							
	Food & Drink		Nature		Social relationship		Civilization
German	45.8	Czech	41.3	Mexican	37.7	Czech	7.6
Mexican	36.0	German	29.0	Korean	30.8	Mexican	7.4
Korean	35.7	Korean	27.6	German	20.1	Korean	5.9
Czech	31.8	Mexican	18.9	Czech	19.3	German	5.0
Mean	37.3		29.2		27.0		6.5
Unpleasant odors							
	Social relationship		Civilization		Food & Drink		Nature
Korean	48.6	Mexican	50.2	Korean	23.4	Mexican	7.4
German	47.5	German	35.5	German	13.7	Czech	5.9
Czech	46.0	Czech	35.0	Czech	13.2	German	3.3
Mexican	32.3	Korean	26.7	Mexican	10.1	Korean	1.2
Mean	43.6		36.9		15.1		4.4

the “Social relationship” odors the most often. In particular, the frequency ratios of the main categories were similar between the Czech and the German data (Table 4).

Furthermore, as shown in Figure 4 the CA accounting for 99.7% of total variance corroborates the regional differences mentioned more clearly. Of interest, for unpleasant odors, the partitions of the biplots generated by the CA were similar to the geographical distribution of the regions: Mexico,



**Figure 3** CA of the cross-regional distribution of odors recalled as being pleasant. Odor categories are represented by dots and regions by squares. Distance and direction from the center of gravity of the distribution (0.0) indicate both difference across and correspondence between odor categories and regions. For example, the “Social relationship” category and the Mexican participants are found in the same quadrant (upper left), whereas the “Nature” category and the Czech participants are found on the opposite side in the upper right quadrant (cf. Table 4 for numerical differences). The biplot explains 99.8% of total variance. This figure appears in color in the online version of *Chemical Senses*.



**Figure 4** CA of the cross-regional distribution of odors recalled as being unpleasant. Odor categories are represented by dots and regions by squares. The biplot explains 99.7% of total variance. For further explanations, see legend of Figure 3. This figure appears in color in the online version of *Chemical Senses*.

Korea, and 2 European countries. In particular, Czech and German positions on the biplot were adjacent to each other.

### Gender differences

For pleasant odors, no significant gender-related difference was present in terms of the frequency ratios of the main categories ( $P > 0.05$ ). However, there were significant gender-related differences in the frequency ratios of the main categories in Korean ( $\chi^2 = 12.0$ ,  $df = 3$ ,  $P < 0.01$ ) and Czech ( $\chi^2 = 14.5$ ,  $df = 3$ ,  $P < 0.01$ ) participants. Specifically, Czech female participants (47.1%) recalled the “Nature” odors as being pleasant more frequently than male participants (26.2%), whereas male participants (39.5%) reported the “Food & Drink” odors more often than female participants (28.8%). In addition, whereas Korean female participants (35.6%) mentioned the “Social relationship” odors as being pleasant more often than males (26.8%), Korean male participants (9.4%) reported the “Civilization” odors more frequently than females (1.7%).

For unpleasant odors, no significant gender-related difference was obtained in the frequency ratios of the main categories ( $P > 0.05$ ). Yet, a significant gender-related difference was present in Czech participants ( $\chi^2 = 10.7$ ,  $df = 3$ ,  $P < 0.05$ ). Specifically, whereas Czech female participants (51.1%) recalled the “Social relationship” odors as being unpleasant more often than males (33.3%), male participants (43.2%) reported the “Civilization” odors more frequently than females (31.7%).

## Discussion

The main findings of the present study were

1. Mexicans were significantly different to other regions (e.g., Korean, Czech, and German) in their general attitudes toward olfaction.
2. In all regions, female participants rated olfaction to be more important than male participants.
3. There was a significant correlation of individuals’ self-rating of olfactory sensitivity with general attitudes regarding the importance of olfaction.
4. There were significant cross-regional differences in affective attitudes toward specific categories of odors.

### Regional differences in general attitudes toward olfaction

Our results demonstrate that peoples’ attitudes toward olfaction can be affected by region, which is in agreement with earlier studies reporting cross-regional variation in attitudes to the sense of smell (Schleidt et al. 1981; Schaal et al. 1997; Ferenzi et al. 2008). Specifically, it seems that Mexicans have more odor-elicited emotions and memories and that they employ more strongly their sense of smell in daily activities and in decision making than residents from the other regions. What might explain this discrepancy between Mex-

ican and the other 3 regions? First, the proxemics theory of Hall (1966) could help answer this question by noting that different cultures maintain different standards of interpersonal space (i.e., proxemics). According to this theory, the Mexican and the other regions (Korean, Czech, and German) can be classified as “contact culture” or “noncontact cultures,” respectively. The interpersonal space is smaller in contact cultures, such as in Latin America, Africa, Southern Europe, and the Middle East, compared with noncontact cultures, including Asia, North America, and Northern Europe. Hall (1963) suggested that the interpersonal distance can be assessed by 8 different dimensions, including olfactory code. In other words, people can set personal distance using olfactory cues (e.g., breath odor) when they interact, and therefore interpersonal distance, established as a function of olfaction, may vary as a function of culture. Also, it seems that noncontact cultures are characterized by relatively low involvement of sensory cues in social contexts, including olfactory, as compared with contact cultures (Schleidt et al. 1981). Therefore, in light of the proxemics theory, it is likely that for Mexican participants the characteristics of contact culture (e.g., relying on and emphasizing olfaction in daily life) induced more attentive and positive attitudes toward olfaction. Even if only 1 country with a contact culture was assessed in this study, the proxemics theory seems a very attractive explanation for the differences found by us. However, differences in attitude toward olfaction between contact and noncontact cultures were not always found by previous investigators (Schleidt et al. 1981; Wysocki et al. 1991; Ferenzi et al. 2008). For example, in the study of Schleidt et al. (1981), no clear difference was seen between Germans (noncontact culture) and Italians (contact culture). Considering, however, that European countries with contact or noncontact cultures show similar preferences for odors (Pangborn et al. 1988), the lack of distinctive differences between German and Italian participants may not be surprising.

A region-dependent use of rating scales, known as a “cultural response set” (Matsumoto and Juang 2004), could be another possible factor to explain differences in the ratings of IOQ between Mexicans and participants from other regions. More specifically, even though participants from different regions may perceive a stimulus or question in a similar manner, they could rate the stimulus or answer the question by making different use of the scale depending on their culture (Ayabe-Kanamura et al. 1998; Johnson et al. 2005). For example, Ayabe-Kanamura et al. (1998) found a difference in the use of the rating scale for olfactory pleasantness between Japanese and German participants; Japanese participants were inclined to use the middle points of the 11-point scale more frequently than German participants. Moreover, Johnson et al. (2005) reported that participants from cultures with higher levels on a power distance index and a masculinity index, defined according to Hofstede (2001), tended to respond to questionnaires more often by using extreme

response categories of the scale than cultures with lower levels. Based on the findings of Hofstede (2001) and Johnson et al. (2005), we may assume that participants from the Mexican region, which have been reported to have a high power distance and masculinity index, might use extreme response categories more often than participants from the Korean region, which have medium and low indices, respectively, or compared with participants from Germany, which have low and high indices, respectively, and from the Czech Republic, which have medium and medium indices, respectively. Indeed, Korean participants appeared to use the mid-range values more often in their self-ratings on olfactory sensitivity than participants from the other cultures. However, apart from Korean participants, this assumption cannot fully explain the lack of differences in ratings of the IOQ between 2 European regions.

Furthermore, one might argue that the different method of data collection in Mexico (internet based) and the other regions (paper and pencil) could be the basis of the difference in the ratings of IOQ. Although internet-based surveys are known to be difficult to control for participants' reliability in reporting their gender and age (Epstein et al. 2001; Riva et al. 2003), the participants of traditional surveys appear to disclose themselves less freely than participants of internet surveys (Buchanan 2000). Despite these differences, many studies have reported no significant differences in participants' responses to on-line and off-line questionnaires (Epstein et al. 2001; Knapp and Kirk 2003; Riva et al. 2003). In our study, a method-induced difference in the ratings of IOQ seems unlikely, first, as it was possible to exclude the non-Mexican respondents of the internet survey (cf. Materials and methods), second, as the mean age of Mexican participants ( $29.5 \pm 7.2$  years) was similar to that of the participants from the other regions (overall:  $32.2 \pm 9.0$  years; cf. Table 1), and third, as the same significant gender differences in responding to the IOQ were found in the Mexican and in the other groups. Finally, the questions posed in the IOQ gave little opportunity for disclosing private matters.

#### Gender differences in general attitudes toward olfaction

Our results demonstrate that females have more attentive and consistent attitudes toward olfaction than males. This is consistent with previous findings that females are more attentive to odors than males (Schleidt et al. 1981; Herz and Cahill 1997; Frasnelli and Hummel 2005; Ferenzi et al. 2008; Croy et al. 2010). For example, Herz and Cahill (1997) reported that male participants employed visual and olfactory cues equally in mate choice, whereas females relied mainly on olfactory cues. Havlicek et al. (2008) extended this gender-specific reliance on olfactory cues to non-sexual contexts. Concerning gender-related differences in attitude toward olfaction, Frasnelli and Hummel (2005) and Croy et al. (2010) argued that the gender difference might be due to females' superior olfactory performance

compared with males (Doty et al. 1984; Hummel et al. 2007). Consequently, females are prone to react to an impairment of olfactory function more strongly.

Another plausible explanation for females' more attentive attitude toward olfaction is the gender difference in interpersonal distance; females generally keep a smaller interpersonal space than males (Sussman and Rosenfeld 1982; Camperio and Malaman 2002). That is, females with a relatively smaller interpersonal distance could judge olfaction as being more important than males with a relatively larger interpersonal distance.

#### Correlation of self-rating of olfactory sensitivity with general attitudes toward olfaction

Our findings show that general attitudes toward olfaction are associated with individuals' self-rating of olfactory sensitivity. Self-ratings seem to be an unreliable measure of olfactory function (Landis et al. 2003; but see also Welge-Luessen et al. 2005). Specifically, several studies have demonstrated that a subjective rating is not significantly correlated with odor thresholds (Philpott et al. 2006), odor identification (Knaapila, Tuorila, Kyvirk, et al. 2008), and combined scores of odor threshold, discrimination, and identification, that is, TDI score of "Sniffin' Sticks" test (Landis et al. 2003).

However, self-assessments of olfactory function were significantly associated with self-ratings of nasal patency (Landis et al. 2003) or experienced odor annoyance (Knaapila, Tuorila, Kyvirk, et al. 2008). Specifically, Knaapila, Tuorila, Kyvirk, et al. (2008) demonstrated that self-ratings of olfactory function were more related to ratings of odor annoyance than odor acuity. The authors reported that people seem to regard their sense of smell as being better than average when they are more annoyed by ambient scents than other people, which provides us with a plausible explanation for our results. That is, it seems that as people are more attentive to odors in daily life, they tend to regard their sense of smell as being sensitive in the present study.

#### Regional differences in affective attitudes toward specific categories of odors

The current findings basically confirm the notion that region influences odor preference (Schleidt et al. 1981, 1988; Pangborn et al. 1988; Wysocki et al. 1991; Schaal et al. 1997; Ayabe-Kanamura et al. 1998; Distel et al. 1999). Specifically, our results showed that participants from 4 different regions generally recalled the "Food & Drink" and "Nature" odors as being pleasant and the "Social relationship" and "Civilization" odors as being unpleasant, which is partly in line with the previous work related to our study (Schleidt et al. 1988). However, in contrast to the results of Schleidt et al., we found regional differences in the distribution of the main categories. The discrepancy could be due to the different countries employed in the 2 studies (see Introduction), to the methods of recall, that is, Schleidt et al.

did not limit the number of odors (while we allowed participants to list only 3 odors as pleasant and 3 as unpleasant), as well as to differences in odor categories and their components (see Introduction and Table 2).

Our findings showed that Mexican participants recalled the “Social relationship” odors as being pleasant more frequently. This result is possibly related to the point that the Mexican culture has been classified as a “contact culture” with shorter interpersonal distance according to Hall’s (1966) proxemics theory. In contrast, the Czech and German participants, who belong to “noncontact cultures,” reported “Social relationship” odors as unpleasant more often compared with Mexican participants. In addition, Mexican participants listed “Civilization” odors as unpleasant more often, whereas European participants reported “Nature” odors more frequently as pleasant. This finding could reflect the different characteristics of the respective countries: air pollution and traffic jams in Mexico (Guarneros et al. 2009) and more nature-friendly environments in Germany and the Czech Republic. Taken together, our results demonstrate cross-regional differences in affective attitudes toward specific categories of odors, in particular, using qualitative data (Figures 3 and 4) and corroborate previous work using quantitative data (Pangborn et al. 1988).

Our results may have also been due to genetic differences in olfactory receptors (ORs) across regions. Several studies suggest that genetic differences in human OR are related to variation in olfactory performance, including odor identification, intensity, and pleasantness (Wysocki and Beauchamp 1984; Keller et al. 2007; Menashe et al. 2007; Knaapila et al. 2007; Knaapila, Tuorila, Silventoinen, et al. 2008). In addition, environmental factors mediated by experience and learning influence variation in olfactory performance (Schleidt et al. 1981, 1988; Pangborn et al. 1988; Wysocki et al. 1991; Schaal et al. 1997; Ayabe-Kanamura et al. 1998; Distel et al. 1999; Chrea et al. 2004; Knaapila, Tuorila, Silventoinen, et al. 2008; for a review, see Hudson 1999). A recent study by Knaapila, Tuorila, Silventoinen, et al. (2008), using twins from Australia, Denmark, and Finland, found that the nonshared specific or individual environmental factor of participants contributed more to cross-regional variation in intensity and pleasantness of 4 odorants than genetic factors. Specifically, according to the multivariate statistical model of their study, the genetic factor accounted for 21% of variance in the pleasantness ratings of cinnamon odor, whereas the nonshared environmental factor explained 79% of the variance.

To summarize, our findings support and extend the notion of region influences shaping general and affective attitudes toward olfaction. Interestingly, across regions women, in comparison with men, seem to be more interested in olfaction.

## Supplementary material

Supplementary material can be found at <http://www.chemse.oxfordjournals.org/>.

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