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SHORT COMMUNICATION

Handedness is a Determining Factor in Lateralized Olfactory Discrimination

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Abstract

The study aimed to re-investigate differences in olfactory thresholds and odor discrimination between the left and right sides in relation to the handedness of healthy subjects. Twenty left- and 20 right-handers participated; all were in excellent health with no indication of any major nasal or health problems, and all were non-smokers. The two groups were comparable in terms of sex and age (left-handers: 11 women, 9 men, median age 25 years; right-handers: 9 women, 11 men, median age 26 years). Odor thresholds did not differ in relation to handedness. However, in the odor discrimination task the left-handers performed significantly better at the left side compared with the right nostril; this pattern was reversed in the right-handers. The data indicate that, similar to other sensory systems, higher olfactory functions exhibit a certain degree of lateralization.

Introduction

Studies on the lateralized processing of sensory stimuli are frequently conducted to get a better understanding of the hemispheric processing of this information (for review see Christman, 1997). For instance, a right-ear advantage for verbal stimuli (e.g. Kimura, 1961) is interpreted as a result of the left-hemispheric dominance in the processing of the verbal information. Within the context of this research aimed at the assessment of hemispheric function, results of left- and right-handed subjects are often compared with each other. This is based on the notion that handedness is related to functional hemispheric asymmetries, although this relation of handedness to cerebral lateralization is indirect and complex (Bryden and Steenhuis, 1991).

Lateralized differences in olfactory sensitivity in relation to the subjects' handedness were reported almost a century ago. Toulouse and Vaschide (1899) measured detection thresholds for camphor. The 64 right-handed subjects exhibited a higher sensitivity on the left side of the nose whereas the five left-handed or ambidextrous subjects had lower thresholds on the right side. This finding was supported by Frye *et al.* (1992), who, when measuring 2-butanone odor detection thresholds, found right-handers (n = 37) to be slightly more sensitive on the left side of the nose, whereas left-handers (n = 38) were more sensitive on the right side. However, other research offers opposite findings. Youngentoub *et al.* (1982) demonstrated in a series of four tests per subject that left-handers (n = 9) were more sensitive on the left-side whereas right-handers (n = 10) had lower n-butanol thresholds on the right side. Another study was unable to find differences for phenyl ethyl alcohol detection thresholds in relation to handedness in 49 left-handers and 50 right-handers (Zatorre and Jones-Gotman, 1990).

However, Zatorre and Jones-Gotman (1990) also reported that, other than with detection thresholds, odors are better discriminated when presented to the right nostril; this phenomenon was not significantly influenced by the subjects' handedness.

Thus, the question of handedness and its relation to the perception of odors is inconclusive (compare Doty *et al.*, 1997). The present study was performed to re-investigate possible differences in olfactory sensitivity between the left and right sides in relation to the subjects' handedness. To this end, both odor detection thresholds and the ability to discriminate odors were tested in subjects who exhibited strong left- or right-handedness.

Methods, results and discussion

Twenty left- and 20 right-handers participated. The two groups did not differ in terms of age (t = 1.70, df = 37.9, P = 0.10) or sex (χ^2 = 0.40, df = 3, P = 0.94) (left-handers: 11 women, 9 men, age 23–40 years, median 25 years; right-handers: 9 women, 11 men, age 19–35 years, median 26

years). Most of them were students attending the University of Erlangen-Nürnberg. All were in excellent health with no indication of any major nasal or health problems, and were non-smokers. A thorough examination ruled out the presence of a major septal deviation or other nasal diseases. Normal olfactory function was ascertained by means of an odor identification test ('Sniffin' Sticks', pen-like odor-presentation devices) comprising 16 items that had to be identified by means of a multiple forced choice from a list of four items (Hummel *et al.*, 1997); no significant difference was observed between the odor identification performance of the two groups [t = 1.23, df = 36.5, P = 0.41]. Handedness was assessed using a translated version of the Edinburgh Inventory (that produced scores from –10 to +10. Only subjects with scores ≤–9 or ≥+9 were allowed to enter the study. None of the subjects was ambidextrous or had a history of being re-educated from a left-hander to a right-hander.

Olfactory testing took place in the Department of Pharmacology of the University of Erlangen-Nürnberg; 'Sniffin' Sticks' were used for olfactory testing. Subjects were instructed to drink nothing but water and to not eat 1 h before commencement of testing. Butanol odor detection thresholds were assessed by the initially ascending single staircase method. Subjects were required, on a given trial, to report which of three stimuli, the odorant plus two blanks, was different. The single staircase always started at the lowest concentration available (1.22 µl butanol/l distilled water). Concentrations were increased until correct detection occurred on two consecutive trials. If an incorrect response was given on any trial, the staircase was moved upward one concentration step. If a correct response was given, the staircase was reversed and subsequently moved downward. The mean of four staircase reversal points following the third staircase reversal was used as threshold measure which entered statistical analyses. After threshold mesasurements were completed, the subjects' ability to discriminate odors was tested using a triple forced choice odor discrimination task comprising 16 triplets of odorants (for details see Hummel *et al.*, 1997). Two of the three odor pens contained the same odorant; the subjects had to discriminate which of the three pens had a different smell. The number of correctly identified odors was entered into statistical analyses.

Measurements of thresholds and discrimination were performed separately for the left and right nostrils; the sequence of testing was counterbalanced across subjects. Throughout testing subjects received no feedback as to the accuracy of their responses. Testing of an individual subject lasted ~2 h, with intervals of ~5–10 min between the various tests. Results were analyzed by means of SPSS 6.1.3 for Windows using MANOVAs (multivariate analyses of variance, repeated measurements design; between-subject factors 'handedness' and 'sex'; within-subject factors 'side tested'; 'age' as covariate); paired t-tests were used for post-hoc testing.

Table 1 Results of olfactory testing in left-handed (n = 20) and right-handed (n = 20) subjects

	Left-handers		Right-handers	
	Left nostril	Right nostril	Left nostril	Right nostril
Odor discrimination				
Mean	12.80	11.30	11.15	11.55
SEM	0.30	0.66	0.45	0.46
Odor thresholds				
Mean	8.58	7.79	8.40	7.61
SEM	0.57	0.73	0.42	0.50

Results for odor detction thresholds are expressed in dilution steps, i.e. lower numbers indicate lower sensitivity or higher thresholds. Results of the odor discrimination task are expressed as the number of correctly identified target odors.

Odor thresholds

Butanol odor thresholds did not differ between the two groups of subjects ['handedness': $F(1,35) = 0.00$, $P = 0.99$; Table 1]. In addition, there was no gender-related difference ['sex': $F(1,35) = 0.00$, $P = 0.98$]. The subjects' sensitivity was slightly higher when the left nostril was tested ['side tested': $F(1,36) = 3.88$, $P = 0.06$]. There was no significant interaction between the factors 'handedness' and 'side tested' [$F(1,36) = 0.00$, $P = 0.96$].

Odor discrimination

Women performed slightly better than men in the odor discrimination task ['sex': $F(1,35) = 3.29$, $P = 0.08$]. No main effect of the factors 'handedness' [$F(1,35) = 2.25$, $P = 0.14$] or 'side tested' [$F(1,36) = 1.39$, $P = 0.25$] was found. However, left- and right-handed subjects exhibited a difference in their ability to differentiate between odorants that was related to the side tested (Table 1, Figure 1). That is, odor discrimination was better in left-handers when the left nostril was tested, whereas it was the other way around in right-handers [interaction between factors 'handedness' and 'side tested': $F(1,36) = 4.49$, $P = 0.04$]. Post-hoc tests revealed that left-handers discriminated odors significantly better than the right-handers when odors were presented to the left nostril [$t(32.9) = 3.07$, $P = 0.004$]; no such difference between left- and right-handers was found when odors were presented to the right nostril [$t(33.7) = 0.31$, $P = 0.76$]. In addition, left-handers discriminated odors better when they were presented to the left nostril compared with right-sided odor presentation [$t(19) = 2.17$, $P = 0.04$]; this difference was not present in right-handers [$t(19) = 0.78$, $P = 0.45$].

The study has thus provided two major findings: (i) lateralized odor detection thresholds did not differ in

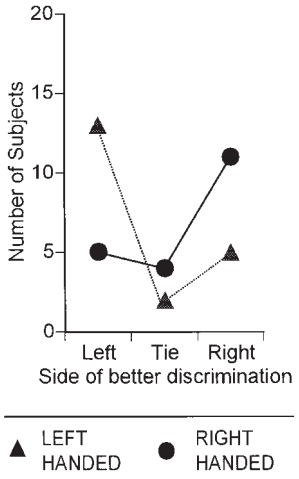

Figure 1 Number of left- (triangles) and right-handed (circles) subjects who discriminated odorants better on the left (L) or right (R) side, or where there was no difference between the left and right nostril (Tie). Left-handed subjects performed better on the left side of the nose compared with right-handers; the converse was found for the right nostril.

relation to the subjects' handedness; and (ii) lateralized odor discrimination was significantly related to handedness with better discrimination when odorants were presented to the nostril ipsilateral to the side of the hand preference.

As pointed out in the introduction, a number of studies have been performed on lateralized testing of odor detection thresholds in left- and right-handers. Two studies have reported thresholds to be lower on the side contrateral to the preferred hand (Toulouse and Vaschide, 1899; Frye *et al.*, 1992), and one study found a higher sensitivity ipsilateral to the side of the hand preference (Youngentoub *et al.*, 1982). One study was unable to detect differences between left- and right-handers in terms of their phenyl ethyl alcohol detection threshold. Specifically, Zatorre and Jones-Gotman (1990) were unable to find differences between left-handers and right-handers. When the present results are also taken into account, the weight of the evidence seems to indicate that there are no differences between left- and right-handers in terms of olfactory detection thresholds.

The contradictory results produced by some of these studies on thresholds may be partly related to characteristics inherent to assessment of thresholds. Shimomura and Motokizawa (1995) presented evidence that thresholds exhibit a large variation when measured in 10 consecutive trials on the left and right sides of the nose of an individual subject. In fact, for thresholds the variation between the left and right sides of the nose was so large that, in conclusion, the nostrils were found to be functionally equivalent. This variability may have contributed to the differences between left- and right-handers that have been reported by Toulouse and Vaschide (1899), Frye *et al.* (1982) and Youngentoub *et al.* (1982).

Apart from these methodological grounds, it may be hypothesized that odor thresholds and odor discrimination represent different stages of processing. That is, thresholds may more directly reflect functions of peripheral structures of the olfactory system whereas the ability to discriminate or identify odors may reflect higher-order functions, or, alternatively, are thought to be a measure of the functional integrity of the entire olfactory pathway. For example, a dissociation between thresholds and other olfactory functions has been reported for schizophrenic patients (Kopala *et al.*, 1993); in this group of patients a deficit is found for the identification of odors while this is not seen for olfactory thresholds. However, recent studies also suggested that 'nominally distinct tests of olfactory function are measuring a common source of variance' (Doty *et al.*, 1994). Thus, specific studies are needed to address the question of how olfactory thresholds are different from results obtained by means of odor discrimination or identification tasks; nevertheless, the present data indicate that different olfactory tasks are processed differently by the two hemispheres, as indicated by the differences in lateralization.

Left-handed subjects scored significantly higher on the left than on the right side, whereas this pattern was reversed in right-handers. These data are in conflict with the results of Zatorre and Jones-Gotman (1990), who reported no significant differences between the two groups of subjects. However, this picture is slightly changed when their data are re-arranged as a function of the nostril which was better in terms of odor discrimination. Specifically, in the study of Zatorre and Jones-Gotman 18/49 left-handed subjects compared with 12/50 right-handers discriminated odorants better when they were presented to the left nostril. The converse was found for the right nostril, where 26/49 left-handers performed better compared with 30/50 right-handers.

The lack of statistical significance of the findings of Zatorre and Jones-Gotman may be partly explained by the use of a test of odor discrimination which, unlike the 'Sniffin' Sticks', has not been investigated for its test–retest reliability. As many psychophysical tests of olfactory function seem to exhibit a relatively low degree of test–retest reliability (Doty *et al.*, 1995), it is conceivable that a higher degree of variability of the previously employed same–different odor discrimination test may have contributed to the non-significant differences between left- and right-handers.

The question remains of how the lateralized difference in odor discrimination relates to a more general 'olfactory' dominance of the hemisphere ipsilateral to the preferred hand. As summarized recently (Doty *et al.*, 1997), due to a large body of conflicting results, it is presently not justified to address one hemisphere as the dominant one in the processing of olfactory information. Rather strikingly, this problem is illustrated by the results obtained for the detection threshold measurements that were related neither to handedness nor to the side tested. However, the present

results clearly indicate that, similar to other sensory systems (Kupfermann, 1991), higher olfactory functions seem to exhibit a certain degree of lateralization. In addition, the study adds further weight to the notion that handedness is among the determining factors in lateralized suprathreshold olfactory function.

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