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Sit Up and Smell the Roses Better: Olfactory Sensitivity to Phenyl Ethyl Alcohol Is Dependent on Body Position

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Abstract

Previous studies have demonstrated that body position can alter auditory sensitivity. Here we demonstrate for the first time that olfactory sensitivity for the commonly used odor phenyl ethyl alcohol (PEA) (rose odor) is also dependent on body position. By using successive dilutions presented in a staircase protocol, we determined olfactory thresholds for PEA in 36 healthy participants (18 women) in both an upright and a supine position. Participants had a significantly greater olfactory sensitivity when tested in an upright than a supine position, with no significant differences between the sexes. This preliminary study sets the stage for further work on the interaction between olfactory functions and our biology. The implications for olfactory neuroimaging studies are discussed.

Key words: body position, neuroimaging, odors, sensitivity, smell

Introduction

Our body position when performing sensory tasks has previously been demonstrated to have implications on our perceptual abilities. A marked decrease in auditory functions such as sensitivity and sound localization has been reported to occur when in a supine position compared to when sitting up (Macrae, 1972; Lackner, 1974; Fukai *et al.*, 2005). In addition to these sensory functions, a supine body position is also known to affect our performance in spatial memory tasks in a negative way (VanderVelde *et al.*, 2005), to increase our susceptibility to thermogenesis (Nakajima *et al.*, 2002), and to modulate visual neglect in brain injured patients (Peru *et al.*, in press). In light of these findings, informal observations from neuroimaging studies conducted in our laboratory indicated that research participants consistently rated the intensity of odors as less intense inside the scanner while in a supine position in comparison to performance outside the scanner and thus sitting up. This phenomenon seems to be independent of individual scanning experience, scanning method, or means of odor delivery; that is, odor presentation in bottles or by olfactometer while performing velopharyngeal closure, a breathing method that results in odor presentation without active sniffing (Kobal, 1981).

Previous reports on body position–dependent effects on olfactory functions have been conflicting. Mester and colleagues (1988) reported that identification performance was decreased while positioned upside down compared to when sitting up, while Vickers and colleagues (2001) reported no significant difference in olfactory threshold due to shift in body position. This discrepancy can, however, easily be attributed to the difference in numbers of participants in the two studies. Vickers and colleagues (2001) tested only six participants using a dilution series with just 10 dilution steps.

In light of the impact of body position on our perceptual system reported by others (Macrae, 1972; Lackner, 1974; Mester *et al.*, 1988; Fukai *et al.*, 2005), the difference in perceived odor intensity that we observed in imaging experiments could be mediated by differences in the positioning of the body. Perceptual ratings of odors outside the scanner environment are commonly performed sitting up whereas, by default, the same task inside the scanner is performed in a supine position. Increasingly, the tendency in olfactory neuroimaging experiments now is to correlate neuronal activity with behavioral measures. Reliable olfactory threshold measures are difficult to obtain inside a scanner owing to environmental constraints and have commonly been recorded outside the scanner with participants in an upright position. If there is a difference in olfactory sensitivity due to body position, this will have obvious implications for later comparisons.

In this initial explorative study, we measured olfactory sensitivity for the odor of phenyl ethyl alcohol (PEA; odor of rose) in men and women, once while lying down and once while sitting up. We hypothesized that sensitivity to odors would be body position dependent in that participants' olfactory sensitivity would be lower in a supine than in a sitting up position.

Experimental procedures

Participants

Thirty-six healthy normosmic subjects (18 women) with a mean age of 22.9 (± SD 4.2; range 18–35) years participated in the study. Inclusion criteria were self-reported absence of nasal congestion, acute infection, or decreased olfactory function. All participating women reported stable menstrual cycles (mean length 28 ± 1.8 days; range 25–32 days). Based on self-reports, nine women were deemed to be in the follicular phase (days 6–14) and nine in the luteal phase of the menstrual cycle (days 15–32). Participants were asked not to wear perfume on the day of testing and not to drink anything other than water 1 h prior to testing. Detailed information about the experimental procedures was given to the participants, and written consent was obtained. The true hypothesis of the experiment was given only after completion. All aspects of the study were performed in accordance with the Declaration of Helsinki and approved by the Montreal Neurological Institute's Research Ethics Board.

Materials

Olfactory thresholds for PEA were assessed using the well-validated ''Sniffin' Sticks'' threshold set (Hummel *et al.*, 1997). The Sniffin' Sticks threshold set consists of felt-tip pens filled with PEA diluted in propylene glycol in 16 different concentrations. The set ranged from 16.3 μM (dilution 16) to 0.54 M (dilution 1) in a geometric series consisting of 16 steps with dilution ratio of 1:2. The Sniffin' Sticks were selected for odor delivery because they lack the volatile headspace that is present in bottles; that is, there were no differences between the two body positions in how the odor was administered.

Procedure

Each participant's sensitivity for PEA was tested twice, once lying down and once sitting up. When lying down, participants were lying comfortably in a supine position and were allowed to rest for 1 min before testing to allow time for stabilization of cephalic circulation. When tested sitting up, participants were seated in a comfortable chair and also allowed to rest for 1 min before testing to prevent any dissimilarities between the conditions. An identical verbal instruction for the testing procedure preceded both conditions. Participants wore a blindfold throughout testing to prevent visual cues. Threshold tests were of an ascending staircase, three-alternative, no feedback, forced-choice design. Each trial included one target (a pen with the odorant in propylene glycol) and two control stimuli (pens with only propylene glycol). Odorants were presented in ascending concentrations until the participant correctly discerned the odorant in two successive trials, which triggered a reversal (cf. Lundstrom *et al.*, 2003). The test ended after seven reversals of the staircase. The mean of the concentration at the last four reversal points was calculated to estimate the olfactory threshold. The position of the target container was randomized with each trial, as was whether the participant was initially tested sitting up or lying down. Participants had a 5-min pause between the threshold tests to prevent sensory adaptation.

Results

Thresholds were nearly one dilution step higher when participants were tested sitting up (11.4 ± SD 3.3; range 3.75–15.75) than while lying down (10.5 ± SD 3.1; range 2.75–14.75). When in a supine position, 23 participants (63.9%) demonstrated a decrease in olfactory sensitivity, 9 an increase (25%), and 4 participants (11.1%) demonstrated no difference when in a supine position. A repeated measure analysis of variance (ANOVA) with ''body position'' as a within-subject variable indicated a significant main effect of body position on participants' olfactory sensitivity, $F(1, 35) = 4.73$, $P = 0.03$; see Figure 1. There were no main effects due to the variables of ''sex,'' $F(1, 35) = 1.43$, $P = 0.24$ or ''starting position,'' $F(1, 35) = 1.10$, $P = 0.29$, as tested with repeated measures ANOVAs with body position as within-subject variable and either the variable sex or starting position as a between subject variable.

Discussion

There was a clear difference in olfactory sensitivity for PEA depending on the body position of the participants during testing. As predicted by our previous informal observations, olfactory sensitivity was greater when in a sitting up position.

One might argue that the underlying cause of the body position–dependent change in olfactory threshold is an increase in sensitivity due to the repeated testing, as previously demonstrated by others (Dalton *et al.*, 2002). However, we consider that interpretation unlikely based on two reasons. First, the previously demonstrated increase in sensitivity due to repeated testing demanded continuous testing over a period of several days. Secondly, the order of testing position was counterbalanced in our experiment, rendering any increase in sensitivity due to testing to be equally spread over the two conditions. The body position–dependent change in olfactory sensitivity is thus most likely unrelated to the increase in olfactory sensitivity demonstrated by Dalton *et al.*

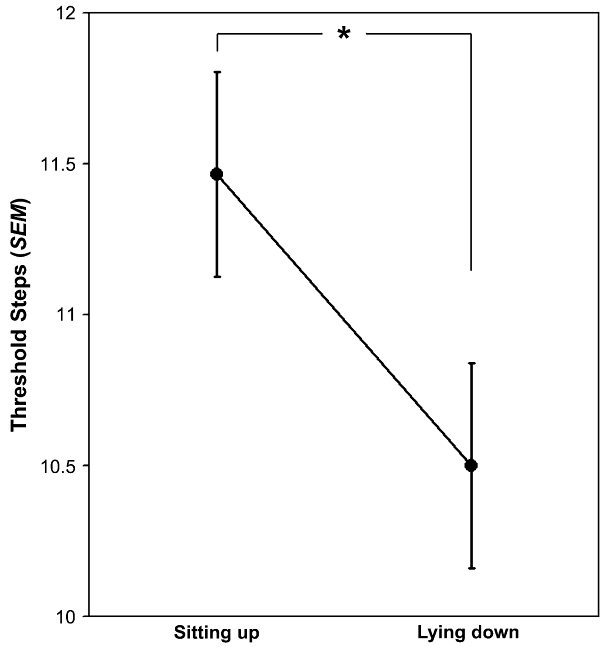

Figure 1 Mean thresholds with standard error of means as expressed in threshold steps and divided by body position when tested. * in figure denotes a significant difference ($P < 0.05$) as indicated by a repeated measures ANOVA.

(2002). The ecological implications of these findings can only be speculated about. Others have suggested that the olfactory system might be depressed when in a supine position due to a potential smaller likelihood of odors acting as a sentinel (Carskadon and Herz, 2004). The ecological rationale of this function might be a sleep preparedness mechanism or mere a learned response.

Previous works have demonstrated that a shift in body position acts as a stressor on the cardiovascular system (Tomaselli *et al.*, 1987; Schondorf and Low, 1992). A rapid shift in body fluid redistribution occurs when shifting from an upright to a supine position, amounting to a 4% increase in size of the neck region (Watenpaugh *et al.*, 1997). Although it has been demonstrated that this redistribution of body fluid does not have a clear effect on the cephalic circulation (Pittet *et al.*, 1989), it has been hypothesized that this shift induces an increase in cephalic circulation and functions as a mediating mechanism behind the supine position's impact on the auditory system (cf. de Kleine *et al.*, 2001). One might then argue that this shift in circulation down-regulates the olfactory functions by altering the nasal blood flow by peripheral processes, thus inducing a congestion of the nasal cavity (Kase *et al.*, 1994; but see Doty *et al.*, 1988 and Riechelmann and Krause, 1994). The total area of the nasal cavity has been demonstrated to decrease when in a supine compared to upright position (Kase *et al.*, 1994), and it has been speculated that this results in a decrease in patency and with that, a decreased sensitivity. Indeed, surgically induced increases in nasal volume do lead to an increase in both measured and subjectively rated nasal patency (Damm *et al.*, 2003), and reduced sniffing abilities in individuals with Parkinson's disease have been demonstrated to correlate with their ability to identify odors (Sobel *et al.*, 2001). These studies together suggest that olfactory sensitivity is dependent on nasal airflow. Measures in healthy participants do not, however, support this direct relationship. Studies in healthy participants have demonstrated that the total nasal resistance remains constant between body positions (Rundcrantz, 1969; Hasegawa and Saito, 1979; Haight and Cole, 1984; Cole and Haight, 1986; Riechelmann and Krause, 1994). Further, there is no simple direct relationship between sniff volume and olfactory sensitivity. Most studies to date have found that neither nasal patency (Doty *et al.*, 1988; Eccles *et al.*, 1989) nor sniff volume (Teghtsoonian *et al.*, 1978; Hornung *et al.*, 1997) affect olfactory functions. It would be of interest to examine under experimental conditions whether the effect of body position on olfactory sensitivity is independent of sniffing, as our previously mentioned informal observations imply. This can be done during passive smelling with stimulus delivery via an olfactometer.

Most olfactory imaging studies obtain the behavioral measures of olfactory function outside the scanner with participants seated in an upright position. These measures are then often used in the analyses as direct or indirect behavioral correlates to measures of brain activity. Our findings that body position influences olfactory sensitivity suggest that behavioral measures, such as pilot data, that will be used either directly or indirectly in the scanning results should be acquired inside the scanner or in a position similar to when in the scanner. This should especially be adopted if these measures are meant to be used as behavioral correlates to measures of neuronal activity, and it may apply to other olfactory measures as well since olfactory sensitivity is known to be correlated with both olfactory discriminatory and identification performance (Doty *et al.*, 1994). Thus, the effect demonstrated here might be valid also for other olfactory measures; this remains to be elucidated with more odorants and different methods.

As for the previously reported posture-related effects on the auditory system, we can only conclude that the mediating mechanism behind the phenomenon reported by us is not known. Future studies using a wider range of odorants are warranted to examine whether this mechanism relates to differences in sniff volumes, whether it is centrally or peripherally mediated, or whether it is due to ecological factors or merely to a change in attention to the odors in question.

These preliminary data are, to the best of our knowledge, the first demonstration of a body position–dependent difference in olfactory sensitivity. Participants were more sensitive to the odor when in the upright position than when in a supine position. This finding implies that future olfactory imaging experiments involving olfactory tests should consider controlling for body position.

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