Brain Research Bulletin 84 (2011) 206–209

Contents lists available at ScienceDirect

Brain Research Bulletin

journal homepage: www.elsevier.com/locate/brainresbull

Research report

Odor perception and odor awareness in congenital blindness

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ARTICLE INFO

Article history:
Received 16 August 2010
Received in revised form
21 December 2010
Accepted 26 December 2010
Available online 12 January 2011

Key words:
Blindness
Olfaction
Odor awareness
Detection threshold
Crossmodal plasticity

ABSTRACT

It is generally acknowledged that people blind from birth develop supra-normal sensory abilities in order to compensate for their visual deficit. While extensive research has been done on the somatosensory and auditory modalities of the blind, information about their sense of smell remains scant. The goal of this study was therefore to compare odor perception and odor awareness in a group of 11 congenitally blind and 14 sighted control subjects. We measured odor detection threshold, odor discrimination and odor identification using the Sniffin'Sticks test. Participants also filled in the Odor Awareness Scale (OAS) to assess consciousness of olfactory sensations. Our data showed that blind subjects had a lower odor detection threshold compared to the sighted. However, no group differences were found for odor discrimination and odor identification. Interestingly, the OAS revealed that blind participants scored higher for odor awareness. The largest group differences were found for items of the OAS that measure responses to body odors and fragrances. We conclude that blind subjects rely more on their sense of smell than the sighted in order to assess their environment and to recognize places and other people.

1. Introduction

Despite the lack of visual input, congenitally blind subjects are able to find their way around, assess objects and their importance, cook, read, and recognize their friends and kins. In short, they are well aware of their immediate environment. It is generally acknowledged that blind individuals develop supra-normal sensory abilities in their remaining senses in order to compensate for their visual deficit. Studies on auditory and tactile modalities support this sensory advantage attributed to the blind. Several studies have indeed shown superior performance of the blind in tactile discrimination [1,5,13,15,35,39,42], sound localization and pitch discrimination [9,7,12,17,18,20,26,29–31,40,41].

In sharp contrast with the wealth of studies on tactile and auditory processing in the blind, little is known about their sense of smell. A Pubmed search of the literature listed only 10 published articles on the topic between 1889 and 2010 and with rather contradictory results. On the one hand, Griesbach (1889; cited in Smith et al. [37]) and Cherubino and Salis [6] and Boccuzzi [3] found no differences between the olfactory abilities of blind and sighted subjects, whereas Mahner (1909) and Bertoloni (1942) (both cited in [37]) concluded that congenitally blind individuals have a more developed sense of smell. In addition, Murphy and Cain [25] reported that although the odor detection threshold was poorer for the blind, they could name 31% more familiar odors than a sighted control group. More recent and better-controlled studies on olfaction in the blind also produced some contradictory results. For instance, whereas a study by Smith et al. [37] showed that blind people (congenital and late onset) are not better at detecting, discriminating or identifying odors, Cuevas et al. [8] reported increased odor discrimination and odor identification. Also, Rosenbluth et al. [34] found that congenitally blind children are better and faster in a free identification of odors paradigm but not when using a multiple-choice paradigm, suggesting superior verbal abilities rather than enhanced perceptual abilities. One of the possible reasons for the discrepancy in results is that these studies did not standardize olfactory testing procedures. In fact, an eclectic assortment of testing procedures was used in the experiments cited above, ranging from home-made dilutions or odorant items from household placed in plastic bottles, to validated tests such as the University of Pennsylvania Smell Test [11] and the Sniffin'Sticks test [19]. With such diversity in testing procedures, it may not come as a surprise that the outcomes of the different studies lack congruity. Moreover, the clinical tests used may not have the power to discriminate normal from supranormal performance.

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doi:10.1016/j.brainresbull.2010.12.014

Table 1
Demographic data of blind participants (M = male, F = female).

Sex	Age	Education (years)	Ethiology blindness	Onset blindness
F	26	16	Retinopathy of prematurity	Birth
M	56	15	Retinopathy of prematurity	Birth
M	57	17	Cataract	6 months
M	21	12	Retinopathy of prematurity	Birth
F	41	14	Retinopathy of prematurity	Birth
M	23	14	Retinopathy of prematurity	Birth
M	19	10	Retinopathy of prematurity	Birth
F	27	14	Retinopathy of prematurity	Birth
F	21	12	Retinopathy of prematurity	Birth
M	35	12	Unknown	<3 months
M	23	10	Glaucoma	Birth

Although odors are omnipresent in the environment, one is not always aware of their presence. In the absence of vision however, people have to rely on the other sensory modalities, including olfaction, to assess their surroundings. So far, no study has investigated whether blind subjects have an increased awareness for odors compared to sighted subjects. The goal of this study was therefore to assess olfactory awareness in conjunction with olfactory abilities in congenitally blind subjects and sighted controls. In line with tactile and auditory studies that have shown an improved performance for the blind, we hypothesized that blind people would exhibit better olfactory abilities than sighted controls and an increased awareness for smells.

2. Methods

2.1. Participants

Fourteen sighted subjects (8 females, mean age: 30 ± 9 years; mean education: 16 ± 2 years) and 11 congenitally blind, age -and sex-matched (4 females, mean age: 32 ± 14 years; mean education: 13 ± 2 years) were enrolled in the study. Demographic data and causes of blindness are summarised in Table 1. None of the participants had any psychiatric antecedents, nasal deformities, fractures, obstruction or allergies, past repeated exposure to vaporous chemicals, consumption of inhaled non-medical drugs, neurological diseases, nor respiratory problems. The local ethics committee approved the study and all participants gave written informed consent.

2.2. Testing procedures

Olfactory perception was assessed with the Sniffin'Sticks smell battery that comprises three olfactory tests (odor detection threshold, odor discrimination, odor identification) [19]. The tests use pen-like odorant devices that are briefly presented to the participants. We administered the tests according to the procedure described in the instruction manual (Instructions Level II Test). We assessed detection threshold using a single staircase method. Using a forced-choice paradigm, participants were asked to identify which pen smelled differently from a set of three, containing two blanks. Pens were presented in ascending concentration. The identification of the odor was considered correct when it was detected twice in a row. Then, a concentration just below the previous one was presented. If this one was also correctly identified twice in a row, we switched to the next lower concentration and so on, until the participant could not detect the odor any longer. Following a non-detected odor, we increased the concentration with one step (staircase reversal 1). If this stimulus was also not identified, we further increased the odor concentration until the participant again correctly identified the odor twice in a row. Then, a second staircase reversal was done, using lower concentrations. Testing was finished after 7 reversals of the staircase. The threshold was calculated as the mean of the 7 reversals. We evaluated odor discrimination by presenting 16 triplets of odorants, of which two were the same and one was different. The participant's task was to indicate which of the 3 pens smelled differently. For odor identification, we presented 16 pens with common smells (for example orange, cinnamon, onion, banana, lemon or fish) and participants had to identify the odor by selecting one of four possible descriptors from a list that was verbally presented. The scores of each test, which could vary between 0 and 16, were summed into a total TDI (Threshold Discrimination and Identification) score. Higher scores indicate better performance.

We used the Odor Awareness Scale (OAS) to assess self-reported odor awareness, that is, consciousness of olfactory sensations [36]. The OAS contains 34 questions assessing to which degree participants notice, pay attention to, or attach importance to smells. Subjects answered to each question with "always", "often", "sometimes", "seldom", or "never".

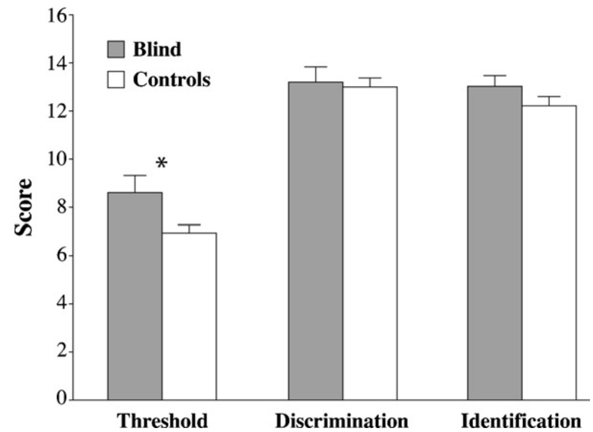

Fig. 1. Bar charts showing the mean ± S.E.M. for the olfactory detection threshold, olfactory discrimination and olfactory identification in blind and sighted controls. The asterisk shows significant results at $p < 0.05$. Blind participants have significantly lower odor detection thresholds but did not differ in odor discrimination and odor identification.

2.3. Statistics

To test for group differences in olfactory perception, we conducted four ANCOVAs with group (blind versus sighted) as independent variable, age and sex as co-variates and the Sniffin'Sticks test scores (threshold, discrimination, identification and TDI) as dependent variables. Group differences on the OAS were assessed using an ANCOVA with group (blind versus sighted) as independent variable, age and gender as co-variates and the OAS score as dependent variable. Olfaction varies as a function of both gender [10] and age [11]. Olfactory abilities increase until the age of 25–30 years after which a plateau is reached. From the age of 40, olfactory abilities start to decline [11]. Therefore, we added these two co-variables to our model. Furthermore, individual OAS questionnaire items were compared by means of independent-samples *t*-tests.

Marks and Wheeler [24] demonstrated that increased awareness is associated with enhanced perceptive abilities. We therefore calculated correlations between the self-rated sensitivity to odors as measured by the OAS (item 24) and the Sniffin'Sticks test scores to control for a possible subjective bias of "popular beliefs". Indeed, blind participants could score higher on this item because they are expected to do so. A lack of correlation could then reflect a possible bias in the OAS scores. Thereto, we calculated Pearson product–moment correlations between the Sniffin'Sticks scores and the OAS score on item 24.

Significance level for all statistical tests was fixed at $p < 0.05$ and the analyses were carried out with SPSS 16.0.

3. Results

3.1. Olfactory perception

Fig. 1 illustrates odor detection, odor discrimination and odor identification scores for the two groups. As the postulate of homogeneity of regression was violated for the odor detection data, we used a *t*-test instead of ANCOVA to analyse these data [45]. The results showed that the blind had a significantly lower odor detection threshold compared to the sighted ($t(23) = 2.139$, $p = 0.05$, corrected for inequality of variance). However, no group differences were found for odor discrimination ($F_{1,24} = 0.009$, $p = 0.92$) and odor identification ($F_{1,24} = 2.003$, $p = 0.17$). Age and sex did not account for a significant portion of the variance of the test scores. The total threshold detection identification score (TDI) was not significantly different between blind (35 ± 1.3) and sighted controls (32 ± 0.6) ($t(13.5) = 1.836$; $p > 0.05$).

3.2. Odor awareness

A significant group difference with large effect size was found for odor awareness. Average OAS scores for the blind and sighted were respectively 132 ± 3 and 118 ± 5 ($F_{1,24} = 4.497$, $p = 0.046$). Age and sex did not explain a significant portion of the variance of the OAS scores. The average OAS sum scores reported by Smeets et al. [36], based upon a large sample of 525 sighted control subjects, was