

# A Different Olfactory Perception in Anosmic Patients: Evidence from Functional MRI

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## Abstract

**Purpose:** Olfactory system is a vital sensory system in mammals, giving them the ability to connect with their environment. Anosmia, or the complete loss of olfaction ability, which could be caused by injuries, is an interesting topic for inspectors with the aim of diagnosing patients. Sniffing test is currently utilized to examine if an individual is suffering from anosmia; however, functional Magnetic Resonance Imaging (fMRI) provides unique information about the structure and function of the different areas of the human brain, and therefore this noninvasive method could be used as a tool to locate the olfactory-related regions of the brain.

**Materials and Methods:** In this study, by recruiting 31 healthy and anosmic individuals, we investigated the neural Blood Oxygenation Level Dependent (BOLD) responses in the olfactory cortices following two odor stimuli, rose and eucalyptus, by using a 3T MR scanner.

**Results:** Comparing the two groups, we observed a network of brain areas being more active in normal individuals when smelling the odors. In addition, a number of brain areas also showed an activation decline during the odor stimuli, which is hypothesized as a resource allocation deactivation.

**Conclusion:** This study illustrated alterations in the brain activity between normal individuals and anosmic patients when smelling odors, and could potentially help for a better anosmia diagnosis in the future.

**Keywords:** Olfaction; functional Magnetic Resonance Imaging; Anosmia; Sniffing Test; Diagnosis.

## 1. Introduction

The importance of the sense of smell in everyday life and evolution is quite clear. From its hedonistic aspect of life and eating satisfaction to its survival aspect, which involves detecting danger in the environment or toxins and the edibility of food, all indicate the importance of having intact olfactory sensation [1]. The olfactory pathway and network in primates can be traced back to the primary regions, including the olfactory bulb to the entorhinal and piriform cortices of the temporal lobes, and also to the thalamus, hypothalamus, and parts of the limbic system [2]. Over time, more olfactory projections are issued into the lateral olfactory regions, which include the orbitofrontal cortex, insula, hippocampus, thalamus, and hypothalamus [3]. Olfactory dysfunction can be divided into two groups in terms of severity. Hyposmia, which is a partial loss of olfactory ability, and anosmia which is applied to complete olfactory dysfunction that leads to inefficiency in daily functioning [4]. The most important causes of olfactory dysfunctions are congenital, infections, age-related disorders, and traumatic disorders [5], and the latter is the subject of this study. Hyposmia and anosmia are the partial or complete loss of the ability to smell. While common conditions, irritating the sense of smell such as allergies lead to a temporary anosmia, and more serious conditions that affect the brain nervous system, e.g. brain tumors or head trauma and in early stages of diseases such as Alzheimer and Parkinson, can cause permanent loss of this sense [5]. While finding precise methodologies for the early diagnosis of these diseases and other sensory modalities is of great interest to researchers, the olfactory system of the brain is still understudied.

Diagnosis of traumatic anosmia and its severity is important in terms of diagnostic-therapeutic interventions and especially in legal claims and compensation. Traditional methods of assessing olfactory disabilities include self-reporting and simple sniffing odors kits [6]. These methods have notable limitations. Because these psychophysiological methods are based on self-report, they require both an appropriate level of awareness and cognition for a reliable cooperation of patients. Also, they can be misdiagnosed through malingering for compensation [7]. Although conventional Magnetic Resonance Imaging (MRI) diagnoses gross olfactory system damages, it has limitations on subtle lesions and obviously in distinguishing underpinning networks. Other

Imaging modalities using metabolic rate changes such as Positron Emission Tomography (PET) scans and Single-Photon Emission Computed Tomography (SPECT) are also used to assess patients with anosmia; however, fMRI is preferable in some respects due to a better temporal and spatial resolution than both modalities [8]. Functional Magnetic Resonance Imaging (fMRI) was utilized in the evaluation of olfactory system pathophysiology in recent years. The results of studies in this field have shown similarities but also inconsistencies, which are due to their differences in the task design, populations, types of anosmia, and stimulations, and therefore a careful interpretation is needed. Studies demonstrated that pleasant or unpleasant odors recruit shared but also different regions of the brain. For example, Rolls *et al.* declared that besides activation of primary olfactory regions in both pleasant and unpleasant odors, Medio-rostral OFC is mostly activated in pleasant odor, while the Blood Oxygenation Level Dependent (BOLD) signal was shown in the left lateral OFC in an unpleasant odor stimulation [9]. In addition, other studies represented that Orbitofrontal Cortex (OFC) and amygdala were involved in odor valence [10]. In contrast with a pleasant odor, studies emphasized on activation of the Anterior Cingulate (ACC) and paracingulate cortex encountering unpleasant stimulation [3, 11]. Furthermore, the body of the literature established ACC as a key area involved in painful stimulation and pain processing [12]. While these findings showed distinct areas of the limbic system responsible for the pleasant and unpleasant odors, a meta-analysis illustrated that limbic lobe activations are overlapped in both types of odors [13].

Given the above, one of the applications of fMRI might be its ability as a reliable neuroimaging biomarker to distinguish patients with post-traumatic anosmia from healthy people. There is still a wide variety of controversies and debates in this area. Previous studies have shown that the major difference in brain activity between healthy individuals and patients is more prominent in the primary and secondary olfactory system, including the piriform cortex, amygdala, OFC, insula, and anterior cingulate cortex [14]. Intertwining of an olfactory and trigeminal pathway in smelling causes loss of cerebral activation in anosmic patients in brain areas related to trigeminal and bimodal stimulation. Two fMRI studies reported diminished activation in the motor areas and cerebellum in anosmia during trigeminal or bimodal stimulation [11]. Early investigation on regions out of the well-known

piriform-OFC circuit showed activations in the inferior frontal gyrus, caudate nucleus and also cerebellum during unpleasant olfactory stimulation [15]. Similar to the population of the current study, a recent study by Moon *et al.* on patients with trauma-induced anosmia showed that brain activity was reduced in both the primary and secondary olfactory regions (specifically the OFC) compared with healthy individuals. This finding was more in the unpleasant odor [7]. All in all, the utility of fMRI in traumatic anosmic patients is not clear yet, and this study is an attempt to shed light on fMRI utilization and limitation for the clinical diagnosis of anosmic patients. The results of this study could be a help for using fMRI as a diagnosis tool for anosmia, and it may also help for prediction purposes.

## 2. Materials and Methods

### 2.1. Participants

Sixteen anosmia patients with a mean age of 36.3 years old (range 22 to 50) were included in the study. An ENT (Ear, Nose, and Throat) specialist introduced us anosmia patients, from the “Amir Aalam” Hospital, Tehran, who were voluntarily referred for their olfaction disorder. In addition to the general examinations, a ‘Sniff-in Sticks’ test (SST) kit was also used to estimate the Threshold, Discrimination, and Identification (TDI) score, which is a reliable tool for measuring the function of the human olfactory system [16]. All patients had lost their sense of smell for at least two years, due to an injury, and none had undergone any pieces of training to recover their olfactory system. The second group included 15 healthy subjects (11M), with a mean age of 30.1 years old (range 20-39); their health criteria were assessed by a general practitioner and based on published criteria [17, 18]. This study was conducted based on the Ethics Statement of Tehran University of Medical Sciences which is in accordance with the principles of the revised Declaration of Helsinki. Informed consent was obtained after outlining the experimental paradigm in the first interview.

### 2.2. Olfactory Test

Psychophysical testing of olfactory function was performed with the SST. In this test, odorants are presented in felt-tip pens. To perform the examination, the pen’s tip is placed, approximately at 2 cm distance, in front of both nostrils for almost three seconds. The test

includes three different scenarios to evaluate the acuity of the sense of smell. First, the odor threshold was investigated through a stepwise rarefaction of 16 N-butanol felt-tip pens. Then, the participants were asked to choose a target odor out of three odors presented to them by three different sticks, repeated for all 16 felt-tip pens. And finally, they were asked to identify 16 odorants in multi-choice lists of four felt-tip pens for each odor. Results from all three tests, ranging 1 to 16, were summarized as the so-called TDI score. According to previous findings, we classified those participants with a TDI score lower than 16 as anosmia, and the participants with TDI scores above 30 were regarded as healthy [19].

### 2.3. Imaging

The data were acquired using a 3T MRI scanner (MAGNETOM Trio; Siemens Healthcare GmbH, Federal Republic of Germany) using a standard receiving 32-channel head coil. Foam cushions were used to diminish the small head movements in the coil during scanning. Following a three-dimensional magnetization, we were prepared with a rapid acquisition gradient echo sequence (repetition time = 1800ms, echo time = 3.4ms, flip angle = 7 degrees, field of view = 192 mm<sup>2</sup>, 176 slices, slices thickness = 1 mm, matrix size = 256 × 256, voxel size = 1 × 1 × 1mm<sup>3</sup>) to obtain high-resolution T1-weighted images of the brain. For fMRI analysis, an Echo Planar Imaging (EPI), T2\*-weighted sequence with 200 whole-head volumes (TR = 3000ms, TE = 30 ms, 40 slices, no gap, flip angle = 90 degrees, FOV = 192 mm<sup>2</sup>, slice thickness = 3mm, and matrix size = 64 × 64) was acquired.

### 2.4. fMRI Paradigm

Olfactory stimulation was administered using a computer-controlled stimulator (Mag-concept Olfactometer, 2010, USA). With a continuous airflow rate of 2 L/min, the olfactometer allows the delivery of odor stimuli without altering relative conditions such as pressure and temperature, in the nasal cavity. It consists of three main parts: a positive air pressure, a nasal mask, and a delivery system consisting of six capsules containing the odorants. The olfactometer is designed so that it can be put in the scanner room as all of its components are made of diamagnetic materials. The participants were eyes-closed during the scan. This system was controlled by a computer program to permit choosing of, and switching between, different types of stimulation. Odor and air

delivery timings, stimulus frequency, and choice of a specific odorant for stimulus presentation within any task were controlled by the software (Psychtoolbox MATLAB).

In this study, we used a block design protocol to perform our task. For each odor, the block consisted of two alternating sections: A 15-second odor presentation (e.g. eucalyptus; nature's alchemy Co. 100% pure natural essential oil), followed by a rest period of 45 seconds (fragrance-free air). These patterns continued for 300 seconds (five complete rounds for each aroma). This protocol ran over for rose odorant as well. We used eucalyptus and rose odor in this study because of the different natures of these odors in order to differentiate the pleasant and unpleasant odor stimulation and its related brain activation.

## 2.5. Data Analysis

### 2.5.1. Preprocessing

All of the analysis of fMRI data was performed by the fMRI Expert Analysis Tool (FEAT), part of FMRIB's Software Library (FSL, <http://www.fmrib.ox.ac.uk/fsl>) (version 5.0.9); details of our analysis is published previously [20, 21]. As a summary, first, we performed the Pre-processing steps, including skull-stripping for removing all non-brain tissues using Brain Extraction Tool, FSL (BET); then motion correction was carried out via MCFLIRT, FSL (Motion Correction from FMRIB's Linear Image Registration Tool). Thereupon, a slice-timing correction was accomplished with the help of Fourier-space time-series phase-shifting. Furthermore, normalization of the functional images to the standard Montreal Neurological Institute (MNI) brain atlas was fulfilled in two steps: Co-registering functional images of each participant to his/her high-resolution T1-weighted scan, with FLIRT (FMRIB's Linear Image Registration) and 7 degrees of freedom (DOF); and registering structural T1 images to the MNI space linearly, with 12 DOF. A Gaussian kernel of FWHM = 5.0 mm was used for spatial smoothing. Multiplicative mean intensity normalization of the volume at each time point was also performed. And finally, the data was filtered with high pass temporal filtering (Gaussian-weighted least-squares straight line fitting, with  $\sigma = 60.0s$ ).

### 2.5.2. First-Level Analysis

The General Linear Model (GLM) was performed using FEAT (version 6.0.0), FSL, for parametric statistical analysis. To make the statistical approaches valid and most efficient, a FILM (FMRIB Improved Linear Model) pre-whitening was utilized for statistical analysis of the fMRI time-series, devoting a "z-score" to the corresponding BOLD signal. In this method, a Boxcar function of tasks versus rest is created and convolved with a canonical hemodynamic response function and its temporal derivatives. As explained earlier, registration of the estimated functional map to the corresponding structural image and ultimately the MNI space was also carried out.

### 2.5.3. Higher-Level Analysis

Group-level analysis was performed under the FLAME procedure (FMRIB's Local Analysis of Mixed Effects), to estimate within-group averages as well as between-group comparisons. A voxel-level probability threshold of z-value > 2.6 was applied to clusters to reveal significantly activated regions only. Also, a False Discovery Rate ( $p\text{-FDR} < 0.05$ ) was used to correct for multiple comparisons.

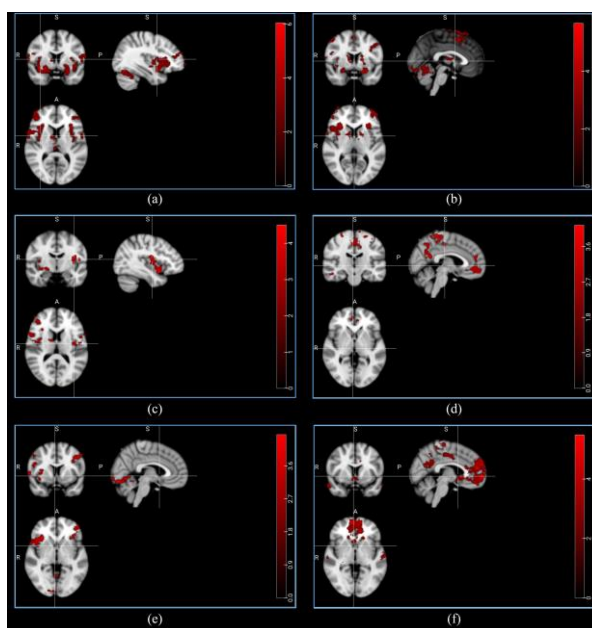
## 3. Results

### 3.1. Brain Activations in the Healthy Group

Brain activations in healthy individuals during the eucalyptus and rose odor stimulations are provided in Table 1 and Figure 1. As shown in this table, on average, in our control group stimulated with eucalyptus odor, significant activations were observed in the well-known primary and secondary olfactory cortices, including piriform cortex (specifically in the left amygdala), left orbitofrontal cortex, and left insula. In addition, regions related to emotion formation/regulation such as bilateral cingulate and paracingulate cortices were also activated. On the other hand, in the rose odor stimulation section, in addition to activating the same areas that were activated in the eucalyptus odor stimulation, the caudate area was also activated. In both odors, the activation of the thalamus was observed. When performing a statistical test between the brain activation patterns of healthy individuals relevant to the two odors, we could not identify any statistically significant difference between the brain activations relevant to the rose and eucalyptus odors.

**Table 1.** Activation of the brain areas when presenting the eucalyptus or rose odors. An average of the activations in the normal individuals, as well as the contrasts of normal > anosmic and normal < anosmic, are provided in the Table for both odors. Z = z-value of the activation; x,y,z = coordinates of the voxel with the highest z-value in the MNI standard space; R = right; L = left. IFG = inferior frontal gyrus; OFC = orbitofrontal cortex; G = gyrus; PSC: Primary somatosensory cortex; Sup = superior; SFG = superior frontal gyrus; Temp = temporal; Mid = middle

Brain Areas	Eucalyptus odor			Rose odor		
	Normal-Average	Normal>Anosmic	Anosmic>Normal	Normal-Average	Normal>Anosmic	Anosmic>Normal
	Z/ x, y, z	Z/ x, y, z	Z/ x, y, z	Z/ x, y, z	Z/ x, y, z	Z/ x, y, z
L cerebellum	5.32/ -26, -62, -22	---	---	5.68/ -8, -86, -24	3.66/ -4, -70, -16	---
R cerebellum	5.22/ 24, -62, -20	4.1/ 22, -64, -20	---	---	---	---
L Amygdala	4.11/ -22, -4, -14	---	---	4.29/ -24, 0, -14	---	---
R Amygdala	---	3.55/ 18, 0, -16	---	---	---	---
L IFG	---	---	---	---	3.82/ -42, 30, 16	---
R IFG	6.05/ 58, 14, 0	3.54/ 50, 8, 18	---	---	---	---
L OFC	4.05/ -20, 6, -22	---	---	---	---	---
R OFC	---	---	---	---	3.8/ 34, 28, -6	---
L lingual G.	---	---	---	5.19/ -10, -82, -18	---	---
L insula	---	4.24/ -38, 6, -14	---	---	3.72/ -28, 26, 2	---
R insula	---	4.5/ 38, -2, 2	---	4.45/ 34, 30, 6	3.8/ 36, 22, -2	---
L Thalamus	---	---	---	3.94/ -10, -4, 10	---	---
R thalamus	4.9/ 12, -4, 14	---	---	---	---	---
L Frontal pole	---	---	---	4.21/ -48, 46, 14	---	---
R Frontal pole	---	3.98/ 44, 42, 10	---	---	---	---
L Middle frontal gyrus	3.53/ -42, 40, 16	---	---	4.81/ -50, 16, 44	4.06/ -40, 28, 24	---
R PSC	4.32/ 66, -12, 20	---	---	---	---	---
R Caudate	---	---	---	4.14/ 10, 2, 12	---	---
R Frontal Operculum	---	---	---	---	3.54/ 42, 22, -2	---
R Putamen	---	3.63/ 28, 0, -10	---	---	---	---
L Precuneus	---	---	3.19/ 2, -62, 30	---	---	---
L Angular Gyrus	---	---	3.79/ -38, -58, 30	---	---	---
L Sup Frontal Gyrus	3.94/ -40, 52, 18	---	3.41/ -20, 26, 56	4.35/ -4, 18, 52	---	---
L Postcentral G.	---	---	4.02/ -2, -26, 66	---	---	3.82/ -44, -22, 58
R postcentral G.	4.32/ 66, -12, 20	---	3.78/ 10, -46, 66	---	---	---
L Precentral G.	---	---	3.76/ -22, -10, 64	---	---	4.2/ -10, -22, 44
R precentral G.	4.84/ 60, 8, 4	---	---	---	---	4.18/ 12, -30, 74
Paracingulate Gyrus	4.3/ -2, 16, 44	---	---	4.33/ -2, 14, 52	---	5.3/ 4, 50, 16
L Cingulate Gyrus	3/ -4, 22, 28	---	3.58/ -2, 38, -6	---	---	3.98/ -2, -4, 40
R Cingulate Gyrus	2.97/ 6, 22, 34	---	3.44/ 4, -50, 20	---	---	---
R SFG	---	---	---	---	---	4.85/ 2, 50, 24
L Sup. Temp. G.	---	---	3.39/ 58, 4, -14	---	---	3.64/ -60, -24, 4
L Mid. Temp.	---	---	---	---	---	4.06/ -52, -2, -24
R Hippocampus	---	---	---	---	---	3.5/ 28, -24, -14



**Figure 1.** The brain activation maps obtained for the six contrasts of interest: a) eucalyptus\_average\_normal; b) rose\_average\_normal; c) eucalyptus\_normal > anosmic; d) eucalyptus\_anosmic > normal; e) rose\_normal > anosmic; f) rose\_anosmic > normal

### 3.2. Brain Activations in Anosmic Patients

Our statistical analyses for averaging the brain activation maps of the anosmic patients, relevant to the two odors, showed that no brain regions survived this analysis, and therefore we could not identify any brain activations in this group.

### 3.3. Comparison of Normal and Anosmic Groups

As provided in Table 1, we compared the normal and anosmic groups in their brain activations in response to the two odors. The normal > anosmic condition shows the brain areas with higher activation in normals; however, as we had not observed any activation for the average of the anosmic group, the normal < anosmic group shows the deactivations of brain areas in the normal individuals during the odor stimuli.

A number of brain regions showed significant activation in the normal > anosmic condition, including bilateral (B) cerebellum, R amygdala, B inferior frontal gyrus, R orbitofrontal cortex, B insula, R frontal pole, L middle frontal gyrus, R frontal operculum, and R putamen. On the other hand, the following brain regions showed lower activation in the normal group, which is interpreted as deactivation in those brain areas: L precuneus, L angular gyrus, L superior frontal, B postcentral, B precentral, B

cingulate, R superior frontal, L superior, and L middle temporal gyri, as well as the R hippocampus.

## 4. Discussion

Our study was designed to distinguish the brain activity in patients with post-traumatic olfactory dysfunction from the normal population, using the fMRI data during the odor presentation. In comparison with the healthy group, patients showed no activation in the primary or secondary brain areas, either in stimulation with bimodal odor (eucalyptus) or unimodal (rose). There were a number of brain areas higher active in normal individuals during the odor stimuli, as well as a number of brain areas that showed deactivations during the stimuli, which will be discussed below.

We found the brain networks which showed activations in response to the two odors in the normal group, but those networks did not show statistically significant differences. Our findings in the normal group on pleasant and unpleasant odors were similar to previous studies [22]. In stimulation with both odors, the areas associated with the primary and secondary olfactory centers were activated. Compared to the smell of roses (pleasant), the smell of eucalyptus (bimodal), areas of cortical cingulate and paracingulate were activated, which was in line with the previous studies [22]. This could be explained by the well-known role of the cingulate cortex in painful stimulation, and pain regulation should be noted [23]. We found the activation of left OFC in the unpleasant odor stimulation which was confirmed in the previous study [15]. Overall, OFC is related to the judgment of hedonic and aversive stimuli and its left side is mostly associated with aversive smell [24]. It is notable to clarify that these differences are seen in average activation in both groups but there was no statistically significant difference in contrast between the two groups.

In the average of brain activations in the normal group, activation of the right supramarginal area was detected only in stimulation with eucalyptus in our results. This area is related to multisensory integration and it can be related to the bimodal nature of eucalyptus, and this activation was consistent with Frasnelli *et al.* study [19]. Most often early pieces of literature emphasized this claim that in contrast to all other sensations, there is no thalamic relay in the olfactory pathway to the neocortex [25].

In our study, activation of the thalamus in both odors was also recorded. Confirming our study, a recent study clarified the role of the thalamus in attention, discrimination, and learning of smells [26]. The thalamic pathway role in olfactory data processing was explored by Plailly *et al.* in a functional connectivity study. They demonstrated that piriform-thalamus-OFC connectivity plays role in attention augmentation to odors [27]. However, the role of the thalamus in olfaction is still a debate.

Besides olfactory-related cortices, areas such as the superior and middle frontal were also activated in both odors. Areas that are known to be part of the ventral attention network, which is responsible for bottom-up sensory-driven exogenous attention and reorienting to unexpected external stimuli [28]. The activation of these regions is because of passive stimulation and the need for reorientation to unexpected stimuli (specific odor in this context). A considerable difference between eucalyptus and rose stimulation in the control group was the activation of the caudate nucleus in the rose group. Savic *et al.* showed that the caudate nucleus accompanied by ACC and prefrontal cortices participate in the quality of odor than intensity [29]. On the other hand, caudate activation occurs in unexpected reward circuits and pleasure [30].

In the current study, inactivation was observed in the primary and secondary olfactory cortex including the amygdala, insula, and OFC, which was consistent with the same study in Korea [7]. Our findings also supported the hypothesis about the activation of the trigeminal nerve-related areas of the brain by pleasant odor which is declared in previous studies [8, 31]. These areas include the superior temporal gyrus, supramarginal gyrus, and prefrontal cortex. Recruitment of the middle temporal gyrus is observed in a previous study of the olfaction process which indicated the multifunction nature of olfaction [32]. Moon *et al.* also confirmed our findings in which an unpleasant odor (beta-mercaptoethanol) was used in their study, and they showed that this odor did not recruit trigeminal nerve-related cortex, and it seemed the unpleasant odor was more suitable for differentiating anosmic patients, than pleasant odor, because of false-positive effects of pleasant odor relating to trigeminal nerve activation [7].

Beyond the differences in primary and secondary olfactory cortices, areas including the inferior frontal gyrus and cerebellum were also inactivated in the

patients during stimulation with both odors (pleasant and unpleasant). These findings were supported by previous studies. Activation of the inferior frontal gyrus during smelling seems related to applying a specific name to the odor [15]. In addition, the role of the cerebellum in the smelling process is under question. We found inactivation of the cerebellum on both sides and in both odors which could be related to higher-order cognitive functions, including language and memory [33-37], which are used in correct odor labeling [16].

We reported some deactivations in particular brain regions, and decreases in the BOLD signal are puzzling for several reasons. The first is the synaptic complexity in the interactive networks, and the second includes the interplay between oxidative demand and perfusion in producing fMRI signal change. The third reason involves the relativity of both activation and deactivation to the choice of baseline in the fMRI task, and the fourth is that deactivations could reflect passive shunting of blood to activating areas as easily as they reflect active inhibition. However, understanding deactivations is necessary to fully understand how excitation and inhibition affect functional images [38]. As a result, observing the deactivation of a brain area during a cognitive task has several reasons. The first would be related to an effect called the “vascular steal” effect, in which a decrease in the cerebral blood flow in a region would most likely be arising from higher activity in nearby brain areas. Second, the inhibitory neuronal activity by other brain regions could be a reason for a decline in regional brain activity. Indeed, some recent studies in humans and rats [39] suggest that the inhibitory neurotransmitter GABA may be a key mediator of the negative BOLD responses. It is also illustrated that negative BOLD responses in fMRI could be produced in non-neuronal tissue. Finally, it is observed that some brain regions actually increase their activity during the so-called resting state, when subjects are instructed to relax and not focus on external or internal stimuli, which is observed as deactivation in fMRI [40].

This study provided supporting evidence for the fMRI's ability to diagnose and differentiate post-trauma anosmic patients from normal individuals, which emphasizes the clinical use of neuroimaging in this area. Despite endeavors to perform a robust study, the work suffers from a number of limitations. First, a larger sample size would be more ideal. Second, performing the functional connectivity estimation would enrich our findings, which is a suggestion for future works. Third, the deactivation

of the brain areas when being stimulated by an odor needs much more detailed interpretations. Finally, providing evidence on the brain activations when imagining an odor would help those centers with no access to the olfactometer to also perform an fMRI study on the human olfactory system.

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