Journal of Neuroscience Methods 218 (2013) 29–38

Contents lists available at SciVerse ScienceDirect

Journal of Neuroscience Methods

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

Clinical Neuroscience

A portable experimental apparatus for human olfactory fMRI experiments

C. Sezille, B. Messaoudi, A. Bertrand, P. Joussain, M. Thévenet*,[1], M. Bensafi*,[1]

CNRS, UMR5292, Lyon Neuroscience Research Center, University Lyon, F-69000, France

HIGHLIGHTS

- We developed a new inexpensive, non-voluminous portable olfactometer adapted for human fMRI experiments.
- The system adjusts odorant stimulus presentation to human nasal respiration.
- PID, psychophysical and fMRI measurements showed that the system can be used to achieve reliable odor percepts by human subjects.

ARTICLE INFO

Article history:
Received 25 March 2013
Received in revised form 23 April 2013
Accepted 24 April 2013

Keywords:
Mobile olfactometer
Human olfaction
Psychophysics
Sniffing
fMRI

ABSTRACT

Human olfactory perception can be measured using psychophysical tools or more complex odor generating devices systems, namely olfactometers. The present paper is aimed at presenting a new inexpensive, non-voluminous portable olfactometer adapted for human fMRI experiments. The system adjusts odorant stimulus presentation to human nasal respiration and records behavioral responses in the same experimental device. Validation by psychophysical measures and photo-ionization detection showed a linear increase in both odor intensity perception and vapor concentration as a function of odorant concentration. Further validation by brain imaging revealed neural activation in typical olfactory areas. In summary, the system represents a new low-cost, easy-use, easy-maintenance portable olfactometry tool for brain imaging, opening up new possibilities for investigating neural response to odors using event-related fMRI designs.

1. Introduction

Olfactory perception in animals and humans enables detection and discrimination of thousands of odorant molecules present in the environment. Odor perception can be assessed in children, young and old adults, with behavioral, psychological and psychophysical examination (Doty et al., 1984; Freiherr et al., 2012; Hummel et al., 1997; Rinck et al., 2011; Thomas-Danguin et al., 2003) or more complex odor generating devices, namely olfactometers. Olfactometry applications comprise exploration of odor perception in animals (Bodyak and Slotnick, 1999; Joly et al., 2004) and humans, using psychophysics (Ikeda et al., 1999; Jacob and Wang, 2006; Johnson et al., 2003; Kermen et al., 2011; Laudien et al., 2008; Pause et al., 2009; Rouby et al., 2009), electroencephalography (Kobal, 1981; Murphy et al., 2000; Pause et al., 2009; Poncelet et al., 2010) and functional brain imaging (Anderson et al., 2003; Bensafi et al., 2012a,b; Gottfried et al., 2002; Johnson and Sobel, 2007; Lorig et al., 1999; Lowen and Lukas, 2006; Lundstrom et al., 2010; Popp et al., 2004; Rolls et al., 2003; Small et al., 2005; Sobel et al., 1997; Sommer et al., 2012; Vigouroux et al., 2005).

Sobel et al. (1997) described a system for generating olfactory stimuli for humans within a functional magnetic resonance imaging (fMRI) experimental design. Their system incorporates a nasal mask in which the change from odorant to no-odorant conditions occurs in less than 500 ms and is not accompanied by visual, auditory, tactile or thermal cues. Vigouroux et al. (2005) presented a semi-automatic olfactometric system suitable for PET and fMRI experiments, enabling multiple odorants to be used within the same study. Johnson and Sobel (2007) described an odor generating devices based on an odorant canister generating known concentrations for a great variety of odorant molecules routinely used in the field. More recently Lundstrom et al. (2010) and Sommer et al. (2012) developed inexpensive devices that can be used in psychophysiological (Lundstrom et al., 2010) or fMRI (Sommer et al., 2012) settings.

In the same vein, the present paper presents a new inexpensive, non-voluminous portable odor diffusion system adapted for fMRI experiments, enabling (i) presentation of odorant stimuli adjusted to human nasal respiration (sniffing), and (ii) behavioral response recording (response time and perceptual rating) on the

* Corresponding authors at: CNRS, UMR5292, INSERM U1028, Lyon Neuroscience Research Center, 50 Avenue Tony Garnier, University Lyon, F-69366, France. Tel.: +33 437287497.
E-mail addresses: mthevenet@olfac.univ-lyon1.fr (M. Thévenet), bensafi@olfac.univ-lyon1.fr (M. Bensafi).

[1] These authors contributed equally to this manuscript.

0165-0270/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jneumeth.2013.04.021

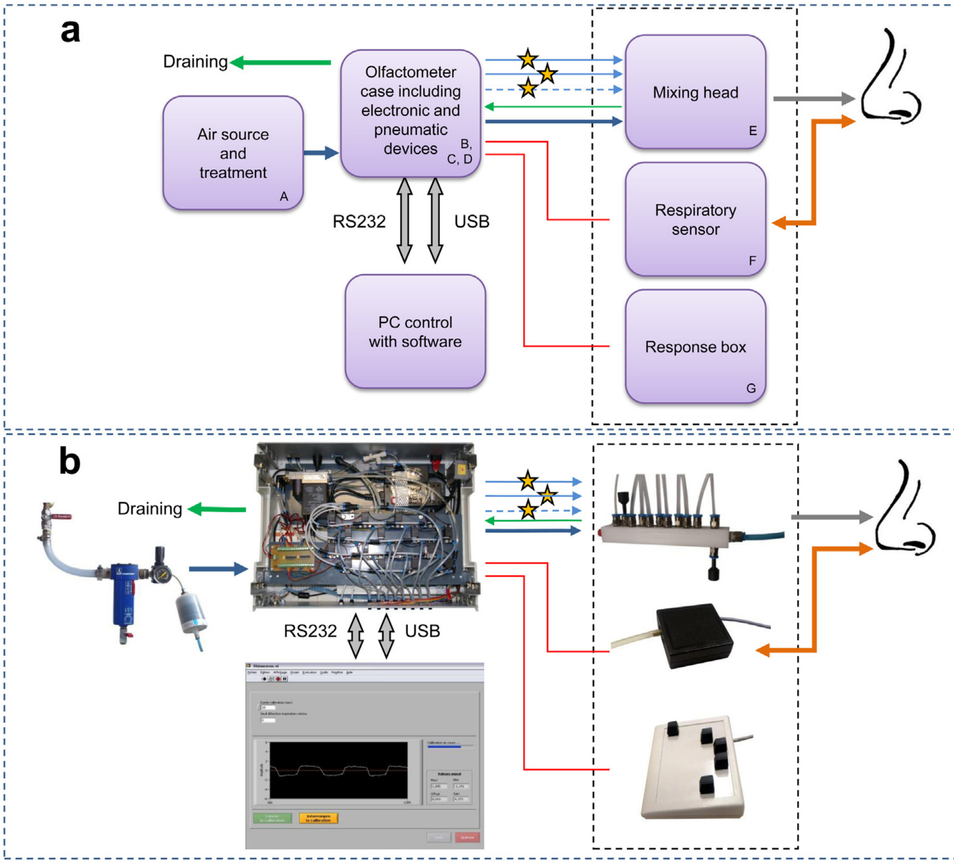

Fig. 1. (a) Diagram; (b) photos: the device is composed of five modules: (1) air source and air treatment system, (2) stimulation apparatus, (3) mixing head, (4) respiratory sensor and response box, (5) software. Stars illustrate odor containers. Letters A–G refer to the components of the olfactometer listed in Supplementary Table 1.

same experimental device. A methodological section presenting the system in detail will be followed by three experimental and results sections recording psychophysical and photo-ionization detection measures and fMRI responses to odors.

2. Materials and methods: the olfactometer

The device is composed of five modules (Fig. 1): (1) an air source and air treatment system, (2) a stimulation system (including both electronic and pneumatic devices), (3) a mixing head coupled to a delivery system enabling diffusion of odorized air in the subject's nose, (4) a respiratory sensory system that triggers the olfactometer according to the subject's nasal respiration, and a response box used to collect subjective odor evaluations, and (5) the software control system. These five "modules" are presented below, followed by a detailed description of all olfactometer components with their maintenance, references and cost.

2.1. Airflow source and air treatment

Vector air directly comes from the laboratory distribution network (Fig. 1) or a portable air compressor. A pressure regulator is used to control exact pressure in a range from 1.5 to 3.0 bar (miniature series 07 regulator, Norgren SAS, France) and the pressure is checked by a manometer (airflow should be set around 10 l/min). Vector air is then conveyed through an activated charcoal filter for odor annihilation (Whatman Inc., New Jersey, USA). After treatment, airflow is directly sent to the olfactometer apparatus through a 6-mm diameter polyurethane tube (SMC, France).

2.2. Stimulation apparatus

2.2.1. General concept and odor source system

The olfactometer produces an odorized airflow controlled in terms of flow, intensity and time activation. Like many other systems, the general concept is to mix an odorized and a pure airflow (air carrier), each flow being controlled independently. It is designed to send a permanent air flow to the subject's nose; the flow is non-odorized by default and becomes odorized only during stimulation. As it will be described below, the pneumatic system (combining equalization and aspiration) allows the odorized airflow to be delivered and stopped with very precise timing. In addition, no variation in tactile stimulation is perceptible, as overall flow remains constant without any pressure variation.

To obtain an odorized airflow with stable intensity over time, the odorous substance can be conditioned under pressure in the saturated steam state using two approaches:

(1) A U-shaped Pyrex® tube (VS technologies, France; volume: 10 ml; length: 50 mm; external diameter: 14 mm) filled with odorized microporous substances (e.g. cotton) closed by two phenolic resin stoppers. Air-tightness is ensured by a polytetrafluoroethylene or silicone joint (Fig. 2a).
(2) Bottles filled with liquid odorants: as described by Sommer et al. (2012), the present olfactometer can also use gas washing bottles comprising an glass input tube and an output (NS 29/32, 250 ml, Wertheim, Germany). In this case, the airflow bubbles through the input tube and reaches a large surface of liquid odorant (volume, 50 ml). The odorized airflow is then diffused to the output of the gas washing bottle. Air-tightness is ensured by silicone tubing (Fig. 2b).