An MR Compatible Olfactometer for Clinical Research Use

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Abstract

Functional neuroimaging of the human olfactory system has gained increased interest during recent years, especially using functional Magnetic Resonance Imaging (fMRI). These studies of the olfactory system place special demands on how to present the odorant stimulus to the participants. There are commercial olfactometers on the market, but most are not MR compatible and are typically used for environmental odor detection. Therefore, the majority of individuals involved in olfaction research with fMRI usually custom-build an olfactometer for their particular research. The aim of this study is to build a cost effective MR olfactometer suitable for clinical and laboratory environments.

Method

Olfactometer:

The custom-built MR compatible olfactometer is based on the principles of air dilution olfactometry [1,2]. The olfactometer is composed of three main components – a controlled valves unit, a signal control unit and a Windows based laptop computer. It also consists of an air compressor and a vacuum pump. The olfactometer is controlled by a laptop computer with a Windows based operating system, which gives the ability to transfer the system to different scanning rooms and it is easy to store. The control interface programs are written in the LabVIEW and communicated with the olfactometer through NI USB-6221. The controlled valves unit contains 12 solenoid valves in 2 groups that provide multiple odor stimuli. Independent solenoid valves, which provide a constant airflow and a vacuum airway, are open when not activated. All connecting tubes are Teflon tubes (low absorbent material); except the tubing for the vacuum. A nasal CPAP mask is used. Gas washing bottles are used to hold different odorant stimuli. The bottle holder is secured on a non-magnetic stand, which can be wheeled as close as possible to the magnet without interference to the subject when lying on the sliding platform. All the tubing is extended through a waveguide connected to the olfactometer, which is located outside the scanning room, since the magnetic environment of the scanning room hinders the use of electronic devices. A simplified schematic is shown in figure 1.

Characteristic Testing:

Since a precise control of the temporal characteristic is important for the analysis of any fMRI paradigm, it is important to know the temporal response of the stimulus device. An apparatus was built to determine the temporal resolution of the custom-built olfactometer in this study. It was built with the method similar to Johnson et al., 2003 [3]. Instead of using a Mercury and Argon lamp as the light source, an ultraviolet light-emitting diode (UV LED), with peak wavelength of 255 nm ± 5 nm, was chosen because of low heat generated and a longer life span. A quartz tube was placed between the UV LED and the UV-sensitive detector, with a spectral sensitivity range of 220 to 360 nm and maximum of 280 nm. Acetone is used as a UV absorber, which is one of the most commonly used solvents, inexpensive, and has a wider wavelength range of the electromagnetic energy spectrum.

The characteristics of the olfactometer would be tested with different durations of the pulse, and the flow rate set at 1 LPM. Through these tests, the delay time of the olfactometer (stimulus being delivered) was examined. Three different flow rates (0.25, 0.5 and 1 LPM) and different lengths of Teflon connecting tubes that are attached to the olfactometer (with 1 LPM) were tested for the length of delay in delivering the testing odorant.

Subjects and stimuli:

Normal healthy subjects participated in testing the olfactometer: 2 males and 4 females, aged 20-43 years (mean age = 28.83 SD = 8.3; mean age for male is 38 and for female is 24.25). Odorant stimuli included chocolate, vanilla, banana, flatulence, cat urine and garbage.

Imaging:

Imaging was performed using a Philips 3T Gemini MRI. fMRI data were acquired using an EPI-acquisition (TR=2000ms, TE=27ms, FOV=21cm, matrix =128x128, 19 slices, thickness=2.5mm, b-factor=1250 s/mm^2). Correlation maps were generated with BrainVoyager.

Results

Olfactometer:

The characteristics of the olfactometer are shown in figure 2. One can notice that there is a time delay before the testing odorant is delivered. After the trigger point (at 1 sec), all pulses have a delay of approximately 0.9 of a second before the voltage starts decreasing. This delay time is caused by the length of the connected tubing used in this study. This delay is very consistent and is linear with the length of the tubing. One can take this delay into account when acquiring or analyzing the functional data. The delay time of the flow rates were approximately 8.13 sec, 1.73 sec and 1 sec (with 0.25, 0.5 and 1 LPM respectively), and the voltage fluctuations were approximately 0.63 mV, 1.85 mV and 2.44 mV (with 0.25, 0.5 and 1 LPM respectively). Temporal response characteristics were also investigated with respect to flow rate. The higher the flow rate, the shorter the delay time. Also, the stronger the flow rate, the stronger the concentration of the odorant stimulus being delivered.

Imaging:

A simple block paradigm was used with a few standard odors (Vanilla, Banana and Chocolate). Activations were found in piriform cortex , insular cortex and DLPFC during the olfactory stimulation with the olfactometer (figure 3). These areas are known to be activated with olfactory stimulation.

Conclusions

We build an MR compatible olfactometer that can reliably present olfactory stimuli into a subject during fMRI. Stimulus was delivered in the absence of thermal, auditory and tactile indication. The whole system is compact and can easily be transferred to different locations, especially in a clinical environment as space is essential. Moreover, the total cost to build this system is just a fraction of the cost of a commercial MR compatible olfactometer.

Reference

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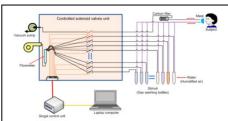
Fig 1: Simplified schematic of the olfactometer.
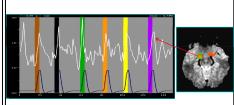

Fig 2: The characteristics of the olfactometer.

Fig 3: The activation of the piriform cortex.