Optimized fMRI imaging protocol and hardware for studying the orbitofrontal cortex in the presence of olfactory stimulation

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Abstract

Research has recently reported an increased number of neurological and psychiatric diseases associated with olfactory dysfunction. These diseases are: Alzheimer's disease (AD), schizophrenia, multiple sclerosis (MS), epilepsy, Parkinson's disease (PD) and obsessive-compulsive disorder (OCD). The most common theme associated with OCD is contamination concern, which is an intense feeling of having been polluted or infected. There is a well-established relationship between olfactory identification and the orbitofrontal cortex (OFC), which is the key structure affected in OCD [1]. Previous studies using functional magnetic resonance imaging (fMRI) show activations in OFC during olfactory stimulation with pleasant and unpleasant odorant stimuli [2,3]. However, there have been limited studies in this area because of two main issues: the non-availability of olfactometers and it is always problematic imaging OFC due to susceptibility artifacts. It is near an air/tissue interface which has large susceptibility differences, which cause image distortions and signal losses [4]. This study is to investigate a method to improve acquiring fMRI images of the OFC in OCD patients using an in-house olfactometer

Method

Fourteen healthy subjects participated in an intensity and pleasantness survey to grade the stimuli which would be suitable to use in the study (figure 1). The magnitude scale for intensity is from range 0 to 100, and the hedonic scale for pleasantness is from range -100 to 100. A custom-built, 12-channel, computer-controlled, MR compatible olfactometer was used to deliver the odorant stimuli to the subject in the MRI scanner. The system is free of auditory, tactile and thermal shifts which could indicate the onset of the odor delivery to the subject. Nine subjects participated in this part of the study. Subjects were requested to count how many stimuli were given, pleasant and unpleasant, and identify what kind of the stimuli were during the fMRI session. Subjects reported the results after the fMRI session.

In order to reduce signal dropout and image distortion, functional data was acquired in the coronal plane using a segmented EPI sequence. Because of the requirement for temporal resolution we were only able to cover 34 slices. For the purpose of group analysis and coregistration we also acquired a one volume larger coronal dataset consisting of the 34 fMRI slices and an additional 34 slices for a total of 68 slices covering the whole brain. In addition local shimming was performed focusing on the OFC regions to reduced filed inhomogeneity. The partial brain images would be co-registered with the full brain images. Then the result images would be co-registered with a MNI template, which would be used for "group analysis" in the future.

Subjects:

Normal healthy subjects participated in testing the olfactometer: 5 males and 4 females, aged 20-43 years (mean age = 28.83; mean age for male is 33.2 and for female is 24.25).

Fourteen healthy subjects participated in the pleasantness and intensity survey: 6 males and 8 females.

Stimuli:

Two groups of odorant stimuli were used: pleasant (positive hedonic value) and unpleasant (negative hedonic value). The pleasant group of stimuli is chocolate, vanilla and banana; and the unpleasant group is flatulence, cat urine and garbage. All 6 of these odors were presented once for 8 seconds followed by a random jittered rest period of 30 to 42 seconds. Each scan was repeated 4 times with a pseudo randomized order of the odors. Each scan lasts about 5 minutes.

Imaging:

Imaging was performed using a Philips 3T Gemini MRI. fMRI data were acquired using a segmented EPI-acquisition (TR=4000ms, TE=18.3ms, 3 EPI segments, FOV=23.1cm, matrix =112x112, 34 slices, thickness=2mm, b-factor=1250 s/mm^2). Correlation maps were generated with FSL (FMRIB Software Library, UK).

Results

Analysis of stimuli versus rest showed activations in the amygdala, insular cortex. In pleasant – unpleasant comparisons, activations were found in OFC and ACC, but not in the amygdala. These areas had very similar activations with olfactory stimulation from previous studies [2,5]. Medial orbitofrontal cortex correlated with pleasantness; activations were shown in both correlation maps. In previous investigation, activations in ACC were negatively correlated with pleasantness [5]. That may be the reason that there were activations in this area with pleasant verse unpleasant, and not in all stimuli verse rest. In Grabenhorst et al. 2007, the activations in the primary olfactory areas were correlated with the intensity rather than pleasantness. This may be the reason that there were activations in the amygdala in stimuli verse rest, but not in pleasant verse unpleasant. Activations of one subject are shown in figure 2.

Conclusions

Subjects could identify the pleasantness and unpleasantness of the odorant stimuli, but could not completely identify what the stimuli were. They also reported that the intensity detection was moderate, and not overwhelmingly strong, especially with the unpleasant stimuli. Axial orientation was tried with EPI-acquisition. However, regions in the OFC were either not visualized or had severe distortion and no activation was detected in the OFC. When acquisition was changed to the coronal plane with segmented EPI-acquisition, there were significant increased activations not only in the OFC area, and were also found in the ACC. These are the pilot data to determine the optimum protocols, improving acquired OFC images and choice of stimuli to be used. We conclude that we have a workable protocol to study the OFC using an olfactometer in and fMRI paradigm.

Reference

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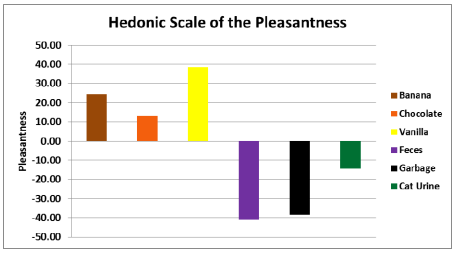

Fig 1: The Hedonic Scale of the pleasantness of the stimuli.

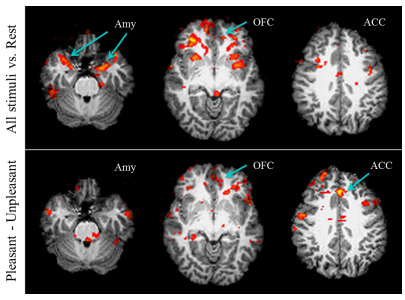

Fig 2: The activations of the correlation maps.