Reduction of Magnetic Susceptibility Artifacts in Olfactory fMRI with SENSE-GESEPI-EPI Method

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Introduction:

The severe magnetic susceptibility artifacts (signal loss and geometric distortion) in the inferior brain areas pose a difficult challenge in conducting functional MRI (fMRI) studies. To remove the artifacts for consistent fMRI mapping, we developed the Gradient-Echo Slice Excitation Profile Imaging (GESEPI) technique [1]. Combining the GESEPI technique with state-of-the-art SENSE technology yields an effective method (SENSE-GESEPI-EPI) for fMRI analyses with magnetic susceptibility artifact reduction. The human olfactory brain structures overlap with these artifact-laden orbito-frontal brain areas. The goal of this study was to investigate the effectiveness of SENSE-GESEPI-EPI for detecting olfactory fMRI activation in brain areas with severe artifacts.

Methods:

Human Subjects Fourteen healthy participants (age = 71.3 $\pm$ 8.9 years, 9m, 5f) were screened for neurological, psychiatric and olfactory diseases and generated normal University of Pennsylvania Smell Identification Test [2] scores (average score = 33.4 $\pm$ 2.9). The investigation was reviewed and approved by the Institutional Review Board of the Penn State University College of Medicine, and all volunteers provided written informed consent prior to participation.

Odorant The two odorants used in this study were lavender and citrus (Quest International Fragrances Co.). Each was diluted to 1% intensity, in 1,2-propanediol (Sigma). The odorant concentrations were determined from prior psychophysical testing.

fMRI Study Protocol The SENSE-GESEPI-EPI images were acquired on a 3.0 T system (Integra, Philips Medical Instrument) with a SENSE Factor = 2 from a transverse brain section of 6.56 cm in the inferior-superior direction using TR / TE / FA (repetition time / echo time / flip angle) = 300 ms / 16.4 ms / 45°, FOV = $230 \times 230 \times 48$ mm^3, matrix = $80 \times 80 \times 48$, and slice thickness = 1 mm. The olfactory stimulation paradigm consisted of two odors, each presented for 6 seconds, followed by a 30 second resting period of clean odorless air; odors were presented a total of four times. During execution of the fMRI paradigm, breathing instructions were given to participants at a rate of 10 cycles / min (3 sec: "Breathe In" and 3 sec: "Breathe Out"). Odor presentation with a home built olfactometer [3] with a flow rate of 8 L / min was synchronized with image acquisition and began 1 sec before breathing in.

Data Processing and Analysis The fMRI data were normalized to the Montreal Neurological Institute brain template [4] and statistically analyzed (student *t-tests*) using SPM2 [5].

Results:

To test the effectiveness of SENSE-GESEPI-EPI in olfactory fMRI in the brain areas with severe artifacts, the subjects received an olfactory fMRI paradigm twice in one session: once with SENSE-GESEPI-EPI and once with conventional EPI. All other imaging parameters were kept the same. The activation maps in the base of the brain with the two acquisition methods were compared. To demonstrate the severity of the artifact and its reduction with our method, Figure 1 shows the same olfactory activation map obtained with the specialized imaging technique overlaid onto T_1 anatomical (a), SENSE-GESEPI-EPI (b) and conventional EPI (c) image sets. Significant activations were now clearly observed in the primary olfactory cortex including the areas of the olfactory tubercle, anterior olfactory nucleus, piriform cortex and amygdala [6].

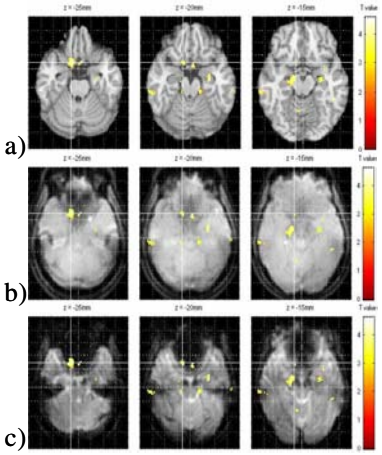

Figure 1: Olfactory activation (n = 14, p = 0.005), in the anterior olfactory nucleus, olfactory tubercle and piriform cortex acquired with SENSE-GESEPI-EPI; overlaid on T1-weighted anatomical (a), SENSE-GESEPI-EPI (b) and conventional EPI (c) images.

Discussion:

Due to the anatomical structure of human brain, the artifacts in the olfactory bulb region are the strongest. The success in detection of olfactory activation in this brain area demonstrates that the SENSE-GESEPI-EPI is highly effective in artifact reduction and fMRI data acquisition. This result is remarkable because it is, to our knowledge, the first time that this has been achieved in humans. The SENSE-GESEPI-EPI technique provides an effective tool for fMRI studies of olfactory activation in ventral brain structures that are usually difficult to image. Olfactory deficits are known to occur in early Alzheimer's disease (AD), brain trauma, and other neurological and psychiatric disorders. The success in detecting functional activity in key olfactory brain areas demonstrates that the SENSE-GESEPI-EPI method is highly effective in artifact reduction and fMRI data acquisition, enabling future research into physiological changes with age and pathophysiology of diseases such as mild cognitive impairment, AD, concussion, and other neuropsychiatric disorders.

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