Default Mode Network (DMN) Activity during Olfactory Processing

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Introduction:

The dynamics of resting state networks during active and passive task performance has received increased attention in recent times [1, 2]. Several studies have reported modulations in the default mode network (DMN) (or deactivations) during the performance of sensory- and cognitive- fMRI tasks [1, 2, 3]. However, no study has investigated such modulations in relation to olfaction. Using olfactory fMRI (with a relatively long rest period), we demonstrate that not only the DMN but also its modulations can be detected by Independent Component Analysis (ICA). The interaction between olfactory network and the DMN is of special interest because both are implicated in higher-order cognitive processing [4, 5].

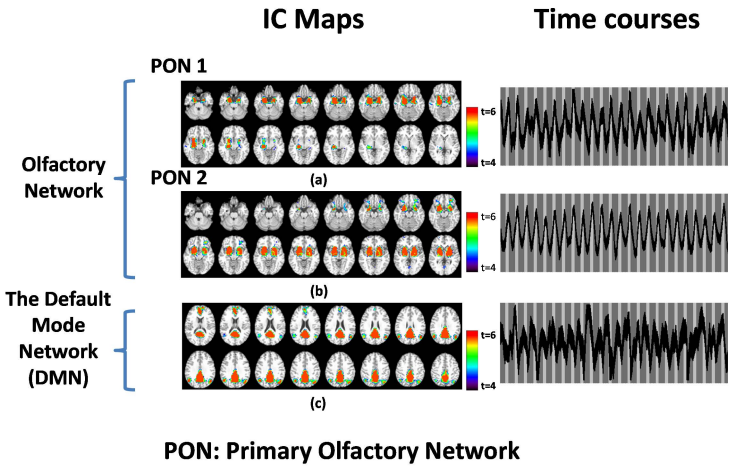

Figure 1. 1). **(a)** & **(b):** Two task-related ICA maps that subserve olfaction and 2) (**c**): The default mode network (DMN). All networks are detected during the performance of the olfactory fMRI task.

Materials and Methods:

Thirty-one healthy subjects (mean age 70 ± 10 yrs.) took part in the study at Hershey Medical Center (Penn State) with IRB approval. The olfactory function of all participants fell within the normal range when assessed using the University of Pennsylvania Smell Identification Test (UPSIT). An MR compatible olfactometer (with a flow rate of 8 L/min and synchronized with image acquisition and visual cues) was used for stimulus presentation. Three rounds of four different odorant intensities (6s per stimulation) were presented to the subject's nostrils sequentially. Odor stimulation was interleaved with a 30 sec rest period of odorless air presentation. This olfactory fMRI task is referred to as four-strength paradigm in the text below [6].

MR images of the entire brain were acquired using EPI on a Siemens Trio 3.0 T system with the following parameters: TR / TE / FA= 2000 ms / 30 ms / 90°; FOV = 220 × 220 mm^2; acquisition matrix= 80 × 80, 30 slices; slice thickness= 4 mm, and the number of repetitions= 234.

The group ICA analysis was based on FastICA algorithm and performed according to the methods outlined elsewhere [6]. We used individual IC time courses of respective subjects as input to perform subsequent correlation analysis.

Results and Discussion:

Figure 1 [(**a**) and (**b**)] shows two task-related group ICA components that sub-serve olfaction [i.e., Primary olfactory network (PON) 1 and PON 2]. These networks encompass: (a) Primary Olfactory Cortex (POC), amygdala, hippocampus, and insula; (b) striatum and putamen. **Figure 1** (**c**) shows the DMN detected during the performance of the four-strength olfactory fMRI task. **Figure 1** (right hand side) shows the associated averaged time courses for each of these networks. **Figure 2** shows the estimated Hemodynamic Response Function (HRF) for the respective networks during fMRI task performance. The two odor-related networks (i.e., PON1 and PON 2) show similar activation patterns based on their respective HRFs. However, the DMN network exhibits clear task deactivation during odor stimulation. This pattern is reversed during the rest condition.

The correlation co-efficients of the average time courses of PON 1, PON 2 and DMN with the on-off task reference function (shifted by 2 TRs) were: 0.54($p<0.001$), 0.75 ($p < 0.001$) and -0.42 ($p < 0.001$).

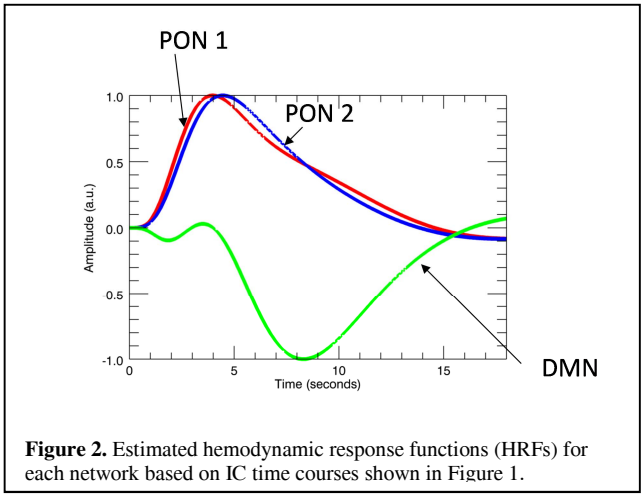

Figure 2. Estimated hemodynamic response functions (HRFs) for each network based on IC time courses shown in Figure 1.

Conclusion:

Our unique imaging paradigm provided a straight forward method to obtain both the spatial and temporal information about task-related as well as DMN during olfactory fMRI task performance. It has been shown that activity in the DMN may persist through both experimental and rest epochs if the experiment is not sufficiently challenging. Since our results clearly show DMN deactivation during odor stimulation, we conclude that our task is subserved by higher-order cognitive processing. This result helps explain why people with cognitive deficits perform poorly in smell identification tasks. Overall, our results establish a functional connection between these three networks and highlight the importance of DMN in olfaction. Deactivation of the DMN during stimulation has also been attributed to better task performance. Therefore, a time-series analysis of the DMN activity should provide a measure of the degree to which a task engages a subject and whether it is sufficient to interrupt the processes mediated by the DMN. Since ICA can provide both the spatial (both task related and unrelated) and temporal information regarding brain network dynamics it is, therefore, uniquely suitable for examining neural network disruptions by neurodegenerative diseases such as Alzheimer's disease (AD) and Parkinson's disease (PD) [7].

References: [1]. Greicius M.D., et al.; Journal of Cognitive Neuroscience 2004; [2]. Fryer, S. L., et al.; Front. In Psy. 2013; [3]. Calhoun, V.D. et al.; HBM 2008; [4]. Gottfried J.A., et al.; Nat Rev Neurosci 2010; 11(9): 628-41; [5]. Yeshurun Y., et al. Annu Rev Psychol. 2010; 61:219-41; [6]. Karunanayaka et al., HBM 2013; [7] Wen Li, et al; Brain 2010; 133: 2714–2726.