An fMRI Analysis of Driving-Related Networks with Independent Component Analysis Applied in a Between-Condition (BC-ICA) and Within-Condition (WC-ICA) Manner

Vince CALHOUN[1], James PEKAR[2], Tulay ADALI[3], Godfrey PEARLSON[4],
[1]Johns Hopkins University, 600 North Wolfe Street, Baltimore, Maryland United States; [2]Johns Hopkins University, F.M. Kirby Research Center, Kennedy Krieger Institute, Baltimore, MD ; [3]University of Maryland Baltimore County, Dept. of CSEE, Baltimore, MD United States; [4]Johns Hopkins University, Baltimore, MD United States;

Introduction

A fMRI paradigm was developed which allows the comparison of virtual in-scanner "driving" with passive watching. Independent component analysis (ICA) was applied to the entire data set in a between-condition manner (BC-ICA). We introduce a within-condition ICA (WC-ICA) which enables the comparison of regions within epochs of a single type without relying upon cognitive subtraction. Results demonstrate the feasibility of importing a driving-related task into the fMRI environment and report on the flexibility of ICA methods.

Methods

ICA is a method for recovering linearly mixed independent signals. [1-3]. ICA is well suited for the analysis of the imaging data produced by our fMRI paradigm. Spatial ICA does not impose constraints upon the time course. This is especially useful as, due to the complexity of our driving task, we do not have a model of the time course. Additionaly, ICA does not require one to make an implicit assumption about the hemodynamic time course of the brain, which is known to vary both across the brain of individuals and across individuals.

Using a Philips NT 1.5 T scanner, 600 functional scans were acquired (EPI, TR=1s, TE=39ms, fov=24cm, 64 x 64, st=5.5 mm, 18 slices). Thirteen subjects were scanned during two runs of a 10 min. paradigm consisting of 1-min. epochs of 1) a black screen, 2) watching the driving game Need for Speed II while moving their hands (passive), or 3) playing the driving game (driving). The driving and passive epochs were randomly alternated across runs to control for order effects. Subjects were trained to asymptote performance prior to scanning. A control device similar to a controller from a video game was built. Subjects saw images on a screen, subtending a visual angle of 25 degrees, via a mirror.

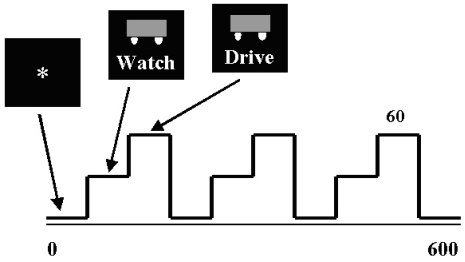

Figure1: Virtual Driving paradigm

Data Analysis: The images were corrected for timing differences between the slices [4,5]. Next data were imported into SPM99, motion corrected, spatially smoothed (6x6x10mm) and normalized into a Tailarach template [6,7]. SPM99 was used to compare active vs. passive epochs after band-pass filtering. ICA was calculated for 1) the entire experiment or 2) each type of condition individually. Twenty components were estimated after reducing the data via principle component analysis (PCA). WC-ICA was performed by concatenating the similar epochs and analyzing only that data, resulting in three ICA calculations (asterisk, driving, and passive). The component maps were analyzed manually for simularity and those that demonstrated a high degree of simularity were grouped. The components within each group were then normalized and averaged across subjects to create a set of "group" ICA images for each type of epoch. Comparisons between conditions can then be performed using the WC-ICA maps. Each group image was thresholded ($p<0.001$) and overlaid onto one of the EPI images.

Results

Driving: We obtained quantitative in-scanner driving measures (e.g. crash ratio, lane deviation, etc.). Performance was consistent across subjects.

SPM: SPM results indicated activation in cerebellum, thalamus and superior parietal regions and deactivation in orbito-frontal and inferior temporal regions.

ICA: BC-ICA results indicated activation in cerebellum, primary visual, superior and inferior parietal, anterior cingulate, primary motor cortex, and supplemental motor areas. WC-ICA results for the driving and passive conditions for two components (Figure 2) indicated frontal-eye fields, increased superior parietal (driving only) and cerebellar activation (larger in driving).

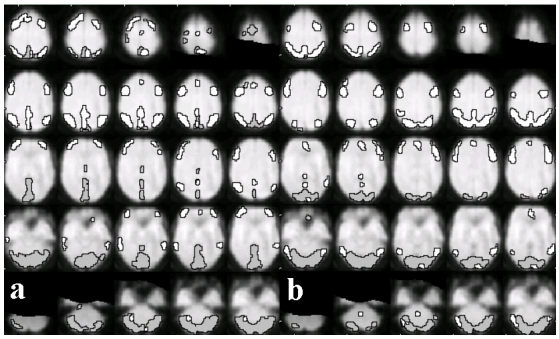

Figure 2: WC-ICA results for (a)passive and (b)driving

We plotted the averaged time course for the cerebellar/visual component (gray in Figure 2) for the driving and passive conditions. Note that the passive condition (Figure 3a) shows a consistent activation whereas the driving condition does not (Figure 3b). The subjects drive differently thus these time courses tend to average to zero whereas the passive condition averages constructively. Note that the beginning of the passive condition is affected by previous epochs.

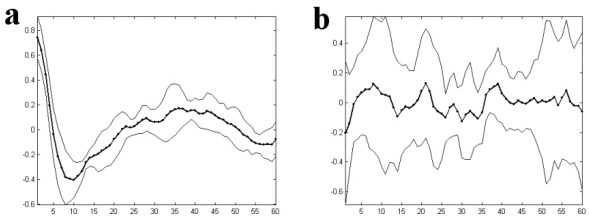

Figure 3: Averaged time courses during the (a)passive or (b)driving condition

Discussion

We have demonstrated the feasibility of importing a quantifiable virtual driving paradigm into the fMRI environment. We have also introduced within-condition ICA analysis (WC-ICA), an extension of ICA, by analyzing concatenated fMRI data from epochs of a single type. This is relating to correlational studies of functional connectivity in the resting state [8]. The success of WC-ICA suggests that the activities under study are effecting discernable hemodynamic changes even within a given condition.

References

1. Bell A and Sejnowski, T Neural Computation 7, 1129-1159 (1995). 2. McKeown M, et al. Hum.Brain Mapp. 6, 160-188 (1998) 3. Calhoun V, Pekar J NeuroImage 11:S682 (2000). 4. van de Moortele P, et al. NMR Biomed 10:230 (1997). 5. Calhoun V, Golay X, and Pearlson G Proc. ISMRM, 9th Ann. Mtg (2000). 6. Worsley, K and Friston, K NeuroImage 2, 173-181 (1995). 7. Talairach J and Tournoux P, Thieme, Stuttgart (1988). 8. Biswal B, et al., MRM 34, 537-541 (1995).