Assessing reliability of ICA estimates by resampling and clustering

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Objective

Analysis of artificially generated fMRI-like data drawn from a single-shot gradient-echo MR EPI block-based visual stimulation paradigm was performed by the stochastic neuromorphic extended Infomax algorithm implementing spatial independent component analysis (sICA) [1]. Reliability assessment of the results was carried out by resampling-based techniques. Fourier and wavelet transforms, which contain weak implicit models of temporal noise, and whitening, which is driven by an explicit noise model, were employed to resampling and setting the appropriate thresholds [2]. Variance estimate that is highly correlated with the separation error [3] was used as model selection criterion for optimizing the parameters of the sICA algorithm.

Methods

ICA is a data-driven multivariate exploratory analysis based on the covariance paradigm and formulated as a generative linear latent variables model. Non-square ICA model alleviates data overfitting and allows statistical assessment of the estimated independent components (ICs) but inevitably deviates from the best linear fit. In contrast to inferential approaches, exploratory analysis like ICA reveals task-related, transiently task-related, and function-related activity without reference to any experimental protocol, including unanticipated activations. Data model selection was performed in compliance with a structural measure introduced in projection pursuit [4]. The first most energetic 6 ICs were used to artificially generate back 6 independent clusters, each consisting of *12* components obtained by resampling and used to assess the reliability of ICA projections (Fig. 2).

Results

A healthy subject run *24* identical sessions while scanned at *1.5* T. Acquisition and reconstruction matrices were *64* x *64* x *35* with voxel size *3.8*mm x *3.8*mm x *3.75*mm. Sessions consisted of *72* volumes acquired at *TR=3*s. All data were subject to some data preprocessing followed by sICA decomposition. The separated components were sorted by temporal regression of their activations with the model TC in the primary visual cortex (WFU PickAtlas [5]) generated by Waver. The sICA decomposition identified a set of cortical bilateral visually responsive regions, yet one single IC displayed activity in bilateral cerebellum (Fig.1) and a highly time-correlated TC ($r > 0.92$) with the experimental paradigm.

Resampling raw data in spectral domain produced degenerated thresholds due to Fourier truncated model used, whereas wavelet-based resampling resulted in a rather conservative threshold due to fairly few wavelet coefficients capturing the low frequency paradigm and enforcing poor randomization. Clustering analysis of the resampled data [6] pointed out that the maximum number of non-overlapping simple conex hulls was *6*, as expected (Fig. 2).

Conclusion

Reliability estimation is used to choose an appropriate ICA model, to boost its separation power, and to detect the estimated components that are most likely to have a neurophysiological meaning. The BOLD response in fMRI time series biases the estimation of temporal autocorrelation depending on the experimental paradigm complexity, which entails biased thresholds. Resampling based on whitening transform proved the most robust in the presence of BOLD signal in a block-type experimental design.

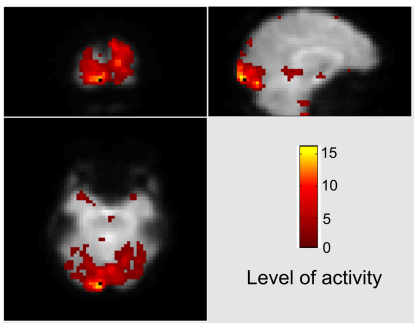

Fig. 1. Orthogonal view of ICA decomposition

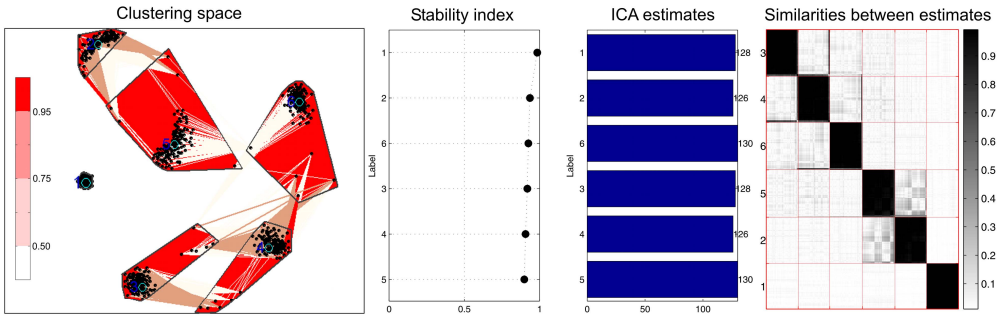

Fig. 2. Cluster analysis of resampled ICA projections

References

1 Bell & Sejnowski, 1995, *Neural Comput.* 7:1129-1159; **2** Friman & Westin, 2005, *NeuroImage* 25:659-867; **3** Meinecke *et al.*, 2001, ICA '01, T.-W. Lee, Ed., 74-79; **4** Friedman, *J. Am. Stat. Assoc.*82(397):249-266, 1987. **5** J.A. Maldjian *et al*., *NeuroImage* 19:1233-1239, 2003; **6** Himberg & Hyvärinen, *Proc. 2003 IEEE Workshop on Neural Networks for Signal Processing*, pp. 259-268, Toulouse, France, 2003.