A Tool for Automatic Anatomical & Functional Labeling of Brain Activity Maps

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Abstract

1 Introduction

[group ICA]

[FNC]

[artifact detection]

[falff and dyn range]

[REST toolbox masks]

[anatomical atlas intro]

[functional atlas intro]

[modularity]

[final]

2 Methods

2.1 Data

We want to demonstrate that the autolabeller can be used in multiple ways. One way is through integration with the group ICA for fMRI toolbox (GIFT) toolbox, and also by simply using functional magnetic resonance imaging (fMRI) volume(s) and/or a [mask todo].

2.1.1 Spatial Maps from Group ICA

The simplest way to use the autolabeller is to execute it with the group independent component analysis (ICA) session information file as the input. We performed group ICA on two different datasets, namely Function Biomedical Informatics Research Network (FBIRN) and Centers of Biomedical Research Excellence (COBRE) datasets to demonstrate the utility of integration with the GIFT toolbox. Prior to that we need to ensure that the

group ICA on the given fMRI dataset has finished successfully, and the ICA post-processing step has been completed. The ICA post-processing step generates the fractional amplitude of low frequency fluctuation (fALFF) and dynamic range values of the independent components (ICs) time courses (TCs) as well as the mean static functional network connectivity (FNC) matrix across all subjects, all of which are used as input to the autolabeller. In the GIFT toolbox, generating the HTML report will ensure that the post-processing step has been run.

2.1.2 Standalone Spatial Maps

We also show how a set of fMRI volumes based on the NeuroMark template (derived from the Human Connectome Project (HCP) and Genomic Superstruct Project (GSP) datasets) can be labelled using the autolabeller.

2.2 Identifying Resting-State Networks

We trained a logistic regression model with different IC characteristics in order to separate resting-state network (RSN) from artifacts. We obtained these training ICs and their labels from the FBIRN dataset (Damaraju et al., 2014). Five different features were used. Two of those are based on the IC TC characteristics, such as fALFF and dynamic range. The other three features are based on the IC spatial map characteristics, such as correlations with edge motion mask, cerebrospinal fluid (CSF) mask and white matter mask.

[the masks come from REST toolbox]

The output of the model is either 0 or 1, indicating artifact or RSN respectively. We obtained the logistic regression model parameters, which could be used on any testing dataset to identify those. We ran a separate group ICA analysis on the COBRE dataset and tested the autolabeller on the resulting IC spatial maps.

2.3 Anatomical Labeling of Spatial Maps

We determined the anatomical label of a region of activation by correlating the spatial map with known regions in a given anatomical atlas. A number of anatomical atlas are available. We first used the Automated Anatomical Labeling (AAL) atlas which is probably the most widely used cortical parcellation map in the literature (Tzourio-Mazoyer et al., 2002). As we develop the autolabeller, we will add more choices of anatomical atlases.

2.3.1 AAL Atlas

[AAL figure]

[table of regions]

2.3.2 [Atlas #2]

[figure]

[table of regions]

2.3.3 [Atlas #3]

[figure]

[table of regions]

2.4 Functional Labeling of Spatial Maps

We determined the functional label of a region of activation by correlating the spatial map with known regions in a given functional parcellation of the brain. Several functional parcellations are available. We first used the Yeo 2011 functional parcellations (17 networks version) in conjunction with the Buckner functional cerebellar

parcellation (Yeo et al., 2011; Buckner et al., 2011). As we develop the autolabeller, we will add more choices of functional parcellations.

2.4.1 Yeo 2011 and Buckner Lab Functional Parcellation

[AAL figure]

[table of regions]

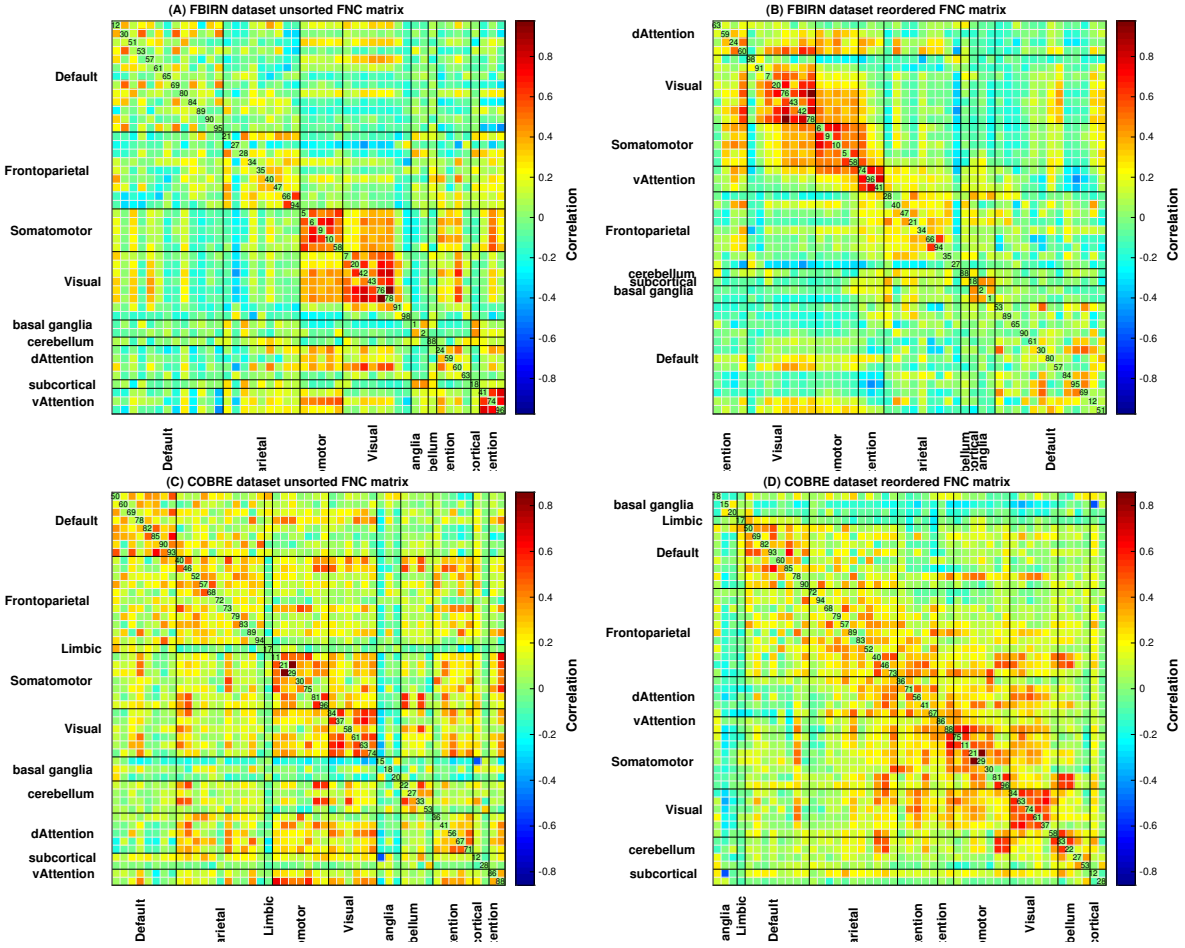

Figure 1: Unsorted vs. automatically reordered FNC matrices

2.4.2 Parcellation #2

[figure]

[table of regions]

2.4.3 Parcellation #3

[figure]

[table of regions]

2.5 Reordering of FNC Matrix

3 Results

4 Discussion

[motion estimate considerations]

[why some IC are mislabelled, eg. fbirn IC 12 is classified as default mode by Bucknerlab even though correlated with calcerine]

[why different atlas/parcellations chosen, pros/cons]

References

Buckner, R. L., Krienen, F. M., Castellanos, A., Diaz, J. C., and Yeo, B. T. T. (2011). The organization of the human cerebellum estimated by intrinsic functional connectivity. *Journal of Neurophysiology*, 106(5):2322–2345, ISSN: 0022-3077, DOI: 10.1152/jn.00339.2011, https://journals.physiology.org/doi/full/10.1152/jn.00339.2011. Publisher: American Physiological Society.

Damaraju, E., Allen, E., Belger, A., Ford, J., McEwen, S., Mathalon, D., Mueller, B., Pearlson, G., Potkin, S., Preda, A., Turner, J., Vaidya, J., van Erp, T., and Calhoun, V. (2014). Dynamic functional connectivity analysis reveals transient states of dysconnectivity in schizophrenia. *NeuroImage: Clinical*, 5:298–308, ISSN: 22131582, DOI: 10.1016/j.nicl.2014.07.003, http://linkinghub.elsevier.com/retrieve/pii/S2213158214000953. 00210.

Tzourio-Mazoyer, N., Landeau, B., Papathanassiou, D., Crivello, F., Etard, O., Delcroix, N., Mazoyer, B., and Joliot, M. (2002). Automated Anatomical Labeling of Activations in SPM Using a Macroscopic Anatomical Parcellation of the MNI MRI Single-Subject Brain. *NeuroImage*, 15(1):273–289, ISSN: 1053-8119, DOI: 10.1006/nimg.2001.0978, http://www.sciencedirect.com/science/article/pii/S1053811901909784. 08299 AAL.

Yeo, B. T. T., Krienen, F. M., Sepulcre, J., Sabuncu, M. R., Lashkari, D., Hollinshead, M., Roffman, J. L., Smoller, J. W., Zöllei, L., Polimeni, J. R., Fischl, B., Liu, H., and Buckner, R. L. (2011). The organization of the human cerebral cortex estimated by intrinsic functional connectivity. *J. Neurophysiol.*, 106(3):1125–1165, ISSN: 1522-1598, DOI: 10.1152/jn.00338.2011.