Human Brain Project Post-doc Proposal: Charting the human brain with fMRI

Context: large-scale functional atlasing

Learning a model of brain organization is one of the major goals of the Neuroimaging community. While many brain atlases have been inferred and released, based on various imaging modalities and experimental procedures, their justification has been weakened by the absence of concomitant release of data to back up the available atlas and by the large-inter-subject variability that makes it impossible to generalize a given atlas to new subjects.
Advances will be made possible by:

i) Acquiring **larger number of functional protocols** on a group of subjects, so that each putative brain region (are or module) can be characterized unambiguously through a unique functional signature and position.
ii) Making the data and ensuing processing steps available to the community, so that the results of this mapping can be easily reproduced and compared to other data.

The **Human Brain Project** (HBP, http://www.humanbrainproject.eu/) aims at developing a model of the Human brain organization; the bottom-up approach that consists in building a brain by going all the way from molecular to system-level organization needs to be informed by high-level constraints that build the macroscopic organization of the brain. A particular task has been defined as part of the HBP, which consists in repeatedly scanning a limited number of subjects with a large class of functional localizers (retinotopic, tonotopic, somatotopic, visual categories, space and number, language, social cognition, resting state) together with high-resolution anatomy and diffusion-weighted scans. The resulting activation maps will provide an objective basis to inform the definition of brain regions. The richness of the dataset will consist in the variety of cognitive function tested. This will be provided by the contributors of the cognitive brain mapping pillar of the Human Brain Project and will last about ten years.

Post-doc proposal roadmap

The post-doc will be in charge of setting a set of protocols up and running to pass them on the pool of 20 subjects for the initial functional mapping phase of the project. These protocols will be either in-house protocols or protocols from close collaborators and will have to be adapted to focus on the localization aspects (see e.g. [1] for an example of such protocols and ensuing analysis). These steps, including the necessary adaptations and implementations of the protocols, will be carried out in close collaboration with the Unicog lab at Neurospin (http://www.unicog.org/pm/pmwiki.php).

The post-doc will take part to the set of acquisitions performed on Neuropsin 3T scanner at high resolution (1.5mm) and analyze the data by using a pipeline provided by the lab. He/she will be involved in the optimization of this pipeline and will obtain activation maps related to these various contrasts, with support from a programmer. The data will be analyzed both in the volume and on the cortical surface (see [2] for a reference). Detailed reports will be provided to assess the quality of the data, motivate the participants and document the content of the database. The analysis of the whole dataset will yield two kinds of results:

- **A parcellation of the brain** volume into functionally specific territories that can be characterized precisely based on the contrasts used in the dataset (see Fig. 1). Care will be taken that all the corresponding regions are identified in all subjects of the group.
- A meta-analysis that will ensure that **each cognitive function** tested can be unambiguously **defined by a unique activation pattern**, in a manner that can be generalized across individuals (reverse inference, see [3]).

The data will also systematically be compared with existing resources (OpenfMRI, human connectome projects, datasets available at Neurospin). The methodological aspects will be carried out in close collaboration with the Parietal team at Neurospin (http://team.inria.fr/parietal/), that has recently developed specific techniques to perform brain parcellation effectively [4] and to discriminate between distributed activation patterns [5]. The post-doc will also re-use the existing pipeline and quality checking tools of the Parietal team.

Results

All the raw and processed data, stimuli, as well as the functional atlases inferred from the data will be put on line to become a **reference for the neuroimaging community**, together with an exhaustive documentation on the acquisition and processing parameters. The candidate will have the opportunity to present the first large-scale analysis of the data to the neuroimaging community and to the HBP consortium. This will include making decision on regions where functional selectivity is not consistent in the literature (e.g. selectivity to categories in the ventral visual cortex). Care will be taken to describe adequately the topographical organization of the maps on the cortical surface, in order to remove possible ambiguities. The post-doc will take part to decisions regarding the choice of functional localizer experiments to carry out for the sake of completeness and accuracy of the functional brain atlas, including high resolution maps acquired in ROIs, possibly at 7T.

Required skills

- [Mandatory] Prior experience on running and analyzing an fMRI protcol, including in particular localization-related protocols (retinotopy, tonotopy, somatotopy etc.).
- [Mandatory] PhD in cognitive neuroscience.
- [Desired] prior experience on meta-analysis
- [Desired] prior experience of working/programming in Python.
- [Desired] basic knowledge of MVPA.
- The candidate should be willing to work in a multi-disciplinary environment (cognitive neuroscience, MRI acquisition, computer science).

References

[1] Pinel P, Thirion B, Meriaux S, Jobert A, Serres J, Le Bihan D, Poline JB, Dehaene S. Fast reproducible identification and large-scale databasing of individual functional cognitive networks. BMC Neurosci. 2007
[2] Van Essen DC, Glasser MF, Dierker DL, Harwell J, Coalson T. Parcellations and hemispheric asymmetries of human cerebral cortex analyzed on surface-based atlases. Cereb Cortex. 2012 Oct;22(10):2241-62.
[3] Hutzler F. Reverse inference is not a fallacy per se: Cognitive processes can be inferred from functional imaging data. Neuroimage. 2013
[4] Varoquaux G., S. Yannick, Pinel P., Thirion B.Cohort-level Brain Mapping: Learning a Dictionary of Cognitive Atoms to Single Out Specialized Regions. Inproceedings of IPMI 2013.
[5] Schwartz Y, Varoquaux G, Pallier C, Pinel P, Poline JB, Thirion B. Improving accuracy and power with transfer learning using a meta-analytic database. MICCAI 2012;15(Pt 3):248-55.

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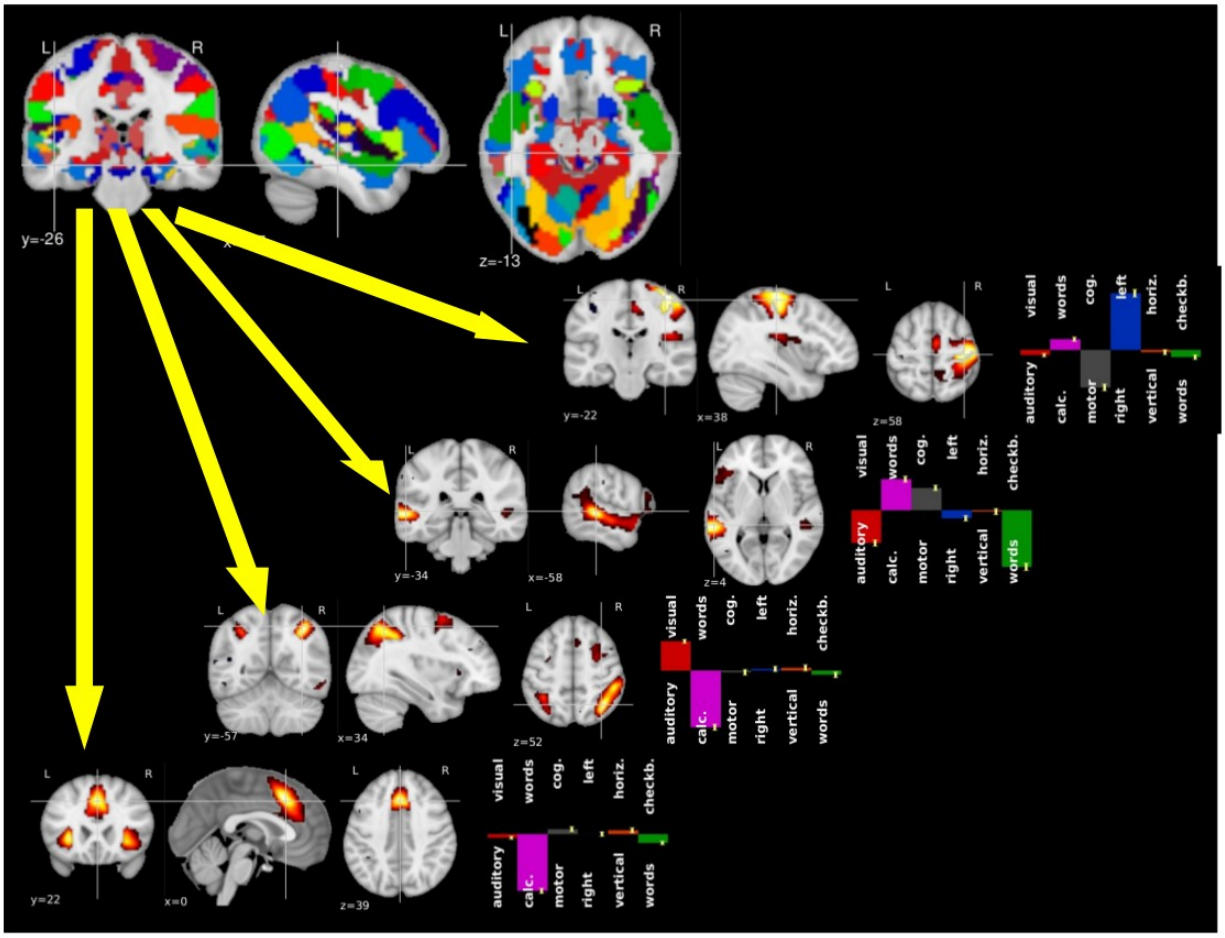

Fig.1. A brain functional atlas can be conceptualized as a parcellation of the brain volume into overlapping networks, where each functional network is characterized by a profile of activation for a set of functional contrasts. Such an atlas can be learned by applying an adapted dictionary learning to a set of images that display the activation observed in different subjects for a (very large) set of cognitive tasks. See [4] dor more details.