

## NEUROSCIENCE

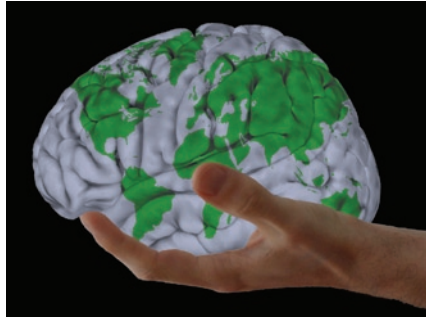
## Collective brain maps

A new study, pooling brain-imaging data from 35 centers across the world, shows the power of data sharing and demonstrates a universal architecture of functional connections in the human brain.

Discovery-based scientific approaches, in which the analysis of large volumes of experimental data can lead to new hypotheses, are enabled by large-scale data sets aggregated through data sharing on a global scale. Although such data sharing has typically been the realm of fields such as genome analysis or protein structure, many other fields of biology can benefit from this. In neuroscience, for example, brain activity is monitored through techniques such as functional magnetic resonance imaging (fMRI). Access to large sets of fMRI data collected from many individuals would provide the neuroimaging community with the opportunity to explore the differences and commonalities of human brain function.

Given the myriad paradigms available for interrogating brain functional systems, many neuroscientists have remained skeptical about whether such a project would be feasible or whether it would produce meaningful results. New work from a large group of researchers now confirms that an approach capable of addressing this challenge is resting-state fMRI (R-fMRI). In this setting, researchers record approximately 5 minutes of brain activity while individuals rest quietly with their eyes open or closed. Paradoxically, imaging the brain at rest has proven an efficacious way of understanding our brains at work.

It has been known for some time that imaging the brain during rest reveals large-amplitude, low-frequency spontaneous fluctuations in the fMRI signal, which are temporally correlated across functionally related brain areas. “One thing that really captured my attention the first time I looked at fMRI images of the brain at rest was that the neural networks that you observe are highly similar to those seen in task based studies,” says Michael Milham, a psychiatrist at New York



The resting-state imaging community has demonstrated the potential of carrying out discovery science in the human brain. Image courtesy of Marteen Mennes and Michael Milham.

University and coordinator of this work.

These correlations yield detailed maps of functionally ‘tuned’ regions in the brain and together constitute an individual’s ‘functional connectome’. As Milham’s group understood it, comprehensive mapping of the functional connectome of many individuals in a multicenter collaborative approach could be an invaluable resource for neuroscientists. Additionally, this work may lead to the development of approaches that allow researchers to discern genetic influences and brain-behavior relationships.

In an a priori uncoordinated fashion, Milham’s group asked researchers across the world to share their R-fMRI scans. The purpose of the project, named the 1000 Functional Connectomes Project after its genomic sibling, “was to prove whether data gathered in different centers in a uncoordinated manner could generate meaningful results and whether there would be any strength to the data,” explains Milham.

Milham’s group and his many collaborators now provide an initial demonstration of the feasibility of pooling R-fMRI datasets across centers, in a project of unprecedented scale for the neuroimaging community. The 1000 Functional Connectomes project has gathered, in one year, R-fMRI data from 1,414 volunteers collected at 35 international centers. Those R-fMRI datasets have now been

deposited in an open-access data repository ([http://www.nitrc.org/projects/fcon\\_1000/](http://www.nitrc.org/projects/fcon_1000/)). In the two months since it was launched, the site has had over 4,000 downloads.

Applying analytic methods to the aggregated data, Milham and co-workers demonstrate a universal architecture of functional connections in the resting human brain. They also demonstrate consistent loci of variability between individuals and centers, and interestingly, brain regions for which age and gender emerged as significant determinants of functional connectivity. But Milham is cautious about drawing too many conclusions from this study alone: “we must not forget that when we discover something through data mining then we have to do follow-up studies to validate it,” he says.

For Milham, the value of resources such as this will be in their capacity to build normative maps of functional systems in the brain. In the future, these could be used for clinical applications in a similar way to how we use normal value ranges to interpret laboratory test results. Subsequent efforts will also tell whether this successful data sharing is a particularity of R-fMRI data or whether it will be reproduced with data from other functional imaging modalities or multimodal studies.

The 1000 Functional Connectomes project is alive and growing, and its creators are actively encouraging the broader community to contribute their R-fMRI data. Also, they are not alone in this endeavor, as other open-access resources for gathering and sharing of functional imaging data are available (fMRI Data Center, Function Biomedical Informatics Research Network, Open Access Series of Imaging Studies, BrainScape and BrainMap). These collaborative studies serve to show how data that are brought together can be much more than the sum of the parts.

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### RESEARCH PAPERS

Biswal, B.B. *et al.* Toward discovery science of human brain function. *Proc. Natl. Acad. Sci. USA* **107**, 4734–4739 (2010).