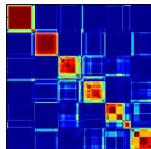


# Bootstrap analysis of stable clusters in resting-state fMRI



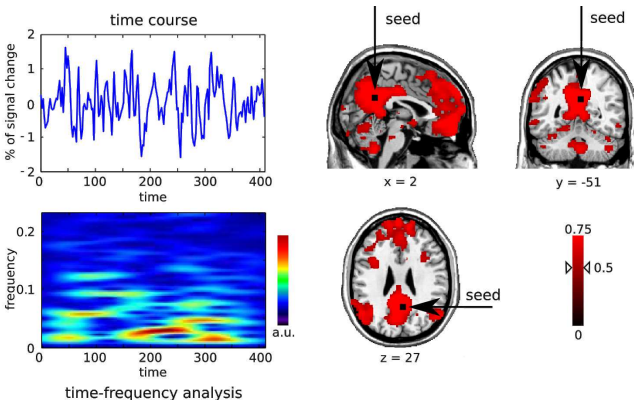
Pierre Bellec

pierre.bellec@criugm.qc.ca

NeuroImaging Analysis Kit

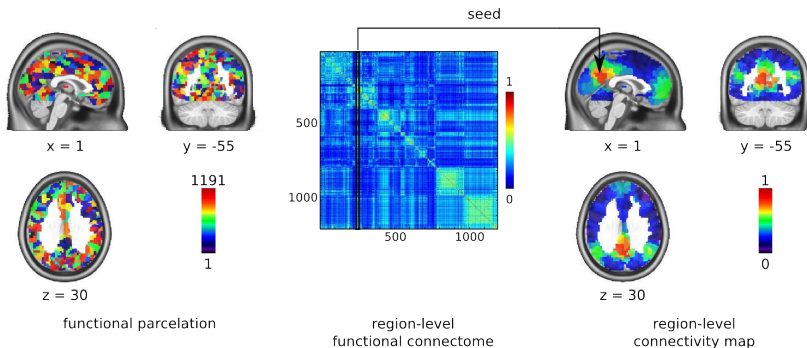
Département d'informatique et de recherche opérationnelle, Université de Montréal

# Resting-state fMRI: functional connectivity map

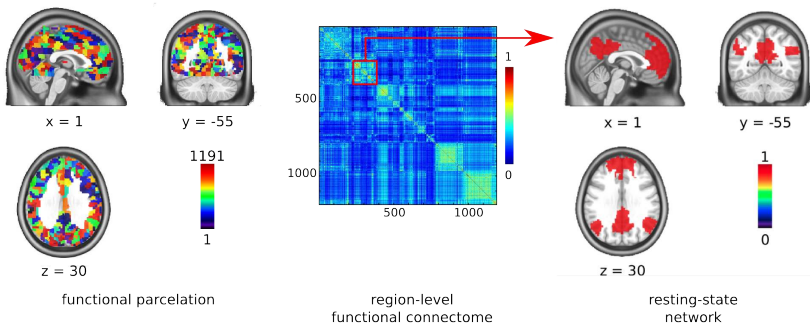


The posterior cingulate cortex is used as a seed to derive an individual resting-state functional connectivity map, identifying the default-mode network.

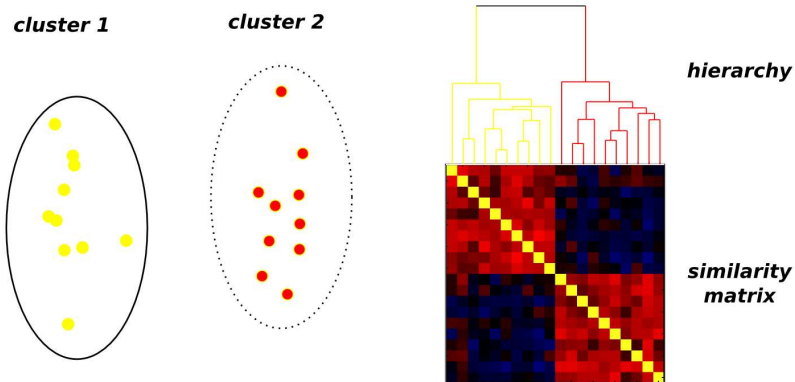
# Resting-state fMRI: functional connectome



# Resting-state fMRI: resting-state networks

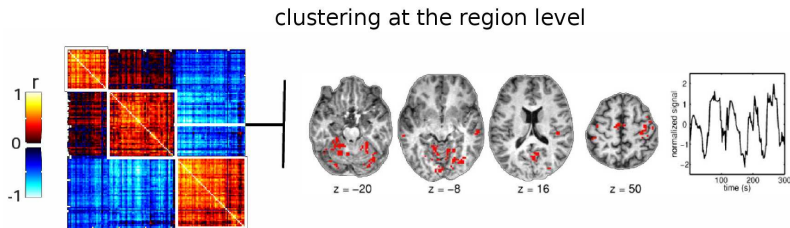
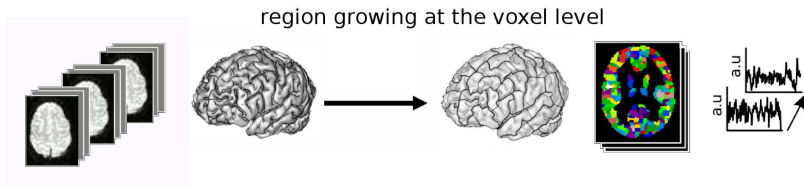


# Clustering : unsupervised classification

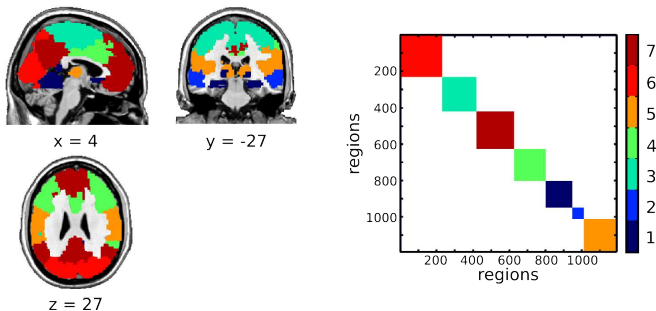


On the left, coordinates of individuals define their similarities; on the right, HC proceeds by iterative mergings. Many clustering algorithms exist, e.g. k-means, fuzzy k-means, spectral clustering, SOM, neural gas. See Jain, Pattern Recognition Letters, 2009, for a review.

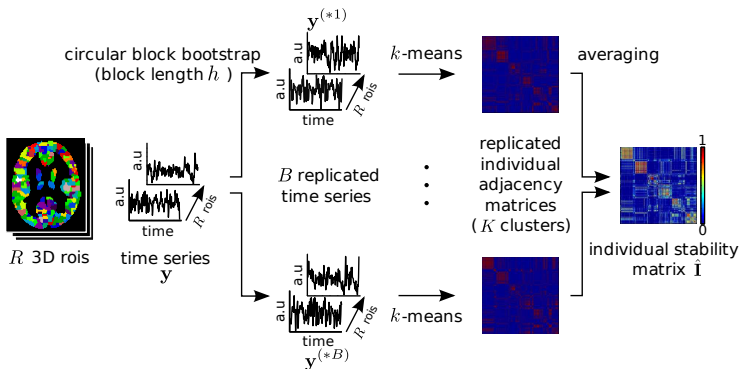
## Clustering : bi-scale approach in fMRI functional connectivity



## Adjacency matrix representation of a clustering

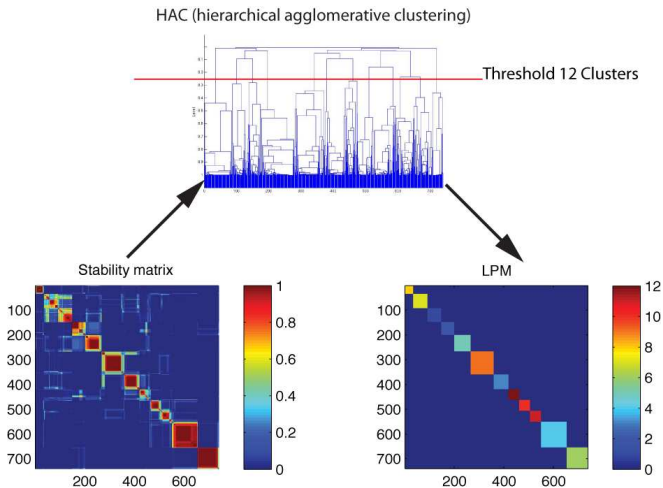


## Individual-level bootstrap stability analysis

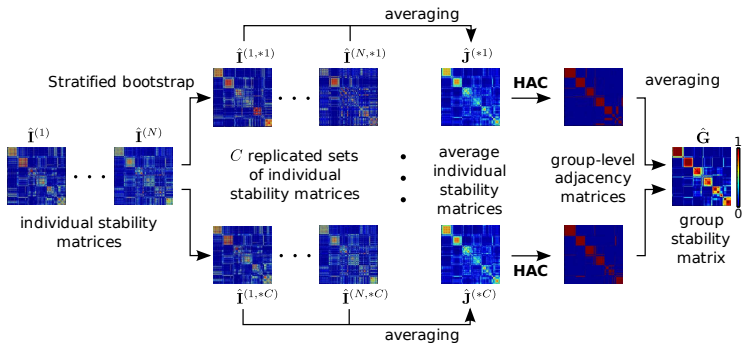




## Consensus clustering

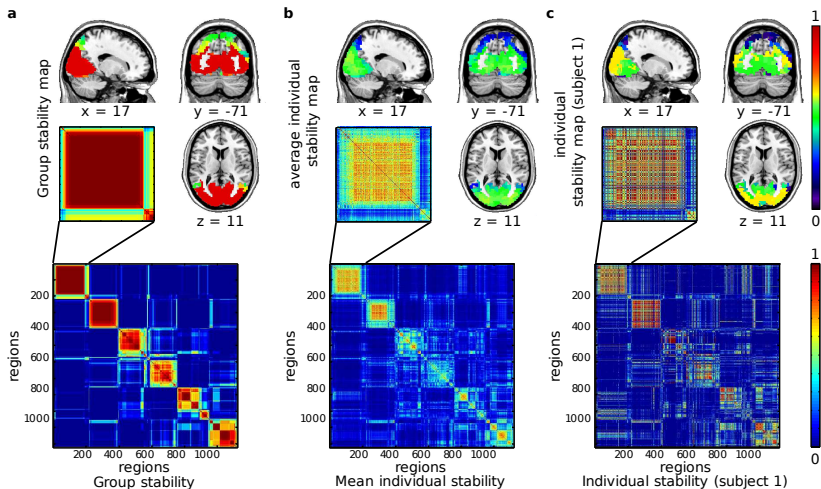


# Group-level stability analysis

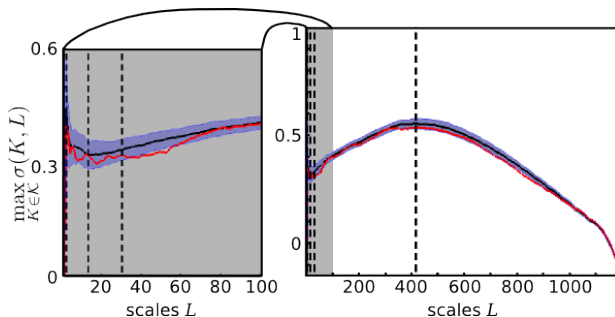


From Bellec et al., Neuroimage 2010.

## Clustering : stability maps

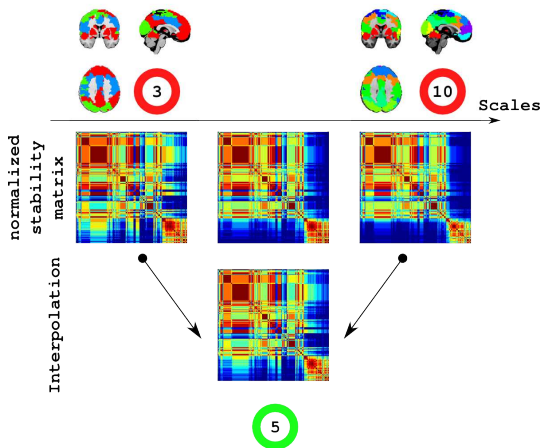


# Local maxima of stability

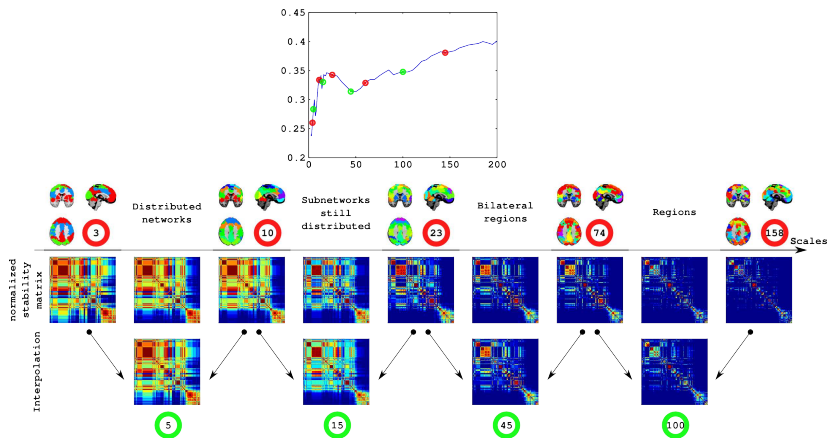


Individual stability contrasts for 43 subjects.

## Interpolation of stability matrices I



# Interpolation of stability matrices II



# Multiresolution stepwise selection (MSTEPS) I

## Forward MSTEPS procedure

- 1 Initialization: no resolution is selected.
- 2 Select a resolution that has not yet been selected, with probability proportional to the residual sum of squares at this resolution.
- 3 Iterate (2-3) until a predefined percentage of residual sum of squares across all resolutions is reached.
- 4 Iterate the model selection  $B$  times, and keep the model with smallest residual sum of squares.

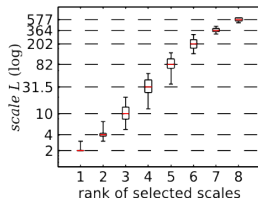
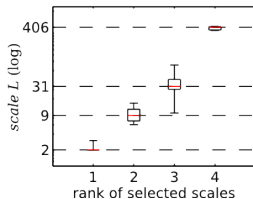
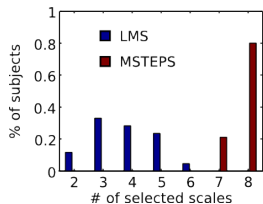
## Multiresolution stepwise selection (MSTEPS) II

### Component-wise MSTEPS procedure

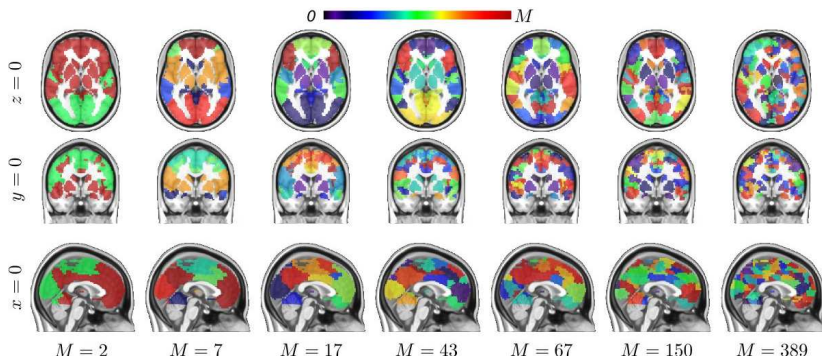
- 1 Initialization: run a forward MSTEPS.
- 2 For each resolution of the model, try to replace it by any of the resolutions not currently in the model.
- 3 Keep the model with the minimal residual sum of squares across all resolutions.
- 4 Iterate (2-3) until it is not possible anymore to reduce the residual sum of squares.



# Reproducibility of resolution selection

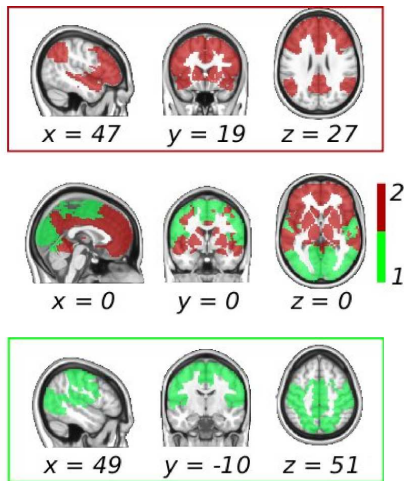


## Group consensus clusters as a function of resolution

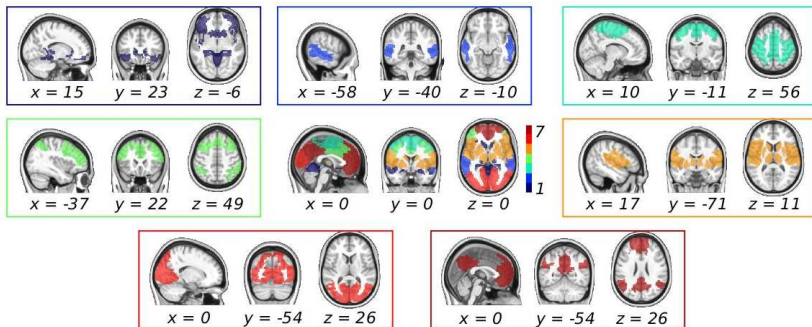


Bellec PRNI 2013.

## Group consensus clusters @ (resolution 2)

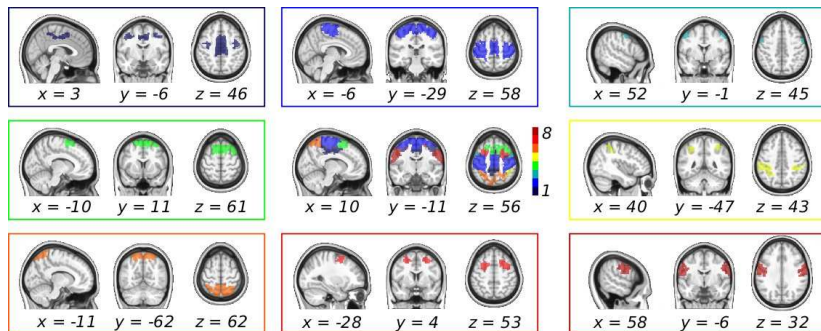


## Group consensus clusters @ (resolution 7)



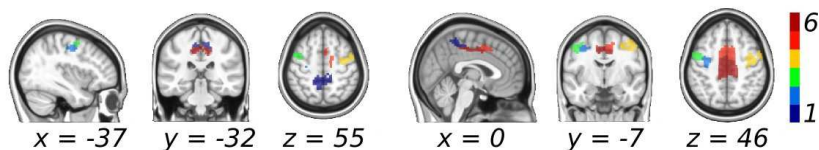
Bellec et al. HBM 2010. See Yeo et al., J Neurophysiol 2011, for more info on this resolution.

# Sensorimotor network @ (resolution 43)



Bellec et al. HBM 2010.

# Sensorimotor network, subnetwork 1 (resolution 43)@ (resolution 150)



Bellec et al. HBM 2010.

# Summary

- It is possible to identify resting-state networks (RSNs) at different levels and resolutions of analysis, using BASC.
- The estimation of the stability of RSNs is an important validation step.
- Rather than identifying the “correct” resolution (an ill-defined problem in fMRI), MSTEPS seeks representative resolutions, to approximate accurately all stability matrices.

# Acknowledgements

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Dr Pedro Rosa-Neto	



More infos on [www.simexp-lab.org](http://www.simexp-lab.org)