Wavelet-based clustering and dynamic analysis of resting state data in the rat

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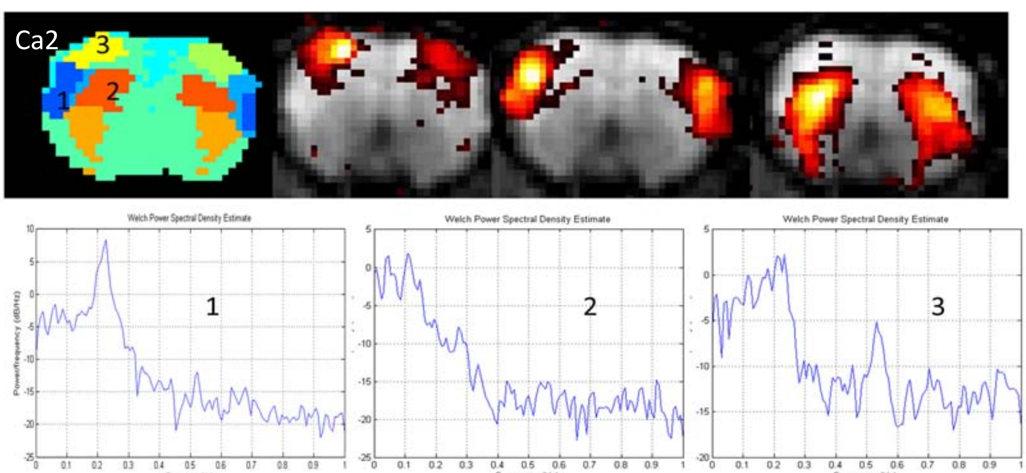
Target: Researchers interested in obtaining dynamic information from resting state MRI

Purpose: While functional connectivity is typically calculated over the length of an entire scan, interest has been growing in dynamic analysis methods that can detect changes in connectivity on much shorter time scales. Dynamic connectivity can be examined using sliding window correlation (1-3), but the results are dependent on the window length, making a data-driven approach more attractive. Wavelet analysis is a promising candidate because it provides both temporal and spectral information. We have developed an algorithm based on wavelet decomposition that clusters voxels into groups with similar temporal and spectral properties. The cross wavelet power can then be calculated to characterize variations in the connectivity of each pair of areas over time.

Methods: Three resting state scans each from 4 rats under dexmedetomidine were chosen from data acquired for another study (1). The images were obtained on a 9.4 T Bruker scanner (7 cm volume coil; 2 cm surface coil). Parameters were GE-EPI; TE 15 ms; TR 500 ms; FOV 2.56 x 2.56 cm; 64 x 64 matrix; 1000 repetitions. A discrete wavelet decomposition was performed on the time course from each voxel (Daubechies 7; 5 levels). At each level of the decomposition, the approximation coefficients (Ca1-5) and detail coefficients (Cd1-5) were recorded. Hierarchical clustering was performed separately based on each coefficient and on the raw signal from the voxels using Ward's linkage method. The power spectrum was calculated for the average raw time course from each cluster. Cross wavelet power was calculated between each pair of clusters to provide an estimate of how the activity in the two regions covaries as a function of time. For comparison, cross wavelet power was also calculated for areas that were randomly matched across scans, which share no temporal relationship.

Results: Wavelet coefficients Ca2 and Cd3 produced the most consistent clusters. Most clusters were bilateral and localized to cortical and subcortical regions, which were largely reproducible across scans and across rats. The clusters correspond well with the patterns of connectivity observed with seed-based correlation (top figure), and each cluster has a distinctive spectral fingerprint (bottom). Secondary somatosensory areas (cluster 1) exhibit a strong peak near 0.2 Hz, while primary somatosensory areas (3) exhibit high power in a broad range of low frequencies (<0.25 Hz). The caudate putamen (2) exhibits power in the low frequencies with a gradual falloff, rather than the plateau and steep falloff seen in SI. Histograms of the cross wavelet power for each coefficient were compared for the real data and the randomly-matched data, and the number of points that lay outside of one standard deviation from the numbers based on randomly matched data were recorded (Table: differences for detail coefficients level 1-5 from homologous areas only or from all areas). The histograms for cross wavelet power in homologous areas in opposite hemispheres tended to show the greatest differences from randomly matched areas, in agreement with previous work (1).

Discussion Wavelet-based clustering identifies functional networks in a data-driven manner. Compared to other data-driven methods such as ICA, we expect wavelet-based analysis to prove more sensitive to time-varying connectivity, due to the combination of temporal and spectral information utilized in the clustering. This is supported by the finding that homologous cortical areas, previously shown to exhibit dynamics distinguishable from randomly matched areas, show variations in cross wavelet power greater than those from other pairs of clusters.



	Cd1	Cd2	Cd3	Cd4	Cd5
Hom. only	25.5±7.3	22.8±6.9	12.0±4.1	4.5±3.0	1.5±1.3
All areas	17.8±7.0	16.4±6.4	9.3±3.6	3.4±2.0	0.8±1.1

References. *1.Keilholz S et al, Dynamic Properties of Functional Connectivity in the Rodent. Brain Connect 2012. 2.Hutchison RM et al. Resting-State Networks Show Dynamic Functional Connectivity in Awake Humans and Anesthetized Macaques. Hum Brain Mapp 2012. 3.Chang C, Glover GH. Time-frequency dynamics of resting-state brain connectivity measured with fMRI. Neuroimage 2010;50:81-98.*