HURST ANALYSIS OF PHYSIOLOGICAL FLUCTUATIONS IN FUNCTIONAL MRI

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Introduction

In the absence of stimuli, "baseline" functional MRI (FMRI) data may contain a wealth of information related to dynamic interactions, i.e. functional connectivity (1), among multiple brain regions. Many biological time series have been found to have time-scale-invariant properties (2), and we were interested in exploring data correlations over both long and short time scales in FMRI data. Traditional signal processing techniques, however, extract only limited information over a single time scale. Thus, we examined one multiscale method, Hurst's Rescaled Range Analysis, as a potential tool to identify brain regions with similar FMRI signal patterns over multiple time scales.

Methods

All imaging was performed on a 1.5-T GE Signa system equipped with a whole-body echo planar gradient set (Advanced NMR Systems) and a quadrature head coil. Baseline fluctuations in signal intensity were examined in a 36-year-old male, who was instructed to remain motionless during the 10 minute acquisition period. A set of 640 echo-planar images was collected (gradient echo, TE=40ms, TR=1s, flip angle=66°, thickness=5mm; in-plane resolution=3.125 x 3.125 mm) in two axial planes through the caudate. Images were corrected for frame-to-frame motion with the DART registration algorithm (3).

The time series were subjected to Hurst's Rescaled Range Analysis (2), a technique which examines correlation within the data set over multiple time scales. In this method, the range R of the cumulative deviation of signal intensities is normalized by the standard deviation S in data windows of increasing length N. For each pixel, the power law exponent H is measured as the slope of log(R/S) vs. log(N). H can be intuitively understood as a probability directional change—how increases in the sequence are likely to be followed by increases and decreases by decreases over various time scales. H = 0.5 indicates an uncorrelated sequence of signal intensity values; H > 0.5 is called "persistence" since changes are in the same direction; H < 0.5 suggests that the directions of change over time will be successively opposite. Although H was computed on a pixel-wise basis, brain regions with similar values of H exhibit fluctuations with similar temporal scaling structures, and thus may be related functionally.

Results

Local clustering of persistent H values (H > .5) was observed bilaterally in the frontal cortical regions in both slices (see Figure 1). As expected, H values near 0.5 dominate the regions outside the head.

Discussion

In this preliminary analysis of fMRI data with the Hurst exponent H, we identified regions with similar patterns of fluctuations over multiple time scales. Although the meaning of H in this context is not yet known, this fractal characteristic may provide insight into functional relationships. Whether the clusters of persistent H values originate primarily from neuronal or other physiological processes (e.g. respiration, pulsatile flow, vasomotor oscillations) (4) or a combination remains to be investigated.

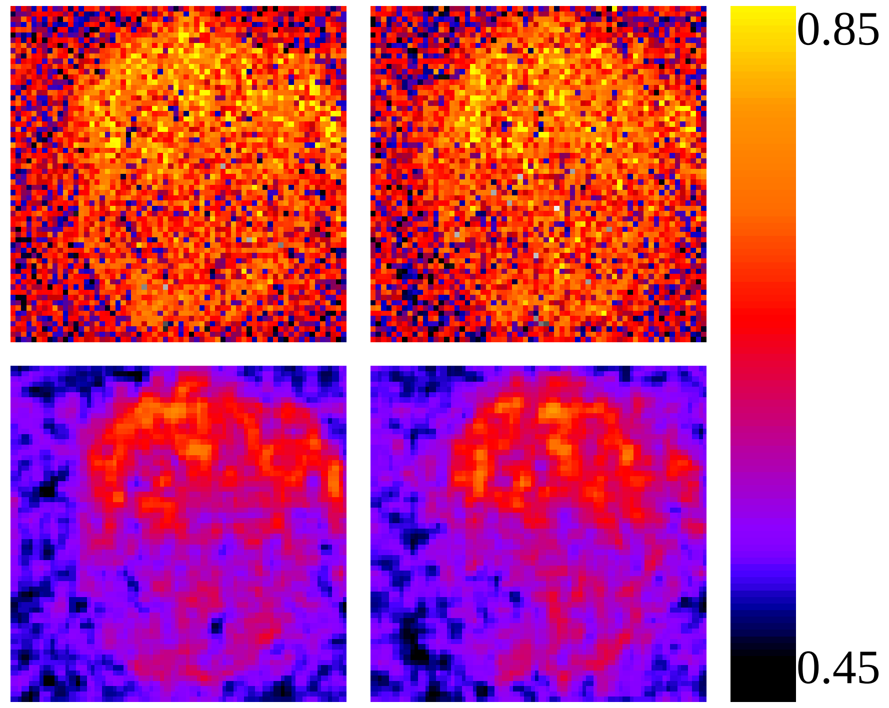

Figure 1. top: pixel-wise Hurst values in two adjacent axial planes through the caudate; bottom: with sd=1.5 Gaussian smoothing; left: superior slice; right: inferior slice.

References

1. Biswal B, Yetkin Z, Haughton VM, Hyde JS. Magn. Reson. Med. 1995, 34: 537-541.
2. Bassingthwaighte JB, Liebovitch LS, West BJ. Fractal Physiology. New York: Oxford University Press, 1994.
3. Maas LC, Frederick BB, Renshaw PF. Magn. Reson. Med. 1997, 37: 131-139.
4. Weisskoff RM, Baker J, Belliveau JW et al. Proc. Soc. Magn. Reson. Med. 12. 1993, p.7.