Fractal Analysis of Preterm Infants Scanned Shortly After Birth and at term-equivalent Age: Implications for Brain Development and Sucrose Administration

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Introduction

It has been found that fractal analysis of the BOLD signal in fMRI can be used to measure brain functioning, development, and health. There has to our knowledge, however, not been any fractal analysis fMRI studies done in newborns. Improved capacity to understand brain health in sick preterm infants is also an important aim of neonatal medicine and is critical to optimize outcomes.

Hypothesis

As measured by the Hurst exponent, a surrogate measure of a signals fractality. Infants scanned at term-equivalent age will have a higher Hurst exponent than infants scanned at pre-term age. This reflects a more structured ordering of brain signal as an infant develops. We were also interested in whether sucrose administration would be correlated with lower H values.

Study Population

After exclusion criteria and preprocessing, 133 scans (mean birth age 27 ± 2.5 weeks) of 3T fMRI data with TR=3s and ~5 minutes was collected from SickKids Toronto (Steven Miller). Infants were born pre-term and scanned shortly after birth and again at term equivalent age, with scan ages varying from 27 - 48 weeks (mean scan age 36.7 ± 4.8).

Method

Data was preprocessed using the dHCP pipelines. 9 RS networks were identified from Group ICA. The Hurst exponent was calculated using Welch's method on the pre-processed data. A Linear Mixed Effects model was used to evaluate how significant the differences of the mean H value in 10 regions of interest was between early and at term-equivalent age scans.

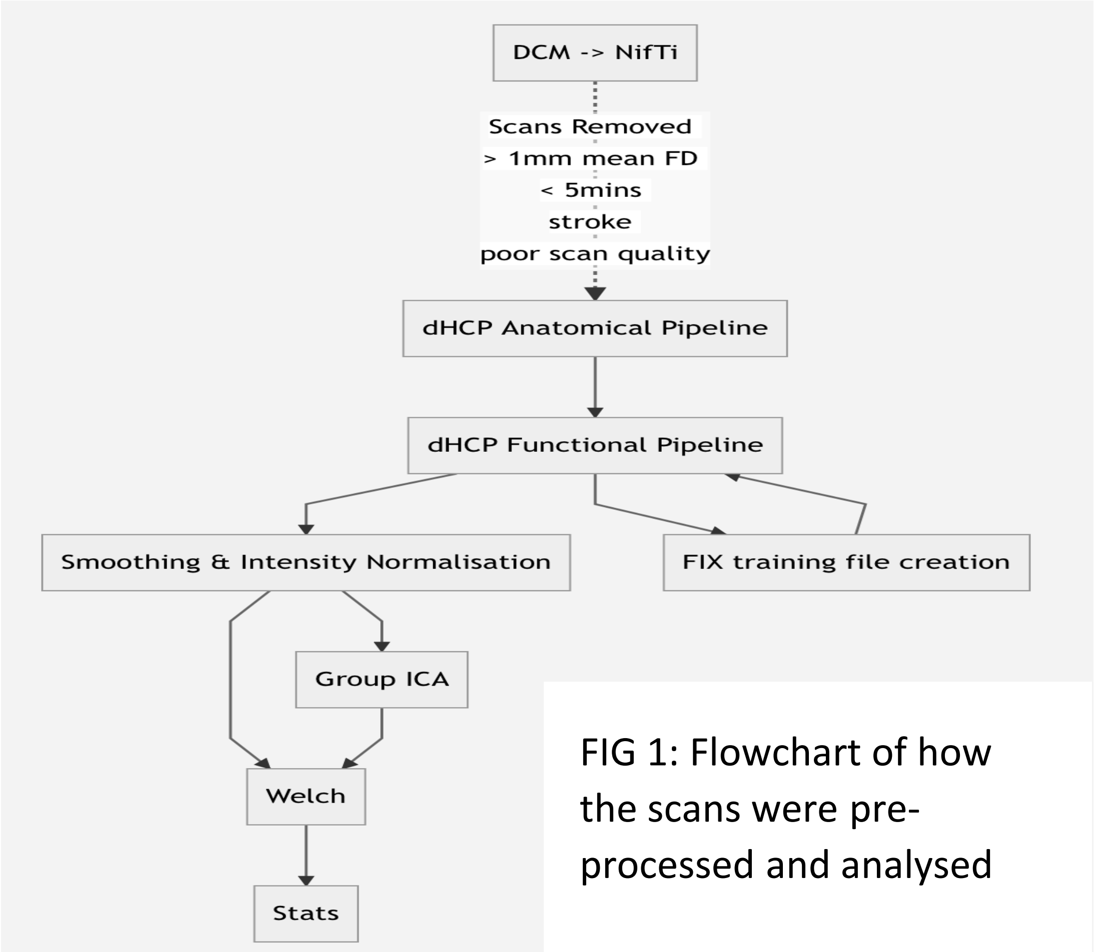

FIG 1: Flowchart of how the scans were pre-processed and analysed

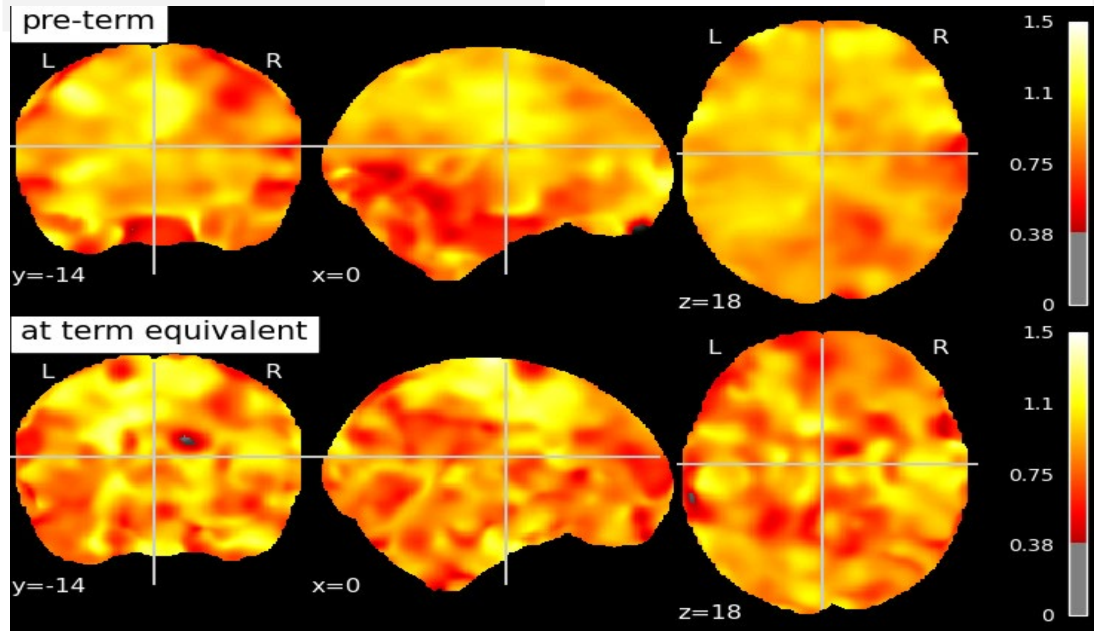

FIG 2: The H values of the same subject at pre-term and at term equivalent scan age in template space

Results

All regions were found to be statistically different in H values between scan ages (preterm and later term). The largest difference in H between the two ages was found in the Visual and Motor network whilst the smallest differences was in the Frontal and Hindbrain. No correlations were found between H values and sucrose intake.

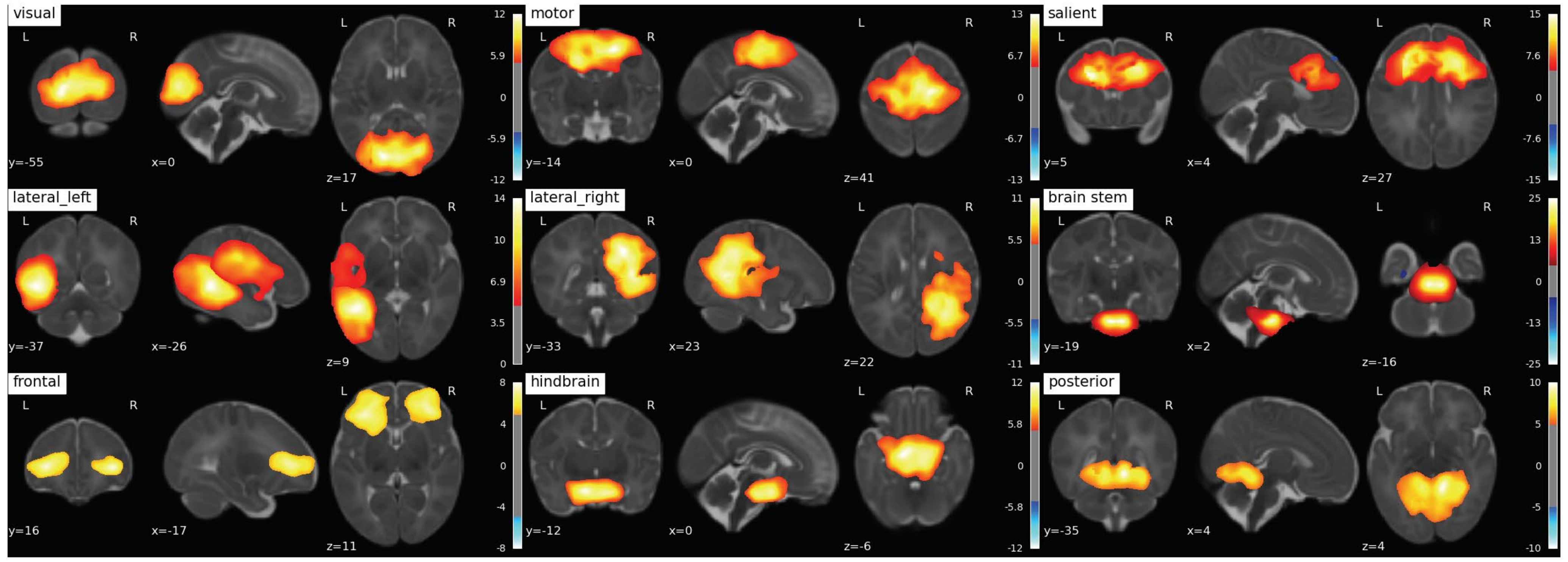

FIG 3: The 9 RS-networks that were identified from Group ICA. The lateral left network was created by combining two different IC maps.

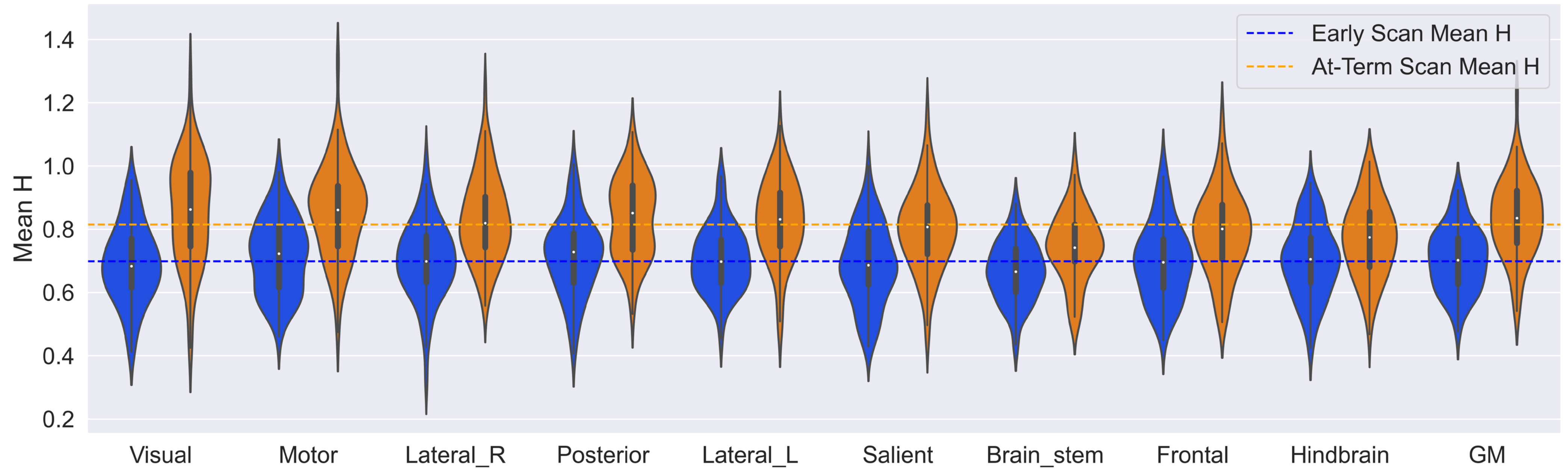

FIG 4: Mean H value in each Network split by the scan age. Ordered from largest change in mean H between the scan ages. The dotted lines give the mean H value for each scan age group. The adjusted p values range from $9.24 \cdot 10^{-25}$ (Visual) to $3.99 \cdot 10^{-6}$ (Hindbrain)

Implications

1) a clear documented pre-processing pipeline (using open-source software) for infants born pre-term;
2) fractal-analysis to reveal and quantify inherent brain dynamics.

This method was able to outline the areas of the brain where we qualitatively would argue have the most development after birth (Visual and Motor networks). With better data, this method may be robust at classifying whether a brains function has been impaired, either from substance or injury.