fMRI Measures of the Human Brain and Associations to Behavior

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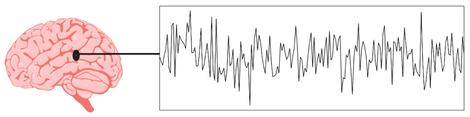
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Introduction

- fMRI measures spontaneous low-frequency blood-oxygen-level-dependent (BOLD) signal as an indirect index of neural activity.
- Many fMRI measures exist, capturing signal frequency, local synchrony, and entropy, but each is usually studied in isolation.
- Their interrelationships and behavioral relevance remain unclear.
- **Goal:** How do fMRI measures relate to each other and predict behavior?

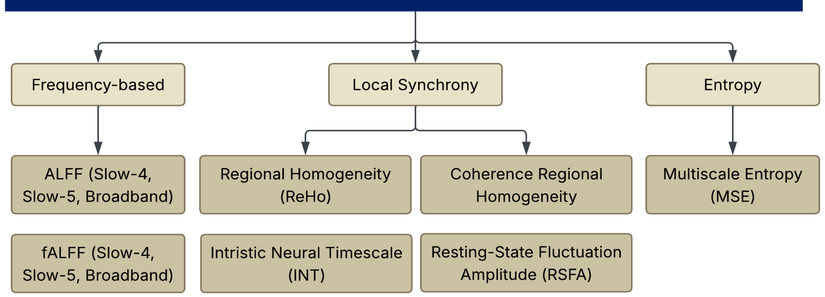


Methods

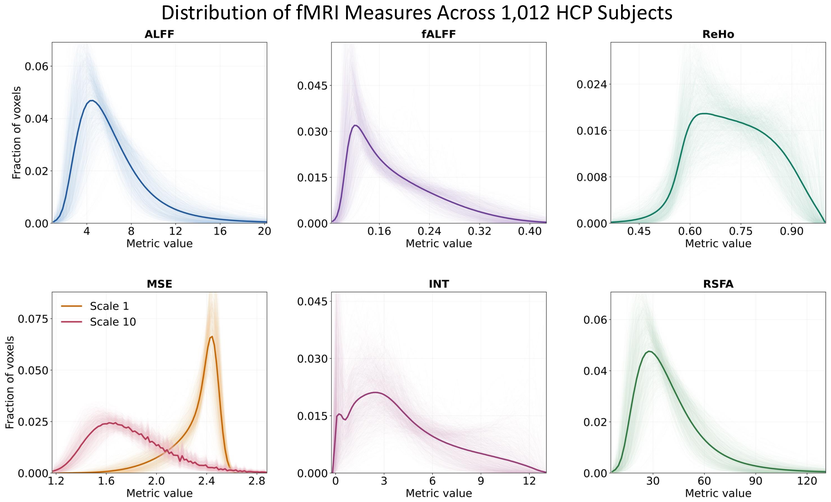
- We used resting state-fMRI data from the Human Connectome Project, comprising 1,012 subjects after excluding those with missing data, with 4 scans per subject (~4,000 scans total), processed at the voxel level.
- We compared fMRI measures spanning three families: frequency-based, local synchrony and entropy.
- We then compared them by testing their ability to predict age, gender, and fluid intelligence (PMAT accuracy, PMAT reaction time).

HUMAN Connectome PROJECT

fMRI Measures



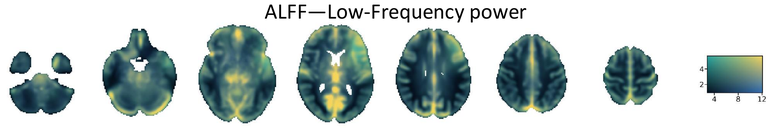
Distribution of fMRI Measures Across 1,012 HCP Subjects



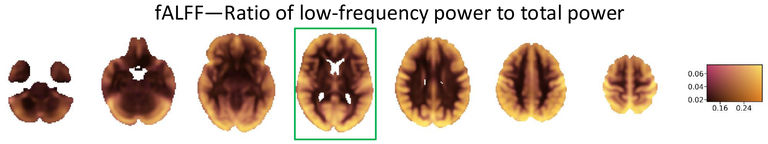
Measures Reveal Similar & Distinct Patterns

fMRI Measures on the Axial Slices of the Brain. Similar Patterns are Highlighted in Green and Distinct in Red. Colorbar: X Axis – Mean, Y Axis – Standard Deviation

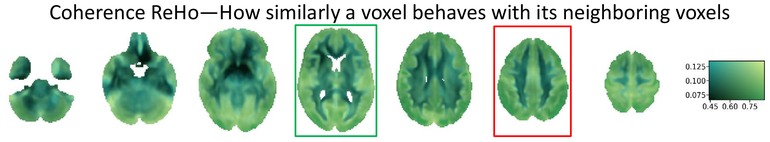
ALFF—Low-Frequency power



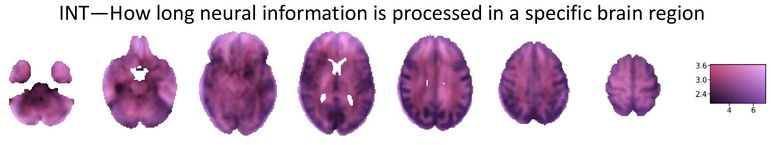
fALFF—Ratio of low-frequency power to total power



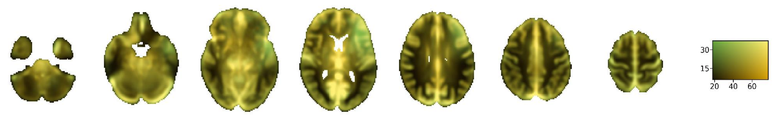
Coherence ReHo—How similarly a voxel behaves with its neighboring voxels



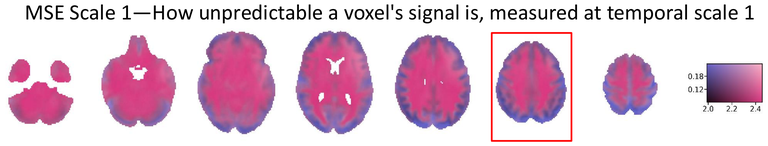
INT—How long neural information is processed in a specific brain region



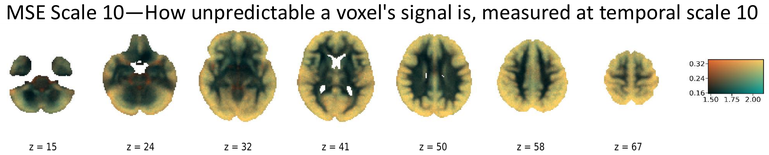
RSFA—Measures the standard deviation of the voxel's BOLD time series



MSE Scale 1—How unpredictable a voxel's signal is, measured at temporal scale 1

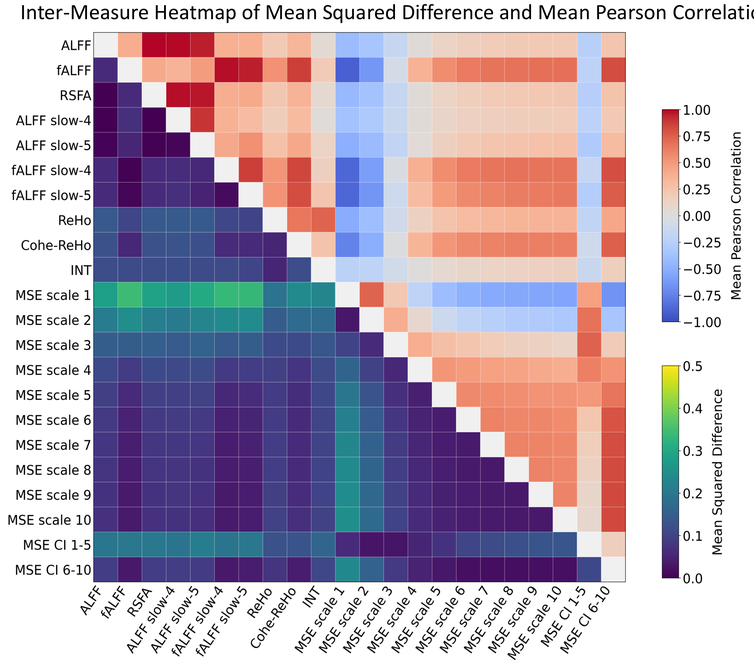


MSE Scale 10—How unpredictable a voxel's signal is, measured at temporal scale 10



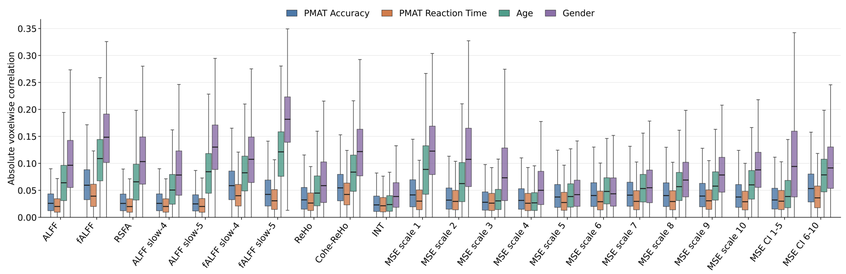
Inter-Measure Similarities and Differences

Inter-Measure Heatmap of Mean Squared Difference and Mean Pearson Correlation



fMRI Measure and Behavior Associations

- We compute correlations between fMRI measures and behavioral variables - age, gender, fluid intelligence.
- Age and gender showed stronger fMRI associations than fluid intelligence performance.
- fALFF-derived measures were the most associated with behavior.
- Gender showed stronger and more widespread voxel associations.
- MSE distributions change across temporal scales: associations weaken around 3-5 and become stronger again at higher scales.
- Most distributions overlap substantially, showing that no single metric provides uniquely strong associations across the whole brain.



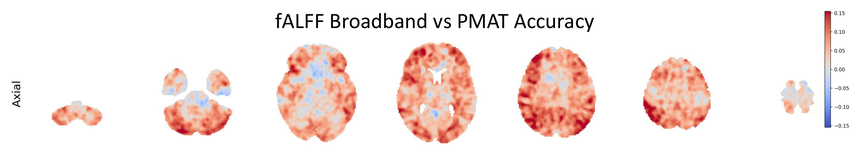
fALFF Slow-5 vs Age



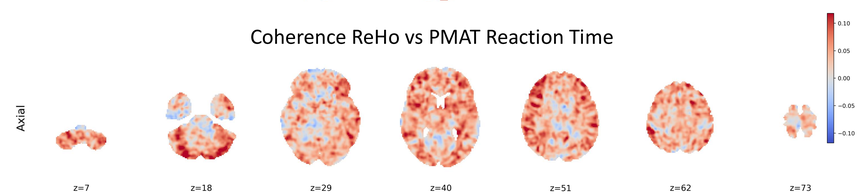
fALFF Slow-5 vs Gender



fALFF Broadband vs PMAT Accuracy



Coherence ReHo vs PMAT Reaction Time



Findings

- Correlation maps reveal distinct spatial patterns of association between fMRI measures and each target variable
- Edge regions in the INT-gender correlation maps exhibit apparent registration artifacts and should be interpreted with caution.
- The spatial distribution of correlated regions differs across target variables, suggesting distinct underlying neural substrates.
- PMAT-C and PMAT-RT share largely overlapping regions of association, indicating common functional networks.

Structure-Function Toolbox

An open-source toolbox for computing brain structural and fMRI measures and comparing any subject against the HCP normative group averages.

Structure-Function Coupling in the Human Brain and Links to Behavior

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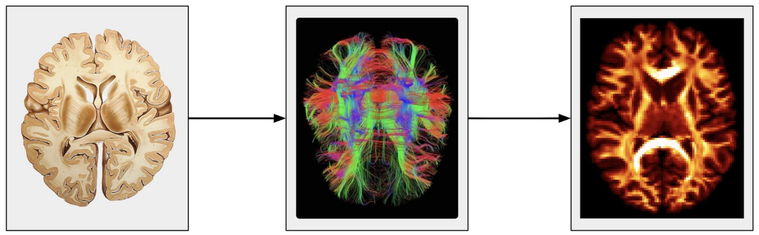
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Introduction

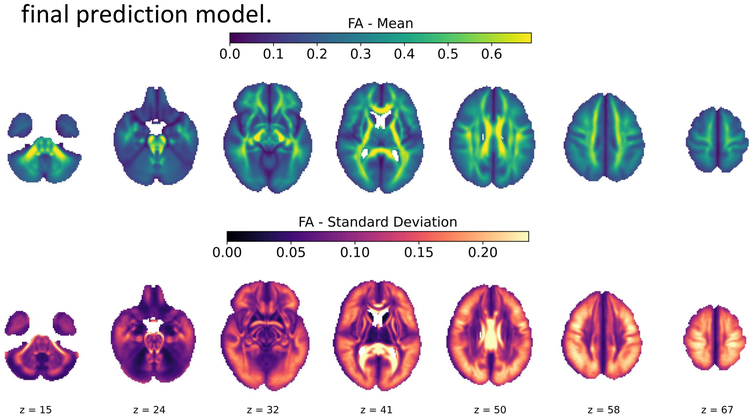
- Diffusion tensor imaging (DTI) measures water diffusion in the brain and maps white-matter tracts yielding Fractional Anisotropy (FA).
- FA provides a voxel-wise measure of white-matter organization, but its links to local fMRI measures and behavior remain unclear.
- **Goal:** How does FA relate to local fMRI measures across brain regions, and can this structure–function coupling predict behavior?

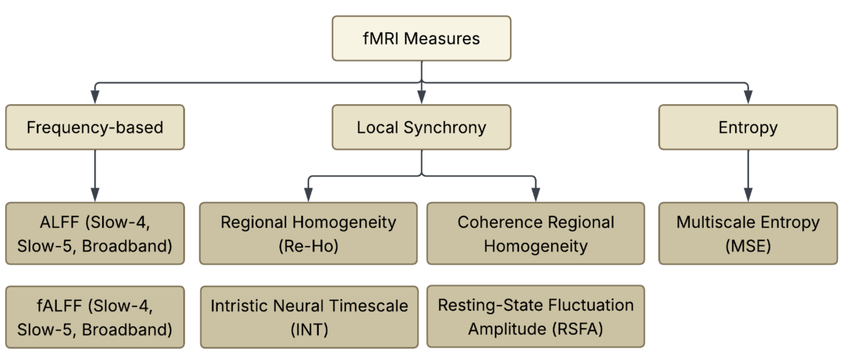


Human Brain | DTI-derived Tractography | Fractional Anisotropy

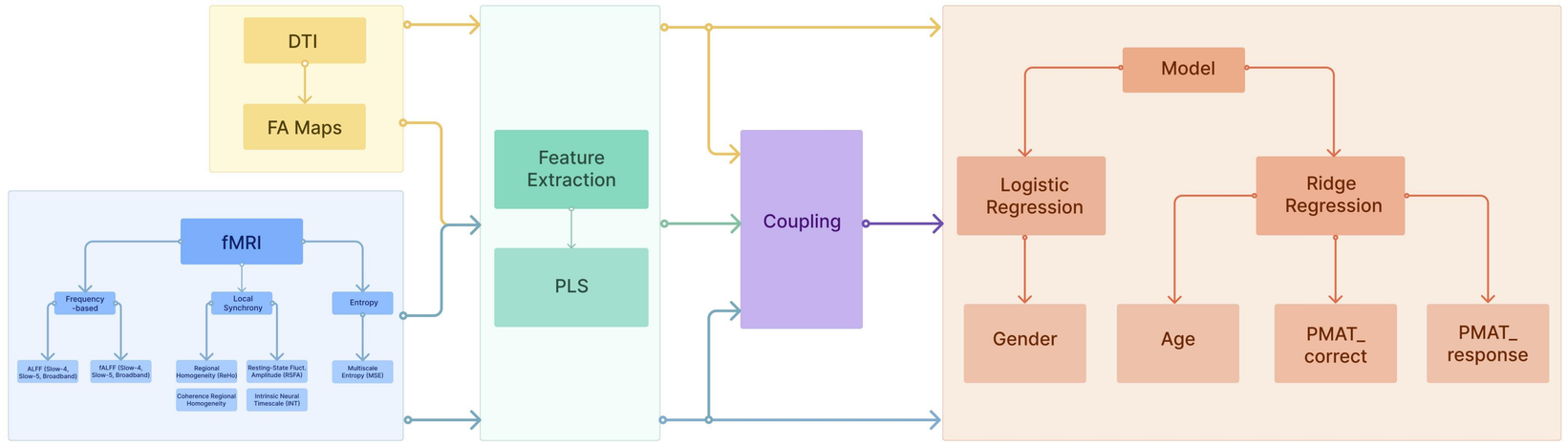
Methods

- Dataset: Used resting state-fMRI and FA maps from 896 subjects from the Human Connectome Project Young Adults (HCP) dataset after filtering for missing FA maps, scans and behavioral variables.
- Feature Extraction: Used Partial Least Squares (PLS) to reduce dimensionality and address multicollinearity, reducing each 200K-dimensional fMRI/FA vector to fewer than 24 features.
- Coupling: Stacked fMRI and FA reduced feature sets.
- 5-fold cross validation Logistic Regression for Gender classification and Ridge Regression for Age and Fluid Intelligence prediction.
- We compare function, structure and combined variants.
- Feature importance is computed as the mean absolute weight across the PLS components corresponding to each input metric within the final prediction model.

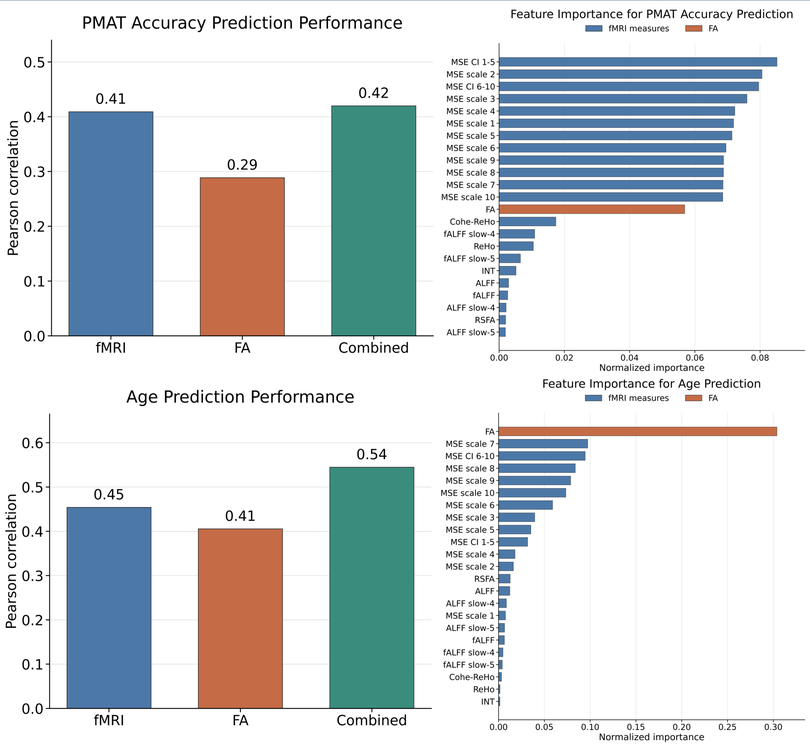


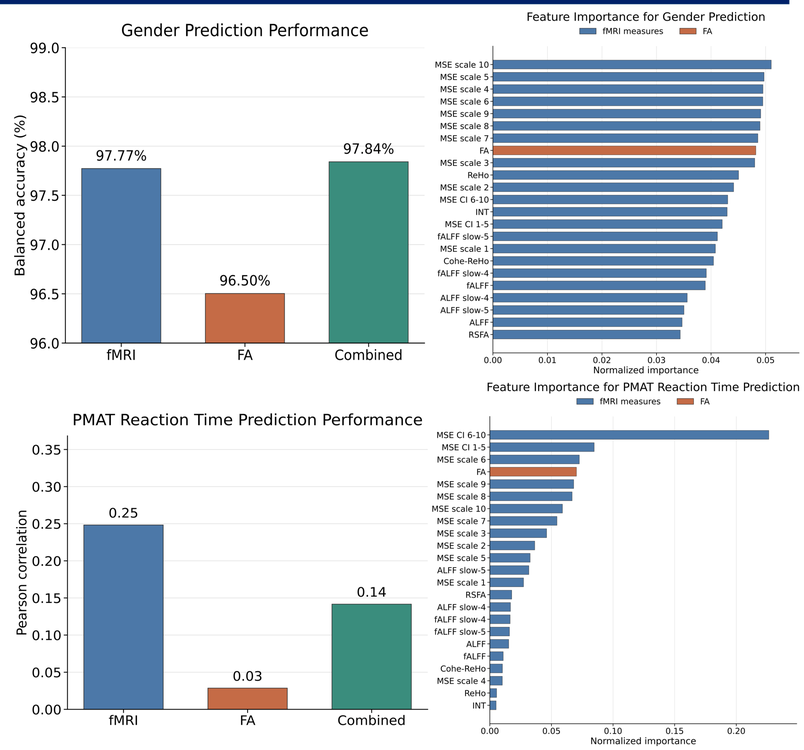


Pipeline



Results





Limitations

- The high gender prediction accuracy may be partly driven by total brain volume, which is a potential confound.
- Registration of scans to a standardized space may introduce boundary misalignment, representing a potential confound for age and gender prediction.

Structure-Function Toolbox

An open-source toolbox for computing brain structural and fMRI measures and comparing any subject against the HCP normative group averages.

Conclusions

- FA provides complementary structural information, improving prediction of age and PMAT-accuracy beyond fMRI alone.
- Age prediction appears to rely more strongly on structural connectivity, with FA emerging as the most influential feature group in the combined model.
- The limited benefit of FA for gender and PMAT-RT suggests that these targets are well captured by functional features, with little additional information provided by white matter microstructure.
- The results for PMAT-C, PMAT-RT, and age consistently demonstrate that incorporating FA values improves predictive performance.