Is resting state fMRI better than individual characteristics at predicting cognition?

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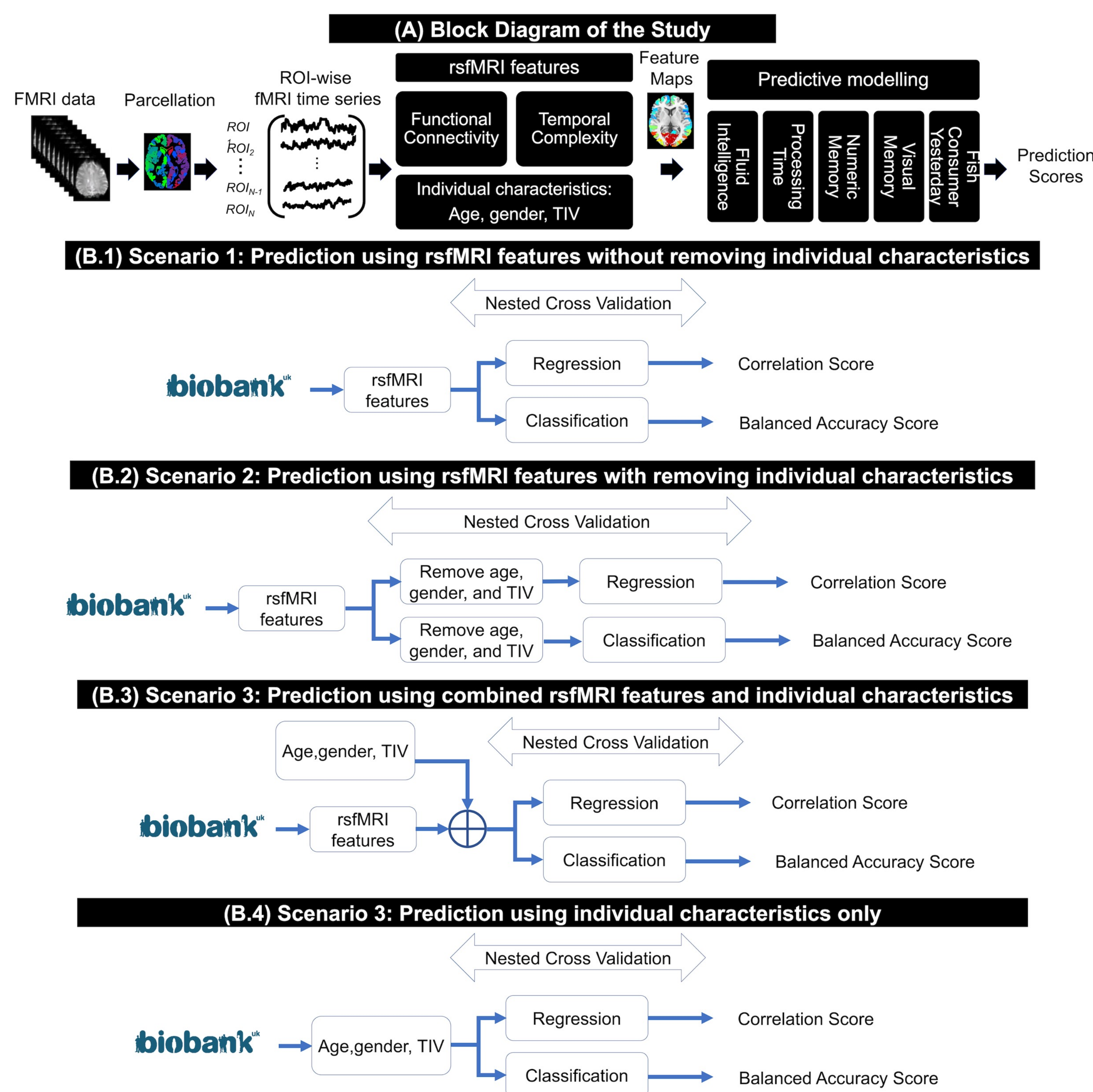
Introduction

Functional magnetic resonance imaging (fMRI) is a technique used to measure changes of blood flow in the brain in the presence or absence of mental task engagement. Over the past two decades, many studies have utilized fMRI at rest (so-called resting state fMRI or rsfMRI) to investigate various questions about behavior and cognition. One of the open challenges is whether information extracted from rsfMRI can predict demographics, behavior and cognitive scores in humans [1], [2]. If so then is the contribution of rsfMRI in behavioral/cognitive prediction a genuine property of brain function or is it confounded by properties such as age, sex, and brain anatomy?

Methodology

We extracted nine measures of rsfMRI from 20,000 unrelated subjects in the UK Biobank database [3]. These features covered a diverse range of properties of brain function such as balanced dynamic in the time domain or temporal complexity [4], signal memory through Hurst exponent [5], and linear relationship between brain areas at the local and global scales or so-called brain functional connectivity [2]. We then used these rsfMRI features to predict multiple aspects of cognition including visual memory, numeric memory, processing speed, and fluid intelligence, using Kernel Ridge regression.


(A) Block Diagram of the Study

(B.1) Scenario 1: Prediction using rsfMRI features without removing individual characteristics

(B.2) Scenario 2: Prediction using rsfMRI features with removing individual characteristics

(B.3) Scenario 3: Prediction using combined rsfMRI features and individual characteristics

(B.4) Scenario 3: Prediction using individual characteristics only

We also compared the rsfMRI features through an identification analysis across all subjects.

References

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Results

- Measures of local functional connectivity and signal entropy represented the highest prediction capacity amongst the eight rsfMRI features.
- Age and assigned sex at birth could be predicted with relatively high accuracy.
- In all cases, the prediction accuracies were significantly improved by increasing the number of subjects but reached a plateau after adding about 2,000 subjects to the analysis.
- Predictability of cognitive scores was considerably lower than age and sex correlation accuracy.
- Amongst the four cognitive scores, visual memory could not be predicted at all. After removing the age and sex as confounds from the targets and rsfMRI features, respectively, the prediction accuracies of numeric memory and processing speed scores were reduced to the chance level almost.
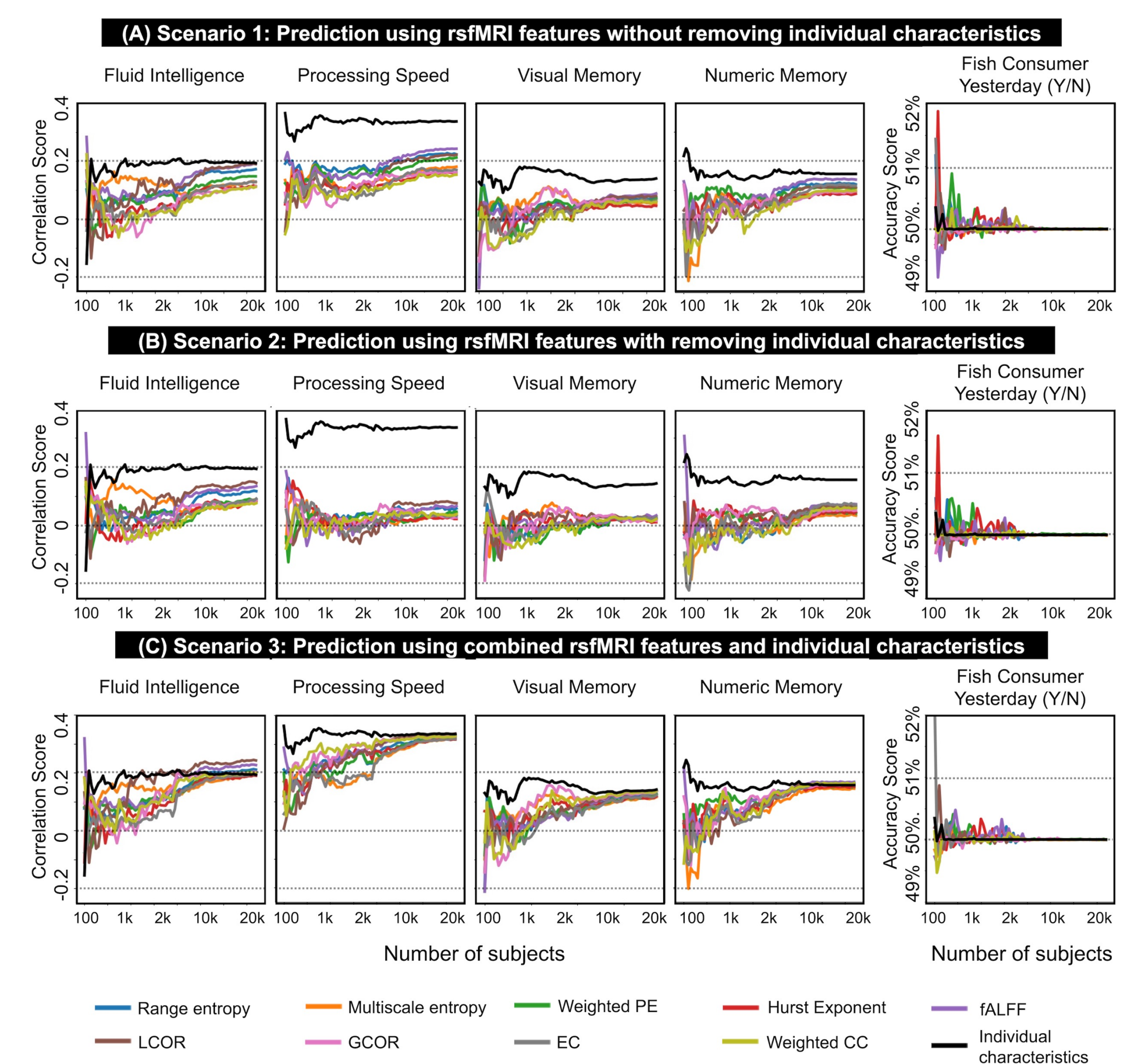
In contrast to the rising patterns of prediction accuracies, feature comparison showed a diminishing pattern. Additionally, some rsfMRI properties were more closely matched than others.
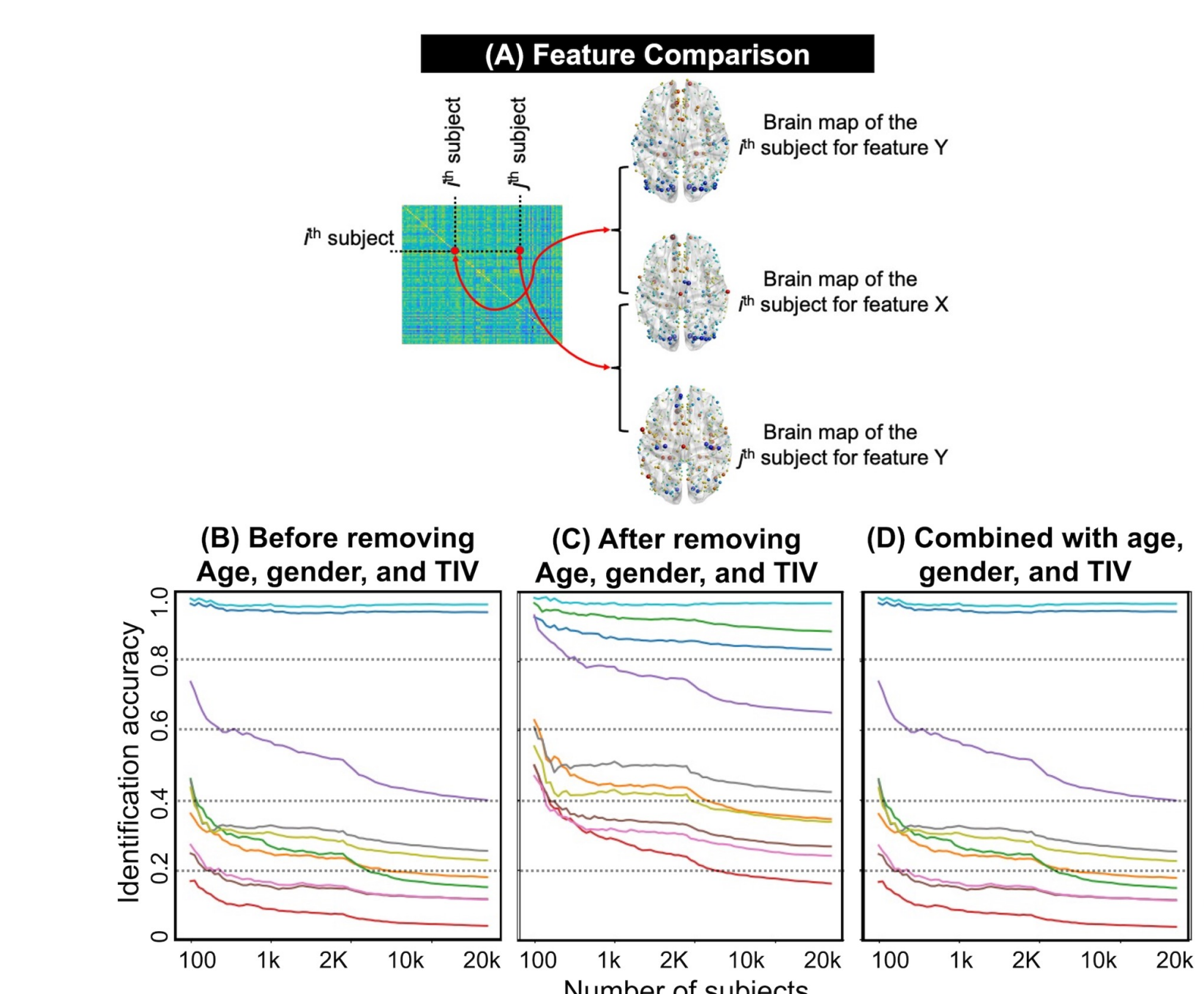
Conclusion

Our findings imply that even in large populations, very accurate predictions of cognition and fluid intelligence may not be possible using the standard measurements of brain function provided by rsfMRI.