Correction of Induced Functional Connectivity in Filtered Resting State FNIRS Data

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Introduction

- FNIRS is a non-invasive neuroimaging modality for monitoring brain oxygenation levels.
- Resting-state functional connectivity methods assume signals are white. Violation of this assumption invalidates statistical tests and induces spurious connectivity. Non-white frequency spectra and temporal filtering in fNIRS signals cause violations to whiteness assumption.
- Corrections to statistical tests of connectivity have been proposed in fMRI for white signals [1].
- We propose a correction to statistical tests of connectivity, accounts for both non-white fNIRS data and filtering.

Theory

- The impact of non-white fNIRS spectra on connectivity statistics, in conjunction with temporal filtering, is analytically established.
- The non-white fNIRS spectra is modelled using ensemble variance.
- Corrected degrees of freedom is calculated from ensemble variance and filter response.

$$\operatorname{corr}\left(x_t^{(f)}, y_t^{(f)}\right) \sim \mathcal{N}\left(\rho_{x,y}, \frac{(1-\rho_{x,y}^2)^2}{D}\right), \qquad D = \frac{\left(\sum_k \sigma_k^2 f_k^2\right)^2}{\sum_k \left(\sigma_k^2 f_k^2\right)^2}.$$

where $x_t^{(f)}$ and $y_t^{(f)}$ are filtered fNIRS signals with underlying correlation $\rho_{x,y}$. D is the corrected degrees of freedom. σ_k^2 is ensemble variance across channels for each frequency index k. f_k denotes the frequency response of the filter.

Methods

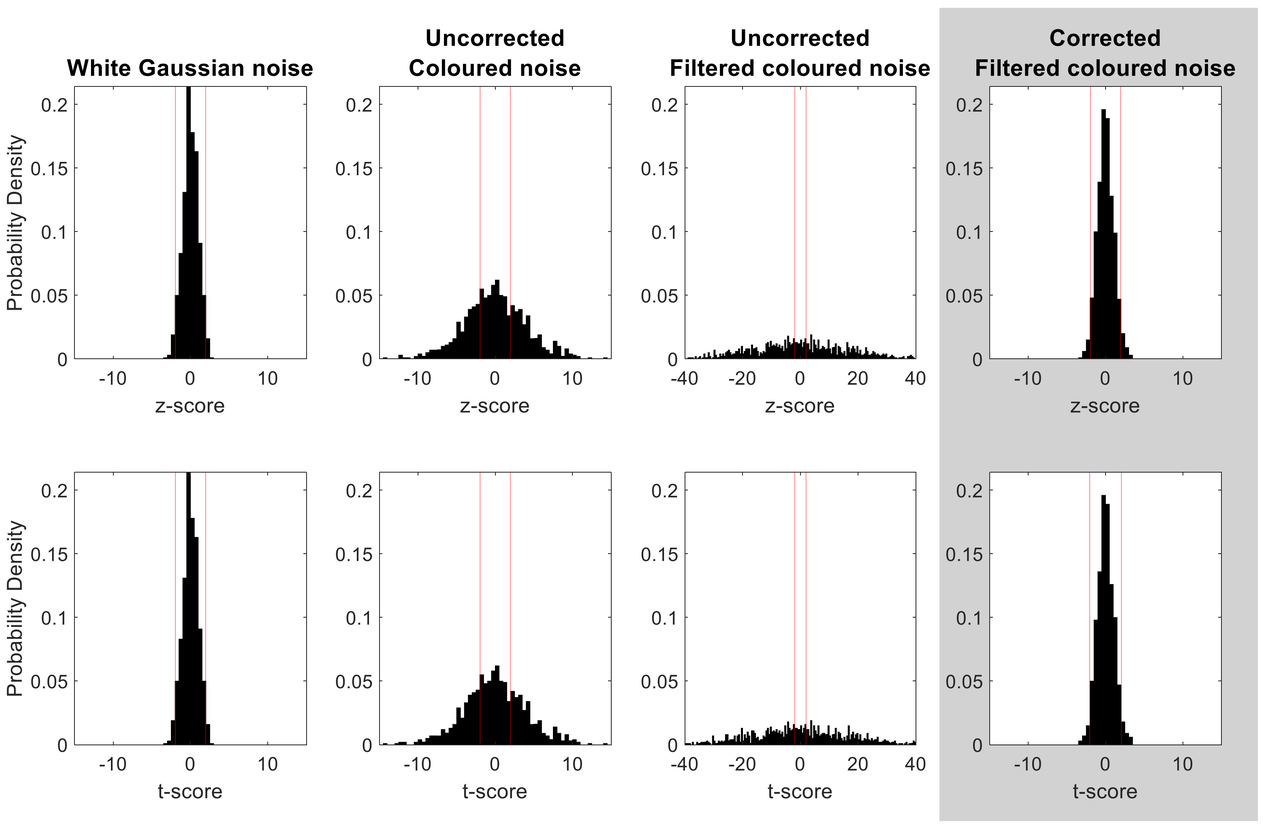
Simulations

- White Gaussian noise, coloured noise using empirical fNIRS spectra and filtered coloured noise using a Butterworth bandpass filter were simulated.
- Null hypothesis distributions with 95% confidence intervals for Fisher's z-transformation and Student's t-statistic were generated.

Experiments

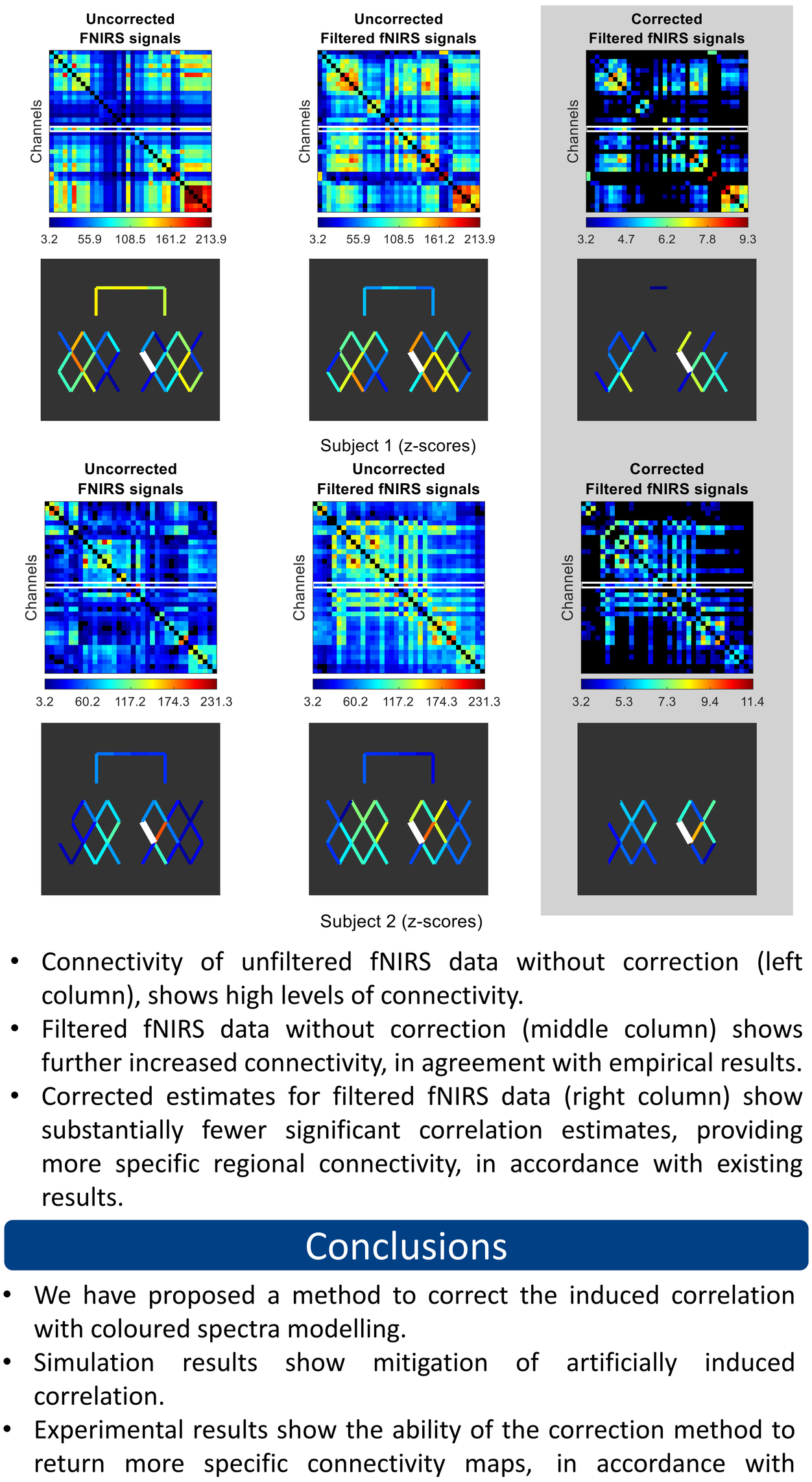
- FNIRS data (two subjects) from a resting-state dataset was used [2]. A seed channel was selected in sensorimotor region.
- Correlation matrices and seed-based correlation maps derived from z-scores with 95% CIs (Bonferroni corrected) were compared between uncorrected and corrected data.

Simulation Results



- Variance of the distribution of sample correlation: white noise < uncorrected coloured noise < uncorrected filtered coloured noise.
- The increases in variances artificially induce correlation if the statistical tests are not modified appropriately.
- After the proposed correction, the variance of sample correlation and appropriate confidence interval have been restored, thereby avoiding artificially induced correlation.

Experimental Results



- Connectivity of unfiltered fNIRS data without correction (left column), shows high levels of connectivity.
- Filtered fNIRS data without correction (middle column) shows further increased connectivity, in agreement with empirical results.
- Corrected estimates for filtered fNIRS data (right column) show substantially fewer significant correlation estimates, providing more specific regional connectivity, in accordance with existing results.

Conclusions

- We have proposed a method to correct the induced correlation with coloured spectra modelling.
- Simulation results show mitigation of artificially induced correlation.
- Experimental results show the ability of the correction method to return more specific connectivity maps, in accordance with expectations.

References

[1] C. E. Davey, D. B. Grayden, G. F. Egan, and L. A. Johnston, "Filtering induces correlation in fMRI resting state data," *NeuroImage*, vol. 64, pp. 728–740, Jan. 2013.
[2] S. Jahani, S. K. Setarehdan, D. A. Boas, and M. A. Yucel, "Motion artifact detection and correction in functional near-infrared spectroscopy: a new hybrid method based on spline interpolation method and Savitzky-Golay filtering," *NEUROPHOTONICS*, vol. 5, no. 1, pp. 015003-1-015003–11, Mar. 2018.

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