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Interrogating Resting-State Networks with Brain-Wide Diffuse Optical Tomography (BW-DOT)

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***Abstract*— We developed a novel brain-wide diffuse optical tomography framework (Fig. 1) that integrates a cap-based whole-head optode placement system with multiple computational and data-driven approaches to reconstruct resting-state networks in dual contrasts of oxygenated (HbO) and deoxygenated (HbR) hemoglobin.**

***Clinical Relevance*— This work is a validation of a novel framework that images large-scale brain networks, which benefits the patient population, such as bedridden patients, and infants, etc.**

I. Introduction

Diffuse optical tomography (DOT), an accessible multi-contrast functional neuroimaging technology, has uncovered resting-state networks (RSNs) covering limited brain areas to a large portion of the brain[1]. However, a collective set of distributed brain-wide networks has not been demonstrated.

II. Methods

The IRB-approved study recruited 13 healthy adult participants (5 females, 31.7±9.3 years) who underwent eye-open resting-state data recording sessions (6 minutes) and one MRI head scan (3T). The fNIRS data were collected by a continuous-wave (760/850nm) system (6.25 Hz, 109 Long channels, 8 Short channels:8 mm). Peripheral sensors (triaxial accelerometer, pulse oximeter, and breathing belt) were simultaneously recorded at 500Hz. The fNIRS data were pre-processed (0.009-0.08Hz) using an automatic denoising procedure[2]. Participant-specific structural MRI scan data were used to create individual finite element method volume meshes. A spectrally constrained linear forward model was used. The sensitivity matrix was calculated using the NIRFAST software. A single-step joint inverse reconstruction using regularized minimum norm estimate yielded the volumetric inverse solution data, which were spatially smoothed and projected to the cortical surface to create brain-wide DOT maps. These maps were subjected to group-level spatial independent component analysis and statistical correlation tomography to estimate spatial patterns of independent components (IC) from inverse tomographic data, each representing an RSN. Obtained spatial patterns of ICs were then matched via visual inspections to fMRI RSN (f-RSN) templates to perform quantitative evaluations of DOT RSNs using spatial matching metrics[2].

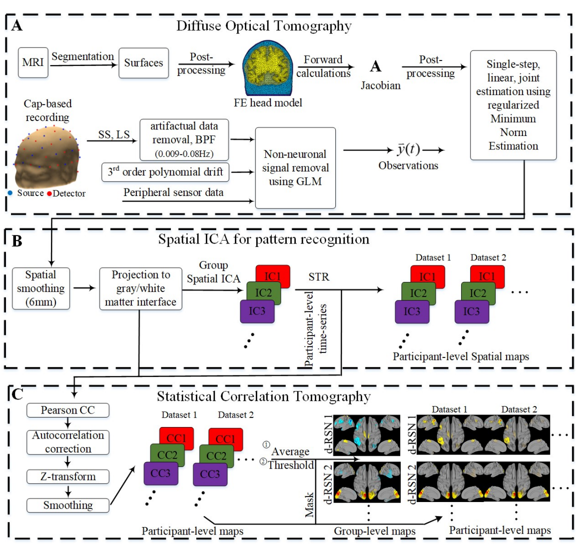

Figure 1. BW-DOT framework

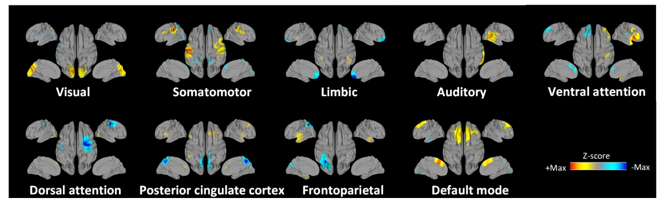

Figure 2. Representative group-level deoxygenated hemoglobin d-RSNs. All spatial maps are on gray/white matter interface and thresholded ($p < 0.01$).

III. Results

Our results revealed a comprehensive set of RSNs and their subnetworks, collectively covering most of the brain's neocortical surface at the group (Fig. 2) and participant level. These maps resembled fMRI RSNs and included regions of the medial prefrontal cortex and precuneus missed in previous DOT studies. HbR RSNs showed statistically more similarity to fMRI RSNs, while HbO RSNs indicated more bilateral patterns over two hemispheres. In addition, the BW-DOT framework allowed consistent reconstructions of RSNs across individuals and recording sessions, indicating its high robustness and reproducibility, respectively.

IV. Discussion & Conclusion

Our present results suggest the feasibility of using the brain-wide DOT, as a neuroimaging tool, in simultaneously mapping multiple RSNs and its potential values in studying RSNs, particularly in patient populations under diverse conditions and needs, due to its advantages in accessibility over fMRI.

References

[1] M. D. Wheelock, J. P. Culver, and A. T. Eggebrecht, "High-density diffuse optical tomography for imaging human brain function," *Review of Scientific Instruments,* vol. 90, no. 5, p. 051101, 2019, doi: 10.1063/1.5086809.

[2] A. F. Khan, F. Zhang, H. Yuan, and L. Ding, "Brain-wide functional diffuse optical tomography of resting state networks," *Journal of Neural Engineering,* 2021.

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