Optica Biophotonics Congress: Optics in the Life Sciences 2023 (BODA, BRAIN, NTM, OMA, OMP) © Optica Publishing Group 2023

Precision Functional Mapping of Cortical Activity Using High-Density Diffuse Optical Tomography (HD-DOT)

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Abstract: We present a single-subject level functional mapping of cortical activity using high-density diffuse optical tomography with the goal to improve reproducibility of maps at an individual level while also revealing subject-specific features that are often ignored by group-level generalizations. © 2023 The Author(s)

1. Introduction

Functional neuroimaging is a valuable technique for localizing brain activity in a non-invasive manner. However, most neuroimaging studies only report group-level results without adequately accounting for variability at an individual level [1]. The functional Magnetic Resonance Imaging (fMRI) dataset by Gordon et.al.[2] revealed spatial and organizational variability in brain networks which emphasizes the risks of group-level generalizations. In this study, we test the effectiveness of using High-Density Diffuse Optical Tomography (HD-DOT) for high precision mapping of cortical brain activity. Our research aims to generate high-fidelity single-subject level maps by improving co-registration of measurements across sessions which will be quantified by a rate-of-convergence of the percentage standard error (%SE) as a function of the number of trials collected across multiple sessions of data.

2. Methods

We present preliminary results from a single subject across six sessions of a retinotopic mapping paradigm where a flickering checkerboard wedge is repeated 6 times in either the bottom left or right quadrant of the visual field (Fig 1.A). Previous DOT studies using this paradigm have been effective in replicating results from fMRI literature and also been used in the context of template-based decoding [3,4].

1.1. *Imaging System:* HD-DOT is an optical imaging technique that uses dense, regularly spaced arrays of near-infrared sources and detectors to obtain overlapping measurements of the underlying hemodynamic activity [5]. This allows a three-dimensional tomographic spatial reconstruction of cortical activity patterns comparable to fMRI maps. However, to obtain single-subject level precision in DOT, we must ensure consistent placement of measurement position across multiple scan sessions. We address this issue by using photometric verification of cap position using the tragus to canthus line as fiducials to determine alignment between separate sessions.

1.2. *Data Analysis:* Data pre-processing was done using the NeuroDOT toolbox based on the principles of modeling light emission, diffusion, and detection through the head [5,6]. Global variance of temporal derivative (GVTD), a motion detection index that identifies parts of the data contaminated by movement or physiological artifacts, was used to censor noisy time points in the data [7]. A voxel-wise general linear model framework was used to estimate the task-related responses and generate statistical maps of cortical activations. A region of interest was isolated by extracting contiguous voxels with a magnitude of at least 50% of peak activation around a seed [-19.5, -102, 3] located in the left visual cortex.

3. Results

The activation across the six sessions of data collection show a consistent pattern of activity in the contralateral visual cortex based on the location of the visual stimuli. Fig 1.B shows the unthresholded beta map corresponding to stimulus presented in the bottom right quadrant. An ROI was extracted from these beta maps and the timeseries for the seed region is visualized in Fig 1. C. Fig 1.D shows a matrix of dice values comparing the overlap of the ROIs across sessions with session 1 and 6 showing the least overlap and session 3 and 4 with the most overlap.

3. Conclusion

Accurate single-subject mapping can inform changes in functional brain activity over time. This valuable resource helps to understand individual brain organization while also improving group-level analyses. HD-DOT can be a promising imaging modality to ensure precise single subject-level functional mapping in a wide range of demographics, including children and clinical populations contraindicated by MRI. Future directions to this project are to expand this approach to other tasks (auditory, motor, language), and resting-state activity.

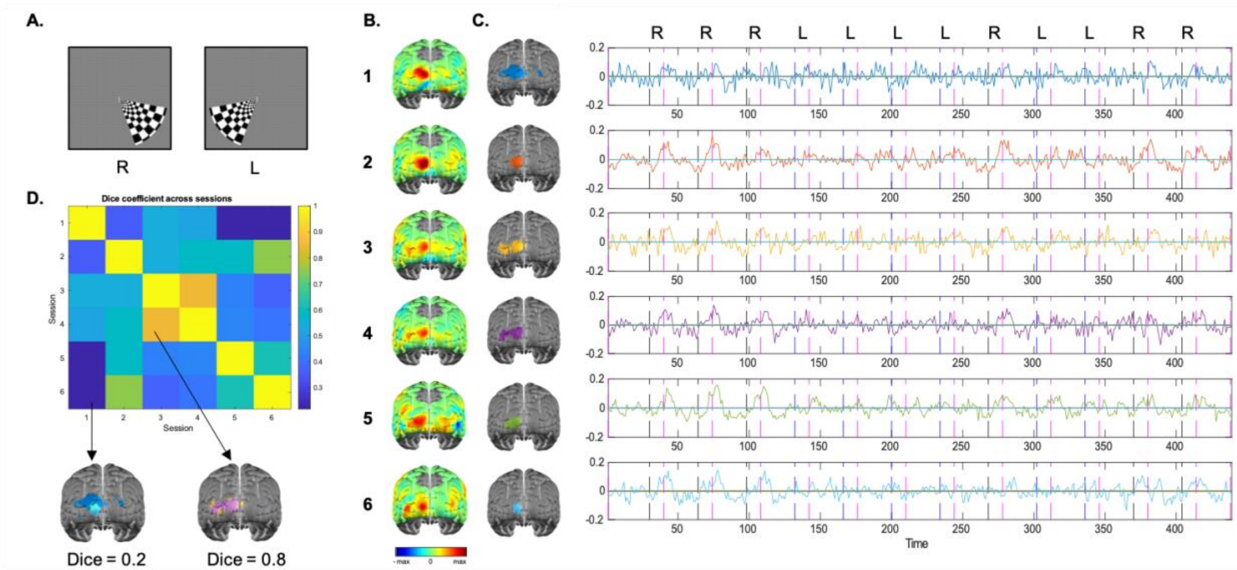

Fig. 1. A: Retinotopic mapping paradigm, B: Unthresholded task activation maps across six sessions of data collection in a single subject, C: Region of Interest (ROI) extracted from the beta maps and the corresponding timeseries from the spherical seed region in the ROI, D: Dice coefficient matrix comparing overlap of ROIs across sessions and example overlap maps from sessions with low and high overlap.

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