Development of Diffuse Optical Tomography Sensitivity in Infants

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http://jerlab.psych.sc.edu/jerpdf/icis2018DOTsensitivity.pdf

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INTRODUCTION

'Near-Infrared-Optical-Spectroscopy' (NIRS) is a tool for neuroimaging in infant participants. NIRS measurement works by source/detector optodes placed on the scalp that measure reflected light from oxygenated / deoxygenated hemoglobin. Diffuse optical tomography (DOT) is used to describe the scattering of light through the interior of the head. The sensitivity profile derived from DOT may be used to identify the underlying cortical anatomy that is reflected to the detector optodes and the relative contributions of anatomical regions. The current study uses simulated photon migration programs to map the DOT sensitivity of infants in the first year. The results map the sensitivity of the infant head to light propagation. The DOT sensitivity profiles for individual infants is used to complement spatial projection methods and adds to a comprehensive database of scalp-location-to-cortical-anatomy for infants. These results were also compared to results for older age participants, and the sensitivity profiles for an age may be used in quantitative methods that use inverse modeling to show NIRS activity in the brain.

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METHOD

1—Structural MRIs of whole head
- Whole head needed for scalp locations; extracted brain for cortex
- Age-appropriate average MRI template (Sanchez et al., 2011, 2012)
- "Closest head", library approach (e.g., Emberson et al, 2017)

2—Scalp locations located on MRI
- Talairach origin is planes normal to AC-PC line, distance from AC
- Virtual 10-10 Electrode positions (Richards et al., 2015)
- Simulated 10-5 Electrode positions

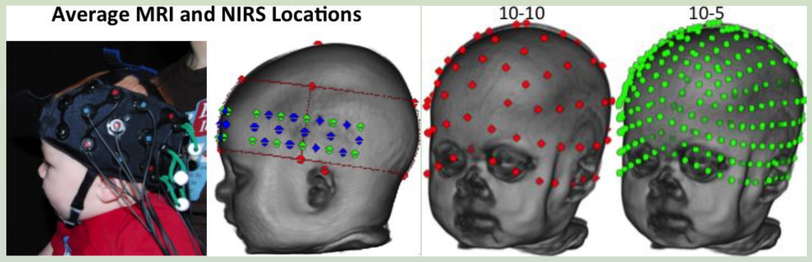
3—Stereotaxic atlas categorizes the brain
- Manually delineated lobar atlas (Phillips-Meek et al, 2013; Fillmore et al...)
- Macroanatomical atlas (Gousious et al; Shattuck et al; Fillmore et al,)
- Manually drawn segments (Onishi et al)

4—Projections between scalp locations and cortical locations
- Shrink the scalp until intersects the brain, find electrode position on cortex
- Expand the brain until it intersects the scalp, find electrode position
- One voxel, 1 cm sphere, NIRS banana shape
- Average MRI, individual MRIs, individual cortex projection
- Participant-defined ROI, channel projections over subjects, channel distributions

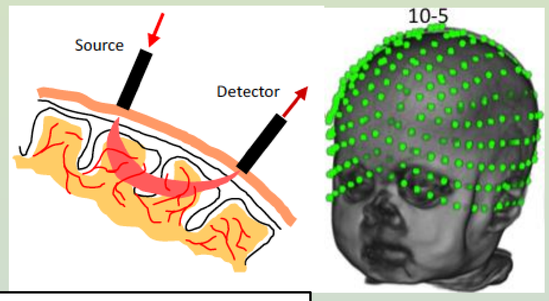
5—DOT Sensitivity Computation
- Photon migration simulation program (MCX; tMCimg; MMC)
- 100M photons projected from 10-5 locations (emitter)into segmented head
- Record flux at each voxel location in the head
- Estimate strength of photon signal at detector
- Distribution of DOT sensitivity (by depth, channel, etc)

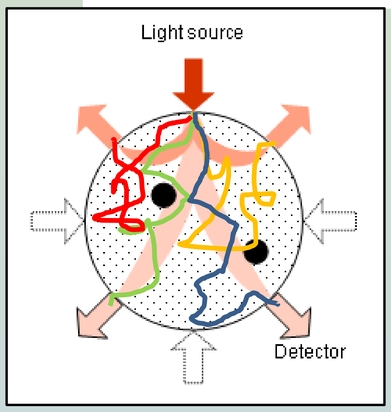
6—Final product
- Tables of scalp-location / distance / atlas location
  - (age X scalp location X voxel/sphere/banana, with probability of atlas location
- Forward and inverse models for Image Reconstruction

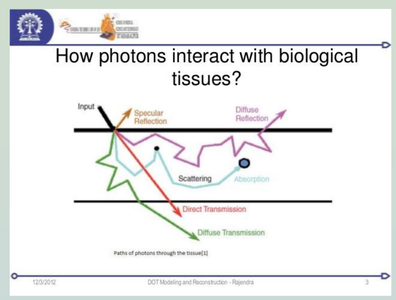
Participant NIRS Recorded on Scalp
Locate Optode Locations on Structural MRI



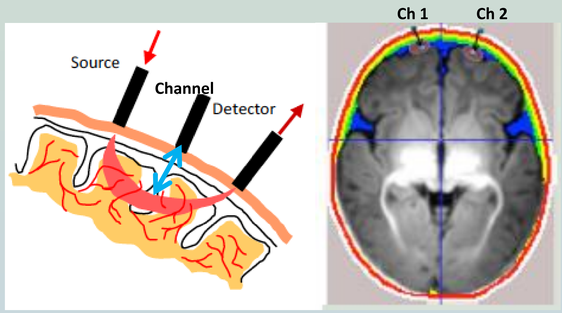
DOT Projection, Emitter, Head-Brain, Detector

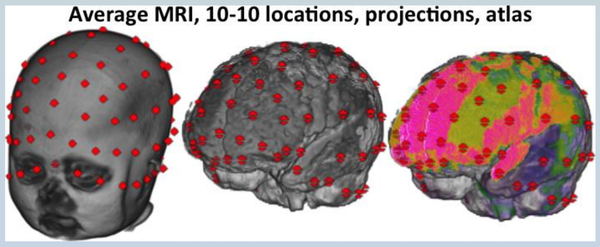


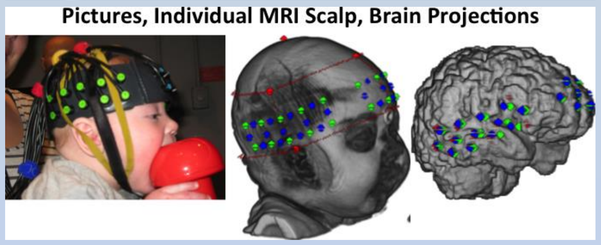


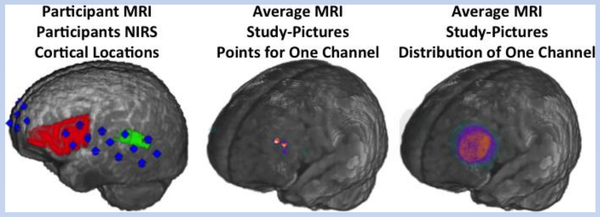


Spatial Projection from "Channel" to Brain

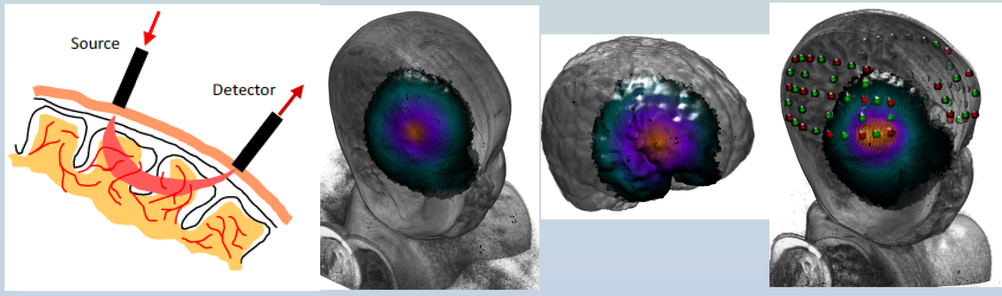




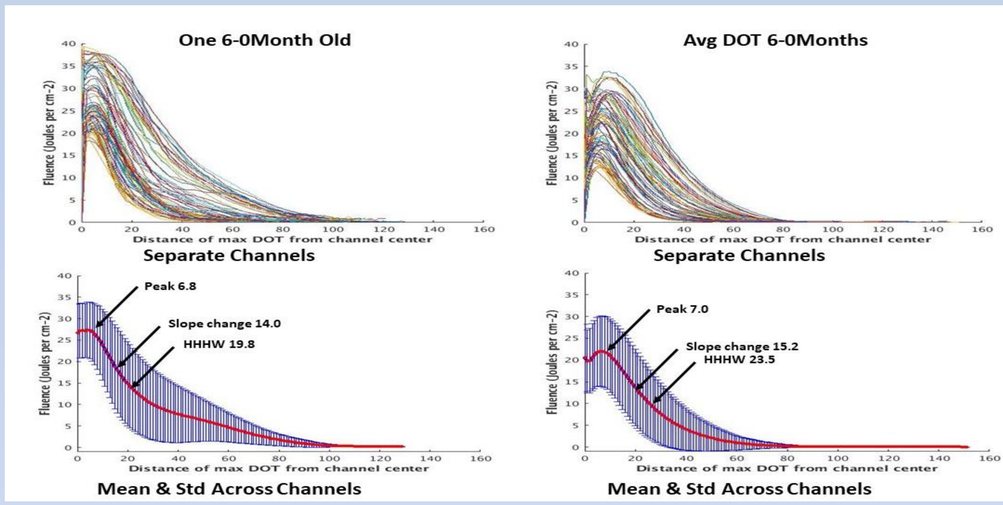




Photon-Simulation DOT Sensitivity One Emitter-Detector

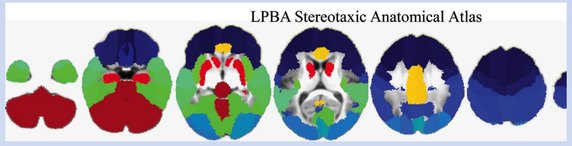


DOT Sensitivity Profile for One 6-Month Old and Average Template

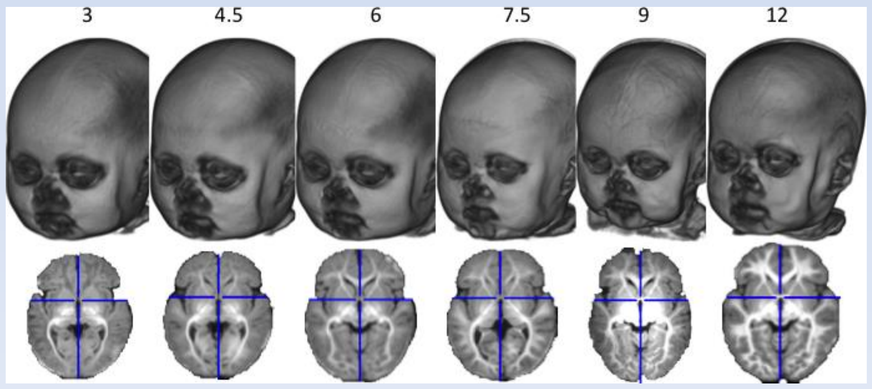


Infant MRI

Stereotaxic Atlas Categorizes the Brain



Average MRI Templates



Tables of Locations

Table 1: Atlas locations of the NIRS channels across the group of infants. The label of the channel is followed by (%) of infants with this region. Regions are reported when the number of allocated infants ≥ 20% of the group.

NIRS Channels	Lobar atlas	Macro-anatomical atlas (LPBA40)
Left lateral NIRS array		
1	Frontal (93)	Inferior frontal gyrus (82)
2	Frontal (100)	Inferior frontal gyrus (100)
3	Frontal (100)	Inferior frontal gyrus (95)
4	Frontal (87)	Inferior frontal gyrus (76)
5	Temporal (76) Frontal (24)	Superior temporal gyrus (66) Inferior frontal gyrus (20)
6	Frontal (84)	Inferior frontal gyrus (44) Precentral gyrus (38)
7	Temporal (65) Frontal (33)	Superior temporal gyrus (66) Precentral gyrus (20)
8	Temporal (100)	Middle temporal gyrus (73) Superior temporal gyrus (24)
9	Parietal (53) Temporal (25) Frontal (21)	Superior temporal gyrus (42) Postcentral gyrus (40)
10	Temporal (98)	Superior temporal gyrus (67) Middle temporal gyrus (31)
11	Temporal (100)	Middle temporal gyrus (86)
12	Temporal (87)	Superior temporal gyrus (71) Middle temporal gyrus (20)
13	Temporal (93)	Middle temporal gyrus (78)
Right lateral NIRS array		
14	Frontal (87)	Inferior frontal gyrus (71)
15	Frontal (100)	Inferior frontal gyrus (95)
16	Frontal (100)	Inferior frontal gyrus (76)
17	Frontal (87)	Inferior frontal gyrus (75)
18	Temporal (69) Frontal (31)	Superior temporal gyrus (51) Inferior frontal gyrus (24)
19	Frontal (84) Parietal (16)	Inferior frontal gyrus (47) Precentral gyrus (35)
20	Temporal (58) Frontal (38)	Superior temporal gyrus (49) Precentral gyrus (26)
21	Temporal (100)	Middle temporal gyrus (62) Superior temporal gyrus (36)
22	Parietal (49) Temporal (33) Frontal (18)	Superior temporal gyrus (38) Postcentral gyrus (35)
23	Temporal (98)	Superior temporal gyrus (62) Middle temporal gyrus (36)
24	Temporal (98)	Middle temporal gyrus (66) Inferior temporal gyrus (29)
25	Temporal (71) Parietal (29)	Superior temporal gyrus (56) Middle temporal gyrus (24)
26	Temporal (85)	Middle temporal gyrus (58) Superior temporal gyrus (20)
Frontal NIRS array		
27	Frontal (100)	Superior frontal gyrus (89)
28	Frontal (100)	Middle frontal gyrus (62) Superior frontal gyrus (38)
29	Frontal (100)	Middle frontal gyrus (95)
30	Frontal (100)	Superior frontal gyrus (96)
31	Frontal (100)	Middle frontal gyrus (100)
32	Frontal (100)	Superior frontal gyrus (73) Middle frontal gyrus (27)
33	Frontal (100)	Middle frontal gyrus (58) Superior frontal gyrus (42)

Distance from Scalp Channel (S/D) to Max DOT Sensitivity Location