Demonstration of the spatial sensitivity of a compact HD-DOT system using a Retinotopy paradigm

Chandran V. Seshagiri[1], Tanmayi Oruganti[1], Jason W. Trobaugh[2], Joseph P. Culver[3], Bertan Hallacoglu[1]
[1]Cephalogics, LLC, 300 Technology Square, Suite 201, Cambridge, MA,
[2]Department of Electrical Engineering, Washington University, St. Louis, MO
[3]Department of Radiology, Washington University School of Medicine, St. Louis, MO
Author e-mail address: chandran.seshagiri@cephalogics.com

Traditional Diffuse Optical Tomography (DOT) systems rely on fiber optic cables to carry optical signals to and from the imaged tissue. As the number of channels increases, the weight and size of the fibers limits both the comfort and the practical utility of such systems in clinical use. We have developed a compact, non-fiber based high-density DOT (HD-DOT) sensor and used it for retinotopic mapping of the visual cortex in human volunteers. The sensor consists of 10 source optodes and 18 detector optodes printed on rigid-flex circuit boards for flexibility. Each source optode contains five lasers operating at five different wavelengths ranging from 690-850nm with source-detector separations ranging from 13-87mm. Data are digitized, processed, and transmitted to a laptop via Ethernet at 10Hz for post-processing.

Retinotopy recordings were performed on two subjects, where the sensor was placed above the inion over the visual cortex. During recordings, seated subjects were asked to stare at a rotating checkerboard wedge stimulus (RCWS) located ~30in away and rotating in 10º/sec steps. Ten full revolutions of the RCWS were presented. Raw optical intensity data were post-processed to generate images of oxy-hemoglobin changes (ΔHbO) using previously described methods. Estimated ΔHbO trends for three pixels from different regions of the imaging field reveal strong periodicity of the response to RCWS with a distinct phase for each region (Fig 1a). ΔHbO images for different RCWS positions (Fig 1b) demonstrate the spatial sensitivity of our HD-DOT system. Phase of the temporal ΔHbO were computed at the frequency of the RCWS rotation for each pixel and the results were mapped to the polar angle of the RCWS position (Fig 1c). Phase map in Fig 1c shows the typical pinwheel pattern associated with retinotopic mapping of the primary visual cortex consistent with earlier works [1].

We have demonstrated the spatial sensitivity of our compact HD-DOT sensor to cortical neurovascular coupling using a retinotopic mapping experiment. Initial results from two subjects highlight the attainable spatial resolution and the utility of this system for functional brain mapping applications.

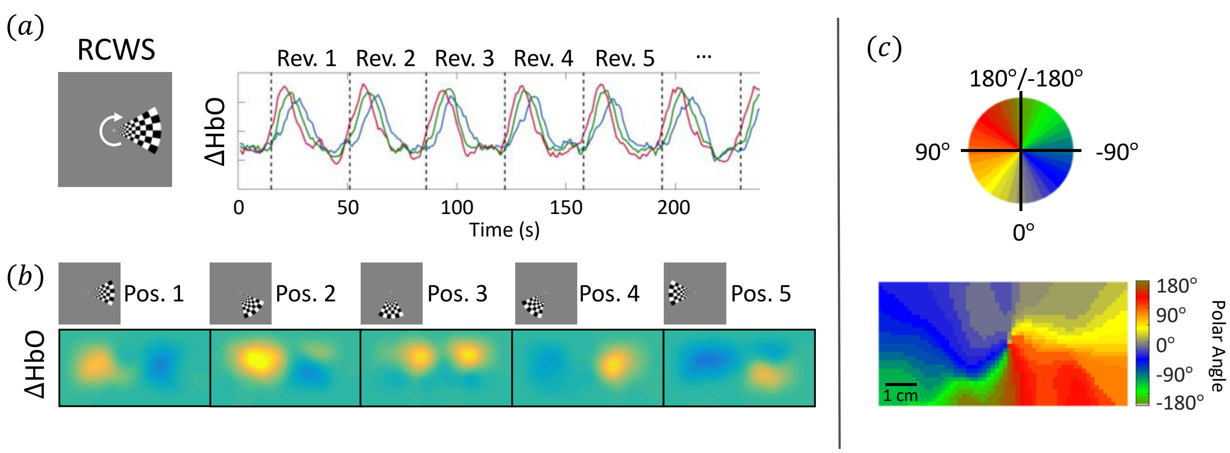

Figure 1 – HD-DOT imaging results from the rotating checkerboard wedge stimulus (RCWS) for a subject. (a) Temporal ΔHbO trends for three arbitrarily chosen pixels are shown for five revolutions (Rev) of the RCWS revealing high contrast-to-noise ratio, periodicity, and phase distribution of the ΔHbO response. (b) ΔHbO images shown below five different RCWS positions, indicating the region of activation in the visual cortex of the brain. (c) Colormap of the wedge position (top); and the phase map of the ΔHbO response showing the typical pinwheel pattern associated with retinotopic mapping of the primary visual cortex (bottom).

[1] Zeff, B.W. (2007), 'Retinotopic mapping of adult human visual cortex with high-density diffuse optical tomography', Proceedings of the National Academy of Sciences, vol. 104, no. 29, pp. 12169-12174