

DEPTH SENSITIVITY IN MULTI-DISTANCE NIRS MEASUREMENTS IN HUMANS

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Abstract

We review different high-resolution diffuse optical tomography (HR-DOT) experiments monitoring functional activation [1] or brain perfusion in humans [2]. We demonstrate the demand of an objective depth correction algorithm especially for weak (i.e., intrinsic) signals.

Methods

Imaging Device

- DYNOT HR-DOT imager (NIRx Medizintechnik GmbH, Berlin, Germany) for measurements of light intensity changes



- $\lambda=760$ nm & $\lambda=830$ nm

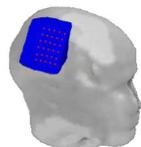
- high-density grid of 30 co-located optical fibers (inter-optode separation: 7.5 mm)



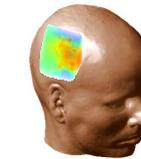
- sampling frequency: 1.81 Hz

Forward Solution and Image Reconstruction

- Forward Model: Diffusion equation on a FE mesh with assumed homogeneous interior optical properties



- reconstruction of time series of relative absorption changes [3] for each node of the volume



- (mention NAVI?)

Experiment I

Vibrotactile Stimulation

- 8 subjects, optical fibers over right (LEFT?) hemisphere
- vibrotactile stimulation of the 1st and 5th finger of right (LEFT?) hand (piezoelectric transducer, vibration frequency 40Hz)
- 40 stimulations /finger, duration: 20 sec followed by 20_sec rest, pseudo randomized order
- Anatomic MR scans for mapping



Cortical activation causes hemodynamic response with an increased HbO concentration and decreased HbR concentration.

HbO and HbR serve as *intrinsic* contrast agents.

Experiment II

Bolus kinetics

- 3 subjects, optical fibers over left hemisphere
- 4 ICG boli (9-15mg)

Expected bolus behavior:



ICG...is injected. ...arrives in cortex. ...arrives in skin. ... is washed out from cortex.

Measuring the arriving time of the absorber allows separation of brain and scalp voxels:

EARLY increase in absorption → BRAIN

LATE increase in absorption → SCALP

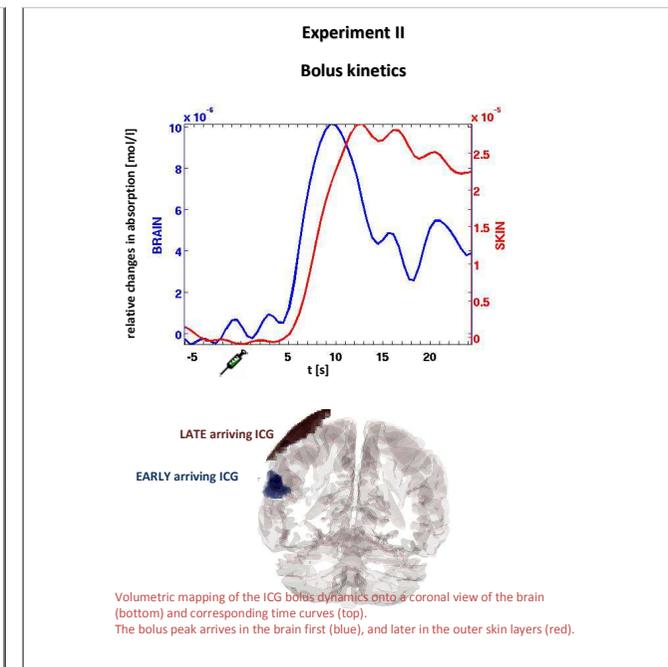
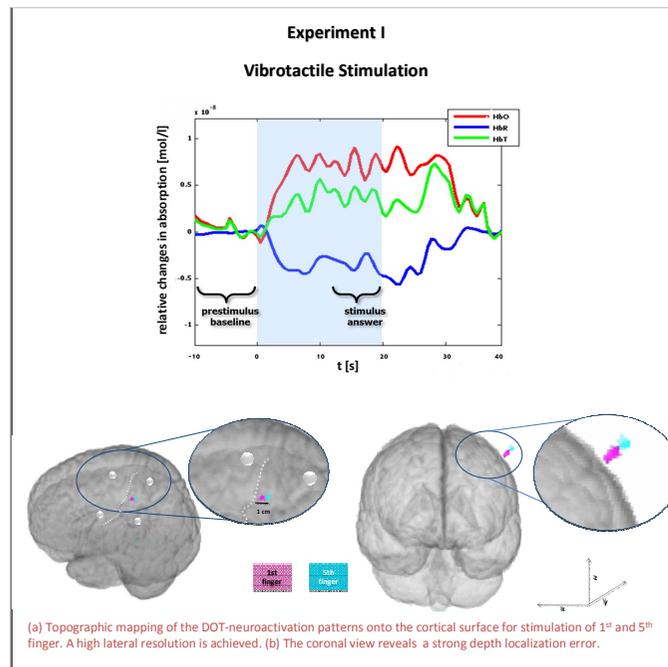
ICG serves as an *exogenic* contrast agent.

Background

- HR-DOT is a 3D modality of near infrared spectroscopy (NIRS)
- uses overlapping photon paths and image reconstruction procedure
- result is a time series of changes of interior optical properties in 3D volumes
- Forward Problem: light propagation in tissue has to be simulated with
 - finite-element-method solution of the diffusion equation or
 - Monte Carlo simulation of photon migration
- The resulting Jacobian assigns the highest sensitivity to optical changes in the outermost voxels (i.e., scalp) and has a strongly decreasing sensitivity toward deeper layers (i.e. brain tissue).

When solving the inverse problem this leads to a *distortion* of the reconstructed results in a way that **contrast features are pulled toward the surface.**

Results



Discussion and Conclusion

- We are able to localize and map in 3D both weak functional neuroactivation patterns as well as strong exogenic contrast features with statistical significance.
- Weak signals are grossly misplaced and projected outside the brain.
- For strong signals such as caused by exogenic contrast agents, the depth localization improves greatly. In most studies, especially in functional NIRS, changes of intrinsic chromophores are measured. Comparing this to exogenic signals may afford a way of benchmarking the depth localization quality of HR-DOT algorithms *in vivo*.
- Various methods have been proposed to correct depth-profiling errors in DOT, e.g. [4, 5]. Comparing intrinsic and extrinsic contrast features *in vivo* may serve to compare the effectiveness such methods.

References

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