A Combined NIR and BOLD FMRI Study of Transient Activation and Deactivation

L. Tang[1], C. J. Cannistraci[1], B. Niederhauser[2], M. J. Avison[1], J. C. Gore[1]

[1]Vanderbilt University Institute of Imaging Science, Nashville, TN, United States, [2]School of Medicine, Vanderbilt University, Nashville, TN, United States

Introduction:

FMRI based on the BOLD effect records the MR signal changes produced by alterations in tissue blood volume, flow and oxygenation. The signal increase following a transient excitation (the hemodynamic response function or HRF) is believed to arise because the flow and oxygenation increase are greater than are required to meet metabolic demand. Conversely, during steady state activation, equilibrium is established between flow and metabolism so that when a transient decrease in activation arises (by interrupting the stimulus) the oxygen demand is reduced. The subsequent HRF for this deactivation corresponds to an MR signal decrease, suggesting that flow is reduced to a degree greater than that required to establish the same level of oxygenation. Unfortunately, fMRI does not directly indicate blood oxygenation. We used transcranial near-infrared spectroscopy (NIRS) [1] and fMRI to investigate the positive and negative BOLD effects and recorded changes in both oxy- and deoxy-hemoglobin in response to transient activations and deactivations.

Method:

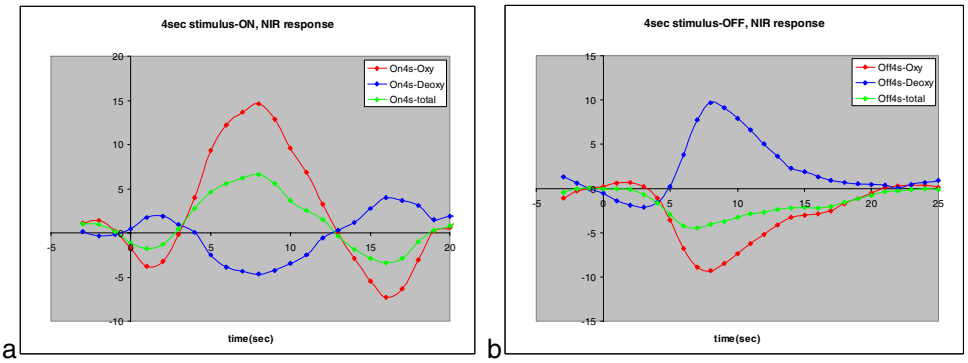
An 8Hz large-field contrast-reversing checkerboard pattern at 100% contrast served as our visual excitation stimulus ("ON"). In our baseline condition subjects viewed a spatially homogeneous black screen ("OFF"). Two event-related paradigms generated by E-prime (Psychology Software Tools, Inc) were presented to healthy subjects: I. Brief stimulus-ON (2sec or 4sec) during otherwise continuous stimulus-OFF; II. Brief stimulus-OFF (2sec or 4sec) interspersed with otherwise continuous stimulus-ON. The target to target interval was fixed to 20sec for all trials. In total 80 trials were presented in 4 runs, and each type of stimulus (2sec/4sec of flickering checkerboard ON and 2sec/4sec of black screen OFF) was presented 20 times.

NIR data were collected using a multi-channel (3x5) near-infrared optical topography system (Hitachi topoETG4000). Optodes were positioned to be able to sample signals from the center posterior region corresponding to primary visual cortex. NIR data were down sampled from 10Hz to 1Hz, temporally filtered (using a linear trend filter), then analyzed assuming a General Linear Model to obtain measurements of the event-related oxy- and deoxy-hemoglobin concentration changes for both ON and OFF stimuli.

MR images were acquired on a 3T Philips Achieva. Ten T1-weighted anatomic images were collected parallel to AC-PC line with 5mm slice thickness and 1mm gap and positioned to cover the visual areas. Then functional images were collected in the same planes, using a gradient echo EPI sequence (TR/TE=1s/35ms, flip angle=70^{o}, FOV=22x22cm^{2} and acquisition matrix size=80x80 reconstructed to 128x128), then analyzed using BrainVoyager and a custom analysis software running under MATLAB.

Results & Discussions:

The NIR data showed transient changes in both oxy- and deoxy- hemoglobins (Figure 1). In response to the transient deactivation (Fig1b), the total hemoglobin in the visual cortical area sampled by the NIR optodes decreased, and there was a corresponding increase in tissue deoxy-hemoglobin. The time course for vasoconstriction when regions deactivate does not appear significantly slower than that for vasodilation when areas activate. Comparing NIR responses with BOLD responses to both stimulus-ON and OFF (Figure 2), they showed similar relative magnitude and temporal properties for activation and deactivation. These data are consistent with a model [2] in which flow is regulated in a manner that leads to over and under swings in blood oxygenation relative to the levels required to maintain metabolic demand. These results also show the value of NIR monitoring of cortical oxygenation, and the ability for NIR to monitor activations in accessible areas.



a b

Figure 1. Transient changes in both oxy-hemoglobin and deoxy-hemoglobin in V1.
a. NIR data in response to 4sec stimulus-ON.
b. NIR data in response to 4sec stimulus-OFF.

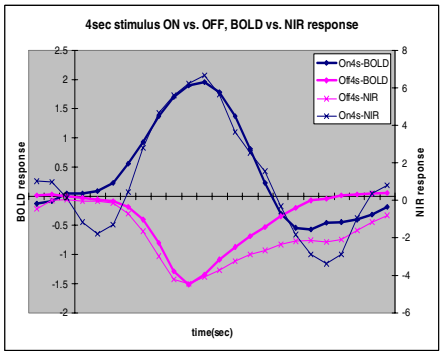


Figure 2. Compare BOLD response with NIR response to 4sec stimulus-ON/OFF in V1.

Acknowledgments:

We thank Donna Butler and Robin Greene-Avison for technical support.

References

[1] Kennan et al., Neuroimage 2002; 16: 587-92; **[2]** Buxton RB, Wong EC, and Frank LR. MRM 1998; 39: 855-864.