Ipsilateral functional deactivation to unilateral sensorimotor tasks measured with fMRI and NIRS/DOT

Frances C. Robertson[1,2], Annerine Roos[3], Tania S. Douglas[1,2], Dan J. Stein[4], Ernesta M. Meintjes[1,2]

[1]MRC/UCT Medical Imaging Research Unit, University of Cape Town, South Africa [2]Department of Human Biology, University of Cape Town, South Africa [3]MRC Research Unit on Anxiety & Stress Disorders, Department of Psychiatry, Stellenbosch University [4]Department of Psychiatry and Mental Health, University of Cape Town, South Africa

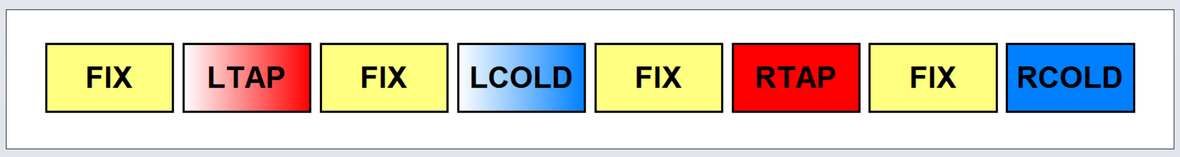
INTRODUCTION

- Several early studies established the correspondence between oxyhaemoglobin **(oxyHb)** and deoxyhaemoglobin **(deoxyHb)** signals measured with near-infrared spectroscopy (NIRS) and the functional MRI (fMRI) BOLD signal in individual subjects [4, 7, 8].
- A question of relevance to NIRS researchers is whether similar conclusions would be drawn using a population of individuals assessed with a specific task, measured with NIRS and fMRI [2, 6].
- In comparison with BOLD signal increases during a task, **BOLD signal decreases** relative to an inactive condition (fixation or rest) are more variable, and less frequently studied.
- Negative BOLD signal changes are believed to reflect suppression of neuronal activity. Ipsilateral inhibition may prevent interference from the opposite hemisphere, and may have a functional significance [1, 5].
- Using **both fMRI and NIRS**, we investigated **ipsilateral deactivation** to a **motor task** and to a **noxious cold stimulus**.

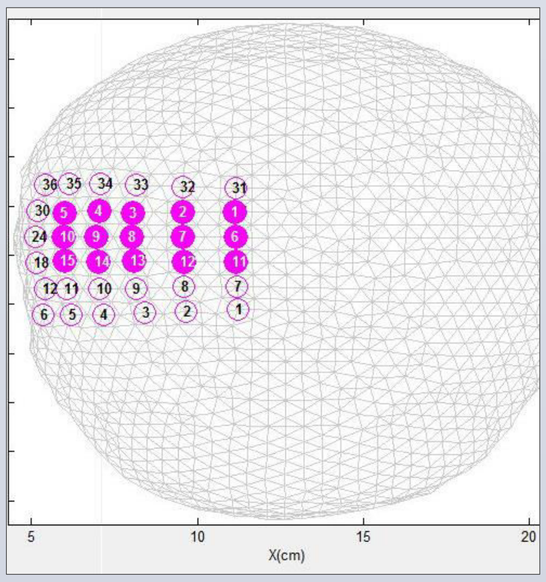
METHODS

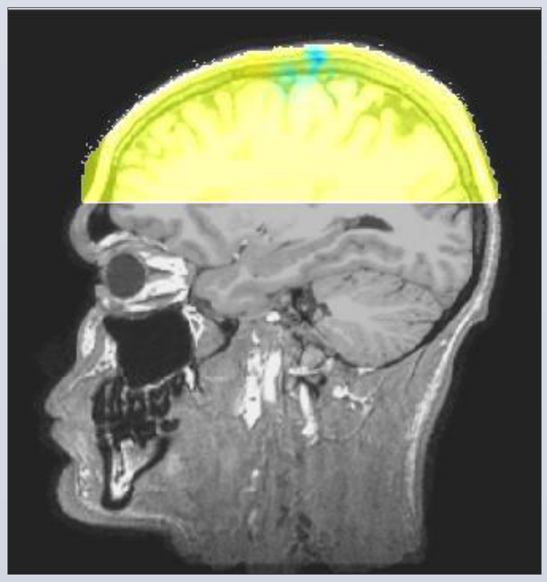
- **Subjects**: 10 right-handed subjects aged 22-35 performed the same experiment twice: once during **NIRS** scanning (DYNOT system, NIRx Medical Technologies, NY) and once during **fMRI** (3T Siemens Allegra, Siemens, Erlangen, Germany). A further 4 subjects participated in the fMRI experiment only, and 4 in the NIRS experiment only. All protocols were approved by the UCT Faculty of Health Sciences Human Research Ethics Committee.

- **Task**: 12s blocks of left hand finger tapping (LTAP), right hand finger tapping (RTAP), and a cold stimulus applied to the left or right hand (LCOLD and RCOLD). The 12s task blocks were interspersed with 12s fixation blocks (FIX). The whole sequence was repeated 3 times.



- **NIRS imaging and registration**: For NIRS imaging, the bilateral motor cortex was targeted using the Cz position from the 10-20 system and a 5x3 optode grid was placed over this location in each of the left and right hemispheres.
- Locations of anatomical landmarks (nasion, inion and left and right preauricular points), the 4 corners of the optode grid and a cloud of points on the head surface were digitised using a Polhemus magnetic tracker.
- The co-ordinates of the optode grid corners were transformed to the subject's MRI space, and then to MNI space. The diffuse optical tomography (DOT) template image was also transformed to MNI space and the precalculated FEM model with the closest grid positions to the optode locations was selected for DOT image reconstruction.





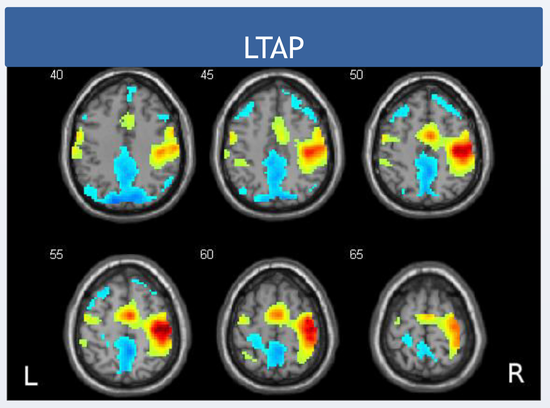
FEM model with optode locations shown (left) and reconstructed DOT image overlaid on a template MR image (right).

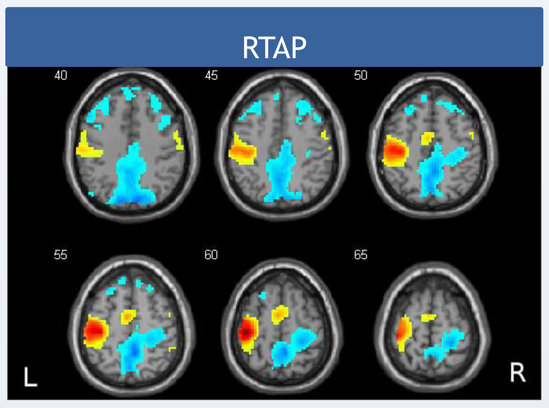
- **Analysis**: NIRS and fMRI image data were analysed using SPM5, including regressors for each task condition (LTAP, RTAP, LCOLD, RCOLD). At the group level, one-tailed contrasts were generated examining where activation in each condition was smaller (for BOLD, oxyHb) or greater (for deoxyHb) than FIX. Statistical maps were thresholded at $p<0.001$ FDR corrected for multiple comparisons.

RESULTS

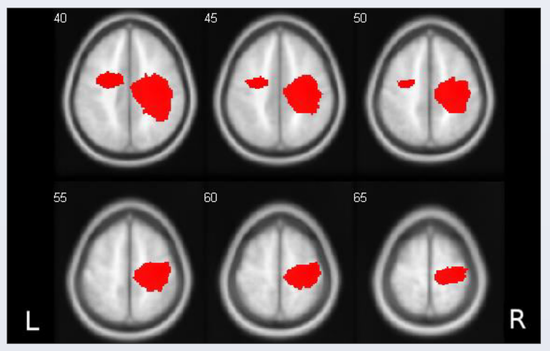
Motor task:

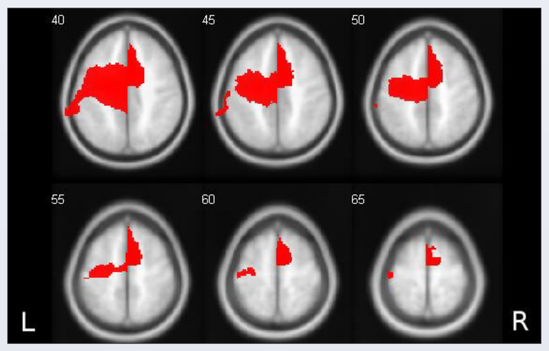
1. Group-level **fMRI** ipsilateral deactivation (shown in blue) was evident, particularly for RTAP.





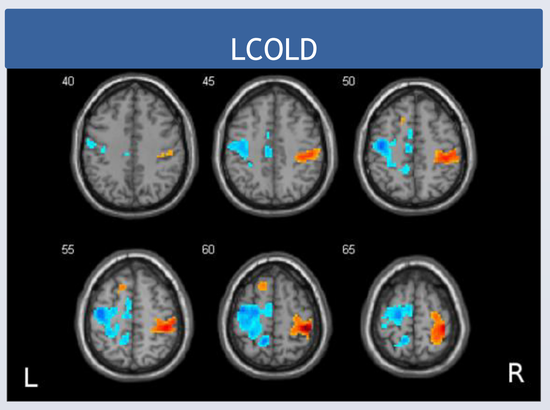
2. By contrast, in the **NIRS** oxyHb data there was bilateral activation (orange).

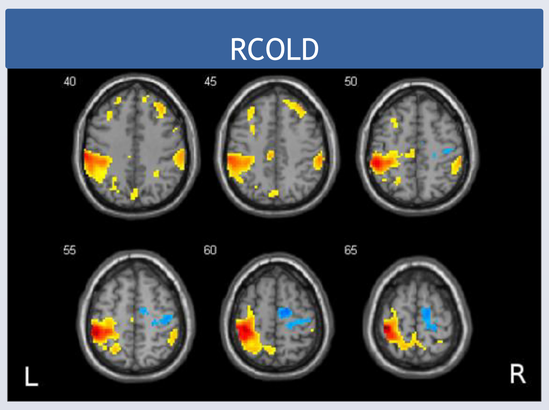




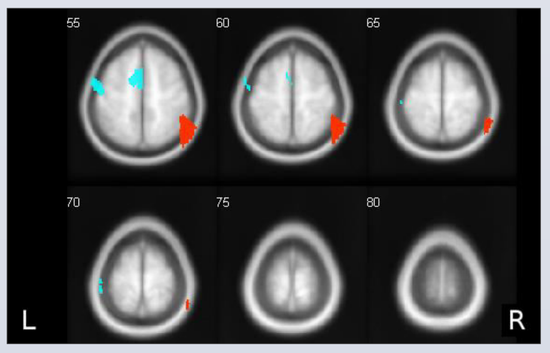
Cold task:

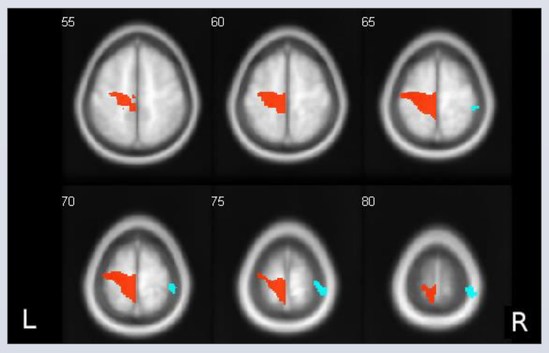
3. Ipsilateral deactivation at the group level was particularly evident for the left-hand cold stimulus in the **fMRI** data.





4. In the **NIRS oxyHb** data, ipsilateral deactivations were observed in both LCOLD and RCOLD tasks.





CONCLUSIONS

- We found ipsilateral deactivations to motor and sensory stimulation in fMRI.
- Localization with NIRS is relatively poor. There are distinct differences between fMRI and NIRS in the measurement of ipsilateral deactivations to a motor task.
- There is correspondence between NIRS and fMRI deactivations to a noxious sensory stimulus.

REFERENCES

[1] Allison, J. D., Meador, K. J., Loring, D. W., Figueroa, R. E. and Wright, J. C. (2000) 'Functional MRI cerebral activation and deactivation during finger movement', Neurology, vol. 54, pp. 135-142.

[2] Cui, X., Bray, S., Bryant, D. M., Glover, G. H. and Reiss, A. L. (2011) 'A quantitative comparison of NIRS and fMRI across multiple cognitive tasks', NeuroImage, vol. 54, pp. 2808-2821.

[3] Hlushchuk, Y. and Hari, R. (2006) 'Transient suppression of ipsilateral primary somatosensory cortex during tactile finger stimulation', Journal of Neuroscience, vol. 26, pp. 5819-5824.

[4] Huppert, T., Hoge, R., Dale, A., Franceschini, M. and Boas, D. (2006) 'Quantitative spatial comparison of diffuse optical imaging with blood oxygen level-dependent and arterial spin labeling-based functional magnetic resonance imaging', Journal of Biomedical Optics, vol. 11, p. 064018.

[5] Kastrup, A., Baudewig, J., Schnaudigel, S., Huonker, R., Becker, L., Sohns, J. M., Dechent, P., Klingner, C. and Witte, O. W. (2008) 'Behavioral correlates of negative BOLD signal changes in the primary somatosensory cortex', NeuroImage, vol. 41, pp. 1364-1371.

[6] Minati, L., Visani, E., Dowell, N. G., Medford, N. and Critchley, H. D. (2011) 'Variability comparison of simultaneous brain near-infrared spectroscopy and functional magnetic resonance imaging during visual stimulation', Journal of Medical Engineering and Technology, vol. 35, pp. 370-376.

[7] Strangman, G., Culver, J. P., Thompson, J. H., Boas, D. A., and Sutton, J. P. (2002) 'A quantitative comparison of simultaneous BOLD fMRI and NIRS recordings during functional brain activation', NeuroImage, vol. 17, pp. 719-731.

[8] Toronov, V., Webb, A., Choi, J. H., Wolf, M., Michalos, A. and Hueber, E. G. D. (2001) 'Investigation of human brain hemodynamics by simultaneous near-infrared spectroscopy and functional magnetic resonance imaging', Medical Physics, vol. 28, no. 4, pp. 521-7.

ACKNOWLEDGEMENTS

This work was supported by the South African Research Chairs Initiative of the Department of Science and Technology and National Research Foundation of South Africa, the Medical Research Council of South Africa, the Brain Behaviour Initiative at the University of Cape Town, and the National Research Foundation under Focus Area Grant FA2005040800024 and Grant FA2007042000022.