Towards Quality Control of Subject Movement in fMRI Studies

D. Cromb[1,2], and A. Simmons[1,3]

[1]Centre for Neuroimaging Sciences, Institute of Psychiatry, London, United Kingdom, [2]Kent Institute for Medicine and Health Sciences, University of Kent, Canterbury, Kent, United Kingdom, [3]Clinical Neuroscience, Institute of Psychiatry, London, United Kingdom

Background

FMRI has proved an effective non-invasive technique for both research and clinical studies, including applications where reliability is critically important, such as neurosurgical planning. The reliability of fMRI results depends on a number of factors including paradigm design, subject compliance and analysis approach. Subject movement during fMRI leads to mis-registration of the time series as well as spin history changes, both of which must be taken into account during analysis (1). Although small gradual movements can be corrected by post-processing, larger movements can render individual subject studies unanalyzable, therefore having detrimental effects on both research and clinical studies. Despite this, the extent and nature of subject movement has not been extensively studied in the past (2). The aim of this work is to develop and apply methods for quantifying the nature and magnitude of subject movement in order to develop quality control measures for fMRI.

Methods

417 multi-slice fMRI studies were carried out on patients and healthy controls performing a variety of fMRI paradigms including a common working memory task for all subjects. Gradient echo EPI data was collected on a 1.5T and a 3.0T GE Signa HDx MRI system (TE=30-40ms, TR=1.8-3s, 25-43 slices). Subjects were positioned in a foam headrest with a restraining strap across the forehead. Estimates of subject translation and rotation were generated for each fMRI study using the FSL MCFLIRT program (3,4). These parameters were analysed using a Matlab based in-house software package designed for quantifying subject movement. The software package automatically calculates a series of key measures of head movement and produces 2D and 3D plots characterising these parameters. These include measures of the magnitude of rotations and translations, periodicity of movement, the number and size of short movements, magnitude and time of the largest short movement and median and standard deviation of these measures. In addition an overall movement parameter consisting of a weighted combination of the individual measures was produced to provide a figure of merit for each fMRI study. We investigated characteristic patterns of subject movement, whether movement was more common in a particular direction of translation or rotation, how subject movement varied between patient groups for the common working memory task and the relationship between time in the scanner and the degree of subject movement.

Results

Analysis of the 417 fMRI studies showed that subject movement could be characterised into four categories – (a) short jerking movements, (b) sudden but sustained changes in subject position, (c) gradual consistent movements and (d) periodic movements which were typically stimulus correlated. Though studies often contained a mix of these categories (particularly (c)), the vast majority could be easily characterised in terms of one dominant category. The largest rotation was about the x-axis (subject nodding) and the largest translation was in the z direction (along the magnet bore). The overall movement parameter tended to increase with time in the scanner indicating that subjects find it increasingly difficult to stay still as time progresses. The overall movement parameter also varied between patient groups (Fig 1).
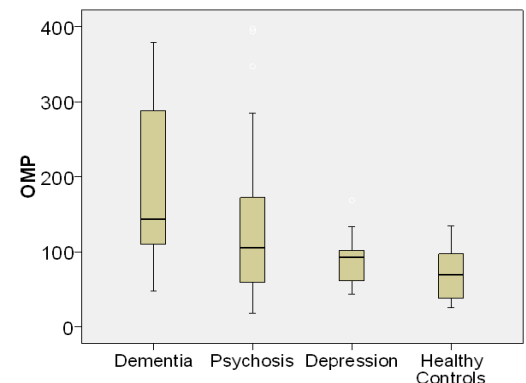

Figure 1: Overall movement parameter as a function of patient group

Discussion

The subject movement software package and overall movement parameter have proved invaluable in investigating patterns of subject movement during fMRI. Characterising subject movement during fMRI is a prerequisite for developing effective quality control measures and is also extremely helpful for reducing subject movement for subsequent studies, for example by modifying head restraints, subject preparation, paradigm design and overall time in the scanner. An automatic parameter summarising subject movement such as that proposed here would be an important addition to the range of tools used for both research and clinical fMRI studies.

References

(1) Friston et al, Magn Reson Med, 35, 346-55, 1996 (2) Kostelec et al, Image registration for MRI, Modern Sig Proc, Vol 48, 2003 (3) Smith et al, NeuroImage, 23, 208-19, 2004 (4) Jenkinson et al, NeuroImage, 17, 825-41, 2002