A Simple Method for Matching Distortions in Functional and Structural Data

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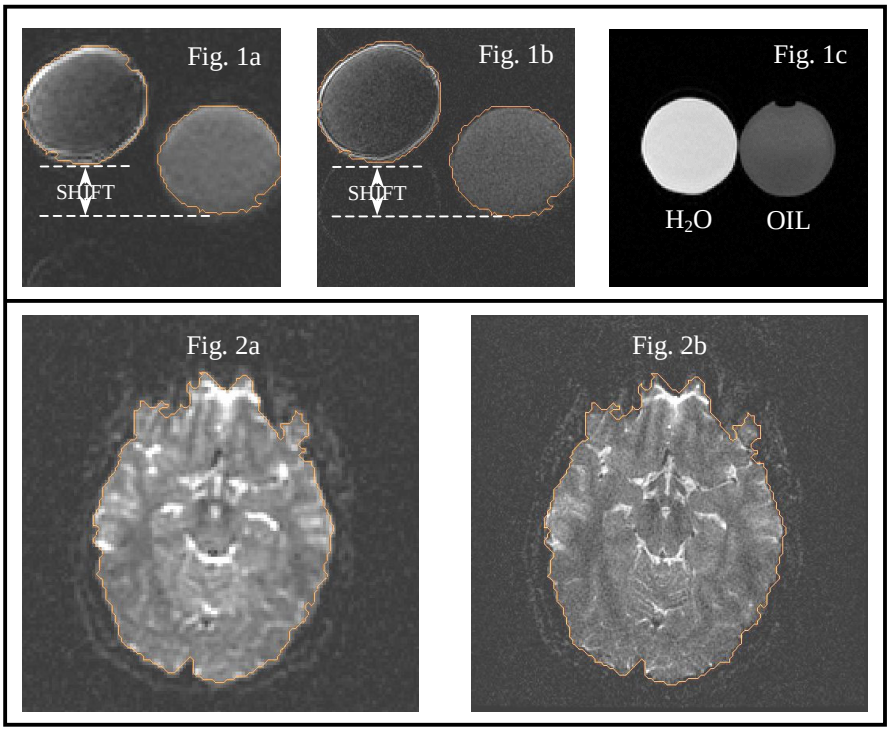
Introduction Functional magnetic resonance imaging (fMRI) and diffusion tensor imaging typically use EPI to map eloquent areas of the brain. EPI is used because it can collect 'real time' data and acquires data with optimal SNR per unit time. However, the EPI technique usually generates images at low resolution, with an image voxel volume typically being 10-100mm^3. Therefore, the EPI results are often overlaid onto a high-resolution "structural" image (Eg SPGR (Spoiled Gradient Recalled Acquisition in the Steady State) acquisition) which shows better the underlying anatomy and allows for improved data display and interpretation. EPI however is sensitive to main field inhomogeneities and susceptibility differences at air/tissue interfaces for example, which lead to geometric distortions. These are usually much greater than those in the structural data set, and as such the activated regions may not be displayed faithfully, resulting in a misrepresentation of results. Often this is ignored, inadequate measures are taken to alleviate the problem, or complicated warping procedures are undertaken (1-4). Areas of signal drop out in the EPI data may also be mapped onto the structural data, where it has been demonstrated that misinterpretation of results is possible (5). We propose the use of a high-resolution data set with identical geometric distortions to the acquired functional data set, so that the accurate mapping of activated areas can take place prior to data interpretation.

Methods Geometric distortions are particularly prominent in the phase encoding (PE) direction of an EPI image. This is because the data has a low image bandwidth (BW_{PE}) and bandwidth per pixel ($BWpp_{PE}$) in this direction. The bandwidth and bandwidth per pixel in the readout direction (BW_{RO} and $BWpp_{RO}$) are much larger, because of the rapid rate of data sampling under the readout gradient, and distortions are limited in this direction. The aim then is to acquire a "high-resolution", structural EPI volume with identical BW_{PE} as the functional EPI data set. The BW_{PE} is given by 1/EESP, where EESP is the effective echo spacing in the PE direction and EESP is given by ESP/N_{SHOTS} where N_{SHOTS} is the number of interleaves in the EPI sequence and ESP is the echo spacing in the EPI echo train. By matching the EESP of a high resolution acquisition to that of the fMRI data set, the distortions become matched in the two data sets and activated regions can be overlaid onto the structural scan faithfully for interpretation.



Results/Conclusions Figures 1a and 1b show axial images of cylindrical water and oil phantoms lying next to each other on a flat horizontal surface. Oil and water phantoms have been used because of their large chemical shift difference (~220Hz (~3.5ppm)). This manifests itself as a quantifiable shift of the oil signal relative to the water (assuming the MR system's center frequency has been set on the water resonance). This "off resonance" phenomena is therefore a good model for assessing an image's sensitivity to distortions. The data in Fig 1a is acquired with a 'standard' functional data set (N_{RO}=128, N_{PE}=128, FOV=22cm, N_{SHOTS}=1, TE=40ms, Nslices=20, slthk=5mm, eesp=704 μs) and Fig. 1b is a 'structural' data set that would be used for interpretation of any activated areas (N_{RO}=256, N_{PE}=256, N_{SHOTS}=2, eesp = 704 us, all other parameters identical). For comparison, Fig. 1c shows an SPGR acquisition of the two phantoms and highlights the differences in distortions (and signal drop out) with this acquisition compared to the EPI acquisitions. The increase in resolution is clear in Fig. 1b (0.86 mm pixel size) relative to Fig. 1a (1.72 mm pixels). By measuring the fat shift relative to the water shift it is evident that the distortions are the same for both images. The calculated bandwidth in Fig 1a and 1b is 1420 Hz, giving a predicted shift of 34.1mm. The measured shift (as depicted in Fig 1a and 1b) in units of distance are 34.4 ± 3.4 mm for Fig 1a, and 35.2 ± 1.8 mm for Fig 1b. This corresponds to a 20 pixel shift and a 40 pixel shift for the two images respectively. Fig. 2a shows an image through the frontal lobes (which are severely affected by geometric distortions in EPI) of a normal volunteer using the same 'functional' acquisition as used in Fig. 1a. Fig. 2b is an image of the same volunteer using the same 'high resolution' acquisition as in Fig. 1b. The red line is an iso-intense contour around the low resolution image. This has been overlaid onto the high resolution image to demonstrate that the distortions are the same. Small discrepancies are due to i) differences in signal drop out that are not the identical in the two data sets because of the different pixel sizes in the two images, ii) slight subject movement between the scans. We believe that collecting 'distortion matched' high-resolution structural scans provides a simple and reliable method of interpreting and presenting functional imaging data.

References 1. Brammer et al. MRI 1997. 15, 7, 763-770. 2. Hutton et al. NeuroImage 2002. 16, 217-240. 3. Jezzard et al. MRM 1995. 34, 65-73. 4. Zaini et al. Med. Phys 1999. 26 (8), 1559-1567. 5. Merboldt et al. NeuroImage 2001. 14, 253-257.