Effects of Simultaneous EEG Recording on MRI Data Quality.

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Introduction:

Although the focus of attention on data degradation during simultaneous MRI/EEG recording has to date largely been upon artifacts in the EEG recording [1-3], the presence of the conducting wires and electrodes of the EEG system also causes some degradation of MRI data [4-5]. This may result from magnetic susceptibility effects which lead to signal drop-out and image distortion, as well as the perturbation of the RF, which can cause local signal changes and a global reduction in the signal to noise ratio (SNR) of magnetic resonance images. Here, we evaluate the effect of 32- and 64-electrode caps on the quality of MR images obtained at magnetic fields of 1.5, 3 and 7 T, via the use of MR-based, field-mapping techniques and analysis of image SNR.

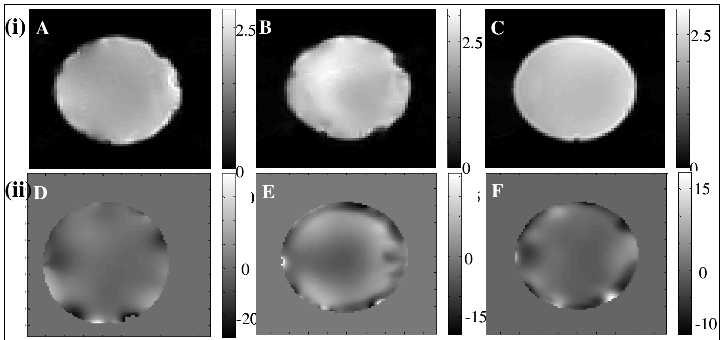

Figure 1(i): EPI data at 3T with 64 channel cap (**A**), 32 channel cap (**B**) and no cap (**C**). **(ii):** B_0 maps with 32 channel cap on at 7T (**D**), 3T (**E**) and 1.5T (**F**).

Methods:

Data were acquired from a human subject and a spherical phantom on Philips Achieva MR systems operating at 1.5, 3 and 7T. The phantom had an 18 cm od/17 cm id and was filled with saline doped with Gd-DTPA so as to yield a T_1 of approximately 700 ms at 3 T. Images were acquired in the presence of 32 and 64 electrode MR-compatible EEG lycra caps (EasyCap: Herrsching, Germany) and with no cap in place. Both EEG caps employed sintered Ag/AgCl ring-electrodes arranged in an equidistant montage. Electrodes included plastic adapters and 5 kΩ resistors, and light-duty copper wires were used for connection to BrainAmp MR EEG amplifier(s) during MR scanning. Three different imaging procedures were carried out. (i) Multi-slice EPI data were acquired on a 64^2 matrix with TR=4.2s and isotropic voxel size (phantom: 3mm; head: 3.3 mm) using echo times conventionally employed at each field strength (1.5 T: 60ms; 3 T: 40ms: 7T: 25ms). Fifty volumes were acquired for each arrangement and after low-pass filtering, the signal to noise ratio of the data was assessed by pixel-wise calculation of the ratio of the temporal standard deviation to mean, averaged over appropriately defined ROI's. (ii) B_0 maps were generated using double echo, 3D GE data acquired with 2 mm isotropic resolution using echo times of 2.2 and 20 ms. The resulting phase maps were unwrapped and scaled by 2πTE to yield maps of the field offset in Hz. Field variations occurring on a large length scale (e.g. due to poor shimming) were eliminated by subtracting a smoothed version of the field map (formed from a 2nd order polynomial fit) on a plane by plane basis, so as to emphasize the local field variations resulting from the presence of the caps. (iii) RF inhomogeneity was assessed by generating 3-D flip-angle maps using a steady state sequence incorporating two identical RF pulses each followed by acquisition of a phase-encoded echo[6]. In the regime where TR << T_1 the ratio of the intensities of images formed from the two echoes is independent of relaxation times and simply related to the flip-angle. Flip angle maps with 2 mm isotropic resolution were generated in this manner in approximately 20 minutes. All imaging procedures were carried out on the phantom for both caps at the three field strengths. EPI data were acquired from the head at all field strengths for both caps, but B_0 and flip-angle mapping was not carried out on the human head at 7 T due to SAR limitations.

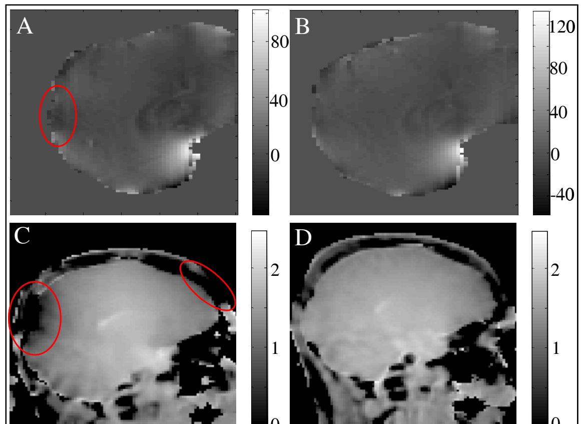

Figure 2: Effects of 32 channel cap at 3T on B_0 maps (in Hz) (**A&B**) and flip angle maps (normalised to average flip angle (**C&D**). **A&C** were acquired with the cap on (regions effected highlighted) and **B&D** are with no cap.

Results and Discussion :

B_0-Inhomogeneity: Figure 1(A-C) shows single slices from EPI data sets acquired at 3T from the phantom. The ring electrodes cause small regions of signal drop-out at the periphery of the phantom, as a result of local susceptibility induced gradients. Similar effects occur for electrodes in the two caps, but a greater proportion of the periphery is affected by the 64 channel cap because of the larger number of electrodes. Figure 1(D-F) shows field maps acquired at the three field strengths with the 32 channel cap, and displays an increase in field offsets with field strength. These effects are localised and are mainly manifested in the scalp rather than brain in the head data (Fig. 2). *B_1-Inhomogeneity:* The presence of the caps causes a significant increase in the spatial variation of the flip-angle produced in the phantom, as shown by the increased standard deviations of relative flip angle in Table 1. The most significant deviations occur in proximity to the ECG and EOG leads, which are significantly longer than the leads linked to the other cap electrodes (58 and 20cm longer respectively than the Tp9 lead). This effect also occurs in the human head data where a significant reduction in flip angle is seen in occipital and frontal areas underlying these leads (Figs. 2 C&D). The reduced flip angle leads to a loss of signal in EPI data in these areas. The corresponding B_0 maps (Figs. 2 A&B) do not show large field gradients in these areas, indicating that signal reduction is not significantly due to magnetic field inhomogeneity. *SNR:* A ROI of approximately 400 voxels in white matter (WM) was used for assessment of SNR effects in the data from the human brain. Table 2 summarises the results of this analysis indicating that the presence of the conducting material in the caps reduces the SNR, with the 64 electrode cap having a larger effect at all fields. Assessment of a WM region (in which the physiological noise is lower than in grey matter) along with the relatively long TR and large voxel size gives these data a high base SNR, leading to a high sensitivity to cap-induced changes.

Field Strength	No cap	32 channel	64 channel
1.5T	0.02	0.08	0.05
3T	0.08	0.12	0.12
7T	0.34	0.43	0.44

Table 1: Std of relative flip angle.

Field Strength	32 Channel	No cap (1)	% Change	64 Channel	No cap (2)	% Change
1.5T	0.021	0.011	45	0.024	0.012	50
3T	0.011	0.010	4	0.012	0.008	32
7T	0.008	0.006	24	0.015	0.007	54

Table 2: Average ratio of temporal std:mean in a WM ROI in EPI data. The percentage change indicates the reduction in SNR due to the cap.

References 1 Allen *et al*. Neuroimage **12**:230-239,2000 **2** Anami *et al.* Neuroimage **19**(2):281-295, 2003 **3** Srivastava *et al.* Neuroimage **24**:50-60, 2005 **4** Krakow *et al* Human Brain Mapping **10**:10-15, 2000 **5** Scarff *et al* NeuroImage **23**: 1129-1142,2004