Automatic Compensation of Local Susceptibility-Induced Signal Loss in EPI using a common Gradient Template and Automatic Slice Positioning

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INTRODUCTION Susceptibility gradients induced by anatomical structure variations in the human head lead to artefacts in echo planar imaging (EPI), which is commonly used for fMRI. These artefacts are pronounced in the prefrontal cortex leading to severe signal dropouts. Previous studies demonstrated compensation of local signal losses by additional compensation gradients [1]. Recently it has been shown that the susceptibility gradient field in the prefrontal cortex has minor variations across different volunteers and also for different head orientations [2]. This study evaluates a common gradient compensation template to reduce the local inhomogeneities in the prefrontal cortex for different subjects. Due to the auto-align functionality of the MR-system the anatomical location and orientation of slices could be reproduced and hence, it was possible to apply the gradient compensation template for different subjects.

METHODS All experiments were performed on a 3T scanner (MAGNETOM Tim Trio, Siemens Medical Systems, Erlangen) equipped with the AutoAlign module (CorTechs) which prescribes identical slice positions in different subjects. The location of the slices is shown in Figure 1. Four volunteers (1 female, 3 male) participated in the study. An EPI sequence with distortion correction [3] (20 slices, slice thickness 2mm, slice gap 0.4mm, matrix size 64x64, FoV 192mm, TE 21ms) was used with and without compensation gradients. The compensation gradients were derived from the field map template [2] in Figure 1 and were optimized for the prefrontal cortex area. The compensation gradients were applied in feet-to-head and anterior-to-posterior direction. The gradient compensation strength is slice-dependent and designed to have a smooth transition for the feet-to-head direction (-5 to 115 µT/m; mean 67.2 µT/m) and the anterior-to-posterior direction (-5 to 120 µT/m; mean 34.2 µT/m). For the right-left direction the gradient strengths were set to 0, assuming a right-left symmetry. The EPI-images were analyzed across two ROIs selected in the prefrontal cortex and posterior white matter. Five slices with and without compensation gradients were used for the evaluation, the ROIs for one slice are shown in Figure 2 and 3.

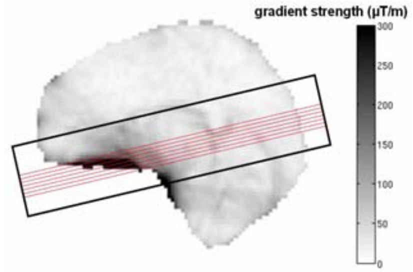

Fig. 1: Sagittal slice of the gradient amplitude. The acquisition volume (black box) is determined by the AutoAlign module. The compensation gradients were derived from slices with strong susceptibility gradients shown in red.

RESULTS and DISCUSSION In the prefrontal cortex the signal intensity of the compensated slices (local shim) showed higher signal intensities compared to the corresponding uncompensated slices (global shim), as shown in Figure 2 and 3. In addition, in Figure 4 can be seen that the increase of the mean signal intensity in the prefrontal ROI, depicted with the green polygon, was comparable for all subjects with an average signal enhancement of 23 ± 5%. This suggests that the general template for compensation gradients is applicable to different subjects. This result is consistent with previous observations [2], that the susceptibility gradient field for different subjects in the prefrontal areas has similar profiles. In the ROI (red circle) outside the prefrontal cortex, the mean signal intensity decreases by 2 ± 0.2% for an echo time of 21ms. A signal decrease is expected for homogeneous regions due to the additional compensation gradient. However the signal decrease is not significant at the echo time used in the experiment.

In general, the areas with strong susceptibility distortion are well compensated by the general gradient template, without significant loss of signal in other areas. Additionally, many important brain functions are located in affected areas, e.g. decision making in the prefrontal cortex. Therefore the compensation method proposed in this study may improve the fMRI accuracy in those functionally important areas significantly without additional scan time for individual adjustments.

CONCLUSION A common gradient compensation template, combined with the auto-align functionality, shows 23% signal improvement and reproducible results for different subjects in brain regions affected by susceptibility gradients. This method can thus improve fMRI sensitivity in areas with strong susceptibility gradients.

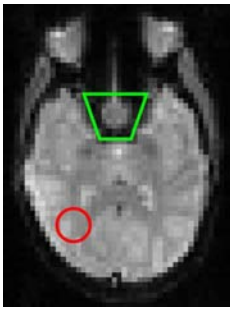

Fig. 2: Uncompensated EPI-image of slice 8 (global shim). The target ROI in the prefrontal cortex (green) and the reference ROI in the posterior white matter (red) are shown.

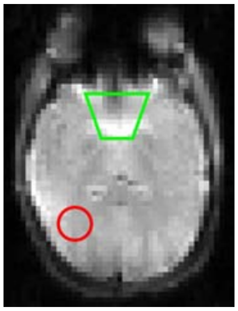

Fig. 3: The same slice as shown in Figure 2, but with slice dependent compensation gradients enabled (local shim).

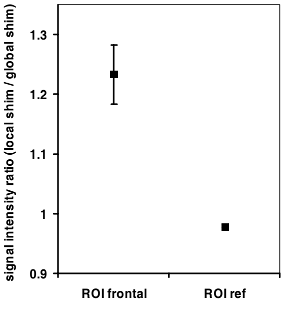

Fig. 4: Signal ratio between compensated and uncompensated measurement calculated from the mean signal intensities in the corresponding ROIs of four volunteers.

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