Temporal noise change of EPI with GRAPPA in multiple runs

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Introduction As coil technology advances, the technique of parallel imaging has been applied in fMRI more often recently. For one kind of parallel imaging, GRAPPA[1], reference scans are performed at the beginning of an fMRI run to compute the GRAPPA weights. The missing lines in the under-sampled k-space of subsequent image scans are interpolated from the acquired lines using these GRAPPA weights. While it is well known that an unpleasant feature of parallel imaging in fMRI is the non-uniform distribution of noise, which can be characterized by the g-factor[2,3], the temporal characteristics of noise have not been well studied. In this study, the temporal noise is examined for multi-run fMRI using a phantom, we found that the temporal noise can vary significantly between runs.

Methods All scans were performed on a Siemens TIM Trio system (Siemens Medical Solutions, Erlangen, Germany).

1. Phantom study: A gel phantom was used for tests, FOV = 200 mm, TR/TE = 2000/30 ms, FA = 70, SLT = 3.8 mm. Matrix = 128×128, BW = 1628 Hz, we tried several combinations of acceleration factor (AF) and number of ACS lines (see Table 1). For each combination, there were 10 runs with 200 measurements each. Additionally, five runs were performed for iPAT2 and 24 ACS lines but with a delay between each run to keep the same center frequency.

Table 1. Experiments for the 32 channel coil.

	AF2	AF3	AF4	AF1
ACS lines	24	24	24	TE = 53, # of slices 17
	48	64	64	
	64	120	120	

2. Numerical simulation: The phantom was scanned with AF2 and AF3 (48 ACS lines) using the same acquisition parameters described previously but for 5 runs. Raw data of run1 and run5 were saved for offline GRAPPA reconstruction. For run 5, two sets of images were reconstructed using ACS lines from itself and from run 1.

3. In vivo study: For comparison purposes, two runs of resting state fMRI (AF2, 48 ACS lines, 100 volumes) were conducted on one human subject.

For all the data, a map of the temporal noise was obtained by calculating the standard deviation of the time course of each voxel, after quadratic detrending to remove scanner signal drift. For the human subject, motion correction was done in SPM 5 before quadratic detrending.

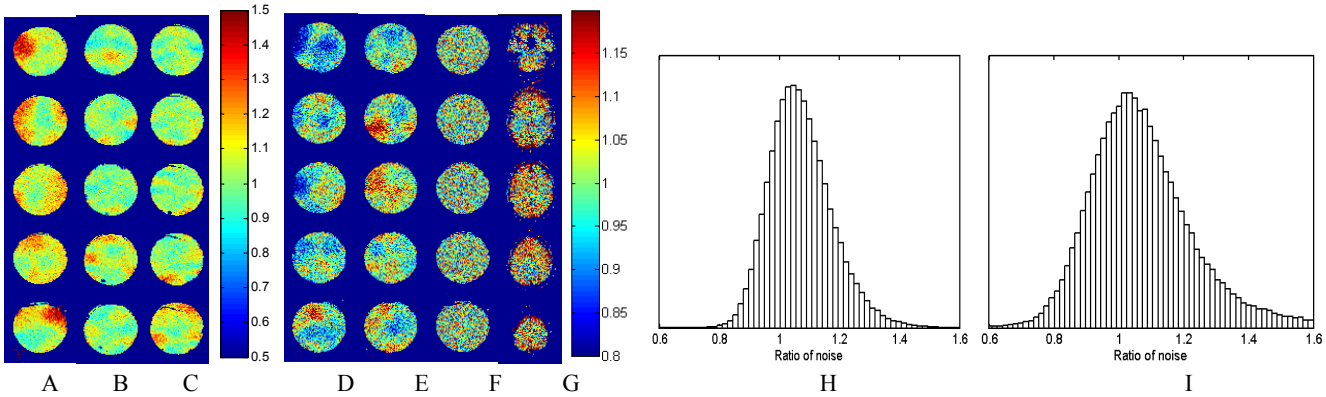

Fig.1. Ratios of the noise from run 10 to the noise from run 1 are displayed on five representative slices for AF2 (A), AF3 (B), and AF4 (C) with 24 ACS lines. (D) shows the ratio of the noise from run 5 to the noise from run 2, and (E) shows the ratio of the noise from run5 to the noise from run 4, all scanned with AF2, 24 ACS lines and identical center frequency. The ratio of the noise in the first half of run 1 to that in the second half of run 1 with iPAT2 and 24 ACS lines is shown in (F). The ratio between the two runs of a human brain at resting state is shown in (G). The histogram of the ratio for all slices with AF2 and 48 ACS lines is displayed in (H) for a phantom and in (I) for a human brain.

Results and Discussion We observed that for AF2, the mean noise increases slightly with time (Fig. 1H). There is not much change for the mean noise with AF3 or AF4. However, the noise distribution varies a lot for all the images. Fig. 1 A-C show the ratio of noise in last run to noise in the first run for AF2, AF3, and AF4, with 24 ACS lines. We can see that for some voxels, the noise can change up to 40% for AF2 and around 15% for AF3 and AF4. The pattern change is also observed in a human brain (Fig. 1G and 1I) in the presence of physiological noise. While the reason of this change is not clear, several factors can be ruled out. First, it's not related to frequency drift. The noise pattern still changes from run to run even when the center frequency is kept the same (Fig. 1D and 1E). Second, the variation is not an accumulated effect. The change can occur for any two subsequent runs (Fig. 1E) and there is no change of noise distribution within a run (Fig. 1F). The variation of the noise indicates the change of g-factor, which is, in this case, solely affected by the reference scans. Numerical simulation demonstrates that the variation disappears if using the same ACS lines in GRAPPA reconstruction for all the runs (Fig. 2). Hence, our results suggest that the GRAPPA algorithm may be sensitive to the noise presented in the reference scans, which can be a confound for multi-run fMRI as the physiological noise also varies between different reference scans.

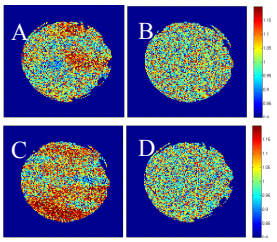

Fig. 2. Results from off-line reconstruction. Ratio of noise from run5 to run 1 using their own ACS lines for AF2 (A) and AF3 (C), and using ACS lines from run 1 for AF2 (B) and AF 3(D);

References

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