Novel correlated noise suppression method substantially improves detection of fMRI response to weak stimuli at 7 T

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Introduction: Higher magnetic field strength has certain benefits for fMRI, such as increased intrinsic contrast and specificity. However, contribution of physiologic and other spatially correlated noise typically increases with field strength, dominating temporal stability in voxels as small as 1 mm^3 at 7 T. Therefore, benefits of high-field fMRI have so far mainly been demonstrated for applications in which high spatial resolution is of the essence. If spatially correlated noise can be effectively suppressed however, high-field fMRI is likely to have benefits for a wider range of applications. To demonstrate this we applied a recently described correlated noise suppression method [1] to improve the detection of localized, short (100-ms duration) isolated visual stimuli at 7 T.

Methods: Data were acquired on a 7 T GE scanner using a 32-channel Nova Medical array (signal acquired only from 12 posterior and 4 anterior elements). Normal volunteers (n=3) were scanned using: gradient-echo EPI; 96×72 resolution; rate-2 SENSE: 240×180 mm^2 FOV; 2-mm thick slices; 0.4 mm slice gap; 1 s TR; 32 ms TE; 60° nominal flip angle. Two sets of experiments were performed, one based on a very-small circular foveal stimulus (Fig. 1a), the other with a narrow wedge (10° of a full circle) in the lower-left quadrant (Fig. 1b). The visual angle of an entire image (Fig. 1) was ~15°. A 5-minute block paradigm scan was performed for each stimulus type (5 blocks of 30 s on / 30 s off). Significantly activated voxels were used as a functional ROI. In a second scan, an ultra-short, ultra-sparse paradigm using the same stimulus was applied: a 100 ms stimulus followed by 14.9 s rest, repeated 32 times for a total paradigm duration of 8 min, followed by 2 min of rest. In these short-stimulus scans, spatially correlated noise was suppressed as was described in [1], using the functional ROI as the initial estimate of the activated area. In a modified version of the method, principal component analysis (PCA) was used to extract the 3 strongest components from the correction region (see [1]) for use as correlated noise regressors. In the original, noise-suppressed and PCA-noise-suppressed data the average time-course signal in the functional ROI was computed. Subsequently, the average short-stimulus response over thirty-one 15-s long stimulus-events (the first was discarded) was calculated.

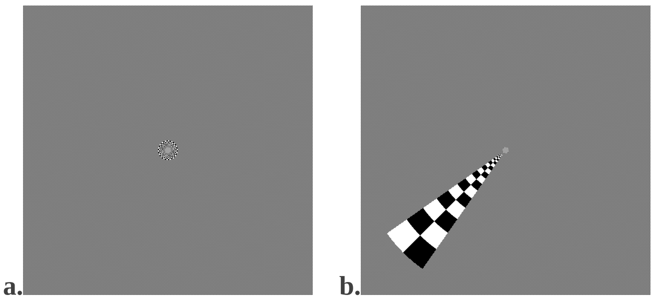

Figure 1: The two visual stimuli used, a very small circular foveal stimulus (a.) and a narrow wedge stimulus (b.). B/W checkers contrast-reversing at 7.5 Hz.

Results & Discussion: Fig. 2 shows an example of the average response to 31 short stimuli for the foveal response for one of the volunteers. The total stimulus exposure time (over ~8 min) is a mere 3.1 s, but the response can be clearly detected. It can be seen that reproducibility, e.g. in terms of decreased standard error, increases substantially when the correction is applied, indicating the large contribution of spatially correlated noise to these data. Note also that the standard error remains approximately constant over time relative to stimulus onset, indicating that this error is not related to response variability but to other noise sources. In order to quantify effectiveness of the noise suppression, the detection power was computed as the peak response amplitude divided by the mean of the standard error for the 15 time points following stimulus onset, taking into account the degrees of freedom. The detection power increase for the noise-suppressed data compared to the original data is shown in Table 1. Detection power increases for all datasets, and correction based on 3 PCA-derived regressors outperforms the original implementation of the method for all experiments on all volunteers. On average, 86 % increased detection power was achieved, versus 64 % for the original implementation of the method.

Conclusion: PCA-based suppression of correlated noise can substantially increase fMRI sensitivity, extending the benefits of fMRI at high field.

References: [1] de Zwart J, et al., ISMRM 2007, p. 1977

volunteer	single noise regressor		3 PCA noise regressors	
	foveal	wedge	foveal	wedge
1	64	30	74	66
2	54	200	65	206
3	33	5	66	32
Average	50	78	68	102

Table 1: Detection-power increase (in %) of noise-suppressed with respect to the original data, on average over the functional ROI and 31 trials.

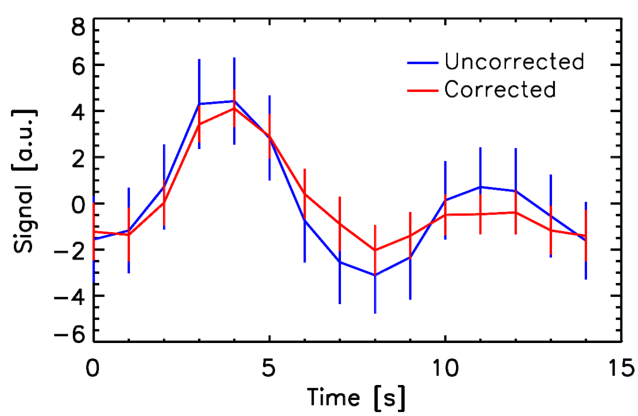

Figure 2: Example time course for a short-stimulus (at t=0) foveal experiment for one of the volunteers (volunteer 1). The average data in the functional ROI is shown, averaged over 31 trials. Original data are shown in blue, noise-suppressed data (single noise regressor) in red. Error bars indicate the standard error over 31 trials.