Efficacy of Data-Driven Respiration Compensation Methods in fMRI Data at 1.5T

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Introduction

One of the sources of noise in fMRI data is due to respiration, as has been experimentally demonstrated [1,2]. This work seeks to identify those circumstances in which respiratory noise compensation techniques are beneficial. Two post-hoc respiratory compensation techniques [1,3] were assessed for improvements (relative to no compensation) in true and false detections of synthetic activations superimposed on human baseline fMRI data. The complex filtering procedure [3] produced significant benefit over both contrasted conditions when the rate of (simulated) stimulus presentation was equal to or near the respiration rate. Additionally, it was found that when the (simulated) stimulus rates was not close to the respiration rate, both compensation procedures produced increased false detections without concomitant improvement in true detection rates.

Method and Procedure

Human Data: Two human subjects participated in three experiments conducted on a General Electric 1.5T Signa LX Horizon imager. In each experiment, 512 images of each of five slices (5mm thickness) were acquired in either the axial, sagittal, or coronal plane using a blipped echo-planar sequence (TR/TE = 360ms/40ms; FOV=20cm; 64x64 acquisition matrix). Subject respiration rates were post-hoc estimated [3] at (subject 1) 18 and (subject 2) 16 breaths per minute. *Synthetic Activation:* Known activity (boxcar) was added to a 10x10 voxel region of the middle three slices. Each of the six experiments was modified in 32 different fashions, using one of 16 activation rates (range: 2-28 cycles per minute) at contrast-to-noise ratios (CNRs) of 0.2 and 0.5. *Compensation Evaluation:* The number of true and false detections (TD and FD) over the three slices was computed for each combination of rate and CNR in three cases: (a) without compensation, Raw; (b) using a Gaussian-shaped magnitude-only band-reject filter centered at the respiration rate [1], Gss; and (c) using a complex image-space based waveform estimation and removal procedure [3], Cpx. Detections were declared based on *z*-score thresholds of 1, 2 and 3. Confidence in observed activation was assessed by computing the empirical conditional probability of true detection, given detection, p(T|D) = TD/(TD+FD), at a given threshold.

Results

Effects of compensation procedure on TD and FD, aggregated over all three imaging planes, are shown in Fig. 1 for subject 1 at a CNR = 0.2 and a detection threshold of $z > 2$. Note that Gss produced TD = FD = 0 when the activation rate equaled the respiration rate. Therefore Fig. 2 presents p(T|D) only for Raw and Cpx. Aggregated over both subjects and CNR values, when the rate of stimulus presentation matched the rate of respiration, Cpx produced 70% fewer FD and 9% fewer TD than Raw, resulting in a p(T|D) = 0.85 for Cpx and 0.65 for Raw. When the rate of stimulus presentation is not similar to the rate of respiration, the three tested cases resulted in comparable TD, but both Cpx and Gss resulted in more FD (approximately 2% for Cpx and 9% for Gss) when aggregated over both subjects and CNRs.

Discussion and Conclusion

For similar activation and respiration rates, compensation for respiration noise using a procedure similar to Cpx enhances results relative to no compensation. Conversely, magnitude-only based filtering procedures such as Gss are likely to eliminate both TD and FD when activation and respiration rates are similar, due to the phase-indiscriminate nature of the removal procedure. Therefore, a clear benefit in the specificity of detected activation is obtained using algorithms that remove a complex-based estimate of the respiration-induced noise waveform when the rate of stimulus presentation approximates the rate of subject respiration. However, there is no compelling evidence that respiration-induced noise waveform estimation and removal algorithms are effective when the rate of stimulus presentation is not near the rate of respiration. Incorporation of actual physiologic recordings (e.g., respiration belt) in the estimation and removal procedure will enhance the specificity of filtering and may impact this latter finding. Therefore, the results obtained with Cpx are expected to represent worst-case outcomes for procedures such as RETROICOR [4].

References

[1] Biswal et al., MRM 35:107-113
[2] Bodurka et al., Proc ISMRM, p.1006, 2000
[3] Ziyan et al., Proc ISMRM, p.1407, 2002
[4] Glover et al., MRM 44: 162-167

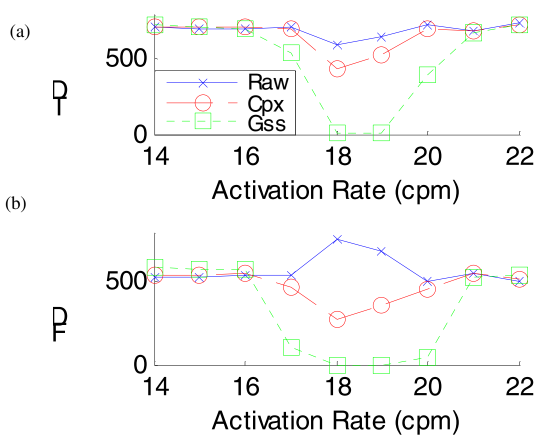

Fig. 1. Plot of (a) true detections, TD, and (b) false detections, FD, for subject 1 at CNR = 0.2 and threshold of $z > 2$. Respiration rate was estimated at 18 breaths per minute. Note that no technique generated more than 700 TD of 900 possible.

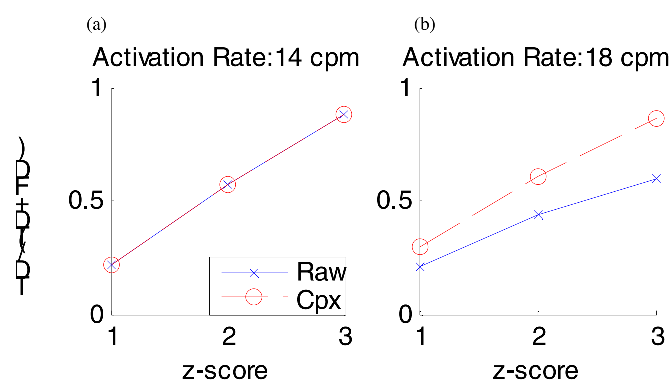

Fig. 2. Comparison of p(T|D) = TD/(TD+FD) for Raw and Cpx at activation rates (a) different from and (b) equal to respiration rate for subject 1 (18 breaths per minute).