Evaluation of Cyclic and Global Retrospective Corrections of Physiological Signals on Activated fMRI

A. L. Ella[1], J. Rick[1], and J. Hennig[1]

[1]Dept. of Diagnostic Radiology, Medical Physics, University Hospital Freiburg, Freiburg, Germany

INTRODUCTION

Cardiac and respiratory fluctuations (physiological noise) are known to be confounding signals in the detection of cortical activation by fMRI. The standard correction method RETROICOR [1] has been used to perform a global correction by folding the whole time series (TS) into only one signal cycle and to use this global template to correct each individual cycle. We extended RETROICOR by the cyclic retrospective correction [2]. The cyclic method performs the correction piecewise at each cycle of a physiological signal. RETROICOR uses a Fourier series fit of order 2 and a respiratory phase based on a histogram (φ_h). In [2], we introduced a respiratory linear phase (φ_l) and a polynomial fit into the retrospective correction method. The goal of this study was to evaluate and compare different approaches to physiological noise correction on fMRI data acquired at different repetition times (TR).

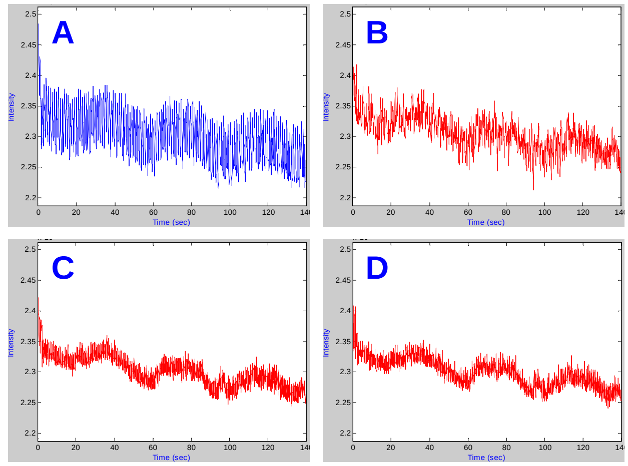

Figure 1. Intensity curves of an activated TS voxel before (**A**) and after correction of cardiac and respiratory signals using: (**B**) RETROICOR, (**C**) cyclic Fourier and (**D**) cyclic polynomial methods.

METHODS

fMRI time series data were acquired on a 3T-system (TIM TRIO, Siemens, Germany) during visual checkerboard stimulations (30s ON/30s OFF) using an EPI sequence. Acquisitions were performed on 3 healthy male volunteers with an echo time (TE) of 30 ms and different TRs as follows: 0.1, 0.2, 0.5, 1.0, 2.0, 3.0 s; number of volumes: 1800, 900, 360, 300, 150, 100, respectively; number of slices: 1, 2, 5, 14, 29, 40; matrix size (FOV): 64x64 (224 mm); slice thickness: 3 mm. External cardiac and respiratory signals were recorded synchronously with acquisitions, at frequencies 400 and 50 samples/s respectively. The correction of cardiac and respiratory signals was performed in all TS using global and cyclic retrospective methods with 2nd order Fourier and 4th order polynomial fits. The global respiratory correction was performed using fits computed with φ_h and φ_l, while the cyclic correction used only φ_l. The cyclic correction was applied only on TS acquired with TR $\leq$ 0.5 s, where enough volumes were acquired per cycle of a physiological signal to perform the cyclic fit. Uncorrected and corrected TS were analyzed using the general linear model of SPM8 (Wellcome Department of Cognitive Neurology, London) to detect Blood Oxygenation Level Dependent (BOLD) activated voxels by performing t-test maps (*p<0.001*). Finally, differences between the number of activated voxels in corrected and uncorrected TS were computed as percentages for each TS of each volunteer.

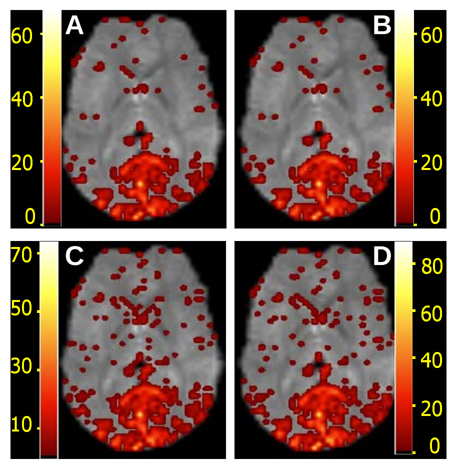

Figure 2. T-test maps performed in SPM to detect activated voxels on a TS (TR 0.2s) before correction (**A**), and after correction of cardiac and respiratory signals using: (**B**) RETROICOR, (**C**) cyclic Fourier and (**D**) cyclic polynomial methods.

RESULTS

Qualitative comparison of correction between RETROICOR (**B**) and cyclic methods (**C**, **D**) on an activated voxel time course modulated by cardiac and respiratory signal (**Fig.1**) showed the stronger effectiveness of cyclic methods over global correction like RETROICOR (global φ_h). T-test maps (**Fig.2**) confirmed the above results by showing increasing t-values and larger clusters of activated voxels after cyclic correction (**C**, **D**) compared to the global correction by RETROICOR (**B**). The comparison between the number of activated voxels computed before and after correction (**Table 1**) showed: **i)** all correction algorithms lead to an increase in the number of activated voxels **ii)** no significant difference between global corrections performed using φ_h and φ_l, either with Fourier or polynomial **iii)** a significant increase of the number of activated voxels after correction with cyclic methods compared to global methods **iv)** no significant difference in cyclic polynomial vs. cyclic Fourier correction.

DISCUSSION & CONCLUSION

The results obtained in this study confirmed those of previous studies [2,3] performed on resting state fMRI TS. This study showed that φ_l can be used instead of φ_h for the respiratory signal correction, thus justifying its implementation in cyclic corrections. Moreover, the Fourier fit used in RETROICOR can be replaced by the polynomial fit, particularly in cyclic correction where it seems to be qualitatively more efficient. The 2nd order Fourier and 4th order polynomial fits were used here, as both fitting methods were shown to be optimal with these orders in [3]. Our findings thus emphasize the advantage and need of faster fMRI acquisition techniques.

TR(sec)	0.1	0.2	0.5	1.0	2.0	3.0
			Fourier Series			
global φ_h	2.8±0.8	7.3±0.6	7.3±2.3	-2.1±3.9	6.9±2.5	7.5±2.6
global φ_l	2.9±1.3	7.0±1.6	7.5±2.7	3.5±3.6	9.4± 0.3	3.9±4.0
cyclic	27.4±2.1	23.5±2.1	27.6±3.1			
			4th Polynomial			
global φ_h	3.1±1.6	6.0±1.7	5.7±3.4	-1.5±7.4	5.6±1.4	6.0±3.4
global φ_l	2.5±1.1	6.4±1.8	6.0±3.7	4.1±0.9	5.7±2.0	5.3±1.8
cyclic	30.7±4.0	25.1±2.6	31.1±2.9			

Table 1. Comparison of the percentage increase of the number of activated TS voxels before (**Nu**) and after correction (**Nc**), presented as: **mean[((Nc-Nu)/Nu)*100]** over n=3.

REFERENCES

[1] Gary H. Glover, et al., *MRM* **44**: 162-167 (2000)
[2] A. Ella, et al., Proc. 15th Ann Joint Meeting ISMRM-ESMRMB, Berlin, 2007. p.3442
[3] A. Ella, et al., Proc. of 14th OHBM, Melbourne, 2008. p. S125

ACKNOWLEDGEMENTS

This work is part of the INUMAC project supported by the German Federal Ministry of Education and Research, grant #13N9208.