Correction of Physiological Noise on fMRI Time Series Using a Cyclic Retrospective Correction at Short TRs

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Objective:

Cardiac and respiration noise were shown to be confounding signals in the detection of activation in fMRI images. A gold standard method (RETROICOR [1]), used to remove both signals, already exists, but showed to reduce cardiac and respiration noises respectively between 61-80% and 31-62% at TR 250ms [1]. Numbers of fMRI studies [2-4] use a TR in the range of 50-500ms. In order to improve the effectiveness of both noise corrections in this range of TR, we introduced the cyclic retrospective physiological noise correction method.

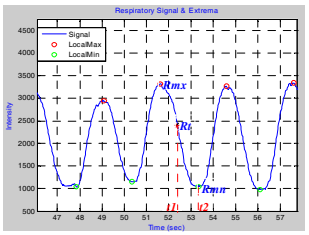

Fig. 1: Part of a respiration signal showing computed local maxima and minima. Phases at time points (Rt for instance) are computed successively between 2 local maxima and minima as: $\varphi(t) = \pi \cdot dR/(Rmx - Rmn) \cdot sign(dR/dt)$, where: $dR = Rt - Rmn$, and: $dt = t2 - t1$.

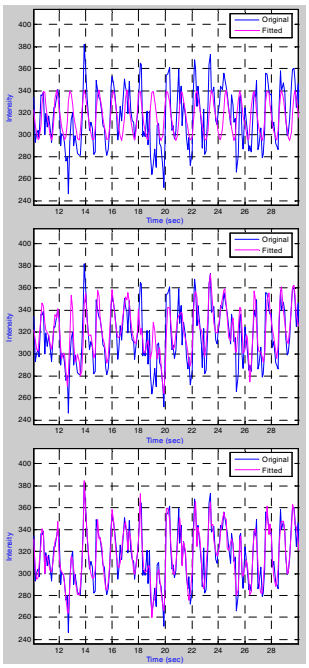

Fig. 2: Part of a Time Activity Curve of a cardiac ROI voxel fitted by RETROICOR (**up**), cyclic Fourier series (**mid**) and cyclic polynomial (**down**) methods.

Methods:

fMRI Time Series (TS) were acquired on a 3T system (MAGNETOM TRIO Siemens, Germany) on 2 healthy volunteers using an EPI sequence. The acquisition was performed on the first subject at resting state with different TRs (100, 200, 500 ms; respectively 1000, 500, 300 time points and 1, 1, 5 slices; TE 30ms, matrix 128x120, FOV 220mm, slice thickness 3mm) and, on the second subject with a single TR in resting state and 2 visual activations (TR 250 ms; 720, 1200 and 1200 time points respectively for the resting state and both activations; 5 slices; TE 30ms, matrix 64x64, FOV 224mm, slice thickness 3.5mm). External cardiac and respiration signals were recorded synchronously with the acquisition respectively at frequencies ~ 400 and 50samples/sec.

The correction of both noises was performed by: **i**) transforming the time at each point of every cycle of the external signal into a phase as described in [1] for cardiac and as in **fig.1** for the respiration **ii**) fitting piece-wise each cycle with a low Fourier series or a 4th degree polynomial (**fig.2**) **iii**) correcting using the formula: $Ic = Io - If + MeanIo$, where Io, Ic, If and $MeanIo$ are respectively original, corrected, fitted and mean original time point intensities (**fig.3**).

ICA was applied to the TS before noise correction. The resulting parametric images and time activity curves (TACs) allowed to locate regions of interest (ROIs) highly related to cardiac and respiration. Power spectra (PS) and integrals of both cardiac and respiration peaks were computed on each voxel of these ROIs before and after noise correction in order to evaluate the effectiveness of corrections.

Results & Discussion:

The results (**fig.3** & **tab.1**) showed that the cyclic correction improves the effectiveness of cardiac and respiration noise corrections at short TR. This is due to the fact that RETROICOR uses a global mean fit for all cycles of the signal, where the cyclic method uses an individual fit for each cycle of the signal allowing the method to be more precise (**fig.2**). The cyclic correction using the polynomial fit showed quantitatively slightly better results than the one using Fourier series. This is emphasized qualitatively by the fact that the polynomial seems to fit better than low Fourier series (**fig.2**). Hence, although the cyclic method showed to reduce significantly cardiac and respiration noise, it is important to notice that this is only at short TRs were limits showed to be TR<=200 ms for cardiac and TR<=500 ms for respiratory noise. Finally, the cyclic correction was incorporated in a global noise correction program which is able to choose automatically the method based on TR and were the user can set as inputs, the fitting method and its order.

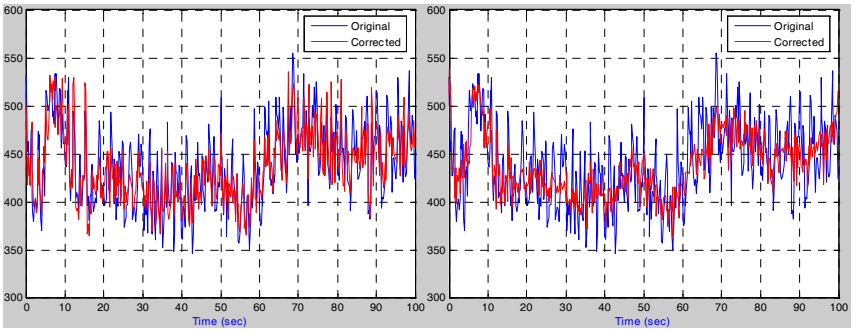

Fig. 3: Voxel time intensity curve (**blue**), cardiac and respiration noise corrected (**red**) by RETROICOR (**left**) and Fourier cyclic (**right**). The cyclic method showed to reduce cardiac and respiration noise significantly better.

	Subject 1			Subject 2		
TR (ms)	100	200	500	250act1	250act2	250rest
Cardiac (F)	98.8±0.2	98.3±0.6				
(P)	99.6±0.1					
Respiration (F)	87.5±1.9	97.5±0.5	87.1±5.6	97.8±0.9	98.4±0.5	96.7±2.5
(P)	88.5±2.7	98.8±0.4	93.7±3.4	97.7±1.0	97.6±1.0	94.9±1.2

Tab. 1: Percentage of the decrease of cardiac and respiration peak integrals from ROI voxel power spectra computed on each image before and after cyclic Fourier (F) and polynomial (P) noise corrections.

References:

[1] Glover G., et al., *MRM* **44**: 162–167 (2000)

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[4] Wise R., et al., *NeuroImage* **21**: 1652–1664 (2004)