Evaluation of Respiratory and Cardiac Peak Detection Using Interactive AFNI Tools

Joshua Dean[1], Daniel Handwerker[1], Paul Taylor[2], Peter Lauren[2], Daniel Glen[2], Peter Bandettini[1,3]

[1]Section on Functional Imaging Methods; [2]Scientific and Statistical Computing Core, [3]Functional MRI Core Facility
NIMH, NIH, Bethesda, MD, USA

#1687

Introduction

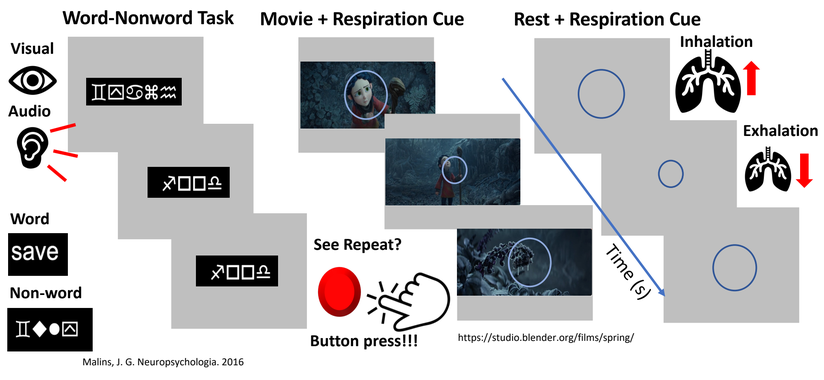
fMRI signal contains physiological (non-neuronal) sources, such as respiration and cardiac pulsations[1,2]. Methods to reduce physiological noise often rely on measurements of breathing and cardiac cycles. These traces can be noisy, and few programs facilitate quality control and manual corrections. AFNI's[3] physio_calc.py (Poster 1690) includes an interface for inspection and correction.

We evaluated physio_calc to understand the types of errors that might appear in this and other peak detection programs. We present preliminary results on how manual correction of errors might affect the quality of physiological model fits.

Methods

Acquisition

25 participants completed several tasks:
8 min (3X): visual vs. audio & word vs. nonword task[4]
8 min: cued breathing tasks (2X) or movie + cued breathing (2X)
Breathing rate and depth slowly changed across the run
Data from 150 runs in total are presented



3T fMRI (CMRR sequence, EPI, SMS=2, iPAT=2, TR=1.5s, TE=13.44, 31.7, & 49.96ms, 3.0mm^3 isotropic voxels)
Cardiac fluctuations and respiratory fluctuations were collected concurrently with fMRI using a pulse oximeter on a finger and belt around the chest.

Data Processing

Respiratory and cardiac time series were processed with physio_calc; every run was manually inspected, and incorrect peaks or troughs were counted and corrected.
For both uncorrected and manually corrected traces, regressors for RETROICOR[1] and RVT[2] noise removal methods were calculated within physio_calc.

For the 113 runs with at least 1 manual correction, fMRI data were processed with AFNI for slice-timing correction, head motion correction, and a weighted combination of the echoes.
fMRI processing scripts are at:
https://github.com/nimh-sfim/ComplexMultiEcho1

The RVT and RETROICOR regressors were fit to the fMRI data with and without the manual corrections. R^2 was used to estimate how much variance in each run was modeled by physiological regressors and a Fisher Z transform was applied to the R^2 values.

Conclusions

physio_calc is highly accurate, but not perfect. Manual quality checks and corrections are important.

For respiratory traces, most errors are spontaneous breath holds or subtle issues that require interpretation. For cardiac traces, noise from finger movement and atypical oximetry traces may require interpolation to fill in missing data.

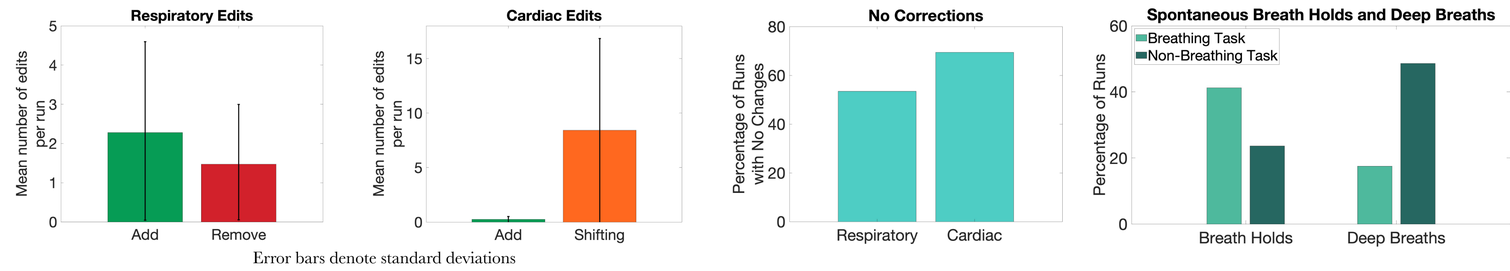
Across the group, fixing mistakes does not reliably improve overall fit of the respiratory and cardiac model.

Future Directions

1. Test if there are certain types of corrections that affect results more than others.
2. Examine other physiological noise removal methods that might benefit from higher accuracy.

Results

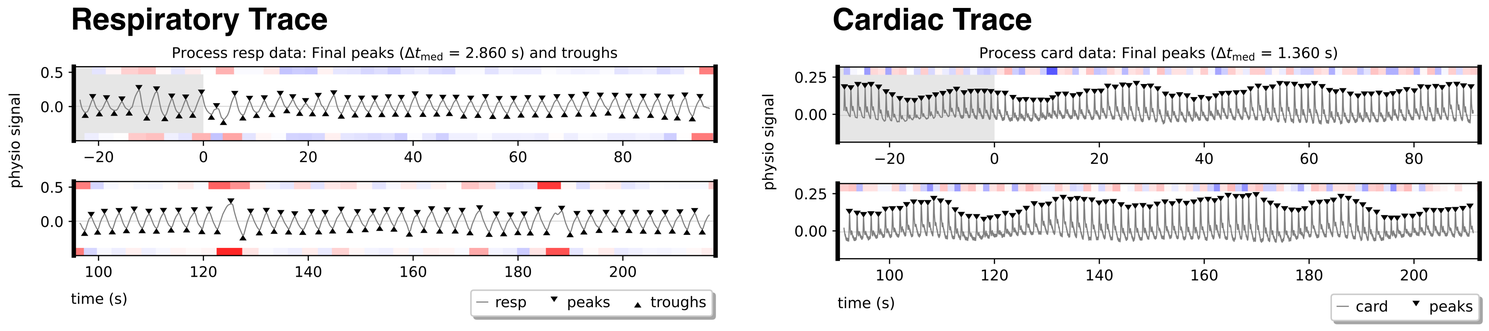
Most runs required no or very few manual corrections



Error bars denote standard deviations

113 of 150 runs required at least one manual correction

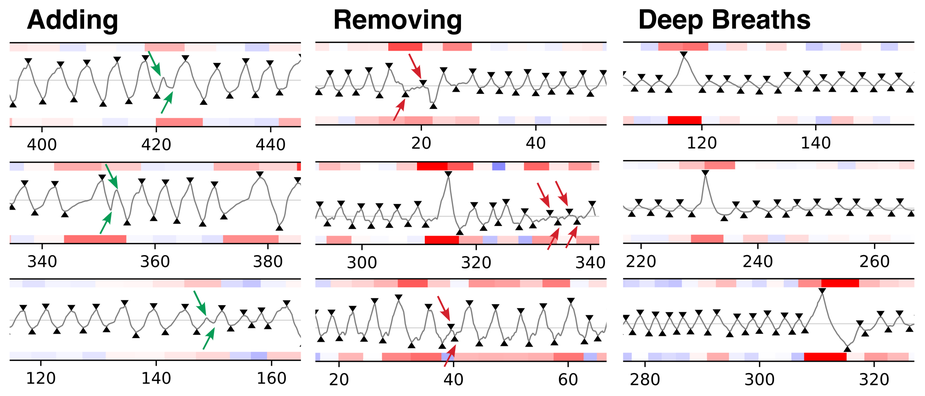
Example data that did not require corrections



physio_calc's interface uses red and blue color bands to highlight longer and shorter peak-to-peak intervals, respectively. This facilitates quick identification of errors.
Peaks and troughs are automatically detected even with large magnitude shifts in cardiac traces.

Example data that did require corrections

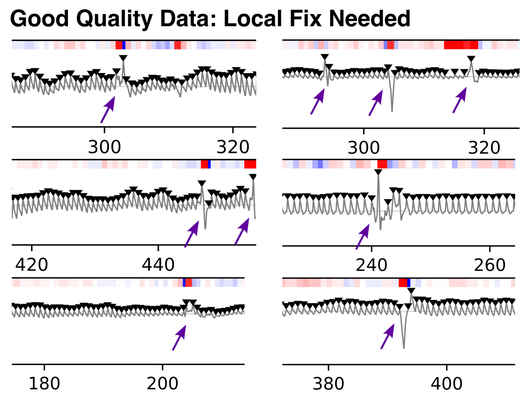
Respiratory Extrema



Large variations in peak height were sometimes missed, and spurious peaks were sometimes selected.

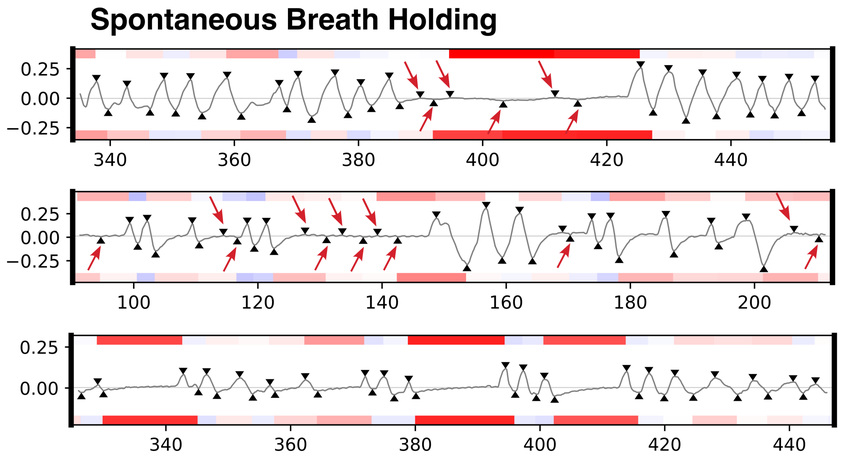
Common in all tasks. Often did not need corrections but could affect noise modeling.

Cardiac Peaks



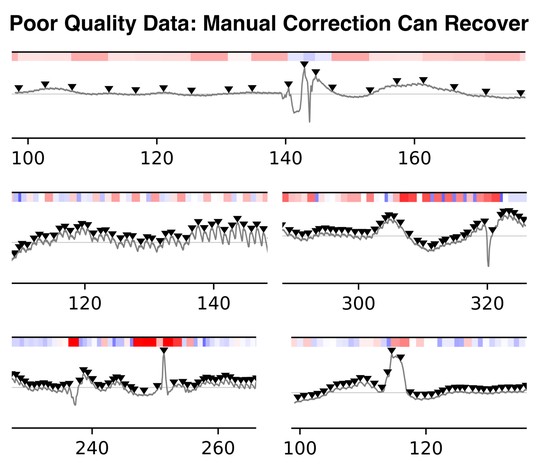
The most common problem were spikes in the cardiac traces, likely due to finger motion.

Spontaneous Breath Holding



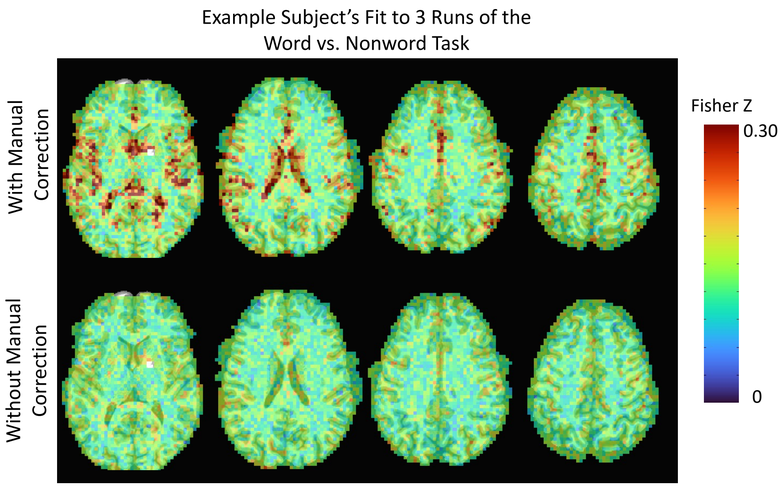
Spontaneous breath holds were sometimes correctly identified but might affect respiratory noise in ways that are not currently corrected using RETROICOR and RVT.

Poor Quality Data: Manual Correction Can Recover

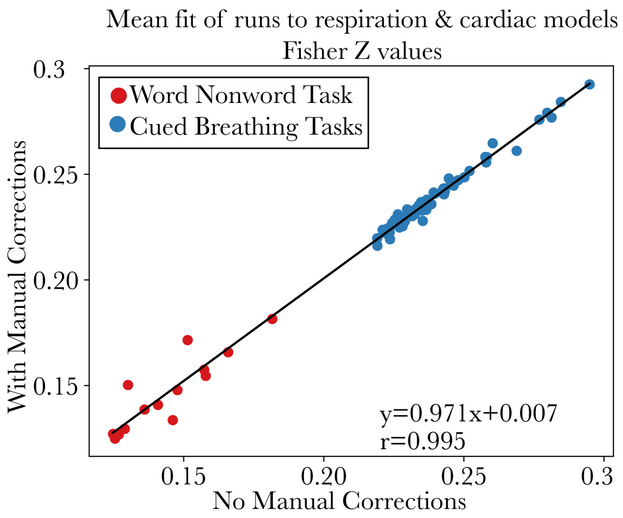


A faulty pulse oximeter was used for several subjects. physio_calc was not designed to automatically detect these slower bumps, rather than sharper spikes. By inspecting data, it may be possible to tune the peak detection algorithm for atypical variations.

Fitting to fMRI data



For this subject, the physiological regressors model more variance in the data after manual corrections.



Across all runs with manual corrections, there was not a consistent increase in fit quality after manual correction. Many runs only had a few corrections.

Acknowledgments

Data were collected by Micah Holness and Dan Handwerker under the NIMH 93-M-0170 protocol with funding from NIH ZIAMH002783.

This work utilized the computational resources of the NIH HPC Biowulf cluster (http://hpc.nih.gov).

References

(1) Glover et al., *Magn. Reson. Med.*, 2000; (2) Birn et al., *NeuroImage*, 2006 (3) Cox, *Comput. Biomed. Res. Int. J.*, 1996; (4) Malins et al., *Neuropsychologia*, 2016.