rtQC: an open-source toolbox for real-time fMRI quality control

Stephan Heunis[1], Lydia Hellrung[2], Johan van der Meer[3], Susanne Bergert[4], Ronald Sladky[5], Gustavo S P Pamplona[5], Frank Scharnowski[5], Yury Koush[6], David M A Mehler[7], Carles Falcon[8], Juan D Gispert[8,9,10], Jose Luis Molinuevo[8,10,11], Stavros Skouras[8,12]

[1]Department of ELectrical Engineering, Eindhoven University of Technology, The Netherlands [2]Laboratory for Social and Neural Systems Research, University of Zurich, Switzerland [3]QIMR Berghofer Medical Research Institute, Brisbane, Australia [4]Westfalian-Wilhelms-University Muenster, Germany [5]Psychiatric Hospital, University of Zurich, Switzerland [6]Biomedical Imaging Department, Yale University, New Haven, United States [7]CUBRIC, Cardiff University, United Kingdom [8]BarcelonaBeta Brain Research Center, Pasqual Maragall Foundation, Spain [9]CIBER-BBN, Madrid, Spain [10]Pompeu Fabra University, Barcelona, Spain [11]CIBERFES, Madrid, Spain [12]Department of Biological and Medical Psychology, University of Bergen, Norway

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The Problem

FMRI quality is impaired by structured noise, leading to limited signal-to-noise ratio (SNR) and attenuated detectability of the blood oxygen level-dependent (BOLD) signal [1]. If unaccounted for, fMRI noise can lead to data loss or false findings [2-3]. Quality control (QC) for conventional fMRI is addressed by various solutions; e.g. fMRIprep [4], MRIQC [5] and PCP-QAP [6]. Despite additional challenges [7], real-time fMRI (rt-fMRI) QC has not seen similar developments. Here, we present the rtQC toolbox, facilitating the widespread adoption of fMRI and rt-fMRI QC practices.

The rtQC toolbox solution

rtQC is operating system independent and runs in Matlab (2016b) with SPM12. It can operate on pre-acquired datasets or incoming volumes in real-time. The GUI architecture (Fig.1) allows three domains of quality control: **Pre-QC**, **Online-QC** and **Post-QC**. Pre-QC defines ROIs to enable region-specific QC in the context of rt-fMRI neurofeedback studies, and ensures the consistency of real-time volume acquisitions. Online-QC includes real-time monitoring of quality metrics (Fig.2). Post-QC provides summary data, triggers established QC pipelines and enables comparison of different images and timeseries (Fig.3).

FIG. 1

A. Pre-QC

- General settings, including FD threshold.
- Anatomical-functional preprocessing for masks and ROIs.
- Mutual information check between offline exported and real-time acquired data

B. Online-QC

- Minimal real-time preprocessing
- Real-time QC metric display
  - FD
  - Global Z-score
  - tSNR
  - Grayplot
- FD-based outlier detection

C. Post-QC

- Offline single session QC metrics calculation and visualization
- Export of scan nulling regressor
- Triggering of standard fMRI QC pipelines

Real-time processing includes realignment, detrending, QC computations and visualization of:

- **Framewise displacement (FD)**, estimating head movement per volume in millimeters [3]. For each volume, FD is used to classify motion-outliers and store scan-nulling regressors that can be used for online or offline denoising.
- **Global Z-score**, reflecting the number of standard deviations that the global intensity of an incoming volume deviates from the temporal mean. Z-score peaks indicate movement or scanner artifacts.
- **Temporal signal-to-noise ratio (tSNR)**, indicating overall data quality and the ability to detect small signal changes [1,8]. It is computed cumulatively within ROIs as the ratio of temporal mean over standard deviation.
- **Grayplot**, providing a compact display of percentage signal change (PSC) across all voxels in time. This serves to visualize sudden intensity changes and slow (task-related or breathing-related) fluctuations [9].

The GUI facilitates quick and effective assessment of acquisitions, helpful for every fMRI study, in order to instantly exclude bad datasets and efficiently meet required sample sizes. Overall, rtQC provides a standardized, user-friendly solution, that empowers all fMRI users, from student novices to experienced clinicians, to perform QC in real-time.
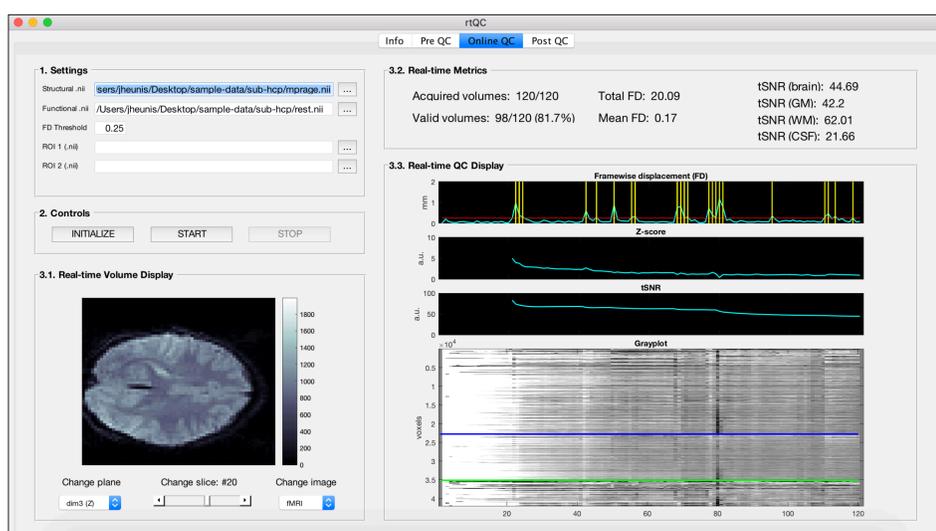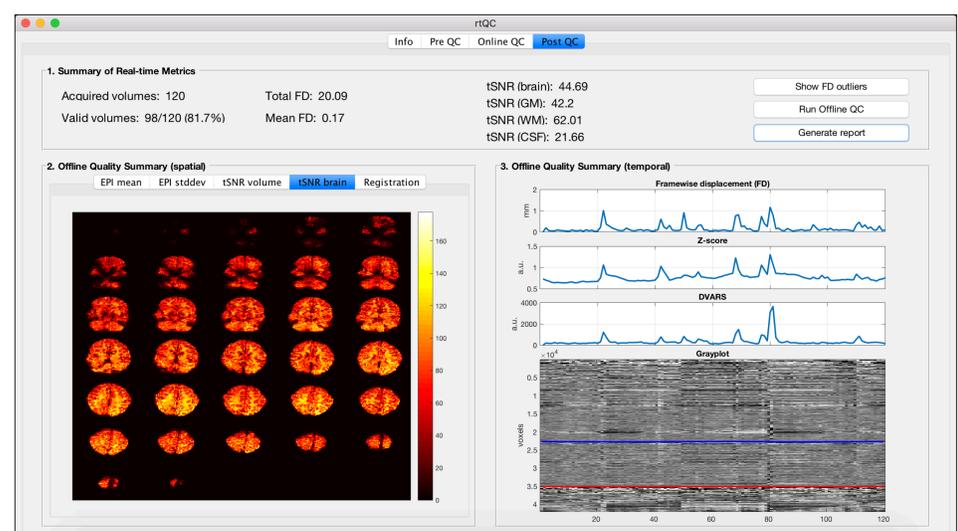
FIG. 2

FIG. 3

Learn more and contribute

Check out booth 1907 on Thursday June 13 in the Auditorium Expo for a software demonstration of rtQC
Code and usage instructions available on Github: https://github.com/rtQC-group/rtQC. Contributions welcome!
For more information, the first author can be contacted via email (j.s.heunis@tue.nl) and via Twitter (@fmrwhy)

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