SLOMOCO-derived slicewise head motion produces physiologic signals and reveals that motion is hard to characterize

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Introduction: Head motion is a serious problem for functional connectivity analyses. We investigate the assumption used by most common motion correction methods that head motion is volumetric in detail and use SLOMOCO[1], to investigate the frequency characteristics (rapidity) of head motion with respect to the volumetric sample rate, and show that slice and volumetric methods result in different distributions of individual motions, implying that thresholds for motion metrics depend on this assumption. These measures were broken down by axis, and it appears motion is not preferentially associated with any axis. We furthermore show that physiologic monitoring signals can be obtained from the data itself via SLOMOCO and introduce a new parallel physiologic noise+slice motion correction. Studies are only now beginning to use slice-oriented motion corrections such as SLOMOCO[1] and SVR[2] and motion characterization methods using these have different sensitivity to motion.

Methods: SLOMOCO was applied to 68 resting state scans of healthy controls to obtain 6 degree-of-freedom (DOF) motion parameters for every slice independently to 50 micron resolution. The distribution of absolute value motion (e.g. amplitude of motion in a given timepoint) was generated across all scans, separately for each DOF. Each DOF timecourse was also converted to Fourier power spectrum and the relative power in each 1Hz bin over 1Hz was computed and normalized to the 0-1Hz bin. Peaks corresponding to possible heart and respiration signals were observed and investigated further by comparison with PESTICA.

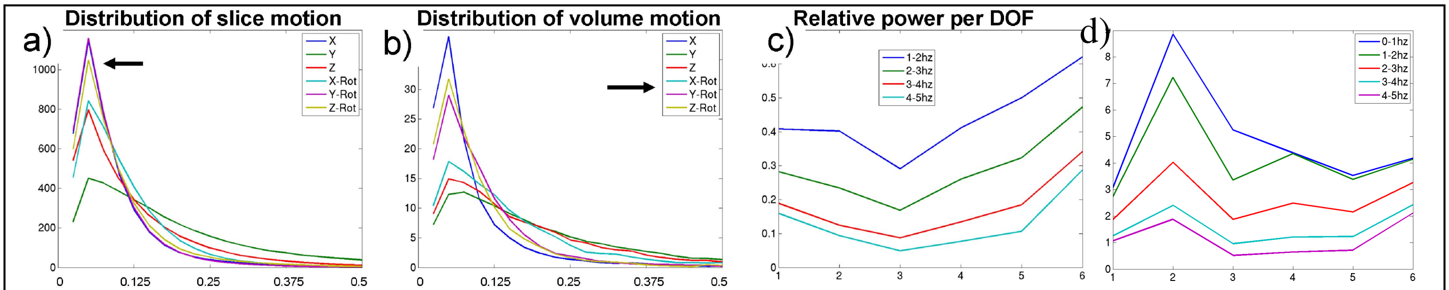

Fig 1: distribution of individual head motions (mm, deg) for a) slicewise and b) volumetric motion for 6 DOF, c) shows relative power per DOF (1=X, 2=Y, etc) in each frequency band (each band is normalized to 0-1Hz band), d) shows non-normalized power

Results: The largest difference observed between the slicewise and volumetric distributions of motion is the motion amplitude peak and tails on out-of-plane motion and rotation. Fig 1a) shows the rotations and x-translation have the bulk of their motion being low-amplitude motion, but this is altered slightly in Fig 1b). The reason for this is the slower timescale with which volumetric methods are sensitive to motion, which is not necessarily a problem on its own, but this indicates that distribution-based metrics will be different when going from volumetric to slicewise. Fig 1c) shows the relative power of motion in each 1Hz bin, averaged across subjects and scans. The non-normalized power is shown in d), and these show there is an effect of DOF on frequency. The peak for DOF=2 at low frequency corresponds mostly to respiratory noise, and an increase from 1-2Hz for y-motion, and this is believed to be an effect of PACE prospective correction interfering with the respiratory effect. Investigating the physiologic noise effects further, we found that we can routinely isolate respiratory signals and cardiac signals from the SLOMOCO slicewise motion parameters. Fig 2 shows use of SLOMOCO as an MRI-based respiratory and pulse monitor in comparison to PESTICA[3], an alternative MRI-based pulse and respiration monitor.

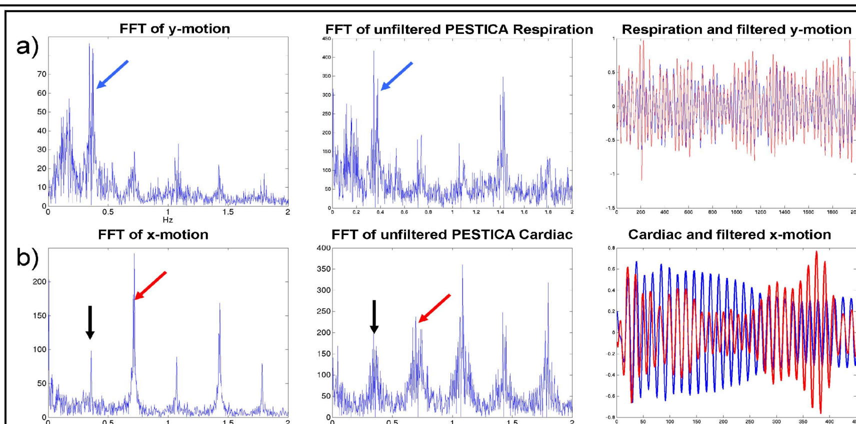

Fig 2: physiologic noise signals isolated from SLOMOCO motion parameters. Cardiac and respiratory frequencies were seen in most motion parameters. FFT of y-motion shows respiratory peaks, FFT of x-motion shows clear cardiac peak (red), and volume artifact peak for 1/TR effects from PACE (black).

Conclusions: The characterization of head motion will be affected by the change to slicewise motion parameters. This is important because it will have a major impact on characterization of head motion when using slicewise methods. However, an important observation is the lack of a preferred DOF for motion. “Nodding” motion or bouncing motion are believed to be more common, but this was not observed here. Many subjects did experience motion predominantly in one axis, but it was unpredictable.

References: 1) Beall EB, NI 2014;101:21. 2) Jiang S, IEEE TMI 2007;26:967. 3) Beall EB, NI 2007;187:216.