Multi-center fMRI Calibration with SMARTPHANTOM:

L. Friedman[1], Q. Zhao[2], H. Cheng[2], R. Duensing[2], D. N. Greve[3], G. H. Glover[4], A. Functional BIRN Consortium[5]

[1]The MIND Institute, Albuquerque, NM, United States, [2]Diagnostic Imaging Department, Invivo Corporation, Gainesville, FL, United States, [3]MGH-NMR Center, Harvard University, Charlestown, MA, United States, [4]Radiology, Stanford University School of Medicine, Stanford, CA, United States, [5]NCRR and Univ Cal Irvine, Bethesda, MD, United States

Introduction: The Functional BIRN Consortium is exploring the usefulness of a BOLD-mimicking phantom (SMARTPHANTOM™ , http://www.mridevices.org/SmartPhantom/poster.pdf, Figure 1) for calibrating scanners across sites. We are hopeful that measures such as temporal CNR, temporal noise, sensitivity, temporal autocorrelation and smoothness could be evaluated with this device. This would save the expense and logistical complications of sending a group of humans to each site, and should provide more objective data. Using data acquired with this phantom at each site, we will examine strategies for minimizing observed inter-site differences by adjustment of acquisition parameters such as flip angle (FA) as well as reconstruction algorithms. Thus, by prospective adjustment of each site's acquisition technique, variability in the acquisition will be reduced and may potentially obviate the need for post-processing correction. Prospective normalization of each site is a novel and potentially superior alternative to post-processing correction of intrinsic differences.

The SMARTPHANTOM™ (Invivo Corporation , Gainsville, FL) employs a novel mechanism (Cheng et al., 2004) to simulate BOLD activation. The phantom uses two perpendicular coils in a resonant circuit whose Q can be controlled by adjusting coil impedance. In this fashion, the B1 within a small Region of Interest (ROI) in the phantom is locally modulated in accordance with external impedance control. This local B1 enhancement appears as an intensity increase (similar to an activation) in the ROI at the center of the phantom coil (Figure 2). We present a preliminary study of the use of this phantom on two 1.5T scanners (one GE and one Siemens).

Methods: Data Collection: EPI data were acquired on a GE Signa Excite 1.5T (with a GE T/R head coil) and a Siemens 1.5T Sonata (with a Siemens receive-only coil) [TR=2.0 sec, TE=30msec, FOV=220cm, slice thickness=4mm, at 4 flip angles (15^o, 30^o, 60^o, and 90^o)]. Each series contains 85 images (Figure 3). The first 5 images are followed by 4 blocks with different enhancement levels. Each block contains 10 "off" states followed by 10 "on" states.

Analysis: For each scanner, a single enhancement level (nominal 3% signal change, GE – 3.00%, Siemens – 2.80% signal change) was analyzed as a single block using conventional fMRI image analysis tools (AFNI,FSL). An ROI was drawn on the center region and only data from this ROI are presented, averaged across the ROI. For each flip angle, the baseline intensity level was estimated (Figure 4). Also, a cross-correlation coefficient was computed between the ideal and the EPI timeseries (the other 3 enhancements were ignored in this analysis). The r-values were converted to effect size [2*r/sqrt(1-r^2)] which we take as a measure of temporal contrast-to-noise (CNR) (Figure 5). The standard deviation of the residuals of this analysis are taken as a measure of temporal noise (Figure 6). Smoothness was measured using FSL's smoothness estimator.

Results: Baseline levels were comparable between scanners and also increased in a comparable manner with flip angle, as would be expected (Figure 4). For both scanners, CNR increases with flip angle in a similar trajectory to the baseline level. This is what one would expect, since increasing the flip angle increases the number of protons that are spinning in the B1 plane. It is interesting to note that CNR does not increase from 60^o to 90^o for either scanner. Further insight comes from the graph of temporal noise (Figure 6). Temporal noise is constant across flip angle for both scanners. However, the GE scanner has an elevated level of temporal noise, although this difference disappears when noise is normalized by the baseline level. The GE scanner was substantially more smooth (63%) than the Siemens scanner (GE: FWHM = 3.35 mm, Siemens: 2.05 mm,).

Discussion: In this preliminary study, 2 scanners from 2 vendors perform quite comparably and well, although the GE scanner is substantially smoother. Any deviance from this normative performance would be quickly detected with the SMARTPHANTOM™, and would enable us to pinpoint certain issues that may need to be addressed prior to initiation of human multi-center fMRI studies. The results of these phantom studies and analyses will be used to compare sites on sensitivity and to examine whether a prospective change in protocol can equalize sensitivity across sites. We will continue to refine our data collection and analysis schemes to optimize the usefulness of these assessments. We will also need to study human volunteers to confirm that the information we get from this phantom is relevant to human data. Also, using the SMARTPHANTOM™, site performance characteristics can be monitored on a weekly basis as part of a QA protocol.

References: Cheng H, Zhao, Q, Spencer D, Duensing, GR, Edelstein, WA: A fMRI study of the SMARTPHANTOM. Presented at the 12th Annual Meeting of the International Society for Magnetic Resonance Imaging (ISMRM). May 15-21, 2004 Kyoto, Japan

Acknowledgements: Supported by NIH Grant 1 RO1 EB00974.

FIGURE 1

FIGURE 2

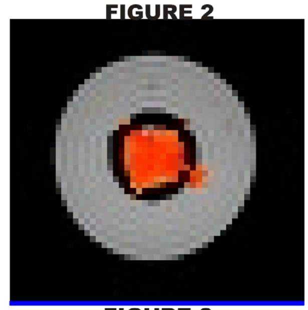

FIGURE 3

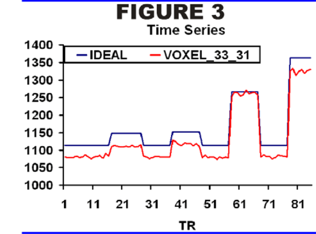

FIGURE 4

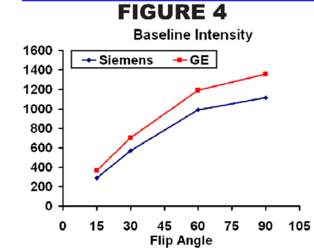

FIGURE 5

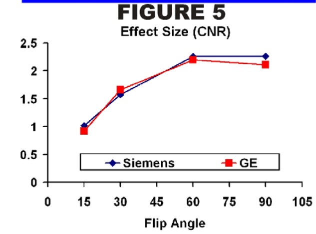

FIGURE 6