Comparing Spatial Resolution of IRON and BOLD in Awake Macaques

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Introduction

Methodologies for imaging awake, behaving, non-human primates are being developed to investigate the spatial characteristics of fMRI signals, and its relation to neuronal activity. Point-image experiments are important to access the point spread function of the vascular response, and similar results have been obtained for BOLD and IRON at 3T: a strong positive correlation between the size of the stimulus' spots and the correspondent activated patches in the primary visual cortex was observed, and the FWHM of the patches was comparable for both methods of contrast[1]. Interestingly, Smirnakis et al. showed that the spread of functional activity into a visual cortical area corresponding to an artificial scotoma, appeared to be markedly greater for IRON than for BOLD[2]. In this study we compared BOLD and IRON point-image activity with the activity observed in the areas of the primary visual cortex that correspond to "holes" in a full field checkerboard stimulus.

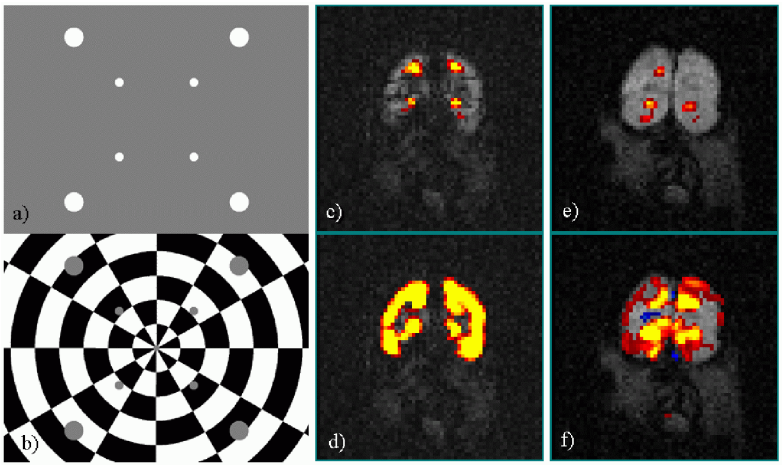

Figure 1. Stimuli for angular aperture of 1.8°. a) Spots and b) Holes. Resulting IRON activation maps: c) Spots and d) Holes. Resulting BOLD activation maps: e) Spots and f) Holes. No "holes" in the activation maps are observed for BOLD and IRON at this angular aperture.

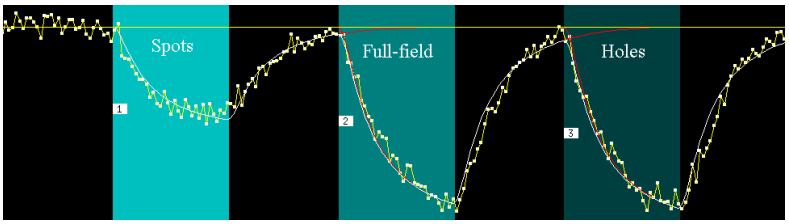

Figure 2. Representative IRON timecourse and fit from the spot's ROI during spots, full-field and holes. The BOLD timecourse is similar but the CNR is much lower.

Methods

Experiments were performed in a 3T Siemens magnet, using a single surface coil as transmitter and receiver, and single-shot GE-EPI. Both BOLD and IRON (Increased Relaxation to Optimized Neuroimaging) images (TE = 21 ms) were acquired. The resolution was 1.25 mm isotropic. Three event types were presented in each run: alternating black and white spots on a gray background (SPOTS), alternating black and white full-field checkerboard (FULL-FIELD), and gray holes on a black and white alternating full-field checkerboard (HOLES). The flickering frequency was 3 Hz. Both spots and holes were positioned in each quadrant of the visual field along the 45° azimuthal line, and at approximately 5° and 11° eccentricity. The eccentricity of the outer spots was chosen such that the activated cells would lie in the periphery of V1, where the receptive fields are smaller. The inner spots were scaled such that the area of the activated patches in V1 would be approximately equal to the area of the outer patches. Three different spot angular apertures were used: 0.6°, 1.8° and 6° of visual angle. A fixation point was present in the center of the screen at all times, and eye position was continuously monitored and recorded. The monkey's fixation accuracy was excellent and comparable during the three stimulus conditions. Block designs were used to maximize detection power.

Results

Figure 1 shows representative IRON and BOLD activation maps obtained for an angular aperture of 1.8°. Holes in the activation maps were not observed for this angular aperture for either BOLD or IRON. In fact, the average signal at the expected location of the holes, (or spots location) was larger than the average signal at the same location for spots and similar to full-field, as shown in Figure 2. By repeating the procedure for every aperture used, and normalizing the spots and holes CNR by the full-field CNR, we get Figure 3. The trends observed for spots and holes are similar for BOLD and IRON, and the small differences in normalized CNR between these two methods are not statistical significant. Even though activation holes were not observed directly from the maps for none of the angular apertures, for the largest hole size used we could detect a subtle decrease in activation in the center of the holes for BOLD, in agreement with Smirnakis data, but also for IRON. For the other two angular apertures, the activity within the expected holes was slightly greater than the activation for a full-field checkerboard, and approximately twice the activity for spots, for both methods of contrast used. As expected, the activation within the spots ROI increased with angular aperture for both methods[1].

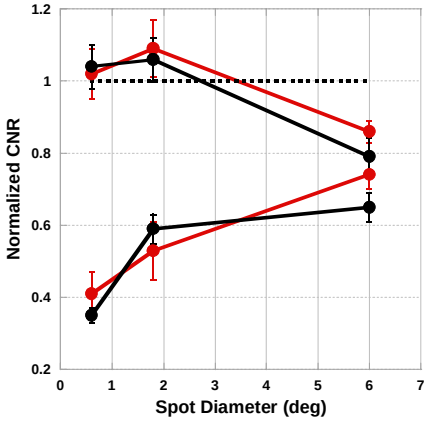

Figure 3.) Plot of normalized CNR for spots and holes in the spots' ROI vs spot size, for BOLD (black) and IRON (red) contrasts. The CNR for spots and holes was normalized by the CNR observed in the spot's ROI for the full-field checkerboard condition.

Discussion

We showed that hole-image and spot-image experiments provide similar results for BOLD and IRON across all angular apertures used. These observations may imply that for the smallest apertures used there is neuronal activity in the hole region, which may result from V1 activity as an edge localizer. As the hole size increases, the activity will accordingly be more confined to the edges of the hole, consistent with a drop in signal observed for both methods. Nevertheless, this interpretation of the data bears further investigation.

References [1] Leite et al., Proc ISMRM 2004; [2] Smirnakis et al., Proc HBM 2004