

Contrast in Single Trial fMRI: Interstimulus Interval Dependency and Comparison with Blocked Strategies

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Introduction:

Hemodynamic changes resulting from < 3 sec "single trial" brain activation durations are detectable using functional MRI (fMRI)(1-5). Advantages of single trial paradigms include: task randomization, trial binning, and overt responses.

In single trial fMRI, contrast is gained as more trials are averaged, but contrast is lost as the hemodynamic response from closely spaced trials increasingly overlaps as the interstimulus interval (ISI) decreases. The hemodynamic response characteristics determine the ISI that maximizes contrast. A second issue is that of how contrast in single trial fMRI compares to that of "blocked" strategies - which allow for the hemodynamic response to reach a steady state for each condition. In this study, these issues: the optimal ISI at a given stimulus duration, and a comparison of single trial contrast with that of "blocked" strategies is carried out experimentally and with the use of simulations.

Methods:

Four subjects were imaged with EPI using a three axis gradient coil at 1.5T (GE Signa). Two imaging planes were obtained: one containing visual cortex and one containing motor cortex. Voxel volume = 3.7 x 3.7 x 7 mm³. TR = 1 sec. TE = 40 ms. Time series length = 360 images. Subjects performed bilateral finger tapping when an 8 Hz flashing red LED matrix (GRASS™) was on. Stimulus duration was 2 sec. Separate time series with ISI's of 2, 4, 6, 8, 10, and 12 sec. were collected. A blocked time series having on/off timing of 20 sec/20 sec. was also collected.

Both functional contrast to noise images and averaged responses were analyzed. Functional contrast to noise images were created by calculating the correlation with a reference waveform, obtained by spatial and cyclic averaging, and then by dividing by the residual noise after the reference waveform was subtracted out. A second method for assessing contrast involved calculating the integral of the rectified area around the mean of averaged responses. Typical average responses are shown in Figure 1. This integral was divided by the time per complete single trial on / off cycle to obtain a measure of contrast per unit time. For the simulations, waveforms were created by convolution of the estimated hemodynamic response function(6) with binary on / off functions representing the input stimuli. The contrast per unit time was calculated in these synthesized responses in the same manner as with the experimentally - obtained response curves.

Results and Conclusions:

Figure 1 shows the averaged visual cortex responses from one subject. The activation - induced response magnitude and shape is highly dependent on the interstimulus interval. Figure 2 summarizes the relative functional contrast calculated from the motor and visual cortex using the two methods described above. The contrast obtained from the simulated responses is also shown.

Figure 3 shows the simulated fMRI contrast for all combinations of ISI and stimulus duration up to 32 sec. each.

The experimental data indicate that the functional contrast in single trial fMRI is about 60% - 70% that of the 20 sec on / 20 sec off blocked timing. A sharp drop-off in contrast occurs at interstimulus intervals of less than about 8 sec. While functional contrast at an ISI of 2 sec was about 10% that of the blocked timing, functional images were still able to be created.

The reason for differences between the simulated and experimental contrast may be that the relative amplitude of the experimental response was consistently greater than the simulated single trial response, suggesting a non-linear hemodynamic response or neuronal input that is not a simple boxcar. (i.e. a "burst" of neuronal activity at activation onset). The data indicate that the optimal ISI of at least 12 sec, while the simulations suggest an optimal ISI of about 10 sec, for the particular hemodynamic response used(6).

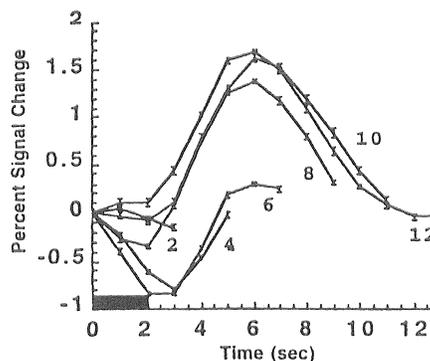


Figure 1: Averaged responses from visual cortex. Stimulus duration was 2 sec. ISI's ranged from 4 to 12 seconds - as labeled.

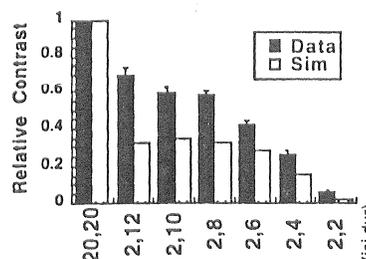


Figure 2: Functional contrast per unit time as calculated from averaged response curves (as in Figure 1) and functional contrast to noise images.

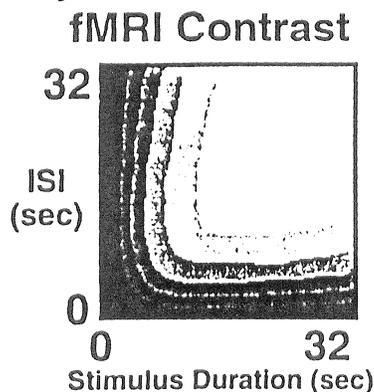


Figure 3: Simulated contrast as a function of ISI and stimulus duration. Hemodynamic response function from ref 6 was used.

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