

Functional Contrast in Event-Related fMRI: Interstimulus Interval Dependency and Blocked Design Comparison

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Introduction: Hemodynamic changes resulting from brief (< 3 sec) brain activation durations are detectable using functional MRI (fMRI). This brain activation strategy has been termed “event-related” fMRI and has some significant advantages over more conventional “blocked” strategies. Statistical power or functional contrast is gained with the averaging of more events, but functional contrast is lost as closely spaced events cause the hemodynamic responses from adjacent events to overlap. A key question regards what the optimal trial spacing or interstimulus interval (ISI) is. A second key question is how contrast in event -related fMRI compares to that of blocked strategies which allow the hemodynamic response to reach a steady state for each condition (i.e. 20 sec off 20 sec on). In this study, the optimal ISI is analytically derived and experimentally demonstrated.

Methods: Three subjects were imaged with EPI using a local 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 was 3.7 x 3.7 x 7 mm. TR = 1 sec. TE = 40 ms. The time series length was 360 images. Subjects performed bilateral finger tapping only when an 8 Hz flashing red LED (GRASS goggles) was on. Stimulus duration was 2 sec. Separate time series with ISI's of 2, 4, 6, 8, 10, 12, 16, 20, and 24 sec. were collected. A blocked time series having on/off timing of 20 sec/20 sec. was also collected.

Functional contrast to noise images and average time courses, as shown in Figure 1, were analyzed. Functional contrast to noise images were created by calculating the correlation with an ideal reference waveform, then dividing by the residual noise after the reference waveform was subtracted out. The integral of the rectified area around the mean of each average time course response 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(1) 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 experimental curves.

Results and Conclusions: Figure2 summarizes the normalized relative functional contrast (blocked design = 1) calculated from the motor and visual cortex of all subjects using the two methods described above. The data indicate that the functional contrast per unit time using an ISI of 12 (optimal) and a stimulus duration of 2 sec is about 65% that of the blocked paradigm timing. Simulated contrast demonstrates approximately the same optimal ISI but a maximum contrast of only 35% that of blocked design. The amplitude of the experimental event - related response was consistently greater than the simulated amplitude. This difference suggests, at short stimulus durations, deviation from linearity in the hemodynamic response or a neuronal input function that is not a simple boxcar. (i.e. a “burst” of neuronal activity at the onset of activation) (2) .

The optimal ISI was derived analytically using a linear shift invariant response model. If the fMRI response to a single stimulus is $r(t)$, then the optimal stimulus period is $T = [\int rdt]^2 / \int r^2dt$. Using the gamma variate hemodynamic response function of reference (1) , we found $T = 12.3$ sec for a stimulus duration of 2 sec, and $T = 11.6$ sec for a stimulus duration of 1 sec. These analytical results agree strongly with the data.

References: 1.M. S. Cohen, *Neuroimage* 6, 93 (1997). 2. G. M. Boynton, et al, *J. Neuroscience* 16, 4207 (1996).

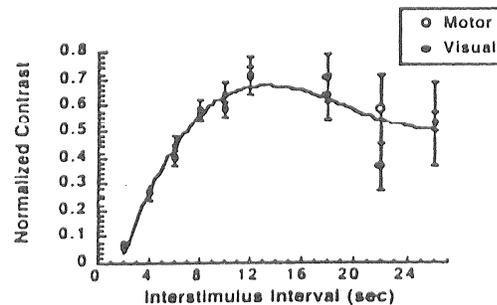
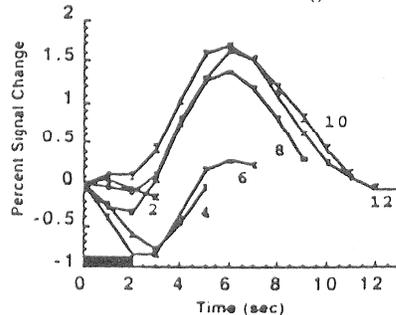


Figure 1: Average V1 response. Stimulus = 2 sec. ISI's ranged from 4 to 12 seconds - as labeled.

Figure 2: Single - event contrast (blocked design = 1). vs. ISI. Stimulus duration = 2 sec. Maximum contrast = 12 sec.