

Estimated BOLD Impulse Response Depends on Stimulus ON/OFF Ratio



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Introduction

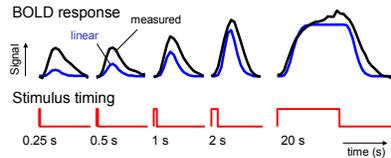
Recent studies of the blood oxygenation level dependent (BOLD) fMRI signal in response to stimuli of different durations have revealed that the signal behaves in a nonlinear manner, with short duration stimuli producing responses larger than expected from a linear system (1-6). This nonlinearity can influence the estimate of the BOLD signal amplitude, particularly in event-related fMRI (ER-fMRI) studies which capture the dynamic BOLD changes in response to brief stimuli. The dynamics of the BOLD signal is determined not only by the adaptation during the stimulus (the "ON" period), but also the recovery after stimulus cessation (the "OFF" period).

The goals of this study are

1. To characterize the BOLD response to varying OFF period durations
2. To compare the estimated impulse response functions (IRF) from stimuli presented in an event-related paradigm with different fractions of stimulus in the ON state.

Linearity

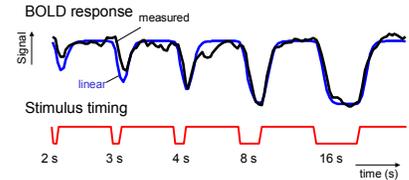
Different stimulus "ON" periods



The responses to visual stimulation (contrast reversing checkerboard) of different durations are averaged over 20 epochs and over the entire activated region. These are compared to ideal linear responses (blue lines) at the particular stimulus duration.

Brief stimuli (ON periods) produce larger responses than expected

Different stimulus "OFF" periods



Visual stimulation was presented for 20 s alternated with varying periods of fixation on a dark screen. The response shown is averaged over 9 epochs and the entire activated region, and is compared to the predicted linear response (blue line).

Brief stimulus cessations (OFF periods) produce smaller signal decreases than expected

Varying ON and OFF periods

Methods

Visual Stimulation:
contrast reversing checkerboard
alternated with fixation on dark screen

310 image volumes / run

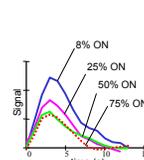
3T GE Signa
EPI, 64x64
TR = 1000 ms
TE = 30 ms
FOV: 24cm, 5mm sl.thick.
8 axial slices

Stimulus time series

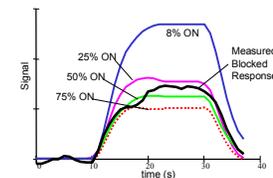


Five series of echo planar images were acquired with visual stimulation presented 8%, 25%, 50%, and 75% of the time, in addition to a blocked design (30 s ON, 30 s OFF).

Estimated Impulse Response

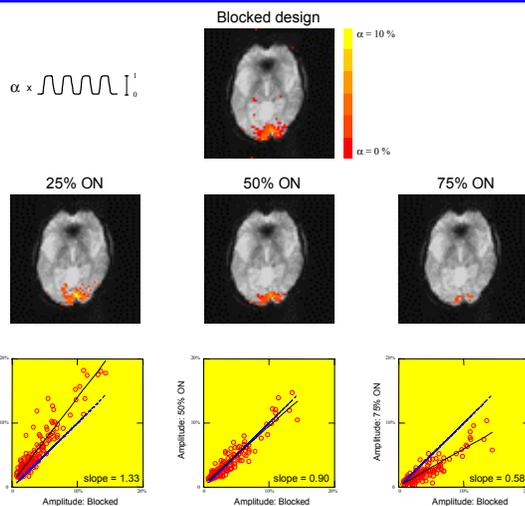


Predicted Blocked Responses



The deconvolved (estimated) impulse response functions (IRF) were smaller when stimuli occurred more frequently. Consequently, IRF's from stimulation occurring less frequently overestimated the true response to a blocked stimulation of 20 seconds, whereas the IRF from a run where half the time was spent stimulating more accurately predicted the true blocked response.

Spatial variation



Functional activation map: blocked design.

The color scale indicates the magnitude of the BOLD signal change. 1 representative axial slice is shown.

Functional activation maps: varying ISI and fraction of stimuli in ON state.

The color scale indicates the magnitude of the BOLD signal change, normalized by the ideal linear response for each time series.

Comparison of (normalized) activation amplitudes between blocked design and variable ISI designs for all activated voxels.

BOLD magnitudes are larger than a linear prediction for infrequent (25%) stimulation, and smaller than a linear prediction for frequent (75%) stimulation.

Even though the normalized amplitude of the response varies with the stimulation pattern, the relative amplitude across space is preserved. Regions with the largest BOLD signal changes in the blocked design are still the largest for other stimulation time patterns.

Conclusions

The amplitude of the deconvolved impulse response depends on the fraction of time spent stimulating.

More frequent stimulation → underestimate blocked (20 s) response
Less frequent stimulation → overestimate blocked (20 s) response

The relative amplitude over space is the same for different stimulus time patterns

References

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