

Non-Linear BOLD Responses for Transient Deactivations in V1

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Introduction:

The BOLD response for transient activations has been well studied, and for successive short stimuli the summed response acts non-linearly [1, 2]. A further characteristic of a linear system is that changes in response to activation and deactivation are reciprocal. We have investigated the hemodynamic response functions (HRFs) in visual cortex in response to both short activations (relative to a resting baseline) as well as to short interruptions of a steady state activating stimulus (deactivations). The extent to which these responses differ may shed light on models of BOLD responses and is important for the design and interpretation of experiments and methods of data analysis.

Method:

An 8Hz large-field contrast-reversing checkerboard pattern at 100% contrast served as our visual excitation stimulus ("ON"). In our baseline condition subjects viewed a spatially homogeneous black screen ("OFF"). Two event-related paradigms generated by E-prime (Psychology Software Tools, Inc) were presented to healthy subjects: I. Brief stimulus-ON (2sec or 4sec) during otherwise continuous stimulus-OFF; II. Brief stimulus-OFF (2sec or 4sec) interspersed with otherwise continuous stimulus-ON. The target to target interval was fixed to 20sec for all trials. In total 80 trials were presented in 4 runs, and each type of stimulus (2sec/4sec of flickering checkerboard ON and 2sec/4sec of black screen OFF) was presented 20 times.

MR images were acquired on a 3T Philips Achieva scanner. Ten T1-weighted anatomic images were collected parallel to AC-PC line with 5mm slice thickness and 1mm gap and positioned to cover the visual areas. Then functional images were collected in the same planes, using a gradient echo EPI sequence (TR/TE=1s/35ms, flip angle=70°, FOV=22x22cm² and acquisition matrix size=80x80 reconstructed to 128x128), then analyzed using BrainVoyager and custom analysis software running under MATLAB.

Results:

The BOLD MR signal in primary visual area V1 showed different hemodynamic responses to stimulus ON and OFF as expected. A positive BOLD effect was found in V1 in response to the brief checkerboard stimuli, whereas a negative BOLD response (or signal decrease) was found when the check board was interrupted (Fig.1). To compare the activation and deactivation responses, we fit the

experimental signal-time curves with a gamma-variate function of the form $f(t) = \left(\frac{t}{d}\right)^a e^{-(t-d)/b} - c\left(\frac{t}{d'}\right)^{a'} e^{-(t-d')/b'} + E$ in the

least-squares sense [3] and obtained the magnitude and temporal parameters of the hemodynamic response functions shown in Table1. Comparing the fitted responses, we found the deactivation response to a 2sec stimulus OFF was very small in V1 compared to the positive signal increase recorded for a 2sec ON stimulus. In addition, while the ON responses for 2sec and 4sec were not related in linear fashion [1, 2], the OFF responses showed a greater degree of non-linearity. The deactivation responses were smaller, had slightly longer latencies and faster times to peak, and showed no significant post overshoots.

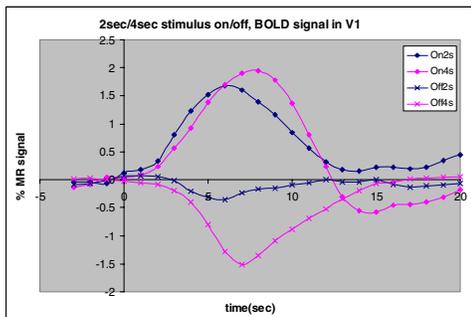


Fig1. BOLD responses in V1

	T_peak(s)	A_peak(%)	T_undershot(sec)	A_undershot(%)
on2s	6.12	1.67	13.88	0.16
on4s	7.53	1.98	15.37	-0.62
off2s	5.90	-0.32	12.01	-0.02
off4s	7.31	-1.43	/	/

Table1. Amplitudes of peak and post undershoot/overshoot, time to peak and post undershoot/overshoot for BOLD response to stimulus-ON (2sec or 4sec) and stimulus-OFF (2sec or 4sec).

Discussion:

These data demonstrate the HRF to deactivation is smaller and has different time course to the HRF for transient activation. During a steady state excitation equilibrium is achieved between blood flow, volume and oxygenation. When this is interrupted the sequence of physiological changes is different from those involved in vaso-dilation in response to transient excitations and the HRF reflects those differences. The implications of these results for the design and interpretation of experiments as well as for models of the BOLD response are being further evaluated.

Acknowledgments:

We thank Donna Butler and Robin Greene-Avison for technical support.

References

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