Deactivations in Primary Visual Area Which Correspond to Activations in Extrastriate Visual Areas Studied by fMRI

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Introduction:

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. Moreover, whereas the expected responses in primary visual area V1 may depend on simple sensory attributes of the stimulus, the responses of higher order visual areas such as V2, V3 may reflect other aspects of visual processing and may not follow the trends of the responses in V1. We therefore investigated the spatial and temporal patterns of the transient hemodynamic responses in both V1 and extrastriate visual cortex for both positive and negative BOLD effects induced by turning visual stimuli either on or off.

Method:

An 8Hz large-field contrast-reversing checkerboard pattern at 100% contrast served as a visual stimulus (denoted as condition "ON"). In our baseline condition subjects viewed a spatially homogeneous black screen (denoted as condition "OFF"). In our comparison condition subjects viewed a spatially homogeneous bright screen (denoted as condition "BRIGHT"). Three 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. Various durations of visual inactivity (stimulus-OFF for 1sec, 2sec, 3sec, 4sec, 6sec, or 8sec) interspersed during otherwise continuous visual stimulation-ON; III. Brief stimulus-BRIGHT (2sec or 4sec) interspersed with otherwise continuous stimulus-ON. The target to target interval was 22sec for 1sec, 2sec, 3sec and 4sec stimuli and 26sec for the 6sec and 8sec stimuli. Each type of stimulus (2sec/4sec of flickering checkerboard ON and 1sec/2sec/3sec/4sec/6sec/8sec of black screen OFF or 2sec/4sec of bright screen BRIGHT) was presented multiple (≈ 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=22x22cm^2 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 opposite hemodynamic responses to stimulus ON and to stimulus OFF, as expected. Figure 1 shows the positive transient BOLD response in V1 after a brief stimulus-ON, as well as the transient negative BOLD response for a brief stimulus-OFF, and the shapes of the BOLD responses are nonlinearly different with different durations of stimulus-OFF. On the other hand, the BOLD MR signal in extrastriate visual area showed positive hemodynamic responses to both transient stimuli ON and OFF i.e. the extrastriate visual area showed the same positive BOLD response even when the sensory strength of the stimulus was reduced. More interestingly, the positive BOLD responses showed no direct relationship with the duration of stimulation switching. E.g. for 1sec Stimulus-OFF, though deactivation is not easy to be seen in V1, a significant signal increase can be seen in extrastriate visual area.

Moreover, when the interruption OFF was replaced by a bright screen (BRIGHT) there was no corresponding positive BOLD response or significant hemodynamic transient change in extrastriate visual areas.

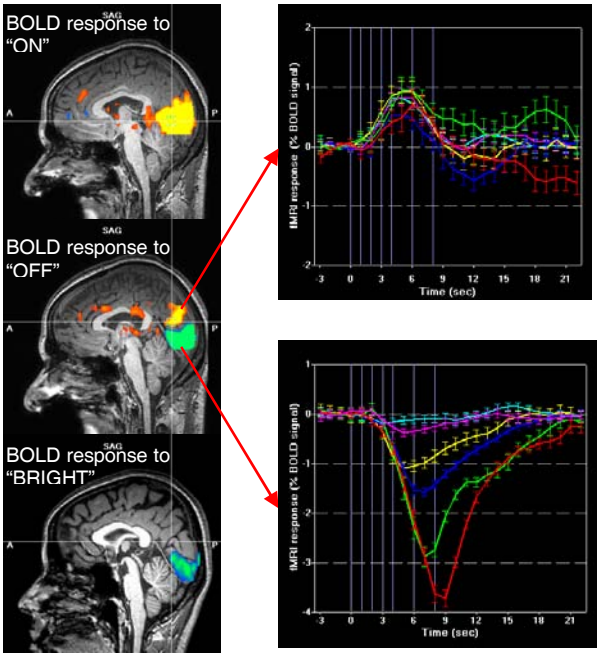

Figure1. 1st column shows BOLD fMRI activation maps; 2nd column shows BOLD signal changes in extrastriate visual area (upper) and V1 (lower) in response to various durations (1sec/2sec/3sec/4sec/6sec/8sec) of stimulus-OFF.

Discussion:

The event-related responses to ON and OFF in primary visual area V1 presumably reflect the effects of a transient onset of activation (in which case blood flow must increase to meet demands) or a transient reduction of activation (in which case blood flow decreases) and thus they may be expected to have different temporal forms reflecting the physiological conditions. Based on recent results that a luminance increment produces similar activation of V1 and extrastriate visual area, whereas a luminance decrement produces activation in extrastriate visual areas but relative suppression in V1, we expect the V1 response to be specific to the luminance change and to be different in response to stimulus-ON, OFF or BRIGHT. It is also likely that feedback from extrastriate visual areas (V2 or higher) plays a role.

While the primary sensory area V1 behaves as expected, the hemodynamic responses for extrastriate visual areas are not easily explained in terms of simple responses to sensory stimuli. Further studies are required to elucidate the mechanism by which the BOLD response is sometimes positive and sometimes neutral in extrastriate visual areas for similar changes in sensory strength in V1.

Reference:

[1] Roe, A. W. (2003) in *The Primate Visual System*, eds. Collins, C. & Kaas, J. (CRC, New York), pp. 109–138.