The nature of the negative BOLD response and its behavioral correlates.
Cosyne 2009, supplementary material. -- Alex Wade and Jess Rowland

Introduction:
The negative BOLD response (NBR) describes a phenomenon seen in functional magnetic resonance imaging in which a stimulated cortical region that responds with a positive blood oxygenation-level dependent (BOLD) signal is flanked by an unstimulated region of cortex exhibiting a negative response (Shmuel, Yacoub et al. 2002; Smith, Williams et al. 2004). It is most easily seen in visual cortex where well-ordered retinotopic maps make it easy to identify stimulated and unstimulated locations.

The NBR is primarily a neural effect: reductions in the BOLD signal correlate with reductions in both LFP activity and firing rates (Shmuel, Augath et al. 2006). Using event-related fMRI, we measured the amplitude of the NBR as a function of ongoing background activity in order to elucidate the neural mechanisms underlying it. We also measured human psychophysical performance using a stimulus very similar to that in our fMRI experiments in order to identify behavioral correlates of the signal changes that we observe.

Methods:
Our stimulus (Figure 1) consisted of a central disk D (diameter 2 degrees) of contrast Cd and a surrounding annulus A (diameter 5 degrees) of contrast Ca presented on a uniform mean gray field with a small gap between them. Cd and Ca could be set independently.

fMRI methods: The difference between BOLD responses in the annulus region to conditions Cd=0% (no center) and Cd=90% (high-contrast center) gave the magnitude of the NBR. We measured the NBR as a function of Ca (0%, 5%, 20% and 45% contrast). An attentionally-demanding letter discrimination task was present at fixation (‘F’) throughout the experiments. N subs=5, B0=3T, EPI TR=2s, resolution 2x2x2mm. All data from independently-localized regions in V1 defined on flattened, retinotopically-mapped cortex.

Behavioral methods: We measured threshold-versus-contrast (TVC) curves (Foley 1994) for both D and A in the presence and absence of high-contrast, spatially-remote maskers (A and D respectively). Using these curves we derived the response-versus-contrast (RVC) functions of both the disk and annulus regions in order to relate them to our functional imaging measurements. N subs=5, thresholds estimated using a QUEST 2 interval forced choice procedure (Watson and Pelli 1983).
Results:
Our fMRI results show that the magnitude of the NBR decreases with increasing background contrast (See Figure 2). This is best modeled as a multiplicative gain control mechanism with a significant baseline metabolic response at zero contrast. In addition, the NBR exhibits a profound spatial asymmetry: We measure a strong NBR in the periphery but not in the fovea.

Our psychophysical data are in agreement with these results: We measure weak or non-existent suppression of a foveal probe due to a high-contrast annulus but strong suppression in the near-periphery due to a high-contrast center.

Conclusion:
The NBR is a manifestation of a long-range, multiplicative gain control mechanism. This mechanism acts to suppress neural activity in the periphery when a high-contrast stimulus is present in the fovea but no equivalent long-range suppression is seen for foveal responses.

References