

# Hemodynamic Correlates of a Perceptual Decision

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Does activity in primary visual cortex (V1) correlate with perceptual choices in a threshold orientation discrimination task? Single-unit physiology in monkeys has shown that the performance of neurons as measured by the so-called neurometric function matches well with the behavioral psychometric function [1], and on individual trials, the response of single neurons weakly covaries with the monkeys' choices. Given that perceptual choices are believed to be based on the population neural activity, we hypothesized that hemodynamic responses might more accurately predict perceptual choices.

Observers fixated a central fixation cross and viewed a circular low contrast (10%), flickering square wave grating (20x20°, TF=8Hz, SF=2 cycles/deg) presented for 1 sec followed by an inter-trial interval of 5.4 to 10.2 secs. The orientation of the stimulus was near psychophysical threshold ( $\pm 2.5$ ,  $\pm 1.5$ ,  $\pm 0.5$ ,  $\pm 0.25$ ,  $0^\circ$ ) and observers reported whether it was tilted left or right of vertical by pressing one of two keys. Concurrently, we measured BOLD fMRI using a 3T Siemens Allegra scanner (gradient-recalled EPI, TR = 0.8 seconds, TE = 30ms, 3x3x3mm voxels, 14 slices perpendicular to the calcarine sulcus).

To compare behavioral choices to the hemodynamic responses, we used a novel classification-based technique to estimate the neural activity for individual trials. Previous work has demonstrated that linear classifiers can decode the orientation of a stimulus from V1 activity in blocked fMRI experiments [2]. We extended the applicability of this approach to an event-related protocol, by analyzing empirical hemodynamic response functions (HRF) in two steps. First, for each voxel, we projected the HRF for every trial onto the principal axis that best discriminated between different stimulus orientations and/or behavioral responses. By doing so we allowed for the possibility that responses to different stimuli might not simply vary in amplitude, but also in time course. Second, we trained linear classifiers using those projections to test how well the HRFs correlated with stimulus conditions and/or behavioral responses.

We quantified the degree to which hemodynamic responses in V1 can be used to discriminate stimulus orientations by a *hemometric function* and found it to be compatible with an observer's psychometric function. Moreover, we found that the pattern of activation across voxels in V1 covaried with the observers' choices on a trial-by-trial basis. Of particular interest are near threshold conditions in which for the same exact stimulus, observers' choices varied across trials. In those cases, the output of the classifier predicted the observers' perception even when they were incorrect. While pooling of responses implicit in fMRI measurements may not match the pooling scheme used by the brain, our results nonetheless provide evidence that observers' choices arise from the correlated fluctuations of the neural activity in the sensory areas that support those choices.

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## References

- [1] Neuronal correlates of a perceptual decision. Newsome, Britten & Movshon *Nature* 1989.
- [2] Decoding the visual and subjective contents of the human brain. Kamitani & Tong, *Nat Neurosci* 2005.