# Latency and Duration of Hemodynamic Response Correlate with Anatomy

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## Introduction

The temporal resolution of BOLD fMRI is limited primarily by blurring introduced by the hemodynamic response (HDR). The HDR-width (FWHM), estimated at 4-6 s [1-3], is much slower than the 10-100 ms timescale of the macroscopic evoked electrical activity and the subsecon timescale of neurovascular control. At average capillary and venular flow speeds of several millimeters per second, a substantial part of HDR-width might be incurred by temporal dispersion during the transfer of oxygenated blood from the pre-capillary dilation site to downstream locations, including the post-capillary venules and veins (see Figure 1).

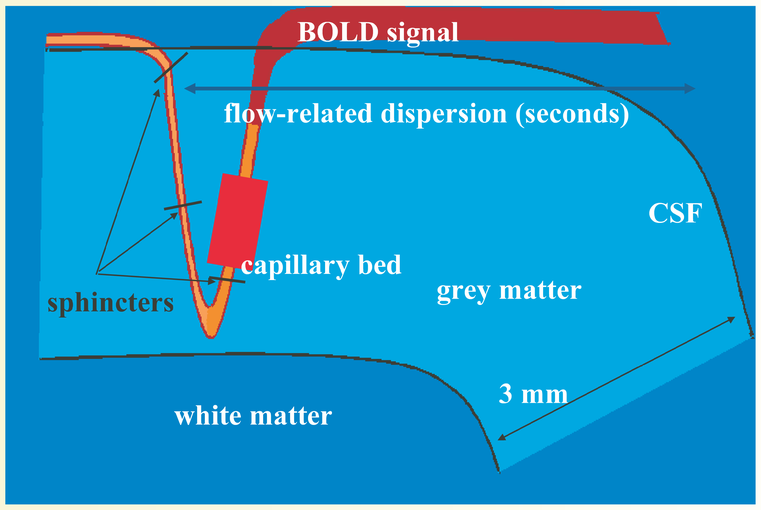


**Figure 1** Capillary bloodflow is controlled by peri-vascular structure. The BOLD signal occurs over a spatial and temporal range determined by the venous flow characteristics. :

Our hypothesis is that the HDR is affected by temporal dispersion that is spatially dependent, and that in fMRI at high spatial resolution, areas with HDRs that have reduced delay and duration will be observed. The intrinsic HDR-width (i.e. HDR-width at infinitely high resolution) might be much closer to the timescale of the neurovascular control mechanisms.

## Materials and Methods

BOLD fMRI of early visual processing in humans (n=8) was performed at 3.0 T with high temporal and spatial resolution (1 s, 1.1×1.1×3.5 $mm^3$) using 0.8 s events of contrast reversing checkerboard stimuli (16 reversals/s). Eight axial slices comprising V1 were acquired (single-shot gradient echo SENSE-EPI [4]). To obtain single-pixel HDR-estimates with high resolution and sufficient image signal-to-noise ratio (SNR), a pseudo-random stimulus sequence was used (m-sequence with 1 s base period) [5]. Furthermore, raw image SNR was boosted 2-3 fold (to 60-80) by using a custom-built 16-channel RF array coil and receiver system [6,posters 646, 656]. HDR widths and latencies were estimated on a pixel-by-pixel basis from time-interpolated responses derived from temporal correlation analysis [5].

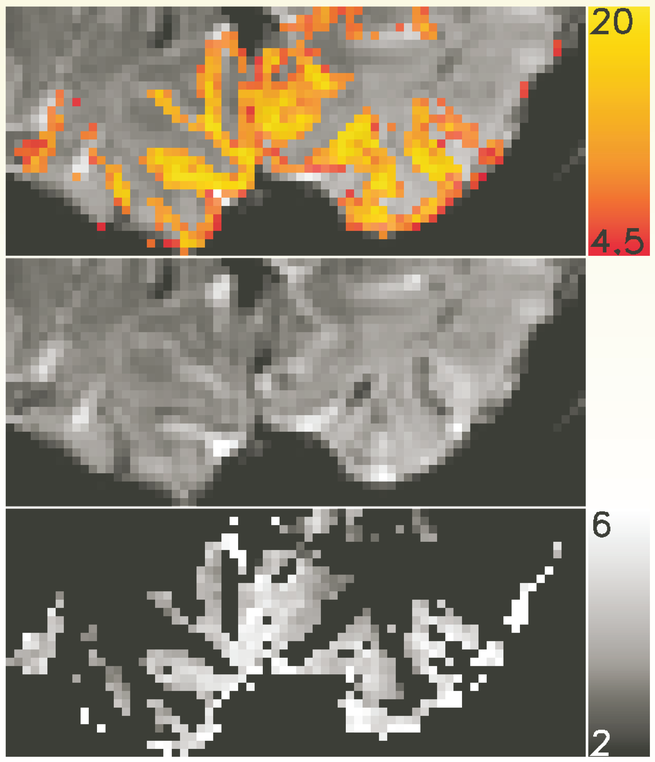


**Figure 2**: Zoomed-in section in occipital brain showing activation t-score overlayed on EPI scan (top), first EPI scan from time series data (middle), and FWHM of HDR in seconds from fit (bottom).

## Results and Discussion

All 5-10 minute scans showed strong activation in early visual areas (example shown in Fig. 2). Single pixel HDR estimates showed peak t-scores up to 25. A large spatial heterogeneity in HDR-widths was observed (Fig. 1, bottom), with FWHM ranging from 1.4-9.1 s (Figures 2-5). HDR becomes wider towards the brain surface, where most of the larger draining veins are located. Significant correlation (R=0.53) between time-to-peak and FWHM was also observed (Figures 3,4). Heterogeneity of the response was observed in all scans, with substantial variation in HDR timing across subjects. Data suggest that the pixels with early response correspond to cortical areas while pixels which longer delays and corresponding wider response are in the vicinity of veins. This, together with HDR FWHMs well below 4-6 s, supports our hypothesis. Studies are under way to evaluate whether HDR time-to-peak and width further reduce at even higher resolution and to what extent the HDR timing is limited by the intrinsic timing of the neurovascular control systems.

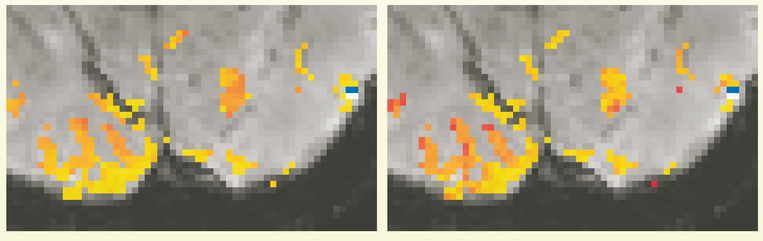

**Figure 3**: Distribution of HDR time-to-peak (left) and width (right) show strong similarity, width a temporal dispersion occurring from regions deeper into the striate cortex towards brain surface.

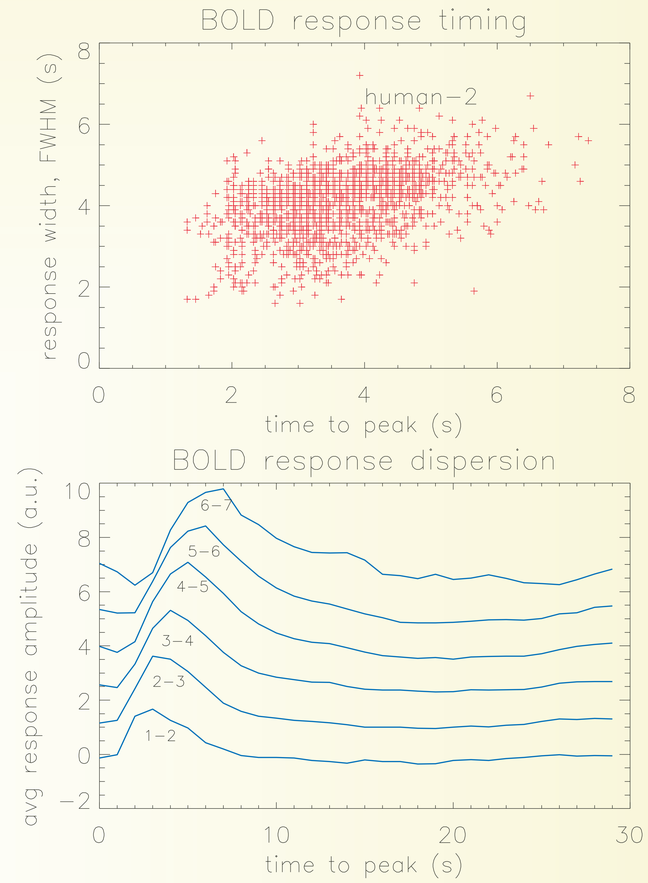


**Figure 4**: Scatter plot of time-to-peak plotted against width for one of the volunteers (top). Stimulus occurred from 0.0-0.8 s. HDR time courses (bottom), averaged over 1-second bins based on time-to-peak, show a substantial broadening for later responses.

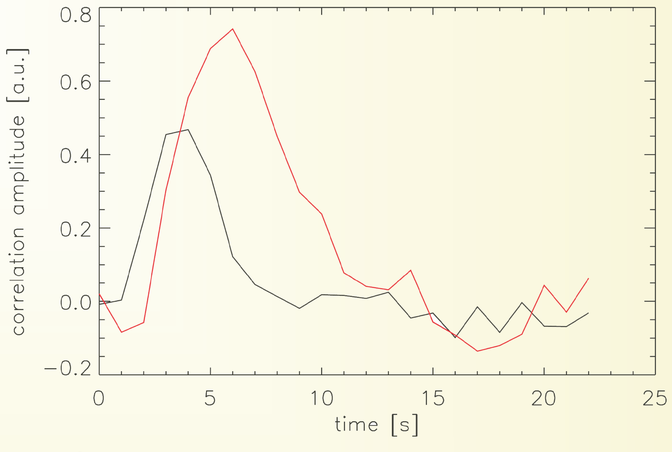


**Figure 5**: Sample single pixel HDR curves, demonstrating spread in width and onset time.

## References

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