Latency and Duration of Hemodynamic Response Correlate With Anatomy

Jacco A. de Zwart[*], Peter van Gelderen[*], Peter Kellman[†], Renxin Chu[*], Jeff H. Duyn[*]
[*]*Advanced MRI section, LFMI, NINDS, NIH, Bethesda, MD, USA*
[†]*Laboratory of Cardiac Energetics, NHLBI, NIH, Bethesda, MD, USA*

The temporal resolution of BOLD fMRI is limited primarily by the blurring introduced by the hemodynamic response (HDR). The HDR is much slower than the 10-100 ms timescale of the macroscopic evoked electrical activity and neurovascular control mechanisms, with reported estimates on the order of 4-6 s [1-3]. At average capillary flow speeds of 1-2 mm/s, a substantial part of the 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. We hypothesize that the observed HDR is affected by temporal dispersion, and that areas with HDRs that have reduced delay and duration will be observed in fMRI with high spatial resolution. The intrinsic HDR-width (i.e. HDR-width at infinitely high resolution) might be much closer to the 10-100 ms timescale of the neurovascular control mechanisms.

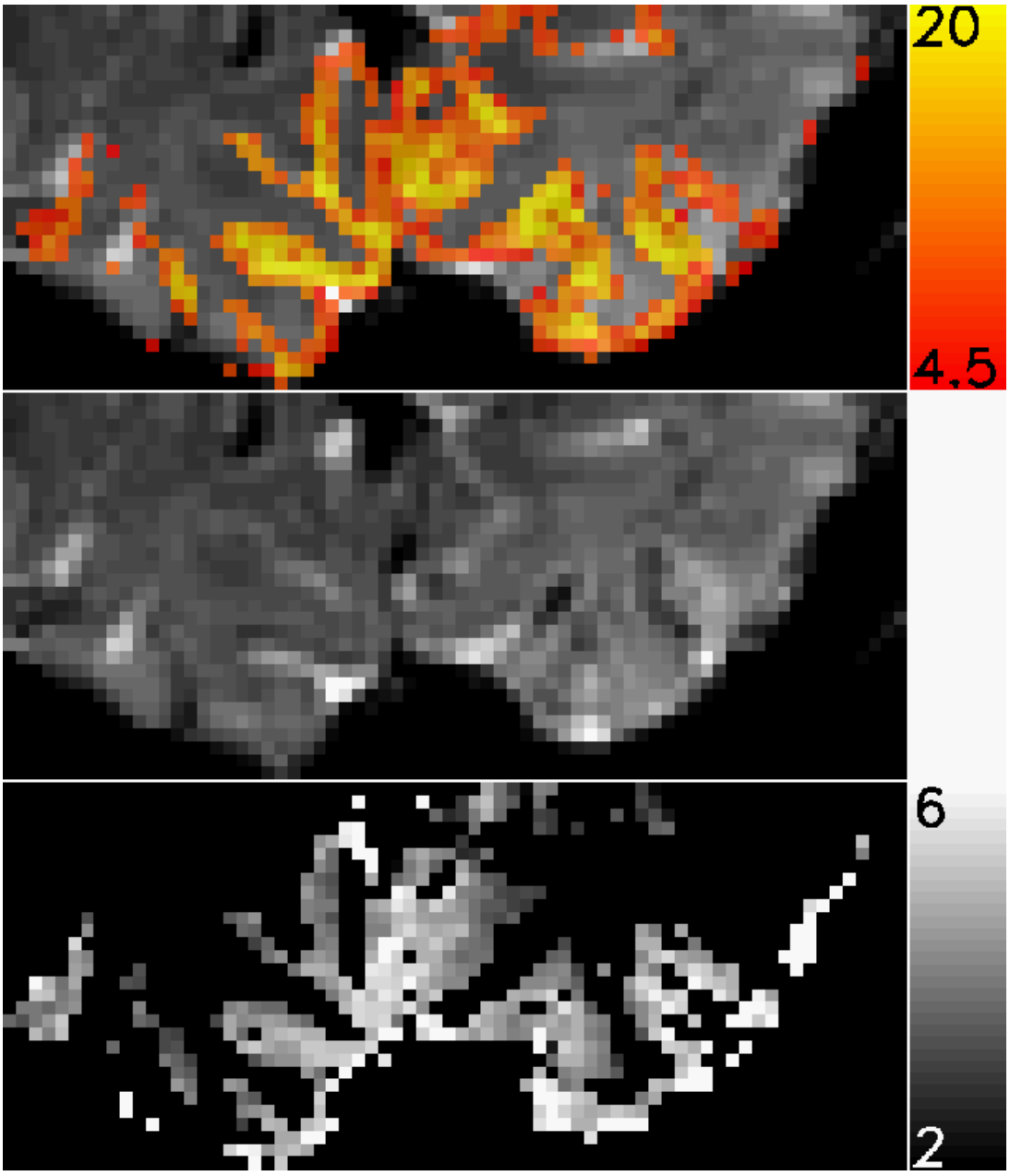

Figure 1: Zoomed-in section in occipital brain showing activation t-score overlayed on EPI scan (top), first EPI scan from time series data (middle), and FWHM of HDR in seconds from fit (bottom).

To test this hypothesis, we performed BOLD fMRI of early visual processing in humans at 3.0 T with high spatial and temporal resolution (1 s, 1.1x1.1x3.5 mm^3) using 0.8 s events of contrast reversing checkerboard stimuli (16 reversals/s). Eight axial slices comprising V1 were acquired with TE/TR=50/1000 ms. To obtain single-pixel HDR-estimates with high resolution and sufficient image signal-to-noise ratio (SNR), a rapid (1 s base period) pseudo-random stimulus sequence was used [4], and raw SNR was boosted 3-4 fold by using SENSE-EPI in combination with a 16-channel brain receive coil array [5,6]. HDR widths and latencies were estimated on a pixel-by-pixel basis from time-interpolated responses derived from temporal correlation analysis [4].

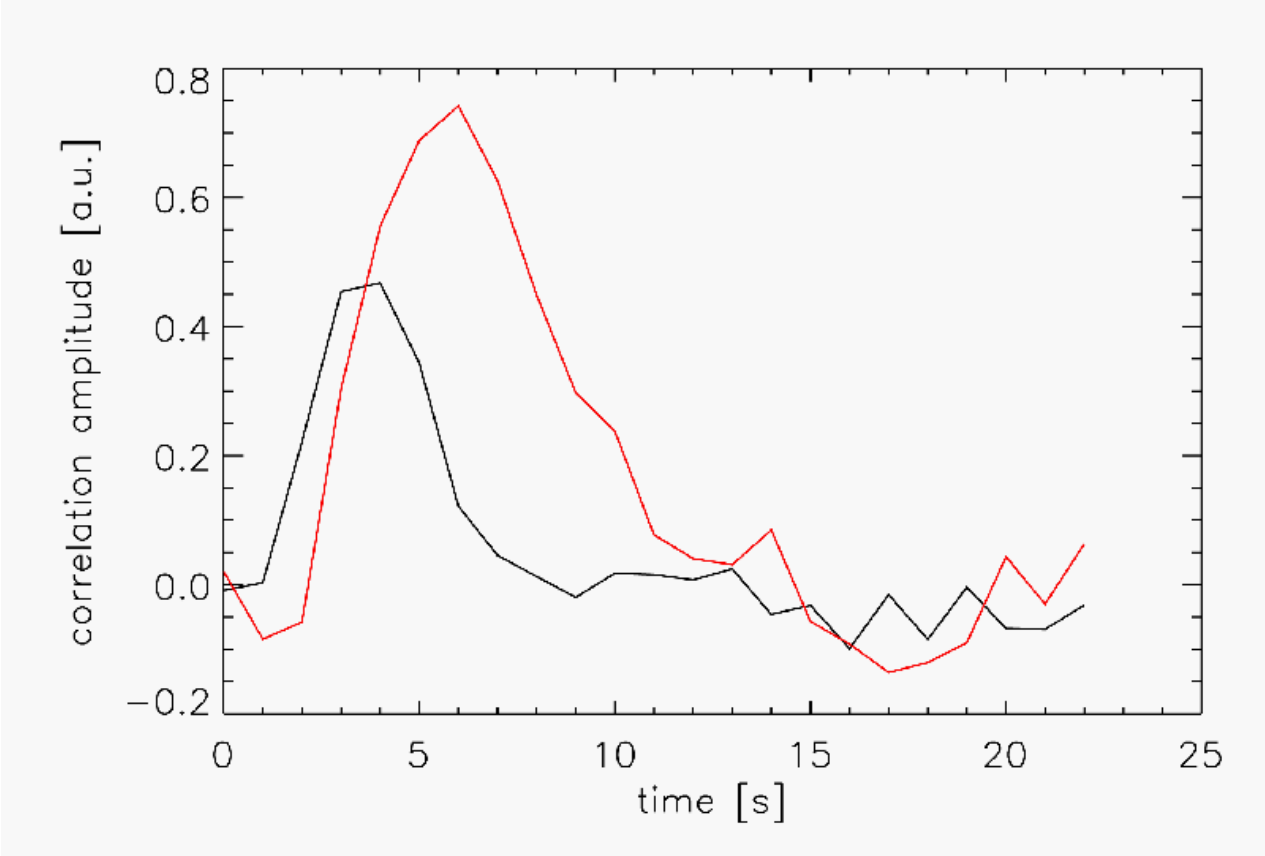

Figure 2: Sample single pixel HDR curves, demonstrating spread in width and onset time.

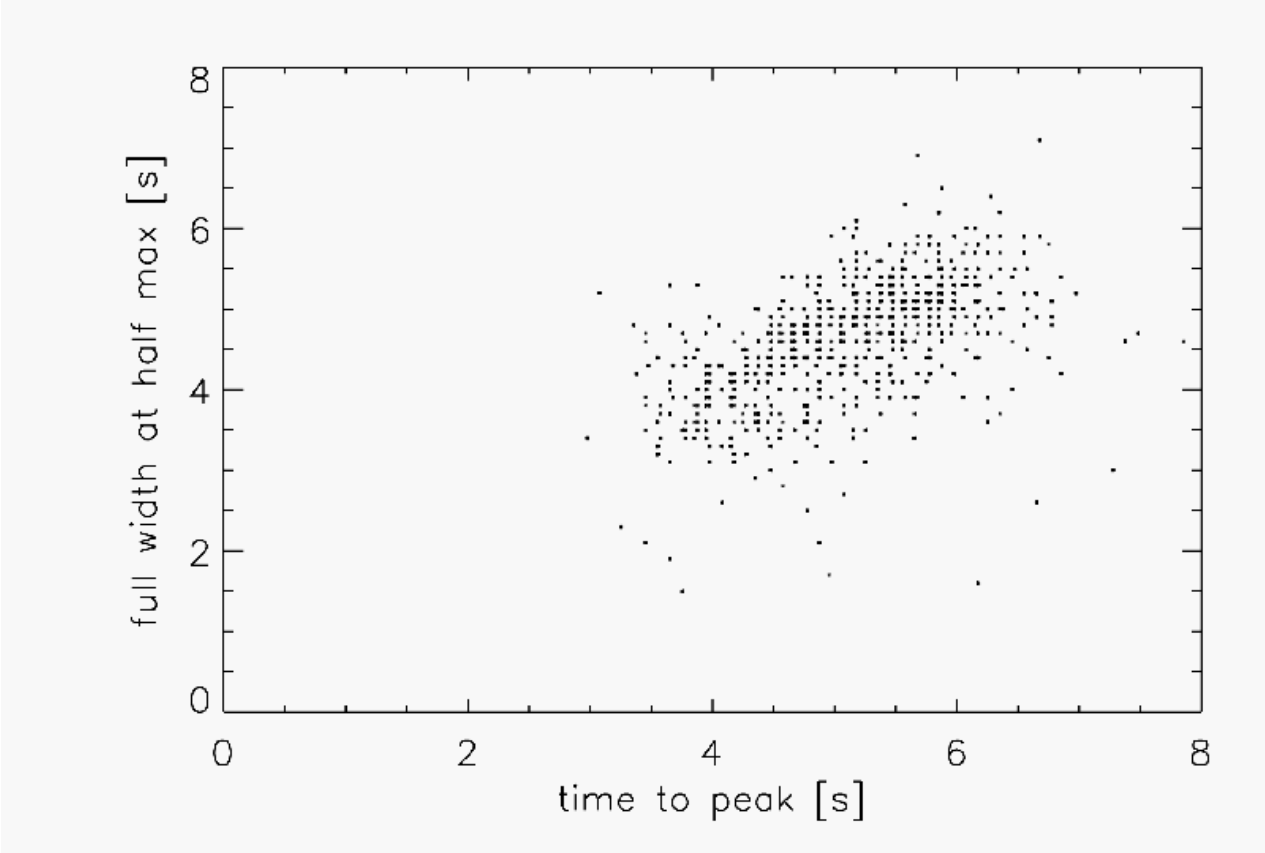

Figure 3: Scatter plot of HDR FWHM versus time-to peak, determined from time-interpolated data.

The high resolution whole brain scans showed high SNR (60-80) and strong activation in early visual areas with 5-10 minute runs (Figure 1). Single pixel HDR estimates showed peak t-scores up to 25. A large spatial heterogeneity in HDR-widths was observed (Figure 1, bottom), with FWHM ranging from 1.4-9.1 s (Figures 1-3). Furthermore, we observed a significant correlation (R=0.53) between time-to-peak and FWHM (Figure 3). Heterogeneity of the response has been observed in repeated trials. Preliminary findings show that the pixels with early activation correspond to cortical areas while the pixels which correspond to longer delays and with corresponding wider response occur in the vicinity of veins. This fact, together with the observation of HDR FWHMs well below 4-6 s, supports our hypothesis. We are currently performing experiments at even higher resolution to further investigate the apparent difference between timescales of the hemodynamic response and the neuronal and neurovascular effects.

References

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