

## Minimum resolvable latency difference of BOLD responses at 7T using autoregressive modeling

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### INTRODUCTION

Functional MRI (fMRI) at 7T has high signal-to-noise ratio (SNR), which allows the use of high spatial and temporal resolution. These together improve our ability to detect small differences in latency of the blood oxygenation level-dependent (BOLD) response [Gizewski]. The differences in latency can imply causal relationships providing information about the directionality of influence of one neuronal system on another (effective connectivity)[Goebel, Roebroeck]. Multivariate autoregressive (MAR) modeling uses latency differences to determine the directed influences by Granger causality [Goebel, Harrison]. Granger causal modeling has been used fruitfully for EEG data [Ding] and has also been applied in fMRI [Goebel]. We used MAR modeling and Granger causality to determine the minimum resolvable latency difference of the BOLD response at 7T.

### METHODS

Following [Menon], visual stimuli, generated by brief flashing of a checkerboard at 8 Hz frequency, were presented to left and right visual hemifields, separated by varying delays. A SV-6011 Avotec projector was used to present the stimuli. Stimuli were 2 sec long and the delay between left hemifield onset and right hemifield onset ranged from 0 to 1000 ms, to produce known relative delays in the BOLD responses in left and right visual cortex. 16 trials were presented over 5 minutes for each latency. Regions-of-interest (ROIs) were defined on a single slice from a block-design localizer. BOLD-sensitive MR images were acquired on a Philips Achieva 7T, with a 16 channel receive coil and quadrature transmit coil, using a gradient echo EPI, voxel size 1mm x 1mm x 2mm, at a 250 ms TR. A bi-variate AR model was fit to the time series from right and left hemispheres of V1, and the Granger causality between the two regions was calculated, following [Goebel]. The overall directed influence of right hemisphere on left was calculated as the difference between the right-to-left and left-to-right directed causal measures. To assess statistical accuracy of the influence, the ROI time series were split into separate trials and bootstrap samples were selected to obtain confidence intervals on the measures of directed influences.

### RESULTS

At zero latency, the difference between right-to-left and left-to-right measures must be zero, representing no preferred directional influence between right V1 and left V1. At other latencies, the difference must be greater than zero to claim that the temporal difference is detected by the modeling technique. Figure 1 shows the BOLD response from left and right hemisphere of V1 when stimuli were presented 125 ms apart in time. Figure 2 shows the directed influences of right V1 on left V1 with 95% bootstrap confidence interval at various latencies in two subjects. The influence was very close to zero at zero latency and well above zero at other latencies in both subjects. The 95% confidence intervals thus show a robust effect of right V1 on left V1 at non-zero latencies.

### CONCLUSIONS

We were able to measure latencies, as short as 112 ms, in a single subject, from only 16 trials (5 minutes). The slightly reduced influence at 250 ms latency in subject 1, as seen in Figure 1, could be due to the fact that the sampling rate was also exactly 250 ms. Future work will examine shorter latencies and the effect of TR on minimal resolvable latency.

### REFERENCES

Ding M et al. *Biol. Cybern.* 83:35-45 (2000). Gizewski ER et al. *NeuroImage* 37:761-68 (2007). Goebel R et al. *MRI* 21:1251-61 (2003). Harrison L et al. *NeuroImage* 15:925-34 (2003). Menon RS et al. *Neurobiology* 95:10902-07 (1998). Roebroeck A et al. *NeuroImage* 25:230-42 (2005).

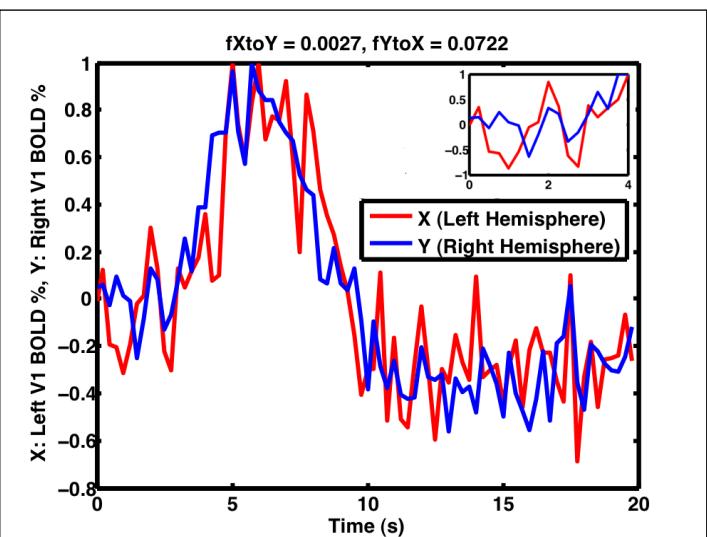


Figure 1: BOLD responses from left and right hemispheres of V1 at 125 ms offset between left and right hemifields of a single subject (Inset: Blow-up of the plot from 0 to 4 sec)

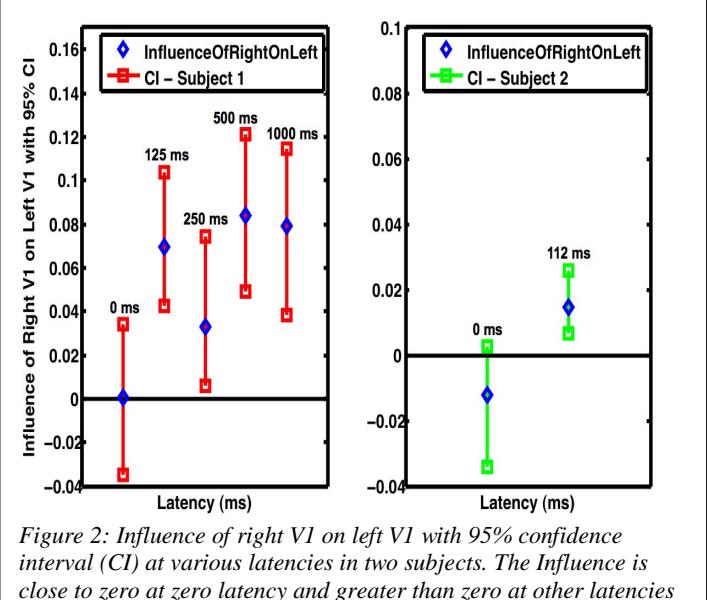


Figure 2: Influence of right V1 on left V1 with 95% confidence interval (CI) at various latencies in two subjects. The influence is close to zero at zero latency and greater than zero at other latencies for both subjects.