# Hemodynamic response timing in human lateral geniculate nucleus and visual cortex

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## INTRODUCTION

Accurate timing information is important for understanding the flow of neuronal activity in the brain. While BOLD-contrast fMRI is widely used to localize brain activations, hemodynamic responses secondary to neuronal events have been considered to have insufficient temporal resolution to detect interregional spread of neuronal activity. Magneto- and electroencephalography (MEG/EEG) have excellent temporal resolution and are directly measuring post-synaptic neuronal activity [1]. However, the sensitivity of MEG/EEG is mainly limited to cortex and accurate localization of activated areas is confounded by the ill-posed electromagnetic inverse problem. This biophysical dilemma has impeded the understanding of relative timing between subcortical and cortical activations in humans.

Recently developed magnetic resonance inverse imaging (InI) that uses highly parallel RF detection has allowed sampling of the BOLD signal at a 100 ms temporal sampling [2, 3]. InI has a whole brain coverage and almost uniform spatial sensitivity throughout the brain. Combining multiple projection acquisitions, InI can even maintain the whole-brain sensitivity and 100 ms temporal sampling without compromising any spatial resolution [4]. Thus it is feasible to use InI to probe cortical/subcortical timing differences at neuronally relevant scales. Here we report timing differences between lateral geniculate nucleus (LGN) and visual cortex (V1) BOLD responses to visual hemifield checkerboard stimuli. These preliminary results indicate that the activity of LGN significantly precedes that of V1 by approximately 500 ms.

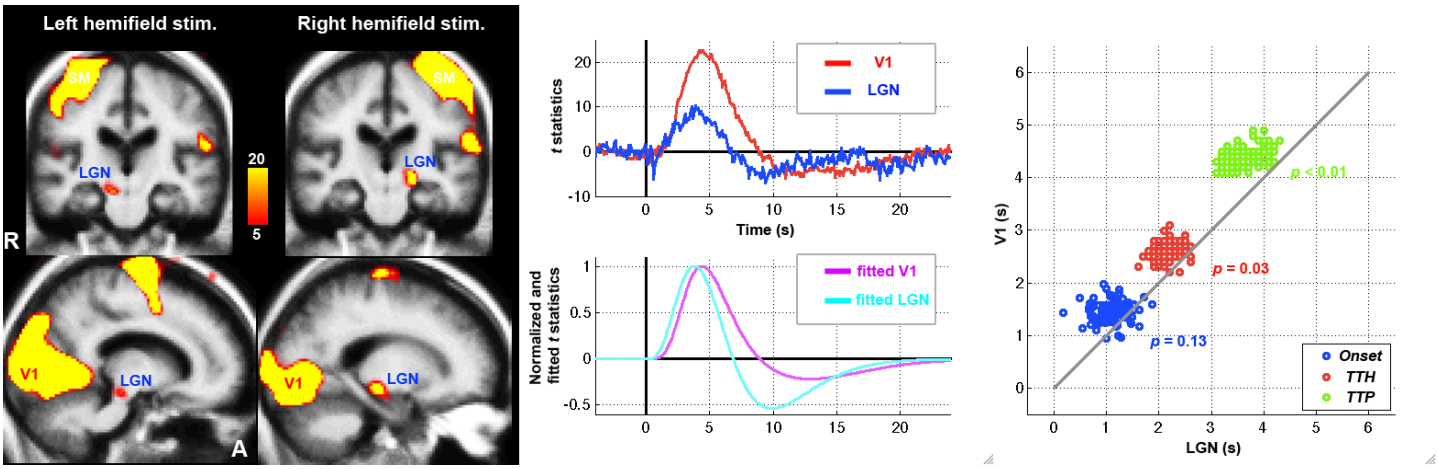
## METHOD

Twelve subjects were recruited with informed consent. Visual stimuli consisted of a radial checkerboard (contrast reversal at 8 Hz) pattern presented in the left or right visual hemifield; stimulus duration was 500 ms, and the latency between the two hemifields was varied parametrically. Subjects were instructed to push a button as quickly as possible for every visual hemifield stimulus using the ipsilateral hand.

InI was used to measure the BOLD signal using a 3T MRI scanner (Tim Trio, Siemens Medical Solutions, Erlangen, Germany) and a 32-channel head coil array. The imaging parameters were: TR=100 ms; TE=30 ms, flip angle=30°. Accelerated InI images in coronal, sagittal, and axial projections were acquired in three separate runs. There were 48 trials randomly presented over each 4-minute run for each subject.

A general linear model (GLM) was applied to deconvolve the hemodynamic responses using finite impulse basis functions. Subsequent volumetric reconstruction was performed using the multiple-projection minimum-norm estimate reconstruction [4]. The hemodynamic responses estimated from each subject were morphed to the MNI template for a random-effect group analysis to identify activated cortical/subcortical areas. We used a canonical model [3] to quantify the Onset, Time-To-Half (TTH) and Time-To-Peak (TTP) of the hemodynamic responses. A bootstrap analysis was used to evaluate the group-level variability of hemodynamic timing.

## RESULTS




(**Left**) The visual cortex (V1), lateral geniculate nuclei (LGN), and somatomotor area (SM1) were activated in the hemisphere contralateral to the visual stimulus/motor response. (**Middle**) The group-level dynamic *t* statistics at V1 and LGN, and the responses fitted to a canonical model. (**Right**) The distribution of *Onset*, *TTH*, and *TTP* timing indices using the bootstrap method with 100 iterations. LGN was activated earlier than V1 for *Onset* (500 ms difference, $p$=0.13), TTH (500 ms difference, $p$ = 0.03) and *TTP* (600 ms difference, $p$ = 0.01).

## DISCUSSION

We have previously reported that InI can identify sequential visual → motor hemodynamic activations using single projection data [3]. In the present study we successfully identified the hemodynamic responses in LGN by combining different projections and therefore minimizing the spatial resolution compromise in InI. Previous fMRI studies have detected LGN activations using block-design [5], whereas the present study was able to observe them using an event-related design. While the order of activation (LGN -> V1) matches known feed-forward connectivity, the BOLD latency between LGN and V1 is much longer than what has been reported in invasive electrophysiological recordings [6]. This may be related to (i) regional vasculature responsiveness and (ii) the coupling between neuronal and hemodynamic responses. Further studies are required to elucidate the physiological mechanism.

## REFERENCES

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