Temporal Frequency- and Time-dependent BOLD and CBV fMRI Signals in Cat Visual Areas 17 and 18

C. C-C. Yen[1], M. Fukuda[2], and S-G. Kim[2,3]

[1]Bioengineering, University of Pittsburgh, Pittsburgh, PA, United States, [2]Radiology, University of Pittsburgh, [3]Neurobiology, University of Pittsburgh

Introduction The relationship between neural activity and hemodynamic response is complex and depends on imaging modality and experimental design. In the cat visual cortex, neurons in area 17 are tuned to a temporal frequency of ~1.5 Hz visual stimulation, while area 18 is tuned to ~4Hz (1). Using this well-characterized model, we examined time-dependent BOLD and cerebral blood volume (CBV) responses to determine which modality is a better substitute for direct measure of neuronal activity.

Materials and Methods A total of six adolescent cats were used for BOLD fMRI (n=4) and CBV-weighted fMRI (n=4). Cats were anesthetized with 1% isoflurane and kept in a normal physiological condition. All MR experiments were carried out on a 9.4 T magnet with a custom-built 1.8-cm surface coil placed over the visual cortex. A single 1-mm thick coronal slice was chosen for fMRI studies from anatomical images, according to a stereotaxic atlas (2) (Fig 1). BOLD fMRI was performed with a single-shot gradient-echo EPI technique (TR = 500 ms, TE = 20 ms, FOV = 1.8x1.8 cm, matrix = 64x64). CBV-weighted contrast was achieved by administering a bolus of 10-20 mg/kg monocrystalline iron oxide nanoparticles (MION); imaging parameters were same as for BOLD studies except TE = 10 ms. Visual stimulation of 32-s duration consists of full-field moving gratings with spatial frequency of 0.2 cycle/degree and temporal frequency of 1, 2, and 10 Hz were pseudo-randomized. Before Fourier transformation, k-space data was zero-filled to 128x128 and a Hamming filter was applied. All runs with the same temporal frequency were averaged. Since a decrease in deoxyhemoglobin reduces CBV-weighted signal changes, correction to CBV-weighted fMRI data was made to remove BOLD contribution (3).

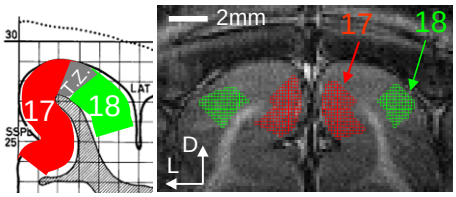

Fig 1. Areas 17 and 18 are overlaid on an altas illustration (2). ROIs defining these regions are then define on T1-weighted images

Results and Discussion In all fMRI studies, significant activation was observed in visual areas 17 and 18 (data not shown). According to previous electrophysiological data (1), in area 17, similar neuronal activity was observed for temporal frequencies of 1 and 2 H, while a smaller response was seen for 10 Hz; in area 18, similar neuronal activity for temporal frequencies of 2 and 10 Hz, while a smaller response for 1 Hz. To examine time-dependent hemodynamic responses, the temporal frequency tuning in areas 17 and 18 were calculated for BOLD and CBV responses during four 8-s time periods. Data for the first and last periods are shown in Fig. 2. Trends in frequency-dependent BOLD and CBV responses at later times may be more reflective of expected neuronal activity. This suggests that with sustained stimulation, later hemodynamic responses better reflect the temporal frequency selectivity of the visual system. This is consistent with the previous observation showing that the spatial specificity of CBV increases with time (4). However, this contradicts previous reports that an earlier hemodynamic response induced by a shorter stimulation is a good indicator of neural activity (5, 6). Thus, interpretation of time-dependent fMRI data as neural activity requires caution.

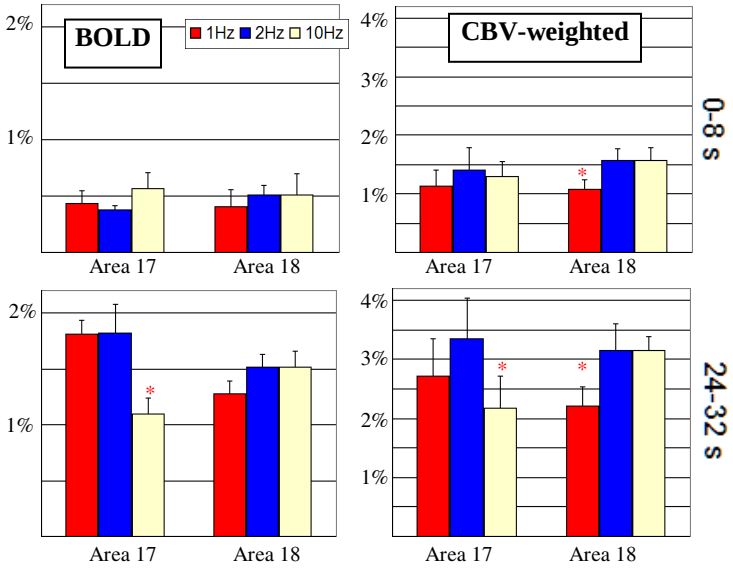

Fig 2. BOLD (left panels) and CBV-weighted (right panels) percentage changes are shown for initial 8 seconds of stimulus (top), and the final 8 seconds of stimulus (bottom) for areas 17 and18.Error bars represent standard error. * indicates significant different with $p<0.05$

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