Observation of the Initial "Dip" in fMRI Signal in Human Visual Cortex at 7 Tesla

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INTRODUCTION

Following intrinsic signal optical imaging studies (1), several MR studies (3-5) have reported an initial decrease in the fMRI signal at the onset of neural activity. These studies generated a great deal of interest because the initial "dip" is believed to arise from an increase in oxygen consumption that is more localized to the site of neuronal activation. However, attempts to map the early response, especially at low fields, are hindered by its low contrast and short duration. Theoretical and experimental considerations have suggested that the early response may increase with the field strength quadratically, and is thereby more readily detectable at high fields. In this study, the early response in the human visual cortex is investigated at 7 Tesla.

METHODS

Experiments were conducted on a 90-cm bore whole body 7 Tesla magnet interfaced with a Varian (Freemont, CA) console. Using a quadrature surface coil sensitive to the occipital cortex, a sagittal slice, 6 mm away from the midline, is selected. An IR prepared Turbo-FLASH sequence (matrix: 256×256, TI: 1.4 s, FOV: 20×20 cm^2, slice thickness: 5 mm) was used to obtain an anatomic image of the slice. For fMRI studies, a T2*-weighted EPI sequence (matrix: 64×64 matrix, FOV: 20×20cm^2, TR: 0.4 s, TE: 15 msec, slice thickness: 5mm, and an average flip angle of 30°) with half-Fourier acquisition was used. During the fMRI data acquisition, the subject's respiration and heartbeat were monitored for subsequent removal of physiological noise.

Four subjects participated in this study, with proper written consent and institutional approval. Two to 4 runs were performed in each subject and each run consisted of an initial baseline of 100 images and 4 epochs, each lasting 50 s. In each epoch, the visual stimulus (red LED goggles flashing at 8 Hz), synchronized with the scanner, was turned on for 4 s and off in the rest of the epoch.

The acquired fMRI data were preprocessed for removing physiological fluctuations. To detect pixels exhibiting the early response, the EPI image time series were correlated with a template depicting the early response as previously described (4, 5). Maps corresponding to the early response were detected by using a correlation coefficient threshold of 0.6 ($p<0.02$) and a spatial cluster size threshold of 4 (combined $p<0.00006$). For comparison, maps corresponding to the positive response were also generated using cross-correlation analysis (thresholded at 0.6). Upon map generation, the correlation models were also fitted to the time course of pixels exhibiting both responses to derive the corresponding amplitudes and their ratio.

RESULTS AND DISCUSSIONS

The dip was found to be statistically significant in all 4 subjects. As shown in Fig. 1 where the results from one subject are illustrated, the map corresponding to the dip is much more localized while that for the late response is more wide spread. This is consistent with results of previous studies (2-5). In agreement with studies at other field strengths (2-5) and optical studies, the dip starts right after the stimulus onset and attains a maximum at 2-3 s. This remarkable agreement indicates that the initial dip observed here has the same origin as that reported previously and is therefore likely due to an increase in oxygen consumption.

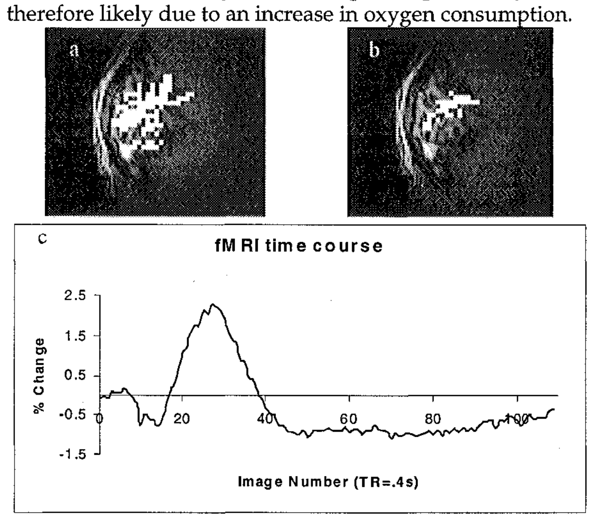

Fig. 1. Results from one subject showing the map corresponding to the positive response (a), the negative response map (b), and the time course for those pixels exhibited the negative response (c).

It is also interesting to note that the amplitude of dip is about 1/3 to 1/2 that of the late response. In fact, quantitative analysis shows that the ratio of early to late response amplitude averaged across subjects was 0.4. This ratio is significantly greatly than the corresponding values at 4 T (0.25; see ref. 3) and 1.5 T (0.1; see ref. 5). This observation confirms the notation that the early response increases with the field strength more rapidly than the late response, suggesting that the early response increases supralinearly with B0 while the late response goes up with B0 linearly. This in turn suggests that the early response arises more from microvascular contributions which are more localized. Of course, the spatial resolution in the present study is not sufficient to fully exploit such an increase in spatial specificity.

CONCLUSION

This study experimentally demonstrates an initial decrease in the fMRI signal at stimulus onset in the human visual cortex at 7 Tesla. The early response map is found to be more focal than that corresponding the late response. The early response detected at 7 T exhibited similar temporal characteristics as that seen at other field strengths and that revealed by optical imaging studies. In addition, the relative amplitude of the response is increased at 7 T, suggesting increased sensitivity for early response mapping, which will permit future high spatial resolution studies in humans to take advantage of the higher spatial specificity.

References

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