The Effects of Stimulus Duration upon Visual Cortical Activation: Evidence from Functional MRI and Intracranial ERPs


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INTRODUCTION

The problem of integrating imaging techniques

The problem of integrating imaging techniques (fMRI and intracranial ERP) is to understand how hemodynamic measures of brain activity, such as that measured by functional magnetic resonance imaging (fMRI), relate to underlying neuronal activity. Combining hemodynamic and electrophysiological techniques poses several challenges. First, hemodynamic measures of brain activity change over seconds, while electrophysiological measures have millisecond-level resolution. Event-related potentials (ERPs) recorded in visual cortex, for example, consist of transient responses within 100-200ms of stimulus onset, well before any measurable (fMRI) activity. Second, volume-conducted makes it difficult to isolate the source of ERP activity using scalp recordings. Thus, even though both fMRI and ERP measures are related to neural activity indirectly, establishing a robust mapping between these measures remains an unsolved problem.

The Effects of Stimulus Duration on Brain Activity

The fMRI hemodynamic response (HDR) increases in amplitude non-linearly with increasing stimulus duration (2-17 seconds). Asynchrony in stimulus duration has large effects on the fMRI HDR, but do not affect early ERP components. Changes in stimulus duration have large effects on the fMRI HDR, but do not affect early ERP components.

1 Experimental Design

- Stimuli: Static radial checkerboards
- Stimuli: Static checkerboards presented singly at fixation in random order
- Subjects: 7 patients under investigation for epilepsy surgery
- Subjects: 12 young adults

2 Methods & Analysis

Functional MRI: Duke BIAC

- Subjects: 12 young adults
- Adolescent: 32-week gestation, 345 days postconception
- Imaging: 4T GE scanner
- Analysis: t-values for each voxel vs. baseline

Intracranial ERP: Yale Epilepsy Clinic

- Subjects: 7 patients under investigation for epilepsy surgery
- Stimuli: Static checkerboards presented singly at fixation in random order
- Subjects: 12 young adults
- Analysis: t-values for each electrode vs. baseline

3 Functional MRI

Results

- Calcarine cortex: HDR increases with increasing stimulus duration.
- Fusiform gyrus: HDR increases with increasing stimulus duration.
- Lateral occipital cortex: HDR similar across stimulus durations.

4 Intracranial ERP

Lat. Occip./Par. (V5)

- Significant onset potentials
- No offset potentials or sustained activity

Calcarine Sulcus

- Significant onset potentials
- No sustained activity

Fusiform Gyrus

- Significant onset potentials
- No offset potentials or sustained activity

5 Hemodynamic Response

Convolution with Stimulus Duration

- Overestimates the HDR

Parameterizing the HDR

- The fMRI hemodynamic response was parameterized using the above equation (modified from Glover, 1998).
- To derive the equation representing each curve, we first fit parameters \( t_1 \) and \( t_2 \) (initial response), and then fit the remaining parameters.

6 Estimated Neural Activity

Modeling Neural Activity

- Each parameterized response was modeled as the convolution of an impulse response function with a series of filters representing neural activity.
- To derive the equation representing each curve, we first fit parameters \( t_1 \) and \( t_2 \) (initial response), and then fit the remaining parameters.
- Duration-related activity was found in the Calcarine and Fusiform, but not in V5.

CONCLUSIONS

- Changes in stimulus duration have large effects on the fMRI HDR, but do not affect early ERP components.
- Naive boxcar convolution overestimates hemodynamic response at short stimulus durations.
- Variation in the amplitude of the fMRI HDR can occur in the absence of variation in early ERP components.
- Variation in the ERP waveform can occur in the absence of variation in the fMRI hemodynamic response.