

Temporal Shift Sensitivity of Event Related fMRI

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Introduction

This work examines the sensitivity of event-related fMRI analysis to discrepancies between the onset times of the events in the model and the actual onset times of the events in the data. This knowledge can be useful to determine the ability to resolve closely spaced events in the experiment, or to determine the tolerance to errors in the paradigm that can arise from lack of control of the timing between the scanner and the stimulus presentation equipment. Such errors can also be caused by lack of knowledge of the timing of underlying events.

The limitation of fMRI to resolve neuronal events arises mainly from the slow hemodynamic response function (HRF) observed by fMRI. The sampling rate of the MRI scanner is also quite limited (it usually takes about two seconds to sample the whole brain), but, since the response function is so slow and smooth (up to 10 seconds in duration), the sampling rate is still adequate under the Nyquist sampling theorem.

Here, we examine the temporal sensitivity within the framework of the General Linear Model approach to functional imaging data analysis. We examine the effects of the experimental parameters, and the errors associated with them, on the time sensitivity of the analysis. The parameters include inter-trial-interval, choice of HRF parameters, and the number of trials completed.

Methods

In the simplest case, the analysis of a time series is equivalent to the computation of the correlation coefficient between data and model. As a first approximation, we derived an analytical equation for the correlation coefficient between the model and the data as a function of noise and time shift discrepancy. The correlation coefficient is given by

$$\rho_{xy} = \frac{(E[B(t)B(t-T)] - \bar{B}^2)}{(\sigma_b^2 \cdot \sqrt{\sigma_e^2 + \sigma_b^2})} \quad \text{eq.1}$$

Where B(t) is the BOLD response to a set of stimuli, T is the time shift between the data and the model, σ_b^2 is the variance of the response function, and σ_e^2 is the variance of the noise. The T- scores can then be readily computed from the correlation coefficient.

Note that the term $E[B(t)B(t-T)]$ in the equation is the definition of the autocorrelation function of B(t). These equations were used to explore the influence of the choice of ITI, and of the underlying HRF on the temporal sensitivity of the analysis. The sensitivity of the analysis to time shifts was measured as the rate of change of the t score of the analysis with respect to the temporal shift the model (dt / dT).

We then simulated a set of event-related experiments (600 images, sampled every second, ITI = 16sec.) in order to explore the effects of different kinds of errors in the hypothesized model. The data were simulated by convolving a train of spikes (representing neuronal events) with a canonical HRF, and adding a noise vector to it. The HRF was one described previously as a gamma variate function(1). The errors explored include errors in the model's HRF parameter t, and errors in the measurement of the events' onset times. Additionally, we examined both the cases where events were missing from the data due to subject non-compliance, and where additional, un-modeled events were present in the data. The effect of the amount of noise present in the data on these errors was also explored.

The sensitivity to time-shifts in experimental data was examined by reanalyzing fMRI data from a simple visual stimulation paradigm (600

secs, sampled every 1 sec., ITI = 16sec.), and introducing some of the above errors into the analysis model.

Results

The sensitivity to time shifts in the acquired data, and in the simulated data were in excellent agreement. The effects of different errors are discussed in the following section.

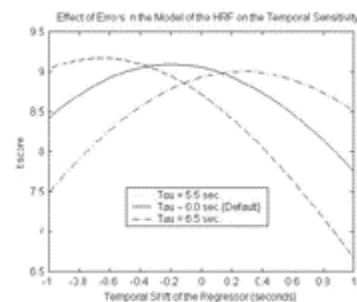


Fig. 1

Figure - Effects of the temporal shift of the model of a visual stimulation paradigm on the t-score of the measurement. The Analysis was repeated using different HRF's in the model to illustrate the effect of errors in the measurement of the HRF.

Discussion

- As the noise increases, the sensitivity to time-shifts decreases and the ability to determine the specific event time is degraded.
- If there is a mismatch between the model's canonical HRF and the subject's HRF, we observe that the t scores peak when the model is temporally shifted. In the case where the modeled HRF is "faster" than the real one, one would predict that the events happen at an earlier time than they actually do (see figure)
- The sensitivity also depends on the ITI, peaking at an ITI of approximately 16 sec.
- Sharper HRFs (characterized by shorter HRF constants) provide a more temporally sensitive analysis. However, the sensitivity within the physiological range of constants does not show significant change.
- When there is a non-uniform uncertainty in the data's onset times, the power of the analysis is reduced, but the time-shift sensitivity is not significantly affected.
- When there is a mismatch in the number or neuronal events between the model and the data, the result is a loss of power of the test (reduced t-scores), but the sensitivity to time shifts is not significantly affected.

References

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