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METHODS - ANALYSIS

Optimal Stimulus Sequence Design for Event-Related fMRI

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The design of stimulus sequences to optimize the efficiency of the statistics has emerged recently an attractive problem in event-related fMRI experiments [Friston, 1999]. For evenly spaced stimuli, it has been demonstrated that using a fixed inter-stimulus interval (ISI) of at least 15s is optimal for estimation of the hemodynamic responses [Cox, 1998]. Nevertheless, some other studies have been argued that using much short ISIs can still remain considerable efficiency [Wagner, 1998]. A sensitive explanation for this is that efficiency critically depends on the distribution of ISIs [Dale, 1999]. An attempt on randomizing the stimulus sequence has also been made by Dumoulin and colleagues to find the optimal mean ISI when deriving the hemodynamic response [Dumoulin, 1999]. In the simulated data the efficiency continued to increase with decreasing mean ISI, whereas in the real fMRI data no significance on mean ISI is observed since there is a plenty of choices for each mean ISI and a realization of the random sequence is hardly to be optimal. In this note, the design of optimal stimulus sequences for estimating hemodynamic response is investigated theoretically. Simulations have also been presented.

Methods:

Consider LSI model of fMRI with white noise: y=Xh+e, where X is the design matrix only dependent on the stimulus sequence, h is the hemodynamic response vector, e is of N(0,sigma). The least square estimate is h∧=inv(X'X)X'y, the convariance matrix is cov(h∧)=sigma*inv(X'X), the estimation accurracy is measured by J=trace cov(h∧).

Results and discussions:

It has been proved theretically that the optimal stimulus sequence has impulse auto-correlations, and the accuracy compared with that of the fixed ISI design are:

$$J(\text{optimal}):J(\text{fixed\_ISI}) \leq 4:n$$

where n is the number of parameters. Therefore, it is clear that the precision of optimal variable ISI design is as 4/n times as that of fixed ISI design. That is, for optimal variable ISI design in event-related fMRI, less than 4/n as much time is needed to achieve the same estimate precision as in the case of fixed ISI design. The realization of optimal stimulus sequences can be designed from pseudorandom binary sequences such as m-sequences or the pseudorandom integer (binary) strings [Hu, 2000].To test the theoretical results, simulations have been done with the hemodynamic response given by [Cohen, 1997], the simulated fMRI data length is 150s, with TR=1s, n=15, sigma=1. The optimal stimulus sequence is designed by m-sequences (a period 127 plus 23 repeated presentation); For comparation, 10 fixed ISI=n=15 trials are also presented to the model. 10,000 runs have been done for each paradigm and the averaged results is

$$J(\text{optimal}):J(\text{fixed\_ISI}) = 0.3827:1.4986$$

Thus, the efficency of optimal stimulus design is much higher.

References:

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