Reduction Of Noise Associated With Stimulus Correlated Motion In Event Related Overt Word Production fMRI Studies

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Introduction

The effect of motion on fMRI time series is not trivial. Artifacts can be caused both by misregistration or misinterpolation and effects of spin history. One way of reducing the noise due to motion in the fMRI time series would be to use the estimated motion parameters from the image registration algorithm and detrend the vector from the fMRI time series. Another method could be to use the parameters of the motion vector along with the stimulus as different inputs to a linear system and use multiple linear regression to evaluate the activation due to the stimulus. Unfortunately the above methods are encumbered with assumptions which may not be justified in practical applications. For instance, in order for the above mentioned methods to work well, it is imperative that there be a linear relationship between the estimated motion parameters and the noise associated with them in the fMRI time series. We have found this not to be the case in our studies.

Overt word production in fMRI involves both random and stimulus correlated motion (SCM), associated with the task of speaking. SCM has been shown in prior studies [1], to produce spurious activation as well as to mask real activation. We have endeavoured to estimate the signal change due to SCM with the aim of detrending the SCM related signal change from the fMRI time series. The impulse response function (IRF) to SCM is evaluated with a paradigm independent method of analysis.

The fMRI signal in a voxel can be expressed in terms of a convolution of the stimulus function with the impulse response function associated with the stimulus, $y(t)= S(t)\otimes H(t) + \varepsilon(t)$, where $S(t)$ is the stimulus time series and $H(t)$ is the IRF, $\varepsilon(t)$ is the gaussian noise and $y(t)$ is the signal at a given voxel. Thus knowing the signal time series and the stimulus vector, one can estimate the IRF by the deconvolution of $y(t)$ and $S(t)$. The above analysis is very general and the IRF associated with the stimulus correlated motion can estimated along with the IRF for cortical activation. For an event related overt word production paradigm we and others [1] have found that the signal changes associated with the SCM are resolvable from the signal changes due to cortical activation. Hence the fMRI time series can be orthogonalized with respect to the SCM time series which is obtained by convolving the SCM related IRF with the stimulus vector. After re-analyzing the detrended fMRI time series we find that the functional activation map is much cleaner than that which is obtained without the orthogonalization.

Methods

Fifteen normal control subjects performed a word generation task. Task: Subjects were asked to generate words to category cues overtly. The inter-stimulus interval between category cues was assigned to be 14, 17.5 or 21 sec in a pseudo-random manner. For some subjects the stimulus was presented just after the monitored response of the subject to the previous category cue.

Image Acquisition Images were obtained using a 1.5T GE Signa with a 2-spiral gradient echo scan with 10 contiguous sagittal or coronal 5.0 mm thick slices of the medial frontal cortex, 180 mm FOV, 128 x 128 matrix, TR/TE/FA = 875ms/40ms/50deg. Four functional runs were acquired with 150 images in each run, 1.75 sec per image.

Image Analysis The four functional runs were concatenated to obtain a 600-image fMRI time series. The hemodynamic (impulse) response was obtained at each voxel by deconvolving the fMRI time series with the the stimulus time series. The estimated response function (IRF) was then convolved with the stimulus vector to obtain a fitted signal time series. An F-test was performed to determine the goodness of fit of the fitted time series to the observed fMRI time series. The coefficient of determination, R^2, was also evaluated to quantify the activation. To estimate the functional signal due to stimulus correlated motion the IRF at activated voxels (at a comparable level to cortical activation) near boundaries of high contrast in the head was averaged [1]. The estimated IRF due to SCM was then convolved with the stimulus vector to obtain a SCM time series to yield the SCM vector. The fMRI time series was then orthogonalized with repect to the SCM vector. Deconvolution analysis was performed on the detrended fMRI time series to examine the efficacy of the SCM noise reduction method. Analysis was performed with the help of AFNI software [2].

Results and Discussion

Figure 1 shows the activation maps obtained with and without SCM noise reduction. Figure 2 shows the estimated IRF due to SCM for a representative subject. It can be seen that the method of SCM noise reduction is effective. We have observed that the IRF to SCM and hence the SCM signal change in overt word production follows similar patterns in all subjects studied and the resulting functional overlay map after detrending shows a marked improvement over the activation map obtained without noise reduction. However some subjects show some unique individual patterns of SCM, apart from the similar patterns of the SCM, which should be detrended to obtain a cleaner activation map. Thus from our studies we observe that it would be advantageous to treat the subjects individually while detrending for SCM. This analysis has promise of clinical application in testing stroke patients (such as aphasics) with overt word production tasks. It has been suggested that a block paradigm would be more appropriate for overt word production in these patients whose responses are often delayed and unpredictable. It must be noted that the above method of detrending does not work well with block paradigms, as the SCM signal changes occur coincident with the cortical activation related signal evolution. However we have observed that by using knowledge about the SCM responses, voxels that exhibit significant SCM can be masked even in block paradigms.

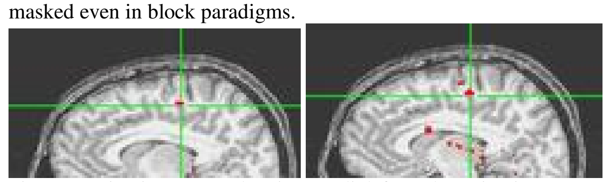


Fig. 1. Activation maps showing medial frontal activation to word generation: (left) after detrending for SCM ; (right) without SCM noise reduction for one subject.

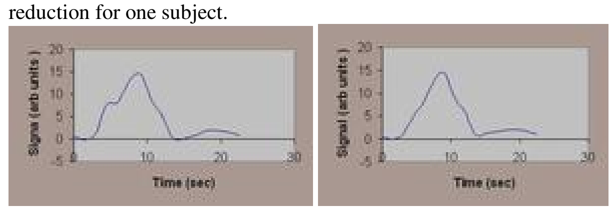
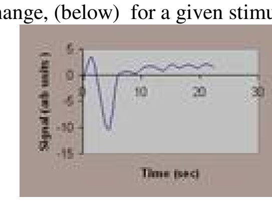


Fig. 2. The estimated cortical activation related signal change, before detrending (above left) and after detrending (above right) for the voxels centered around the x-hair in Fig 1 and the estimated SCM related signal change, (below) for a given stimulus cue.



References

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