Comparing sensitivities of head coils in fMRI using ROC methods with real data

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Introduction

The most important step in any fMRI study is the actual acquisition of fMRI data, which primarily depends on the actual MRI scanner and the head coil used for the acquisition. Usually the investigator has the option of choosing a head coil for the acquisition of fMRI data. Hence, the optimal choice of the head coil for a particular study may play a significant role in the success of the study. Hence it is immensely beneficial to have a quantitative method to actually compare the available coils for a particular task of interest. Although it is possible to directly measure the signal-to-noise ratio (SNR) for a particular head coil, it may not directly reflect upon the sensitivity of the coil in detecting activation for a specific fMRI paradigm. The best way to make a comparative assessment of the sensitivities of competing coils in detecting activation is to use actual fMRI activation data acquired using the respective coils. One possible way to make such a comparison is the use of Receiver Operating Characteristic (ROC) based methods [1]. Unfortunately, conventional ROC methods require the knowledge of the actual locations of the active voxels, which is not available for fMRI data. ROC methods based on simulated data is not applicable in the present context. However, a novel ROC method using real fMRI data has been introduced recently which can be used in comparing coil performances [2]. The method is described below.

Methods

By definition, an ROC curve is a plot of True Positive Fractions (TPF) against False Positive Fractions (FPF) for all possible values of the test statistic used in the analysis. TPF cannot be estimated with sufficient accuracy from real fMRI data as we do not know which of the voxels among the detected voxels are truly active. However, it is possible to estimate FPF from real resting state fMRI data. If the subject from whom the fMRI data is acquired refrains from any active task, it is reasonable to assume the data to be pure noise with respect to the specific stimuli we are interested in. In such a case, all the voxels can be assumed to be inactive and FPF can be estimated for different values of the test statistic. However we already mentioned the difficulty in estimating TPF. Therefore instead of trying to estimate TPF, we estimate the fraction of all voxels detected to be active for different values of the test statistic. Clearly this includes both active and inactive voxels. Then it is possible to obtain a modified ROC curve using real data by using the fraction of detected voxels instead of TPF. At a given threshold for the value of the test statistic, active voxels are detected from the two collections and are respectively called Active Positives and Resting Positives as opposed to True and False Positives. We calculate the fraction of Active Positives (FAP) and the fraction of Resting Positives (FRP) and then plot the modified ROC curve. For the ROC method, we need two sets of fMRI data obtained with identical scanner protocol, where the first set is pure resting-state data (the subject refrains from any active task) and the second set is the activation-state data. We analyze both datasets using the same set of basis functions and plot the fraction of active positives (FAP) against the fraction of resting positives (FRP) for different thresholds to plot a modified ROC curve. It is possible to reconstruct conventional ROC curves from the modified ROC curves [2].

This method can be easily applied to compare competing set of head coils. For each head coil, we run our analysis on the resting-state data as well as the activation data and then plot the corresponding ROC curve. For a fair comparison, an identical paradigm and scanner protocol should be used (whenever possible) for each of the head coils. Once all the curves are plotted, we can compare the curves to choose the optimal head coil. Since in fMRI, we are mostly concerned with thresholds at which FPFs are small, it may be more meaningful to plot restricted ROC curves for smaller values of FPF as opposed to the entire ROC curves running from (0,0) to (1,1).

Results

As an example, we have compared the performances of a commercial GE 1.5T Signa quadrature head coil and a custom head coil developed in our lab known as CMOHR (Capacitively Mirrored Open-faced High Resolution) head coil [3]. For both the coils, we used a standard periodic visual activation paradigm (30 sec flashing checkerboard and 30 sec fixation running for 5 periods) acquired with identical scanner parameters (FOV 24 cm x 24 cm, BW +/- 62.5 KHz, TR 2 sec, Flip 82 deg, slice thickness 6 mm/skip 1 mm, 64x64 resolution, whole brain axial acquisition). Resting-state data with identical scanner protocol were also acquired. In Figure 1 (left), we have plotted the modified ROC curves for the two coils by using a t-contrast for the single activation condition. We have restricted the curves to values of FRP less than 0.002 for a better comparison, since the activation maps in fMRI always are produced using thresholds corresponding to very small values of FRP. Note that the line "y=x" corresponds to pure guessing and both curves are well above this line. The CMOHR head coil appears to perform much better than the GE coil. It is also possible to make a direct comparison of activation positives for the two coils without using resting-state data. In Figure 1 (right), we plot fraction of CMOHR positives (FCP) against fraction of GE positives (FGP). Here the line "y=x" corresponds to the curve where both coils perform equally. As expected, CMOHR outperforms GE.

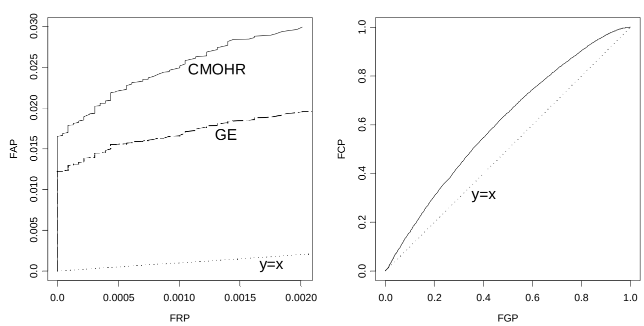

Figure 1. Modified ROC curves for the GE and CMOHR head coils. The line "y=x" corresponds to pure guess.

Discussion

The result presented here is only a preliminary one. For a more accurate comparison it will be necessary to acquire a large number of datasets to reduce or eliminate the variability involved in the acquisition process itself. However, the preliminary result is consistent with our expectation since from direct measurement of echo-planar images, the CMOHR coil has an increased SNR of about 32% compared to the GE coil. Also, the CMOHR coil is designed to be most sensitive at the cortical surface of the brain and hence it is no surprise that CMOHR performs better for cortical visual activation. The result may be different for sub-cortical activation, but it is difficult to compare sub-cortical activations using the two coils, since it is difficult to produce robust activation at the sub-cortical regions of the brain. Finally, the proposed method using modified ROC curves can easily be extended further to compare performances of different scanners for a specific paradigm.

References

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