Multivariate discrimination in natural and urban scene viewing

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INTRODUCTION

The discrimination of visual scenes is a complex task that the human mind can achieve rapidly. Using biofeedback techniques we may be able to decode neural responses to visual scenes in a real-time manner. Multivariate pattern classification and prediction offers an alternative approach to standard univariate analysis techniques, and has recently been applied in MR imaging using support vector machines (SVM) [1], and to improve real-time imaging [2]. Previous work [3] has investigated scene identification using MVPA, but required large numbers of training examples. This study applied SVM techniques to predict the viewing of natural and urban scenes, and to calculate prediction accuracy based on the number of training examples as a first step towards real-time biofeedback.

METHODS

MRI Data acquisition: BOLD functional images were acquired on a 3.0 Tesla GE Signa scanner (Milwaukee, Wisconsin) using T2*-weighted single-shot custom reverse spiral sequence with the following parameters: TR/TE/FA/FOV = 2000 ms/30 msec/90°/220 mm, 64 x 64 matrix size; in-plane resolution of 3.44mm x 3.44 mm, 40 oblique axial slices in line with AC-PC, thickness = 3 mm. Participants' motion was minimized using foam pads placed around the head along with a forehead strap and motion parameters were entered as covariates in the design matrix. A rear-projection display with an MR-compatible button-response pad was employed.

FMRI Task: 18 healthy participants were scanned in this study. Each participant was shown 3 photographs of a particular type (nature images or urban images) and rated each photograph on a scale of 1 to 3 for how much they liked the photograph (1 = did not like it, 2 = neutral, 3 = liked it). Each image was presented for 5 seconds, for a total of 15 seconds. After each set of images there was 15 seconds of fixation. There were 10 interleaved image blocks and fixation blocks within each type of picture viewing (nature or urban). The order of presentation of the nature/urban blocks was counterbalanced across participants (i.e., first ten nature blocks, then ten urban blocks, or vice versa). FMRI data were pre-processed and analyzed using SPM5. Preprocessing steps included head motion correction, spatial normalization, and spatial smoothing (8 mm).

SVM analysis: SVM training and testing were done using the 3dsvm package [1] in AFNI [4]. Labels corresponding to natural or urban pictures were generated for each run, with fixation blocks ignored during SVM training. The nominal labels were then delayed by eight seconds to account for hemodynamic delay. Training was then done using a linear classifier, with data masked to include only those voxels within the brain. Leave-one out cross validation was done on the block level; for each permutation, training was done on nine blocks of the natural scenes, and nine blocks of the urban scenes. Testing was then done on the omitted blocks, and all permutations (n=100) were calculated. Additionally, one permutation of removing 2-9 blocks of each picture type was calculated for each participant to investigate the amount of data needed for proper classification.

RESULTS AND DISCUSSION

Cross validation leaving one block left out from both nature and urban yielded an accuracy of 94(±13)% across all participants and block permutations. Accuracy was reduced when either the first or last block of a particular picture class was excluded from training (Fig. 1), likely reflecting the uniqueness of transition blocks. When examining the effect of excluding a greater number of blocks, high classification accuracy is maintained even when excluding seven blocks of each picture type in the training step (Fig. 2). It should be noted that block 10 was the last to be excluded, and block 1 was included in all training, based on the single-block exclusion results.

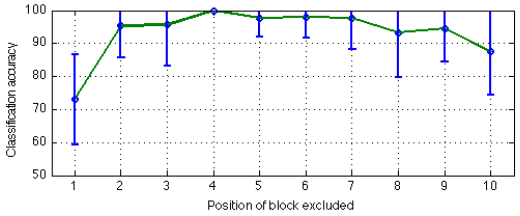

Figure 1. Classification accuracy vs. position of single image block excluded in both nature and urban viewing, averaged over all participants.

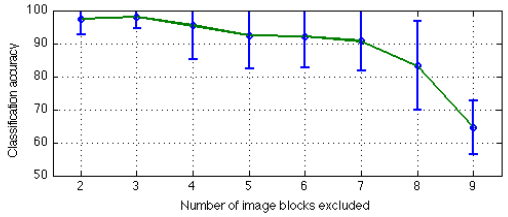

Figure 2. Accuracy vs. number of image blocks excluded for each picture type, averaged over all participants.

CONCLUSION

Multivariate analysis was successful in distinguishing between natural and urban scene viewing with a minimal amount of data. In addition, the multivariate approach allows easy identification of unique trials. These features will form the basis for future biofeedback investigations using scene viewing. In addition, research has shown that viewing nature pictures has a restorative psychological effect [5], and these multivariate techniques may be implemented in a biofeedback context to serve to improve the psychological benefits attained from nature picture viewing.

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