Distributed Pattern of BOLD fMRI: Neuronal Activity or Hemodynamic Artifact

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Introduction

Multi-voxel pattern analysis (MVPA) methods aim at determining how mental representations map onto patterns of neural activity and constitute a useful new tool for a better understanding of neural coding and information processing[1]. Although distinct brain patterns consist of voxels are widely studied to classify recognizing specific object categories[2], the signal characteristic of the generated patterns on the human ventral stream remains elusive. Ultra-high field MRI enables imaging at higher spatial resolution and improved localization, thereby potentially leading to improved discrimination between different neuronal patterns. The goal of the presented study is to determine whether distributed patterns of BOLD fMRI are more discriminative at 7Tesla than at 3Tesla.

Methods

BOLD activation patterns were measured in three healthy volunteers (two female and one male) with a gradient echo echoplanar imaging sequence on a 3T and a 7T Philips Achieva whole-body MRI scanners (Philips healthcare, Best, The Netherlands) with similar protocols (TR=2500ms, 36 2.5-mm-thick transverse images, FOV=23cm, acquisition voxel size=2.0x2.0mm^2, TE=30ms, flip angle=85° at 3T; TR=2500ms, 38 2.5-mm-thick transverse images, FOV=21cm, acquisition voxel size=2.0x2.0 mm^2, TE=17ms, flip angle=80° at 7T).

The stimuli were gray-scale images (angle coverage ~2.9-16.7 degrees) of the following eight categories: faces[3], houses, cats, bottles, scissors, shoes, chairs, and nonsense images. The control nonsense patterns were phase-scrambled images of the other category images. Six time series were obtained in each subject on both 3T and 7T MRI. Each time series began and ended with 15s of rest and included eight stimulus blocks of 30-s duration. Each block was separated by 15-s intervals of rest. Stimuli were presented for 500ms with a 2-s interstimulus interval. Four different views of each object were included and the subjects were asked to perform a one-back repetition detection task.

In order to identify object selective BOLD regions or patterns, a 22-regressor model was used. The data was split into two (odd and even runs) and the first eight regressors modeled the response to each category for the odd run, whereas eight other regressors modeled the response for the even run. The other six regressors were included to remove the mean signal change for each run. The beta weights for the 16 regressors modeling each response, were used as an estimate of the strength of the activation. Volumes of interest (VOI) for the ventral temporal cortex consisting of the fusiform and inferior temporal gyri were obtained from automatic anatomical labeling (AAL) tool. Voxels within these VOIs that were significantly object-selective ($P<10^{-6}$) were considered, and two different voxel sets based on 7T or 3T object-selective regions were used in the analysis. The beta weights of selected voxels were considered to be patterns of MVPA. Within-category and between-category correlations were used to identify object selective patterns.

Results

The patterns of beta weights in the VOI responding to faces or houses at 7T and 3T are shown in **Figure 1. (b)** and **(c)**, respectively. The locations of the patterns in a single subject are shown on the normalized anatomical images. The top four patterns were measured on odd-numbered runs while the bottom four patterns were measured on even-numbered runs. The within-category correlations (red) and the between-category correlations (blue) between patterns at 7T and 3T are shown in **Figure 1. (a)** and **(d)**, respectively. Each row indicates one of object categories on even-numbered runs, and each column represents odd-numbered runs. The mean within-category correlations were 90.6±3.2% larger at 7T and 65.6±3.2% larger at 3T than the mean between-category correlations across two different VOIs based on 7T and 3T object-selective regions.

Discussion

The distributed patterns of 7T BOLD fMRI were better to distinguish each object category than patterns of 3T. Two different effects could explain the improved discrimination at 7T: first of all, the BOLD-response results in a larger signal change at a higher field strength, thereby improving SNR; secondly, it has been hypothesized that the BOLD signal at 7Tesla is located closer to the neuronal activation side than at 3T, because it is mainly caused by extravascualr signal. In the current study we kept the spatial resolution of the BOLD-scan equal on both field strengths to provide a fair comparison, but it could be anticipated that the discrimination at 7Tesla might be further improved by scanning at a higher spatial resolution. Because of the improved discrimination at ultra-high field MRI, this might constitute the favorable field strength for MVPA methods to achieve a better understanding of neural coding and information processing[1].

References

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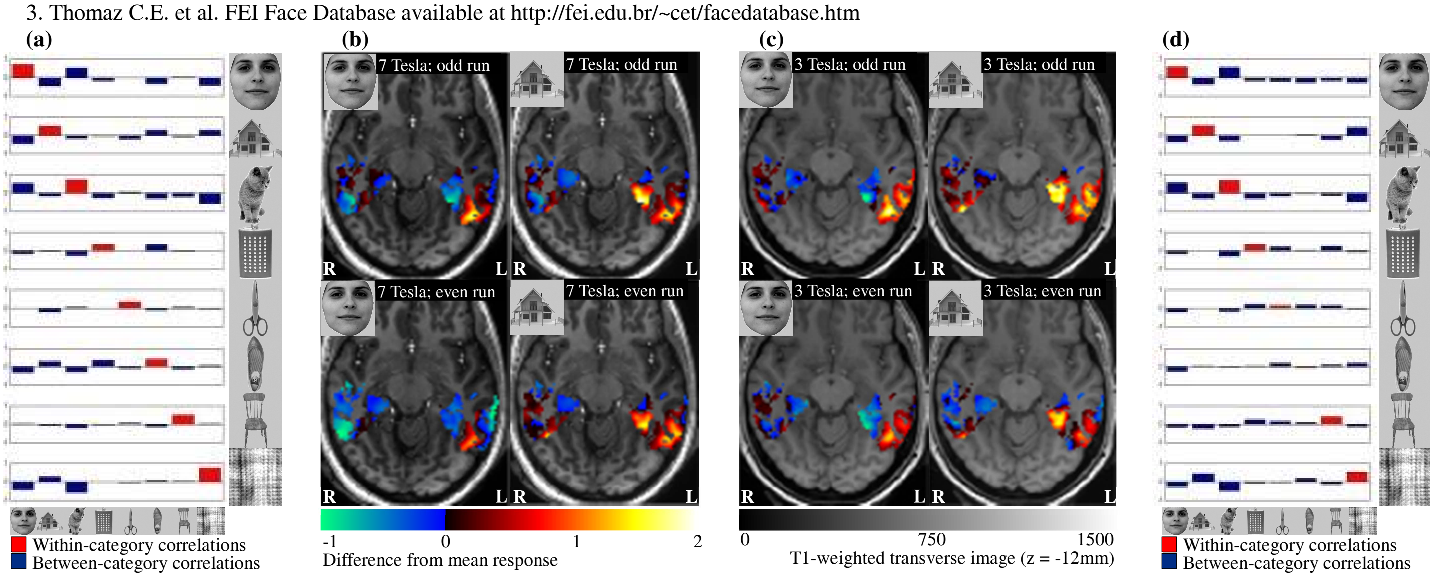

Figure 1. (a) Within-category and between-category correlations between patterns of response at 7T. **(b)** The patterns of response to face or house at 7T. **(c)** The patterns of response to face or house at 3T. **(d)** Within-category and between-category correlations between patterns of response at 3T.