Single trial classification of complex hand movements using high field fMRI

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Introduction

An essential aspect of building brain computer interfaces (BCI) is the identification and classification of brain states. The underlying assumption is that every behavior leads to a specific and unique pattern of neuronal activation, and that this pattern can be identified on a single trial basis. Here we examine whether complex hand gestures as used in sign languages show sufficiently discriminable patterns of neuronal activation to be used as control signals for a BCI.
It is known that hands and individual fingers are topographically mapped on the motor and the sensory areas [1]. It has be shown that the movements of individual fingers can be discriminated and predicted using single cell recordings and population activity as measured by electrocorticography. Here we study in a group of healthy volunteers whether complex hand gestures can be differentiated on a single trial level using high field (7 tesla) fMRI.

Materials and Methods

Task: Participants had to execute four hand gestures taken from the American Sign Language. This was done using a rapid event related design (used as training set), and a slow event related design (used as test set). The rapid event related task consisted of 256 trials (32 trials for each of the 4 movements and 128 rest trials with a variable inter -trial interval (2.6 sec – 18.2 sec). The stimuli were ordered according to an interleaved m-sequence. All participants saw the same stimuli sequence. The slow event related design consisted of 40 trials (10 for each movement) with an inter-stimulus interval of 13 sec, which assured that the effects of the previous trial were washed out. Each stimulus was presented for 500 msec. During the inter-trial interval a fixation cross was shown. The actual hand movements were recorded with a data glove.
Data acquisition: Two participants were scanned on a Philips 7T system with a 32-channel headcoil with the following scan parameters: single-shot EPI (TR/TE=1300/27 ms; FA=70; 21 slices, slice thickness 1.5 mm, no gap, FOV 168 mm by 168 mm, in-plane resolution 1.5 mm). The volume covers the pre- and postcentral gyrus of the left hemisphere (contralateral to the moving hand) .
Data analysis: The data were slice time corrected and the individual scans were realigned to a reference scan to reduce motion artifacts. Data were detrended to eliminate slow signal drifts. The rapid event related task was analysed using a standard FIR analysis. This provided an estimate of the average BOLD response of every voxel for the four gesture types. For each movement (M1 to M4) we created activity maps (versus rest). For the individual maps the 300 most active voxels were selected and were grouped to form a mask of relevant voxels. For those voxels the height of the BOLD response 6 scans after stimulus onset was selected. These activity voxels then form four template vectors representing M1 to M4. The slow event related data were epoched; for each epoch the BOLD response 6 scans after stimulus onset for the voxels within the mask form the single trial representation. The classification was done using a matched filter approach. The single trial representation was correlated to the four templates. Using a 'winner takes it all' classification the trial was classified as the gestures type it had the highest correlation value with. Trials that were executed incorrectly by the participant were excluded from the analysis.

Results

The single subject analysis showed a classification accuracy of above 80% correct when participants executed the gestures accurately (fig 1, chance level is 25%). The best classification accuracy was achieved using less than 300 voxels. The areas that are most informative for the classification are the hand knob area on M1 and the adjacent sensory areas on the postcentral gyrus (fig 2).

Discussion

Our results reveal that the classification of complex hand movements (gestures) is possible with high field fMRI. A simple matched filter approach was sufficient for 'close to perfect' classification. This shows that different gestures exhibit highly stable, characteristic spatial representations. The information used for classification is confined to small areas on the posterior part of the the pre-central gyrus and the anterior part of the post-central gyrus.
We conclude that hand gestures are potentially interesting as BCI control signal. The identified regions can be targeted with high density electrode grids implanted subdurally, given that BOLD correlates with power in the high gamma frequency range [3].
As a next step we will attempt to classify also imagined and observed hand gestures.

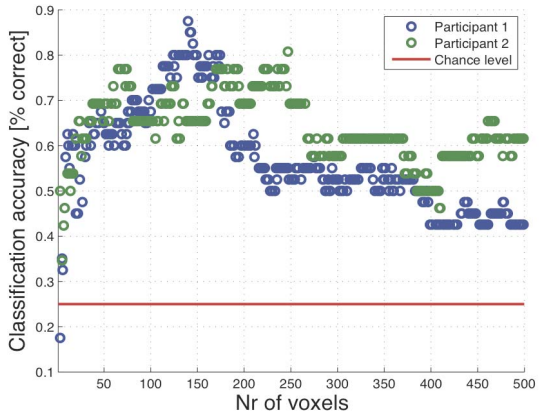

Figure 1: Classification accuracy (percentage correct) in relation to the number of voxels used for classification shown for two individual participants. Chance level for four classes is 25%.

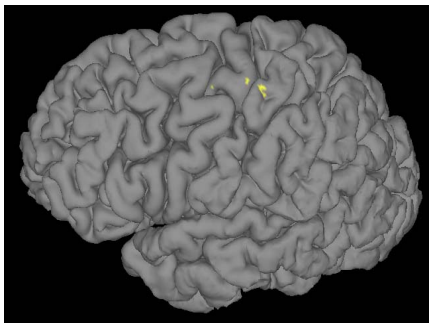

Figure 2: Reconstruction of the cortical surface of one of the participants. Voxels used for classification are shown in yellow. Informative voxels are primarily located on the posterior part of the precentral gyrus and the anterior part of the postcentral gyrus at the location of the hand knob.

References
[1] Sanchez-Panchuelo, et al, J Neurophysiol 2010
[2] Yousry, et al, Brain 1997
[3] Hermes, et al, Hum Brain Mapp, 2011

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