Decoding and reconstructing movement direction using fMRI

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Recent invasive brain-machine interface (BMI) studies demonstrated that people with tetraplegia could successfully control a robotic arm by imaging reach and grasp movement. In order to avoid the invasiveness of electrophysiological recording, we used neuroimaging approach based on fMRI to demonstrate the feasibility of driving robotic arm noninvasively. Five healthy subjects (age 24–41) participated in the study. Each participant performed a center-out reaching task (moving a cursor from a center to one of eight equidistant targets), and completed two consecutive runs. Each run lasted 27.1 min and contained 135 trials, 15 in each direction and no movement. Arm movements were recorded with an MR compatible touch panel (KTT-120LAM-USB, USA). Each trial lasted 6 sec. The targets were located in eight different directions between 0° and 315°, 45° apart. When the target appeared in the screen, participants moved the cursor toward the target during 2 sec. After reaching the target, the movement was fixed at the target for 2 sec. Then, the participants were instructed to move the arm to its starting position at the center. The BOLD fMRI measurement were performed in a Siemens 3T MRI scanner with the following parameters: TR = 1s, TE = 20ms, voxel size = 3×3×5 mm³. fMRI data were preprocessed using standard procedures using SPM8 and custom-written MATLAB software. The region of interest (ROIs) was individually defined for each participant using general linear model. The parietal reach region (PRR) showed higher activation during movement to target than during rest. Previous studies showed evidence that populations of neurons in human primary motor cortex (M1), PRR were tuned to movement direction. In order to decode and reconstruct directional movement from the spatially distributed patterns of voxel responses, we defined an encoding model using six half-wave rectified and squared basis tuning curves. We assumed that response of each voxel was represented as a weighted sum of the six basis tuning curves. First, we compared the decoding performance of the encoding model and Multi-voxel pattern analysis (MVPA) within the PRR. The decoding accuracy of each subject was calculated by 10-fold cross validation. The average decoding accuracy of all subjects obtained using the forward model was 24 ± 4.1(SD)% and the accuracy of MVPA was 27.08 ± 11(SD)%. The accuracy from the encoding model and MVPA showed similar performance. Furthermore, it showed a significantly higher than chance level (12.5%). The encoding model could also be applied to reconstruct novel directional movements not used to train the model by generating a lookup table for all 360 different directional movement.