The Correlation between the BOLD Contrast and Motor Execution Quantified by Motion-capture Analysis of the Movements

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Introduction

The relationship between the brain activation in the primary motor area (M1) and the motor performance quantified by a motion-capture analysis was investigated. Although finger tapping tasks have been widely used to evaluate motor function, the assessment of task performance frequently depended on subjective reports by the subjects and experimenters. Recording systems, such as turnkeys, can report the timing of button pressing precisely, however, the finger movements are spatially limited. Sensor devices to detect the finger movements tend to restrict finger movements. Thus, we attempted to evaluate the potential of the color marker tracking to quantify the finger movements by using a conventional CCD camera. This method enables non-contacting observation of unrestricted finger movements during fMRI sessions with minimum costs.

Material and Methods

Twelve healthy normal subjects (20 - 52 years old, one female, all right handed) who gave written informed consent participated in this study. Six block designed fMRI sessions were conducted; simple finger tapping opposing a thumb and an index finger at 0.75, 1.5 and 2.25 Hz on the right or left side. Four task and 5 rest blocks (each 30 sec) were interleaved. The visual stimuli for pacing were generated by using E-prime (PST, Pittsburgh). Functional data were obtained using a T2* weighted gradient recalled echo EPI sequence (3T, TR = 3000 ms, TE = 30 ms, matrix 64 x 64, 39 axial slices, 3 mm thick / 1 mm gap, FOV = 192 mm). The functional images were realigned, normalized, smoothed and the peak height and the activation cluster size of the M1 were obtained by using SPM8 (RFX, $p<0.001$).

The finger movements were captured by using a CCD camera (Qcam, S7500, Logicool) and the trajectory of the color makers attached to the finger tips of a soft cotton glove were extracted by determining the coordinate of gravity center in each color area (Fig.1). The velocity and amplitude of the movements were computed by the trajectory curves. The amplitude of the movement trajectory was normalized to remove individual variation depending on image capture conditions, the cognitive, physiological or anatomical backgrounds of the subjects. A homemade motion capture software for fMRI was developed to assemble these analysis modules (FMT, Fig.2).

Results

The velocities of the finger movements detected by using color marker tracking were; Right: 0.73±0.09 (0.75Hz), 1.44±0.13 (1.5Hz), 2.19±0.18 (2.25Hz) and Left: 0.74±0.11, 1.42±0.14, 2.24±0.20, respectively. The normalized amplitudes were Right; 0.906±0.29, 1.00±0.00, 0.78±0.20 and Left; 0.80±0.25, 1.00±0.00, 0.82±0.33. The performance of tapping frequency was less than 10% variance, however, the average amplitude had more than 25% variance. The average correlation ratios between the activation cluster size (masked with BA4 template) were; Right: 0.73±0.56 (uncorrected), 0.74±0.57 (corrected by the average velocity; mV), 0.77±0.37 (normalized amplitude; nA), 0.74±0.46 (corrected by mV*nA) and Left: 0.79±0.20, 0.76±0.22, 0.77±0.25, 0.75±0.27.

The gradient index of the correlation curve (the ratio between the activation cluster size and movement velocity) depended on the normalized amplitude of the movements at 2.25 Hz ($p < 0.05$) on the right side (Fig.3), while it was not significant on the left side. There was no significant change of normalized amplitude based correction on the correlation coefficient of the BOLD linearity on both sides.

Discussion

It was demonstrated that color marker tracking using conventional video system sessions is a practical method to confirm the motor performance during fMRI without physical restriction of the movements. The frequency of movements could be precisely confirmed and the variance was less than 10% in this subject group. The amplitude of movement decreased at higher frequency (2.25Hz). Although the correlation between BOLD signal and the amount of motor execution remained significant (CC>0.7, dF=12) even with this extent of performance change, the gradient of the regressors was significantly decreased. This may suggest the potential confounds induced by the movement amplitude variation in spite of the robustness of BOLD signal to quantify the movements. Since this bias could not be compensated by the average amplitude of movements, further investigations for the performance correction should be conducted. The results also suggested that the BOLD linearity in the M1 is more stable by the movements of the preferred hand than that of non-preferred hand.

Fig.1 Setting of a CCD camera

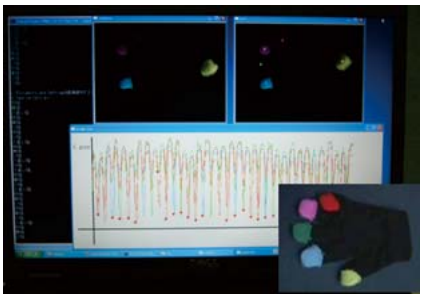

Fig.2 The motion-Capture system (FMT)

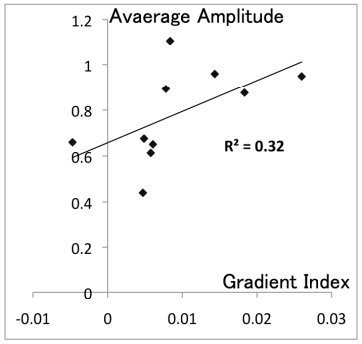

Fig.3 Accuracy of the movements