Temporal Activation Features in Human Motor Cortex During Executed and Imagined Movements

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Introduction:

Even simple movement tasks require a number of processes, including motor planning, preparation and execution. Analogies between imagined and executed movements such as similar completion times [1], vegetative responses [2] and constraints (speed/accuracy tradeoff) [3] indicate that part of the neural circuits involved are active also for imagined movements [4]. However, controversy still remains whether the primary motor cortex (M1) is also part of the shared neural resources recruited [5] and whether the temporal evolution of SMA activation might be different during imagery. In this study we have used event-related fMRI with very high temporal resolution in combination with a finite impulse response (FIR) data analysis to examine specifically the role of M1 and the supplementary motor area (SMA) in a pre-cued, imagined movement task.

Subjects and Methods:

We studied 8 healthy, right-handed subjects on a 3 Tesla Medspec S300 scanner (Bruker Biospin, Germany) with gradient-recalled EPI (MA=64x64, 4 slices, TE=40ms) using a repetition time of 300ms. Twelve trials (110 time points) with 1350 scans each were acquired for imagined movement and repeated for executed movement, balanced across subjects. During each trial subjects listened to a voice counting down from ten to zero and back to five and were instructed to execute or imagine a brief finger to thumb movement when they heard "zero". They were monitored for movement speed and precision.

Data analysis was performed in SPM. Data sets were spatially smoothed with a Gaussian kernel of 9mm FWHM. A FIR approach with separate regressors for every time point per trial period was applied. As such, 110 regressors were constructed, each representing intensity changes at a certain time after trial onset. In this way no assumptions were made regarding the neuronal activation and shape of haemodynamic response functions, apart from reproducibility over all trials. This approach makes it possible to generate activation maps for every single time instance within a trial, allowing unbiased study of brain activation. From the activation maps and the corresponding anatomical images, we defined ROIs for M1 (contralateral to the movement side) and SMA and calculated mean time courses, both for executed and imagined movements.

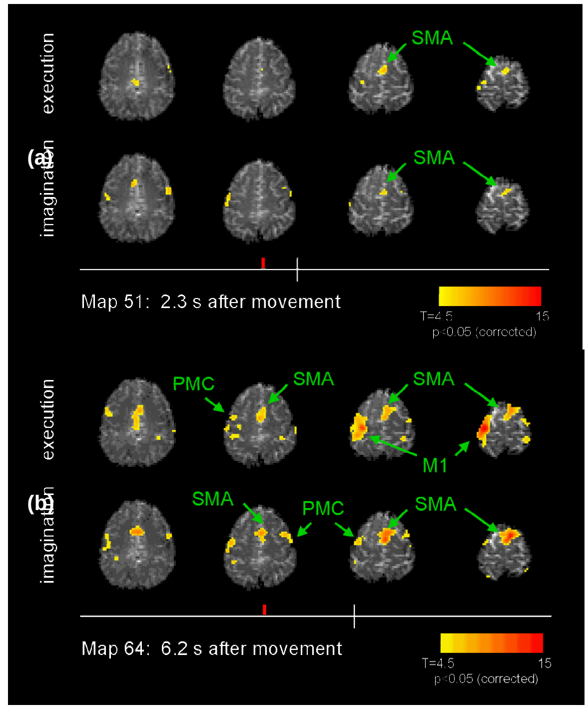

Figure 1: Activation maps for a single subject 2.3s (a) and 6.2s (b) after movement onset.

Results:

Figure 1 shows the activation maps of a single subject for executed and imagined movements. Map #51 (fig. 1a) represents activation 2.3s after the movement onset and shows similar SMA activation for executed and imagined movements. M1 activation reaches maximum in map #64 (fig. 1b), i.e. 6.2s after movement onset. Again, SMA activation is very similar for both conditions, but no activation in M1 during imagery reaches significance. Figure 2 displays ROI intensity time courses averaged over all eight subjects (mean +/- SEM). Start of the auditory cue and movement onset are indicated by green and red arrows respectively. Comparing both conditions it can be seen that there is only a minimal intensity enhancement in M1 during motor imagery (fig. 2a), while SMA activation is virtually identical (fig. 2b). Focussing on the executed movement condition fig. 2c shows that peak SMA activation precedes M1 activation on average by about 1s, reflecting the BOLD analogue of the Bereitschafts- or readiness potential, well known in EEG and MEG.

Discussion:

Our results indicate that there is no or only minimal involvement of the primary motor cortex in imagined finger movements. In addition, the analysis approach presented in combination with very high image repetition rate allows monitoring of brain activation on a subsecond scale with the excellent spatial resolution of fMRI. Except for the trial length, no information about the actual stimulus or the haemodynamic response is necessary. As such, brain activation films can be calculated rather than single activation maps, helping to better understand the interplay of different neural circuits.

References:

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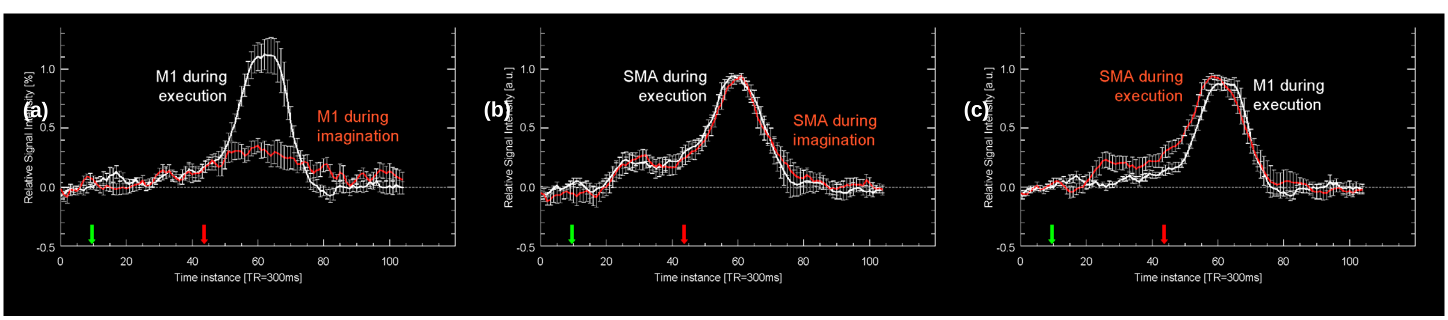

Figure 2: Mean signal time courses in M1 and SMA over all eight subjects studied. Values are given as mean +/- SEM. Note that for (b) and (c) individual time courses have been normalized to a maximum value of 1 for better comparison.