Motor Imagery and Perceptual Prediction Share the Premotor Cortex: fMRI Evidence for a Habitual Pragmatic Body Map

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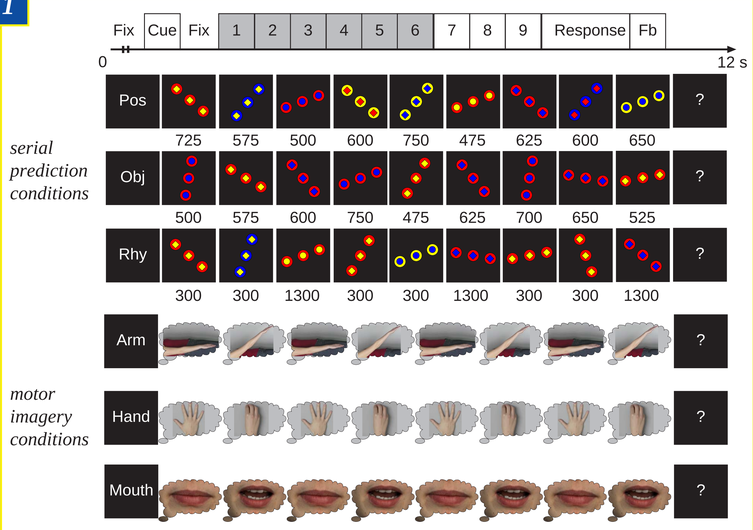
Introduction

Recent findings suggest that the premotor cortex might be exploited not only for anticipatory processes in action performance [1] and action observation [2, 3] but more generally for the prediction of any biological and non-biological dynamics in our environment [4, 5, 6].

The present study set out to test the main hypotheses derived from the habitual pragmatic body map account [5]: namely that the premotor cortex "mirrors" spatial dynamics in the arm field (dorsal), object dynamics in the hand field (superior ventral) and rhythmic dynamics in the vocal field (inferior ventral).

Methods

1



Serial prediction tasks (Fig. 1)
The serial prediction task [7] requires participants to detect a sequential pattern within a series of stimuli and to predict its further course. Here we employed three prediction conditions (spatial, object, rhythm). The sequential pattern of a given trial referred to the instructed stimulus property only, whereas the to-be-ignored stimulus properties were randomly varied. At the end of each trial, participants had to indicate by button press whether the sequential pattern had been violated or not.

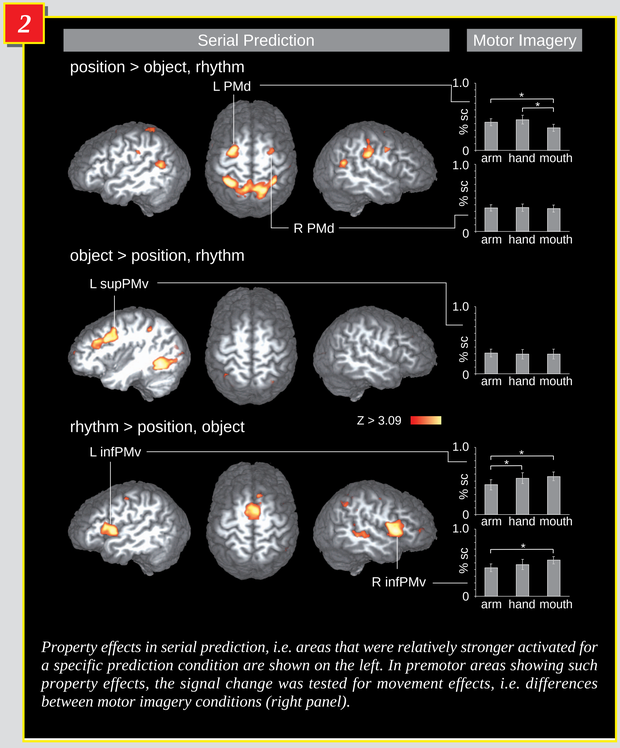
Motor imagery tasks (Fig. 1)
Participants were instructed to repetitively imagine the arm, hand or mouth movements from a first-person perspective. At the end of each trial they indicated by button press whether or not they had succeeded in concentrating on the to-be-imagined movement.

Data acquisition
3T scanner (Siemens TRIO, Erlangen, Germany), 22 axial slices (64 x 64 pixel matrix, FOV 192 mm, 4 mm, spacing 0.8 mm), EPI (TE = 30ms, flip angle 90°, repetition time 2000 ms)

Data analysis
Software package LIPSIA[8]: preprocessing: 1/160 Hz highpass filter, spatial smoothing (FWHM = 5.65 mm); statistics: boxcar function (3800 ms), convolved with the hemodynamic response function, including a delay of 6 s, General Linear Model (random effects), second-level t-tests, regions of interest (ROI) analyses.

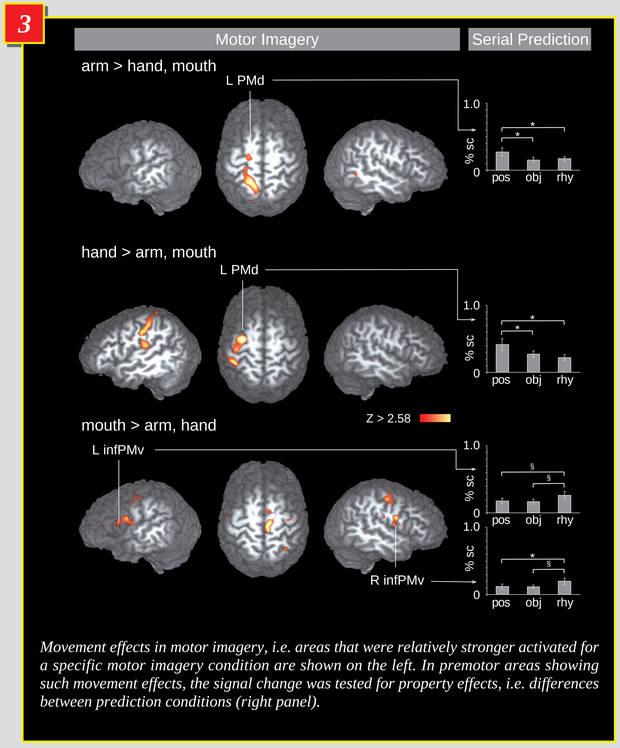
Results

2



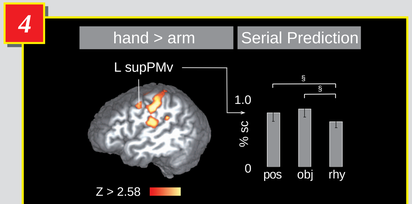
Property effects in serial prediction, i.e. areas that were relatively stronger activated for a specific prediction condition are shown on the left. In premotor areas showing such property effects, the signal change was tested for movement effects, i.e. differences between motor imagery conditions (right panel).

3



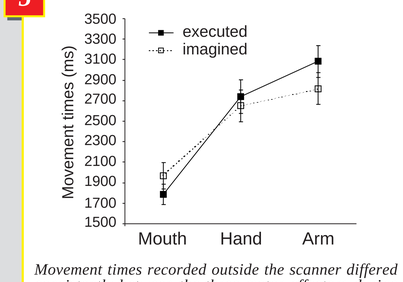
Movement effects in motor imagery, i.e. areas that were relatively stronger activated for a specific motor imagery condition are shown on the left. In premotor areas showing such movement effects, the signal change was tested for property effects, i.e. differences between prediction conditions (right panel).

4



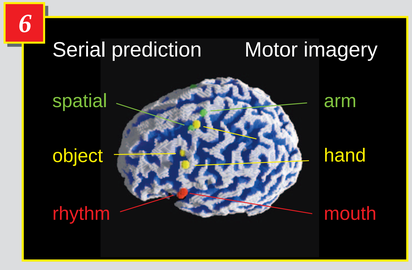
Areas that were relatively stronger activated for hand motor imagery as compared to arm motor imagery are shown on the left. In the superior ventral premotor cortex, which showed such a movement effect, the signal change was tested for property effects, i.e. differences between prediction conditions (right panel).

5



Movement times recorded outside the scanner differed consistently between the three motor effectors during movement execution and motor imagery (mouth < hand < arm, $t(15) > 2.59$, $p < .05$). Moreover, execution and imagery times were highly correlated for all movements (Pearson's $r = .77$ - $.88$, $p < .001$).

6



Serial prediction (Fig. 2)
Position → bilateral dorsal PM
Objects → left superior ventral PM

Rhythm → inferior ventral PM bilaterally

Movement effects in ROIs showing property effects (Fig. 2)
left dorsal PM (spatial prediction) → arm, hand motor imagery
inferior ventral PM (rhythm prediction) → mouth motor imagery

Motor imagery (Fig. 3)
Arm → left dorsal PM
Hand → left dorsal PM (Fig. 3)
left superior ventral PM (Fig. 4)
Mouth → bilateral inferior ventral PM

Property effects in ROIs showing movement effects (Fig. 3)
left dorsal PM (arm, hand) → spatial prediction
inferior ventral PM (mouth) → rhythm prediction

Discussion

1. The functional data on abstract prediction confirm an attentional modulation of lateral premotor cortex in dorsal-ventral direction [4, 6].

2. A corresponding dorsal-to-ventral distribution was confirmed for premotor fields that were relatively more activated for several motor imagery conditions supporting the notion of a restricted somatotopy in lateral premotor cortex.

3. Direct correspondences were confirmed for mouth movement imagery and rhythm prediction in inferior ventral premotor cortex, and for arm movement imagery and spatial prediction in dorsal premotor cortex. Thereby the present results partly confirm the hypotheses derived from the habitual pragmatic body map account [5]: To-be-predicted stimulus dynamics and motor effectors are coupled in lateral premotor cortex according to a pragmatic default.

4. Finally, the present data further underline the functional relevance of the premotor cortex for non-motor processes in general, and more specifically for (abstract) anticipatory processes that are not devoted to understanding another person's behavior.

References

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