Supplementary Table

Supplementary Table 1: Seed regions

		MNI coordinates		
ROI	**Anatomical label**	***x***	***y***	***z***
S1	primary somatosensory cortex, BA3, c.	20	-34	66
SII	secondary somatosensory cortex, c.	56	-20	20
SPL	superior parietal lobule, c.	34	-46	64
SMG	supramarginal gyrus, c.	56	-32	46
M1	primary motor cortex, BA4, c.	38	-24	66
PMC	premotor cortex, BA6, c.	36	-6	46
SMA	supplementary motor area, c.	8	-8	54
PT	putamen, c.	32	-6	-2
CB/c	cerebellum, lobule VI, c.	28	-52	-30
CB/i	cerebellum, lobule VI, i.	-28	-52	-30

Supplementary Methods

Behavioral procedures.

Seat height was adjusted for each patient so as to have approximately 70 degrees of shoulder abduction. Two 16 digit optical encoders at the robotprovided the position of the hand (Gurley Precision Instruments). Applied forces were measured using a force-torque sensor (ATI Industrial Automation) that was mounted above the robot handle. A semi-silvered mirror placed just below eye level was used to project the target and hand position. The mirror blocked vision of the arm and the robot handle.

Reaching movement task.

On the first day of the experiment (Day 1), patients first underwent an initial test of reaching accuracy. The start position was defined for each patient separately and was approximately 20 cm from patient's chest along the body midline. Two circles, 1.5 cm in diameter, represented movement start and end points. The target position was 15 cm from the start point in the sagittal plane. A smaller yellow circle (.5 cm in diameter) provided the patient with feedback of hand position. Patients were asked to move as straight as possible and they were instructed to finish each movement in 700 ms following a visual cue. After completion of each trial, visual feedback of movement speed was provided. However, no trials were removed for movements faster or slower than the required duration. Patients were also told that reaction time was not a factor in their performance. Visual feedback of the target and hand position was removed as soon as the patient left the start position. The target and cursor position reappeared at the end of movement. Patients were instructed not to correct any end-point error when visual

feedback was reintroduced. At the end of the trial, the robot moved the patient's hand straight back to the start position, without visual feedback.

fMRI acquisition.

The whole-brain functional data were acquired using a T2* weighted EPI Multi-Slice WIP sequence (Setsompop et al., 2012) as follows: slice acceleration factor 6; TR 400 ms; TE 28 ms; slices 42; thickness 3 mm; FOV 252 mm x 252 mm; and flip angle (FA) 50°. The functional images were superimposed on a T1 weighted anatomical image (resolution 1 mm isotropic, 176 slices, 256 x 256 matrix). We used a multi-band accelerated imaging sequence in the current study because we could acquire more data in a relatively short scan time. Moreover, the very short TR (a sampling frequency of 2.5Hz) allowed us to critically sample the effects of cardiac (~1Hz) and respiratory (~0.3Hz) related artifacts during the resting-state scans. Each functional scan lasted for 6 min 40 s and yielded 1000 volumes. Two resting-state scans were performed on each scanning session (2000 volumes in total).

Image pre-processing.

We used the same pre-processing pipeline as described previously [1]. This includes (1) the removal of the first 10 volumes in each scan series, (2) slice time correction, (3) non-brain tissue removal (manually corrected using the lesion mask) (4) motion correction, (5) global intensity normalization, (6) spatial smoothing (Gaussian kernel of FWHM 6 mm), (7) temporal high-pass filtering. To achieve the transformation between the low-resolution functional data and the standard space (MNI152: average T1 brain image constructed from 152 normal subjects), we performed two transformations. The first was from the T2*-

weighted image to the T1-weighted structural image (using a 6 degree of freedom (DOF) transformation), and the second was from T1-weighted structural image to the MNI standard space (using a 12 DOF linear affine transformation, voxel size=2×2×2 mm). We further applied temporal band-pass filtering (Butterworth filter with zero phase lag) to the resulting residual image to retain frequencies in the 0.009 to 0.08 Hz band, since in resting state fMRI we expect a neuronal activity related signal within this range [2].

For the seed-based analysis, the average ROI time-course was used as the regressor of interest in a subject-level GLM to assess the functional connectivity of each ROI with every other voxel in the brain. Nuisance signals as confound regressors were included in the model, to account for physiological artifacts: artifact-related spatial and temporal ICA components, WM and CSF average signals, and motion correction parameters. Furthermore, we included the time derivative of each ROI's signal as a regressor in the GLM to account for possible time differences in the haemodynamic response function (HRF) of different cortical areas, as well as the latency for signal propagation from one cortical area to another [4]

We used independent component analysis (ICA) to extract and remove the artifact/noise-related components from the resting-state BOLD signals. Both spatial and temporal ICA [3,4] were conducted and the times series of components that met the following criterion were included as confounds in the subsequent subject-level GLM analysis. Confound components were defined as those which had a relatively high power outside the neural-related frequency range (power in [0.1-1.25 Hz] > 4 * power in [0.009-0.1 Hz]). The confound components mainly represented signals related to the cardiac (~ 1 Hz), respiration (~ 0.3 Hz), interaction of cardiac and respiration, or motion

related artifacts. On average 4.8 (2 to 7) components were selected based on spatial, and 5.7 (3 to 10) components were selected based on the temporal ICA. We used both temporal and spatial ICA to increase our sensitivity in detecting artifact components [3]. Our high sampling rate (low TR) allowed us to maximally remove the linear effects of cardiac and respiratory related artifacts in the BOLD signal. Note that, since we acquired 2000 time points for each patient in each session, we were able to successfully perform the temporal ICA. In addition to the artifact-related ICA components, we also included another 8 confound regressors as described previously [1], including the average white-matter BOLD signal, the cerebro-spinal fluid signal, and 6 motion parameters obtained from the motion correction step (translations and rotations).

Functional localizer task.

We used an event-related design for passive movements as described previously [5]. A first level GLM analysis was carried out using FEAT (FMRI Expert Analysis Tool), part of FSL, which modeled the period of passive movements convolved with a gamma haemodynamic response function. For each patient, a lesion mask, defined based on his/her structural scan, was used to exclude the lesion area from this analysis. The Z statistic images obtained in the subject level analysis were input to a group-level GLM. The group-level analysis used the FEAT mixed-effects model with a cluster threshold ($Z \geq 2.3$, corrected for multiple comparison using Gaussian random field theory, cluster significance threshold of $p < 0.05$).

Supplementary references

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