Motor network connectivity following training with an MR compatible hand induced- robotic device

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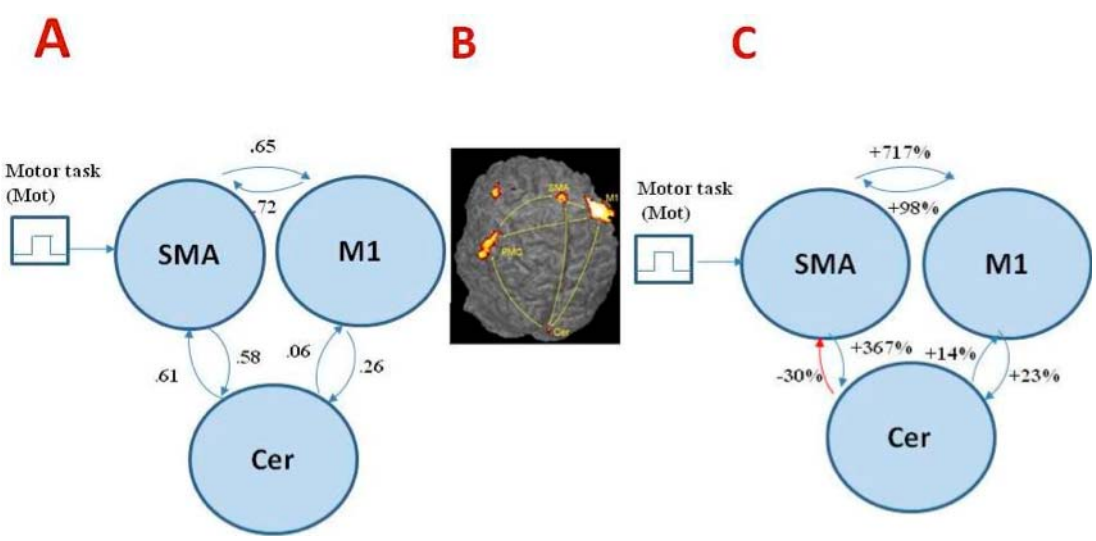
Target Audience: Radiologists, Neuroradiologists, Neurologists, Neurosurgeons, Physicians, Rehabilitation therapists.

Purpose: Previous brain imaging work suggests that stroke alters functional connectivity of motor execution networks. Recent studies showed a significant role of effective coupling of neuronal activity in the SMA-M1 network for motor outcome in patients after stroke (1-3). After a subcortical stroke, functional magnetic resonance imaging (fMRI) during movement reveals cortical reorganization that is associated with the recovery of function. Here, our purpose to investigate functional reorganization of motor systems by exploring connectivity alterations within the motor related areas combining motor fMRI with a novel MR-compatible hand-induced robotic device (MR_CHIROD(4)).

Materials and Methods: Patients completed a training at home and underwent serial MR evaluation at baseline and after 8 weeks of training. Training at home consisted of squeezing a gel exercise ball with the paretic hand at approximately 75% of maximum strength for 1 hour/day, 3 days/week. For each patient, reference (100%) was own maximum force, defined as the force at which subjects could just completely squeeze the MR_CHIROD [group max force: 128 N ± 13 N (n = 5, male)]. All studies were performed on a Siemens Tim Trio (3T) and BOLD fMRI was performed using GRAPPA gradient-echo EPI (TR/TE=3000ms/30ms, 1.56 mm×1.56 mm×3 mm). A block design paradigm was used for fMRI. During the action period, subjects squeezed the MR_CHIROD and released continuously. A fixation cross was projected during rest. Each volunteer performed the paradigm at 45%, 60%, and 75% of their maximum grip strength and could fully squeeze the device at all levels. The percent levels compensate for performance confounds. The DCM model was constructed using brain regions that were activated in all subjects (Figure A) and comprised of three regions: M1, SMA, and cerebellum (Cer). Volumes of interest were defined in these regions using a sphere centered at the maximum activation from the second-level analysis and with a radius of two voxels. We allowed all possible connections between the brain areas to account for plasticity changes in the stroke group. We also allowed Mot to connect to the SMA, which is the only region in the model responsible for motor planning. Connectivity strengths and posterior probabilities were calculated using the DCM utility in SPM5.

Results: The fMRI analysis revealed activations in M1, SMA, premotor cortex and Cer in both stroke patients and controls (Figure B). Greater connection strength translated into a greater absolute value of the parameter shown, and thus a more prominent effect of one area on another. Connectivity strengths of healthy subjects are shown in Figure 4A and percent changes in connectivity strengths after training relative to baseline are shown in Figure C. The DCM analysis produced the following four noteworthy results: a) In healthy subjects performing a simple motor task, there was minimum effective connectivity from Cer to M1 (Fig. A); b) Training significantly increased coupling between M1 and SMA, suggesting an induction of SMA recruitment (Fig. C). This possibility has been suggested by earlier fMRI studies in healthy subjects (5) and c) SMA-Cer coupling and Cer-M1 coupling were induced by training (Fig. C).



DCM connectivity (in Hz) for healthy volunteers

Percent change of connectivity strengths between brain areas in stroke patients (after training relative to baseline)

Discussion: Connectivity alterations in motor-related areas suggest functional reorganization of motor systems in stroke (3). Our findings suggest that enhancement of SMA activity could benefit M1 dysfunction in stroke survivors. Enhancement of SMA activity through training has been suggested as a potential means for ameliorating M1 dysfunction after stroke. These results highlight the importance of the SMA not only for the preparation and execution of intended movements, but also for suppressing movements that are represented in the motor system but not to be performed. These results also demonstrate that connectivity alterations between motor areas may help counterbalance a functionally abnormal M1 in chronic stroke patients.

Conclusion: Assessing changes in connectivity by means of fMRI and MR_CHIROD might be used in the future to further illustrate the neural network plasticity that underlies functional recovery in chronic stroke patients. Our findings suggest that rehabilitative exercise training could induce functional connectivity alterations.

References:

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