Improving the vividness of motor imagery tasks for future application in Brain-Computer Interfaces

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Introduction

Motor imagery (MI) is the task most commonly used for imagery-based brain-computer interfacing (BCI). A BCI is a device that enables communication without movement - via thought alone. There are different approaches to improve the performance of BCIs but most studies focus on signal processing, feature extraction and classification. However, BCI performance can also be improved by optimizing the user's control strategies by using more intuitive mental tasks for control [1,2]. We used functional magnetic resonance imaging (fMRI) to investigate neural correlates of more vivid motor imagery tasks like sports motor imagery (Experiment 1) and joint action motor imagery (Experiment 2).

Experiment 1

Method: 3 T Siemens Magnetom Skyra whole body scanner with standard 32 channel head coil was used. Functional imaging was obtained using a BOLD-sensitive T2*-weighted EPI-sequence (TR = 3000 ms, TE = 31 ms, flip angle = 90°, FOV = 240mm). A flexible factorial design analysis was performed.

Participants: 23 healthy right handed participants (15 male, 8 female, mean age 28.4 years, SD ± 4.3, range 19–39).

Paradigm: The experiment consisted of three parts (MI-ME-MI) illustrated in Figure 1. For the MI task, two very common sports, tennis and soccer, were chosen because they integrate both effectors. [3]

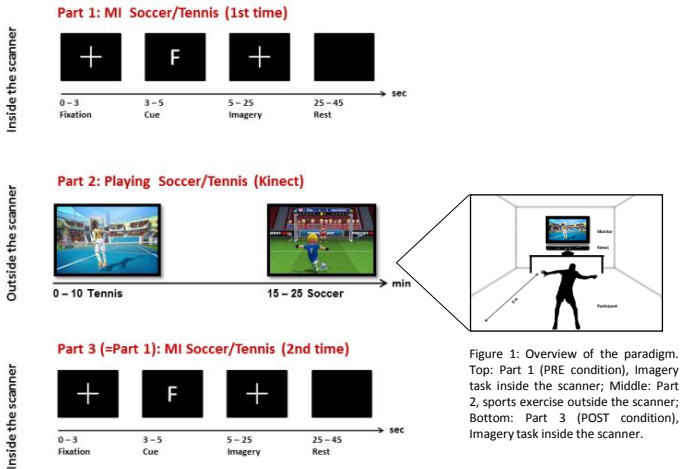

Figure 1: Overview of the paradigm. Top: Part 1 (PRE condition), Imagery task inside the scanner; Middle: Part 2, sports exercise outside the scanner; Bottom: Part 3 (POST condition), Imagery task inside the scanner.

Results

- Overall increased activation patterns in the POST condition (=Part 3) but with a greater degree for soccer MI.
- Activation within posterior parietal regions like the IPL and SPL for soccer MI exclusively (Fig. 2).

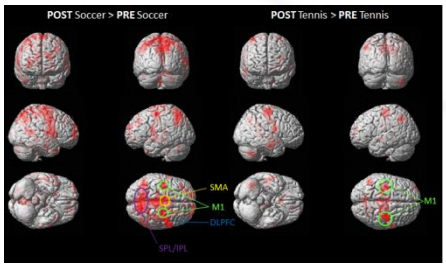

Figure 2: Group activation maps showing activated brain regions in condition " POST Soccer > PRE Soccer (left side) and POST Tennis > PRE Tennis (right side). All regional activations above initial significance threshold P < 0.05 (FWE corrected) and extent (kE) of 30 voxels are depicted on a rendered MNI brain.

Experiment 2

Method: A 3 T scanner was used (= Exp. 1). Statistical analysis: A first-level analysis was performed for each subject using the general linear model (GLM; in SPM). The second level analysis was performed extending the inference of single (each participant) activation to the population.

Participants: 21 healthy right handed participants (16 male, 5 female, mean age 26.3 years, SD ± 4.4, range 21 - 35).

Paradigm: The stimuli were black pictograms showing two persons acting together (=joint action; JA), acting alone (=single action; SA) or they indicate no action (NA) like simply sitting or standing together.

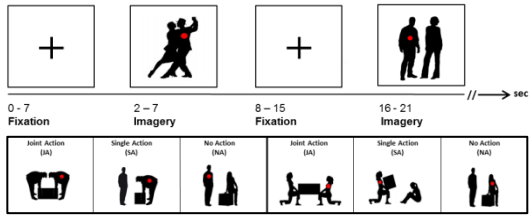

Figure 3: Top: Timing of trials; Bottom: Examples of used stimuli (male/female).

Results

- MI of a cooperative task activates more frontal motor related areas (Fig. 4,5).
- Single Action MI: activation in the middle occipital lobe, cerebellum and precuneus → Clear distinctive activation areas for JA and SA MI

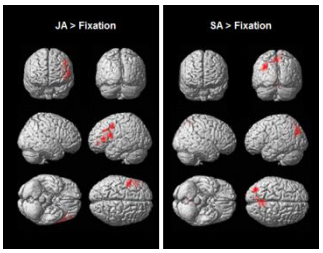

Figure 4: Group activation map showing activated brain regions in "Joint Action MI" (left), "Single Action MI" (right) condition. All regional activations above initial significance threshold voxel-wise p < 0.005 (uncorrected) and cluster-wise p < 0.05 FWE corrected are depicted on a rendered MNI brain.

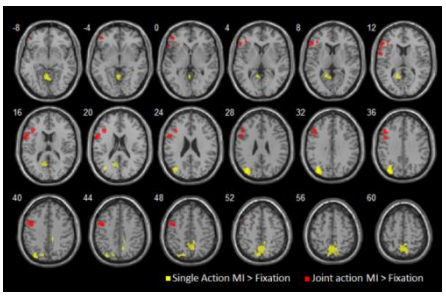

Figure 5: Group activation map showing activated brain regions in both conditions, Single Action MI (yellow colour) and Joint Action MI (red colour). All regional activations above initial significance threshold voxel-wise p < 0.005 (uncorrected) and cluster-wise p < 0.05 FWE corrected are illustrated.

Discussion

The results show on one side that vivid mental imagery tasks, enhancing neural activity in related motor areas (Exp 1). Especially the soccer task elicited enhanced neural activation in a more distributed motor-related network. On the other side we found clear dissociable neural patterns in the frontal lobe (inferior frontal gyrus) and precuneus for joint and single action motor imagery, respectively (Exp 2). The enhanced activity and the clear spatial separation might be relevant for future motor imagery-based BCI systems leading to better classification results. Currently Experiment 1 is replicated with EEG testing the suitability of the paradigm in offline classification procedures for future BCIs.

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[3] Wriessnegger, S.C., Steyrl, D., Koschutnig, K., Müller-Putz, G., 2014. Short time sports exercise boosts motor imagery patterns: implications of mental practice in rehabilitation programs. Frontiers in human neuroscience. 8:1–9.

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