Cerebellum Involvement in Hand Movements: a Functional MRI Study

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Abstract— **To investigate the contribution of the cerebellum to motor behavior, I used a simple motor task inside an MRI scanner.**

I. INTRODUCTION

The cerebellum plays a critical role in behavior and motor control (Fox et al., 1985; Seitz et al., 1990; Sabatini et al., 1993; Ellerman et al., 1994). Here I provide further evidence for cerebellar contribution to simple hand movements (sequential fist opening and closing), using functional Magnetic Resonance Imaging (fMRI). I hypothesized that blood-oxygenation level dependent (BOLD) signal will increase for the cerebellar hemisphere ipsilateral to the active hand.

II. MATERIALS AND METHODS

All materials and methods were determined prior to data collection, and were time-locked using the preRNG procedure (Mazor et al., 2017). The protocol folder is available on github.com/alicemdphd/cerebellum

A. Experiment

1) Participants: One subject (26 year old, right-handed female) participated in the experiment.

2) Procedure: The subject laid supine on the scanner bed, and viewed visual stimuli back-projected onto a screen through a mirror. Foam pads were used to minimize head motion. Stimulus presentation and timing of all stimuli were achieved using Python and PsychoPy (Peirce, 2008). The subject's eye movements were monitored using an EyeLink 1000 Plus eye-tracker. The experiment consisted of four 6 minutes experimental runs. The task was presented in a block design (8 seconds task blocks alternated with 10 seconds of rest, 20 blocks per run). During experimental blocks an arrow appeared on the screen, to which the subject was asked to react with sequential fist opening and closing of the appropriate hand (right or left, as indicated by the arrow direction), at her own pace. A fixation-cross appeared during rest periods. For each run, a right arrow was presented in 10 blocks, and a left arrow was presented in the other 10. The order of blocks was randomized within and between runs, using the preRNG procedure (Mazor et al., 2017) and based on the predetermined protocol folder (github.com/alicemdphd/cerebellum).

3) MRI Data Acquision: A Siemens 3-T Prisma scanner (located at the Edersheim-Levi Gitter Center for human brain imaging, Tel Aviv University, Israel) with a 64-channel Siemens Matrix head coil was used to collect all functional and anatomical scans. A single high-resolution structural scan was acquired using a magnetization-prepared rapid acquisition gradient echo (MP-RAGE) sequence (1 x 1 x 1 mm voxels). All functional runs were acquired parallel to the anterior-posterior commissure plane using the Center for Magnetic Resonance Research (CMRR) multiband accelerated gradient-echo EPI sequence (66 contiguous interleaved axial slices, 2 mm thickness, no gap; TR = 2000 msec; flip angle = 82; TE = 32.2 msec; in-plane resolution = 2 x 2 mm; matrix size = 96 x 96).

B. Data Analysis

1) Image Preprocessing and Statistical Analysis: The acquired data were analyzed using FEAT v6.00 (FMRI Expert Analysis Tool), part of FSL (FMRIB software library, version 5.0, www.fmrib.ox.ac.uk/fsl). Images were realigned to the central volume of each run to correct for head movements, and spatially smoothed using a 5 mm kernel. The data were then temporally filtered using both a high-pass filter with a cutoff of 50 seconds, and the FILM prewhitening tool. Functional images were registered to the brain-extracted T1 image, using boundary based registration. The anatomical image was registered to the standard MNI space (MNI152, 2mm) by first performing a linear registration with 12 degrees of freedom, and then using the FNIRT nonlinear registration tool with a warp resolution of 10 mm on the linearly registered image. First level analysis was executed using FILM. The model included 4 regressors: right-hand and left-hand blocks were modeled and convolved with a Double-Gamma HRF (Rh and Lh, accordingly). The temporal derivative of each of the resulting regressors was added to the design matrix as a second explanatory variable to account for minor temporal offsets. The design matrix then went through the same temporal filtering process as the empirical data, before beta values were extracted for each voxel in the brain by fitting the model to the voxel's time series. The four runs were modeled as a fixed effect. A GLM contrast between right-hand and left-hand regressors (Rh-Lh) was performed. I chose to restrict the analysis to the cerebellum, which was identified anatomically using the MNI atlas provided with FSL (MNI-maxprob-thr50-2mm). A small-volume false discovery rate (FDR) correction was applied to the voxels within this region, using the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995).

III. RESULTS

In line with my prior hypothesis, I found stronger activation in the right cerebellar hemisphere for right-hand movements, and stronger activation in the left cerebellar hemisphere for left-hand movements (see Fig. 1). These

results survived FDR correction. Furthermore, exploration of the statistical parametric maps for this contrast revealed a positive linear modulation of the effect size in the left cerebellar hemisphere as a function of the run serial number. Results for this post hoc contrast survived FDR small volume correction, using the same anatomical mask that was used for the main contrast.
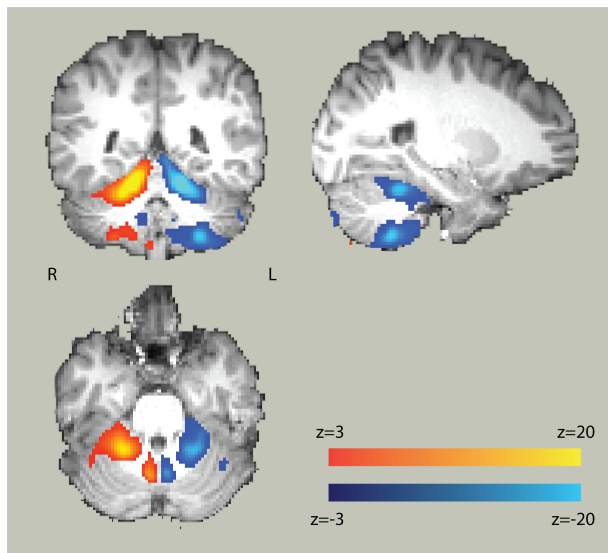

Fig. 1.   Main contrast: Right-hand (red-yellow) - Left-hand (blue-light-blue). The contrast was restricted to the cerebellum only

IV. DISCUSSION

The current study provides evidence for robust ipsilateral activation in the cerebellum for single-hand movements. These findings are in line with previous research reporting ipsilateral involvement of the cerebellum in motor processes (Fox et al., 1985; Sabatini et al., 1993; Ellerman et al., 1994).

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