A functional dissociation between the left and the right cerebellum during sensorimotor synchronization: a BOLD fMRI study

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Objective: Sensorimotor synchronization (SMS) requires the ability to produce sequential finger taps time-locked to a pacing stimulus. To sustain a consistent tap-tone relationship, a dynamic "error correction" process is required. We investigated the neural basis of error correction by introducing both unperceivable and perceivable perturbations into a conventional sensorimotor synchronization task using temporally-correlative fMRI ('functional connectivity').

Methodology: Sixteen subjects (7 male, age 24±5) performed three SMS tasks (a standard, 3% and 15% condition) using their right index finger. The standard SMS condition consisted of isochronous tones with a stimulus onset asynchrony of 600ms. In the two other conditions either small, undetectable (3%, 18ms) or large, perceivable (15%, 90ms) phase perturbations were introduced. Functional data were acquired at 3T (Acheiva 3.0T, Philips Medical Systems) adopting an echo-planar technique (TR=1.5 sec; 370 time points; 23x6mm transverse slices, SENSE factor=1.5). A random-effect analysis was performed ($p<0.001$, uncorrected, extent threshold over 20 voxels) using Statistical Parametric Mapping (SPM5).

Findings: Compared with baseline rest, the standard condition showed activations in the right deep cerebellar nuclei (20 -52 -28, 2157 voxels), bilateral auditory cortices (60 -18 -2, 2381 voxels and -54 -20 0, 1094 voxels) and left primary motor cortex (-48 -8 54, 1211 voxels). No additional activations were found during the 3% condition, but in the 15% condition significant activations were located in the left cerebellar cortex (-20 -80 -44, 161 voxels), right inferior parietal cortex (IPC, 50 -40 54, 247 voxels) and bilateral inferior frontal gyrus (IFG, -48 4 40, 34 voxels and 42 8 34, 45 voxels). Furthermore, a seed voxel functional connectivity analysis revealed that the right cerebellum was associated with primary auditory cortex and primary- and pre-motor areas and caudate and pulvinar nuclei, whereas the left cerebellum was correlated with bilateral inferior parietal and frontal cortices and the putamen and ventral lateral nucleus of the thalamus.

Conclusion: These results show a dissociable functional lateralization in the cerebellum during a sensorimotor synchronization task. The right dentate nucleus is activated in all three active conditions compared with rest, whereas the left posterior cerebellar cortex is only engaged in the condition during which perceivable perturbations are introduced. Furthermore, the functional network that is co-activated with the right cerebellum includes primary motor and sensory cortices, whereas the left cerebellar cortex was associated with inferior parietal and frontal areas. This suggests that the right cerebellum may be involved in general timing and motor planning required in all task conditions, whereas the left cerebellum may play a significant role in error correction. These results invite further interest in functional lateralization in the cerebellum and functional networks for timing and error correction.