Comparison of Unilateral and Bilateral Complex Finger Tapping-Related Activation in the Precentral Gyrus

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Abstract
Sixteen healthy right-handed subjects performed unilateral right/left and bilateral complex finger tapping tasks. During unilateral tapping, ipsilateral activation occurred in all subjects, mainly in the ventral premotor (PMv) and dorsal premotor (PMd) cortex. Ipsilateral primary sensorimotor (SMC/M1) cortex activation was observed in 6/11 subjects for each hemisphere. These regions of ipsilateral activation were also activated during contra- and bilateral finger tapping for all subjects, suggesting that they reflect part of a bilateral network involved in motor control.

Introduction
The role of the ipsilateral precentral gyrus in motor control is not well understood. FMRI studies have shown that this activation is shifted with respect to the M1 activation during a contralateral hand task[1]. This activity may reflect part of a larger bilateral network involved in the control of complex motor tasks[2], or it may play a role in the inhibition of unwanted movements by receiving transcallosal inhibitory input from the contralateral cortex[3]. To assess these possibilities, we present the first study to compare precentral gyrus activation during right, left and bilateral complex finger tapping within the same study. We hypothesize that if the ipsilateral motor and premotor activation is due to transcallosal inhibition, then this activity should not be present during the contralateral and bilateral tasks. However, if the ipsilateral precentral activation represents part of a bilateral network for control of complex finger movements, then these same cortical regions will be activated by the contralateral and bilateral tasks.

Methods and Materials
Gradient echo EPI fMRI exams at 3T were performed on 16 right-handed controls who performed right hand, left hand and bilateral complex finger tapping tasks in a block paradigm. One hundred-sixty volumes of 31-4mm thick axial slices (TE/TR/flip=29ms/2000m/80°, matrix=64x64, 256mm x 256mm FOV, receive bandwidth= 125KHz) were acquired. Fingers were tapped sequentially in the following order: thumb, middle, pinky, index and ring finger. Performance was monitored with a data glove (Fifth Dimension Technologies, Irvine, CA) and analyzed for tapping rate, error rate and unwanted mirror movements. Head motion was monitored using a prospective motion correction methodology[4]. Datasets with clear visual evidence for motion corruption were discarded. FMRI timeseries data were spatially filtered with a Hamming filter [5] and analyzed for activation by least-squares fitting the timeseries for each pixel to a boxcar reference function plus a slope[6]. Student's t maps were overlaid onto high resolution T1-weighted images. Talairach transformed data sets were averaged together voxel-by-voxel to generate composite activation maps for each task. In each individual subject, ROIs were defined bilaterally around the SMC, PMv and PMd. For all 3 tasks, activation volume and Student's t/location of the maximally activated voxel were determined for each ROI. For both the right hemisphere (RH) and left hemisphere (LH), we also identified the percentage of ipsilaterally activated SMC, PMd and PMv voxels (Student's t>3.5, uncorrected $p<5x10^{-4}$) that had spatial overlap with the activation from the contra- and bilateral tasks. We then compared the mean percent signal change of the overlapping voxel populations using a paired t-test and visually inspected the overlapping regions to determine if there were any unique brain areas activated only during the ipsilateral task.

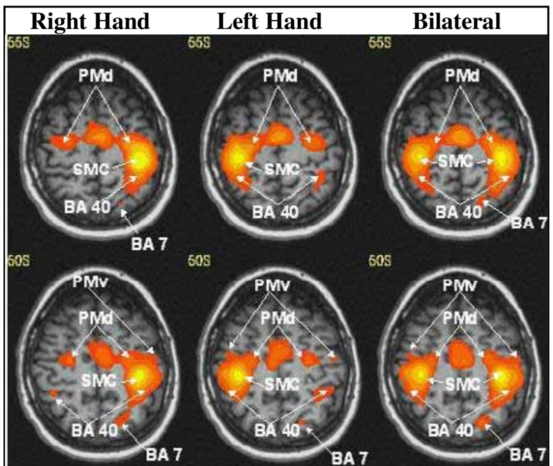

Fig 1. Composite activation maps during unilateral right, left and bilateral finger tapping.

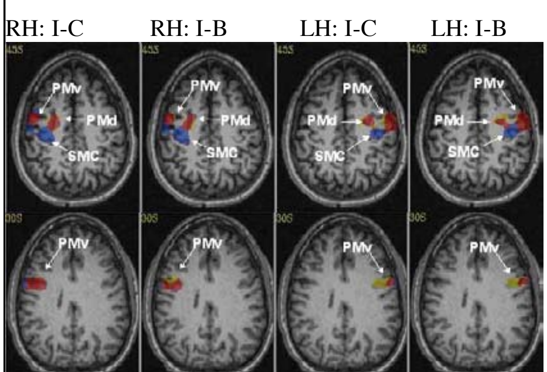

Fig 2. Spatial overlap analysis from a representative subject. Red represents activation during both tasks. Yellow represents activation during the ipsilateral task only. Blue represents activation during the contralateral/bilateral task only. (RH: right hemisphere, LH: left hemisphere, I-C: Ipsilateral vs. Contralateral , I-B: Ipsilateral vs. Bilateral comparison)

Results
All subjects performed the task well. Mean finger tapping (210 +/- 60) and error (2% +/- 3%) rates were similar for all 3 tasks. No mirror movements occurred in any subjects. Data from 5 subjects was discarded due to motion corruption. Composite activation maps (Figure 1) revealed significant ipsilateral cortical activation ($p<5x10^{-17}$) in 2 distinct regions of the precentral gyrus corresponding to the PMv (lateral and ventral to the hand knob extending inferiorly to the roof of the Sylvian fissure) and the PMd (medial and dorsal to the hand knob) extending superiorly towards the dorsal convexity (Figure 1). There was also significant ipsilateral parietal activation in BA7 and BA40. No significant activation of the ipsilateral SMC was seen in the composite maps. Individual subject analysis revealed similar right and left hemisphere PMv and PMd activation volumes for all 3 tasks. Ipsilateral SMC activation volume was significantly less compared to contralateral ($p<4x10^{-10}$) and bilateral finger tapping ($p<2x10^{-9}$). The maximally activated precentral gyrus voxel during contralateral finger tapping was located in the SMC for 9/11 subjects during right hand tapping and 11/11 subjects during left hand tapping. For ipsilateral finger tapping, the maximally activated precentral gyrus voxel was located in the SMC for only 2/11 subjects during left hand tapping and 1/11 subjects during right hand tapping. In all other cases, the maximally activated ipsilateral voxel was premotor. The spatial overlap analysis (Figure 2) revealed no unique areas of activation during ipsilateral finger tapping. The mean percent signal change of the overlapping SMC voxel population was significantly less for the ipsilateral task compared to the contralateral task ($p<1x10^{-6}$) and when compared to the bilateral task ($p<2x10^{-6}$). However, the mean percent signal change of the overlapping voxels in the PMd and PMv was similar for all 3 tasks. Overall, ipsilateral activation within the SMC/PMd/PMv had an 88%/80%/65% spatial overlap with the activation occurring during contralateral/bilateral finger tapping

Conclusion
During unilateral finger tapping, ipsilateral activation occurred in all subjects, mainly in the PMv and PMd. Ipsilateral M1 activation was observed in 6/11 subjects for each hemisphere. These regions of ipsilateral activation were also activated during contralateral and bilateral finger tapping for all subjects. The mean percent signal change of activated voxels was similar in PMv and PMd between all tasks, but was significantly less in M1 during ipsilateral tapping than contra- or bilateral tapping. These results suggest that the ipsilateral fMRI activation in unilateral motor tasks is not inhibitory in nature, but may reflect part of a bilateral network involved in the planning and/or execution of tapping in the ipsilateral hand.

References: [1]Cramer, SC, et al. J Neurophysiol 1999;81:383 [2]Hanakawa, T, et al. J Neurophysiol 2005;93:2950 [3]Kobayashi, et al. Neuroimage 2003;20:2259 [4]Thesen S, et al. Magn Reson Med 2000; 44:457 [5] Lowe MJ, et al. Magn Reson Med 1997; 37:723 [6]Lowe MJ, et al. J Comp Assis Tomog 1999; 23:463