Overlapping neural representation in the control of lingual and hand movements

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Introduction: A significant number of functional neuroimaging (fMRI) studies have examined the neural representation of hand movements (1), and several studies have examined orofacial motor systems such as tongue movements, chewing and swallowing (2). A previous investigation of swallowing in humans described cortical networks active during swallowing that shared many features with those classically described for object manipulation by the hands (3). The purpose of this investigation was to determine whether shared neural substrates exist for sensorimotor tasks involving the same motor demand or goal but executed by effectors with different biomechanical properties (e.g. the hands versus the tongue). Five healthy neurologically intact human subjects were imaged using Functional Magnetic Resonance Imaging (FMRI) Techniques. Each subject each performed two hand movement tasks (finger-tapping and balloon squeeze), a tongue-tapping task and a swallowing task. The data demonstrated that each of these tasks activated the primary sensorimotor cortices, the premotor cortex, the parietal cortex and the cerebellum. Analysis of the patterns of cortical activation across the tasks revealed similarities among the balloon squeeze, the tongue tapping, and the swallowing tasks that were distinct from the finger-tapping task. In addition, analysis of activation in cortical regions between the left and right hemisphere showed functional groupings among different regions. These results suggest the cortical representation of movements by biomechanically different effectors shares a network involving sensorimotor, premotor and parietal cortex and the cerebellum.

Materials and Methods: Functional images with BOLD contrast were obtained using a gradient echo echo-planar pulse sequence on normal adults. Adults (3F,2M) ranging in ages from 27 to 39 years performed two self-paced hand movement (finger tapping and balloon squeeze) and two self-paced tongue movement (tongue tapping and dry swallowing) tasks that were designed to be motorically "goal equivalent". The finger and tongue tap represent one set of paired motor equivalent tasks, and balloon squeeze and dry swallow the other. A total of 65 images were acquired for each task trial of four minutes and twenty seconds. The EPI raw images were analyzed using AFNI. The data were motion corrected and aligned to the base image in order to eliminate possible motion artifacts. The data were analyzed by voxel-by-voxel regression with a model that included a linear base-line, a standard impulse response convolved with the stimulus time-series, and the motion parameters deduced from the alignment process. Regions of interest (ROIs) were chosen consisting of active voxels chosen on the basis of statistical significance using an F-statistic threshold of F=6.48, $p<0.0001$. Subsequent analyses were performed on the mean signal intensity (MSI) and number of voxels (MNV) computed for these ROIs. ANOVA was performed to examine significant differences in MSI, MNV,and Stot (MSI times MNV) across tasks for a subset of cortical regions which were consistently activated in all four tasks and between left and right hemispheres. In addition, principal components analysis (PCA) was performed to further characterize the structure of the variance in the mean total signal, Stot, between hemispheres. PCA analysis reveals that there are cortical areas that appear to form functional groupings, while other areas appear independent. Thus, similarities or differences in activity between the tasks can be characterized by the activity in those cortical areas that form functional groups and in the independent areas. Finally, k-means cluster analysis was performed on ROIs to test for similarities of the mean Stot among the tasks.

Figure 1: Mean Number of Voxels for Six Cortical Regions Across Tasks

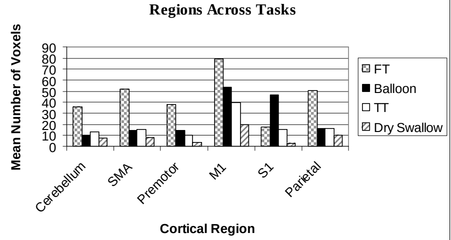


Figure 2: Mean Total Signal (Stot) for Six Cortical Regions Across Tasks

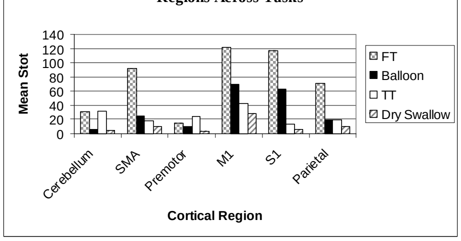


Figure 3: Mean Total Signal (Stot) in the Left and Right Hemispheres Across Tasks

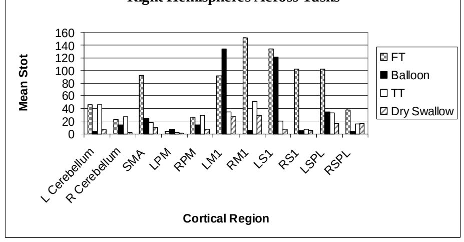
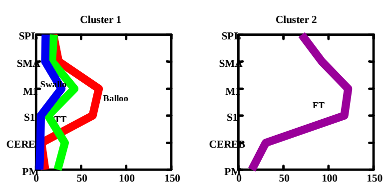


Figure 4: Cluster Plots of the pattern of activation across cortical regions for hand movement and tongue movement tasks



Results: This study demonstrates that cortical regions activated during hand and tongue movement tasks overlap to a substantial degree. In particular, regions of the cerebellum, premotor cortex, SMA, primary and sensory cortices and the superior parietal lobule were consistently activated for all four tasks. The ANOVA analysis for regions common to all tasks showed that significant differences are only evident in the mean number of active voxels between regions across different tasks (Friedman Stat=13.857, p=0.017), but no difference wither in the Stot or in the mean signal intensity. However, differences were observed in the mean Stot within cortical regions between left and right hemispheres (p=0.0003). The k-cluster analysis showed that based on mean Stot, two clusters could be described: one for finger tapping and one containing the rest of the tasks, with the tasks being mainly differentiated by the activity in the SPL and the SMA

Conclusions

These results suggest that cortical regions activated during hand and tongue movement tasks have a large overlap and, thus, share a common neural network in the control of these movements. The cluster analysis result suggests that patterns of activity may be similar according to motoric demands or task goals, rather than specific organ or structure. Finally, the PCA results indicate that specificity of in the network for a particular task may arise from the particular combination of activity in different regions.

References:

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