Functional Network of Hand Prehension : validation by fMRI network connectivity

T-C. Yeh[1,2], C-M. Cheng[1], B-Y. Hsu[1], and J-M. Huang[2]

[1]Department of Medical Research and Education, Taipei Veterans General Hospital, Taipei, Taiwan, [2]Insitute of Brain Science, National Yang-Ming University,

Taipei, Taiwan

Introduction

Prehension is defined as the capacity to reach and grasp which involves complex neuro-coginitive architectures. Hand prehension is composed of selection of grasp model and transformation of motor command. Wide network of motor hierarchy involves action initiation of parietal cortices, premotor, supplementary motor area (SMA), primary motor cortex, basal ganglion, cerebellum, brainstem and spinal cord (Grafton, 2010). The concept of distinct dorsal and ventral streams for processing the visual information in prehension control is well accepted. A visuo-motor task was implemented for the fMRI study to validate the prehension control model via the dorsal stream. By lag correlation of the prehension-related components derived from spatial independent component analysis (ICA), the functional network of hand prehension echoed the theoretical construct and demonstrated temporal events in order of visual, superior parietal, SMA and primary motor correlates of bilateral hemispheres.

Subjects and Methods

(1) a visuo-motor FMRI for hand prehension

Eleven right-handed subjects (male, age: 25 +/- 4 years old, no history of major medical diseases or head injury with consciousness loss) was recruited for MRI study using a 3T MR system (GE MR 750) equipped with an 8-channel head coil and rear-projection of visualization. Handedness was evaluated by modified Edinburgh handedness inventory for laterality index (www.brainmapping,org). An event-related paradigm applying a flanker test of five arrows was delivered as attention task for detecting congruent (e.g. <<<<< or >>>>>) and incongruent (e.g. <<><< or >><>>) combinations, with incongruent incidence rate of 10%. Stimuli were pseudo-randomized in order with jttered inter-stimuli interval of 8.1 seconds in average. Subjects held an MR-compatible response pad in right hand for button response for congruent and incongruent traisl using index and middle fingers, respectively, using the as-fast-as-possible strategy. Image sequences included (1) single-shot echo planar images of fMRI (64x64 matrix, voxel size = 3.6x3.6x4 mm, 40 slices, TR/TE=2000/30 milliseconds, acceleration factor of 2, repetition number = 405) and T1-weighted structural image (256x256x176 matrix, voxel size = 0.9x0.9x0.9 mm).

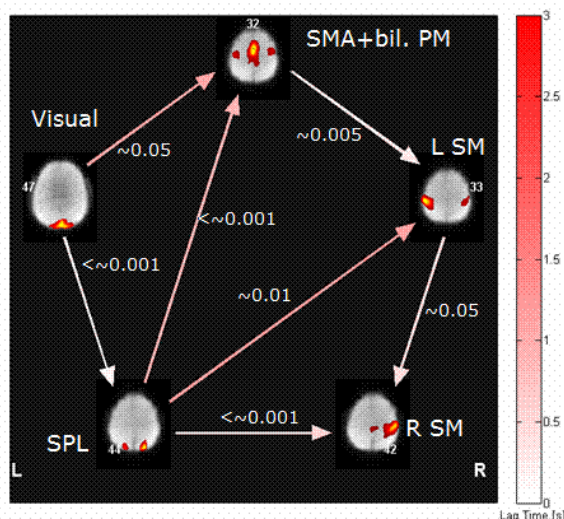(2) analysis of functional network (FN)

Processing of FN included (1) preprocessing of individual data sets using SPM8 (Functional Imaging Laboratory, UCL, UK) was applied with slice timing, co-registration, spatial normalization and smoothing using a kernel of 2x2x2 mm; (2) group ICA was applied to detect fifty-three spatial components by minimum description length using GIFT (Calhoun et al, 2001) of informax ICA (Computational Neurobiology Laboratory, The Salk Institute for Biological Studies, USA); (3) temporal course of was derived for each individual from GIFT as the regressor for GLM estimation after co-registration/normalization to MNI T1 template and smoothing of 8x8x8 mm in SPM8 for verifying five components of bilateral visual, bilateral superior parietal lobules (SPL), bilateral SMA, premotor (PM) /primary somatomotor cortex (SM) of left cerebrum and premotor (PM) /primary somatomotor cortex (SM) of right cerebrum; and (4) group analyses of maximal lag correlation among selected five components was tested using (1) band-pass filter of 0.1-0.4 Hz after normalization, (2) interval of time lag = -3 to +3 seconds, and (3) one-sample t-test of 11 subjects with statistical criteria of $p<0.001\sim0.05$.

(3) Correlation of laterality index and FN

Maximal lag correlation among selected components was tested with laterality index by linear fitting as R2.

Results

Accuracy of flanker test was 94% in average, and fMR data of all siubjects were included in group ICA. Five functional networks of bilateral visual, bilateral SPL, bilateral SMA/PM, SM of left cerebrum and SM of right cerebrum was confirmed by the correlates in Talaraich space as Brodmann areas of bilateral 17/18, bilateral 7, bilateral 6,left 4/6 and right 4/6. The major connectivity of prehension-related FNs was illustrated by **Figure 1** with starting at visual FN followed by bilateral SPL, bilateral SMA+bilateral PM, right SM and left SM, respectively (statistical criteria: p<0.005). Other less dominant connectivity was noted (1) between bilateral SPL and left SM (p<0.01), (2) between bilateral visual and bilateral SMA+bilateral PM (p<0.05) and (3) between left SM and right SM (p<0.05). The R2 of linear correlation of laterality index and maximal lag correlation of the major connectivity path (visual-SPL- SMA+bilateral PM-right SM-left SM) was 0.6-0.7.

Figure 1 : Connectivity of functional networks related to prehension was demonstrated by the averaged lag time (0-3 seconds as indicated by arrow color-scale) and one-sample t test, respectively.

Discussion and Conclusion

For validation of the analysis of network connectivity by applying the lag correlation, the visuo-motor fMRI paradigm mimicking prehension confirmed the well-accepted prehension model involving bilateral visual, bilateral parietal cortices of dorsal stream, SMA and premotor/primary motor cortices. And the strength of connectivity can be verified by the laterality index. Dominant connectivity between SPL and right somatomotor cortex suggested motor modulation at high parietal level other than inter-hemispheric modulation. And minor connectivity between bilateral SPL and left SM suggested alternative pathway for essential function. Confounding effects of physiological signals in the lag correlation analysis was in progress for addressing the temporal auto-correlation of fMRI time course of ICA components.

Acknowledgement

References

Grafton ST 2010 Exp. Brain Res 204:475-491; Calhoun et al (2001) Hum. Brain Map., 14, 140