Preoperative Mapping of Language with fMRI: Frequency Maps and Comparison of Three Tasks in Healthy Subjects

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Background

Preoperative mapping of language with fMRI is often requested by neurosurgeons to determine accessibility and extention of resectability of a brain tumor. Large interindividual variability in location of cortex responsible for speech production has been shown with intraoperative electrocortical mapping (ECM) by Ojemann et al.[1]. Validation of fMRI results with ECM has shown a sensitivity of 75% [2] for the verb generation (VGEN) paradigm. Sensitivity of fMRI might improve with more than one paradigm.

Aim

Compute and compare frequency maps of fMRI activations of three language paradigms in healthy subjects. Determine which task activates best IFG (Broca), DLPFC, STS and STG (Wernicke), IPL and SMG (Geschwind).

fMRI Methods

fMRI was performed at 1.5 Tesla in 30 healthy subjects (F:M=15:15, range 27-40 yo, mean age 30 yo) with SS-EPI (TR/TE= 3000/52 ms; 2x2x4mm^3 voxel size; 24 slices). In the same session three paradigms were presented: Word Generation (WGEN), Verb Generation (VGEN) and Sentence Comprehension (SC). A block design with two conditions (rest and the language task), 8 epochs/block and 72 volumes was administered with visual input using Eloquence (In Vivo Inc.).

Image Analysis

Analysis were performed in Brain Voyager QX (Brain Innovation B.V.). For each subject, grey matter was automatically segmented from T1-weighted images after realignment to the AC-PC place, and the results were visually controlled and manually corrected. A surface rendering of the each hemisphere was build, inflated, distortion-corrected and mapped onto a standard sphere (40962 vertices). After this, each surface entered into a process of dynamic multi-level cortex-based alignment that employs informations about the curvature of the cortex to account for the sulcal and gyral morphology of each subject. EPI volumes' preprocessing involved slice scan time correction, motion correction, linear trend removal, gaussian spatial smoothing. After registration with the anatomical scan a statistical group-analysis of functional data was carried out on the cortical voxels only, with separate predictors for each subject. Data for each voxel were regressed against the boxcar waveform of the design, convolved with a canonical HRF. The computed statistical maps were corrected with a false discovery rate of $q(FDR) < 0.05$, which led to a $p < 0.0004$. After that, each subject's thresholded map was binarized, and with an in-house Matlab script we calculated for each vertex of the standard sphere how many subjects had an above-threshold statistics in that vertex. This allowed us to to build frequency maps for each vertex with values ranging from 0 (no subject) to at most 30 (all subjects).

Results

In Broca's area frequency of activated subjects par voxel was higher for the WGEN than for the VGEN and SC task. VGEN resulted the best task to activate the left DLPFC, while the SC task activated Wernicke in a larger number of subjects. The pattern of variability shown by the frequency maps appears to be consistent with cytoarchitectonical maps of area 44 and 45 as reported by Amunts et al. [3], and with the notion of Broca's, Wernicke's and Geschwind's territories proposed by Catani et al. [4]. The high intersubject variability shown by the low frequency of subjects per vertex in the right hemisphere is a strong indicator of the fact that the vertices overlapping in the left hemisphere has not been achieved by chance. The highest variability across paradigms was shown in posterior parietal areas, particulary in the regions of supramarginal gyrus, inferior parietal lobule and intraparietal sulcus. A consistent result was also recorded in the supplementary and pre-supplementary motor areas of the mesial surface of the left hemisphere, again with variability across tasks.

Conclusions

Frequency maps for WGEN, VGEN and SC were strongly consistent with known location of frontal, temporal and parietal regions of the language network. This study highlights the importance of employing different language paradigms according to the area of interest in presurgical planning.

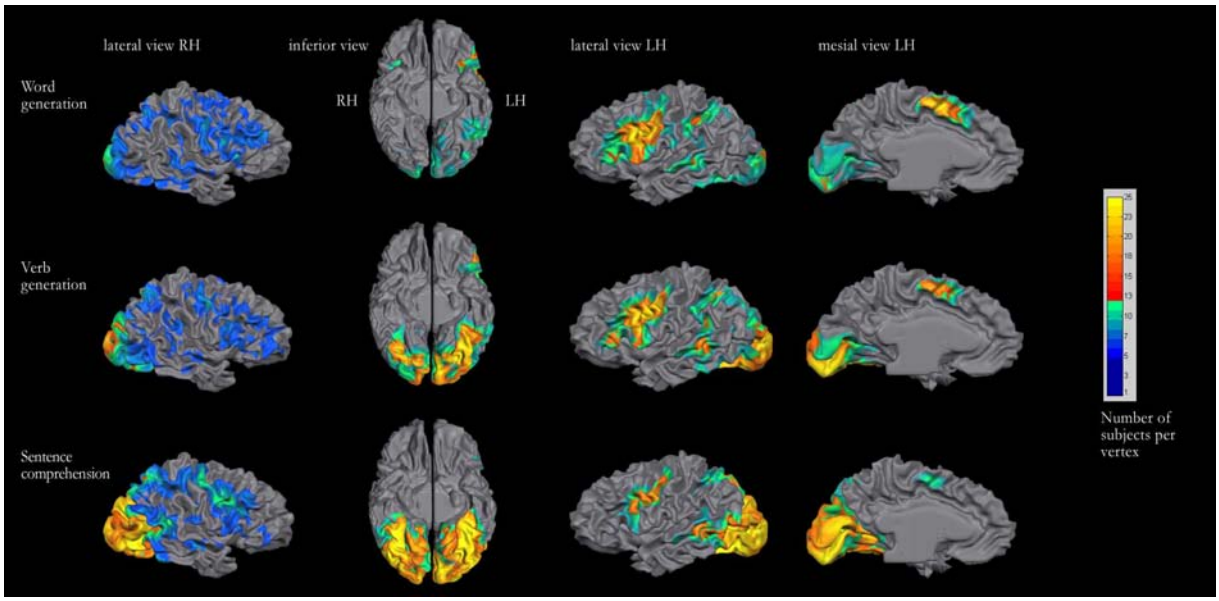

Fig. 1. Frequency maps of the 3 language paradigms in N=30 subjects. Different colors refer to different number of subjects each showing above-threshold t value in their own statistic map. In the left hemisphere values have been thresholded at q(FDR)<0.05 (p<0.0004) *and* N>=5. In the right hemisphere, values have been thresholded at the same statistical value but with N>=1 for subjects to show the high variability compared to left hemisphere.

References

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