Contribution of Language Processing Areas to Verb Generation and Picture Naming: fMRI Evidence

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INTRODUCTION

Noninvasive functional imaging methods are a potential source of new data on language organization in the intact human brain. The capabilities of fMRI for localizing primary sensory and motor areas are now well established, and preliminary studies of higher cognitive functions also have been reported, but the validity of the activation procedures used and the reliability of responses in these procedures remain controversial. In this study, the text and picture stimuli were used to investigate the activation patterns of semantic and lexical retrieval using fMRI with verb generation (VG) as well as picture naming (PN) paradigms, for the further purpose using in clinical neurosurgery [1].

MATERIALS AND METHODS

Fifteen right-handed healthy volunteers (8 male, 7 female, 35.7±13.6 yrs) were recruited and informed written consents were provided. All studies were carried out on a 3T MR system (Siemens Trio). High-resolution anatomic images were obtained for each participant. Functional images were collected with standard EPI measurement (TR 3000ms, TE 30ms, matrix 64*64, 30 axial slices including all cerebral areas, isotropic resolution of 3mm) with retrospective motion and distortion correction. Three functional scans were performed for every subject, including two language tasks and one motor task based on block-designs. Covert VG and PN were used as the linguistic stimulation paradigms, each with 96 repetitions (15s task and 21s control state alternately). As well as right fingers tapping with 64 repetitions (24s task and 24s rest alternately) was added as intrinsic statistic references for evaluation individual neuronal activation. The participant viewed the display through an angled mirror attached to the head coil. All data sets were processed with SPM5. After smoothing with an 8 mm Gaussian kernel voxel exceeding a statistical threshold of $p<0.001$ (FWE corrected) were considered to be activated under a general linear model. Group activations were extracted from the 2nd level group analysis with a uniform threshold ($p<0.01$, FWE corrected). The coordinates of activations were transferred into Talairach and corresponding Brodmann areas (BA).

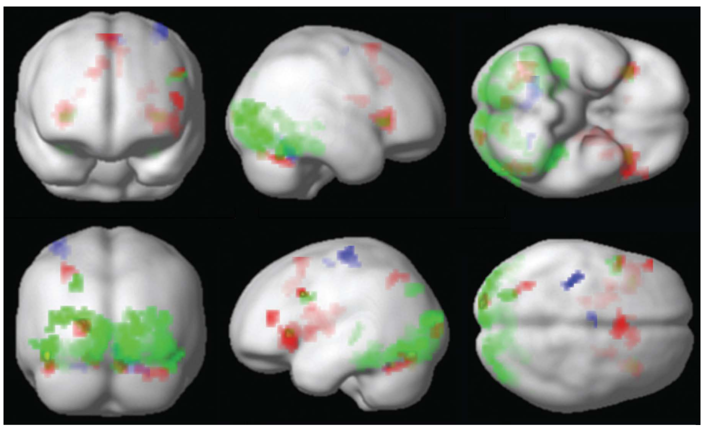

Fig. 1: Brain activity of group analysis for 15 volunteers performing language and motor tasks. Statistical parametric maps of the *t* statistics for Verb Generation (red), Picture Naming (green), and Right finger-tapping (blue) rendered onto a smooth brain, thresholded at $p<0.01$, FWE corrected.

A Lateralization Index (LI) was calculated for each subject based on respective language activations from VG and PN, excluding the occipital cortex. LI was defined as the difference between the number of activated pixels in the left (L) and right (R) hemispheres divided by the total number of activated pixels [$LI= (\sum L-\sum R)/(\sum L+\sum R)$, a positive LI indicates left hemisphere lateralization and a negative number indicates right lateralization. Numbers close to zero (i.e., $-0.1 \leq LI \leq 0.1$) indicate a bilateral language distribution].

RESULTS

VG activated mainly the bilateral Broca's area (BA45), the left dorsolateral prefrontal cortex (BA46), Wernick's area (BA39), as well as supplementary motor area (BA6) and fusiform gyrus (BA37). PN activated visual cortex (BA18) significantly, as well as BA37, BA7, BA45, and BA9 areas, mostly in the left cerebrum. Left primary (BA4) and supplementary motor cortex (BA6) were moderately activated during finger-tapping task. Representative maps are shown in Figure 1. The diagnostic accordance rate of LI from PN and VG was 93.3% (14/15), which included 12 cases of left hemisphere lateralization, 1 left lateralization as well as 1 bilateral language distribution. The results of the quantitative evaluation are shown in Table 1.

sub	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LI (VG)	0.62	-0.15	0.80	0.86	0.76	-0.08	0.36	0.70	0.10	0.86	0.57	0.55	0.76	0.54	0.60
LI (PN)	*	-0.54	0.46	0.16	0.58	-0.01	0.05	0.63	0.54	0.45	0.47	0.18	0.72	0.87	0.39
Lateralization	L	R	L	L	L	**	L	L	L	L	L	L	L	L	L
L: left lateralization; R: right lateralization; *: only visual cortex activation, excluding from calculation; **: bilateral distribution															

Table 1. Quantitative evaluation of Lateralization Index (LI) and language distribution.

DISCUSSION

1) This study demonstrates that PN and VG generate two different activation patterns. In VG, the participants must creatively link a noun to a verb with freedom to choose amongst competing response alternatives, requiring more executive-level semantic selection, and the activations highlighted the main semantic processing area and lateralized by the hemispheric language dominance [2, 3]. For PN, there is usually only one correct answer, and the task of associating a concretely presented object with a noun is one of the earliest linguistic skills mastered developmentally [4]. PN activated most of the occipital cortex and reflected an early developmental language area without prominent contribution from hemispheric dominance. 2) Defining language lateralization is important in order to minimize the risk of postoperative functional deficit in patients surgically treated in the language dominant hemisphere. But the optimal LI calculation method remains unclear [5]. Using our modified LI formula excluding the occipital activations, the coincidence rate of LI retrieved separately from VG and PN for the same subject were 93.3%, which indicated the two linguistic paradigms could produce significant consistency for determination of language dominance.3) fMRI provides more detailed information about the localization of language cortex, but it is difficult to dissociate true activations from spurious ones. The use of threshold can both help and hurt [6]. In present study the threshold of motor activation was set as intrinsic statistical criteria for language tasks, this could help reducing the spurious activations to some extent and indicating the performance while subject's finger-tapping. Therefore, VG is a reliable method for linguistic functional mapping while PN could detect the early developmental area. Combined could reveal the localization of areas involved in language processing and evaluate language lateralization. Our study laid the practical and theoretical foundation for a routine component of the presurgical evaluation.

REFRENCES

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