Cognitive Modules Utilized for Covert Verb Generation in Children: A Functinal Magnetic Resonance Imaging Study

P. R. Karunanayaka[1], V. J. Schmithorst[1], and S. K. Holland[1]

[1]Imaging Research Center, Department of Radiology, Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, United States

Introduction

Group ICA is a data-driven technique that has been applied to functional MRI (fMRI) data in order to reveal the dynamic functional organization of the human brain [1, 2, 3]. To investigate the neuroanatomical bases of covert verb generation in children we used the fMRI paradigm of silent verb generation (VG). Group Independent Component Analysis (ICA) was used to investigate the cognitive modules involved in covert verb generation [4].

Materials and Methods

Three hundred thirty-six children (165 boys, 171 girls) took part in the study using a Bruker 3T Medspec imaging system. EPI-fMRI scan parameters were: TR/TE = 3000/38 ms; BW = 125 kHz; FOV = 25.6 X 25.6 cm; matrix = 64 X 64; slice thickness = 5 mm. The fMRI paradigm consisted of a silent verb generation task detailed in [3]. A 30 second on-off block design was used. During the active epochs, the subjects silently generated appropriate verbs, such as "throw" or "kick", to aurally-presented nouns such as "ball". During the control epochs, subjects tapped their fingers when they heard a warble tone, designed to control for sublexical auditory processing.

The group ICA analysis was based on FastICA algorithm and performed according to the methods outlined in [3]. Furthermore, a random-effects GLM analysis was performed to generate a group activation map for the entire cohort.

Results and Discussion

Fig. 1 shows the group activation map from a random-effects GLM analysis (p < 1e-10, corrected). The group ICA method has detected several additional language circuits which were not detected in the standard GLM analysis (Fig. 2).

Fig. 2 shows the seven task-related group ICA maps ordered according to the phase of the average Fourier component of each ICA map makes with the on-off task reference time course. Table 1 shows the brain region coordinates for the first three component maps shown in Fig.1. The presence of different cortical regions in the same ICA map implies that the regions are functionally connected. The correlation co-efficients of average time courses with the on-off task reference function were 0.73, 0.77, 0.84, 0.92, 0.63, 0.86 and 0.43 respectively.

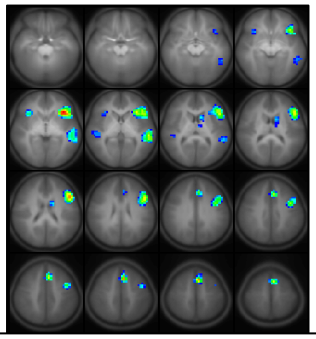

Figure 1. Results from a random-effects GLM analysis of 336 children performing a verb generation task.

The power of ICA over GLM for detecting additional activated brain regions has been discussed elsewhere [5]. ICA detects classic left language areas shown in Fig. 1. In addition, bilateral activation is detected in Parahippocampal Gyrus, Inferior Temporal Gyrus, Medial Temporal Gyrus and the Inferior Frontal Gyrus. VG task is highly left lateralized. A similar, left hemispheric specialization is detected in the group ICA analysis (fig. 1d). The group ICA has the advantage of not requiring any prior knowledge of the design matrix or the hemodynamic response function (HRF) across subjects. This is a huge advantage in fMRI data analysis as macro-level cognitive processes show large variance across subjects and may not correlate well with the typical regressor used in standard GLM.

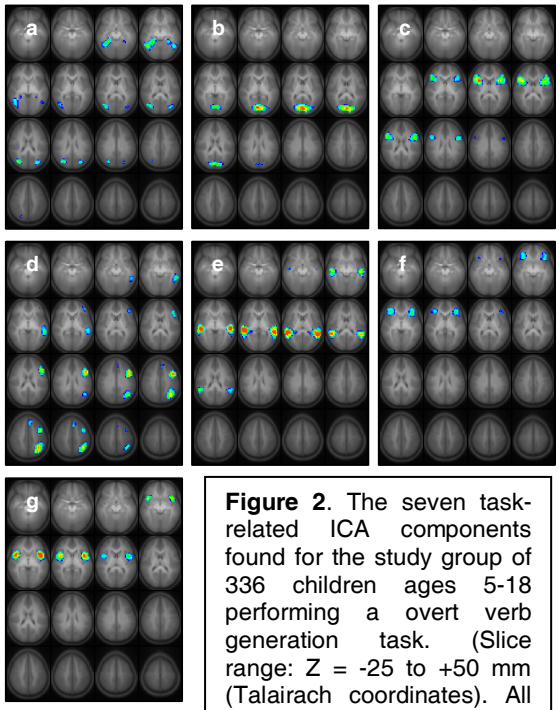

Figure 2. The seven task-related ICA components found for the study group of 336 children ages 5-18 performing a overt verb generation task. (Slice range: Z = -25 to +50 mm (Talairach coordinates). All images are in radiological orientation.)

Component	Region	BA
1a	R. Parahippocampal Gyrus	30/35
	L. Parahippocampal Gyrus	30/35
	R. Inferior Temporal Gyrus	19/37
	L. Inferior Temporal Gyrus	19/37
	R. Medial Temporal Gyrus	19/39
	L. Medial Temporal Gyrus	19/39
1b	Cuneus	17
1c	R. Inferior Frontal Gyrus	44
	L. Inferior Frontal Gyrus	44

Table 1. Brain regions for the first three ICA maps shown in Figure 2.

The development changes associated with individual IC time courses can also be investigated using similar data-driven methods discussed in [3].

Conclusion

The cognitive modules of verb generation were investigated using the fMRI paradigm of silent verb generation and group ICA. Group ICA is a powerful data-driven technique capturing more information from data than conventional hypothesis driven techniques. Group ICA can also be combined with functional and effective connectivity analysis techniques [6]. The results show the advantage of investigating covert verb generation in terms of cognitive modules.

References

[1] Calhoun VD, et al., *Hum. Brain Mapp.*, 14, 140-151, 2001. [2] McKeown MJ, et al., *Hum. Brain Mapp.*, 6, 160-188, 1998. [3] Schmithorst VJ, Holland SK, et al., *Neuroimage*, 29:254-266, 2005. [4] Holland SK, Plante KE, et al., *Neuroimage*, 14 (4):837-843, 2001. [5] Schmithorst VJ, Brown RD, *Neuroimage*, 22 (3):1414-1420, 2004. [6] Karunanayaka PK, Holland SK, et al., *Neuroimage,* Inpress.