AGE-RELATED CONNECTIVITY CHANGES IN fMRI DATA FROM CHILDREN PERFORMING A COVERT VERB GENERATION TASK

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Introduction

The neuroanatomical bases of covert verb generation ((VG) in children is investigated using a functional MRI (fMRI) paradigm. Structural Equation Modeling (SEM) and group independent component analysis [1] was combined to investigate the age-related connectivity changes among brain regions associated with covert verb generation. Group ICA is a powerful data-driven technique capable of revealing the functional networks of the human brain based on fMRI data [1, 2, 3].

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 [4, 5]. 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 [1]. The components of the SEM were identified based on the group ICA maps (**Fig.1**). For each subject the SEM was evaluated using the Amos software based on individual IC time courses [6]. The model fits were verified based on the $\chi 2$ statistic ($p > 0.05$). Finally, a correlation analysis was performed on the standardized path coefficients to determine any age dependencies.

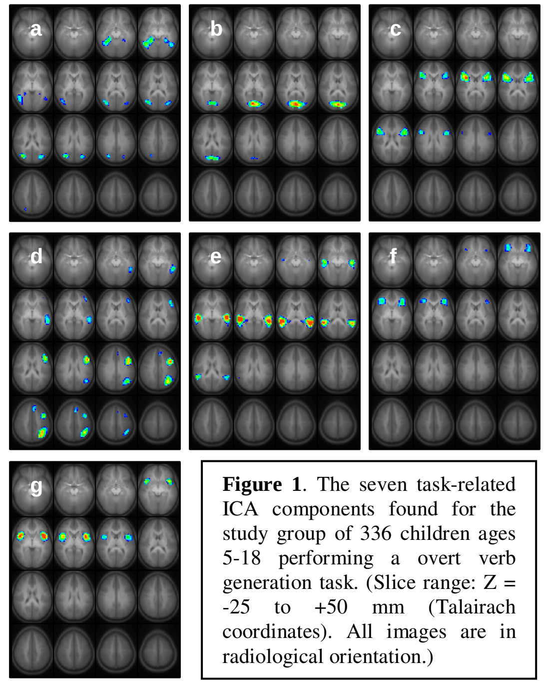

Figure 1. The seven task-related ICA components found for the study group of 336 children ages 5-18 performing a overt verb generation task. (Slice range: Z = -25 to +50 mm (Talairach coordinates). All images are in radiological orientation.)

Results and Discussion

The group ICA method has detected several additional language circuits which were not detected in the standard GLM analysis [7]. **Fig. 1** shows the seven task-related group ICA maps. Table 1 shows the brain region coordinates for the component maps shown in **Fig.1**. The power of ICA over GLM for detecting additional activated brain regions has been discussed elsewhere [1, 7].

The developmental changes associated with individual IC time courses can also be investigated using similar data-driven methods discussed in [1].The neuroanatomical bases and their development trajectories (in terms of path coefficients) of covert verb generation in children were investigated using the fMRI combined with ICA and SEM. A second level random effects analysis determined that each path coefficient to be significantly different from zero. Some path coefficients in the SEMs exhibited age dependent changes.

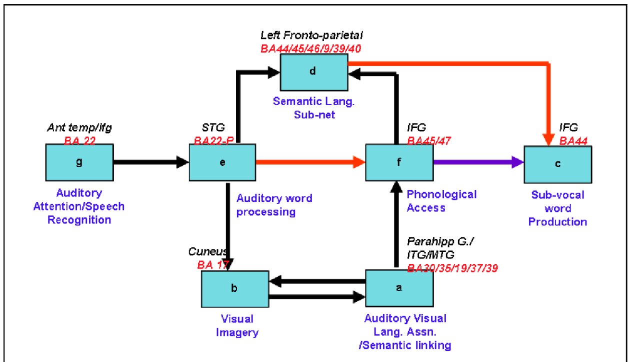

Figure 2. The SEM for the covert verb generation based on ICA maps shown in **Figure 1. Red:** paths that are positively correlated with age**. Purple:** paths that are negatively correlated with age.

Component(IC map)	Region	BA	X, Y, Z
1a	R. Parahippocampal Gyrus L. Parahippocampal Gyrus R. Inferior Temporal Gyrus L. Inferior Temporal Gyrus R. Medial Temporal Gyrus L. Medial Temporal Gyrus	30/35 30/35 19/37 19/37 19/39 19/39	22, -41, -5 -26, -41, -5 42, -57, -5 -46, -57, -5 34, -69, 20 -26, -73, 25
1b	Cuneus	17	2, -77, 10
1c	R. Inferior Frontal Gyrus L. Inferior Frontal Gyrus	44 44	34, 11, 10 -34, 11, 10
1d	L. Medial Temporal Gyrus L. Inferior Frontal Gyrus L. Inferior/Medial Frontal Gyrus L. Middle Frontal Gyrus L. Angular Gyrus/Inferior Parietal Lobule	21 45/46 44/9 6/8 39/40	-54, -41, -5 -46, 27, 15 -42, 7, 35 -6, 23, 45 -30, -65, 40
1e	R. Posterior Superior Temporal Gyrus L. Posterior Superior Temporal Gyrus	22 22	50, -29, 5 -54, -45, 10
1f	R. Inferior Frontal Gyrus L. Inferior Frontal Gyrus	45/47 45/47	30, 31, 0 -38, 23, 0
1g	R. Anterior Superior Temporal Gyrus L. Anterior Superior Temporal Gyrus	22 22	38, 11, 0 -38, 11, 0

Table 1. Brain regions and activation foci for the ICA maps shown in **Figure 2.**

The path coefficients BA 22p → BA 45 BA 39 → BA 44 showed significant increases in connectivity with age ($R = 0.15$, corrected $p < 0.05$ and $R = 0.19$, uncorrected $p < 0.006$) while the path coefficient BA 45 → BA 44 ($R = 0.14$, uncorrected $p < 0.01$) showed a marginally significant decrease in age-related connectivity. The increased ability for language processing with age can be attributed to these changes in path coefficients

The large sample size provides confidence in the results of these statistical methods used in the present analysis. We will discuss the relation of the age dependent path coefficients in our model to brain development and language proficiency.

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] to investigate the age dependent trends in language circuitry. The results show the advantage of investigating covert verb generation in terms of cognitive modules and the associated developmental trends in connectivity.

References

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