AGE RELATED CONNECTIVITY CHANGES IN fMRI DATA FROM CHILDREN LISTING TO STORIES

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Introduction

Connectivity analysis methods have recently been applied to fMRI data to investigate the directional flow of information across neural networks in the brain [1, 2]. To investigate age-related changes in brain connectivity associated with language development in children we performed fMRI of narrative story comprehension in a large number of children [3]. Structural Equation Modeling (SEM) was applied to the results obtained from a group independent component analysis (ICA) [3] and the age related differences were examined in terms of changes in path coefficients between brain regions.

Materials and Methods

Three hundred thirteen children (152 boys, 161 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 listening to a story read by an adult female and detailed in [3]. A 30 second on-off block design was used. During the active epochs, the subjects were presented with stories read by an adult female speaker. During the control epochs, to control for sublexical auditory processing, 1 s duration tones at random frequencies (400-2500 Hz) and intervals (1-3 sec) were presented.

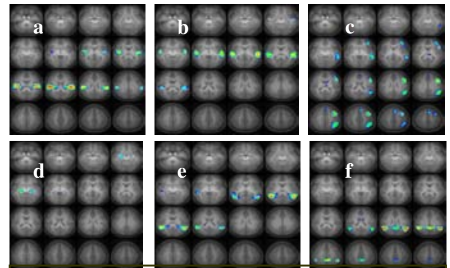
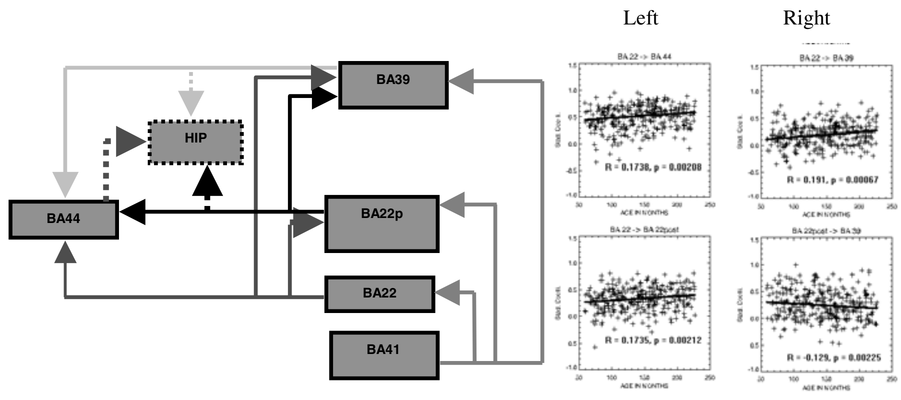


Fig.1. The six task-related ICA components found for the study group of 313 children ages 5-18 performing an auditory narrative comprehension task. The components of the proposed SEMs are based on the six ROIs shown above. (Slice range: Z = -25 to +50 mm (Talairach coordinates). All images are in radiological orientation.)

The components and the corresponding time courses for the SEM were identified based on the ICA maps and the ROIs shown in **Fig. 1**. The classical Wernicke-Geschwind model for speech processing is expanded to a two-route model involving a direct route between Broca's and Wernicke's area and an indirect route involving the parietal lobe (**Fig. 2.(a)**).The left and right hemisphere circuits were analyzed using two representative SEMs and were forced to have equal components to facilitate a consistent comparison. This was achieved by generating a time course consisting of Gaussian white noise to represent the BA 44 in the right hemispheric SEM. The equations were solved using the Amos software as described by Arbuckle [4], which utilizes an iterative maximum likelihood method to determine the optimal connection strengths in the SEMs. The model fits were verified based on the $\chi 2$ statistic ($p < 0.05$). A second level correlation analysis was performed to determine any age dependencies of the standardized path coefficients.

Results and Discussion

Several path coefficients of the proposed SEMs for narrative comprehension exhibited age dependent changes (Figure 2). For the simplified SEM (excluding the Hippocampus) the left hemispheric circuit exhibited age dependent changes in three path coefficients. The path coefficient BA 41 -> BA 22 showed a nominally significant increase in connectivity with age ($R = 0.11$, $p < 0.044$). The path coefficients BA 22 -> BA 44 ($R = 0.1738$, $p < 0.00208$) and BA 22 -> BA 22post ($R = 0.1735$, $p < 0.00212$) showed highly significant age related connectivity changes. The increase in the left hemispheric dominance for language processing with age can be attributed to the maturation of these two path coefficients. As for the right hemispheric circuit three path coefficients BA 41 -> BA 22 ($R = 0.15$, $p < 0.0065$) and BA 22 -> BA 39 ($R = 0.191$, $p < 0.00067$) and BA 22post -> BA 39 ($R = -0.129$, $p < 0.00225$) showed highly significant age related connectivity changes. The involvement of BA 39 in these connectivity changes signifies the importance of right hemisphere in narrative comprehension.



(a) (b)

Fig.2. **(a)**. The SEM for the narrative language comprehension circuit based on ICA maps shown in **Fig. 1**. The simplified SEM for the narrative language comprehension does not include the hippocampus, drawn in dashed lines. **(b)**. The age related changes in the standardized path coefficients in the left and right hemispheres for the simplified SEM.

For the simplified SEM, 83% of subjects exhibited good model fits for the left hemisphere and all subjects provided satisfactory model fits for the right hemisphere. As for the complete SEM, exactly the same path coefficients showed age dependent changes but with diminished model fit parameters. This may be due to the involvement of hippocampus in episodic memory thereby accounting for a large inter subject variability [3].

Conclusion

The neuroanatomical bases and their development trajectories (in terms of path coefficients) of narrative comprehension in children were investigated using the fMRI paradigm of story comprehension. Some path coefficients in the SEMs exhibited age dependent changes while others did not. The results support recent hypotheses regarding the functional segregation in Broca's and Wernicke's areas [5], the key role of the right hemisphere in narrative comprehension and the increased left hemispheric dominance for language processing with age. We will discuss the relation of the age dependent path coefficients in our models to brain development and language proficiency.

References

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