Differential cerebellar activation patterns for perception of sign language and written text

E. R. Gizewski[1], N. Lambertz[1], D. Timmann[2], M. Forsting[1]

[1]Dept. of Diagnostic and Interventional Radiology, University Hospital Essen, Essen, Germany, [2]Dept. of Neurology, University Hospital Essen, Essen, Germany

Introduction

For a long time the cerebellum was considered to be involved only in sensorimotor processes. Recent findings suggest that the human cerebellum may be involved in various cognitive and language functions [1,2].

Deaf individuals have been volunteers in fMRI studies to investigate cross modal plasticity for the auditory cortex during sign language perception. Sign language was also used to study the language functions of the human brain, in particular the hemispheric specialization for language [3,4].

German sign language (GSL) demonstrate a language system with a different way of perception compared to written texts. Deaf subjects can perfectly understand GSL, but they often have problems with written texts and especially with its grammar structure. On this background the question arose, whether there is cerebellar activity during GSL perception due to language performance.

Materials and Methods:

Twelve deaf right handed volunteers (mean age 46 years), with good or excellent knowledge in GSL and basics in written text understanding. The reading skills were judged by each subject on a scale from 0 to 10. The range in deaf subjects was from 6 to 10 for sign language and 3 to 6 for text reading. Control group: twelve hearing right-handed volunteers, none able to understand GSL.

BOLD contrast images were acquired using an echo-planar technique (TR 3300 ms, TE 50 ms, flip angle 90°, FOV 220 - 240 mm, matrix 64 * 64, 34 transversal slices, thickness 3 mm, 0.3 mm slice gap) using a 1.5 T MR (Sonata) with a standard headcoil. A 3D FLASH sequence was acquired for individual coregistration of functional and structural images.

Condition 1: video with a female translator telling a narrative text by performing GSL during the active period and senseless gestures in the resting period. Condition 2: written narrative text alternating with senseless characters. All stimuli were presented using a computer driven light projector and a screen. All stimuli were presented in a block design.

Data analysis: SPM 99 (Wellcome Department of Cognitive Neurology, London, UK). Prior to statistical analysis images were realigned, normalized and smoothed. A voxel-by-voxel comparison according to the general linear model was used. For group analysis single subject contrast images were entered into a random effects model. The threshold was set to $p < 0.001$ (uncorrected for multiple comparisons). Cerebellar lobules were defined according to the 3D MR atlas of the human cerebellum developed by Schmahmann et al.[5].

Results:

Sign language tasks: Group analysis of all deaf individuals perceiving sign language revealed significant cerebellar activation in hemispheral lobule Crus I bilaterally with a right pronouncement (Fig. 1 a). In hearing volunteers who had no knowledge in sign language, only a small activation of cerebellar hemispheral lobule Crus I was revealed (Fig. 1 c).

Text reading tasks: Deaf individuals did not reveal any activation of Crus I (Fig. 1 b) and had a poor text understanding. In hearing adults with good text understanding an activation of Crus I during text reading could be revealed (Fig. 1 d).

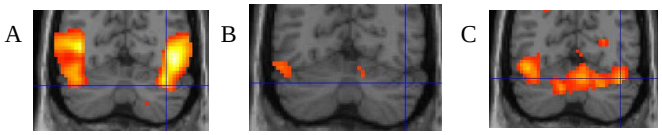

Fig. 1:
A: Statistical parametric maps of cerebellar activation within the group of deaf subjects perceiving sign language compared with rest period. B: reading a written text.
C: Activation within the group of normal hearing subjects during reading a written text compared with rest period Statistical corrected threshold is $p<0.05$.

Discussion:

The present finding reveal activation of the posterior cerebellar hemispheres (that is of Crus I) during different language perception tasks which has been described by Fulbright et al. for reading tasks [6]. The same area was activated in our group of hearing volunteers reading the narrative text and the deaf volunteers perceiving sign language as well as blind subjects during Braille reading [1]. Therefore, activation in Crus I may be related to language or reading specific processes. However, further possibilities besides involvement of Crus I in higher speech functions need to be considered: it may reflect increased attentional demands during a reading task compared to rest condition. We would assume a higher attention in deaf subjects for the more difficult task of text reading than perceiving sign language. But, we found Crus I activation during the sign language task. Even more importantly, activation in Crus I may reflect sensorimotor activation based on inner speech. Deaf subjects perceiving sign language and sighted subjects reading a written text may use inner speech during these tasks which may involve the same cerebellar areas during both tasks.

In conclusion, bilateral cerebellar activation in Crus I in deaf subjects during sign language perception may be due to processes similar to these found in normal hearing volunteers during text reading and correspond to activation extend of language related cerebral areas.

References:

1. Gizewski, E.R., Timmann, D. & Forsting, M. *Hum Brain Map* **22**, 229-35 (2004).
2. Gruber, O. *Cereb Cortex* **11**, 1047-55. (2001).
3. Bavelier, D., Corina, D.P. & Neville, H.J *Neuron* **21**, 275-8. (1998).
4. Newman, A.J., Bavelier, D., Corina, D., Jezzard, P. & Neville, H.J. *Nat Neurosci* **5**, 76-80. (2002).
5. Schmahmann, J.D., Doyon, J., Toga, A.W., Petrides, M. & Evans, A.C. (Academic press, San Diego, 2000).
6. Fulbright, R.K. et al. *AJNR Am J Neuroradiol* **20**, 1925-30. (1999).