ACTA NEUROBIOLOGIAE EXPERIMENTALIS

Acta Neurobiol. Exp. 1993, 53: 263-267

# Brain lateralization and severity of stuttering in children

**Elżbieta Szeląg**[1], **Danuta Garwarska-Kolek**[2], **Anna Herman**[1] and **Janina Stąsiek**[1]

[1] Department of Neurophysiology, Nencki Institute of Experimental Biology, 3 Pasteur St., 02-093 Warsaw, Poland; [2] Monument Hospital of the Child's Health Centre, 20 Dzieci Polskich St., 04-796 Warsaw, Poland

**Abstract.** Cerebral lateralization in visual perception was investigated in 9 severe stuttering, 11 mild stuttering and 48 fluent speakers. The subjects were asked to identify words presented in the left or right visual field for 20 ms. Children responded by pointing to the exposed test word on a response card which contained four different words. Errors committed in the left and right visual fields were analyzed. The data showed a left hemisphere superiority in the processing of words in both the mild stutterers and the fluent speakers, but a right hemisphere advantage in the severe stutterers. The results suggest a close relationship between the severity of stuttering and functional brain organization.

**Key words:** hemispheric asymmetry, severity of stuttering, severe stuttering, mild stuttering

## INTRODUCTION

A number of investigations have shown that linguistic organization of the brain in stutterers is similar to those of non-stutterers (Fox 1966, Dorman and Porter 1975, Pinsky and Mc Adam 1980). A series of other studies, however, has provided data suggesting that stutterers have linguistic processing capacities different from those of normal speakers (Moore 1976, Rosenfield and Goodglass 1980, Hand and Haynes 1983, Rastatter and Dell 1987, Wells and Moore 1990). The data of these studies indicate a greater right hemisphere involvement during the processing of linguistic stimuli, or a decrease in left hemisphere participation in stutterers, when compared to fluent control group. Recent speculations about possible mechanisms responsible for these differences include right hemisphere interference (Rastatter and Loren 1988), callosal gating (Webster 1988) and increased levels of particular neurotransmitters (Rastatter and Harr 1988).

It is not clear why the results of the above researches are inconsistent. Based on both speech therapists' experience and relevant literature, it might be postulated that severe stuttering constitutes not the same speech disturbance as mild. The therapy is also much more complicated in severe stuttering than in mild. Therefore, the disagreement of authors' opinion concerning hemispheric organization in stutterers could be attributed to the fact that in previous researches the severity of stuttering was considered only exceptionally.

In fact, Rastatter and Dell (1987 a, b) compared the hemispheric asymmetry in severe and moderate stuttering but they found no interdependence between stuttering severity and functional hemispheric organization. On the other hand, using the alpha rhythm asymmetry technique, Moore (1980), Moore and Haynes (1980), Moore (1986), Wells and Moore (1990) found greater right hemisphere activation associated with dysfluent speech and a shift to more left hemisphere activation with increased fluency. Furthermore, Wood et al. (1980) revealed greater right anterior cerebral blood flow in stutterers during reading and a shift to the left with increased fluency. According to this, the purpose of the present study was to compare the hemispheric asymmetry in processing verbal information in severe and mild stuttering.

## METHOD

### Subjects

Three groups of subjects were tested: nine severe stutterers (7 boys and 2 girls), eleven mild stutterers (9 boys and 2 girls) and forty eight normal speakers (24 boys and 24 girls). The severity of stuttering was assessed on the Iowa 7-point scale (Johnson and Darley 1963). On the basis of this scale stuttering was defined as part- and whole- word repetitions, sound prolongations, tension, dysfluency and distracting associated movements of body, arms, legs and head. The fluency data for the stuttering subjects were collected during two speaking conditions: monologue in isolation and reading aloud. All stutterers were Rehabilitation Centre patients. They were tested prior to the stuttering therapy. All subjects were 14-16 years old, right-handed as determined using Briggs and Nebes (1975) questionnaire and had normal vision. They were native Polish speakers. They reported neither brain damage, neurological disorders or systematic diseases nor use of medicaments affecting the central nervous system.

### Material

The material consisted of 21 concrete 3-letter nouns. The stimuli were presented in the form of slides projected on a screen by a Kodak-Carousel projector equipped with an electronic shutter. The stimuli were projected to the right or to the left side of a fixation point which was a black spot (0.38 degrees in diameter) placed in the centre of the screen. The distance between the fixation point and the stimulus was 2 degrees. The words were exposed vertically. The height of each word was 2.5 deg., its width 0.42 deg. and the distance between letters 0.3 deg. The exposure time of each word was 20 ms.

### Procedure

The experiment was conducted in a sound-proof chamber. A child sat at a distance of 1.7 m from the screen on which the words were presented. The subjects' task was to concentrate his or her vision on the fixation point and recognize the exposed test word. The subjects answer consisted in pointing to a chosen test. The task was to recognize the test word on a response card containing four different words. To increase the probability that the identification of material was done on semantic rather than the visuo-spatial level of processing, the words were presented vertically on the screen and horizontally on the response cards (Czachowska-Sieszycka and Szeląg 1985).

Of the four words presented on the response card, one differed from the test word in one letter, one in two letters, one in three letters. The fourth word was identical with the test word. There were 21 response cards. The words which differed in one letter contained that letter either in the initial position (7 times), in the middle of the word (7 times) or in the final position (7 times). In the words which differed in two letters, the letter common with the test word was in the initial position (7 times), in the centre (7 times) or in the final position (7 times). Moreover, the position of the four words on each card was random. Neither group of subjects had difficulty reading words used in the experiment. At the beginning of the experiment the condition of stimuli exposure was adjusted by setting the brightness of stimuli individually for each subject in order to obtain 20-30% of errors. The experiment consisted of one experimental session lasting approximately 1 hour. In the session 84 stimulus words were presented (each word was presented 4 times). In half of the trials of each session, the stimuli were exposed in the right visual field and in the other half in the left visual field. The order of exposure was random. The stimuli were presented in 21-element series separated by 2-minute rest breaks. Throughout the experiment, one of the researchers monitored on a TV screen the subject's behaviour, especially his eye movements. Trials where eye movements occurred were dismissed.

## RESULTS

The data were submitted to a two factors analysis of variance with repeated measures. Visual field (left, right) and the group of subjects (severe stuttering, mild stuttering, normal speaking) were the within-subjects and the between-subjects variables, respectively. The analysis of variance showed significant interaction between the two factors ($F$=15.01, $df$=2/65, $P$<0.001). This interaction resulted from different visual field asymmetry in severe stuttering, mild stuttering and controls (Fig. 1).

In normal speakers the mean percentage of errors in the right visual field was significantly lower than in the left one ($P$<0.001, 2-tail-Student $t$-test). In mild stuttering the pattern of relationships was similar to that found in normal speakers i.e. the mean percentage of errors in the right visual field was significantly lower than in the left visual field ($P$<0.003, 2-tail-Student $t$-test). The opposite direction of differences was observed in severe stuttering. The mean percentage of errors in the right visual field was higher than in the left one. This difference, however, did not reach statistical significance.

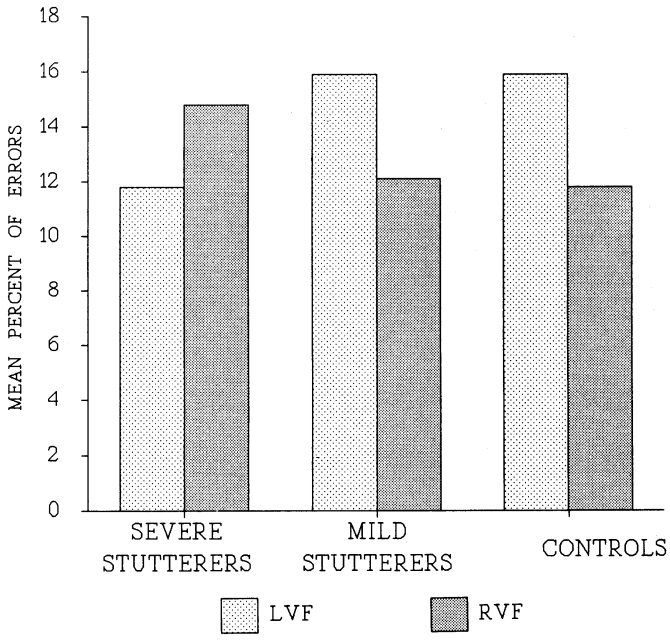


Fig. 1. The mean percent of errors in the left and right visual fields in the severe stutterers, the mild stutterers and the fluent speakers.

Additionally, a Chi-square test revealed that the three groups of subjects differed in the number of children showing the left or right visual field advantage ($P<0.001$). For 45 normal speakers and for 10 mild stutterers the percentage of errors in the right visual field was smaller than in the left one; for the remaining 3 normal speakers and 1 mild stutterer the opposite direction of difference was observed i.e. fewer errors on words presented in the left visual field than in the right one. The normal speakers did not differ from mild stutterers in the number of subjects showing the advantage of the right visual field. On the other hand, for the severe stutterers in 8 subjects the mean percentage of errors in the right visual field was higher than in the left one, whereas the opposite pattern of difference was observed for 1 subject only who committed fewer errors in the right visual field than in the left one. Severe stuttering differed significantly from normal speakers as well as from mild stutterers in the number of subjects showing the advantage of the left or right visual field ($P<0.001$ and $P<0.007$ respectively).

It is also noteworthy that the opposite visual field advantage in severe stuttering as compared to control group and mild stuttering, resulted from both significantly higher performance in the left visual field and significantly lower performance in the right visual field (Tukey-HSD test, $P<0.01$, Fig. 1).

## DISCUSSION

One of the major findings of our investigation was that the group of the severe stutterers demonstrated the opposite pattern of hemispheric asymmetry than the mild stutterers and the normal speakers. Indeed, the performance of the severe stutterers showed that in the processing of verbal material, the right hemisphere prevailed. On the contrary, the pattern of hemispheric asymmetry in the mild stutterers was similar to that found in the normal speakers. Both the mild stuttering and the fluent speakers demonstrated the dominance of the left hemisphere in the recognition of words . Moreover, the opposite pattern of asymmetry in the severe stutterers resulted both from higher capacities of their right hemispheres and from lower capacities of their left hemisphere in word processing (see Fig.1). Thus the results of our study suggest that in the severe stutterers the right hemisphere plays a crucial role in the analysis of verbal stimuli.

According to Moore and Haynes (1980), we might also hypothesize the possible mechanisms responsible for these differences. The fluent speech of normal-speaking subjects has been shown to be dependent on left hemispheric perceptual and motor programming functions of language (i.e. Beaumont 1982). If, as Poppel suggests, language is a segmental phenomenon (Poppel 1987, Poppel et al. 1991) and the motor planning for speech also involves the arrangements of segments in the articulatory program then the left hemisphere mode of processing seems to be more adequate for such functions. As in the severe stutterers the right hemisphere seems to play more important role in both language perception and motor programming (Moore and Hayness 1980) the efficiency of there processes might be insufficient, leading at a behavioural level to a severe dysfluency. In the mild stutterers, on the other hand, the right hemisphere is probably less involved in processing of linguistic information, so they demonstrated only rather mild dysfluency, in 1-2% of words (Johnson and Darley 1963). This hypothesis is in agreement with the literature data pointing to the association between the severity of stuttering and functional hemispheric lateralization (Wood et al. 1980, Moore 1986, Wells and Moore 1990). Hitherto literature on hemispheric asymmetry has not quoted any research differentiation between mild and severe stutterers. It seems that comparisons between moderate and severe stutterers have not given clear data (Rastatter and Dell 1987 a, b), because according to the Iowa scale, these two grades are relatively not so distinct comparing to the difference between mild and severe stutterers.

Our data also suggest that different neuropsychological mechanisms might be involved in severe and mild stuttering, however, further experiments are needed to explain this problem in more details.

**ACKNOWLEDGEMENTS**

This research was supported by a statutable grant from the State Committee for Scientific Research to the Nencki Institute and, in part, by the Humboldt Fellowship awarded to Elzbieta Szelag for her study in the Institute for Medical Psychology in Munich. With appreciation to Krzysztof Szamburski from Postgraduate Study for Speech Therapists, Warsaw University and to the speech terapists from Rehabilitation Clinic, Hoża St., Warsaw for their assistance in selection of stuttering subjects for this research.

**REFERENCES**

Beaumont J.G. (1982) Divided field studies of cerebral organization. Academic Press, London 305p.

Briggs G.C., Nebes R.D. (1975) Patterns of hand preference in a student population. Cortex 11: 230-238.

Czachowska-Sieszycka B., Szeląg E., Jastreboff P. (1985) Task variables and hemispheric asymmetry for words matching. Pol. Psychol. Bull. 16: 87-97.

Dorman M.F., Porter R.J. (1975) Hemispheric lateralization for speech perception in stutterers. Cortex 11: 181-185.

Fox D.R. (1966) Encephalographic analysis during stuttering and non- stuttering. J. Speech Hearing Res. 9: 488-497.

Hand C.R., Haynes W.O. (1983) Linguistic processing and reaction time differences in stutterers and non-stutterers. J. Speech Hearing Res. 26: 181-185.

Johnson W., Darley F.L. ( 1963) Diagnostic methods in speech pathology. Haper and Row Publishers, New York.

Moore W.H. (1976) Bilateral tachistoscopic word presentation of stutterers and normal subjects. Brain Lang. 3: 434-442.

Moore W.H., Haynes W.O. (1980) Alpha hemispheric asymmetry and stuttering: some support for a segmentation dysfunction hypothesis. J. Speech Hearing Res. 23: 229-247.

Moore W.H. (1986) Hemispheric alpha asymmetries of stutterers and non-stutterers for the recall and recognition of words and connected reading passage: some relationships to severity of stuttering. J. Fluency Dis. 11: 71-89.

Poppel E. (1987) Time perception. Encyclopedia of neuroscience, Birkhauser, Boston, p. 1215-1216.

Poppel E., Chen L., Glunder H., Mitzdorf U. Ruhnau E., Schill K., Steinbuchel N. (1991) Temporal and spatial constraints for mental modelling. In: Frontiers in knowledge-based computing (Eds. Bhatkar V.P. and K. M. Rege), Narosa Publishing House.

Pinsky S.D., Mc Adam D.W. (1980) Encephalographic and dichotic indices of cerebral laterality in stutterers. Brain Lang. 11: 374-397.

Rastatter M.P., Dell C. (1987 a) Reaction times of moderate and severe stutterers to monaural verbal stimuli: some implications for nonlinguistic organization. J. Speech Hearing Res. 30: 21-27.

Rastatter M.P., Dell C. (1987 b) Vocal reaction times of stuttering subjects to tachistoscopically presented concrete and abstract words: a closer look at cerebral dominance and language processing. J. Speech Hearing Res. 30: 306-310.

Rastatter M.P., Loren C.A. (1988) Visual coding dominance in stuttering: some evidence from central tachistoscopic stimulation (tachistoscopic viewing and stuttering). J. Fluency Dis. 13: 89-95.

Rastatter M.P., Haar R. (1988) Measurements of plasma levels of adrenergic neurotransmitters and primary amino acids in five stuttering subjects (biochemical aspects of stuttering). J. Fluency Dis. 13: 127-138.

Rosenfield D.B., Goodglass H. (1980) Dichotic listening for cerebral dominance in stutterers. Brain Lang. 11: 170-180.

Webster W.G. (1988) Neural mechanisms underlying stuttering: evidence from bimanual handwriting performance. Brain Lang. 33: 226-244.

Wells B.G., Moore H.W. (1990) EEG alpha asymmetries in stutterers and non-stutterers: effects of linguistic variables on hemispheric processing and fluency. Neuropsychologia 28: 1295-1305.

Wood F., Strumps D., McKeehan A., Sheldon S., Proctor J. (1980) Patterns of regional cerebral blood flow during attempted reading aloud by stutterers both on and off haloperidol mediation: evidence for inadequate left frontal activation during stuttering. Brain Lang. 9: 141-144.

*Paper presented at the 1st International Congress of the Polish Neuroscience Society; Session: Hemispheric asymmetry*