Instability of hemispheric asymmetry in dyslexic children*

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Abstract. The study tested the hypothesis of abnormal brain asymmetry in dyslexic children. Two dyslexic groups classified as "phonetic disorder" and "language disorder" and a control group participated in two experiments. In both experiments was employed a dichotic listening procedure consisting in recalling pairs of words presented simultaneously to two ears. In Experiment I the children were to recognize four words presented at a level of loudness typical for natural speech. In Experiment II only two words were used in each trial but they were presented at a low intensity level. The recognition scores for stimuli presented to the left and right ears were compared. In Experiment I all groups of children showed a typical right ear/left hemisphere superiority, i.e. their recognition scores were higher for the right than for the left ear. Dyslexics, however, performed significantly less well. In Experiment II the control children and those from "phonetic disorder" group again performed better when words were presented to their right ears. Unlike those two groups, the children from "language disorder group" showed the right hemisphere superiority, i.e. they performed better in the left ear presentation condition. The results do not support the hypothesis that dyslexic children have abnormal lateralization of verbal functions. They suggest that the pattern of hemispheric asymmetry in dyslexics is less stable and depends both on the kind of dyslexia and on task variation.

Key words: dyslexia, reading disabilities, brain asymmetry, dichotic listening

*Parts of the results of the present study were presented at the 40th Annual Meeting of the Orton Dyslexia Society, Dallas TX, Dec. 1989.
INTRODUCTION

Great development of studies on brain asymmetry (see e.g. Beaumont 1982, Bryden 1982, Benson and Zaidel 1985, for review) strongly influenced the understanding of the nature of several brain disorders such as mental illness, speech disorders and reading disabilities (dyslexia). The foundation of a new approach to those deficits was the belief that they were caused by atypical or abnormal brain asymmetry (Witelson 1977, Gur 1978, Colburn 1982, Bruder 1988).

Many experiments have been carried out to test the hypothesis that dyslexic children differ from good readers in the pattern of lateralization of their brains. The results appeared to be highly inconsistent. Some authors provide data that children with reading disorders show, opposite to controls, right hemispheric advantage or no hemispheric asymmetry for verbal functions (Zurif and Carson 1970, Witelson and Rabinovitch 1972, Thomson 1976, Kershner et al. 1984). Others, however, claim that dyslexics do not differ from their colleagues with normal reading abilities in respect of their brain asymmetry (McKeever and Huling 1970, Yeni-Komshian et al. 1975, Bouma and Legein 1977), although they frequently perform at a lower level (Satz et al. 1971, Marcel et al. 1974, Marcel and Rajan 1975, Leong 1976).

The inconsistency of those data might have resulted from two possible sources: great variability of the methods used by different authors and different and frequently unprecise criteria of sampling from heterogenous population of dyslexic children. In the present study, which is another attempt at studying the brain lateralization in dyslexics, we tried to avoid those difficulties. First, children were presented with two different verbal task to study a possible effect of task variation on hemispheric asymmetry. Second, we gave a special attention to the procedure of selecting children for our research and formed two distinct dyslexic groups demonstrating different types of dyslexic symptoms: "phonetic disorder" and "language disorder".

Our classification of dyslexia differ from that proposed for English speaking dyslexics (Boder 1970, Mattis et al. 1975, Critchley and Critchley 1978). This is due to a specific character of the Polish language (Smoczyńska 1985). Below we give a short characteristic of it stressing those features that cause special difficulties for children in the process of acquiring reading skills.

Polish is highly inflected and not positional, as is English. The meaning of each word thus depends on its morphological composition and not on its position in a sentence. The inflected forms are crucial for understanding the whole sentence, since they inform the reader about the agent, patient, possessor, etc., about time and place, about singularity and plurality. Inflections also differ for masculine and feminine forms. A characteristic feature of the Polish language is that it uses many suffixes and infixes. Polish dyslexic children have therefore not only difficulties in letter-sound analysis and synthesis but also many problems with the proper inflections of words and grammatical rules.

METHODS

Subjects

Twenty nine children showing dyslexic disorders participated in the experiments. At the moment of testing they were under psychological rehabilitation. Nevertheless they all showed severe reading problems (their reading attainment was downwardly discrepant from chronological age by about 2 years in the Polish Reading Test - Straburzyńska and Śliwińska 1983), but showed no gross physical, sensory, neurological or social handicap.

Basing on the experience of the first author (B.K.) in diagnosis and rehabilitation of dyslexia, two groups of dyslexic children, showing different types of dyslexic symptoms, "phonetic disorder" and "language disorder", were selected. The "phonetic disorder" group, consisted of 17 dyslexics (10 boys and 7 girls). These children showed difficulties in the analysis and synthesis of speech sounds and letters, in speech sound discrimination and in letter sound integration. They often changed position of letters in words or omitted letters. They could read globally only short and well known words and used mainly a letter-by-letter reading technique. They generally did not make semantic errors. These children showed a deficit in rhythm perception measured by the Stamback's test. On the other hand, they had no visual perception disorders as measured by the Bender-Santucci test and they had normal spoken language and comprehension. This group constitutes the most common set of disorders within the Polish dyslexic population - 71.2% (Spionek 1975).

The "language disorder" group, consisting of 11 dyslexic children (6 boys and 5 girls), showed difficulties which could be characterized as disturbances in the use of
of language as an instrument of cognition. Their difficulties were strongly connected with the Polish language system since they were mainly of grammatical origin (they tended to blend tenses, persons and pronouns). They also had problems in naming objects (they often could not recall the right names for objects or they tended to blend similar names), difficulties in separating words from their meaning context, and in synthesis of letters, syllables and words into more complex structures. They often made semantic errors and showed slightly disordered comprehension. Their vocabulary was generally adequate to their age and they had no disorders in the Stambak and Bender-Santucci tests.

The control group comprised 12 good readers (7 boys and 5 girls) with no perceptual disturbances. All subjects were 8-9 years old, right handed (as measured by the Zazzo test) and none had any known history of left-handedness. Their cognitive development was assessed by the Raven Coloured Progressive Matrices (Raven 1956) and Polish Verbal Intelligence Test (Choynowski 1980). Only children with normal intelligence were selected (their results were between 75-95 centile in Polish Verbal Intelligence Test). Recent audiological assessment indicated that the dyslexics and controls had normal pure tone hearing.

Procedure

The subjects were tested individually in a low distraction environment. Each child took part in two experiments with Dichotic Listening Test, which consisted in simultaneous presentation of two different words to both ears of the subject. Half of the children in each group started from the first experiment and half from the second. Besides, in the middle of each experiment the position of the earphones was reversed in order to control any possible differences between the earphone channels.

At the beginning of testing all subjects were acquainted with the experimental material. Words that would be presented later on the dichotic tape were played to each child one at a time through loud-speakers. The subject were asked to repeat each word and were corrected if they made a mistake.

In Experiment I, the children were presented with a dichotic listening test in which two pairs of words separated by 500 ms interval were exposed to the subjects’ ears. Then a 10 s break was given for the children’s oral response. Their task was to reproduce as many words as they could. Each exposure was preceded by a warning sound. One hundred eight pairs were presented. The words’ sound level was typical for normal speech.

Experiment I was preceded by a short test which investigated whether four words could be kept in each subject’s short-term memory. We delivered (through earphones) consecutively four words binaurally (i.e. the same words to two ears), and asked each child to reproduce them. All children were able to reproduce all the presented words.

In Experiment II only one pair of two different words was presented to the two ears of the subjects, but the loudness of the stimuli was very low (it considerably exceeded, however, the sensitivity threshold - Emmerlich et al. 1988). It was adjusted individually to each subject in a preliminary session. We established for each child such intensity of dichotically presented words with which they made 20-40% of errors. We did so since children differed in their ability to recognize words presented at a low intensity level. We did not observe, however, any significant differences in that respect between the three groups of subjects. In Experiment II one hundred fourteen different pairs were used.

RESULTS

The analysis of data was performed by a two-way ANOVA (group x ear) and a post-hoc Duncan test. We analyzed: (1) the order of reproduction, i.e. whether the first correctly reproduced word came from the left or right ear and (2) the level of performance, i.e. the number of correctly reproduced words from each ear.

Experiment I

ORDER OF REPRODUCTION

The two way ANOVA indicated a significant effect of the ear factor \(F = 2.42; df = 2/37; P < 0.001\). All groups started their recollection more frequently with words presented to the right ear (Fig. 1). The effect of group and the interaction were not significant.

LEVEL OF PERFORMANCE

Both main factors appeared to be statistically significant \(F = 9.69; df = 2/37; P < 0.01\) and \(F = 20; df = 2/37;\)
The interaction was nonsignificant. Inspection of Fig. 2 shows that in all three groups the subjects attained significantly higher scores ($P<0.01$) for the right than for the left ear. Moreover, the mean recognition level for both ears was considerably lower in the dyslexic groups than in the control one ($P<0.001$ and $P<0.01$ for the phonetic disorder and "language disorder" dyslexic groups respectively).

**Experiment II**

**ORDER OF REPRODUCTION**

The analysis revealed no significant main effects of ear and group but a significant interaction between them ($F=3.84$; $df=2/37$; $P<0.03$). The Duncan test showed that in good readers the first correctly reproduced words

![Graph showing the proportion of first correct recalls in left and right ear presentations in three groups.](image1)

Fig. 1. Experiment I. Proportion of the first correct recalls in the left and right ear presentations in three groups of subjects. The data indicate how often the first correctly reproduced words come from the left or right ear. The percentage for the left and right ears do not sum to 100 since there were also cases of false first recalls.

![Graph showing the proportion of all correct recalls in left and right ear presentations in three groups.](image2)

Fig. 2. Experiment I. Proportion of all correct recalls in the left and right ear presentations in three groups of subjects.
came more frequently \((P<0.05)\) from the right than from the left ear. Children from the "phonetic disorder" dyslexic group showed a similar tendency, although the difference between the right and the left ear was not significant. The opposite effect was observed in subjects from the "language disorder" dyslexic group, who started their responses more frequently \((P<0.05)\) with words presented to their left than to their right ear (Fig. 3).

That dyslexic group showed, therefore, a reverse preference than that of controls in the order of reproduction.

**LEVEL OF PERFORMANCE**

None of the main factors of the analysis of variance was significant, but the interaction reached significance at a level of \(P<0.022\) \((F = 4.23; df = 2/37)\). Good readers

![Fig. 3. Experiment II. Proportion of the first correct recalls in the left and right ear presentations in three groups of subjects. The data indicate how often the first correctly reproduced word come from the left or right ear. The percentages for the left and right ears do not sum to 100 since there were also cases of false first recalls.](image-url)

![Fig. 4. Experiment II. Proportion of all correct recalls in the left and right ear presentations in three groups of subjects.](image-url)
and children from the "phonetic disorder" dyslexic group were better able to recognize words delivered to their right ear ($P<0.05$). In the "language disorder" dyslexic group the results were opposite. The inspection of Fig. 4 indicates also that both groups of dyslexics performed at a lower level than controls (significant difference - $P<0.05$ was found only for comparison of controls and "language disorder" children in the right ear recognition scores).

**DISCUSSION**

It is interesting to consider our results from two points of view: (1) whether dyslexics show typical or reversed pattern of hemispheric asymmetry and (2) whether the performance of dyslexics is impaired or not in relation to that of good readers.

Our results indicate that good readers and children from one of the dyslexic groups ("phonetic disorder") show a typical for verbal material right ear/left hemisphere superiority. That pattern of hemispheric asymmetry is relatively stable, i.e. it does not change with task variation. On the other hand, children from "language disorder" group show either left or right hemisphere dominance, depending on the task requirements.

These results contrast with the hypothesis of the "reversed" brain asymmetry in dyslexic children. They suggest that the pattern of hemispheric asymmetry may differ in different groups of dyslexics and, what is most interesting, that it may change even in the same group of subjects due to some test variations.

The observation that dyslexic children are highly sensitive to changes in experimental procedure which may shift cerebral dominance from one hemisphere to the other is also reported by other authors (Thompson 1976, Kershner et al. 1984). Instability of hemispheric control of processing verbal information in dyslexics is specially evident in investigations of the effects of attentional or selective activation factors on hemispheric asymmetry. Several authors (Henninger et al. 1981 and Obrzut et al. 1981, 1985, 1988, Boliek et al. 1988) reported no hemispheric differences or even a reversal of hemispheric dominance i.e. left ear/right hemisphere superiority in dyslexic children when they were asked to direct their attention to the left ear. Good readers, on the contrary, showed a consistent right ear advantage independent of the instruction given to them.

All these data suggest that dyslexics show a less stable left-right pattern of hemispheric processing of verbal information. Our results are in agreement with this statement, indicating at the same time that it specifically concerns dyslexic children who, according to our classification, show "language disorders". It is worth noting that the reversal of hemispheric asymmetry pattern observed in those children was accompanied by a significant decrease of their right ear/left ear performance when compared to that of control children. It could be postulated, therefore, that the "language disorder" group suffers from a left hemisphere deficit in processing verbal information. That deficit, however, came into appearance only in Experiment II, in which children had to be highly attentive to correctly recognize hardly heard words presented simultaneously to their left and right ears. The hypothesis of a deficient functioning of the left hemisphere in some dyslexic children (developed originally by Lenneberg 1967) gets support from the observations that children from "language disorder" group were impaired in several language functions, such as using grammatical rules or naming objects (see the "subjects" section).

A number of models have been proposed to account for changes in lateralization of brain functions in reading disabled children. They associate these changes with a maturational lag of the left hemisphere (Lenneberg 1967), with the effects of testosterone promoting growth of the right hemisphere in the fetal brain (Geschwind and Galaburda 1985), with disturbances in the prenatal cytoarchitectonic formation of the left hemisphere (Galaburda and Kemper 1979) or with the attentional deficits resulting from the lack at fully developed mechanism for inhibition of the nondominant hemisphere by the dominant one (Obrzut and Boliek 1988). Although it would be difficult to define the brain mechanisms responsible for the results obtained in our experiment, the concept that assumes some attentional deficit seems to be the most adequate, since the pattern of hemispheric asymmetry showed by our children was unstable and depended on attentional requirements of the task.

Another finding of the present study was the lower level of performance of dyslexic children in comparison to that of children with average reading abilities. In literature there are many reports that dyslexic children perform less well in a task where a number of verbal stimuli presented dichotically is to be reproduced (McKeever and Van Deventer 1975, Yeni-Komshian et al. 1975, Keefe and Swinney 1979). The authors suggest that dyslexic children are impaired in their capacity to process several competing items to be remembered and repro-
duced. Our data are in agreement with that interpretation, since the recognition scores of our dyslexic children were specially reduced in Experiment I, where they had to recall four competing words.

To sum up, the results do not support the hypothesis that dyslexic children have abnormal lateralization of cerebral functions. They suggest that the pattern of hemispheric asymmetry in dyslexics is less stable and depends both on the kind of dyslexia and on task variation.

REFERENCES


Received 25 June 1991, accepted 20 December 1991