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ABSTRACT

Examined with 38 right-handed boys who were either dyslexic or normal readers and matched for age and IQ (mean age both groups=10.6, mean IQ normal readers=106, mean IQ dyslexic readers=105) were the weak, strong, and equal lateralization theories of dyslexia. Cerebral lateralization was measured for linguistic material (digits) using the dichotic listening technique. No difference was found in mean lateralization score between normal and dyslexic groups; however, the distribution of the lateralization scores of the normal Ss appeared unimodal whereas that of the dyslexic Ss appeared bimodal. The results suggested support for both the weak and the strong lateralization theories of dyslexia. (Author/IM)

A Comparison of Laterality Between Normal and Dyslexic Readers

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Dyslexia is a severe reading disability which persists in individuals who demonstrate normal intelligence and motivation, who possess intact perceptual mechanisms and who have received proper and often remedial instruction. Dyslexia has been hypothesized to be the result of an abnormal organization of the cerebral hemispheres. However, the specific abnormality which underlies the dyslexic condition is disputed among investigators. This paper is concerned with the hemispheric functioning of the dyslexic child.

A neurophysiological hypothesis for the etiology of dyslexia was originally developed from clinical observation of dyslexic children. Orton (1937) observed both directional difficulties and inconsistent manual preferences in dyslexic children and he was the first to propose that incomplete specialization of the cerebral hemispheres was the source of the dyslexic's reading problems. In neurological examinations, Critchley (1968) also found that dyslexic children demonstrated incomplete cerebral dominance. Critchley reported that normal patients usually exhibit 80% left hemisphere dominance and 20% right hemisphere dominance whereas, dyslexic patients usually display about 65% left hemisphere dominance and 35% right hemisphére dominance. Even further support for the hypothesis of incomplete cerebral dominance in dyslexic children comes from Bender (1968). Bender has found that dyslexic childr demonstrate a wide range of slight neurological disorders including immature motor skills, spatial difficulties and perceptual plasticity. Bender suggested that these disorders may be due to a lag in the cerebral maturation of dyslexic children.

Despite the clinical reports of 'slight' neurological disorders in dyslexic children, these disorders have been difficult to demonstrate in research. Investigations of spatial awareness and body laterality in poor and normal readers are two good examples. Tests of spatial concepts both on his own body and in the environment. Coleman and Deutsch (1964) found no difference between poor and normal readers with these tests. Similarly, Belmont and Birch (1965), as well as Benton and Kembel (1960), reported only a slight trend toward greater spatial difficulty of poor readers as compared to normal readers. In contrast, Keefe and Swinney (1976), using highly controlled matched groups of subjects, found that poor readers demonstrated greater spatial difficulty than normal readers.

Research investigating body laterality in poor readers has also been inconclusive. Tests of body laterality measure the extent to which one side of the body is used in preference to the other. In a test of manual preference, Sparrow & Satz (1970) and Corkin (1974) found that poor and normal readers demonstrated approximately equal lateralization. Harris (1957) found weaker hand lateralization in dyslexic than normal children, but did not find lateralization differences in the eyes or the feet. Keefe and Swinney (1976) found that dyslexic children exhibited incomplete eye lateralization more often than normal subjects but did not find lateralization differences in either the hands or the feet.

The discrepancies between the clinical reports and the research findings, as well as the discrepancies within the research findings themselves, most likely have two bases. First, the dyslexic children observed in the clinical settings and the poor readers measured in the research studies may not have been from the same population. Some of the clinical reports are based upon children who were sent to clinical settings because of neurological disorders other than those directly related to reading difficulties. Similarly some of the research findings included with the dyslexic readers, children with problems of a more general nature (i.e. low IQ, low socioeconomic status or only slight reading difficulties). Secondly, the clinical reports usually described a wide range of neurological behaviors in dyslexic children; any one of these behaviors may have been displayed by a given child, but most likely, all of these behaviors were not exhibited by any one child. In contrast, the research studies generally measured the presence or absence of a single behavior in a group of poor readers.

In order to further discuss evidence for neurological differences in dyslexic and normal children, two techniques of measuring hemispheric lateralization will be described. The techniques of dichotic listening and tachistoscopic viewing have been used to measure hemispheric lateralization for specific types of stimuli. In the dichotic listening technique, two different auditory stimuli are presented to a subject simultaneously, one stimulus to each ear. In the tachistoscopic viewing technique, two different visual stimuli are presented to a subject simultaneously, one stimulus to each visual field. Because the contralateral connections between the peripheral organs and the cortex are stronger and perhaps more numerous than the ipsilateral connections, the general paradigm is such that information received from the right ear or visual field is taken to reflect processing in the left hemisphere and information from the left ear or visual field is believed to reflect the processing in the right hemisphere (Kimura, 1961). Thus, the degree of lateralization for information depends on the relative involvement of the two hemispheres.

Both of these methods of examining hemispheric laterality have been used in studying the processing of linguistic material in normal and poor readers. Essentially three different results have been found; each result has been taken as evidence for a different theory of lateralization in dyslexia. We will term these theories the weak lateralization theory, the strong lateralization theory and the equal lateralization theory.

The weak lateralization theory is currently the predominant theory. It is based on the notion that as the normal brain matures, the cerebral hemispheres become more specialized and the left hemisphere becomes dominant for language (Lenneberg, 1967). According to this theory, the dyslexic child's failure to read is correlated with insufficient specialization of the left hemisphere which, in turn, may be related to a lag in a neurological maturation of the brain. Thus, the insufficient processing of the left hemisphere results in weak lateralization for linguistic material. The weak lateralization theory is supported by the research of Zurif and Carson (1970), Satz, Rardin and Ross (1971) and Marcel, Katz and Smith (1974)

The strong lateralization theory rests on the idea that reading requires involvement from both hemispheres. Further, is is believed that, while the left hemisphere of dyslexic children participates sufficiently in the processing of linguistic material, the right hemisphere does not. Thus, the insufficient processing of the right hemisphere results in strong lateralization for linguistic material. The strong lateralization theory is supported by the findings of Yeni-Komishian, Isenberg and Goldberg (1975).

The equal lateralization theory rejects the idea that dyslexia is related to a dysfunction in cerebral lateralization. Instead, dyslexia is thought to be the result of a dysfunction in numerous other areas such as intersensory integration, serialization or associative reasoning. The equal lateralization theory is upheld by the results of McKeever and Huling (1970); these results indicated no differences in lateralization between poor and normal readers for linguistic material.

The discrepancies in the hemispheric laterality studies of dyslexia may be due to methodological inadequacies which include equating poor readers with dyslexic readers, using uneven ratios of boys and girls, neglecting to report the ages of subjects and failing to control for intelligence. In none of the studies cited above were dyslexic and normal readers matched on the variables of age and IQ. The purpose of the present study was to provide a more clear assessment of differences in the hemispheric laterality research by matching normal and dyslexic subjects on age and IQ and by carefully controlling for reading level. Linguistic material was presented to the subjects with the use of the dichotic listening technique.

Method

Subjects

The subjects were 38 right-handed boys: 19 dyslexic readers and 19 normal readers. No children with uncorrected perceptual impairments or diagnosed brain trauma were included in the study. The Gray Oral Reading Test was administered to all subjects. Dyslexic readers were defined as children who read at least two years below their reading level. Normal readers were defined as children who read on or above their grade level. The mean score for the normal for the dyslexic subjects was two years, seven months behind the individual reading level. The mean score for the normal subjects was eight months above the reading level.

Subjects in the two groups were matched by the following criteria: they had to be the same age (within five months) and had to have the same IQ (within one SD of each other on the WISC Performance and on the PPVT). Actually, the subjects chosen were more closely matched than these criteria imply. The mean age for both groups was ten years, seven months. The mean IQ scores for the normal readers were 106 on the WISC Performance and 108 on the PPVT The mean IQ scores for the dyslexic readers were 105 on the WISC Performance and 105 on the PPVT.

Procedure

The materials for the dichotic listening test comprised the digits from one to ten with the exception of seven. These digits were paired in order to be used in the 3 practice and 18 test trials of the dichotic digits. On each trial, three digit pairs were dichotically presented through stereo headphones and heard by the subject at a rate of two seconds per trial. No two of the digits within a given trial were ever in ordinal sequence. Tape channels were counterbalanced during presentation.

The subjects heard the three pairs on each trial and were required to recall the digits from the ear indicated by the experimenter Recall was required nine times from each of the right and the left ears so that the maximum score for either ear was 27. The ear scores (e.g. -10) indicate greater left than right ear accuracy; positive scores (e.g. +10) indicate graater right ear than left ear accuracy.

Results

Data from the dichotic listening test were examined with a two by two analysis of variance which was performed on the main variables of Group and Ear Accuracy. Group means are summarized in Table 1. As can be seen, the normal group responded more accurately than the dyslexic group ($F_{1,35}$=6.14, p<.01) and both groups showed a right ear superiority for recall ($F_{1,36}$=10.94, p<.01). No interaction was observed between normal and dyslexic groups and ear accuracy; this was confirmed by the identical mean lateralization score of +14 for both the dyslexic and normal groups.

Although the two groups appear to lateralize similarly on the dichotic test, an interesting difference in the distribution of scores for the two groups was observed. Figures 1 and 2 represent linear distributions of subjects as a function of lateralization scores. The distribution of the normal population indicates a distinct central tendency between the scores of +11 and +23. However, the distribution of the dyslexic population appears to be bimodal; one cluster of subjects is found between the scores of -5 and +5 and the other cluster of subjects is found between the scores of +18 and +38.

The bimodal distribution could not be attributed to group differences in IQ, age or degree of reading difficulty. In order to investigate differences in ear accuracy in the two dyslexic subgroups, the distribution was divided with respect to the bimodality. The subgroup found on the right side of the mean lateralization score of +14 is the strongly lateralized subgroup. Table 2 presents the left and right ear accuracy scores of the two dyslexic subgroups and the normal group. In comparison to the ear accuracy scores of the normal group, the weakly lateralized dyslexic subgroup demonstrates a processing deficit only in the right ear (left hemisphere whereas, the strongly lateralized dyslexic subgroup demonstrates a processing deficit only in the left ear (right hemisphere).

In order to evaluate lateralization free from error, that is, ceiling and floor effects, the data were also analyzed with the phi test of significance. The findings are consonant with the results just discussed.

Discussion

The results of the present study appear capable of pealing away some of the confusion surrounding hypotheses of dyslexia. For example, the fact that the mean lateralization scores were equal for the dyslexic and normal groups appears to support the equal lateralization theory of dyslexia. However, as is shown in Figures 1 and 2, the performance of normal and dyslexic subjects was actually different. While, the mean lateralization score of the normal group is fairly representative of the performance of the individual subjects, the mean lateralization score of the dyslexic group was not at all representative of the individual subjects. The distribution of the dyslexic subjects was bimodal with a cluster of subjects on either side of the group mean. I should add that a bimodal distribution of lateralization scores in dyslexic subjects has recently been replicated. Thus, it appears that the dyslexic population is not homogeneous but rather is composed of two different populations: those dyslexic who are weakly lateralized with an apparent deficit in left hemispheric processing and those dyslexics who are strongly lateralized with a deficit in right hemispheric processing.

Independently, each of these two subgroups have support in the dyslexia literature. Zurif and Carson (1970) found that dyslexic subjects showed weaker lateralization for linguistic material than normal subjects, however, a deficient score of the right ear (left hemisphere) was solely responsible for the difference between the groups. The performance of the dyslexic subjects in the study of Zurif and Carson corresponds with the weakly lateralized subjects in the present study. Conversely, Yeni-Komishian, Isenberg (1975) found that dyslexic subjects showed stronger lateralization for linguistic information than normal subjects, however, a deficient accuracy score of the left visual field (right hemisphere) was solely responsible for the difference between the two groups. The performance of the dyslexic subjects in the study of Yeni-Komishian and her associates corresponds with the weakly lateralized dyslexic subjects in the present study. Thus, the results of the present study seem to support both the weak and the strong lateralization theories of dyslexia. Moreover, the findings suggest that there are at least two types of dyslexic children: one with a left hemisphere deficit and one with a right hemisphere deficit.

In order to understand the meaning of the left and right hemisphere deficit found in the dyslexic subgroups, it will be useful to briefly describe what are presumed to be the characteristic functions of the left and right hemisphere. The left hemisphere has been described as logical and sequence perceiving; it is thought to operate analytically and be primarily involved in language and logical reasoning (Fisher & Rhead, 1974). In contrast, the right hemisphere is described as symbolic and synthesis oriented; it is thought to operate analogically and be primarily involved in visual-spatial gestalts and symbolic understanding (Fisher & Rhead, 1974).

Certainly, as both linguistic analysis and visual-spatial processing are necessary for reading, a maldevelopment of either hemisphere may produce difficulties in learning to read. We can speculate that a child with a left hemisphere deficit might have difficulty analyzing words into their phonetic parts, while a child with a right hemisphere deficit might have difficulty perceiving words as a whole configuration or gestalt.

If indeed there are different kinds of dyslexic children, then the gross discrepancies in the dyslexia literature become understandable. Research in dyslexia has generally been designed to find similar deficits across all dyslexic children. However, if the dyslexic population is heterogeneous, then the many research investigations have unavoidably led to inconsistent results. Each research finding may be a direct result of the types of dyslexics employed in each study. In recognition of the possible heterogeneity of dyslexia, future research and remediation programs should observe different patterns of deficits within the population. In addition, relationships between hemispheric processing and types of reading disorders certainly need investigation beyond the modest beginnings indicated in this paper.

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Table 1
Mean Scores of Ear Accuracy and Lateralization for
Normal and Dyslexic Groups

	Right Ear	Left Ear	Lateralization Score
Normal	80.5	66.5	14.0
Dyslexic	72.3	58.3	14.0

[illegible]le 2
Ear Accur[illegible] for the Normal Group
a[illegible]ic Subgroups

	Right Ear	Left Ear
Normal	80.5	66.5
Weakly Lateralized Dyslexics	64.1	66.3
Strongly Lateralized Dyslexics	81.5	49.4

Figure 1
A Distribution of Normal Subjects as a
Function of Lateralization Scores

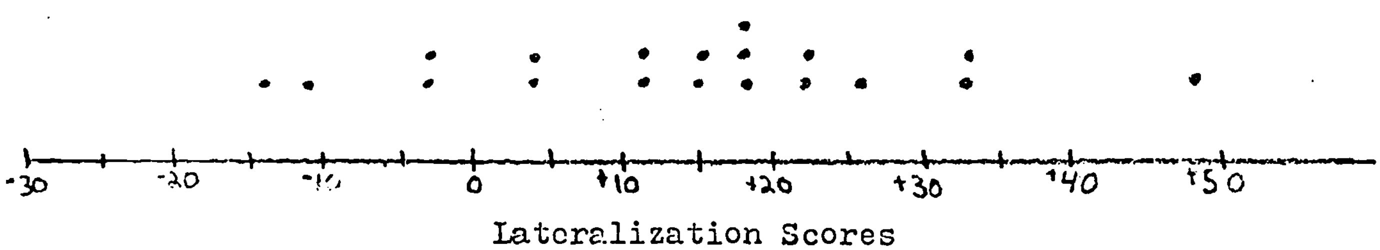

Figure 2
A Distribution of Dyslexic Subjects as a
Function of Lateralization Scores