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# Developmental Dyslexia: Evidence for a Subgroup with a Reversal of Cerebral Asymmetry

Daniel B. Hier
*Missouri University of Science and Technology*, hierd@mst.edu

Marjorie Lemay

Peter B. Rosenberger

Vincent P. Perlo



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# Developmental Dyslexia

## Evidence for a Subgroup With a Reversal of Cerebral Asymmetry

Daniel B. Hier, MD; Marjorie LeMay, MD; Peter B. Rosenberger, MD; Vincent P. Perlo, MD

**• The computerized brain tomograms of 24 patients with developmental dyslexia were analyzed for cerebral asymmetry. Ten patients showed a reversal of the pattern of asymmetry regularly observed in normal right-handed individuals so that the right parietooccipital region was wider than the left. The ten dyslexic patients with this reversal of cerebral asymmetry had a lower mean verbal IQ than the other 14 dyslexic patients in this study. The reversal of cerebral asymmetry that occurred in ten of the dyslexic patients may result in language lateralization to a cerebral hemisphere that is structurally less suited to support language function and thus act as a risk factor for the development of reading disability.**

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Children with developmental dyslexia experience difficulty in learning to read despite adequate intelligence, motivation, and instruction. It has been estimated that 1% to 3% of school-age children have developmental dyslexia. The cause of this disorder is unknown.[1,2]

The human brain is now recognized to possess both functional and structural asymmetries. In nearly all right-handed individuals and most left-handed individuals, the left hemisphere is dominant for language. A possible neuroanatomical basis for left hemisphere dominance for language has been disclosed by the studies of Geschwind and Levitsky.[3] They found that the posterior portion of the temporal lobe, known as the planum temporale, is larger on the left than the right in most brains. Subsequent studies have indicated that the entire posterior region of the left hemisphere is usually wider than the right.[4] The greater size of the left posterior region may provide a more favorable anatomical substrate for the development of language. These structural asymmetries are present in fetal and newborn brains and thus predate and may presage the development of language in the left hemisphere.[5-8]

In this study we have used computerized brain tomography to assess the pattern of cerebral asymmetry in 24 individuals with developmental dyslexia. Evidence is presented that a variant pattern of cerebral asymmetry may be a factor contributing to the reading disability of certain dyslexic individuals.

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From the Neurology Service (Drs Hier, Rosenberger, and Perlo) and the Department of Radiology (Dr LeMay), Massachusetts General Hospital, and the Departments of Neurology (Drs Hier, Rosenberger, and Perlo) and Radiology (Dr LeMay), Harvard Medical School, Boston.

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Reprint requests to Massachusetts General Hospital, 32 Fruit St, Boston MA 02114 (Dr Hier).

## METHODS

**Patients.**—Twenty-four dyslexic patients between the ages of 14 and 47 participated in this study. The mean age of patients was 25. Two of the patients were women and six were left handed (Table 1). Twenty of the patients were evaluated by the staff of the Language Disorders Unit or the Learning Disorders Unit at the Massachusetts General Hospital, while four of the patients were diagnosed as dyslexic at outside facilities. All of the patients either scored below the fifth grade level on the Gray Oral Reading Test or had a history of reading at least two years below grade level while in school. Depending upon age, either the Wechsler Adult Intelligence Scale or the Wechsler Intelligence Scale for Children was administered (Table 1). All patients had normal neurological examination results.

**Computerized Brain Tomography.**—Cerebral asymmetry was assessed by analyzing computerized brain tomograms obtained on all patients. Four or six transaxial sections were made through the cerebral hemispheres using a 25° angle with respect to the anthropological baseline of the skull. Measurements were made on self-developing pictures (Polaroid), which showed the brain in transaxial section reduced in size by a factor of 3.3 times. Using either

the falx or interhemispheric fissure as a midline structure, widths of the posterior portions of the cerebral hemispheres were measured on the scans at a point approximately 5 mm anterior to the inner table of the vault. The brains were classified as wider in the left parietooccipital region if the left width exceeded the right by 1 mm or more, wider in the right parietooccipital region if the right width exceeded the left by 1 mm or more, or symmetrical if the two widths were within 1 mm of each other (Figure).

**Statistical Methods.**—Where appropriate, the $t$ test or $\chi^2$ test was used to ascertain level of statistical significance.[9]

## RESULTS

None of the computerized brain tomograms showed evidence of brain injury. Ten of the dyslexic patients had brains that were wider in the right parietooccipital region than the left; eight patients had brains that were wider on the left; and six patients had brains that were approximately symmetrical (Table 1).

As shown in Table 2, the dyslexic individuals with brains wider in the right parietooccipital region than the left had a mean verbal IQ that was less than the other dyslexic patients ($P < .01$). The mean performance IQ scores of these two groups did not differ significantly ($P > .05$). Four of the ten patients with brains with a wider right parietooccipital region reported delays in the acquisition of speech, while only one of the other 14 dyslexic patients reported delayed speech; however, this difference between the two groups was not statistically significant ($P > .05$).

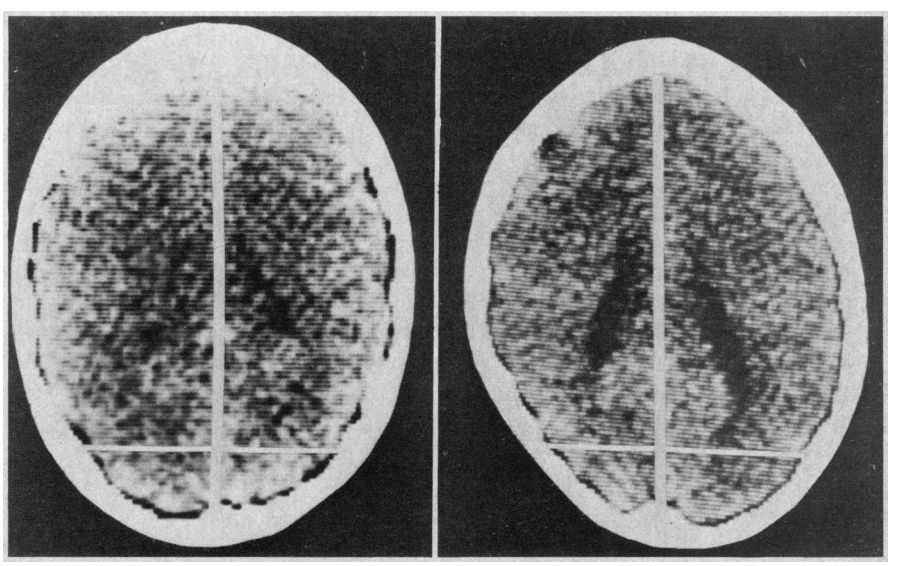
## COMMENT

Examination of the computerized brain tomograms of the 24 dyslexic patients in this study shows that an unexpectedly large number of them exhibit a reversal of the pattern of cerebral asymmetry found in most right-handed individuals so that the right parietooccipital region is wider than the left. Only 9% of normal right-handed individuals and 27% of normal left-handed individuals have this reversed pattern of cerebral asymmetry.[10] The expected number of patients that would exhibit this reversed pattern of cerebral asymmetry given that six of the 24 dyslexic patients are

Table 1.—Clinical and Radiological Data From 24 Dyslexic Patients

| Patient/Sex/Age, yr | Handedness | Reading Level* | IQ | | Widths of Parieto-occipital Regions | Delayed Speech† |
|---|---|---|---|---|---|---|
| | | | Verbal | Performance | | |
| 1/M/21 | R | HX | 113 | 116 | R > L | Yes |
| 2/F/33 | R | 1.6 | 74 | 94 | R > L | Yes |
| 3/M/30 | R | 1.9 | 97 | 99 | R > L | No |
| 4/M/17 | R | 2.8 | 71 | 83 | R > L | Yes |
| 5/M/40 | R | 4.2 | 91 | 100 | R > L | No |
| 6/M/18 | R | HX | 74 | 97 | R > L | No |
| 7/M/16 | R | 3.2 | 88 | 95 | R > L | No |
| 8/M/14 | L | HX | 95 | 104 | R > L | Yes |
| 9/M/17 | L | HX | 94 | 86 | R > L | No |
| 10/M/31 | L | 0.0 | 76 | 82 | R > L | No |
| 11/M/22 | R | 2.8 | 94 | 107 | R = L | No |
| 12/M/30 | R | HX | 110 | 118 | R = L | No |
| 13/F/35 | R | HX | 84 | 98 | R = L | No |
| 14/M/45 | R | 0.0 | 93 | 99 | R = L | No |
| 15/M/20 | R | HX | 124 | 106 | R = L | No |
| 16/M/35 | R | HX | 88 | 93 | R = L | No |
| 17/M/47 | R | HX | 105 | 109 | R < L | No |
| 18/M/22 | R | 1.9 | 93 | 109 | R < L | No |
| 19/M/22 | R | 0.0 | 92 | 98 | R < L | Yes |
| 20/M/24 | R | 4.4 | 99 | 97 | R < L | No |
| 21/M/17 | R | HX | 114 | 102 | R < L | No |
| 22/M/28 | L | HX | 105 | 118 | R < L | No |
| 23/M/17 | L | HX | 103 | 120 | R < L | No |
| 24/M/43 | L | 0.0 | 91 | 75 | R < L | No |

*Grade level equivalent as determined by the Gray Oral Reading Test. HX indicates patients who scored above 5.0 but who read at least two grades below grade level while in school. A score of 0.0 indicates a nonreader.
†Onset of speech in phrases after age 3 years.



Computerized brain tomograms of two dyslexic patients. Both transaxial sections are at the level of the bodies of the lateral ventricles. The heavy white stripe lays vertically along the interhemispheric fissure; the thin white stripe lays horizontally across the posterior parietooccipital region. Brain at left (case 18) shows the common pattern of cerebral asymmetry with the wider left parietooccipital region. Brains at right (case 4) shows a marked reversal of usual cerebral asymmetry with a wider right parietooccipital region.

Table 2.—Intelligence Test Scores According to Pattern of Cerebral Asymmetry

| Asymmetry | No. of Patients | Mean IQ (± SD) Verbal | Performance |
|---|---|---|---|
| Right parietooccipital region wider than left | 10 | 87 ± 13* | 96 ± 10 |
| Left parietooccipital region wider than or equal to right | 14 | 99 ± 11* | 103 ± 12 |

*Difference is significant ($P < .01$).

left handed is 3.2 (9% of 18 + 27% of 6). This is significantly less than the ten dyslexic patients who actually showed this reversed pattern of cerebral asymmetry ($P < .01$).

The ten patients with reversed cerebral asymmetry differed from the other 14 dyslexic patients in that they had lower verbal ability. The mean verbal IQ score was 12 points lower in the subgroup of dyslexics with reversed cerebral asymmetry. Further, four of the ten patients in the reversed cerebral asymmetry subgroup reported delays in the acquisition of speech, while only one of the other 14 dyslexic patients had delayed speech acquisition.

The reversal of cerebral asymmetry found in ten of the dyslexic patients may have contributed to their reading disability. Among most right-handed individuals, structural asymmetry of the brain tends to correspond to functional asymmetry so that the left hemisphere is both wider in the parietooccipital region and dominant for language. This correspondence between structural asymmetry and functional asymmetry may be disrupted in those dyslexic individuals with reversed cerebral asymmetry. Other studies indicate that language is lateralized normally to the left hemisphere of dyslexic children.[11,12] Language may be lateralized normally to the left hemisphere in the ten dyslexic patients in this study with reversed cerebral asymmetry even though, the anatomic configuration of the left hemisphere more closely resembles that of the right hemisphere of most normal individuals. Further, the linguistic capabilities of the right hemisphere appear to be inherently less than those of the left hemisphere.[13] Thus, the dyslexia and verbal disability of the ten patients with reversed cerebral asymmetry in this study may be a partial reflection of the mismatch between hemispheric specialization for language and structural asymmetry of the hemispheres.

It should be emphasized that a reversal of cerebral asymmetry alone does not produce dyslexia or verbal disability. A reversed pattern of cerebral asymmetry occurs in about 10% to 12% of the population, while dyslexia is rarer (about 1% to 3% of the population). Thus, only in certain vulnerable individuals does reversed cerebral asymmetry interact with other factors to produce dyslexia. Reversed cerebral asymmetry may prove to be an important risk factor for dyslexia much as male sex is a risk factor (boys have four times the incidence of dyslexia as girls). Although only a minority of individuals with a reversed pattern of cerebral asymmetry will have dyslexia, a rough calculation based on the data above suggests that these individuals are at five times greater risk to have dyslexia than individuals with the more regular patterns of cerebral asymmetry.

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## References

1. Critchley M: *The Dyslexic Child.* London, Heinemann Books, 1970, pp 1-137.
2. Benton AL: Developmental dyslexia: Neurological aspects, in Friedlander WJ (ed): *Current Reviews of Higher Nervous System Function.* New York, Raven Press, 1975, pp 1-48.
3. Geschwind N, Levitsky W: Human brain: Left-right asymmetries in temporal speech region. *Science* 161:186-187, 1968.
4. LeMay M: Morphological cerebral asymmetries of modern man, fossil man, and nonhuman primates. *Ann NY Acad Sci* 280:349-366, 1976.
5. LeMay M, Culebras A: Human brain: Morphologic differences in the hemispheres demonstrable by carotid arteriography. *N Engl J Med* 287:168-170, 1972.
6. Witelson SF, Pallie W: Left hemisphere specialization for language in the newborn: Neuroanatomical evidence of asymmetry. *Brain* 96:641-646, 1973.
7. Wada JA, Clarke R, Hamm A: Cerebral hemispheric asymmetry in humans: Cortical speech zones in 100 adult and 100 infant brains. *Arch Neurol* 32:239-246, 1975.
8. Chi JG, Dooling EC, Gilles FH: Left-right asymmetries of the temporal speech areas of the human fetus. *Arch Neurol* 34:346-348, 1977.
9. Colton T: *Statistics in Medicine.* Boston, Little Brown & Co, 1974.
10. LeMay M: Asymmetries of the skull and handedness: Phrenology revisited. *J Neurol Sci* 32:243-253, 1977.
11. Witelson SF: Developmental dyslexia: Two right hemispheres and none left. *Science* 195:309-311, 1977.
12. Springer SP, Eisenson J: Hemispheric specialization for speech in language-disordered children. *Neuro psychologia* 15:287-294, 1977.
13. Dennis M, Whitaker HA: Language acquisition following hemidecortication: Linguistic superiority of the left over right hemisphere. *Brain Lang* 3:404-433, 1976.

### CORRECTION

**Incorrect Data.**—In the article titled "Perinatal Intracranial Hemorrhage," published in the September ARCHIVES (34:570-573, 1977), the sentence starting on line 32 of the "Results" section (page 571) should read "In the other infant, the malformation was discovered at autopsy."