Journal of Medical Genetics (1972). **9**, 48.

Genetical Investigations in Dyslexia

M. ZAHÁLKOVÁ, V. VRZAL, and E. KLOBOUKOVÁ

From the Paediatric Research Institute and the Department of Psychiatry, The Children's Hospital, Brno, Czechoslovakia

Dyslexia is a specific developmental disorder which manifests itself in difficulty in learning to read despite educational instruction, adequate intelligence, and sociocultural opportunity. This disorder, which is frequently constitutional in origin, depends on fundamental cognitive disabilities. By means of the differential diagnosis we can separate those defects in reading and writing which can be explained by sensory disorders or by other somatic defects; by different grades of mental defect, lack of training caused by disease, and absence from school; by change in the teaching language; by a bilingual education, wrong teaching methods, a bad relationship between the pupil and the teacher etc. These cases are regarded as secondary disorders of reading or pseudodyslexia.

The aetiopathogenesis of dyslexia has not been clearly elucidated up to this time. Some authors mention the defect in connection with central lesions in the region of the gyri angularis and supramarginalis. Bender (1938) localizes the lesion in the temporal lobe, regarding dyslexia as a functional disorder of the speech region. Rabinovitch (1954) differentiates primary and secondary affected cases and regards the defect as a developmental deficiency rather than the result of acquired cerebral damage. Orton (1937) takes the disorder to be a genetically conditioned functional variant in the development of the dominance of the hemispheres. Bronner (1917) connected congenital dyslexia with disorders of intrauterine development, birth injury, infections, and disorders of postnatal development. Gesell and Amatruda (1947) include reading disorders in the sequelae of minor cerebral damage. Kawi and Pasamanick (1959) proved that the appearance of dyslexia was influenced by factors which are genetically held to cause encephalopathies in children. Kučera *et al* (1961) estimated that disorders of reading and writing were the principal symptoms in 10% of cases of postnatal infective lesions (pertussis, encephalitis, morbillosa, meningitis etc). Vrzal *et al* (1968) also found a high incidence of partial reading defects as a late psychic sequela in children after asphytic forms of pertussis. According to some authors neurotic mechanisms play the main part in the origin of dyslexia. In a small group of children the specific cause of dyslexia could not be determined; and these cases suggest that there are further causes which have not yet been elucidated.

In 1905, first Thomas and then Fisher drew attention to the familial incidence of dyslexia. Norrie (1939) found hereditary factors in almost all affected people. Kågén (1943) found hereditary factors in about 30% of affected cases, and Ramer (1947) in 50–60%. The most extensive and detailed study is that of Hallgren (1950), who examined 116 propositi and ascertained 160 further cases in their families. He suggested an autosomal dominant mode of inheritance, and thought that it was not possible to differentiate the hereditary and non-hereditary cases by clinical means alone; the only useful criterion was the occurrence of further cases in the family. Lenz (1970) considered the possibility of the polygenic inheritance or a compromise solution between dominant and multifactorial inheritance, namely the hypothesis of a dominant major gene the manifestations of which are influenced by a number of minor genes (W. Lenz, personal communication).

Dyslexia is relatively frequent. In English-speaking countries as many as 20% of affected school children have been reported (Huessy, 1966); in Scandinavian countries the number is about 10% (Huessy, 1966). In German-speaking countries Huessy found a frequency of about 5%, while in Germany Kirchhof (1954) estimated the incidence to be between 2 and 4%. This corresponds to the frequency reported for France (Roudinesco, 1951) and for the Argentine (de Quiros, 1962). In Czechoslovakia, Matějček (1968) reported that 2% of children were affected. We found 21 dyslexic children among 1272 pupils of two large schools in Brno (1·7%). The lowest frequency reported up

Received 13 July 1970.

TABLE I
SIBS OF DYSLEXICS

	Healthy	Affected	Genotypically Endowed, Phenotypically not Manifested	Total
Male probands				
Brothers	12	14	0	26
Sisters	19	4	4	27
Total	31	18	4	53
*Female probands**				
Brothers	12	8	0	20
Sisters	10	5	3	18
Total	22	13	3	38

* Enlarged sample (see text below).

to this time is in Japan where Makita (1968) found only 0·98% affected children.

Materials and Methods

Our sample contains 65 dyslexics randomly selected as they visited the counselling unit for dyslexics. This sample was divided into 3 subgroups according to the aetiopathogenesis of the disorder. A hereditary group (group A, 29 children) with a familial incidence and without any demonstrable somatogenic or sociogenic effects. An encephalopathic group (group C, 9 children) in which the disorders could be traced to extrinsic factors: prenatal, perinatal (birth injury), or postnatal (infections, injuries, intoxications etc), ie, cases of demonstrable (though minimal) cerebral injury or cerebral disfunction (disorganization or immaturity of nervous function). A hereditary-encephalopathic group (group B, 27 children) where both components were represented in varying range and depth.

All probands were blood grouped (ABO, Rhesus, MN, Pp, Duffy A).

Heredity was studied only in members of group A which was a reduced but homogenous sample. Where affected parents were found they were taken as probands. In this way the total number of families evaluated was 49. However, the small number of female propositae in our sample does not permit a statistical evaluation of the proportion of dyslexics among the sibs of female patients and the sibs of the male patients. Therefore we completed our sample with a group of 38 female dyslexics. All these patients could, according to our criterion, be included in group A (the hereditary group). These 38 women were not included in any other evaluation so as to preserve the randomness of our selection.

Clinical differences between group A (hereditary aetiology) and group C (encephalopathic and sociogenic aetiology) were also evaluated with particular reference to verbal and non-verbal levels of intelligence; partial defects—singly or in combination; disorders of perception; concentration and memory; instability; bradypsychism; disorders of speech; left-handedness; disorders of adaptation; disorders of personality; organic signs of a neurological character; defects of ossification; disorders of cerebral activity shown in the EEG; and endocrinological disorders.

Results and Discussion

The existence of pedigrees with affected individuals in 2, 3, and exceptionally 4 generations suggested the features of a dominant trait.

The degree of affection of the sibs of our propositi is shown in Table I. We found no significant difference in the proportion of dyslexics among the sibs of the female patients and among the sibs of the male patients. This information is important in connection with the possibility of polygenic inheritance.

Among the sisters of dyslexics there were 7

TABLE II
PARENTS OF DYSLEXICS

Father	Mother			
	Affected	Genotypically Endowed, Phenotypically not Manifested	Healthy	Total
Affected	6	2	14	22
Genotypically endowed, phenotypically not manifested	0	0	4	4
Healthy	5	11	7	23
Total	11	13	25	49

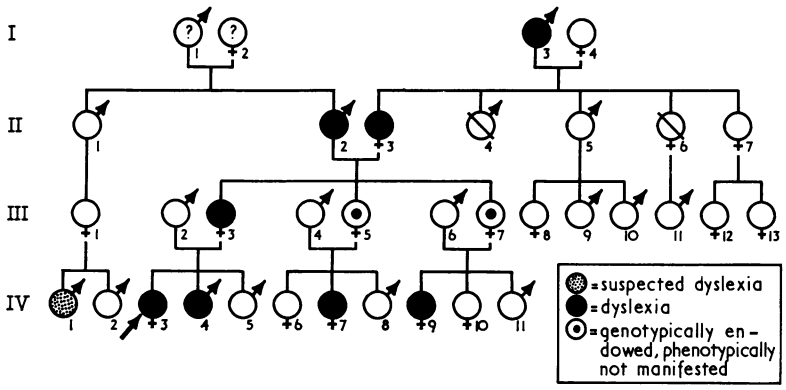

FIG. 1. Pedigree of family D.

women who were themselves clinically asymptomatic, but who had one affected parent as well as one affected child; their husbands were not affected. In our pedigree of one of our families (Fig. 1) we can see two instances of this in cases III.5 and III.7. Further similar cases are certainly hidden in the group of healthy sisters of our patients because there are many young girls who at the time of the study had had no children. In agreement with Warburg (1911), who says that the disease is often transmitted by non-affected mothers, we would suppose that these women are to be classified as gene carriers.

The evaluation of the parents is shown in Table II; there are also male gene carriers who show no clinical signs of dyslexia but female gene carriers are substantially more frequent (13:4). The number of cases where *both* parents are affected is surprising. The different number of affected parents and the incidence of the defect cannot be balanced even though the incidence of dyslexia does not include carriers without clinical manifestations. The same may also hold for mild forms of dyslexia which may escape the screening in schools, but which were found during a more detailed examination of affected families. We assume that the occurrence of this extremely high proportion of affected parents is mainly due to the fact that our series is not only quite small but, above all, because it is considerably incomplete in respect of the non-differentiation of the intermediate group B and because children whose parents were also affected had a greater probability of being included in our group A. This inaccuracy, of which we are aware, was due to our desire to ensure the homogeneity of the sample. Theoretically, this fact should not influence the segregation ratios but it is reflected in a greater number of affected parents than had been expected.

Boys are affected by dyslexia much more frequently than girls. Different authors (see Critchley, 1964) report 66–86% of boys in their samples, most frequently about 80%. The sex distribution of our series is given in Table III. Consistent with the literature our series contains more boys. It is interesting that most of the girls were found in group A. In the sibs and parents of the propositi males predominate among the phenotypically affected; among the gene bearers the male-female ratio is balanced. The total absence of females in group C is striking.

In observing the segregation ratios we logically started from the genotype. The percentage of affected children on a sibship is $43 \pm 6{\cdot}0$ (Just's method), $42 \pm 6{\cdot}0$ (Weinberg's method), and $43 \pm$

TABLE III

SEX RATIO

IIIa **Probands**

Group	Male	Female	Total
A	23	6	29
B	24	3	27
C	9	0	9
Total	56	9	65

IIIb **Affected Sibs and Parents of Probands**

	Phenotype		Genotype	
	M	F	M	F
Parents	14	5	18	16
Sibs				
Male probands	14	4	14	8
Female probands*	8	5	8	8
Total	22	9	22	16

*Enlarged sample.

TABLE IV

OCCURRENCE OF CLINICAL AND PSYCHOLOGICAL TRAITS IN GROUPS A AND C

Trait	Group A (n=29)	Group C (n=9)
Verbal intelligence		
Normal	14	7
Weak average	10	1
Weak to below average	2	0
Below average	3	1
Non-verbal intelligence*		
110	3	0
100–110	6	1
90–100	7	4
80– 90	3	2
Personality disorders	6	4
Parvuloid and infantile personality	5	2
Bradypsychism		
Slight	3	2
More severe	4	0
Developmental defects in speech functions	4	1
Combinations of partial defects		
Legastheny dysorthography	17	5
Dyslexia dysorthography	8	4
Psychomotor instability 10	10	6
Left-handedness	5	4
Defects of adaptation	4	3
Defects of personality	6	4
Neurological microsymptoms (strabismus, tics, extrapyramidal symptoms, abnormal EEG)	9	5
Retarded ossification	13	3
Average age when present (years)	2·5	2
Maximum age (years)	5	2

* Two methods were used; Raven's Progressive Matrices and the method of Khos.

6·1 (proband method). These results are in good accordance with the hypothesis that dyslexia is a dominant condition.

Clinical comparisons between groups A and C are shown in Table IV.

In our sample there was one consanguineous marriage in the generation of grandparents. The consanguinity, then, is not increased.

The frequency of blood groups observed in the present series does not differ from the control population. No association with any of these blood groups was found.

Conclusions

On the basis of our results we may suppose that the hereditary form of dyslexia is a dominant condition with partial sex limitation in that the gene is manifested less frequently in women. The present state of knowledge does not allow us to decide to what extent the clinical manifestations are due to the effects of minor genes or due to environmental factors.

Summary

A series of 65 dyslexics (56 boys and 9 girls) was studied and divided according to the aetiopathogenesis of the impairment into 3 groups: a hereditary group (29 children), an encephalopathic group (9 children), and an intermediate group of 27 children who exhibited some signs of the other two groups. It is concluded that the hereditary form of dyslexia is inherited as an autosomal dominant influenced by sex. Among the women we found substantially more gene carriers with no clinical manifestations. Neither a high consanguinity nor an association with some of blood groups of the ABO, Rhesus, MN, Pp, or Duffy A groups were found.

On the basis of the differentiation of clinical differences between the marginal groups the authors found some variations of 13 clinical traits in the groups.

REFERENCES

Bender, L. (1938). *Visuo-Motor Gestalt Test* (Research Monograph No. 3). American Orthopsychiatric Association, New York.

Bronner, A. F. (1917). *The Psychology of Special Abilities and Disabilities.* Little, Brown and Company, Boston.

Critchley, M. (1964). *Developmental Dyslexia*. Heinemann Medical, London.

Fisher, J. H. (1905). A case of congenital word-blindness (inability to learn to read). *Ophthalmic Review*, **24**, 315–318.

Gesell, A. and Amatruda, C. S. (1947). *Developmental Diagnosis*, 2nd ed. Hamish Hamilton, London.

Hallgren, B. (1950). Specific dyslexia ('Congenital word-blindness'): A clinical and genetical study. *Acta Psychiatrica et Neurologica*, Suppl., **65**, 1–287.

Huessy, H. R. (1966). *The Comparative Epidemiology of Reading Disability in German and English Speaking Countries*. Based on a paper read at the World Congress for Mental Health in Prague.

Kågén, B. (1943). Om ordblindhet. *Pedagogiska Skrifter*, **60**, 179–180.

Kawi, A. A. and Pasamanick, B. (1959). Prenatal and paranatal factors in development of childhood reading disorders. *Monographs of the Society for Research in Child Development*, **24**, no. 4.

Kirchhof, H. (1954). Cited in Matějček (1968).

Kučera, O., Macek, K., Jirásek, Y., Matějček, Z., Žlab, Z., Šteřbáková, E., Dittrich, Y., and Poledne, Y. (1961). *Psychopatologické Projevy při Lehkých Dětských Encefalopatiích*. Státní Zdravotnické Nakladatelství, Prague.

Lenz, W. (1970). *Medizinische Genetik—Grundlagen, Ergebnisse und Probleme*, 2nd ed. Thieme, Stuttgart.

Makita, K. (1968). The rarity of reading disability in Japanese children. *American Journal of Orthopsychiatry*, **38**, 599–614.

Matějček, Z. (1968). Dyslexia, and international problem—A report from Czechoslovakia. *Bulletin of the Orton Society*, **18**.

Norrie, E. (1939). *Om Ordblindhet*. Copenhagen.

Orton, S. T. (1937). *Reading, Writing, and Speech Problems in Children*. Chapman and Hall, London.

Quiros, de (1962). Cited by Matějček (1968).

Rabinovitch, R. D. (1954). A research approach to reading retardation. *Association for Research in Nervous and Mental Disease*, Proceedings 34, 363–396.

Ramer (1947). Cited by Critchley (1964).

Roudinesco, J. (1951). Cited by Matějček (1968).

Thomas, C. J. (1905). Congenital word-blindness and its treatment. *Ophthalmoscope*, **3**, 380–385.

Vrzal, V., Klobouková, E., Wiedermannovaá, D., Kluska, V., and Misurec, J. (1968). Pozdní psychické následky u dětí po onemocnění asfyktiou formou pertuse. *Československá Pediatrie*, **23**, 6–16.

Warburg, F. (1911). Über die angeborene Wortblindheit und die Bedeutung ihrer Kenntnis für den Unterricht. *Zeitschrift für Kinderforschung*, **16**, 97–113.