SPECIFIC VISUAL DISABILITY IN RELATION TO ONTOGENY OF BRAIN ASYMMETRY

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Abstract. Children with retarded development of visual perception were compared with previously tested normal children. Verbal and non-verbal patterns were presented either to the left or to the right hemisphere. In both groups of children the results showed a functional equality of the hemispheres during analysis of the non-verbal patterns. Left hemisphere superiority for verbal material in Normal group was not confirmed by the results in Retarded children. The data are discussed in terms of the relation between the ontogeny of brain asymmetry and specific visual disability in children.

INTRODUCTION

The results of many studies indicate that in adults different functions are lateralized either to the left or to the right hemisphere (6, 8, 10, 12, 24). The small number of works carried out on children still did not conclusively investigate the ontogeny of this brain asymmetry. Some investigators suggest that the mature pattern of the specialization for verbal and non-verbal material is present from birth (25), while other claim that left hemisphere dominance for verbal material is not evident before 4 or 5 years of age, suggesting that specialization develops very early (16, 18, 26). Yet according to another group, brain asymmetry is achieved much later (4, 9, 22, 28).

The majority of experiments on children deal with problems of hearing and point to early development of specialization in the left hemisphere (14). Only a few studies have been concerned with the
ontogeny of lateralization of visual functions in children, particularly with functions of the right hemisphere. In sum one can only conclude that there are still basic questions in this area which need study. Among them are: (i) which hemisphere initiates the shaping of asymmetry of verbal and non-verbal analysis? (ii) in which ontogenetic period does this asymmetry stabilize? (iii) what are the consequences of its abnormal development? The last problem for example can be solved by determining the relation between the level of asymmetry and perceptual disturbances such as reading disability in dyslexis (2, 23, 30, 31). To clarify this point it is fundamental to determine whether the brain asymmetry is a result of the inherent properties of the human brain, or whether it evolves during ontogenesis as a result of perceptual experience.

In this study children with disturbed visual perception were studied to obtain some understanding of the genesis of functional asymmetry in the human brain. The results were compared with those obtained previously in the group of normal children investigated with identical method (15). To make the comparison easier for a reader the results for normal children were described again in this paper.

METHODS

Subjects. Experiment I. As a result of selective tests, carried out routinely among 300 children in Warsaw nursery school, two groups of children were chosen (an average age 5 years 5 months): a group of 10 children displaying normal development in all basic psychological functions (Normal children) and a group of 8 children (Retarded children) which differed from the normal group only in having lesser developed visual perception (retardation by 18 months to — 2 years, according to Bender and Spionek test). All subjects were right-handed. Clinical tests excluded children with detectable organic disease and defects in the peripheral visual system. The same groups of children took part in two experiments, involving the same tests. The first experiment was performed at the pre-school age of 5 years and the second when they were 7-year old and had already receiving some training in reading and writing.

Material. Four printed, capital letters, Helvetica type (K, T, Y and Z) were used. The angle size of each letter was 1°10' in vertical height and 48' in the horizontal plane, such that the test pattern did not exceed the macula lutea. During the experiment either a single letter or a pair of letters was displayed. The letters were paired in all possible combinations of the four letters, such that each of them would be shown in the first (I) or second (II) position within the pair.
The same material was used in both experiments. When the children were 5-year old the letters constituted for them the nonverbal material (Experiment I). However, when they were 7-year old the same letters were the verbal material for them (Experiment II).

Procedure. Experiment I. This experiment consisted of two parts. The first, lasting about a month involved teaching the Normal and Retarded children to point at one of four, colored (white, red, blue and black) buttons during the presentation of one of the four letters. The second part of the experiment was carried out employing lateral vision. Single letters or pairs were presented at a distance of $3^\circ 36'$ to the right or left of the fixation point. Single patterns and pairs of patterns were presented in a separate series. The exposure time was 66 ms. After each eight exposures the children rested while listening to music. The viewing was monocular and always with the right eye. The task of the child was to fixate his eyesight on the central point and recognize the single letters or pairs of letters in the right or left visual field and press the appropriate button. If during a given exposure, eye ball movement was registered (using the ERG method), the trial was repeated.

Experiment II. This experiment was carried out about two years after the first experiment and consisted of the same material as in Experiment I, however, the letters now had a verbal character for the children which at the age of 7 had already received training in reading and writing.

All children were able to name all four letters, though the Retarded children manifested trouble in learning to read (the cases of dyslexia). The task now involved naming the letters and pressing the appropriate button.

RESULTS

The analysis of the results employed a method of comparing: (i) percentage correct identifications of each letter in the I or II position of the pair (which was presented in a given visual field) with the percentage correct identifications of the same letter presented singly (in the same visual field); (ii) the mean reaction time (RT) values for single letters with the RT values for the pair of letters (presented in the same visual field).

1 In order to eliminate any doubts that the use of the right eye may support the predominance of the left hemisphere, due to greater effectiveness of the contralateral pathway a control experiment using left eye was carried out with two children. The results of this experiment did not support the supposed bias in the applied experimental conditions.
Experiment I. Perception of nonverbal material (letters for 5-year old children, non-readers)

An analysis of variance showed that only one factor was statistically significant, namely, the grouping of the children (Normal and Retarded: \( P < 0.001 \)). In Fig. 1 the results of recognition of nonverbal material by Normal and Retarded children are shown with reference to the hemisphere to which the material was directed.

Fig. 1. Correct reaction during lateral perception of nonverbal patterns (5 year olds).

The mean percentage of correct identifications and detailed dependences between the results achieved during lateral presentation of nonverbal material showed an absence of difference between the results of perception of patterns directed to the right and left brain hemispheres (Fig. 1). This refers to both Normal and Retarded children.

The letters in the I position in the pairs were identified with the same level of difficulty as were the single letters. The letters in the II position were recognized with greater difficulty (\( P < 0.05 \)), than when presented singly. In the Retarded children, pattern recognition in pairs was more difficult than the recognition of single patterns when the presentation was directed equally to the right and left hemisphere. The general level of correct identifications achieved by Retarded children in comparison with the Normal group was significantly lower (\( P < 0.001 \)).

The analysis of the RT data confirmed the finding that the difference between the processing of nonverbal material in the left and right hemispheres in both groups of tested children was not significant (Fig. 2).
Experiment II. Perception of verbal material (letters for 7-year old children who can read).

An analysis of variance revealed that three of the variables were significant: (i) the brain hemisphere to which the material was directed ($P < 0.01$); (ii) the group of children (Normal and Retarded ($P < 0.01$)) and (iii) the position of the letters within the pair ($P < 0.01$); Figure 3 illustrates the results on recognition of verbal material by Normal and Retarded children, depending on the hemisphere to which the material was directed.

Fig. 3. Correct reaction during lateral perception of verbal patterns (7 year olds).

The results obtained during the presentation of verbal material in the group of Normal children showed a statistically significant difference ($P < 0.01$) between the right and left hemispheres. This difference was
revealed in a lower level of correct identifications of the letters when directed to the right hemisphere. Other hemispheric differences appeared within interdependencies between the results of single letters and letters in the pairs. Paired letters in the I position in the pair were recognized significantly more easily ($P < 0.01$) during their presentation to the left hemisphere, than single letters. However, paired letters in the II position were more difficult ($P < 0.05$) than letters presented separately. These interdependencies, however, were not confirmed for the projection of the same material to the right hemisphere. The scores of Retarded children in comparison with Normal children were significantly lower ($P < 0.01$). In addition, the Retarded group showed no significant difference between the results of analysis by exclusively the right or left hemisphere.

The analysis of RT registered in Normal children during the presentation of verbal material confirmed the finding of a difference between the hemispheres, showing that better results were achieved when the task involved the left hemisphere ($P < 0.05$). These interdependencies were not confirmed in the results obtained from the Retarded group. Figure 4 shows RT during the lateral perception of nonverbal patterns in the Normal and Retarded children.

![Fig. 4. Reaction time during lateral perception of verbal patterns (7 year olds).](image)

**DISCUSSION**

The comparison of results of behavioral tests with nonverbal material (letters for 5-year olds) in both groups of children (Normal and Retarded) demonstrated that in the early stage of development both hemispheres are equally predisposed to the analysis of the nonverbal patterns. This functional equality is expressed by the lack of significant difference between RT in either of the hemispheres, a similar level of correct identifications and interdependencies between the analysis of single
patterns and paired patterns. According to these interdependencies, nonverbal patterns are recognized with more difficulty when they are within the pair than during their single presentation. The different results for both groups of children were achieved using verbal material (letters for 7-year olds). A predominance of the left hemisphere in Normal children in comparison with Retarded group, was demonstrated in a higher level of correct identifications and a facility for recognition of paired letters. These data are not similar to the results obtained with the Retarded children. Also the general level of recognition of nonverbal and verbal patterns was lower in the Retarded than in the Normal group.

Observations on the mature form of brain asymmetry for verbal patterns in 7-year olds (Normal) and in children younger than in our experiment (13, 17) suggest that the dominance of the left hemisphere developes at a very early period. The formation of the left hemisphere superiority may be based on certain inherent characteristics of the brain. They are probably connected with the fixation of a right-handedness in our civilization, which decides the localization of the speech center in the left hemisphere. However, the lack of right hemispheric dominance in the analysis of nonverbal patterns in our 5-year olds indicate that this type of specialization is formed at an older age as a result of perceptual training. These results then seem to follow the hypothesis that the initiation of the brain asymmetry gives the left hemisphere predominance which manifests itself at any early stage and is probably related to the inherent features of the brain (1). Our position does not agree with the interpretations emphasizing the localization of the speech center in the left hemisphere (and therefore the specialization of this hemisphere for verbal tasks) as a result of experience, and being formed not before 10 years of age (7, 21). We also disagree with the suggestion (5) that the right hemisphere specializes early on the analysis of the physical features of patterns because of the better developed blood system than in the left hemisphere.

In trying to determine, in context of our hypothesis, the connection between the development of brain asymmetry and reading disability in Retarded children, we consider the role of two factors: an inherent predisposition of the left hemisphere for verbal functions, and the efficiency of ontogenetic perceptual training. Taking into consideration the fact that one of the criterions in choosing the children for the experiment was right-handedness, we may suppose that both Normal and Retarded children had similar, inherent left hemisphere predisposition for verbal tasks. Selective tests excluded also the cases with marked injury to the brain, which could have been held responsible for
brain asymmetry. If we then accept, that at the early ontogenetic period, the properties of the hemisphere were similar in both groups of children (Normal and Retarded), we may suppose that the incomplete functional asymmetry demonstrated in Retarded children is probably related to the second factor, i.e., a lower efficiency of perceptual training. This admission is supported by the lack of facilitation between letters within the pair, which indicates an inability to grasp two letters as one pattern, well known from the previous experience (3) and also by the general decrease in the scores of the Retarded group as compared with the Normal group. The decrease in scores relates to the perception of both nonverbal and verbal material. This fact suggests that the reason for the lower efficiency of perceptual training is connected not with a specific damage of brain hemispheres, but with the beginning of ontogenesis, inherent disturbances of more basic neurological activity were present and common for both verbal and nonverbal functions. Some studies state that there are disturbances in bioelectrical functions, resulting in the insufficient development of the inhibitory processes in the brain (19, 29) or in a partial development of alpha activity in parieto-occipital cortex (11, 27).

While accepting such an explanation we cannot regard the incomplete lateralization of the visual function in the brain as a basic cause of dyslexia. However, we can suppose that it is connected with inherent disturbances of more elementary neurological processes, which also cause delay in development of visual functions and impede ontogenetic perceptual training. A promising methodological approach in a search of the nature of these disturbances seems to be an application of electrophysiological techniques (11, 20).

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