A Neurolinguistic Study of Autistic Children
Employing Dichotic Listening

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A neurolinguistic study of 20 high functioning right-handed autistic children (19 males and 1 female) was carried out using a dichotic listening test of two-syllabic meaningful words with which to detect the level of binaural separation ability and the condition of hemispheric lateralization of language by examining the degree of ear advantage.

The autistic children ranged from 5 to 15 years in age. Their IQ ranged from mildly retarded to normal. (The mean IQ was 67.6 and the mean mental age was 5yr.9mo.)

We compared them with non-autistic mentally retarded and normal children as controls, being matched by mental age and right handedness.

The autistic children were found to be significantly lower on the level of binaural separation ability than the controls and to have a clearly higher incidence of a left ear advantage than the controls. The autistic and mentally retarded children showed lower advantage than normal children.

These results indicate that the autistic children have a dysfunction or immaturity of the central auditory nervous system and an abnormality in the process of hemispheric lateralization of language.

(Key Words: infantile autism, dichotic listening test, binaural separation ability, ear advantage, lateralization of language)

INTRODUCTION

The cause of infantile autism is not clearly known, but is assumed to be a developmental disorder leading to dysfunction of the central nervous system (1).

There is general agreement that the primary symptom of autism is language deficit (16, 17). Therefore, studies of neurolinguistics in autistic children are being made extensively.

At present, it is believed that language functions are lateralized to the left hemisphere of the brain in infancy (5, 10, 20). In most cases of left hemisphere damage in right-handed children, language impairment is provoked. Therefore, it may not be unreasonable to speculate that the language impairment in autism is produced by dysfunction of the left hemisphere. Several reports have shown that autistic children often were not right handed (4, 6, 15, 18). This led to the hasty conclusion that the left hemisphere functioned abnormally in autistic children (4, 18). However, we do not think it is rational to draw such a conclusion based solely on hand preference.

In contrast, we consider that the dichotic listening test (DLT) is one of the more useful methods to detect the dominant hemisphere of language according to ear advantage (11, 12). It is generally accepted that the crossed auditory pathway is more efficient than the non-crossed one, and that the contralateral hemisphere plays an important role in receptive language. Furthermore, when different verbal stimuli are presented to both ears simultaneously, the dominant hemisphere recognizes more efficiently the stimulus which arrives at the contralateral ear than that which arrives at the ipsilateral ear. That is, the right ear advantage will indicate left hemisphere dominance in regard to perception of speech sounds.

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Until now, there have been several studies using DLT in autistic children, but with contradictory results (2, 8, 15, 19). We have uncovered some problems concerning the selection of subjects and procedures in those studies. In this report, we selected a group of autistic children as homogeneous as possible by mental age and hand preference, and used normal and mentally retarded children as controls.

Based on the DLT, we report and discuss our findings on the level of binaural separation ability and the condition of hemispheric lateralization of language of both the autistic and control children.

MATERIALS AND METHODS

Subjects
In order to increase homogeneity, we divided the autistics into three subgroups according to the level of mental age (MA), as shown below.

- group I. 7 children, MA range: 2 yr. 10 mon.—4 yr. 10 mon. (mean: 4 yr. 3 mon.)
- group II. 5 children, MA range: 6 yr. 8 mon.—7 yr. 6 mon. (mean: 7 yr. 1 mon.)
- group III. 8 children, MA range: 8 yr. 4 mon.—11 yr. 3 mon. (mean: 9 yr. 11 mon.)

As controls, groups of 10 normal (NOR) and 10 mentally retarded (MR) children, matched for MA and handedness, were assigned to each autistic subgroup. All subjects, given preliminary tests of the words used in our DLT by monaural hearing of audiometry of pure tones, disclosed little right and left differences in their hearing ability.

Procedures
Our DLT method has been described in detail (7). In this study, we used only two-syllable meaningful words as dichotic stimuli, because we had found that meaningless words were too difficult for the very young, the mentally retarded, and the autistic children.

The seal subjects sat and were fitted over both ears with stereophonic headphones. They heard, simultaneously, 25 pairs of words at 65 decibel, e.g. KUTSU-KASA (shoes-umbrella), INU-NEKO (dog-cat) and so on, at five second intervals. They had been instructed to repeat immediately what they heard. Every subject was tested twice, the headphones being reversed on the second run, so that the right and the left channels of the equipment would be balanced.

Scoring
The total ear response of the subjects (TER) consisted of: both-ears response (BER), right-ear response (RER), left-ear response (LER), and compound response (CR) (14).

BER: The subject correctly identifies the stimulus pair of words, one to each ear.

RER: The subject identifies only the right (or left) (LER) word of the stimulus.

CR: The subject cannot correctly identify the stimulus, but transposes syllables within the stimulus words, e.g. from KUTSU-KASA to KUSA-KATSU.

The degree of ear advantage was expressed as a laterality index: 

$$LI = \frac{(R - L)}{(R + L)} \times 100$$

where R (or L) is the total number of correctly identified right (or left) ear responses, i.e. $R = BER + RER$, and $L = BER + LER$. 

$LI > 0$ means a right ear advantage.

$LI = 0$ means neither ear has an advantage.

$LI < 0$ means left ear advantage.

We considered that the BER shows the level of binaural separation ability and that LI shows the degree of ear advantage.

RESULTS

The ratios of BER, RER, LER and CR to TER were calculated for each subgroup of autistic, mentally retarded (MR), and normal (Nor) children, and are shown in Fig. 1.

CR had been observed frequently in DLT with meaningless word stimuli in our previous report (7). However, as shown in Fig. 1, it was rarely found in the present series of tests, probably because we used only meaningful word stimuli. Therefore, didn't think it necessary to take CR into account in this report.

1. The level of binaural separation ability.

The mean value of the BER of each autistic subgroup was composed with its controls by student's t test. The results are shown in Fig. 2.

In group I, no significant differences were found.

In the second group, the mean values of the BER of the autistic and MR subgroups were significantly lower than the Nor subgroup. No significant difference was found between the autistic and MR subgroups, although the autistic children were approximately two years
older than the MR group, as shown in Table 1.

In group III, the mean value of the BER was also significantly lower in the autistic and MR subgroups than in the Nor subgroup. It should be noted that the IQ of the autistic subgroup was within the normal range and was comparable to that of the Nor subgroup. Nevertheless, the mean value of the BER of the autistics was not significantly different from that of the MR subgroup.

2. The degree of ear advantage.

The mean values of $R$ and $L$, and $L_I$ were calculated for all the autistic, MR and Nor subgroups. At the same time, the number of $R$ and $L$ were collated by the $t$ test. The results are shown in Table 2.

The numbers of $R$ and $L$ showed no significant differences in any autistic subgroup. However, a right ear advantage clearly existed in the MR and Nor children of groups I and II, but not in group III.

In group I, the mean $L_I$ was much lower in the autistics than in the MR and Nor subgroups.

In groups I and II, the MR and Nor subgroups had a clear right ear advantage ($+L_I$), whereas the autistics did not.
Table 1 Number, sex, handedness, CA, MA, IQ of subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Sex</th>
<th>Hand</th>
<th>CA</th>
<th>MA</th>
<th>IQ(S-B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7</td>
<td>M</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>9:1 4:3 47.9</td>
</tr>
<tr>
<td>I</td>
<td>10</td>
<td>MR</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>4:10 4:10 100.0</td>
</tr>
<tr>
<td>Nor</td>
<td>10</td>
<td></td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>4:10 4:10 100.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>11:1 7:1 66.4</td>
</tr>
<tr>
<td>II</td>
<td>10</td>
<td>MR</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>9:1 7:1 73.6</td>
</tr>
<tr>
<td>Nor</td>
<td>10</td>
<td></td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>6:7 6:7 100.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>9:9 9:11 95.9</td>
</tr>
<tr>
<td>III</td>
<td>10</td>
<td>MR</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>12:5 8:10 65.5</td>
</tr>
<tr>
<td>Nor</td>
<td>10</td>
<td></td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>8:8 8:8 100.0</td>
</tr>
</tbody>
</table>

* A: Autism, MR: Mental retardation, Nor: Normal
The approximate mental age of the children in Groups I, II, and III was 4, 7, and 9 years, respectively.

Table 2 Ear advantage and laterality indices

<table>
<thead>
<tr>
<th>Group</th>
<th>R</th>
<th>L</th>
<th>t-test</th>
<th>LI**</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>23.0 ±4.84</td>
<td>22.4 ±4.50</td>
<td>NS</td>
<td>0.99 ±17.26</td>
</tr>
<tr>
<td>I</td>
<td>29.1 ±4.94</td>
<td>21.9 ±8.48</td>
<td>p&lt;0.05</td>
<td>15.76 ±23.77</td>
</tr>
<tr>
<td>Nor</td>
<td>29.1 ±2.77</td>
<td>18.2 ±4.02</td>
<td>p&lt;0.01</td>
<td>27.14 ±10.51</td>
</tr>
<tr>
<td>II</td>
<td>27.6 ±5.94</td>
<td>21.9 ±8.48</td>
<td>NS</td>
<td>-5.73 ±23.13</td>
</tr>
<tr>
<td>MR</td>
<td>34.9 ±7.08</td>
<td>21.8 ±9.13</td>
<td>p&lt;0.01</td>
<td>22.81 ±22.06</td>
</tr>
<tr>
<td>Nor</td>
<td>38.6 ±3.88</td>
<td>32.0 ±6.23</td>
<td>p&lt;0.01</td>
<td>26.71 ±18.16</td>
</tr>
<tr>
<td>A</td>
<td>33.3 ±4.29</td>
<td>33.8 ±4.74</td>
<td>NS</td>
<td>-0.69 ±8.50</td>
</tr>
<tr>
<td>III</td>
<td>37.9 ±5.45</td>
<td>33.1 ±6.69</td>
<td>NS</td>
<td>7.22 ±5.30</td>
</tr>
<tr>
<td>Nor</td>
<td>41.8 ±3.92</td>
<td>39.0 ±4.12</td>
<td>NS</td>
<td>15.89 ±31.49</td>
</tr>
</tbody>
</table>

* The groups are the same as in Table 1.
** LI = Laterality Index = (R + L)/R-L × 100

The percentage of autistic, MR and Nor children who had positive, 0 and negative LI are listed in Table 3. The ratio of positive and negative LI children was similar in the autistic group, while the ratios of positive LI in the MR and Nor groups were very high.

The percentage of children with a small LI (|LI| < 10) or a large (|LI| > 10) is shown in Table 4. The ratio of large to small LI was remarkably high in the Nor group, while the ratios of large to small LI were similar in the autistic and MR groups.

For clarity, the distribution of individual LI values in the autistic, MR and Nor groups is shown in Fig. 3.

The autistic group was characterized by a low, -LI (a low left ear advantage). The MR group was characterized by a low, +LI (a low right ear advantage). In contrast, the Nor group was characterized by a high, +LI (a high right ear advantage).

DISCUSSION

The twenty autistic subjects in this study were all male except one. The very low ratio of female autistic subjects may possibly have influenced our results. Thus, it still is an open question whether the conclusions derived from this study are applicable in general to autism. However, in a previous study, no significant sex differences were found in normal children by our dichotic listening test (7). What's more, autism occurred in boys four to five times as frequently as in girls, and the autistic boys typically
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Table 3 Percentage of positive and negative LI in Autistic (A), mentally retarded (MR), and normal (Nor) groups

<table>
<thead>
<tr>
<th>LI</th>
<th>Group</th>
<th>A</th>
<th>MR</th>
<th>Nor</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td></td>
<td>45.0</td>
<td>73.3</td>
<td>83.3</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>0.0</td>
<td>6.7</td>
<td>6.7</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td>55.0</td>
<td>20.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* +: R > L, 0: R = L, -: R < L
The percentage of + LI and − LI was similar in A group, while the percentage of + LI in the MR and Nor groups were very high.

Table 4 Percentage of large and small LI in autistic (A), mentally retarded (MR), and normal (Nor) groups.

<table>
<thead>
<tr>
<th>LI</th>
<th>Group</th>
<th>A</th>
<th>MR</th>
<th>Nor</th>
</tr>
</thead>
<tbody>
<tr>
<td>large</td>
<td></td>
<td>60.0</td>
<td>50.0</td>
<td>90.0</td>
</tr>
<tr>
<td>small</td>
<td></td>
<td>40.0</td>
<td>50.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* large: | LI | ≥ 10 small: | LI | < 10
The percentage of large to small LI was remarkably high in the Nor Group, while similar in the A and MR groups.

Fig. 3 Distribution of laterality indices (LI) in autistic, mentally retarded, and normal children.

showed clinical features more frequently than did autistic girls. Therefore, we considered that the very low ratio of female autistics had little influence on the results and does not negate any of our conclusions.

1. The level of binaural separation ability.
In Fig. 2, the autistic, MR and Nor children of group I showed very low BER levels, without significant differences between any two subgroups. We think it was difficult for the children of group I, in which the mean CA or MA was the lowest, to perform tasks such as the
DLT. It produced a "floor effect". Therefore, group I was not suitable to study the BER.

Referring to groups II and III, the autistic and MR children definitely had lower BER levels than the Nor children, in spite of their equivalent MA.

In Table 1 and Fig. 2, when the autistics in group II were compared with the MR subgroup, with an equivalent MA, we found that it took more years for the autistic children to reach the same BER level. This indicated that autistic children had a greater developmental delay or dysfunction of binaural separation ability than did the mentally retarded children. The autistics in group III had IQ's within the normal range, and their CA, MA and IQ were almost on the same level as those of the Nor children. Nevertheless, their BER level was as low as that of the MR subgroup.

Nagafuchi suggested that the BER score correlated closely with age and intelligence (13). However, we found that the autistic children showed developmental delay and/or dysfunction of binaural separation ability independent of intelligence. This indicated that the autistic children had some sort of dysfunction of the central auditory nervous system.

2. The degree of ear advantage.

As shown in Table 2, referring to the mean value of R (or L) of the autistics in groups I, II and III, neither significant differences between R and L nor in ear advantage, were found in any of the autistic subgroups.

On the other hand, the mean value of R differed significantly from L in the MR and Nor children in and groups I and II, that is, a right ear advantage was recognized.

As to the mean value of R or L, contrary to the speculation by Colby et al. (4) and Blackstock (3), that language function of the autistic children was under right hemisphere dominance, we found that the autistic children showed rather very low differentiation and that left hemisphere dominance was indicated for the MR and Nor control children in groups I and II.

The mean value of R and L were not significantly different in the MR and Nor subgroups in group III. Concerning that result, we thought as follows:

Firstly, referring to the Nor subgroup, the right ear advantage was expected, but the binaural separation ability of the group III children (Fig. 1 and 2) was so high that a "ceiling effect" emerged in our method. (In case the ratio of BER to TER is so high, ear advantage is not detectable, which is called "ceiling effect".)

Secondly, the binaural separation ability of the MR subgroup in group III (Fig. 1 and 2) was not so high that we could not expect "ceiling effect". Taking the mean value of the LI of this subgroup into account, we interpret it as a rather low ear advantage and that hemisphere dominance of language function still had not occurred.

We could not determine the ratio of subjects with a right (or left) ear advantage, or with the lower advantage in each group, merely by comparing the mean values of R (or L) as was stated. The distribution of individual LI values was listed in Fig. 3 and the ratio of positive, 0 and negative LI in Table 3. It was notable that the ratio of children with a left ear advantage (−LI) was definitely higher in the autistic than in the MR or Nor groups. Besides, our finding that the number of MR children with + LI was comparable with the Nor group, coincided with the findings of Jones, et al. (9). Namely, it indicate that the MR group had almost as many children with left hemisphere dominance of language function as the Nor group.

Furthermore, as shown in Table 4, the autistic and MR subgroups clearly had children with a lower LI than the Nor group, which would suggest the low differentiation of dominant hemisphere of language function. Consequently, when we compared the autistic, MR and Nor groups on the distribution of ear advantage, it was characteristic that only the autistic group clearly showed a higher incidence of left ear advantage.

We suggest a possibility exists that some autistic chi.dren have dysfunction or immaturity of the left hemisphere, and their language function may be governed by the right hemisphere as in the view of Prior et al. (15) and Hoffman et al. (8).

Arnold et al. (2) reported results contrary to Prior's ours. They examined autistic, language impaired, and normal children with a ULT, and found that the autistic children showed a higher incidence of right ear advan-
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tage, as did the normal children, while the language impaired children showed a higher incidence of left ear advantage. From their data, they thought that autism had a basis essentially different from language impairment.

In their method, which was quite different from ours, the subjects were instructed to point to whichever ear, with the corresponding hand, according to the first sound they heard in a dichotic stimulus pair.

Although it was usual that finger-pointing was done by the preferred hand and that autistic children showed a characteristic tendency to keep the sameness, which was rarely seen in language impaired or normal children, they did not write about the hand preference of their subjects. If their autistic children were mostly right-handers, it was to be expected that they would point to the right ear more often than the left. Thus, it was expected that a right ear advantage would predominate in the autistic children as a result.

Wetherby et al. administered a DLT to echolalic children, and reported that their DLT results reverted to normal after the children were no longer echolalic. If so, it would be necessary for us to divide the autistic children into those with and without echolalia, and to repeat the DLT again. Arnold et al. also failed to consider echolalia in their report (2).

The results of administering the DLT to the autistic, mentally retarded and normal children leads us to draw the following conclusions:

1. The autistic children had a low level of binaural separation ability, due to an assumed dysfunction or immaturity of central auditory nervous system.

2. Children with both a left ear and low ear advantage were dominant in the autistic group, and was assumed abnormality in the process of language laterализation.

REFERENCES


