Hemispheric Specialization for Speech Perception in Language Deficient Kindergarten Children

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Twenty right-handed kindergarten children with superior language skills and twenty with deficient language skills (as defined by performance on an elicited sentence repetition task) were tested (1) for hemispheric specialization for speech perception with a dichotic CV syllable task and (2) for relative manual proficiency by means of a battery of hand tasks. Reading readiness and aspects of other cognitive abilities were also assessed. The superior children evidenced a mean right-ear advantage of 14.5%, which is consistent with normal values reported by other investigators using the same stimuli. The language deficient group evidenced essentially no mean ear advantage (0.5) with half of these subjects exhibiting left-ear superiority. The findings suggest relationships among cerebral dominance, language proficiency (including reading readiness), and general cognitive functioning.

Orton's theory of mixed dominance (Orton, 1937) associates speech, language, and reading disorders with the failure of one hemisphere to dominate in the control of both motor and speech processes. Until recently, attempts to test this hypothesis have been hampered by the absence of reliable measures of handedness and by the absence of a nonintrusive method for assessing cerebral dominance for language. These obstacles

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have been partially overcome with the development of tests of relative manual proficiency (Annett, 1970; Satz, Achenbach, & Fennel, 1967) and with the establishment of dichotic listening techniques as measures of hemispheric specialization for speech perception (Kimura, 1961b).

Orton's speculations linking various disorders with abnormal cortical lateralization have received, at best, equivocal support. Early dichotic studies suggested that stutterers evidenced abnormal lateralization (Curry & Gregory, 1969; Brady, Sommers, & Moore, 1973). However, a recent study, using a dichotic nonsense syllable task (Dorman & Porter, 1975), found no difference in lateralization for speech perception between normals and stutterers, and other studies using different dichotic tasks have reported similar results (Slorach & Noehr, 1973; Sussman & Mac-Neilage, 1975).

Variability of outcome also characterizes the reports of lateralization for speech perception in learning disabled populations. Several studies have shown learning disabled children to evidence abnormal lateralization (Dermody, Noffsinger, Hawkins, & Jones, 1975; Kimura, 1963, for boys only; Witelson & Rabinovitch, 1972; Zurif & Carson, 1970). Once again, however, the use of a dichotic nonsense syllable task has revealed no difference in lateralization for speech between dyslexic children and normal controls (Fischer, 1972). This outcome, in turn, is similar to those reported by Bryden (1970), Satz (1975), Witelson (1977), and Yeni-Komshian, Isenberg, and Goldburg (1974).

Language deficient children, the target population of the present study, have also been subjected to diverse dichotic tasks, again with mixed results. Pettit and Helms (1974) and Starkey (1974) reported the absence of a right-ear advantage in language disordered children. However, Sommers and Taylor (1972) and Tobey, Cullen, and Fleischer (1976) found normal ear advantages in similar populations.

In the present study, we assessed hemispheric specialization for speech perception in an extensively tested group of language deficient children and normal controls with superior language skills. For each child, aspects of overall intellectual functioning, articulatory ability, language comprehension and performance, reading readiness, and visual–motor integration were assessed and then correlated with handedness and dichotic listening performance. The dichotic task, Shankweiler and Studdert-Kennedy's nonsense syllables (1975), has been used before with normal children (Dorman & Geffner, 1974; Geffner & Dorman, 1976; Orlando, 1971) and is known to yield a right-ear advantage of between 9 and 15%. Moreover, the task has also been used with two abnormal populations (stutterers and learning disabled children) with the outcome of no differences between the normal and abnormal populations. Since the nonsense syllable test has proved to be conservative, in that it does not readily admit differences between the normal and abnormal populations, it would be par-

ticularly striking if a difference were found in lateralization for speech perception between normal and language deficient children.

METHOD

Subjects. Twenty language superior children (10 male; 10 female; mean CA = 69.9 months) and twenty language deficient children (10 male; 10 female; mean CA = 68.5 months) were selected from a pool of approximately 600 public school kindergarteners by the administration of an elicited sentence repetition task, the Stephens Oral Language Screening Test, experimental version (SOLST) (Stephens, 1974). The control group was composed of children who made less than two error points in both repetition and articulation; the experimental group was composed of children who earned an error score of 25 or more in repetition, with articulation scores ignored.[1] All children were right-handed as defined by performing at least two of three tasks (throwing a ball, writing, cutting with scissors) with the right hand. All children had normal and equal hearing in both ears and scored at least at the 90 IQ level on the Peabody Picture Vocabulary Test (Dunn, 1965). No child was bilingual, known to be organically impaired, a twin, a stutterer, a kindergarten repeater, or from the lowest economic level (Group 7, Hollingshead, 1965).

Dichotic listening task. Synthetic signals appropriate for the six English stop consonant–vowel syllables (/ba, da, ga, pa, ta, ka/) were generated in the Haskins Laboratories parallel resonance speech synthesizer. Under computer control, these six stimuli were recorded dichotically in a fully counterbalanced, randomized order onto magnetic tape. The resulting tape contained 60 stimulus pairs with each member of a pair occurring twice on each channel. The interpair interval was 4 sec, with a 10-sec interval occurring after every 10 pairs. The signals were reproduced on a Panasonic RS 296 tape deck and presented via matched and calibrated TDH 39 headphones. The outputs of the tape channels were equated to within 2 db and monitored before each test session. The signal level was 81 db SPL.

The listeners were familiarized with the synthetic speech signals by three binaural presentations of the six test syllables. The 60 dichotic pairs were then presented twice, separated by an interval of 15–20 min, during which handedness tasks were administered. The headphones were reversed on the second run to control for channel effects. Only one response was elicited for each stimulus pair.

For each subject, a right-ear advantage score (REA) was computed by the index $R - L/$

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[1] The SOLST was designed as a language screening instrument for kindergarten and first grade children. Its use for this purpose is based on the premise that, when a child repeats a sentence which is too long for rote repetition, the errors in repetition will reflect the child's level of linguistic development, thus revealing immature or atypical rule systems. The SOLST version used for this study consisted of 17 sentences, each of which could be scored both for a hierarchy of language errors and for misarticulations. In order to accommodate the control group articulation criterion (fewer than three errors) misarticulations were scored only up to three error points. When scoring language performance, a perfect repetition received a score of zero, and at the other extreme, an unintelligible or no response was scored 7. Sentences which earned intermediate scores are illustrated in the following examples in which an actual test sentence is followed by an incorrect repetition, the error score assigned, and the reason for the assignment: (i) Somebody burned a hole in the rug/ Someone burned a hole in the rug (1), minor change on a single word; (ii) There's no reason for fighting with him/ There isn't any reason to fight with him (2), paraphrase; (iii) Where will they sing for the children?/ Where would they sing with the children? (3), grammatical but with meaning changed; (iv) Robert found a shiny penny/ Robert finded a shiny penny (3), ungrammatical but with meaning retained; (v) Joe must have bought three oranges/ Joe bought (or buyed) oranges (5), greatly changed or reduced; (vi) We thought the baby knew how to say thank you/ uh, say thank you (6), first or last few words only.

$R + L \times 100$, where R (or L) is the number of syllables correctly reported from the right (or left) ear. An absolute ear advantage score (AEA) was derived by simply eliminating the sign preceding the ear advantage score. This index estimates the strength of lateralization without regard to side of dominance.

Measures of handedness.[2] Each subject was tested on the hand preference section of the Harris Test of Lateral Dominance (Harris, 1957) and for relative manual proficiency for peg placement, stylus tapping, card dealing, scissors cutting, and strength of grip. For each subject, a dextrality index (DI) was computed for each task using the same formula as for the ear advantage, except for the scissors cutting where $L - R/R + L \times 100$ was used. A manual dexterity score was obtained by summing the raw scores on all the hand tasks.

Measures of cognitive and other development. The IQ of each child was assessed by administration of the Goodenough Draw-a Person Test (Goodenough, 1926) and the Peabody Picture Vocabulary Test (Dunn, 1965). Articulatory ability was assessed by the Fisher–Logemann Test of Articulation Competence (Fisher & Logemann, 1971). Language was measured by the Boehm Test of Basic Concepts (BTBC) (Boehm, 1971), a Complexity Measure of Expressive Language (CMEL) (Wurtzel, Roth, & Cairns, 1976)[3], and the Developmental Language Comprehension Test (DLCT) (Weiner-Mayster, 1975)[4]. Reading readiness was determined by the Murphy–Durrell Reading Readiness Analysis (MDRRA) (Murphy & Durrell, 1965). The single measure of nonlinguistic ability was the Developmental Test of Visual–Motor Integration (Beery, 1967).

RESULTS

IQ, language, reading, and visual–motor tasks. The mean scores on these tasks for both groups are shown in Table 1. In addition to their inferior performance on elicited sentence repetition, which was the sole determinant for group placement, the language deficient group performed significantly poorer on the following tasks: Goodenough Draw-a person and manual dexterity (both $p < 0.05$) and Peabody Picture Vocabulary Test, sentence comprehension (DLCT), comprehension of basic language concepts (BTBC), expressive language complexity (CMEL), and visual–

[2] For details of administration of these and other measures see Rosenblum (1976).

[3] This is an experimental version of a metric which was used to score 50 of each child's spontaneous utterances recorded during a play session, for each occurrence of 37 grammatical forms, sentence forms, and grammatical relations. Among the grammatical forms credited are nouns, verbs, verb inflections, plurals, etc.; grammatical relations include subject/verb, verb/object, modifier/noun or verb, etc. Where appropriate, these are scored according to what is known of the way children's rule systems develop into adult forms. For example, correct past tense inflection of a regular verb earns 2 points, correct past tense inflection of an irregular verb earns 2.5 points, and overregularization of past tense earns 1.5 points. A child's total score represents the number of occurrences of these forms and grammatical relations in the set of 50 utterances examined. Subtotals for each category can also be used for individual and group comparisons. See Rosenblum (1976) for a complete description of scoring protocols for this and the other unstandardized measures.

[4] This test measures the ability of the child not only to comprehend syntactic and morphological forms, but also to draw inferences from the information given in the sentence. Twelve sentences in each of four sets test simple syntax (passives, negatives, reflexives), complex syntax (relatives, comparatives, equatives and complements), and semantic inference (consequences of action, presupposition, instrumental inference). The child's task is to select one of four pictures which best exemplifies the spoken test sentence.

TABLE 1

Means and t Tests on All Nonlaterality Variables

	Experimental	Control	t	p
Criterion variables				
Sentence repetition (SOLST)[a]	32.70	00.85	−13.36	<0.01
Age[b]	68.45	69.90	1.48	n.s.
Test variables				
Sentence comprehension (DLCT)	26.45	34.95	6.71	<0.01
Comprehension of basic concepts (BTBC)	30.74	42.20	6.16	<0.01
Syntactic complexity (CMEL)	425.99	610.73	5.90	<0.01
Articulation (error score)	13.05	00.80	Not tested	
Peabody IQ	105.30	119.80	4.17	<0.01
Goodenough IQ	107.60	121.25	2.27	<0.05
Visual–motor integration[b]	64.25	76.15	4.75	<0.01
Manual dexterity	298.82	332.22	2.55	<0.05
Reading readiness (MDRRA)[c,d]				
Phoneme identification	72	99	Not tested	
Letter naming	82	89	Not tested	
Learning rate	78	99	Not tested	
Total score	82	96	Not tested	

[a] Articulation errors were not scored above three errors during the administration of this test. In order to qualify for the control group, children could make no more than two such errors. Articulation was not a criterion for experimental group placement.

[b] In months.

[c] Median percentiles.

[d] Only 16 subjects in the experimental group and 18 subjects in the control group were tested on this variable.

motor integration (all $p < 0.01$). The two groups also differed in performance on all of the subtests of the Murphy–Durrell Reading Readiness Analysis. However, since these scores were reported as percentiles, significance levels were not determined. There were no sex differences found on any of these measures.

Handedness. The two groups were right-handed to an equal degree on all six handedness tasks. There was a sex difference found for scissors cutting, with the girls achieving a greater between-hand difference ($p < 0.05$).

Dichotic listening. The REA of the language deficient group (mean = 0.5) differed significantly from that of the superior children (mean = 14.5; [$t(38) = 3.41, p < 0.01$]. By-subject inspection reveals that, while only two of the control group children were left-eared (10%), nine of the language deficient children were left-eared and one showed no preference (50%). (See Fig. 1 for the distribution of both groups' ear advantages.) The AEA also differed significantly between the two groups [mean = 9.35
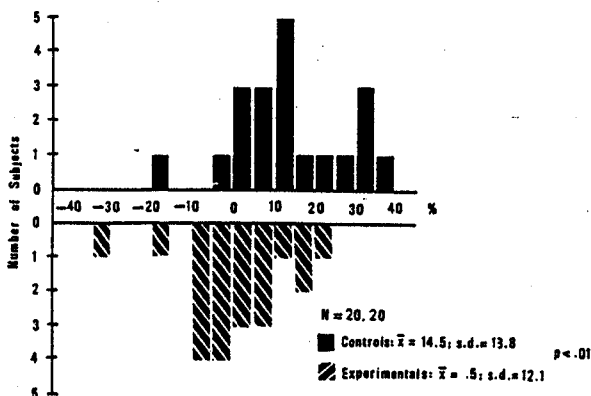
FIG. 1. Distribution of the right-ear advantage.

and 16.29, respectively; $t(38) = 2.26$, $p < 0.05$], indicating that the language deficient children were less lateralized even when direction of lateralization was ignored.

An error analysis of the dichotic listening results indicated that the two groups did not differ either in terms of the total number of errors or the kind of errors (blend or place). The former outcome indicates that the absence of a REA in the language deficient group was not a floor effect due to poor overall performance on the task. In this respect, the language deficient children differed from developmental dyslexics (Witelson, 1977) who, although showing a normal REA, had fewer total correct responses than a normal control group. The language deficient children also performed differently than left hemisphere-damaged adults, who do not benefit from trials in which both members of the dichotic pair share the same place of articulation (double place cues) (Oscar–Berman, Zurif, & Blumstein, 1975). In the present study both groups performed better with double place cues, but did not differ from each other in this respect. Only one sex difference was noted: The girls made somewhat more blend type errors than did the boys ($p < 0.05$).

IQ as a factor in the REA. Since the two groups differed significantly in both Peabody IQ and Goodenough IQ, it is possible that the difference in lateralization between the two groups simply reflects the IQ difference. To determine whether lateralization for speech perception was related to IQ, the 40 subjects were pooled and then divided into two new groups: those most strongly lateralized (mean AEA = 20.48) and those most weakly lateralized (mean AEA = 5.14). The difference in the resulting Peabody IQ means (strongly lateralized = 114.7; weakly lateralized = 110.4) was not significant. Therefore, Peabody IQ was independent of strength of lateralization. To assess in yet another manner the relationship between IQ and the ear advantage, two subsets of subjects from the two

TABLE 2

SIMPLE CORRELATIONS AMONG LATERALITY MEASURES

	Harris	Pegs	Tapping	Cards	Scissors	Grip	Absolute ear advantage
Experimental group							
Right-ear advantage	.21	.26	.02	.71	−.05	−.05	−.15
Harris		−.26	.33	.04	.02	.21	−.13
Pegs			−.21	.47	−.02	−.31	−.01
Tapping				.07	−.02	.36	−.01
Cards					.05	−.04	−.31
Scissors						.35	.17
Grip							−.09
Control group							
Right-ear advantage	.12	.26	.19	−.19	.10	−.29	.84
Harris		.15	.04	−.45	.47	−.05	.23
Pegs			.63	.27	.10	.16	.31
Tapping				−.05	.18	.18	.22
Cards					−.24	.29	−.07
Scissors						−.17	.03
Grip							−.03

groups were matched on Peabody IQ (mean IQ = 116.5, $n = 8$) and the REAs were examined. The REA of the language deficient group (mean = −5.47) remained significantly different from that of the superior group (mean = 18.45) ($p < 0.01$). Matching on the Goodenough IQ produced similar results (mean = 1.53 and 11.30 respectively, $n = 8$), although the difference failed to reach significance. In sum, the outcome of these several measures suggests that the REA difference between the two groups was not related to the IQ difference.

Simple correlations. Intercorrelations among all the laterality measures are displayed in Table 2. For the normal group no correlations above 0.5 are found between the REA or AEA and any of the handedness tasks (this is an arbitrarily selected figure, based on the problems of determining a level of significance for a correlation matrix of the size constructed for this study, where measures were taken on only two samples).[5] In the language deficient group, however, a correlation of 0.71 between the REA and card dealing is shown. Among the handedness measures themselves, there is only one correlation of note, that between stylus tapping and peg placement in the control group (0.63). Thus, the hand tasks appear to measure a set of unrelated skills, which may be lateralized independent of one another. It also appears that no strong relations exist between the REA and any nonlaterality measure. Only a few correlations above 0.5 are found between the six sets of dextrality indexes and the other measures; some of these are negative. Intercorrelations among the language measures ranged from low to moderate; however, discussion of these

[5] Hays (1963), p. 576.

relationships will be dealt with in subsequent articles dealing with the linguistic aspects of this study (Rosenblum & Stephens, in preparation; Rosenblum, Johnson, & Cairns in preparation).

Stepwise multiple regression. Where generally positive but weak correlations exist, as was true in this sample, weighting the scores of several variables differentially may predict a dependent variable better than any one of them alone. A stepwise multiple regression method has been used previously for this purpose, with handedness measures combining to improve prediction of ear advantage (Orlando, 1971, with 8- and 10-year-old boys; Shankweiler & Studdert–Kennedy, 1975, with adults). In the present study, when the handedness measures were used as the predicting variables for REA, there were no significant increments above the simple correlation of the first variable used in the equation.[6]

Birth order. Fifteen of the twenty language superior subjects were first-born or only children, whereas only three of the language deficient subjects held that position; the remainder of the experimental subjects were middle or last born.

DISCUSSION

Our results indicate that inability to repeat sentences accurately is associated with deviant ear asymmetries[7] and a lower level of cognitive (linguistic and nonlinguistic) functioning. Elicited sentence repetition appears to reflect many of the components underlying children's language usage, including not only some facets of motivation and the ability to attend, but also short- and long-term auditory/linguistic memory. It is difficult then to isolate the factor or factors which may be responsible for poor performance on this task and for the accompanying atypical configuration of ear advantages found in these children. Indeed, the weak correlations of sentence repetition scores and REA with the other measures suggests that the language deficient children in this study differ idiosyncratically in their areas of deficit.[8] It may be that the holistic nature of

[6] The handedness of children under the age of 8 has been found to be extremely unreliable; it is believed that it has not yet achieved its full strength at the younger ages (Harris, 1957). This could explain the failure to improve ear/hand correlations in our sample with the multiple regression technique.

[7] It could be argued that the dichotic task reliability has not been established for these samples and that there are two types of subjects whose side of ear advantage is likely to be reversed upon retesting; those who are left-eared and those who are weakly lateralized to either side (Blumstein, Goodglass, & Tartter, 1975). Granted that this is the case, the fact remains that the experimental group in this study contains many more such subjects than does the control group, indicating that, at the very least, their dominance cannot be determined as readily as can that of the control group children.

[8] Reliability may be low for many of our measures; retests could not be done, and for several of the tasks reliability has not yet been established. But even if reliability were found to be acceptably high in all cases, accurate prediction of sentence repetition scores could be expected only from those variables in which most of the children had deficits. There was no one area of which this was true.

the elicited sentence imitation task is what makes it a good screening task: it will select children with a variety of deficits, any one or combination of which may be associated with abnormal lateralization.

Since the repetition task is not standardized, our use of the term "language deficient" is operational; we do not suggest that a score of 25 error points defines the borderline of deficient language performance. Although some subjects who are indeed language disordered in the clinical sense were probably selected by this measure, the relatively low error score chosen as the lower limit for inclusion in the "language deficient" group undoubtedly led to the selection of others who merely inhabit the lower end of the spectrum of normal language ability.[9]

Although both experimental and control groups were right-handed to an equal degree, the group of children who met our criterion of language deficiency evidenced virtually no ear advantage, while the language superior group evidenced a sizeable REA. An interpretation of these results must be tempered by at least two considerations: (i) There are many individuals in the general population who have no lateral dominance as measured by dichotic testing, yet who have normal or superior language skills, and (ii) the differences found in the present study were between sample means—the distribution of scores overlapped. Thus, there were language deficient and language superior children who had similar ear advantages. These considerations indicate that the absence of a large REA does not necessarily imply abnormal language functioning.

Nevertheless, the difference between the mean REAs of our two groups was large and significant, and it is a striking fact that in dichotic studies of different right-handed populations, only neurologically impaired subjects have consistently exhibited such deviations from the expected magnitude and/or direction of the REA as were evidenced by the language deficient group of the study (Curry, 1968; Goodglass, 1967; Kimura, 1961a, 1961b; Schulhoff & Goodglass, 1969). In light of this, several hypotheses might account for some aspects of our data, although none is entirely satisfactory. One hypothesis is based on the fact that birth stress has been implicated with anomalous dominance and language deficiencies (Bakar, Dibb & Reed, 1973; Kinsbourne, 1975). Right-handedness and no ear advantage (or left-ear advantage) may then arise from covert lesion effects, and in these cases language development may be adversely affected.[10] On

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[9] On three measures for which norms are available (Peabody IQ, Goodenough IQ, and reading readiness), the language deficient group means did not fall below the norms even though they were substantially lower than those of the control group (See Table 1). In the case of the Visual–Motor Integration Test, the mean of the deficient group was 6 months below their chronological age, while that of the superior group was 6 months above.

[10] It is interesting that the two mixed dominant (right-handed/left-eared) children in the language superior group earned scores below the median in more of the areas tested than did any one of the other superior subjects. This occurred for both children in manual dexterity, comprehension of basic concepts, sentence comprehension, syntactic complexity, Goodenough IQ, and number of dichotic errors, and for one or the other child in reading

this view all the dichotic scores in the experimental group would be interpreted as lesion effects. In other words, but for the postulated lesions, the degree of right-ear advantage in the right-eared children would have been greater, and the ear advantages of most of the left-eared children would have been shifted toward the right, bringing about a distribution of ear advantages that would approximate that of the control group.

However, this hypothesis has difficulty accounting for the fact that the language superior children were mostly only or first-born children while the language deficient children were mostly middle or last born. The lesion model would have to suggest that middle or last-born children suffer greater prenatal or perinatal trauma than do first-born children, and it is by no means clear why this should be so.

An alternative hypothesis, consistent with the birth order findings, would suggest that influences such as reduced linguistic input from adults and different quality of input from siblings might account for the relatively poor linguistic skills of the experimental (later born) groups of subjects. However, it is unlikely that such factors are so malevolent as to shift cerebral dominance.

A third hypothesis (Orton, 1937) suggests that the absence of a clear lateral preference arises from genetic mixing of right and left dominance. Once again, it is unclear why such intermixing should occur overwhelmingly in middle- and last-born children.

In summary, the birth order data appear incompatible with any of the three hypotheses. A resolution of this problem must await future dichotic studies in which the interactions among variables such as birth order, birth stress, major source of linguistic input during early childhood, handedness, and cerebral dominance for language are thoroughly explored.

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readiness, visual–motor integration, and Peabody IQ. In contrast to this low overall pattern of achievement, each of the right-handed/right-eared children in the language superior group did very well in some areas and less well in others (for individual scores see Rosenblum, 1976).

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