MANUAL MOTOR FUNCTIONS

IN

DEVELOPMENTAL DYSPHASIA

By

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ABSTRACT

The term developmental dysphasia refers to children who fail to develop speech and language at the normal time and in the normal manner although they do not have a primary emotional disturbance nor a physical handicap, and are not globally mentally retarded or deaf. Empirical investigations of the disorder have studied auditory perception, visual perception, linguistic and articulatory function, attention and orientation, scholastic performance and reading ability, and hemispheric specialization. With the exception of the studies of auditory perception and hemispheric specialization little promising data have been generated. Investigators of auditory perception have suggested that the language disorder in developmental dysphasia may be attributable to an impairment in auditory perceptual processing. Data from studies of the hemispheric specialization of development dysphasics suggest that dysphasics may have aberrant hemispheric specialization.

Neuropsychological investigations of adult language disturbance, i.e. adult aphasia, have concluded that the left hemisphere is specialized for certain kinds of motor function, speech and language being one such function, and

that it is an impairment in certain kinds of motor function which is crucial to speech and language disturbances, and not an impairment in linguistic processing or symbolic function as has been suggested by many researchers.

This research studied developmental dysphasia with the hypothesis that since this disorder involves speech and language difficulties perhaps it might be related to a deficit in certain aspects of motor functioning, specifically, the organization and execution of fine (as contrasted with gross) actions. This motor performance was also considered within the context of hemispheric specialization since: i) previous work has indicated atypical patterns of hemispheric specialization in developmental dysphasics, ii) motor functions appear to be lateralized and iii) the motor tasks lend themselves to being performed by each hand separately.

Ten developmental dysphasics were selected according to strict criteria and were administered seven measures of motor ability, several of these being nonstandardized tests designed specifically for this research. Five of these were lateralized tests (i.e., it was required that the task be performed by each hand separately), while the remaining two were nonlateralized measures. The lateralized measures were a repetitive tapping task, the Annett peg

moving task, a children's sequence box task, a hand posture imitation task and a hand movement imitation task. The Illinois Test of Psycholinguistic Abilities manual expression test and an oral movement imitation task were the non-lateralized measures. It was found that the dysphasics performed more poorly than their matched control subjects on the hand posture imitation task, the hand movement imitation task and the ITPA manual expression test. On the repetitive tapping, Annett peg moving, children's sequence box and oral movement imitation tasks the dysphasics performed as well as their control subjects. A laterality effect was not observed on any of these measures for either the normal subjects or the dysphasics.

These results were interpreted to mean that developmental dysphasics have a deficit in certain aspects of manual motor function. It is proposed that this is a specific and higher order deficit, not observed in all types of motor function. Moreover, it is suggested that it is a deficit in the initiation, organization and execution of motor behavior and not in the perception. Given that a laterality effect was not observed for any of the measures, no definitive conclusions were possible regarding the hemispheric specialization of developmental dysphasics.

Data from linguistic measures administered in addition to those used for subject selection, further confirmed the receptive language deficit in the developmental dysphasics and also indicated difficulties in the processing of written language. These latter data were interpreted to mean that developmental dysphasia may represent a language disorder which encompasses all forms of language behavior, not just oral language reception and production.

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TABLE OF CONTENTS

Page

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 The Syndrome of Developmental Dysphasia

Over the past thirty years there have been a number of accounts of children who display severely delayed speech and language development which cannot be attributed to global mental retardation, primary emotional disturbance, profound hearing loss or physical disability (e.g. Benton, 1964; Eisenson, 1968a,b; Landau, Goldstein and Kleffner, 1960). This failure to develop speech and language at the normal time and in the normal manner has been variably labelled as developmental aphasia (Benton, 1964; Cohen, Caparulo and Shaywitz, 1976; Eisenson, 1968a,b), congenital aphasia (Landau, Goldstein and Kleffner, 1960), auditory agnosia (Rapin, Mattis, Rowe and Golden, 1977; Stein and Curry, 1968), specific speech and language disorder or disability (Springer and Eisenson, 1977; Rodda, 1976; Sommers and Taylor, 1972), developmental dyspraxia or apraxia of speech (Edwards, 1973; Yoss and Darley, 1974). In this thesis the term developmental dysphasia will be used. The term is not intended to imply a specific etiology of the dysfunction. "Dysphasia" is intended as a general descriptive term implying impairment of or delayed emergence of language, rather than total loss of language ability, while

"developmental" implies a disorder of unknown origin present from birth. When discussing the work of other authors the terms they have chosen to describe their subjects will be used.

Included in the introduction is a review of the literature of developmental dysphasia; a discussion of recent neuropsychological investigations of adult aphasia, which it is hypothesized here may have relevance for the condition of developmental dysphasia, and a statement of the hypotheses of the present research.

1.2 Literature Review

Empirical investigations of developmental dysphasia have studied auditory perception, visual perception, linguistic and articulatory function, attention and orientation and hemispheric specialization. A small number of follow-up studies have reported on the scholastic performance, particularly the reading ability, of developmental dysphasics.

In all the areas of investigation mentioned above, methodological rigor has generally been lacking and the criteria for subject selection have been poorly defined. In many studies the experimental tasks were poorly described, or when sufficient description was provided it was questionable whether the stimuli and/or response mode used were appropriate for the question posed or the subjects being

tested (e.g. Kracke, 1975; Monsees, 1968; Rudnick and Berry, 1975; Weiner, 1969a; Wilson, Doehring and Hirsh, 1960; Stark, Poppen and May, 1967). An example of an inappropriate response mode was the use of an oral response by Weiner (1969a) on an auditory discrimination task. The use of an oral response with a subject population whose primary problem is oral communication seems clearly inappropriate.

A number of difficulties are discernible with the selection of subjects. In many studies the subjects were poorly described (Lowe and Campbell, 1965; Stark, Poppen and May, 1967) or the criteria for selection were inadequate or not indicated (Lowe and Campbell, 1965; McReynolds, 1966; Rudnick and Berry, 1975; Stark, Poppen and May, 1967; Wilson, Doehring and Hirsh, 1960). In other studies although the subjects were adequately described, it was apparent from the description that they were not developmental dysphasics. In some instances the dysphasia coexisted with another disorder which confounded interpretation of the data strictly in terms of developmental dysphasia. Kracke (1975) included in her sample of "receptive aphasic" children, children with an acquired form of aphasia. Mackworth, Grandstaff and Pribram (1973) included children who were mentally retarded and deaf as well as being dysphasic, while Poppen et al. (1969) included some "aphasics" whose aphasia coexisted with cleft palate or cerebral palsy.

Tallal (1978) has commented on the heterogeneity of subjects in studies of developmental dysphasia. She writes:

> One of the difficulties of analyzing and comparing results of previous experiments is the lack of homogeneity both within and between groups used in different experiments. Our inadequate understanding of developmental dysphasia makes the selection of subjects difficult and to some extent arbitrary. Each author used his own criteria for including a subject in an experimental group, so comparisons between experiments must be of a provisional character. (p. 33)

1.2.1 Auditory Perception

Auditory perceptual function is the area that has received the most attention. Early theorists and researchers (Benton, 1964; Eisenson, 1966, 1968a,b) in the field hypothesized that the fundamental deficit in developmental dysphasia is an impairment in auditory perceptual function. This hypothesis stemmed primarily from clinical and empirical reports of auditory perceptual difficulties in adult aphasia (Efron, 1963).

Researchers have investigated the ability of developmental dysphasics to process both verbal and non-verbal stimuli across a variety of dimensions separately or in combinations thereof, e.g., frequency, stress, duration, interstimulus interval, sequence, consonants versus vowels.

Bearing in mind that methodological rigor has been lacking and that subjects have often been poorly defined and selected, the data suggest that: a) developmental dysphasics perform as normal control subjects do on auditory perceptual tasks which require only the discrimination of one sound from another (using speech and nonspeech stimuli) with no time or memory constraints (Lowe and Campbell, 1965; McReynolds, 1966; Tallal and Piercy, 1973) but that, b) when the task requires discrimination in a fixed time interval and/or retention of a particular pattern or sequence, developmental dysphasics do not perform as normal control children do (Kracke, 1975; Lowe and Campbell, 1966; Monsees, 1968; Rudnick and Berry, 1975; Stark, Poppen and May, 1967; Tallal and Piercy, 1973, 1974, 1975; Weiner, 1969a; Wilson, Doehring and Hirsh, 1960; Yoss and Darley, 1974).

Kracke (1975) reported that subjects she termed receptive aphasics had difficulty perceiving rhythmic sequences presented auditorally and cutaneously. Lowe and Campbell (1966) reported that "aphasics" could not order pure tones in terms of pitch as quickly as could the control subjects. Monsees (1968) reported that children with an expressive language disorder performed poorly on tasks of phonemic discrimination, repetition and blending.

Rudnick and Berry (1975) observed that "aphasic" children displayed reduced comprehension of sentences, as compared with normal control children, when the sentences were presented either slower or faster than the normal speaking rate and when the correct word order was not retained. Stark, Poppen and May (1967) found that some "aphasics" had difficulty associating a series of words to pictures in the correct sequence, while Wilson, Doehring and Hirsh (1960) observed that "aphasics" had difficulty associating and learning to associate pure tones with alphabet letters. Yoss and Darley (1974) reported that children they termed developmental dyspraxics had difficulty discriminating single words and reproducing sequences of up to six words. Similarly, Weiner (1969a) reported that "developmental dysphasics" had difficulty discriminating single words and repeating various consonant/vowel combinations from memory.

Tallal and Piercy (1973, 1974, 1975) have done the most careful and extensive investigation of auditory perceptual function in developmental dysphasics. In a series of experiments in which they evaluated the ability of developmental dysphasics to discriminate and sequence both speech and nonspeech stimuli presented for varying lengths of time at varying rates, they found that dysphasics performed significantly more poorly than control subjects

after a critical processing time was reached. This critical processing time was a function of stimulus duration and/or interstimulus interval. Tallal(1978) interpreted her data to indicate that, ". . . the observed gross language impairment of developmentally dysphasic children does not result, at least primarily from a specific inability to analyze the verbal or 'linguistic' components of language. Rather, the language impairment of these children appears to reflect their primary inability to analyze the rapid stream of acoustic information that characterizes speech and is essential to normal speech perception and language development" (p. 56).

In conclusion, there appears to be some strong and consistent evidence to suggest that developmental dysphasics have difficulty in certain aspects of auditory perceptual functioning. While it is held that normal language functioning requires intact auditory perceptual function (Tallal, 1978), further study is necessary to clarify the precise nature of the auditory perceptual deficit in developmental dysphasics, and also the nature of the relationship between auditory perceptual performance and language function in normal individuals as well as developmental dysphasics. As well, it is unclear whether this deficit in auditory perceptual function is the cause or effect of the observed language disturbance.

1.2.2 Visual Perception

Studies in visual perceptual function have stemmed primarily from conceptualizing developmental dysphasia as a deficit in the sensory or input modality (as contrasted with a deficit in the motor or output modality), and subsequently from questioning whether the proposed perceptual deficit in dysphasic children is specific to the auditory modality, or involves other sensory modalities.

Researchers have studied visual discrimination (Tallal and Piercy, 1973), visual spatial memory (Doehring, 1960; Weiner, 1969a; Wyke and Asso, 1979), visual sequencing ability (Furth, 1964; Poppen *et al.*, 1969; Tallal and Piercy, 1973; Weiner, 1969a) and visual motor function Weiner, 1969a,b, 1972).

On a task requiring the discrimination of two shades of a color, with variations in the interstimulus interval, dysphasics performed as well as control subjects (Tallal and Piercy, 1973). On a task of visual spatial memory requiring the retention of the position of a spot of light, with variations in stimulus duration or stimulus/response interval, Doehring (1960) reported that aphasic children performed more poorly than normal control subjects. Similarly, Wyke and Asso (1979) reported that developmental dysphasics experienced difficulty performing a spatial memory task when a time lag was introduced between the

stimulus and response. Weiner (1969a) found no difference between developmental dysphasics and control children on standardized measures of visual discrimination and memory. On tasks of visual sequencing ability requiring the retention of sequences of different colors, lights and geometric shapes dysphasics performed as well as control subjects (Tallal and Piercy, 1973; Poppen et al., 1969). Furth (1964) found no differences between normal, deaf and aphasic children on discrete, simultaneous sequence and successive sequence paired association visual matching tasks.

It is difficult to make definitive conclusions regarding the visual perceptual abilities of developmental dysphasics. As with the investigations of auditory perceptual function, studies of visual perceptual function have lacked methodological rigor (e.g. Furth, 1964; Poppen, et al., 1969) and strict selection of subjects (e.g. Doehring, 1960; Furth, 1964; Poppen, et al., 1969). Furthermore, the actual number of studies in the area has been limited. In those cases in which dysphasics were reported to have difficulty, i.e. on tasks of visual spatial memory and visual sequencing (Doehring, 1960; Wyke and Asso, 1979), it is not clear whether the deficit was in fact a deficit in visual perceptual functioning, or a deficit in some aspect of memory functioning.

1.2.3 Linguistic and Articulatory Ability

Investigations of linguistic and articulatory function in developmental dysphasics have involved evaluation of: phonologic (articulatory) function (Aram and Nation, 1975; Menyuk and Looney, 1972b; Tallal, Stark and Curtiss, 1976; Weiner, 1969a,b, 1972; Yoss and Darley, 1974), syntactic function (Aram and Nation, 1975; Menyuk, 1964; Menyuk and Looney, 1972a,b; Morehead and Ingram, 1973; Sommers and Taylor, 1972; Tallal, 1975; Weiner, 1969b, 1972), semantic function (Leonard, Bolders and Miller, 1976), and oral praxis (Weiner, 1969a,b, 1972; Yoss and Darley, 1974). (Oral praxis is the term that has traditionally been used to refer to the voluntary production of nonspeech oral movements.)

The number of investigations in each of the subsections (i.e. phonologic function, syntactic function, etc.) is limited, and it is difficult to make summary statements. The phonological evidence only permits conclusions that are very general and not particularly surprising, i.e. developmental dysphasics have greater difficulty producing consonant sounds (as contrasted with vowel sounds) than normal children; positive correlations exist between the percentage of phonological errors that dysphasics make and the percentage of auditory perceptual and syntactic errors made.

The conclusions that can be drawn from the syntactic investigations are also very general. Developmental dysphasics begin talking at a later time, but appear to follow the same pattern of syntax acquisition as do normal children. The errors made by dysphasics in sentence repetition tasks appear to be a function of syntactical complexity and not sentence length.

The only study that evaluated semantic function concluded that developmental dysphasics used language reflecting immature semantic relationships.

Studies of oral praxis derived from the hypothesis that a basis for the speech and language difficulties of developmental dysphasics might be an inability to perform the necessary tongue and lip movements. Investigators have evaluated the ability of dysphasics to perform various tongue and lip movements after verbal instruction or demonstration. Preliminary findings suggest that dysphasics do not perform as well as the normal control subjects on any of the above measures. Further study is necessary to define the extent and precise nature of the deficit.

In conclusion, while it is clear that language acquisition in developmental dysphasia is delayed, the linguistic data suggest that it may only be delayed, and not deviant as well, i.e. language acquisition in develop-

mental dysphasia follows the normal developmental course but at a much slower rate. This provides support for Tallal's (1978) proposal that the poorer auditory perceptual performance of developmental dysphasics is a perceptual, and not a linguistic difficulty.

Studies of oral praxis are promising but further research is necessary to define the precise nature of the deficit and its relationship to developmental dysphasia.

1.2.4 Attention and Orientation

It has been observed that developmental dysphasics are often distractible and display attention difficulties (Cantwell, Baker and Mattison, 1979). Some researchers have proposed that these attention difficulties might be a basis for or a contributing factor to the language disturbance.

Mackworth, Grandstaff and Pribram (1973) studied orientation to pictorial novelty in children they termed mildly and severely aphasic. They reported that the severe group showed significant immediate and prolonged orientation to a novel stimulus with almost no habituation, while the mildly impaired group was significantly slower in noticing the novel stimulus. Unfortunately the conclusions of Mackworth *et al.* are difficult to apply to developmental dysphasia given that they themselves indicated that some

of the subjects were deaf and some mildly retarded. Wiig and Austin (1972) reported that "aphasic" children made significantly more errors on a visual vigilance task than normal control children.

The role of attention difficulties in developmental dysphasia is almost impossible to define at this time. Only two studies were found, both of which are confounded by poor subject selection. It is unclear whether the reported attention/orientation deficits are real or attributable to subject heterogeneity or task inappropriateness. If an attention deficit exists it is not known whether it is secondary or primary to the language disturbance. Certainly if the latter is the case it would have serious implications for all other areas of investigation.

1.2.5 Scholastic Achievement and Reading Ability

The nature and extent of the language deficit in developmental dysphasia is not well understood in respect to the question of whether the language disturbance is limited to oral language function or also encompasses written language. It has been observed that many children with reading difficulty have had or continue to have difficulty with oral language (Blank, Weider and Bridger, 1968; Mason, 1967; Rutter, 1972). It is reasonable to query whether it is almost predictable that a child with

developmental dysphasia will experience difficulty with reading. A small number of researchers (Butler, Peckham and Sheridan, 1973; Hall and Tomblin, 1978; Tallal and Piercy, 1973 and Weiner, 1974) have reported on the scholastic performance (in particular the reading ability) of older developmental dysphasics. A variety of measures of academic achievement and/or reading ability were administered. All of the aforementioned researchers reported that the dysphasics displayed reading difficulties. Hall and Tomblin (1978) in summarizing their data wrote: "The pattern of performance . . . showed a definite and persistent limitation of achievement in the area of reading accompanied by equally persistent but less profound restriction in the other academic areas" (p. 238).

In conclusion the data clearly indicate a strong association between developmental language disorder and subsequent difficulty with reading. The precise nature of the reading difficulty has not been defined nor is it clear whether all children with developmental dysphasia experience reading difficulties, and if not, why not. Clinically, the latter point is important for both the short term and long term management of developmental language disturbance, while at an academic and theoretical level it has implications for how the condition of developmental dysphasia should be defined and conceptualized,

i.e. it may not be only a disorder of oral language function, and how it may relate to the syndrome of developmental dyslexia.

1.2.6 Studies of Hemispheric Specialization

Some researchers have hypothesized that the language deficit in developmental dysphasia might be attributable to aberrations in hemispheric specialization, e.g. failure to establish cerebral dominance, or reversed hemispheric specialization (Pettit and Helms, 1979; Rosenblum and Dorman, 1978; Sommers and Taylor, 1972; Springer and Eisenson, 1977; Witelson and Rabinovitch, 1972). All investigators have used the dichotic listening procedure to make inferences about the hemispheric specialization, but the actual stimuli presented have varied. While the results of these investigations are yet inconclusive, due to the small number of studies and variations in subject selection and test stimuli, there is a strong suggestion that the hemispheric specialization of the dysphasics is not completely normal. Four of the five studies reported less lateralization (Pettit and Helms, 1979, Rosenblum and Dorman, 1978) or reversed lateralization in the dysphasic subjects (Sommers and Taylor, 1972; Witelson and Ravinovitch, 1972). Springer and Eisenson

(1977) did not report a statistically significant reversed or decreased lateralization in the dysphasics. However, they noted that a subgroup of dysphasics, dysphasics with both oral language and reading problems (as contrasted with the remaining dysphasics who had had oral language difficulties at one point but at the time of the study had only reading problems), appeared to achieve a smaller right ear advantage than the dysphasics with reading problems only. They indicated that statistics could not be performed on the two experimental subgroups because of an age difference of one and a half years. Although Springer and Eisenson (1977) reported that they did not observe reversed or decreased lateralization in dysphasics, their data are suspect and one wonders had a more careful selection of subjects been made if they would have come to the conclusions they did.

Investigation of the hemispheric specialization of developmental dysphasics is promising, although further study is necessary before definitive conclusions can be made. Certainly, positive confirmation of abberrant hemispheric specialization in developmental dysphasia would suggest a possible mechanism for the observed language disturbance. This might in turn influence the interpretation of the existing evidence, particularly the auditory perceptual data, and shape the direction of future research.

1.2.7 Summary

Summarizing the research to date, it is apparent that after many years of investigation the condition of developmental dysphasia is poorly understood, at all levels of inquiry, i.e. symptomatical, etiological, and conceptual. Moreover, this fundamental lack of understanding in turn confounds efforts to define the disorder. There is not a consensus among researchers regarding a label for the condition, or the criteria necessary to operationally define the disorder, and, as discussed earlier, the results of many of the investigations are seriously clouded by a lack of methodological rigor and poor subject definition and selection.

It is not clear what it is that the dysphasics are unable to do, and what the etiology of the disorder might be. The results from investigations of auditory perceptual function and hemispheric specialization appear most promising, but clearly more study is warranted in both these areas. Tallal (1978) has appropriately cautioned that "Merely pinpointing specific perceptual deficits in children with retarded language development does not necessarily indicate that the perceptual deficits are 'causal' or even related to the language disorder" (p. 26).

1.3 Motor Function, Hemispheric Specialization and Developmental Dysphasia

In this section neuropsychological investigations of adult aphasia which it was hypothesized may have relevance for the condition of developmental dysphasia, and from which the present research departed, will be discussed.

It is now conceived that the two hemispheres of the brain differ in the type of processing that each does, i.e. the left hemisphere processes stimuli in a sequential, analytic, propositional manner while the right hemisphere processes stimuli in a spatial, holistic fashion (Witelson, 1977). Accordingly, it is inferred that tasks or material presumed to require sequential or analytic processing will be processed predominantly by the left hemisphere, while tasks requiring processing in a spatial, holistic manner will be mainly processed by the right hemisphere.

Liepmann, working at the turn of the century, first identified a syndrome which he named apraxia, and which he defined briefly as a disorder of learned movement (see Geschwind, 1975). More specifically, apraxia has been defined as a disorder in ". . . the execution of learned movement which cannot be accounted for either by weakness, incoordination, or sensory loss, or by incomprehension of or inattention to commands" (Geschwind, 1975, p. 188). Subsequently Liepmann noted an association

between aphasia (in the general sense), Broca's aphasia and apraxia. He observed that many Broca's aphasics displayed oral apraxia (impairment of voluntary non-speech oral movements), and that in cases of Broca's aphasia and apraxia, motor function did not improve with imitation. Liepmann suggested that these observations could not simply be accounted for by disconnections between language and motor areas. He suggested that the phenomenon might be accounted for by cerebral dominance. More specifically, Geschwind (1975) wrote, "Liepmann suggested that the hemisphere dominant for handedness is a storehouse of the learning involved in the acquisition of motor skills" (p. 191). Liepmann suggested that the left hemisphere was the major repository for learned motor skills.

More recently, Goodglass and Kaplan (1963), De Renzi, Pieczuro and Vignolo (1966), and Kimura (1977) and Kimura and Archibald (1974) have studied the association between apraxia and aphasia. Goodglass and Kaplan (1963) studied the disturbance of gesture and pantomime in aphasia. They noted that such has been accounted for from two perspectives, one being that gestural and pantomime disturbance is part of a central communication disorder (i.e. aphasia), the other suggesting that gestural and pantomime disturbance is part of a movement disorder, (i.e. apraxia). Goodglass and Kaplan (1963) noted that

Liepmann relegated all disorders of gesture and pantomime to the category of apraxia. They reasoned that if gestural deficiency was part of a central communication deficit then one should observe: 1) increasing gestural deficiency with increasing severity of aphasia and, 2) if the disturbance was one of formulation and not execution, then the ability to imitate should be retained. Goodglass and Kaplan's results indicated no change in gestural ability with increasing severity of the aphasia and no improvement with imitation, and they concluded that such was evidence for an apractic disturbance. De Renzi, Pieczuro and Vignolo (1966) observed a strong association between oral apraxia and Broca's aphasia, but found oral apraxia usually absent in Wernicke's aphasia. They did not observe limb apraxia in cases of oral apraxia, and concluded that oral apraxia could not be regarded as part of a general practic disturbance, contrary to Liepmann's observations.

Kimura, working with nonclinical as well as clinical populations, conducted a number of studies which addressed the question of the association between language function, motor function and left hemisphere function. Working primarily with nonclinical populations she studied:

1) the association between hand movements and speaking in normal individuals, and vocal

utterances with hand signing in the deaf (Kimura, 1973a,b; Kimura, 1976),

2) the differential performance of the left and right hands on manual skill tasks such as: tapping rate, dowel balancing, hand posturing, finger flexions, and the differential performance of the left and right hands on tasks requiring simultaneous performance of the above mentioned motoric tasks and vocalization or verbalization (Kimura, 1976; Kimura and Vanderwolf, 1970; Lomas and Kimura, 1976),

3) disorders of manual communication in the deaf occurring from left hemisphere lesions (Kimura, Battison and Lubert, 1976),

4) impairment of nonverbal oral movements in aphasia (Mateer and Kimura, 1977).

On the basis of the data acquired from the preceding studies, as well as data obtained from a study of adults who sustained unilateral left or right hemisphere lesions (Kimura and Archibald, 1974), aphasic and nonaphasic, Kimura concluded that the left hemisphere is specialized for certain kinds of motor function, speech and language being one such function -- and that it is an impairment in certain kinds of motor function which is crucial to

speech and language disturbances, and not an impairment in linguistic processing or symbolic function as has been suggested by some researchers (Duffy, Duffy and Pearson, 1975; Gainotti and Lemmo, 1976). Kimura and Archibald (1974) required the above subjects to perform such motor tasks as: a) flexion of a single finger at the middle joint, with the requirement that other fingers not make associated flexion movements, b) imitation of static hand postures demonstrated by the experimenter and, c) imitation of unfamiliar meaningless manual sequences demonstrated by the experimenter. They found that subjects with left hemisphere lesions performed more poorly than subjects with right hemisphere lesions when required to imitate unfamiliar meaningless manual sequences. There was no difference between the two groups for the other tasks.

In a later study Kimura (1977) attempted to define more precisely the motor functions of the left hemisphere. Subjects with unilateral left or right hemisphere lesions were required to operate a "manual sequence box" which involved pressing a button, pulling a vertical bar and pressing a horizontal bar, in that sequence, with specified finger combinations. Subjects with left hemisphere lesions, with and without aphasia, performed significantly more poorly than subjects with right hemisphere lesions. Kimura

(1977) speculated that the left hemisphere is specialized for producing specific limb or articulatory postures and for controlling the transition from one position to another.

To sum up, considerable data has accrued to support the hypothesis that the left hemisphere is specialized for certain types or aspects of motor function. The precise nature of this motoric specialization is yet to be defined. Secondly, there is a body of data which supports the hypothesis that a special association exists between language function and certain types of motor function. The basis of this association and whether it goes beyond the known neural contiguity that exists between hand and mouth movement in the primary motor gyrus region (Penfield and Rasmussen, 1955) awaits further investigation.

1.4 Statement of Research Aims

Recent research in adult language disturbance, as indicated in earlier discussion, has suggested an association between nonlinguistic motor functions and adult aphasia. This research studied developmental dysphasia with the hypothesis that the disorder might be related to a deficit in certain aspects of motor functioning, specifically, the initiation, organization and execution of fine (as contrasted with gross) actions. A variety of motor tasks, many similar to those described in the preceding

section, were administered to test this hypothesis. These tasks will be described in the Method which follows.

Data obtained from clinical neurological evaluations and developmental histories have suggested a general clumsiness and delay in motor milestones (Bartak, Rutter and Cox, 1975; Butler, Peckham and Sheridan, 1973; T. T. S. Ingram, 1959; Sheridan, 1973; Yoss and Darley, 1974) in developmental dysphasics and some researchers (Menyuk, 1975; Weiner, 1972; Yoss and Darley, 1974), on the basis of the performance of dysphasics on tasks of oral movement imitation, have speculated that developmental dysphasics may have a motor deficit, although they have not specified what the nature of it might be. No work to date has specifically tested the current hypothesis that motor functions, unrelated to linguistic or nonlinguistic oral tasks may underlie the speech and language difficulties in developmental dysphasia. It is noted that this hypothesis, contrary to previous hypotheses, was not derived from clinical or empirical studies but was theoretically derived from studies of adult aphasia and hemispheric specialization. This motor performance was also considered within the context of hemispheric specialization, since, as previously discussed: i) some data have suggested that atypical patterns of hemispheric specialization may be implicated

in the disorder, ii) motoric functions appear to be lateralized, and iii) the tests lend themselves to being performed separately by each hand.

CHAPTER TWO

METHOD

2.1 Subjects

Ten developmental dysphasics (experimental group) were obtained from the Department of Communicative Disorders, Chedoke-McMaster Hospital, Hamilton. They ranged in age from 4.1 years to 9.3 years, with a mean age of 6.6 years. All were right-handed and male of lower to lower-middle socioeconomic status; however, they had not been selected for socioeconomic status or handedness. Hand preference was determined by administration of a ten-item handedness inventory; socioeconomic status was determined from the father's occupation using the Blishen Scale (Blishen, 1967; Blishen and MacRoberts, 1976).

Subjects were included in the experimental group only if they displayed:

1) normal hearing acuity, indicated in the audiological report in the Department of Communicative Disorders,
2) normal physical and emotional growth, indicated in the pediatric report at the Child and Family Center, Chedoke-McMaster Hospital,

3) reduced language function, defined operationally as performance at or below the second standard deviation on either the receptive or expressive portion of the Northwestern Syntax Screening Test (Lee, 1970), and/or a 50% reduction in articulatory function as determined by the Arizona Articulatory Proficiency Scale (Barker, 1960; Barker and England, 1962). These language tests were administered by the experimenter.

4) an intelligence quotient of at least 80 on the Arthur Adaptation of the Leiter International Performance Scale (Arthur, 1949) or Leiter International Performance Scale (Leiter, 1940), as determined by the experimenter. The former scale was used for subjects 2.0-7.11 years of age, and the latter for subjects 8.0 years of age and older.

Of the ten control subjects, two preschool age subjects were needed and were obtained from a local daycare center while all the eight school age children were obtained from the same school within the Hamilton-Wentworth Roman Catholic Separate School Board System. The control group ranged in age from 4.3 years to 9.1 years with a mean age of 6.5 years. Each control subject was individually matched

to an experimental subject on the basis of age, sex, handedness, nonverbal intelligence and socioeconomic status. All control subjects displayed:

1) normal hearing acuity, as determined by a public health nurse,
2) normal physical and emotional growth as reported by the public health nurse and/or classroom teacher,
3) normal language and articulatory function as determined from the Northwestern Syntax Screening Test and the Arizona Articulatory Proficiency Scale, administered by the experimenter,
4) an intelligence quotient within ±5 points of the intelligence quotient of the matched experimental subject, as determined from the Arthur Adaptation of the Leiter International Performance Scale or Leiter International Performance Scale, administered by the experimenter.

All subjects included in the experimental group were male because very few females were found. However, the data from the small number of female subjects were not pooled with those of the male subjects since sex has been related to the dependent variables (Annett, 1970b; Denckla

1973, 1974; Wolff and Hurwitz, 1976; Harris, 1978). It might also be noted that of 74 subjects in the initial selection pool, 58 were male and 16 were female. This concurs with numerous reports in the literature of the greater incidence of males in various developmental disorders, e.g. infantile autism (Bartak, Rutter and Cox, 1975), developmental dysphasia (T. T. S. Ingram, 1959, 1975), stuttering (Sheehan and Costley, 1977; Van Riper, 1971), developmental dyslexia (Witelson, 1976, 1977a).

Regarding the handedness of the experimental subjects, as indicated earlier, subjects were not selected for right handedness. In fact, seven non-right handed children met the selection criteria for experimental subjects and were administered the experimental measures. However, since matched control subjects were obtained for only 3 of these subjects, after screening 19 children, these data are not included in the present analysis.

2.2 Materials

2.2.1 Independent (Selection) Measures

The Northwestern Syntax Screening Test (NWSST), Arizona Articulatory Proficiency Scale (AAPS), Arthur Adaptation of the Leiter International Performance Scale (Arthur) and the Leiter International Performance Scale (Leiter) were used to screen for language performance,

articulatory performance and intellectual function, respectively.

The NWSST is a measure of language performance which evaluates both language reception and language expression and is standardized for children 3-8 years of age. Administration and scoring were as indicated in the test manual. A perfect score on each of the receptive and expressive sections was 40.

The AAPS is a measure of articulatory function which is standardized for children 3-12 years of age. It evaluates the ability to produce various consonant and vowel sounds. The test was administered and scored as indicated in the test manual. For purposes of this research, raw scores were converted to a 0,1,2 scale reflecting the degree of articulatory deviation (normal, moderate, severe -- as indicated in the manual) and permitting comparison across ages.

The Arthur test, because it had revised norms for children 2.0-7.11 years of age, was used to assess intellectual function in subjects 7.11 years and younger. The Leiter test, although standardized for children 2.0-18.0 years, was used only for subjects 8.0 years and older. The test is unique and especially useful for the present research in that no verbal instructions or verbal responses are required. Administration and scoring were as indicated in the respective test manuals.

Hand preference was determined through administration of a ten-item handedness inventory adapted from Annett (1970a,b). Subjects were required to demonstrate with the actual object how they would: comb their hair, throw a ball, brush their teeth, write with a pencil, cut with scissors, sweep the floor, put buttons in a bottle, eat with a spoon, bang with a hammer, and point to pictures in a book. If a subject performed 8 or more items with his right hand he was classified as a right hander. If 7 or fewer items were performed with the right hand, the subject was classified as a non-right hander.

2.2.2 Dependent Measures

i) Tests of Motor Function

Seven measures of motor ability were administered. Five of these were lateralized tests (i.e. it was required that the task be performed by each hand separately), while the remaining two were nonlateralized measures. The lateralized measures were a repetitive tapping task, the Annett peg moving task, a children's sequence box task, a hand posture imitation task and a hand movement imitation task. The manual expression test (a subtest of the Illinois Test of Psycholinguistic Abilities, Kirk, McCarthy and Kirk, 1968) and an oral movement imitation test were the non-lateralized measures.

The repetitive tapping task measured the number of taps produced by the index finger in a 10 second time interval. While the index finger was tapping the other fingers of that hand were kept extended and the forearm was kept flat to the table. The time interval and number of taps were determined automatically by a microswitch connected to an electronic counter (Peters, 1977). After one practice trial with each hand, two test trials per hand, alternating between hands, were administered. Subjects were instructed to tap as fast as they could until told to stop. The score was the average of the two test trials for each hand. The hand tested first was counterbalanced across all the subjects.

The peg moving task measured the time required to move ten pegs as quickly as possible, one at a time, in order, from one side of a pegboard to the other. The task was developed by Annett (1970b). After two practice trials with each hand, three test trials per hand were conducted for children younger than 7.11 years while five test trials per hand were conducted for children over 7.11 years. In each case hands were tested alternately. If a peg was dropped, the trial was started over again. Subjects performed the task from a standing position. The score was the average time taken for the three or five test trials for each hand. The hand tested first was counterbalanced across all the subjects.

The children's sequence box was an adaptation of the manual sequence box developed by Kimura (1977). The children's sequence box task required the subject to push a button with his index finger and pull a handle with all four fingers and thumb, in that order. To standardize task performance, a buzzer was activated when the button was depressed sufficiently and also when the handle was pulled out fully. Criterion for learning the task was five successive performances of the above two movements in the specified manner and order. There was no time limit. The subject was instructed simply to continue performing the movements in the required manner until told to stop. A practice session involving demonstration and verbal instruction was conducted until the subject reached criterion. A stopwatch was started when the practice session began and stopped when the subject reached criterion. The time of the total practice session was recorded as the acquisition time.

For the test session the subject was instructed to perform the task as fast as he could in the specified manner and order until he was told to stop. The test time was the time required for the two movements to be performed in the specified manner as quickly as possible five consecutive times. If errors were made, the timing was stopped and begun again. The hand tested first was counterbalanced across all the subjects.

The hand posture imitation task was adapted from Kimura and Archibald (1974) and D. Ingram (1975) and required that eight separate hand postures taken from the alphabet for the deaf be imitated. Before presenting the eight test postures, five practice postures were done with each hand and it was stressed to the subject that he should attempt to make the posture exactly as the examiner had done. Each posture was presented to the subject across a table. It was made out of the subject's sight, but remained as a model until the subject had completed copying it. Testing was completed with one hand before proceeding to the other.

Each posture was broken into component features and points were allotted for each feature correctly produced. The number of features scored per posture ranged from three to eight depending on the complexity of the posture. A score for accuracy of production was derived for each hand by adding the individual scores for the eight separate postures. These scores in turn were converted to a percentage figure to permit possible comparison between performance on the hand posture task and performance on the hand movement imitation task. The maximum possible score was 40 (100%).

The time required to produce each posture was also recorded, although the task was not a timed task in the usual sense in that the timing was done covertly and the subject was not instructed to make the posture as fast as he could. There was no time limit. A score for production time was derived for each hand by averaging the individual time scores for the eight test postures. The hand tested first was counterbalanced across all subjects.

The hand movement imitation task, adapted from Kimura and Archibald (1974) required that single movements and sequences of two and three movements be imitated. The movements were unfamiliar and meaningless. They were not taken from the deaf alphabet and in that respect they differed from the postures presented in the hand posture imitation task. After a practice session which required that two single movements be imitated, two single movements, four two-movement sequences and two three-movement sequences were presented. The movements were presented to the subject across a table for an exposure time of approximately one second per movement and then removed. In the case of two- and three-movement sequences it was stressed to the subject that he should not begin making the movements until all the movements in the sequence had been demonstrated. Testing was completed with one hand before proceeding to the other. The score was the total number of

movements produced correctly for each hand, regardless of order, across the three levels. Scores were expressed in percentage form to permit comparison with the hand posture imitation task. The maximum possible score was 16 (100%). (While order was not scored at this time it was recorded for possible subsequent analysis). The hand tested first was counterbalanced across all the subjects.

The manual expression test (a subtest of the Illinois Test of Psycholinguistic Abilities, standardized for children 3.0-10.0 years of age) was included in the test battery as representative of the traditional test for limb apraxia (De Renzi, Motti and Nichelli, 1980; Geschwind, 1975), which requires the production of everyday actions following verbal instruction, presentation of a visual stimulus, or demonstration. In addition to the stimuli presented, it differs from the hand posture and hand movement imitation tasks in that the subject is required to generate his own response rather than imitate one provided by the experimenter. The task, which was administered and scored as indicated in the test manual, requires the subject to demonstrate what to do with common objects (e.g. comb, toothbrush, hammer) presented in pictorial form with the verbal instruction, "Show me what you do with a hammer". Points are given for the number of components of the pantomime the child performs, i.e. in response to a

picture of a hammer, two components are required -- holding the nail with one hand and hammering with the other. Scores were scaled for age permitting comparison across ages.

The oral movement imitation task, which required the imitation of various tongue and lip movements, was administered in order to define further the motor ability of developmental dysphasics as compared with control children. The subject was required to copy single movements and sequences of two- and three-movements. The movements were presented to the subject for an exposure time of approximately one second per movement. In the case of a sequence of two or three movements it was stressed to the subject, that he should not begin making the movements until all had been demonstrated. The score was the total number of movements produced correctly, regardless of order, across the three levels of the task. (While order was not scored at this time it was recorded for possible subsequent analysis.) The maximum possible score was 23.

ii) Control Measures

The pantomime recognition task and visual sequential memory task were administered as control measures for the hand posture and hand movement imitation tasks.

The pantomime recognition task was devised for purposes of the present research and was administered to ensure that subjects were at least able to receive a pantomime, and that therefore poor performance on the tasks of hand posture and hand movement imitation could not simply be attributed to difficulties in stimulus reception. A pantomime is an action which conveys an idea or proposition and may replace speech (Goodglass and Kaplan, 1963; Ross and Mesulam, 1979). [While the term "gesture" is often used, and not incorrectly, to represent all expressive and communicative movements, more precisely it refers to those movements which accompany and emphasize, rather than replace, speech (Goodglass and Kaplan, 1963; Ross and Mesulam, 1979).] For the pantomime recognition task the subject was asked to choose from a group of four pictures the picture which matched (Part A) or best represented (Part B) the pantomime performed by the experimenter. In Part A for the action of brushing teeth the subject was expected to point to the picture of someone brushing teeth, whereas for Part B, for the action of brushing teeth the subject was expected to point to a picture of someone sitting in a dentist's chair. Thus, Part B was considered to be more symbolic than Part A. Only Part A was the control measure for the motor tasks. Part B addressed the question of whether the dysphasics

could do more than receive pantomimes and relates to comments in the literature that aphasia is fundamentally a disorder of symbolic processing (Duffy, Duffy and Pearson, 1975; Gainotti and Lemmo, 1976). One point was allotted for each correctly identified pantomime. For each part a perfect score was 7.

The visual sequential memory task is a subtest of the Illinois Test of Psycholinguistic Abilities and was administered to ensure that poor performance on any task which involved a memory component could not simply be attributed to a memory deficit. Administration and scoring were as indicated in the test manual. The subject is required to reproduce in the correct order from memory, displays of increasing length, of abstract geometric forms presented for five seconds and then removed. Points are allotted only for totally correct arrangements. Two trials were allowed with more points awarded for correct performance in the first trial. Scores were scaled for age permitting comparison across ages.

iii) Linguistic Measures

As well as the language tests used for subject selection, the Token Test and Wide Range Achievement Test were administered as dependent measures in order to define

other aspects of the language function of developmental dysphasics.

The Token Test is a test of language comprehension developed by De Renzi and Vignolo (1962). The test is unique in its design in that it attempts to provide a rigorous evaluation of linguistic processing ability of syntax by controlling strictly for the redundancies inherent in language. It was administered to provide a further and somewhat different assessment of the receptive language abilities of the dysphasics over and above the tests administered as independent (selection) measures.

The Token Test consists of several commands, all of which refer to stimulus "tokens" which vary in shape (circles and squares), size (large and small) and color (red, yellow, blue, green and white). The test is divided into five distinct parts with each succeeding part having commands of increasing length and complexity. Examples of commands from each section are as follows: Part I -- "Touch the red circle", Part II -- "Touch the large red circle", Part III -- "Touch the red circle and the yellow square", Part IV -- "Touch the small blue square and the large green circle", Part V -- "After picking up the green square, touch the white circle".

Administration and scoring were as indicated by De Renzi and Vignolo (1962). Points are allotted for correct performance of each command with a perfect score being 62. (While the test requires comprehension of the labels for color, shape and size it is not intended to measure such, and thus a screening session is conducted first to determine if the subject comprehends the particular color, shape and size concepts used in the test. If they are not unequivocally comprehended, the test cannot be administered.)

The Wide Range Achievement Test (Jastak, 1965) is a standardized test of oral reading (word recognition and pronunciation) and written spelling ability with normative values beginning at five years of age. It was administered in the present research to determine whether the dysphasics' difficulty with language would be manifested in written language as well as oral language. Follow-up studies of children who presented with delayed speech and language have reported subsequent difficulties with reading (Butler, Peckham and Sheridan, 1973; Hall and Tomblin, 1978). Administration and scoring were as indicated in the test manual. Raw scores were converted to standard scores to permit comparison across ages. This test was administered only to those subjects 5.0 years of age and older.

2.3 Procedure

Since certain of the dependent measures (hand posture imitation, hand movement imitation, children's sequence box, repetitive tapping, peg moving, oral movement imitation and pantomime recognition) had not previously been done with children, or only to a limited degree, pilot testing was done to assist in the design of these tasks. Twenty normal children, 4-12 years of age, and four developmental dysphasics, 4-9 years of age, were tested. After this pilot testing the experimental subjects were selected.

The names of prospective experimental subjects were obtained from speech pathologists, psychometrists and pediatricians at Chedoke-McMaster Hospital, Chedoke Division. Before administering the selection measures to prospective subjects the medical chart of each subject was reviewed to determine that the medical and audiological requirements described earlier were met. Those subjects who met the selection criteria were then given the experimental tests individually during two or three one-and-a-half hour sessions.

A preliminary selection of control subjects was made on the basis of age, sex, academic performance and father's socioeconomic status. This group consisted of male children who were reported by their teachers to be at least

average students with no known learning disabilities. The individual ages of these children were within three months (plus or minus) of the age of the experimental child to whom they might be matched. The father's occupation of the prospective control subject was in the same socioeconomic category as the occupation of the father of the experimental subject to whom he might be matched, as determined by the Blishen Scale. To ascertain that language and articulatory function were within normal limits the NWSST and AAPS were administered. These were followed by the handedness inventory and the Arthur or Leiter test in order to match for handedness and intelligence, respectively.

The order of administration of the experimental tests was:

1) hand posture imitation,
2) repetitive tapping,
3) pantomime recognition,
4) hand movement imitation,
5) oral movement imitation,
6) children's sequence box,
7) peg moving,
8) visual sequential memory,
9) manual expression,
10) Token Test,
11) Wide Range Achievement Test, reading section, spelling section.

The test order was the same for all subjects.

For the lateralized measures the hand tested first was counterbalanced across all the subjects, and for each subject the same hand was tested first for all the lateralized measures.

CHAPTER THREE

RESULTS

3.1 Independent (Selection) Measures

The data for the independent (selection) measures are displayed in Table 1. A paired t-test performed on the IQ scores derived from the Arthur and Leiter tests revealed no significant difference between the control group and the experimental group ($t = .30$, $df = 9$).

Paired t-tests performed on the receptive and expressive sections of the Northwestern Syntax Screening Test revealed a significant difference between the two groups for both sections (Receptive: $t = 3.80$, $df = 9$, $p < .005$, one-tailed test; Expressive $t = 6.57$, $df = 9$, $p < .0005$, one-tailed test).

For the Arizona Articulatory Proficiency Scale raw scores were converted to a 0,1,2 scale reflecting the degree of articulatory deviation (normal, moderate, severe). Since there was no variance in the control group a Wilcoxon Matched-Pairs Signed-Ranks Test was performed. No significant difference was found between the groups ($T = 28$).

TABLE 1

INDEPENDENT (SELECTION) MEASURES

TEST/SCORE	GROUP			
	Control (n = 10)		*Experimental (n = 10)*	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Arthur/Leiter (*IQ Score*)	99.70	10.87	99.40	11.87
NWSST (*Raw Score*)				
Receptive Section	32.20	4.51	26.50*	6.56
Expressive Section	28.60	5.37	12.20+	11.01
(*Max. Score = 40*)				
AAPS	0	0	1.30	.95
(*Degree of Articulatory Deficit: 0 = normal; 1 = moderate; 2 = severe*)				

* $p < .005$, one-tailed test

\+ $p < .0005$, one-tailed test

3.2 Dependent Measures

3.2.1 Tests of Motor Function

i) Repetitive Tapping

The number of taps per ten second time interval was averaged for the two test trials for each subject. A two-way analysis of variance performed on these data with Group (Control and Experimental) and Hand (Left and Right) as the two factors revealed no significant main effects (Group: $F(1,36) = 1.49$; Hand: $F(1,36) = 3.49$) and no interaction ($F(1,36) = .498$). These data are displayed in Table 2.

ii) Peg Moving

The time (seconds) required to move the pegs was averaged over three test trials for children younger than 7.11 years, and over five test trials for children older than 7.11 years. A two-way analysis of variance performed on these scores revealed no significant group ($F(1,36) = 1.50$) or hand ($F(1,36) = 2.05$) effects and no interaction ($F(1,36) = .11$), as shown in Table 2.

iii) Children's Sequence Box

Two time scores, acquisition time and test time, were obtained for each hand for each subject. A two-way analysis of variance performed on the acquisition time

TABLE 2

REPETITIVE TAPPING AND PEG MOVING

GROUP	HAND: Left $\bar{X}$	Left S.D.	Right $\bar{X}$	Right S.D.
A. Repetitive Tapping (Number of Taps/10 secs.)				
Control (n = 10)	28.25	4.38	31.85	4.00
Experimental (n = 10)	27.25	3.95	29.06	6.01
B. Peg Moving (Time in Secs.)				
Control (n = 10)	19.90	4.07	18.31	4.34
Experimental (n = 10)	21.05	4.38	19.42	4.64

scores revealed no significant main effects (Group: $F(1,36) = 2.66$; Hand: $F(1,36) = .008$) and no interaction ($F(1,36) = .038$), as shown in Table 3.

For the test time scores, a logarithmic transformation was first performed on the data in an effort to stabilize the variance. The variance was not stabilized despite the logarithmic transformation and thus the non-parametric Friedman Rank Two-Way Analysis of Variance was used. No significant differences were observed between the two groups (Friedman Rank $\chi^2 = 4.051$, df = 3). These data are displayed in Table 3.

iv) Hand Posture Imitation Task

The data for this task are displayed in Table 4. Two scores were obtained for each hand for each subject: 1) a score for accuracy of production, which was derived by summing the individual scores for the eight hand postures and then converting to a percentage and, 2) a score for time for production, which was derived by averaging the individual times for the eight postures. A two-way analysis of variance performed on the accuracy scores revealed no significant group ($F(1,36) = 1.35$) or hand ($F(1,36) = 2.01$) effects and no interaction ($F(1,36) = .92$).

TABLE 3

CHILDREN'S SEQUENCE BOX

(Time in Seconds)

GROUP	HAND: *Left* $\bar{X}$	*Left* S.D.	*Right* $\bar{X}$	*Right* S.D.
A. Acquisition Time				
Control (n = 10)	13.72	8.73	12.84	7.81
Experimental (n = 10)	18.21	12.57	18.54	9.74
B. Test Time				
Control (n = 10)	8.57	1.94	7.93	1.09
Experimental (n = 10)	10.68	4.12	9.15	3.12

TABLE 4

HAND POSTURE IMITATION

GROUP	HAND: Left $\bar{X}$	Left S.D.	Right $\bar{X}$	Right S.D.
A. Accuracy of Production (Percentage) Max. Raw Score = 49				
Control (n = 10)	93.00	7.25	94.00	6.46
Experimental (n = 10)	86.60	13.37	93.40	7.24
B. Time for Production (Seconds)				
Control (n = 10)	4.75	1.26	4.92	2.18
Experimental (n = 10)	11.61*	4.25	7.73*	3.07

*$p < .001$

The scores for production time were logarithmically transformed, in order to stabilize the variance in the experimental group, before the analysis was performed. A two-way analysis of variance performed on the transformed data revealed a highly significant main effect for group ($F(1,36) = 21.26$, $p < .001$), but not for hand ($F(1,36) = 3.53$). The interaction was not significant.

v) Hand Movement Imitation Task

An accuracy score was taken for each hand for each subject and was derived by summing the number of movements produced correctly across the three levels of the task. The figures were converted to percentages and a two-way analysis of variance was performed. A significant main effect was observed for group ($F(1,36) = 7.54$, $p. < .009$), but not for hand ($F(1,36) = .899$). The interaction was not significant ($F(1,36) = .453$). These data are displayed in Table 5.

To explore what might account for the poorer performance of the dysphasics additional analyses were performed. The data from Part I (one movement) were analyzed separately to evaluate the extent to which movement was a factor in the dysphasics' performance. For each subject the scores for each hand were summed to obtain a total accuracy figure (R + L). Paired t-tests performed on

TABLE 5

HAND MOVEMENT IMITATION:

Accuracy of Production, Summed Across Parts I, II and III

Expressed in Percentage

(Maximum Raw Score = 16)

GROUP	HAND			
	Left		*Right*	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Control (n = 10)	50.90	18.85	56.90	11.16
Experimental (n = 10)	40.10*	14.82	41.40*	10.16

*$p < .009$

these values revealed no significant difference between the two groups ($t = .80$, $df = 9$), as shown in Table 6.

Another analysis using a scoring system different from that used in the preceding analyses was done on Parts II and III. The question addressed was whether dysphasics appeared to be able to produce the correct number of items in a sequence regardless of accuracy or order. Paired t-tests performed on the total accuracy (R + L) figures for each subject revealed no significant differences between the two groups when two movements were required ($t = .83$, $df = 9$), or when three movements were required ($t = 1.44$, $df = 9$). These data are displayed in Table 7.

A tabulation was also made of the number of order errors which occurred. Order errors were scored for a variety of reasons. First, and most simply, the hand movement task has an obvious sequential component and a difficulty in this regard might explain the dysphasics' poor performance. Secondly, language has a temporal/order component (Efron, 1963; Tallal, 1978) and since dysphasia is a language disorder it might be expected that dysphasics would display errors in order. Thirdly, it is well documented that the hemisphere primarily responsible for language functions, the left hemisphere, is also the hemisphere to which sequential, analytical processing has been accorded

TABLE 6

HAND MOVEMENT IMITATION: PART I -- ONE MOVEMENT

(Total Accuracy, R + L)

Maximum Score = 4

GROUP					
Control (n = 10)			*Experimental (n = 10)*		
R + L			R + L		
$\bar{X}$	(%)	S.D.	$\bar{X}$	(%)	S.D.
3.10	(78)	.74	2.70	(68)	1.25

TABLE 7

HAND MOVEMENT IMITATION:

Production of Correct Number of Items in a Sequence, Scored without Reference to Accuracy or Order (Total Accuracy, R + L)

Number of Movements	GROUP: Control (n = 10) R + L $\bar{X}$	Control (n = 10) R + L S.D.	Experimental (n = 10) R + L $\bar{X}$	Experimental (n = 10) R + L S.D.
A. Two (Max. Score = 8)	6.90	1.19	6.30	1.70
B. Three (Max. Score = 4)	1.90	1.19	1.00	1.25

(Witelson, 1977b). Thus, given that the dysphasics have a language deficit, and language functions are accorded to the left hemisphere, it seems reasonable to question if dysphasics also have difficulty with sequencing.

Because of difficulties in recording and interpreting subject responses, an order error was scored as such only when: 1) the required number of movements were generated, i.e. three movements when three were presented, and 2) each movement in the sequence was distinct and separate from the others. A tabulation of the data is presented in Table 8. Very few order errors were observed for either group and the nature of the raw data was such (i.e. very little variance, most subjects scores were zero) that parametric statistical analysis was not appropriate and nonparametric analysis (Wilcoxon Matched-Pairs Signed-Ranks Test) could not even be performed when attempted.

Since the hand posture and hand movement tasks are not totally dissimilar in their stimuli and response requirements and since there was such a large difference in the accuracy of performance between the tasks, for both groups, (see Table 4, hand postures; Table 5, hand movements) it was questioned whether the intertest difference was significant. For each subject the scores for each hand were summed (Right + Left) to obtain a total accuracy value (R + L) for each task. Paired t-tests performed on these values (R + L)

TABLE 8

HAND MOVEMENT IMITATION: COUNT OF NUMBER OF ORDER ERRORS OCCURRING DURING IMITATION OF TWO AND THREE MOVEMENT SEQUENCES

	Number of Movements	GROUP	HAND Left	HAND Right
A.	Two	Control (n = 10)	2	4
		Experimental (n = 10)	4	1
B.	Three	Control (n = 10)	1	3
		Experimental (n = 10)	2	3

revealed significantly greater accuracy of performance on the hand posture task versus the hand movement task for both the control group ($t = 9.19$, $df = 9$, $p < .0005$, two-tailed test) and the experimental group ($t = 11.68$, $df = 0$, $p < .0005$, two-tailed test), as shown in Table 9.

vi) Manual Expression Test

A paired t-test performed on the scaled scores for accuracy of performance (Table 10) revealed a significant difference between the two groups ($t = 2.11$, $df = 9$, $p < .05$, two-tailed test).

vii) Oral Movement Imitation Task

A paired t-test performed on the scores for accuracy of production, derived by summing the number of movements produced correctly across all three levels of the task, revealed no significant differences between the control group and the experimental group ($t = .30$, $df = 9$), as shown in Table 11.

3.2.2 Control Measures

i) Pantomime Recognition Task

The data for this task are displayed in Table 12. Two scores (Part I and Part II) were derived for this task. For Part I almost perfect scores were obtained by both groups

TABLE 9

COMPARISON OF PERFORMANCE ON HAND POSTURE TASK VERSUS PERFORMANCE ON HAND MOVEMENT TASK

(Total Accuracy of Performance (R + L) Expressed in Percentage)

GROUP	TEST			
	Hand Posture		*Hand Movement*	
	R + L		R + L	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Control (n = 10)	187.00	12.76	107.80*	28.89
Experimental (n = 10)	180.00	20.25	81.50*	20.54

* $p < .0001$, one-tailed test

TABLE 10

MANUAL EXPRESSION TEST

(Scaled Scores for Accuracy of Performance)

	GROUP			
	Control (n = 10)		*Experimental (n = 10)*	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
SCORE	40.55	6.81	34.75*	5.96

* $p < .05$, two-tailed test

TABLE 11

ORAL MOVEMENT IMITATION

(Number of Correct Items)

Maximum Score = 23

	GROUP			
	Control (n = 10)		*Experimental (n = 10)*	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
SCORE	18.70	2.35	18.30	3.01

TABLE 12

CONTROL MEASURES

A. PANTOMIME RECOGNITION TASK

B. VISUAL SEQUENTIAL MEMORY

	GROUP			
	Control (n = 10)		*Experimental (n = 10)*	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
A. Pantomime Recognition *(Number Correct)*				
Part I *(Max. Score = 7)*	7.00	0	6.70	0
Part II *(Max. Score = 7)*	5.90	.87	4.90	1.44
B. Visual Sequential Memory *(Scaled Scores Number Correct)*	38.20	5.51	42.70	9.40

creating almost no variance in the data. Due to this ceiling effect nonparametric analysis (Wilcoxon Matched-Pairs Signed-Ranks) was deemed to be the most appropriate, however, it could not be performed due to the nature of the data which created an "n" too small for analysis. Thus, although formal statistical analysis could not be performed the descriptive statistics strongly suggest that there is no difference between the groups for Part I of this task.

A paired t-test performed on the scores for Part II revealed no significant difference between the two groups ($t = 1.58$, $df = 9$).

ii) Visual Sequential Memory Test

A paired t-test performed on the scaled scores for accuracy of performance (Table 12) revealed no significant differences between the two groups ($t = 1.46$, $df = 9$).

3.2.3 Linguistic Measures

i) Token Test

The data for this test are displayed in Table 13. For this test the total number of commands performed correctly across all five parts was tabulated for each subject. A paired t-test performed on these scores revealed a significant difference in the performance of the two groups ($t = 3.04$, $df = 8$, $p < .01$, one-tailed test). In order to

TABLE 13

TOKEN TEST

(Number of Correct Items)

		GROUP					
		Control (n = 9)			*Experimental (n = 9)*		
		$\bar{X}$	(%)	S.D.	$\bar{X}$	(%)	S.D.
FULL TOKEN TEST *(Max. Score = 62)*		43.55	(70)	7.12	35.61*	(51)	11.51
PART *(Max. Score)*							
I	*(10)*	10.00	(100)	0	9.89	(99)	.32
II	*(10)*	9.33	(93)	.86	7.89	(79)	2.47
III	*(10)*	7.55	(76)	2.40	6.33	(63)	2.78
IV	*(10)*	4.88	(49)	2.71	3.77	(38)	2.53
V	*(22)*	11.77	(53)	3.38	7.66+	(35)	4.15

* $p < .01$, one-tailed test

\+ $p < .005$, one-tailed test

determine whether the difference between the two groups could be attributed to particular parts of the test, post hoc analyses were performed on the five different parts of the test. For Part I statistics were not applied since a perfect score was obtained by the control group and an almost perfect score by the experimental group. A Wilcoxon Matched-Pairs Signed-Ranks Test performed on the data for Part II, due to heterogeneity of variance, revealed no significant differences between the groups ($T = 7.5$). Paired t-tests performed on Parts III, IV and V revealed a significant difference between the two groups for Part V ($t = 4.15$, $df = 8$, $p < .005$, one-tailed test), but no difference between the groups for Parts III and IV (Part III: $t = 1.79$, $df = 8$, Part IV: $t = 1.07$, $df = 8$).

ii) Wide Range Achievement Test

The data for this test are displayed in Table 14. Paired t-tests performed on the scaled scores for the number of correct items revealed a significant difference between the two groups for both the reading ($t = 2.19$, $df = 8$, $p < .05$, one-tailed test), and spelling ($t = 1.92$, $df = 8$, $p < .05$, one-tailed test) sections.

TABLE 14

WIDE RANGE ACHIEVEMENT TEST

(Scaled Scores for Number of Correct Items)

Subtest	GROUP			
	Control (n = 9)		*Experimental (n = 9)*	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Reading	110.00	13.07	94.44*	13.92
Spelling	99.22	13.79	88.22*	14.35

* $p < .05$, one-tailed test

CHAPTER FOUR

DISCUSSION

The term developmental dysphasia refers to children who fail to develop speech and language at the normal time and in the normal manner although they do not have a primary emotional disturbance, or a physical handicap and are not globally mentally retarded or deaf.

The hypothesis of this research is that a deficit in certain aspects of motor functioning, specifically the initiation, organization and execution of fine (as contrasted with gross) actions might be a factor in the disorder. This motor performance was also considered within the context of hemispheric specialization since previous work has indicated: i) atypical patterns of hemispheric specialization in developmental dysphasics, ii) motor functions appear to be lateralized, and iii) the motor tasks lend themselves to being performed by each hand separately.

While not directly related to the primary hypothesis of this research, in order to explore more fully the nature of the language deficit in developmental dysphasia, some oral and written language measures in addition to those used for subject selection were administered.

The following issues will be discussed in this section: the existence of developmental dysphasia, the linguistic capabilities of developmental dysphasics, the motor ability of developmental dysphasics, concluding remarks.

4.1 The Existence of Developmental Dysphasia

Although it was not a predefined question for this research, since there has been sufficient discrepancy and comment in the literature regarding the theoretical and operational definition of developmental dysphasia, some comments about the experimental group in the present research seemed warranted.

In the present research there is considerable evidence to suggest that the experimental group is different from the control group -- and that the syndrome of developmental dysphasia does exist, as proposed most clearly by Benton (1964) and reiterated by Tallal (1978). Benton (1964) defined developmental dysphasia as:

> . . . the condition in which a child shows a relatively specific failure of the normal growth of language functions. The failure can manifest itself either in a disability in speaking with near normal speech understanding or in a disability in both understanding and expression of speech. The disability is called a "specific" one because it cannot readily be ascribed to those factors which often provide the general setting in which failure of language development is usually observed, namely, deafness, mental deficiency, motor disability or severe personality disorder. (p. 41)

In the present research the experimental subjects did not have a hearing loss, a physical handicap, a primary emotional disturbance, nor were they globally mentally retarded.

The experimental subjects in the present research were chosen on the basis of performance at a predefined level of deficit on the language selection measures. Subsequent statistical analysis revealed that they performed significantly more poorly than the control subjects on both the receptive and expressive portions of the Northwestern Syntax Screening Test, despite the absence of hearing loss, primary emotional disturbance, physical handicap and global mental retardation. It should also be recalled that the experimental subjects were matched individually to control subjects on the basis of sex, age, IQ, handedness and socioeconomic status. Thus, presumably these variables cannot account for the different performance of the control subjects and experimental subjects on the Northwestern Syntax Screening Test.

The two groups did not differ in their performance on the Arizona Articulatory Proficiency Scale (AAPS). It is uncertain whether the failure to achieve a statistically significant difference between the two groups on this linguistic measure is a true observation, or whether it is an artifact of the assessment tool which was chosen, i.e. perhaps the AAPS was not sufficiently sensitive to reflect

an articulation deficit in the dysphasics. Also, the sample size may have been too small to permit a difference to be observed. However, although the data did not permit rejection of the null hypothesis it does not mean that it is therefore accepted. It cannot be denied that 60% of the experimental group had a rating of two on the AAPS indicating a severe articulation deficit; whereas 100% of the control group achieved a rating of zero indicating articulatory ability within normal limits.

It may be that language and articulatory deficits are not perfectly correlated. Therefore, an articulation deficit may not be observed in every child presenting with a language disturbance, while a language disturbance may not be observed in every child presenting with an articulation deficit.

The literature is unclear in respect to this matter. Studies of children with language disturbance tend not to provide data on their articulatory ability, while studies of children with articulation difficulties tend not to provide data on the language performance. In one study where both language and articulatory ability were examined (Shriner, Holloway and Daniloff, 1966), children with defective articulation were found to use significantly shorter and grammatically less complex sentences than normal children.

The statistical analysis in the present research did not indicate that the dysphasics and the control subjects differed in their performance on the AAPS, however, as noted above, there is a clear trend in the data to suggest that the performance of the two groups is not comparable. Subsequent research will need to clarify the nature of the relationship between childhood articulation difficulties and language difficulties, and to what extent articulatory function is impaired in a language disorder and to what extent language function is impaired in an articulatory disorder.

4.2 Linguistic Capabilities of Developmental Dysphasics

In addition to the language measures administered as part of the selection procedures other language measures were administered to probe different aspects of speech and language function. These additional measures were the Token Test and the Wide Range Achievement Test (WRAT), reading and spelling sections.

Analysis of the data from the Token Test revealed a statistically significant difference between the dysphasics and the control subjects for the Full Token Test and for Part V of the test (Table 13). A statistically significant difference was not found for Parts I to IV, although in each instance the dysphasics performed more poorly than the

control subjects. The data from the Full Token Test further confirm that the dysphasics have a deficit in receptive language function. The increasingly poor performance of both groups on Parts I to IV suggests that as linguistic stimuli increase in length and in grammatical and syntactical complexity they become more difficult to process. The significant difference between the two groups on Part V of the test reflects an improvement in the performance of the control subjects (relative to their performance on Part IV) but continued impaired performance for the dysphasics. Observation of the data reveals a 38% accuracy level for the dysphasics on Part IV compared to a 35% accuracy level on Part V. The control subjects achieved a 49% accuracy level on Part IV and a 53% level on Part V. It should be noted that while the commands in Part IV are generally longer than those in Part V, the commands in Part V are more grammatically and syntactically complex. It is not entirely clear therefore which is the more crucial factor to the dysphasics' continued poor performance -- sentence length or syntactical complexity. Tallal (1975) administered the Token Test to developmental dysphasics and reported for both the control subjects and the dysphasics a pattern of performance similar to that found for the control subjects in the present study. She argued that while it cannot be denied that dysphasics have difficulty with the

grammatical aspects of language, their errors, ". . . rather than indicating specific difficulty based on the degree of syntactic or grammatical complexity of the command, in Part 5, were characterized predominantly by a recency memory effect as evidenced by subjects' responding most often to only the final part of each of the longer commands" (p. 203). She interpreted her data to mean that:

> . . . the language impairment of developmentally dysphasic children does not result, at least primarily, from a specific inability to analyze the linguistic components of language. Rather, the language impairment of these children appears to reflect their primary inability to analyze the rapid stream of acoustic information which characterizes speech and is essential to normal speech perception and language development. (p. 205)

Menyuk and Looney (1972a) specifically studied the question of length versus structure in the language disorder of developmental dysphasia by having dysphasics repeat sentences which had been controlled for length and syntactical structure. They concluded that the crucial factor was grammatical and syntactical complexity, and not length. Given that Menyuk and Looney set out specifically to test the hypothesis of length versus structure and devised their empirical tasks accordingly, whereas Tallal did not, their conclusions seem more acceptable and

prompt one to conclude that the difficulties that the dysphasics experienced on the Token Test were primarily a function of structure and not length. However, further research is necessary to address more specifically the question of a short-term memory deficit in developmental dysphasia raised by Tallal.

The poorer performance of the dysphasics on both the reading and spelling sections of the WRAT indicates that dysphasics have difficulty with language not only in its oral form, but also in its written form. Such data may be predictive of the level of future academic performance. No other studies were found in which the WRAT was administered to dysphasics. However, in studies by Butler, Peckham and Sheridan (1973), Hall and Tomblin (1978), Tallal (1973) and Weiner (1974), other measures of written language were administered and all reported that the dysphasics displayed deficits in reading, the precise nature of which was not indicated. Rutter (1972) in a review of this literature wrote,

> Because most children who are late in talking ultimately speak normally, there is a tendency to assume that speech delay is of no consequence in most cases. These findings emphasise how mistaken this view is. Although most children catch-up in their speaking, many are left with subtle language handicaps which may continue to impede their educational progress. The association between speech delay and later reading retardation is quite strong. (p. 181)

The poorer performance of dysphasics on reading and spelling tasks suggests that it may not be sufficient, and far too simplistic, to regard developmental dysphasia as only a disorder of oral language function. The reading and spelling data imply that there exists a more pervasive and fundamental disorder of language function and although oral language performance may improve and develop sufficiently with maturation to permit functional communication, the residual effects of this fundamental language deficit continue to be evidenced in written language.

4.3 The Motor Ability of Developmental Dysphasics

Seven measures of motor ability were administered. Five of these were lateralized tests (i.e. it was required that the task be performed by each hand separately), while the remaining two were nonlateralized measures. The lateralized measures were a repetitive tapping task, the Annett peg moving task, a children's sequence box task, a hand posture imitation task and a hand movement imitation task. The ITPA manual expression test and an oral movement imitation task were the nonlateralized tasks. The data from all the tasks were analyzed in terms of accuracy of performance. For the lateralized measures the data were also analyzed in terms of laterality of performance. While some tasks (i.e., hand posture imitation, hand

movement imitation, manual expression) revealed a significant difference between the groups in terms of accuracy of performance, no laterality (hand) effects were observed for any of the tasks.

4.3.1 Accuracy of Motor Performance

As discussed earlier, it has been reported (Goodglass and Kaplan, 1963; Kimura, 1977; Kimura and Archibald, 1974; Mateer and Kimura, 1977) that adults with language problems (i.e. adult aphasics) have difficulty performing certain tasks of motor function, i.e. hand movement imitation, oral movement imitation, the manual sequence box task and the production of everyday actions following verbal instruction or demonstration (i.e. test for limb apraxia). On the basis of these findings it was predicted that developmental dysphasics might also display some difficulties in motor function, at least on the hand movement imitation task, oral movement imitation task, children's sequence box task and manual expression task. The other motor measures (i.e. hand posture imitation, peg moving and repetitive tapping) were selected and administered in order to provide a profile of the motor ability of developmental dysphasics. (The hand posture task was primarily selected for its laterality factor in that it was the only measure for which a left-hand superiority, suggesting right hemispheric

processing, had been reported [D. Ingram, 1975]). Since the repetitive tapping and peg moving tasks have not previously been done with adults or children with a language disorder no specific predictions were made regarding the performance of the dysphasics. The hand posture imitation task had been administered to aphasic and nonaphasic adults with unilateral left and right hemisphere lesions (Kimura and Archibald, 1974), but no differences were observed between any of the groups. On the basis of these data it was predicted that no difference would be found between the experimental group and the control group on the hand posture imitation task.

The data from the three tasks on which the dysphasics showed some deficiency, i.e. hand posture imitation, hand movement imitation and manual expression, will now be discussed.

For the hand posture imitation task two performance measures, accuracy of production and production time, were taken. The dysphasics produced the postures as well as the control subjects but took significantly longer to do so. Production time was not recorded in previous studies using such a measure, in other populations (D. Ingram, 1975; Kimura and Archibald, 1974). During the pilot testing for the present research it was observed that while the dysphasics were able to produce the postures accurately they took con-

siderably longer to do so, and it was thus decided to record the production time.

Taken together, the two sets of data (accuracy of production and production time) indicate that while the dysphasics can perform this task as accurately as their matched control subjects they take much longer to do so. This is true for both hands.

Various factors may be suggested to account for the slower performance of the dysphasics. Firstly, the fact that the dysphasics performed as well as the control subjects on many of the other measures in the test battery suggests that their slower performance is not simply attributable to a lack of co-operation and attention. Secondly, the fact that the dysphasics produced the hand postures as accurately as the control subjects (combined with the fact that they performed as well as the control subjects on the pantomime recognition task) suggests that the difficulty is not in the perception of the stimuli, but in the execution.

In summation, it is suggested that the impaired performance of the dysphasics on the hand posture imitation task reflects a deficit in the execution of motor stimuli, and not in their perception. The dysphasics produced the postures as accurately as the control subjects but took much longer to do so, suggesting a difficulty in initiating, organizing and/or executing the required posture. The

manner of production was not formally recorded. However, it was noted in casual observation that the dysphasics seemed to grope and search for the correct finger positions and had considerable difficulty organizing and "instructing" their fingers into the required postures.

On the hand movement imitation task, which required the production of single movements and sequences of two and three movements, the dysphasics performed significantly more poorly than the control subjects. A variety of factors (i.e. movement, order, memory, movement reception) were explored in order to examine why the dysphasics performed more poorly than the control subjects.

In respect to the movement factor, a separate analysis was made of the data from Part I (one movement) of the hand movement imitation task. It was thought that the difference in the performance of the two groups might be attributable to the movement component (i.e. the hand posture imitation task does not have a movement component and the two groups did not differ in level of accuracy of performance on that task). No difference was found between the two groups. More careful consideration of what was required to imitate a single hand movement versus what was required to imitate a hand posture suggested that because the two groups did not differ in imitating a single movement, did not mean that movement was therefore not a

factor in the poorer performance of the dysphasics on Parts II and III of the hand movement imitation task. At least two factors counter this conclusion. Firstly, it may have been that if the time required to produce a single hand movement had been recorded a difference would have been observed between the two groups. On the hand posture imitation task a group effect was observed for production time, but not for general level of accuracy of performance.

Secondly, the stimuli used in Part I of the hand movement imitation task were not the same as the stimuli used in the hand posture imitation task. Observation of the per cent accuracy scores for the hand posture task (Table 4) versus the per cent accuracy scores for Part I of the hand movement task (Table 6) indicates that for both groups the level of accuracy was lower for the hand movement task. This suggests that Part I of the hand movement task is more difficult than the hand posture imitation task. Whether this can be attributed to the movement factor is not clear at this time and further research will be necessary to clarify this issue.

It was also thought that order or the ability to produce more than one movement when required might be factors in the reduced performance of the dysphasics. However, the dysphasics produced no more order errors than the control subjects nor did they have any more difficulty

than the control children in knowing that a specific number of movements needed to be produced, regardless of accuracy or order.

The visual sequential memory and pantomime recognition tasks were specifically administered as control measures for the hand movement task. On both tasks the dysphasics performed as well as the control subjects.

The comparable performance of the two groups on the pantomime recognition task suggests that the reduced performance of the dysphasics in the production of hand movements is not due to a deficit in the perception of such stimuli.

The comparable performance of the two groups on the visual sequential memory task suggests that the reduced performance of the dysphasics on the hand movement imitation task cannot simply be attributed to a visual memory deficit, although it is granted that the question is not totally resolved in that the memory demands of the two tasks may not be the same.

In conclusion, although a variety of factors (i.e. movement, order, memory, movement reception) were explored to account for the poorer performance of the dysphasics on the hand movement imitation task, it is still not definitive why the two groups performed differently. Subsequent research will need to develop other measures

(i.e. perhaps a measure of production time, error analysis) if the performance of the dysphasics is to be better understood.

The accuracy of performance on the hand posture task was compared to the accuracy of performance on the hand movement task and revealed that for both groups the hand posture task was performed significantly more accurately than the hand movement task. This suggests that for both groups the hand movement task is more difficult. The extent to which this is a function of the movement and greater memory demands of the hand movement imitation task is not clear at this time. It may also be that the difference in accuracy of production on the hand posture and on the hand movement tasks is a matter of degree of difficulty and not of a fundamental difference in the manner in which the two tasks are performed. The hand movement imitation task may place greater demands on motor organization.

The manual expression test on which the dysphasics performed more poorly than the control subjects was administered to represent the traditional limb apraxia test. While measures of oral apraxia have been administered (Weiner, 1969a,b; 1972; Yoss and Darley, 1974), there are no reports of the performance of developmental dysphasics on limb apraxia measures. Adults with a Broca's aphasia have classically demonstrated limb apraxia (Geschwind, 1975).

While there has been no comparable discussion in the developmental dysphasia literature, in the adult aphasia literature there is disagreement as to why limb apraxia occurs in aphasia. As indicated in the introduction some have argued that the apractic disturbance was attributable to the general aphasic disability in coping with symbolic material (Duffy, Duffy and Pearson, 1975; Gainotti and Lemmo, 1976); while others have contested that the disability is attributable to an impairment in motor function (Geschwind, 1975; Goodglass and Kaplan, 1963; Kimura, 1977; Kimura and Archibald, 1974).

Since the developmental dysphasics in the present research displayed no deficit on the pantomime recognition task, but did perform more poorly than the control subjects on the hand posture and hand movement imitation tasks there is more basis to interpret their impaired performance on the manual expression test as attributable to a deficit in motor function, and not a deficit in symbolic processing.

The dysphasics performed as well as the control subjects on the repetitive tapping, peg moving, children's sequence box and oral movement imitation tasks. Why this might be so will be considered in the ensuing discussion.

As indicated earlier, the repetitive tapping and peg moving tasks have not previously been done with dysphasic children or aphasic adults and no specific

hypotheses were made regarding the dysphasics performance on these measures. The fact that the dysphasics performed as well as the control subjects on the repetitive tapping and peg moving tasks suggests that if the dysphasics have a defect in motor function it is a selective deficit which does not encompass all forms of motor performance. More specific discussion of this possible motor deficit will occur at a later point.

The children's sequence box was an adaptation of the manual sequence box which Kimura (1977) used with adult aphasics. Neither sequence box has been used with dysphasic children but because Kimura (1977) reported that adult aphasics had difficulty with the task, it was predicted that the developmental dysphasics in the present research might also experience difficulty. Why the dysphasics performed as well as the control subjects is not entirely clear and can only be speculated upon. While the children's sequence box involved a certain degree of motor sequencing and organization, it may be that these were at a lower order of difficulty, when compared with the hand posture and hand movement imitation tasks. It might also be contended that the children's sequence box required the production of motor units which had a high degree of redundancy, were overlearned, or were within the day to day repertoire of motor function. Since one usually pushes a button with the

index finger and pulls a handle with all fingers, such a task may not require the same motor organization as might be necessary if the task was to push the button with the ring finger and pull the handle with only the middle finger or some other finger combination. As well, the fact that the task involved an external factor, that being a piece of equipment, which might serve as a possible cue may also have contributed to making the task less demanding in terms of motor organization and execution.

It was also expected that the dysphasics would perform more poorly than the control subjects on the oral movement imitation task. Although there have been only a small number of studies (Weiner, 1969a,b, 1972; Yoss and Darley, 1974) in which oral movement imitation tasks have been administered to dysphasics, with inconclusive findings, the general trend is to suggest that dysphasics do not perform as normal children on such measures. In a study with aphasic adults Mateer and Kimura (1977) found that both aphasics with and without an oral motor deficit (oral apraxia) displayed impaired performance in the production of nonverbal oral movements.

Some of the discrepancy between the present results and those of prior research (Weiner, 1969a,b; Yoss and Darley, 1974) may be accounted for by differences in test stimuli and subject pool. In the present research the

child was required to imitate only after demonstration. Verbal instructions were not used. Only nonverbal, not phonemic stimuli were used. Weiner (1969a,b) utilized two different measures: imitation of phonemic stimuli - and production of oral movements following verbal instruction. More points were given if the child did not require demonstration and could produce the movement just with verbal instruction. Clearly a poorer performance on the dysphasics' part could be attained because of failure to comprehend the instruction and not from any inability to perform the movement. The use of phonemic stimuli enlists the linguistic modality which for dysphasics may demand an extra degree of complexity not required for the imitation of nonverbal oral movements or, may require function in an entirely different area, which is an area of deficit for dysphasics.

Yoss and Darley studied oral movement production in subjects whose presenting problem was defined as defective articulation and not language disability. Recalling earlier discussion, if articulatory and language disorders are regarded at least in part as separate clinical entities then the difference between the findings of the present research and Yoss and Darley's data may be a function of the different subject pools.

In summation, it is difficult to interpret the dysphasics' adequate performance on the oral movement imitation task. It may be that the sample size was too small to reflect a difference between the two groups or it may be that there is in fact no difference between the groups. It is somewhat puzzling that the dysphasics had difficulty imitating the hand postures and hand movements but not the oral movements in that the stimuli in the three tasks seem to make similar demands on motor performance Perhaps if the task had been timed, as with the hand posture task, a difference in production time would have been observed even though there was no difference in the accuracy of production. It may also be that the production of nonverbal (but not necessarily verbal) oral movements is mediated by a neural substrate different in some regions from that required for the production of manual motor movements. This will be discussed in more detail in the following section. In conclusion, further research is necessary to define more precisely the oral practic and articulatory ability of developmental dysphasics, and the motor components thereof.

4.3.2 An Hypothesis of the Motor Deficit in Developmental Dysphasia

To sum the results of the motor tasks, the dysphasics performed significantly more poorly than the control subjects on the hand posture imitation task, the hand movement imitation task and the manual expression task (to be designated Group 1). They performed as well as the control subjects on the repetitive tapping, peg moving, children's sequence box and oral movements imitation tasks (to be designated Group 2). It is proposed that developmental dysphasics have a deficit in certain aspects of motor function. An hypothesis of this motor deficit will be presented in the following discussion.

The absence of a group difference on the repetitive tapping, peg moving, children's sequence box and oral movement imitation tasks suggests that if the dysphasics have a defect in motor function it is a selective deficit which does not involve all forms of motor performance. The question then is why do the dysphasics perform as well as the control subjects on the repetitive tapping, peg moving, children's sequence box and oral movement imitation tasks (Group 2) but not on the hand posture, hand movement and manual expression tasks (Group 1)? Do the tasks in Group 1 have a common factor? Similarly, do the tasks in Group 2 have a common factor?

The factor or issue most germaine to the tasks in Group 1 may be that they all require considerable motor organization before the motor behavior, be it a hand posture, a hand movement or a pantomime (manual expression test) can be executed. In each instance the individual is required to organize spatially and temporally, and perhaps retain, the motor stimulus which was presented. For example, the task of placing the thumb under the index and mid fingers requires the "spatial concept" of under and a "temporal concept" of closing the index and mid fingers only after the thumb has been placed under them. The fact that the tasks in Group 1 are not repetitive, do not have a high degree of redundancy and are not likely to be within the day to day repertoire of motor function contributes further to the motor organizational demand or loading. Similarly, for the tasks in Group 1 it is required that an action be organized and executed without an external referent.

Conversely, most of the factors which are descriptive of the tasks in Group 1 do not apply to the tasks in Group 2. The tasks in Group 2 all involve the production of motor stimuli which have a high degree of redundancy, are repetitive and overlearned, or are within the day to day repertoire of motor function. Three of the measures involve an external factor, that being a piece of equipment.

This too may contribute to making the task less demanding in terms of motor organization.

As regards the oral movement imitation task, in addition to the factors discussed above, the fact that the dysphasics performed as well as the control subjects may also be attributable to a difference in the neural substrate required for the production of oral motor behavior as compared to manual motor behavior, as indicated in the previous section. There are at least three possibilities in this regard. Firstly, while it is well known that within the primary motor cortex the areas for oral and hand control are very close to each other (Penfield and Rasmussen, 1955), this does not mean that there is not separate neural tissue for the control of hand movement and separate neural tissue for the control of oral movement. Secondly, the neural control for tongue movement is bilateral (Peters, 1976) whereas the neural control for hand movement is primarily unilateral (Brinkman and Kuypers, 1973). Thus, a unilateral lesion that impaired manual motor function need not necessarily impair nonverbal tongue movement. Thirdly, while there may be one neural center responsible for the organization and execution of motor behavior, within this center the tissue relegated to nonverbal oral motor behavior may differ from the tissue relegated to manual motor behavior. Further research will be necessary to clarify these questions.

There is very little data from which to speculate why dysphasics, at a cognitive level, might have difficulty performing manual motor tasks. It has been suggested that dysphasics have a deficit in visual spatial memory or spatial discrimination (Doehring, 1960; Poppen et al., 1969; Wyke and Asso, 1979), but these investigations have been very unsystematic and thus definitive conclusions are not possible. It should also be noted at this time that the manner in which complex motor skills are represented and mediated in the normal individual is only just beginning to be appreciated (Keele and Summers, 1976; Kelso and Stelmach, 1976). Kelso and Stelmach write, "The major problem, however, is that psychologists are still measuring product most of the time, rather than process. While the presence of certain processes may be inferred on occasion by measuring reproduction error, they cannot be explicated. Only by developing more analytical indices of performance can we expect to reveal underlying mechanisms" (p. 35).

In conclusion, the data provide some support for an hypothesis of a motor deficit in developmental dysphasia. It is proposed that this is a specific and higher order deficit, not observed in all types of motor function and that it is a deficit in the initiation, organization and execution of motoric stimuli, and not in the perception of motoric stimuli. The precise nature of the deficit is

not fully appreciated at this time. The extent to which, and whether, such factors as visual memory and visual spatial discrimination operate in the deficit requires further investigation.

4.3.3 Laterality of Performance and Implications for Hemispheric Specialization

The motor function of the dysphasics was explored in a laterality context for two main reasons. Firstly, other lateralized testing (the dichotic listening procedure) with dysphasics has reported atypical performance for dysphasics, i.e. a left ear superiority when a right ear superiority was expected (Sommers and Taylor, 1972; Witelson and Rabinovtich, 1972) and a reduction in the expected difference between the two ears (Pettit and Helms, 1974; Rosenblum and Dorman, 1978). Secondly, motor functions are lateralized and most of the tasks readily lend themselves to being performed separately by each hand. Thus the laterality (hand) factor is easily assessed.

While the issue of laterality of motor performance is clearly an area worthy of exploration, it was felt that a specific hypothesis about the laterality of the dysphasics' performance was not possible or justified given that there has been so little research on motor function. Some of the measures used in this research have not previously been

done with normal subjects (i.e. children's sequence box, hand movement imitation), while others have been done to only a limited extent with normal subjects (i.e. peg moving, hand posture imitation, oral movement imitation).

A hand (laterality) effect was not observed in the control or experimental group with any of the lateralized measures administered. Possible reasons why a hand effect was not found will be discussed for each of the tasks individually.

Reports in the literature have consistently indicated a right hand superiority for repetitive tapping in both normal children and adults (Bowen, Hoehn and Yahr, 1972; Denckla, 1973, 1974; D. Ingram, 1975). Failure to observe a right hand superiority in the present study can probably be attributed to a small sample size in that there is a clear trend in the data to suggest a right hand superiority for both groups. In the control group all ten subjects obtained a right hand superiority and in the experimental group eight out of the ten subjects displayed a right hand superiority. Previous research (Denckla, 1973; D. Ingram, 1975) was conducted on samples of at least 100 subjects. Examination of the data from small subgroups of these larger samples (i.e. different age groups) reveals that the difference between the mean values reported for the left and right hands was comparable to that observed in the present study.

For the peg moving task, in the only other study (Annett, 1970) where the task was administered, a right hand superiority was reported in normal children (boys and girls), 3-15 years of age. At least two factors, sample size and subject sex, might account for the failure to observe a right hand superiority in the present study. Although Annett's total sample size was over 200, the number of children in each of the subgroups was only 8-13. When the mean left hand and mean right hand scores for the various subgroups are studied, the difference between those values (i.e. L - R) is often comparable to the difference between the mean left hand and mean right hand scores for the two groups in this study. Thus, the absence of a laterality factor in the present research might be attributable to an overly small sample. The difference between studies might also be attributable to differences in group variability. Examination of standard deviations reveals much greater variability in both groups of the present research as compared with comparable age subgroups in Annett's study. The standard deviations for both hands for both groups in the present research are almost twice those reported by Annett. Thus the greater variability in the present research might have the effect of masking a laterality effect.

A further factor which may have contributed to the failure to observe a hand effect in the present study is the sex of the subjects. Annett tested both boys and girls and while she reported a right hand superiority for both sexes she also observed that the boys were significantly less lateralized to the right than the girls. Only boys were tested in the present research.

The hand posture imitation task has been administered on two other occasions (D. Ingram, 1975; Kimura and Archibald, 1974). In a study with children (boys and girls) 3-5 years of age Ingram found a left hand superiority. It is interesting to note that Kimura and Archibald (1974) observed no differences between hands when they administered the task to adult subjects with unilateral left or right hemisphere lesions. A variety of factors might account for the failure to observe a left hand superiority in the present study, i.e. differences in subject age, differences in administration, and differences in scoring.

Perhaps the most significant difference between the two studies is that of the age of the subjects. Ingram tested both boys and girls, 3-5 years of age. The mean age of subjects in the present study was 6.6 years with a range of 4-9 years. It may be that the laterality effect for hand posture imitation is lost as the child gets older, or that insufficient task complexity permits a ceiling effect

in older children, thereby clouding a laterality factor. At age 5 years Ingram reported 88% correct across both hands, as contrasted with 63% correct at 3 years of age. In the present research the accuracy across both hands for five year olds was 97% in the control group and 86% in the experimental group. For subjects 6-9 years of age the accuracy across both hands was 95% for both groups.

Regarding administration and scoring differences, Ingram allowed the child to observe the posture being formed and presented the posture to the child sitting beside him. In the present study the posture was formed behind a screen and was presented across from the child. Ingram scored each posture along a general accuracy scale of 0-3, whereas in the present research each posture was broken down into component parts and a score derived in terms of the number of component parts that were correctly produced.

The children's sequence box required that specific actions be produced in the correct order as quickly as possible. In the only other study where the task was administered Kimura (1977) reported that adults with unilateral left hemisphere lesions performed significantly more poorly than adults with unilateral right hemisphere lesions. On the basis of Kimura's data a right hand superiority was predicted in the present study, at least for the control subjects. It is important to realize, however, that such a prediction is derived primarily from theoretical con-

siderations and not empirical findings. The fact that a right hand superiority was not observed in either group in the present research is difficult to interpret. It may be attributable to a small sample or insufficient sensitivity in the task to centrally lateralized function, thereby clouding a laterality factor. At this point further research is necessary to clarify these questions.

The hand movement imitation task required that single movements and sequences of two and three movements be imitated. A right hand superiority was predicted given Kimura and Archibald's (1974) report that adults with unilateral left hemisphere lesions performed more poorly than adults with unilateral right hemisphere lesions. Why the control subjects at least, did not display a right hand superiority is difficult to interpret. Again, it must be borne in mind that the prediction of a right hand superiority was based almost solely on theory and not on empirical findings. As indicated earlier, the task has not previously been done with children and only once with adults, aphasic adults.

Studying the mean percent accuracy values (the highest figure is 56% for the right hand of the control group), it may be that a right hand superiority was not observed because the complexity of the task was too great, creating a floor effect and thereby clouding a laterality component. Again it may also be that the sample size was too small.

In conclusion, whether the manual asymmetry of developmental dysphasics in the performance of lateralized motor tasks is typical or atypical is not possible to indicate on the basis of the present data. The fact that for most of the motor measures used in this research the performance of the "normal" individual is not well understood compounds interpretation of the dysphasics' performance. As indicated earlier, the administration of lateralized motor tasks is a relatively new field of endeavor, and previous administration of most of the tasks used in this research has been limited. It is also unclear how much small sample size and limitations in task design contributed to the failure to observe the predicted laterality direction. Further study is necessary before the performance of developmental dysphasics on lateralized motor tasks is understood.

While the data suggest that developmental dysphasics may have a deficit in certain aspects of motor function, it is far more difficult to interpret the data in respect to the question of hemispheric specialization. It must be stated that any inferences made about the hemispheric specialization of developmental dysphasics are highly speculative in that a hand (laterality) effect was not observed in the control group or the experimental group with any of the lateralized measures administered. That being

so, three possible inferences that might be drawn regarding neural factors in developmental dysphasia will be discussed.

Firstly, if the control subjects had displayed a clear laterality factor on the motor measures, and if the dysphasics displayed no left-right differences, it might have been inferred that the dysphasics were less lateralized since their data reflected neither a left or a right laterality component. However, as reported, neither group displayed a laterality effect. This may simply be a function of sample size and methodology, but further testing is necessary to confirm this.

Secondly, it might be inferred that the dysphasics' reduced accuracy on the hand movement task and longer production time on the hand posture task is due to a deficit in motor function, neurological in origin, but not related to hemispheric organization. Their hemispheric organization may be normal and the deficit in motor function may be attributable to a more generalized neurological dysfunction, i.e. neurochemical or neurophysiological in nature.

The third inference that might be drawn is that the reduced motor performance of the dysphasics stems from a deficit in left hemisphere function. The basis for this inference is as follows. Liepmann, as indicated earlier, proposed that the left hemisphere was responsible for certain types of motor function that were not shared

by the right hemisphere. More recent data provided by Kimura (1977) and Kimura and Archibald (1974) have supported this hypothesis. Thus, it may be contended that the fact that the dysphasics performed more poorly on some of the motor measures implies left hemisphere dysfunction. As Kimura and Archibald (1974) speculated, "The impairment in movement copying in the left hemisphere group was bilateral and equal for the two hands, in those patients (without hemiplegia) in whom both hands could be tested . . . suggesting that the motor control exerted by the left hemisphere on this type of movement is bilateral . . ." (p. 346).

4.4 Conclusion

In this research it was found that developmental dysphasics have a deficit in certain aspects of manual motor function. It is proposed that this is a specific and higher order deficit, not observed in all types of motor function and that it is a deficit in the initiation, organization and execution of motoric stimuli and not in the perception of motoric stimuli. How, and if, this putative motor deficit relates to the hemispheric specialization of developmental dysphasics awaits further investigation. To the extent that higher order motor function is the responsibility of the left hemisphere one might speculate that this suggests some dysfunction in left hemisphere functioning.

How a motor deficit relates to and whether it is a basis for the observed language disorder is a separate question. It has been argued (Kimura and Archibald, 1974) that the left hemisphere is primarily specialized for certain types of motor function, and that speech and language function, which are also under left hemisphere control, are overlaid on this motor function.

Given that auditory perceptual function is also under left hemisphere control (Efron, 1963), and has also been found to be deficient in developmental dysphasics (Tallal and Piercy, 1973, 1974, 1975), the present data further strengthen the argument for left hemisphere dysfunction in developmental dysphasia. Together, the two sets of data, auditory perception and motor function, support Liberman *et al.*'s (1967) motor theory of speech perception, which proposes that speech is perceived through the motor/articulatory system.

In conclusion, there is some evidence to suggest a motor deficit in developmental dysphasia. Further research is necessary to define the nature and extent of the deficit, how it relates to the hemispheric specialization of developmental dysphasics and how each in turn relates to the observed language disorder.

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