LANGUAGE ACQUISITION IN YOUNG BOYS AND GIRLS IN RELATION TO MANUAL MOTOR FUNCTION AND LATERALITY

By

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LANGUAGE, MOTOR FUNCTION AND LATERALITY IN CHILDREN

This work is dedicated to my husband Mark Cornfield, and my sons Joshua and Tobiah. You were always there. Thanks guys.

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ABSTRACT

Language acquisition in relation to sex, manual motor skill and laterality was studied in forty-nine middle class normally developing children. A longitudinal design was employed and testing was done at 18, 24 and 30 months of age. Measures of language function, motor function, lateral asymmetry and general cognitive ability were used. It was predicted that: a) girls would perform better than boys on the language measures, b) children who scored high on manual motor tasks would talk better, c) handedness would not be related to language ability, and that, d) handedness and motor asymmetries would be observed at 18 months and not change at 24 and 30 months.

The girls performed better than the boys on almost all the language measures. There were no sex differences for any of the other tests given. A weak association was found between manual motor skill and language productivity, but handedness and language ability were not related. Hand preference and motor asymmetries were observed at 18 months and maintained at 24 and 30 months.

These results further our understanding of language development in young children and may help the assessment and treatment of children with developmental language

problems. The measurement of handedness and lateral behaviors in young children permits inferences about hemisphere specialization in the young child. The results of this research support the position that hemispheric specialization does not develop with age but is present from a very early age.

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CHAPTER ONE

INTRODUCTION

1. Introductory Comments

Anthropologists, philosophers and linguists have long proposed that there is a special association between language and hand use. The oldest basis for this belief is the gestural theory of language origin which has persisted for over two millenia (see Hewes, 1975, 1976 for historical reviews) and which states that man's first form of language was gestural involving hand and arm signals and that only later did vocal and verbal forms of language evolve (Dingwall, 1979; Hewes, 1973). Recent efforts to teach sign language to apes (Gardner and Gardner, 1969, 1971; Patterson, 1978) met with some success and have served to buttress the gestural theory. Two other lines of work have provided further evidence to support the idea of an association between language and hand function: studies of brain damaged adults who had language and praxis difficulties after left hemisphere lesions (Kimura and Archibald, 1974; De Renzi, Motti and Nichelli, 1980); reports of the use of gestures prior to and in conjunction with the emergence of verbal language in normal children (Bates, Benigni, Bretherton, Camaioni and Volterra, 1978; Jancovic, Devoe and Wiener, 1975).

The work reported in this thesis was directed to the development of language in young children and set out to examine how the development of language is related to hand use. More specifically, language development was studied in relation to manual motor skill and lateral dominance in hand use. Accordingly the research has been directed to studying variability in normal language acquisition in relation to differences in manual motor ability and differences in laterality of hand function. This analysis represents a modern trend in the study of language development. In the 1960's and '70's psycholinguists sought to identify universals in language acquisition (Brown, 1973; Chomsky, 1965). However, there has been a move away from that focus and the current trend is to acknowledge and define individual differences, styles and strategies in the acquisition of language (Fillmore, Kempler and Wang, 1979; Nelson, 1973, 1981; A. Peters, 1977).

Language development in relation to sex has also been examined, and because measures of laterality were administered within a longitudinal design the question of hemispheric specialization in young children was addressed.

The hypotheses which the study was designed to test arose from a review of existing knowledge; the relevant literature is reviewed under the following headings:

a) Language development in relation to manual motor function;

b) Language development in relation to handedness;

c) Sex differences in language development;

d) Lateral behaviors and hemispheric specialization in young children.

2. Language Development in Relation to Manual Motor Function

2.1 Introduction

The primary question under study is language development in young children in relation to the emergence of manual motor function. The theoretical basis used in establishing the question for this research was based in large part upon data derived from neuropsychological investigations with brain damaged adults (Kertesz and Hooper, 1983; Kimura and Archibald, 1974; Kimura, 1977). In these studies language breakdown -- aphasia -- was studied in relation to manual motor function, termed "praxis" in the neurological literature. Liepmann, working at the turn of the century, defined apraxia 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" (cited in Geschwind, 1975, p. 188). He (Liepmann, 1913) observed that apraxia occurred more frequently after damage to the left cerebral hemisphere and that it was present not only in the right hand, but also in the left hand. He proposed that the left hemisphere is the major repository for learned motor skills, and that language functions are overlain upon these motor functions. Contemporary research has attempted to define more precisely the motor functions of the left hemisphere and the relationship between language function and manual motor function (Kimura, 1977; Lomas, 1980). Kimura (1977) has proposed that the left hemisphere is specialized for certain kinds of motor function, speech and language being treated as one such function and that it is an impairment in certain kinds of motor function which is crucial to speech and language disturbances.

The main interest of this thesis is the relations between language function and manual motor function in young children. Adult neuropsychological studies, however, will be reviewed before the research with children is examined because they have tended, more than studies with children, to examine specifically the relationship between language ability and manual motor skill. The developmental research may assume a broader meaning against the background of the adult research.

2.2 Studies with Adults

Adults who suffer unilateral left hemisphere lesions frequently display disturbances in higher order manual motor skills, apraxia, as well as disturbances in language function, aphasia (Geschwind, 1975; Kimura and Archibald, 1974). Conversely, the occurrence of aphasia and apraxia after a right hemisphere lesion is relatively rare (Searleman, 1977). While there is agreement regarding the occurrence of aphasia and apraxia after a left hemisphere lesion, what is less clear is the frequency with which this occurs and whether there is indeed a special association, i.e. an interdependence, between aphasia and apraxia (Kertesz, 1979). There are a small number of reports of disturbances in gestural (Goodglass and Kaplan, 1963) and praxic function (Kertesz, 1979; Kimura, 1977; Kimura and Archibald, 1974) in association with aphasia.

De Renzi, Motti and Nichelli (1980) studied the incidence of impairment of the ability to copy hand movements in brain damaged adults and its association with aphasia. They reported that 53% of subjects with left hemisphere lesions were apractic (versus 20% of subjects with right hemisphere lesions) and of subjects with left hemisphere lesions who displayed aphasia, 80% were apractic. A significant correlation (r = .56) was found between performance on a movement imitation test and performance on a test of receptive language ability. De Renzi et al. commented however, that although the correlation was significant, it was ". . . not sufficiently high to warrant the inference that the severity of the movement disorder is strictly dependent on the severity of the language disorder, and would seem more supportive of the view that the lesion responsible for apraxia very frequently encroaches on the cerebral areas specialized for language" (p. 9).

Kertesz (1979) reported a high correlation between apraxia and severe comprehension deficit, i.e. receptive aphasia. He proposed that apraxia is not related simply to a lack of comprehension but to an associated phenomenon, higher order cognitive function, which is common to language comprehension and praxis.

Kertesz and Hooper (1983) studied praxic ability in various types of aphasia. They found that the severity of the aphasia and the extent of the comprehension deficit, in particular, correlated highly with deficits of purposeful movement. They concluded,

> The fact remains that disturbances of language and praxis are closely tied together, caused by the same lesions, yet they are clearly not causative and can occur independently one from another. Careful measurement of both sets of parameters are needed in a variety of lesion localizations to further analyze the underlying neural and psychological factors. (p. 285)

Kimura (Kimura, 1977; Kimura and Archibald, 1974) studied the performance of brain damaged adults, aphasic and nonaphasic, on a variety of manual motor tasks, e.g. finger flexion, hand posture imitation, hand movement imitation, manual sequence box performance. Subjects with unilateral left hemisphere lesions performed significantly more poorly than subjects with unilateral right hemisphere lesions on the manual sequence box task and hand movement imitation task. A correlation analysis between the language measures and the hand movement imitation task was not significant (Kimura and Archibald, 1974). Kimura interpreted this to mean that poor performance on the movement copying task could not be accounted for by the aphasics' verbal deficits. Using these data, as well as data obtained from testing normal adults (Kimura, 1973; Lomas and Kimura, 1976 to be reviewed later), Kimura proposed 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 symbolic processing as has been suggested (Duffy, Duffy and Pearson, 1975).

Studies with normal adults can also be used to make the argument that language function can best be seen as an example of motor ability. Kimura (1973) studied the tendency of people to move their hands while speaking. Two main types of movement were observed: self-touching movements and free or "gestural" movements. More hand movements occurred during speaking as compared with non-speaking conditions and free movements almost never occurred during non-speaking conditions. Free movements during speaking were made significantly more often by the right hand. In addition subjects who showed significantly greater right hand free movement during speaking were also found to display left hemisphere specialization for speech as determined by a dichotic listening task.

Kimura concluded that:

> . . . speaking is strongly tied to other motor behaviors, as evidenced by the greater activity during speaking than during non-speaking activities. That this association is not entirely explicable on the basis of a diffuse motor facilitation is suggested by the fact that free movements . . . occurred almost exclusively during speaking, whereas self-touching movements occurred frequently during non-speaking as well as during speaking activities. (p. 49)

Some researchers have used dual task performance to examine hemispheric specialization (Kinsbourne and Hicks, 1978; Kinsbourne and Cook, 1971; Lomas, 1980; Lomas and Kimura, 1976). Subjects are required to perform two tasks concurrently. Most relevant to the questions proposed for this research are those studies in which subjects were required to perform concurrently a vocal task (e.g. reciting a nursery rhyme, humming or singing) and a manual motor task (e.g. repetitive tapping, sequential tapping, dowel balancing). What is generally reported for right-handed individuals is a decrement in the performance of the right hand, but not the left hand, while speaking, but not while humming or singing. Two explanations have been offered. Kinsbourne and Hicks (1978) propose that the speech task interferes with right hand performance because of competition for contiguous functional space within the same hemisphere. Lomas (Lomas, 1980; Lomas and Kimura, 1976) observed that speech does not interfere with performance of the right hand to the same extent for all motor tasks and proposed that, "It is no longer reasonable to attribute this effect simply to the processing of two tasks within one hemisphere . . ." (Lomas, 1980, p. 14[illegible]). He suggests that there is competition for a specific left hemisphere system ". . . which is specialized for the control of movement transitions made with minimal visual guidance . . ." (Lomas, 1980, p. 148).

All the research reviewed so far describes the brain organization for language and praxic functions in the right-handed person. The organization of these functions, in particular praxis, in the left hander is less well understood. It is known that 70% of left handers (versus 98% of right handers) have language represented in the left hemisphere (Rasmussen and Milner, 1977). For the remaining 30%, 15% have language represented in the right hemisphere and 15% have language represented bilaterally, i.e. in both hemispheres. There have been no large scale studies of praxis in the left hander. Heilman, Coyle, Gonyea and Geschwind (1973) and Margolin (1981) each described language and praxic functions in a left hander who had right hemisphere damage. In both cases a dissociation of language and praxic functions was found; language was represented in the left hemisphere and praxic function in the right hemisphere. The patient displayed apraxia but no aphasia. These reports suggest that language and praxic functions can exist independently of each other.

2.3 Developmental Research

Studies of the relations between language ability and manual motor function in young children have been limited in number and design. Few of the studies which will be reviewed assumed the theoretical orientation of the adult research. However, it may not be totally desirable to adopt adult models since it is unlikely that language and praxic function in young children are like language and praxic function in the adult.

There have been few studies with normal children and those done with the very young child have been primarily concerned with describing early communicative behavior and defining precursors to the emergence of verbal language. It so happens that some of the findings have relevance for the question with which this research is concerned.

2.3.1 Studies with Normal Children

Bates et al. (1979) studied the development of language in children 9 to 13 months of age. They measured in a longitudinal design language comprehension, language production, symbolic play, imitative ability and gestural production. They proposed that there is a "Gestural Complex" which develops between 9 and 13 months of age and is reflected in giving, showing, communicative pointing and ritual requests and that there is ". . . some form of interdependence between language development and the measures that form the Gestural Complex" (p. 128).

In concluding they stressed, ". . . we see no evidence to suggest that a 13 month old is in any way biased toward the development of vocal language as opposed to gestural language" (p. 177). They refer to studies of the acquisition of American Sign Language in deaf children (Newport and Ashbrook, 1977) which show that deaf children acquire their manual-visual code as rapidly as hearing children acquire speech.

A pantomime is an action which conveys an idea or proposition and may replace speech (Goodglass and Kaplan, 1963). The term gesture in its precise sense refers to those movements which accompany and emphasize rather than replace speech. However, it is often used in a broader sense to encompass all expressive and communicative movements. Jancovic, Devoe and Wiener (1975) examined pantomime and gestural movements in children 4 to 18 years of age. They noted that investigators have usually assumed that nonverbal communication behaviors (i.e. gestures) are ". . . a) nothing but early precursors to later verbal forms; b) nothing but primitive substitutes for more complex verbal forms; and therefore, c) trivial in comparison to verbal communication behaviors . . ." (p. 922). Challenging the traditional view that gestures decrease with age, i.e. as verbal fluency increases, Jancovic, Devoe and Wiener predicted that the number of gestures would remain the same or increase with age and that more complex gestures would be seen as the children got older. They found that the use of hand and arm movements did not decrease, but increased, with age and in the degree of complexity. They concluded that, ". . . it is unreasonable to maintain the view that non-verbal communicative behaviors are 'nothing but' primitive precursors to more complex communicative behaviors in the verbal channel" (p. 927).

Diana Ingram (1975) examined the hand movements made by children as they talked. A total of 103 children, 3 to 5 years of age were tested. Movements were classified as self-touching or gesture-like movements. Gesture-like movements were found to be made significantly more often by the right hand, while self-touching movements were made equally often by the left or right hand, but most often they were produced bilaterally. No age or sex effects were found.

Condon and Sander (1974) performed an elaborate frame-by-frame microanalysis of adult speech and infant movement and proposed that infants as young as 12 hours of age synchronized their body movements to adult speech. Infants ranging in age from 12 to 14 hours were exposed to live adult speech, tape recorded speech, disconnected vowel sounds and tapping sounds. Condon and Sander reported that the infants synchronized their movements to the first two stimulus situations while in the latter situations they ". . . failed to show the degree of correspondence associated with natural, rhythmic speech" (p. 101).

Condon and Sander concluded that their findings ". . . suggest that infant motor organization, entrained by these organized patterns for many months after birth, may prepare operational formats for later speech" (p. 101).

Trevarthen (1974, 1977) studied infant communicative and prespeech behaviors. He aimed to document and describe communicative behavior in 6 week old infants by filming interactions between infants and their mothers. In the course of analyzing these films Trevarthen (1977) observed, "Accompanying prespeech and vocalization to persons are movements of the whole body -- changes in head position, trunk movements, movements of all the limbs. Most conspicuous among these are hand and arm movements which are frequently closely synchronized (to within 0.1 sec.) with utterances or grimaces" (p. 251). In addition Trevarthen (1977) writes, "Vigorous calls or shouts are generally combined with longer movements including waving of the hand with palm directed forward from a position above shoulder level. Prespeech is frequently combined with more complex and individuated finger movements, including pointing with the index finger" (pp. 251-252).

Describing work in progress Trevarthen (1977) reported that subjects that had been studied longitudinally all showed a ". . . marked change in manner of communication at the time they attain workable control of prehension, at 16 to 18 weeks" (p. 254).

Segalowitz and Chapman (1980) studied changes in limb tremors in short gestation infants (mean age 36 weeks) following exposure to speech, music and non-patterned control stimuli. Arm and leg movements were measured by an accelerometer which recorded the length of the movement arc as well as the vigor of the movement. There was a significantly greater reduction in arm movements as compared with leg movements and this occurred only in the speech condition. In addition, the reduced arm movement was significantly greater for the right arm as compared with the left arm in the speech condition.

Segalowitz and Chapman's results clearly suggest an association between language functions and manual behavior, although they did not focus on it because they were primarily concerned with the question of the ontogeny of hemispheric specialization. The fact that leg tremors were not significantly reduced, whereas arm tremors were; the fact that the right arm tremors were reduced more than tremors in the left arm and the fact that tremors were only reduced in the speech condition suggests language functions and arm/hand behavior are linked from a very early age.

The dual-task procedure described earlier in the discussion of adult studies has been used with children as young as 3 years of age (Hiscock and Kinsbourne, 1978, 1980; Piazza, 1977). The adult findings have been replicated supporting the speculation that neural competition and overlap between language and hand activity is present also in children as young as 3 years of age.

One would be remiss if one did not include Lenneberg's comments about the relationship between language and motor skill. In his landmark work, Biological Foundations of Language (1967), Lenneberg writes, "The evolvement of various motor skills and motor coordinations also has specific maturational histories: but the specific history for speech control stands apart dramatically from histories of finger and hand control" (p. 131). It is unclear, however, what Lenneberg's evidence is to support this position. He makes reference to tables of developmental milestones which present the development of language and motor function in a general sense. However, more precise measures of language development and motor function as used in some of the preceding studies were not used by him and therefore he may have missed subtle relationships between language and manual motor skill.

2.3.2 Studies with Clinic Populations

The clinical impression has been that children with articulatory and language dysfunction are more likely to be clumsy and/or delayed in motor milestones (T. T. S. Ingram, 1959; Sheridan, 1973). Sheridan (1973) reported a significantly greater frequency of clumsiness and delayed walking in 215 children with "marked speech defect" as compared with normal control children.

Only one study is to be found which examined manual motor function in children with disturbances in language function, termed "developmental dysphasics" (Archer, 1980).

Developmental dysphasics are children who display difficulties in receptive and expressive language function which are not attributable to deafness, mental retardation, physical disability or primary emotional disturbance such as autism (Benton, 1964; Eisenson, 1968). Archer (1980) examined manual motor function in ten developmental dysphasics. The dysphasics, in comparison to matched control subjects, took significantly longer to imitate hand postures from the sign language for the deaf, and displayed significantly reduced performance on a traditional test for apraxia and a hand movement imitation test. There was no difference between the two groups on a repetitive tapping test, peg moving test, children's sequence box test, oral movement imitation test or in the accuracy with which the hand postures were imitated. It was proposed that developmental dysphasics had a deficit in certain aspects of manual motor function, particularly the initiation, organization and execution of motor behaviors.

There have been a small number of studies of motor proficiency in children with speech articulation problems. These are children who comprehend and generate language adequately, but produce some or many of the individual speech sounds incorrectly.

Dickson (1962) examined the motor proficiency of 30 children who outgrew functional articulation errors (Group A) as compared with 30 children who did not (Group B). The Oseretsky Test of Motor Proficiency was used to assess motor proficiency. Dickson reported that the children in Group A completed significantly more motor tasks successfully than the children in Group B.

Prins (1962) studied the motor abilities of 92 children with defective articulation. Tests of gross motor (tandem walking) and fine motor coordination (pellet and bottle test) were used. No significant differences were found between the experimental group and the control group.

Frisch and Handlen (1974) administered the Reitan-Indiana Neuropsychological Test Battery to 10 children diagnosed as having "functional articulation disorders".

They reported that while none of the subjects had any gross difficulties in performing motor acts, many had difficulty ". . . in patterning their motor actions and, therefore, performed motor tasks on a lower level" (p. 441).

A small number of reports about "clumsy" children, also termed developmental dyspraxics, are of interest. The oral language function of clumsy children has not been studied for its sake, however, it is consistently reported as part of the clinical description (Gubbay, Ellis, Walton and Court, 1965; Walton, Ellis and Court, 1962) that at least 50% of developmental dyspraxics are delayed in speech development and/or display articulatory errors and unintelligible speech.

2.4 Summary

Several kinds of evidence suggest there is an association between hand use and language function. The words "hand use" are chosen because the precise aspect of hand function associated with language function is unclear. Studies with infants and young children describe an association between language usage, and hand and arm gesture, pointing or giving. Research with brain damaged adults has examined in some detail disturbances in praxic function in relation to language ability. These studies have paid attention to gesture, hand postures and complex finger and hand sequential actions.

It is still unclear whether the aspects of hand function attended to by those working with infants, as compared to those aspects of hand function described in the adult research, are separate and different or represent an underlying continuum of increasing complexity in manual motor skill.

Whether a particular aspect of language function, i.e. language production versus language reception, is to be related to hand function is not clear. Most research has focused on language production and not on the reception of language. However, Kertesz and Hooper (1983) argue strongly for an association between language comprehension and praxis.

In conclusion, as Kertesz and Hooper (1983) note, in future researchers will need to be much more precise in defining what aspects of motor function are related to what aspects of language function. At this time it is not clear whether the two are related because of neural contiguity and/or because they have a common cognitive underpinning, i.e. both require motoric, sequential processing.

3. Language Development in Relation to Handedness

3.1 Introduction

The possibility of an association between language development and hand preference has been noted by clinicians and researchers for almost a century. Baldwin (1890) and Woolley (1910) reported that handedness is established at the same time that spoken language begins. They noted that the centers for the control of speech and the control of the dominant hand are both in the left hemisphere and hypothesized that the association between the determination of handedness and the development of language indicates that the two centers are maturing at the same time. Others (Brain, 1945; Dreifuss, 1963; Koch, 1933; Nice, 1918; Orton, 1937) observed that when language development was delayed or aberrant, ambidexterity or left handedness was often also present. Orton (1937) studied this issue extensively and concluded that ambidexterity or left handedness reflected a failure to establish a dominant hemisphere for speech.

There have been very few studies which have actually examined language acquisition in the normal child in relation to hand preference. These studies will be reviewed first followed by investigations of handedness in children with language dysfunction. In the final section the results of recent investigations with adults of the association of handedness, language proficiency and brain organization for language functions will be given.

3.2 Studies with Normal Children

Woolley (1910) observed language and handedness in one child from 7 to 18 months of age. She noted that the time when the child began to babble in syllables (middle of the 7th month) corresponded to preponderant use of the right hand.

Ramsay (1980, 1983, 1984) has made several studies of the relations between handedness and language in the young child. He (Ramsay, 1980) studied the relationship between ". . . the onset of bimanual handedness and the appearance of dissimilar syllables in speech" (p. 68). He predicted that the first complex expression (i.e. dissimilar syllables) would be used at the same time that bimanual handedness was observed. (Bimanual handedness refers to the hand which assumes the manipulative role (versus the supportive role) when two hands are required for a task). Infants were studied longitudinally, beginning at 10 months of age, until bimanual handedness was established, and cross-sectionally at a mean age of 11 months. The infants' speech development was measured from records kept by the mothers. Ramsay reported a significant relationship between the onset of bimanual handedness and the use of complex utterances. In the cross-sectional group a significant difference in the use of complex utterances was observed between infants who displayed bimanual handedness and those who did not. He concluded that, "In view of research with adults linking handedness to hemispheric specialization for speech, the present findings suggest that this ability might reflect developmental change in hemispheric specialization toward the end of the first year of life" (p. 73).

Ramsay (1983) also examined the establishment of unimanual handedness in relation to the emergence of bisyllable babbling. Unimanual hand preference in 6 month old babbling and non-babbling infants was assessed and Ramsay reported that babbling boys, but not non-babbling boys, demonstrated unimanual hand preference. This dichotomy was not seen in girls. Ramsay (1983) also reported that two longitudinal studies did not show that the emergence of babbling and the establishment of unimanual hand preference coincided in time.

Most recently Ramsay (1984) measured handedness and babbling behavior at weekly intervals beginning at 5 months and continuing for 8 weeks after bisyllable babbling was first observed. Bisyllable babbling was first reported in the same week that unimanual right handedness was first observed. However, by 3 to 4 weeks after the first observance of unimanual right handedness, unimanual right handedness was no longer observable, although bisyllabic babbling persisted. At the 5th week, unimanual right handedness was observed again. It is hard to accept, on the basis of these data, that the establishment of handedness and speech developmental milestones are especially linked, as Ramsay concludes.

Annett (1970a) studied the relationship between hand preference and vocabulary development in 210 children ranging in age from 3 1/2 to 15 years. The children were classified as right, left or mixed handers and vocabulary development was measured by the Peabody Picture Vocabulary Test. The vocabulary test means for the mixed handers were noticeably lower than the means of the left or right handers, for both sexes; the difference approached but was not statistically significant. The vocabulary test means for the consistent left handers tended to be considerably higher than the means of the right and mixed handers.

Annett also compared the number of right, mixed and left handers displaying below average, average and above average vocabulary ability. An excess of mixed handers of low ability and left handers of high ability was observed, but statistical significance was not achieved. Annett stressed the importance of making a third category of hand preference, i.e. mixed handedness, in that reduced language performance appeared to be associated primarily with mixed handedness and not with consistent handedness, be it right or left.

Treves, Goldshmidt and Korczyn (1983) concluded that speech and lateral preference develop independently of each other. Studying 1 to 3 year old children, they compared language production and reception ability on the Reynell Developmental Language Scales (1977) to the degree of right-sided preference. Those children who demonstrated a clear right arm preference did not obtain higher language scores than those children who did not show a clear right preference.

3.3 Studies with Clinic Populations

The idea that children with articulatory or oral language difficulties (developmental dysphasics) are more likely to be left handed or ambidextrous has persisted for several decades (Brain, 1945; Dreifuss, 1963; Koch, 1933; Nice, 1918; Orton, 1937; T. T. S. Ingram, 1959; Zurif and Carson, 1970). Inherent in this argument is the assumption, first argued by Orton (1937), that handedness and cerebral dominance are related and that aberrant handedness is suggestive of a failure to establish a dominant hemisphere for speech. A close examination of the data on which the assumption about left handers and their language dysfunction rests, shows it is far from convincing.

In the early studies samples were small (Dreifuss, 1963; Nice, 1918) and statistical analysis often lacking (Koch, 1933). T. T. S. Ingram (1959) reported that in his sample of 80 children with developmental speech disorders 50% were left handed and 4% were ambidextrous. The measure he used to determine handedness, however, is questionable. Each subject was asked to turn a door handle, break a stick, throw and catch a ball. Each of these tasks was performed three times. It is not clear whether any effort was taken to present the test objects in the midline. This is a necessary precaution in these tests. Moreover Annett (1970b) has shown, by association analysis, that not all handedness items elicit the preferred hand equally. She reports that the two most reliable items are writing and throwing a ball, and the two least reliable items are sweeping and unscrewing a jar lid.

McBurney and Dunn (1976) reported on associations between the development of language and laterality in 390 children, 74% of whom were low birth weight infants. Infants with known mental retardation, cerebral palsy, emotional disturbance, and visual or hearing defects were excluded from the study. Language skills were assessed at 3, 6, 12, 18 months; and at 4 years and 6.5 years. Laterality ratings were determined for hand, foot and eye. Three major associations were tested: 1) the association between the speech and language variables and the strength of handedness; 2) the association between speech and language variables and laterality congruity versus laterality noncongruity [i.e. were the hand, foot and eye laterality ratings all right or all left or a combination of the two]; and 3) the association between speech and language variables and right congruity versus left congruity. A significant effect was found for the first two associations at age 9 months, 4 years and 6.5 years, while the third association tested was significant only at 4 and 6.5 years of age.

McBurney and Dunn concluded that

> . . . in certain aspects of language development at 9 months, 4 years and 6.5 years and in Verbal and Performance IQ at 6.5 years, children whose handedness is other than strongly right or whose handedness, footedness and eyedness are not uniformly dextral are less likely to be achieving above age level and are more likely to be achieving below. (p. 145)

3.4 Handedness, Language Ability and Cerebral Dominance for Speech in Adults

Up to this point the discussion has centered on the association between handedness and speech proficiency -- or lack thereof. It is important to acknowledge a second relationship which is frequently proposed in the literature: the association between hand preference and cerebral dominance for speech. There are thus three factors which are claimed to be related -- handedness, speech proficiency, and cerebral dominance for speech. Orton (1937) proposed that the failure of some individuals to establish a dominant hemisphere for speech is exemplified in ambidexterity and speech problems. Individuals with speech/language problems are more likely to display aberrant handedness and fail to establish a dominant hemisphere for speech.

Two assumptions about the relationship of handedness to language proficiency and to brain organization for language have persisted for many years. Recent work, primarily with adults, has brought these assumptions into question.

The first assumption, which has already been alluded to, states that individuals who are left handed or ambidextrous are more likely to have language problems or intellectual deficits (Levy, 1969; Orton, 1937). Large scale studies of left handers (Hardyck, Petrinovich and Goldman, 1976; Newcombe and Ratcliff, 1973) have failed to report any cognitive deficits in left handers. Annett (1970a) and Swanson, Kinsbourne and Horn (1980) caution, however, that individuals with mixed handedness, as compared with strongly left-handed individuals, do appear to score lower on language and IQ measures. They propose that in subsequent research an effort be made to separate these individuals from the strongly left-handed subjects.

It is also important to distinguish between "natural left handedness" and "pathological left handedness" (H. Gordan

1920; Satz, 1972). It is known that left handedness is more prevalent in populations in which brain damage is known or very likely, i.e. mental retardates, epileptics (Bingley, 1958; H. Gordan, 1920). This is pathological left handedness. Some have argued (Bakan, 1971) that all left handedness results from brain damage and that therefore all left handers are at risk for intellectual deficits because they are brain damaged. However, some left handers will be left handed by reason of genetic variation, i.e. natural left handers. In these cases brain damage is very unlikely, and there is no reason to expect intellectual deficits.

The second assumption, also described earlier, holds that handedness and brain organization for language are closely related.

It is well established that 90 to 95% of the adult population is right handed and that for 95 to 98% of right handers, language function is controlled by the left cerebral hemisphere (Rasmussen and Milner, 1977). The remaining 5 to 10% are left handed and 70% of these will have language controlled by the left hemisphere.

Segalowitz (1983a) has shown that while hand preference and cerebral dominance for speech are related the correlation coefficient between the two, although statistically significant, is low: $r = .34$, and only

11% of the variance is accounted for. Segalowitz concludes that problems with defining hand preference and cerebral dominance for speech may be reflected in these low figures.

3.5 Summary

There is a history of claims that handedness is especially related to the development of language, be it normal or abnormal, or that it is in effect a marker of language competence or aberrant cerebral dominance for speech. However, the evidence on which this argument rests is scanty. Most of the early studies lack statistical and methodological rigor. The recent studies by Ramsay (1980, 1983, 1984) and by Treves et al. (1983) represent the clearest attempts to examine the relation of handedness to language development in normal children. Their conclusions however, are contradictory. Treves concludes that language proficiency and lateral preference develop independently whereas Ramsay (1980) concludes that a "temporal correspondence" exists between the onset of bimanual handedness and the occurrence of dissimilar syllables, and that this is suggestive of a developmental change in hemispheric specialization. In the later paper Ramsay (1983) qualified this by noting that the developmental relations between infants' hand preference and speech could also be attributable to: 1) the development of sensorimotor intelligence as described by Piaget (1954) or, 2) changes in the asymmetrical organization of subcortical brain structures.

Ramsay must contend with two major methodological problems: the measurement of hand preference and the measurement of speech behavior in the very young child. His sole measure of speech -- changes in babbling behavior and the emergence of first words -- is derived from maternal report. Darley and Winitz (1961) discuss at some length the difficulty of discriminating first words from babble. Secondly, Ramsay must contend with the problem of what is to be taken as established hand preference in the 10 to 12 month old child. Fluctuations in handedness in the young child have been reported (Gesell and Ames, 1947; Liederman, 1983; Seth, 1973). Further research using better measures will be necessary to clarify the contradictory findings of Ramsay and Treves.

In respect to the increased likelihood of left handedness or ambidexterity in children with a language disorder, there has never been any systematic attempt to examine handedness in a large number of children with developmental language problems. The supposition rests on a limited data base. Kinsbourne's (1975a) observations about handedness in the learning disability population might apply equally well to children with developmental language disability. Kinsbourne writes:

> If the evidence that left-handedness is associated with an increased probability of intellectual deficit is uncertain on the basis of studies with adults, the same can be said of claims that left-handedness is more frequent than expected for children with learning disabilities. The same can be said of the notion that learning-disabled children tend to establish reliable hand preference later than usual. This type of finding is customarily based on cross-sectional group comparisons, which at times show learning-disabled children as a group to be less firmly right-handed than controls. The inference that their handedness is more slowly established than usual is an undocumented presumption, which calls for a longitudinal followup. Apparently, no such study has been done. (p. 207)

4. Sex Differences in Language Development

It is generally accepted that young girls talk earlier and with greater complexity and intelligibility than do young boys (Gesell, 1940; Moore, 1967; Nelson, 1973; and see McCarthy, 1954; Maccoby, 1966; Maccoby and Jacklin, 1974 for detailed reviews). Gesell (1940), for example, reported the vocabulary size of 20 boys and 20 girls at 18 months of age as recorded by the mother. He concluded, "The sex differences are not striking, but it may be observed that the four largest vocabularies were reported for the girls" (p. 193). In addition he noted, ". . . most investigators have agreed that girls are relatively accelerated over boys in language development during the first two or three years of life" (p. 193). McCarthy (1954) reported that girls start talking at an earlier age, that their utterances are comprehensible at an earlier age and that they precede boys in the use of short sentences. Irwin and Chen (1946) reported that from 24 to 30 months girls produce a greater variety of speech sounds. Moore (1967), who is frequently cited, followed a sample of children longitudinally from 6 months of age to 8 years of age. Language function was assessed at 6 months, 18 months, 3 years, 5 years and 8 years. The girls obtained a significantly higher speech quotient at 18 months, but no differences were found between the sexes at any of the other ages. Moore concluded, "In general ability the sexes started virtually equal, the girls scored a little higher during the period of acquisition of language and were then overtaken and surpassed by the boys" (p. 99). Nelson (1973) observed that girls obtained a 50 word vocabulary before boys by four months. However, this difference was not tested for statistical significance.

Maccoby (1966) and Maccoby and Jacklin (1974) made the most exhaustive examination of the literature on sex differences in verbal abilities. They (Maccoby and Jacklin, 1974) grouped the studies according to subject age: a) 0 to 2 1/2 years, b) 3 to 5 years, c) 5 to 12 years and d) adolescence, and concluded that ". . . there are distinct phases in the development of verbal skills in the two sexes through the growth cycle. One occurs very early

-- before the age of 3" (p. 84). However, "At about 3 the boys catch up, and in most population groups the two sexes perform very similarly until adolescence" (pp.84-85). They also concluded that "Female superiority on verbal tasks has been one of the more solidly established generalizations in the field of sex differences. Recent research continues to support the generalization to a degree" (p. 75).

Female superiority in linguistic functions has been argued by many. However, it should be noted that in critical reviews by Fairweather (1977) and Macaulay (1978) the idea of female superiority in language development has been contested. In a paper entitled, "The Myth of Female Superiority in Language" Macaulay argues that if the actual data and the statistical analyses of often cited studies are examined, the results do not warrant the interpretations that have been made by the authors or others. Certainly if the actual data and statistical analysis (often consisting of only means and standard deviations) are examined -- and not just the interpretations drawn at the end -- then it is apparent that Macaulay's arguments are well founded. Gesell (1940) did not apply a test of statistical significance to his data. Moore (1967) reported only one statistically significant difference between the sexes, this is out of several linguistic measures given over an eight year time period.

The arguments of Fairweather and Macaulay are not easily dismissed. Nevertheless Witelson (1978) concludes, "The differences may be small in some cases but they are consistent in direction. Although some studies find no differences, the majority do and they almost always favor females" (p. 288). The evidence to support a female superiority in linguistic skills is suggestive but by no means conclusive. Subsequent research will need to be far more precise in the linguistic measures and statistical procedures which are used.

5. Lateral Behaviors and Hemispheric Specialization in Young Children

In adults 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 (Dimond and Beaumont, 1974; Kimura, 1967; Milner, 1974; Zangwill, 1960). Thus, tasks or material presumed to require sequential or analytic processing (e.g. verbal tasks, motor organizational tasks) will be processed predominantly by the left hemisphere, while tasks requiring processing in a spatial, holistic manner (e.g. facial recognition, spatial orientation) will be mainly processed by the right hemisphere. The concept of relative specialization of the cerebral hemispheres has been termed "hemispheric specialization" and has gained wide acceptance (Bryden, 1982; Dimond and Beaumont, 1974; Witelson, 1977).

It is currently of some interest to determine if a similar functional brain organization exists in children and if so, when it is first apparent (Kimura, 1967; Kinsbourne and Hiscock, 1977; Witelson, 1977). For a number of years it was believed that hemispheric specialization developed with age and that the specialization of the hemispheres observed in adults was not achieved until puberty. This position was espoused by Lenneberg (1967) who based his theory in large part on data reported by Basser (1962). Basser (1962) examined the intellectual and language function of a large sample of children who had suffered unilateral left or right hemisphere lesions. In examining Basser's data Lenneberg (1967) noted that: 1) from 0 to 2 years of age speech disturbance was equally possible with a left or right sided lesion, 2) up to age 10 years there was an 85% chance of a speech disturbance with a left sided lesion, and a 45% chance with a right sided lesion and, 3) the course of recovery was better in younger children, and worsened with age. Lenneberg concluded that from 0 to 2 years the cerebral hemispheres are equipotential for the development of speech and that this continues, but declines with puberty. At 11 to 14 years of age Lenneberg states, "Language (is) markedly lateralized and internal organization established irreversibly for life" (p. 181).

Current thinking holds that specialization of the cerebral hemispheres does not develop with age but that it is present from birth. The adoption of this position follows from a critical reexamination by Kinsbourne (1975b) and by Woods and Teuber (1978) of Basser's data and Lenneberg's interpretation. In addition new evidence is at hand from investigations of laterality and hemispheric specialization in infants and young children.

Basser's data are faulty because of difficulties to do with excluding patients with bilateral brain damage. In addition he identified and measured aphasia imprecisely. Woods and Teuber (1978) completed an extensive and critical review of the early literature on aphasia after childhood lesions. They concluded that the higher incidence of aphasia (i.e. 30% versus 3% in adults) after right hemisphere lesion in the early literature very likely reflects bilateral damage which may have occurred in the absence of antibiotic treatment.

The results of a number of recent investigations of lateral behavior in young children (Entus, 1977; Molfese, 1977; Petrie and Peters, 1980; Ramsay, 1979) permit the inference that hemispheric specialization is present from a very young age and that the degree of asymmetry observed at birth probably does not change with age (Hiscock and Kinsbourne, 1978, 1980).

Asymmetries in posture have been shown in newborns and infants only a few days old. When placed on their backs over 80% of infants will turn their heads to the right (Turkewitz and Birch, 1971). This is the asymmetric tonic neck reflex (ATNR) assumed by infants up to about 3 months of age when placed on their backs. The head is turned to one side, the arm on the side to which the head is turned flexes and the contralateral leg extends.

A right hand preference in the length of time a rattle is grasped has been shown in infants as young as 17 days of age (Petrie and Peters, 1980). Ramsay (1979) reported a right hand preference on a tapping task in 10 month old infants.

Perceptual asymmetries similar to adult perceptual asymmetries have also been reported. Entus (1977) used the dichotic listening procedure and reported a right ear superiority for speech and a left ear superiority for music in infants whose mean age was 50 days.

Molfese (Molfese, 1977; Molfese and Molfese, 1983) has made extensive use of electrophysiological methodologies and demonstrated asymmetries in the auditory evoked response (AER) in infants as young as 1 week of age. Differences in the amplitudes of the AER responses taken from the left and right hemispheres reflect differential response of the hemispheres to speech and nonspeech stimuli. Larger AER amplitudes occurred in the left hemisphere in response to speech stimuli, while larger AER amplitudes occurred in the right hemisphere in response to nonspeech stimuli.

Hiscock and Kinsbourne using the dual task performance procedure (Hiscock and Kinsbourne, 1978) and the dichotic listening procedure (Hiscock and Kinsbourne, 1980) with children 3 to 12 years of age reported that the degree of asymmetry found with these measures did not change across the age range tested. They concluded that their results supported the "developmental invariance hypothesis of cerebral lateralization" and not the traditional view that the cerebral hemispheres become progressively lateralized until puberty.

To sum up, there is extensive and varied evidence to support the hypothesis that asymmetry of behavior is present from a very early age and that the degree of asymmetry does not change with maturation. One major limitation in the data is the almost exclusive use of cross-sectional or very short term longitudinal methods. Future research will do well to utilize longitudinal designs in order to clarify some of the inconsistencies in the data and also to place early asymmetry, or lack thereof, in relation to later functioning.

6. Statement of Hypotheses

Data from a number of distinctly different lines of work -- clinical, developmental, anthropological, neuropsychological -- all suggest that in a man a special association exists between language function and manual motor behaviors. The nature of this relationship is not clear in a functional sense or in a neuroanatomical sense. In young children while the maturation of language functions clearly coexists with the maturation of manual behaviors it is not clear to what extent, if any, the two are interdependent.

To cast light on these issues the relation between language functions and manual behaviors in children 18 to 30 months of age, will be examined. It is between these ages that language functions and manual behaviors are, at once, emergent, dynamic and measurable. After 3 years of age the maturational changes in language and manual behaviors are less remarkable and it may be more difficult to observe interactions between the two.

Four main hypotheses will be tested.

1) Language function/manual motor skill hypothesis: Language ability will correlate positively with manual motor skill. I predict that children who are more proficient in language function will also display more skill in manual motor function,

and conversely, children who display a reduced manual proficiency will also display depressed linguistic ability. Thus variability in language ability in young children may be explained by variability in manual motor skill. To test the hypothesis a variety of measures of language reception and production will be used. I expect that measures of language production, but not measures of language reception, will be more likely to correlate with the manual motor measures.

2) Language function/handedness hypothesis: Whether and how handedness and language behavior are related is a matter of controversy. It has long been proposed on the basis of case reports and clinical observation that handedness and language ability are closely related, although the results from some recent investigation have suggested that this is not so. In the light of the more recent evidence I propose that there will be no difference in the linguistic ability of children who do not display a clear hand preference when compared to children who do display a clear hand preference.

3) Sex difference hypothesis: I predict that the girls will perform better than the boys on measures of language function.

4) Laterality invariance hypothesis: I predict that the degree of asymmetry or lateral preference observed at 18 months will remain the same at 24 and 30 months.

Implications of This Research

A study to test these predictions will contribute to our understanding of the emergence of language, in particular if manual motor function and/or handedness relates to language production. This information may be useful for early diagnosis of children with communication problems. The question of sex differences in early language development can be clarified if a number of rigorous measures of language function in a longitudinal design are used.

Administration of a number of measures of lateral motor function in a longitudinal study will contribute to understanding laterality and hemispheric specialization in an age range which, to date, has received little attention.

CHAPTER TWO

METHOD

1. Subjects

The fifty-one children selected to participate in this study were obtained from the following sources:

a) a university family practice clinic (11),

b) community family practice clinics (17),

c) a university research study of normal infant vision (5) and,

d) by personal contact (18).

All the subjects met the following admission criteria:

1. Normal development, confirmed by the referral source or the parent;
2. Age between 18 and 20 months at the time of the first test session;
3. Only one language spoken in the home;
4. Intact family at the time of the first test session;
5. Parental education: both parents had completed at least Grade 12. Because the socioeconomic status of a family is usually fixed by the father's education and occupation (Susser and

Watson, 1974), two children were included whose mothers had Grade 10 education only; their fathers had completed at least Grade 12. If the father had not completed Grade 12, but the mother had, the child was not included in the study.

6. Full term at birth, i.e. delivery at 37 weeks gestational age or greater as reported by the referral source or the parent. (Because this criterion was not instituted in the early stages of subject acquisition one child was included who was born at 32 weeks. No correction was made for prematurity when the child was tested (premature children may obtain lower scores than children born at term).

7. Parental agreement to permit and assist with repeated testing of their child over a one year time interval.

A description of the sample is given in Table 1.

The initial subject selection pool consisted of 85 children. Eight families refused to participate. Twenty-six children were excluded because: a) the child's age was wrong (n=10), b) the father didn't meet the educational requirement (n = 8), c) family couldn't be reached (n=4), d) bilingual family (n=1), e) premature birth (n=1), f) single parent (n=1), g) child untestable (n=1). The final

TABLE 1. Description of the sample.

	Girls	Boys
Sample size	n = 22	n = 27
Number of first borns	n = 11 (50%)	n = 11 (41%)

Age (months)	$\bar{X}$	Range	$\bar{X}$	Range
1st testing	18.9	(18-20)	18.6	(18-20)
2nd testing	24.9	(24-26)	24.6	(24-26)
3rd testing	30.8	(30-32)	30.5	(30-32)

Parental Education (years past Grade 12)	$\bar{X}$	$\bar{X}$
Mother	4.2	2.8
Father	5.7	4.5

sample included two sets of twins and two adopted children; all were female.

Ninety-six percent of the subjects remained with the study to completion. There were two dropouts from the study (4%). One family moved out of the area; the second encountered marital difficulties.

Several factors may account for the small number of dropouts. All the subjects belonged to the middle class. With the exception of one of the dropouts all of the subjects lived in houses and the majority of parents were owners. The majority of subjects had siblings and because all the testing was done in the subjects' homes the mother did not need to arrange baby sitting. A third factor which may account for the low dropout rate is the fact that the examiner had experience working with preschool children and their parents. In most instances excellent rapport was established with the children and the mothers. Most children really did enjoy the test sessions so the mother was at greater ease to support continued testing. Lastly, the study was a longitudinal study but the duration was not so long that keeping the subjects became a problem.

2. Procedure

Before the study proper was started pilot tests were made with a number of children between 12 and 36 months of age. All of the tests used in the battery, with the exception of some of the standardized tests, were developed and revised during this time.

For the study proper subjects were followed for a one year time period and were tested at about 18, 24 and 30 months of age. A child might be between 18 and 20 months at the first test session, 24 and 26 months and 30 and 32 months of age at the second and third test sessions, respectively. A six month time interval was fixed between test sessions so that a child tested at 19 months of age would be tested again at 25 months and 31 months of age. At each age level two visits of approximately one hour each, and sometimes a third visit of 20 to 30 minutes, were required to complete the test battery. A maximum of three visits at each age level was set to complete the test battery. Any tests not completed after that were recorded as missing.

All testing was done in the subject's home. Before including the child in the study the need for quiet and no distractions was discussed with the mother. Excellent cooperation was achieved in this respect. With few exceptions the subjects enjoyed the testing and participated eagerly.

3. Tests

The tests can be grouped into five categories (see Table 2):

1) Measures of language function;
2) Measures of motor function;
3) Measures of laterality;
4) Control measures;
5) Measures to describe the sample.

With the exception of the measure of different utterances, all the tests given at 18 months of age were repeated at 24 and 30 months. A number of new measures were introduced at 24 months and also at 30 months.

At each of the test ages the tests were administered in a predetermined, but not unalterable order. The tests that were more demanding in terms of cooperation and attention were placed at the beginning of the battery with the less demanding items being placed at the end. If a child was inattentive or uncooperative to a particular test, the test was discontinued and given again at a later point.

3.1 Tests of Language Function

The evaluation of language function involved tests of language comprehension, language production and phonological ability.

TABLE 2. Tests used and age of administration.

Variables	Age (months)		
I. Language	18	24	30
1. Language comprehension:			
a) Reynell Developmental Language Scales (RDLS)	x	x	x
b) Peabody Picture Vocabulary Test (PPVT)	x	x	x
2. Language production:			
a) Total utterances	x	x	x
b) Different utterances	x	-	-
c) Mean length of utterance (MLU)	x	x	x
3. Phonetic inventory	x	x	x
II. Motor			
1. Manual motor tasks:			
a) Manual dexterity inventory*	x	x	x
b) Bayley pegs*	x	x	x
c) Archer mystery box*	-	x	x
d) Annett peg moving (modified)*	-	x	x
e) Bead stringing	-	-	x
2. Oral motor task	x	x	x
3. Bayley gross motor inventory (modified)	x	x	x
III. Laterality			
1. Hand preference	x	x	x
2. Lateral preference inventory	x	x	x

TABLE 2 (continued)

Variables	Age (months)		
IV. Control	18	24	30
1. Bayley formboard (blue)	-	x	x
2. Seguin formboard	-	-	x
3. Height	-	x	x
V. Sample Descriptors			
1. Familial handedness			
2. Parent education			

* Laterality score also derived

3.1.1 Language Comprehension

Two tests of language comprehension were used, the Reynell Developmental Language Scales (RDLS) -- Comprehension Scales "A" (Reynell, 1977) and the Peabody Picture Vocabulary Test (PPVT) (Dunn, 1965).

The RDLS is a standardized test intended for use with children from 6 months to 6 years of age. The test is divided into nine sections and each section requires the processing of increasingly complex instructions, for example: in Section Two the child is asked "Where is the comb?"; in Section Nine she is asked "Put the brown horse beside the black horse". The stimuli are miniature sized toys.

At 18 and 24 months Sections One to Seven were administered; a maximum raw score of 35 was possible. At 30 months Sections Eight and Nine were also administered making the maximum possible raw score 62.

The PPVT is a measure of vocabulary comprehension, standardized for use with children from 2 1/2 to 18 years of age. The subject is shown four pictures at a time and is asked to point to the picture named by the examiner. The test manual provides for conversion of raw scores to scaled scores; because the subjects in this study were younger than the recommended age range for use of the test the raw scores were not converted to scaled scores.

3.1.2 Language Production

At each age level a sample of the child's language production was taken by tape recording a play session with the mother and the child. A selection of toys, books and puzzles appropriate to the child's age was brought to the house. The mother was given only minimal instructions as to how she should proceed during the play session. She was told to play with her child and the toys in their usual fashion and that, in the course of this play, a sample of the child's language would be taken.

At the 18 month test a 30 minute tape recording was made for each child; at 24 and 30 months the recording time was cut to 20 minutes because the introduction of additional tests made it unlikely that the total battery of tests could be completed in three visits. In addition it was desirable to try to obtain a fixed number of utterances for each child rather than to record for a fixed time interval. At 24 and 30 months an effort was made to obtain 100 utterances ("utterance" is defined below). This is generally regarded as a number adequate to provide a representative sample of a child's productive language (Miller, 1981). If 100 utterances were obtained during a 20 minute recording then only 20 minutes were taken. However, if 100 utterances were not obtained in 20 minutes additional recording was done until 100 utterances were obtained or until the 30 minute mark was reached, whichever came first. A written record of the child's output was made by the examiner at the same time that the tape recording was being made (Brown, 1973). The tape recording was then transcribed with the assistance of the written record. The following measures were derived from the transcription obtained from each child:

1) Total number of utterances,
2) Total number of different utterances (18 months only),
3) Mean length of utterance.

Each of these measures will now be described.

1) Total number of utterances: An utterance may consist of one or several words. One utterance is separated from another by a rise or fall in the intonation level at the end of a question or statement, respectively. This measure is a measure of language productivity without regard to syntactical and grammatical complexity. It is a count of the total number of utterances (including repetitions) produced during the time the tape recording was being made. To maintain consistency across the three age levels and across subjects for whom tape recordings of longer than 20 minutes may have been required, only those utterances produced in the first 20 minutes of the tape recording were counted for each child at all age levels.

2) Total number of different utterances: This measure is a variation of the preceding measure. Repetitions were not included in the count and therefore, only different utterances were counted. This measure was used at the 18 month level only to show the variability in language productivity which had been observed during the testing and in the transcriptions of the tapes, but had not been reflected in the mean length of utterance.

3) Mean length of utterance (MLU) in morphemic units: This measure was developed by Brown (1973) and has been used extensively (de Villiers and de Villiers, 1973; Kramer, James and Saxman, 1979; Morehead and Ingram, 1973). It provides an index of syntactical development since MLU correlates highly with level of syntactical and grammatical complexity. A morpheme is the smallest unit of meaning (Gleason, 1961) and each utterance is scored with regard to the number of morphemic units (distinct units of meaning) it contains. The total number of morphemic units is then divided by the total number of utterances giving a mean length of utterance in morphemic units.

Brown (1973) has set out five stages in syntactical and grammatical development based on increases in MLU (see Miller, 1981, pp. 55-65 for details of these stages).

Brown's (1973) rules for determining MLU in morphemic units were followed with one exception which is described later. Brown's (1973, p. 54) rules are:

1. Start with the second page of the transcription unless that page involves a recitation of some kind. In this latter case start with the first recitation-free stretch. Count the first 100 utterances satisfying the following rules.
2. Only fully transcribed utterances are used; none with blanks. Portions of utterances, entered in parentheses to indicate doubtful transcription are used.
3. Include all exact utterance repetitions (marked with a plus sign in records). Stuttering is marked as repeated efforts at a single word; count the word once in the most complete form produced. In the few cases where a word is produced for emphasis or the like (<u>no</u>, <u>no</u>, <u>no</u>) count each occurrence.
4. Do not count such fillers as <u>mm</u> or <u>oh</u>, but do count, <u>no</u>, <u>yeah</u>, and <u>hi</u>.
5. All compound words (two or more free morphemes), proper names, and ritualized reduplications count as single words. Examples: <u>birthday</u>, <u>rackety-boom</u>, <u>choo-choo</u>, <u>quack-quack</u>, <u>night-night</u>, <u>pocketbook</u>, <u>see saw</u>. Justification is that no evidence that the constituent morphemes function as such for these children.
6. Count as one morpheme all irregular pasts of the verb (<u>got</u>, <u>did</u>, <u>went</u>, <u>saw</u>). Justification is that there is no evidence that the child relates these to present forms.
7. Count as one morpheme all diminutives (<u>doggie</u>, <u>mommie</u>) because these children at least do not seem to use the suffix productively. Diminutives are the standard forms used by the child.
8. Count as separate morphemes all auxiliaries (<u>is</u>, <u>have</u>, <u>will</u>, <u>can</u>, <u>must</u>, <u>would</u>). Also all catenatives: <u>gonna</u>, <u>wanna</u>, <u>hafta</u>. These latter counted as single morphemes rather than as <u>going to</u> or <u>want to</u> because evidence is that they function so for the children. Count as separate morphemes all inflections, for example, possessive [<u>s</u>], plural [<u>s</u>], third person singular [<u>s</u>], regular past [<u>d</u>], progressive [<u>in</u>].

The only rule which was not followed exactly was rule number one which required that the first page of the transcription not be used to calculate the MLU. Because the tape recording time was much less for this study than it had been in Brown's study, there was a concern that for some children, particularly at the younger ages, 100 utterances would not be obtained if the first page of transcription was not used.

An inter-rater reliability was calculated for transcription of the audio-tapes and for the morphemic units used to calculate MLU. To determine inter-rater reliability for transcription of the tapes a second rater experienced in assessing young children's language listened to six tapes (12% of the sample) picked randomly from the 30 month tape recordings. Inter-rater reliability calculated by percentage agreement on words ranged from 88 to 96%, with a mean of 90%.

To determine inter-rater reliability for morphemic units a second rater was trained to use Brown's rules (Brown, 1973, p. 54) for determining morphemic units. Four written transcriptions were selected randomly from the transcriptions of the 30 month tape recordings. Two hundred and fifty-four utterances incorporating 591 morphemic units were represented in these four transcriptions. Inter-rater reliability calculated by percentage agreement on morphemic units ranged from 98 to 100%, with a mean of 99.25%.

3.1.3 Phonological Function

Development of the ability to produce specific speech sounds was assessed with a picture labelling task devised for this research. It was administered at 18, 24 and 30 months of age. Thirty-five pictures depicting objects which represented 11 target speech sounds (phones) were used. The target phones which were selected were some of those expected to emerge before 18 months of age or from 18 to 30 months of age. The specific phones to be elicited were /d, t, b, p, k, g, f, sh, ch, s, z/. The child was encouraged to label the picture on her own after a prompt sentence, i.e. "What is it?", "The boy is putting on his ______" (shirt). If that method of elicitation was not successful she was asked to repeat the word after the examiner or her mother. Each phone was elicited five different times, with the exception of /z/ which was only elicited four times. Each phone was scored: 1 -- correct production, 0 -- incorrect production. The maximum score was 54.

3.2 Tests of Motor Function

The tests of motor function will be discussed under three subheadings: a) manual motor, b) gross motor, and c) oral motor.

3.2.1. Manual Motor Tests

The five measures of manual motor function, and the ages at which they were given are:

1. Manual dexterity inventory -- at 18, 24 and 30 months,
2. Bayley pegboard (Bayley, 1969) -- at 18, 24 and 30 months,
3. Annett peg moving (modified) (Annett, 1970a) -- at 24 and 30 months,
4. Archer mystery box -- at 24 and 30 months,
5. Bead stringing -- at 30 months.

With the exception of bead stringing all of the tasks were measures of laterality as well as measures of manual dexterity. The laterality aspects of these tasks will be described in this section as part of the initial description of each task. Each of the tasks will now be described in detail.

1. Manual dexterity inventory: The final version of this test was achieved after pilot tests with children 12 to 30 months of age. During pilot testing stimuli were examined and chosen to represent a broad spectrum of manual motor skill likely to be in the repertoire of 18 to 30 month old children or likely to be acquired over that time period; refinements to the scoring system were also made.

The inventory was designed to measure accuracy and laterality in manual skill and dexterity. It is composed of nine tasks expected to be in the manual motor repertoire of 18 to 30 month old children. Items were chosen to represent aspects of manual dexterity, e.g. rotary turning, eye-hand coordination, motor sequencing. Some of the tasks are similar to standardized tests of infant intelligence (e.g. block stacking, cutting with scissors) while others were devised for the present project (e.g. telephone dialing, turning bolt on rod).

Each task was demonstrated by the experimenter and then presented to the child in the midline. The child was encouraged to do what the examiner had done. The items were presented in the order listed below; if a child was uncooperative or inattentive to a particular item it was presented again later. Each item was scored for accuracy of performance and by the hand which did the task. (Details of the scoring system for laterality are described below.) The inventory comprised nine tasks:

1) Bottle cap turning -- a plastic bottle and its cap are presented at the midline and the child is requested to put the cap back on.

   Scoring: 0 -- cap placed on the bottle but no turning action is seen

1 -- cap placed on the bottle accompanied by some turning but not sufficient to afix it to the bottle.

2 -- cap placed on the bottle and turned sufficiently to secure it to the bottle.

2) Telephone dial turning -- a toy dial telephone is presented and the manner in which the dial is turned is scored.

Scoring: 0 -- no attempt at turning

1 -- turning of the dial achieved by a whole hand action

2 -- turning of the dial achieved by placing one finger in a hole

3) Zipper pulling -- a cloth doll wearing pants with a 3 inch zipper and a 1/2 inch zipper tab is presented and the child is requested to pull the zipper down (3a) and pull the zipper up (3b).

Scoring: 0 -- zipper not pulled up or down

1 -- zipper pulled up

1 -- zipper pulled down

2 -- zipper pulled up and down

4) Button fastening -- the same doll used for the zipper task is presented and the child is encouraged to do up a 3/4 inch button (4a) and then to undo the same button (4b).

Scoring: 0 -- no attempt made or only gross patting at the tab (4a) or pulling of the tab (4b)

1 -- an attempt made to push the button through the hole (4a); an attempt made to pull the cloth tab and/or manipulate the button through the hole

2 -- button is done up (4a); button is undone (4b)

5) Scissors -- scissors and paper are presented and the child is encouraged to cut the paper with the scissors. (Right-handed scissors used.)

Scoring: 0 -- no attempt or scissors opened and closed with two hands

1 -- scissors opened and closed with one hand but paper is not cut

2 -- scissors opened and closed with one hand and paper is cut

6) Bolt on rod -- a 7 inch plastic rod, 3/4 inch in diameter, and a plastic bolt are presented and the child is encouraged to turn the bolt on the rod.

Scoring: 0 -- no attempt or bolt pushed on rod with no turning action

1 -- some turning action observed but threads are not actually engaged

2 -- sufficient turning action occurs that the threads are engaged and the bolt is fixed on the rod

7) Paper folding -- an 8 x 10 inch piece of paper is folded in half from bottom to top and then from side to side to make a "little book", as the child watches. A fresh paper of the same size is then presented to the child who is encouraged to make a "little book" also.

Scoring: 0 -- no attempt; paper crumpled into a ball; multiple folds

1 -- single fold made

2 -- two folds made producing an approximation of a "book".

8) Bead stringing -- the child is encouraged to thread a bead on a string and then pull it down to the bottom of the string. A small bead and a large bead are used and each is scored separately. The small bead is presented first. Dimensions of the materials:

String -- length: 5 inches; string is supple except for one end stiffened with tape and one end knotted;

Small bead -- length: 1/2 inches; outside diameter 1 inch, diameter of hole 5/16 inch

Large bead -- length: 1 1/2 inches; outside diameter 1 inch, diameter of hole 5/16 inch

Scoring: 0 -- no threading achieved

1 -- string threaded through the hole but bead not pulled to the end of the string

2 -- string threaded through hole and bead then pulled to the end of the string

9) Block stacking -- a tower, several blocks high, is constructed first by the examiner. Then the child is asked to build a high tower. The blocks are given to the child one at a time at the midline. Two trials were conducted. The score is the greatest number of blocks stacked on either of the two trials. Materials: 10 wooden coloured cubes one inch in size.

Scoring: 0 -- 2 blocks stacked

1 -- 3 to 4 blocks stacked

2 -- 5 to 6 blocks stacked

3 -- 7 to 8 blocks stacked

4 -- 9 to 10 blocks stacked

The maximum total score possible for accuracy on the manual dexterity inventory is 24 points.

To evaluate laterality in performance of the manual dexterity inventory eight items from the battery were selected: bottle cap turning, telephone dialing, pulling zipper up, pulling zipper down, cutting with scissors, turning bolt on a rod, threading a small bead, threading a large bead. Not all of the items in the inventory were scored for laterality because some involved considerable bimanual manipulation (i.e. button fastening) and it was not always clear which was the dominant hand. Each of the eight items selected was scored for the hand which first attempted the task regardless of whether or not it was subsequently performed successfully by that hand or the other hand. This scoring strategy was adopted to deal with the confound of subjects who switched back and forth between hands because they lacked the necessary cognitive strategy and/or manual dexterity to successfully perform the required task. The scores were converted to percentage of right handedness because not all subjects attempted all the items, particularly at the 18 month level.

Inter-rater reliability was calculated for two scores: accuracy of performance and laterality of performance for the manual dexterity inventory. A video-tape was made of three children (ages 19, 28 and 31 months) who were not subjects in the study. Three raters who had been taught the scoring system and who had previous experience testing young children saw the tapes. One rater viewed all three tapes and the two other raters each viewed two tapes. The principal investigator scored the tapes at these sessions.

For the accuracy component composite test scores were used and nine pairs of rater comparisons were obtained. Using the Spearman Rank statistic a reliability coefficient of Rs = .97 was obtained.

For the laterality component nine pairs of rater comparisons were also obtained. Percentage agreement was calculated for each of these pairs, with figures ranging from 75% to 100%, yielding a mean percentage agreement of 95%.

2. Bayley pegboard: This test was included in the battery as a measure of manual skill and speed which could be performed at all the three age levels. The protocol set out in the manual was followed (Bayley, 1969) but, to encourage the child, the task was demonstrated by the examiner first. The task requires six pegs to be placed in a pegboard. The equipment consists of a plastic pegboard (14 inches x 3 inches) and six plastic pegs 3/8 of an inch in diameter and 4 inches long. The pegboard is set in front of the child and the pegs are set out perpendicular to the board in the center and on the far side of the board from the child. The child is instructed to put all the pegs in the holes as the examiner had demonstrated. There was no instruction to perform the task as quickly as possible. Three trials were conducted and for each trial the time to complete each trial and the hand which placed each peg was

recorded. The best time of the three trials was chosen for statistical analysis.

The laterality of performance was determined by recording which hand placed each peg. The total number of pegs to be placed was 6 (pegs) x 3 (trials) = 18. The number of pegs placed by each hand was recorded. For some aspects of the statistical analysis a laterality quotient (LQ) was derived from the formula, LQ = R - L / R + L.

3. Annett peg moving task (modified): This task is a modification of Annett's peg moving task (1970a) which she used with children from 3 to 15 years of age. The task was included as a measure of motor organization and manual speed as well as a measure of laterality. The subject is required to move pegs, one at a time, out of their holes on one side of a pegboard and place them in holes on the opposite side of the pegboard. The task is performed separately by each hand. For this study modifications in equipment and administration were made because of the younger ages of the children. The equipment is a 14 x 10 inch wooden board with a row of eight holes at each side and eight pegs 2-1/2 inches in length and 1/2 inch in diameter. The task was first demonstrated to the child and she was instructed to move them from one side of the board to the other. Unlike Annett's administration there

was no requirement that the pegs be moved in a set order. In order to obtain separate performance by each hand the child was asked to hide her idle hand, place it in a pocket or let her mother hold on to it while the other hand moved the pegs. There were no practice trials. Four test trials (two per hand) were conducted, alternating between the hands. The time required to move the eight pegs from the one side of the board to the other was recorded. Two scores were obtained for each hand and to compare the performance of the two the best right hand time and the best left hand time were used. For those analyses which required a single number measure of laterality the best right hand score and the best left hand score were put into the formula: LQ = R - L / R + L. Hand order was counterbalanced separately for the boys and the girls.

4. <u>The Archer mystery box</u>: This toy was developed for this research and was intended to be a measure of manual dexterity and motor planning, and laterality. The equipment is a brightly colored box 8 inches long by 5 inches high by 4 inches wide. On the top of the toy is a spring action lever 1 inch in length and two doors which fall open when the lever is pulled (see Plate 1). When the lever is pulled and the doors are opened, a hole 1 1/2 inches deep and 3/4 inch in diameter containing a button 3/8 inch in diameter is revealed. The button is recessed within

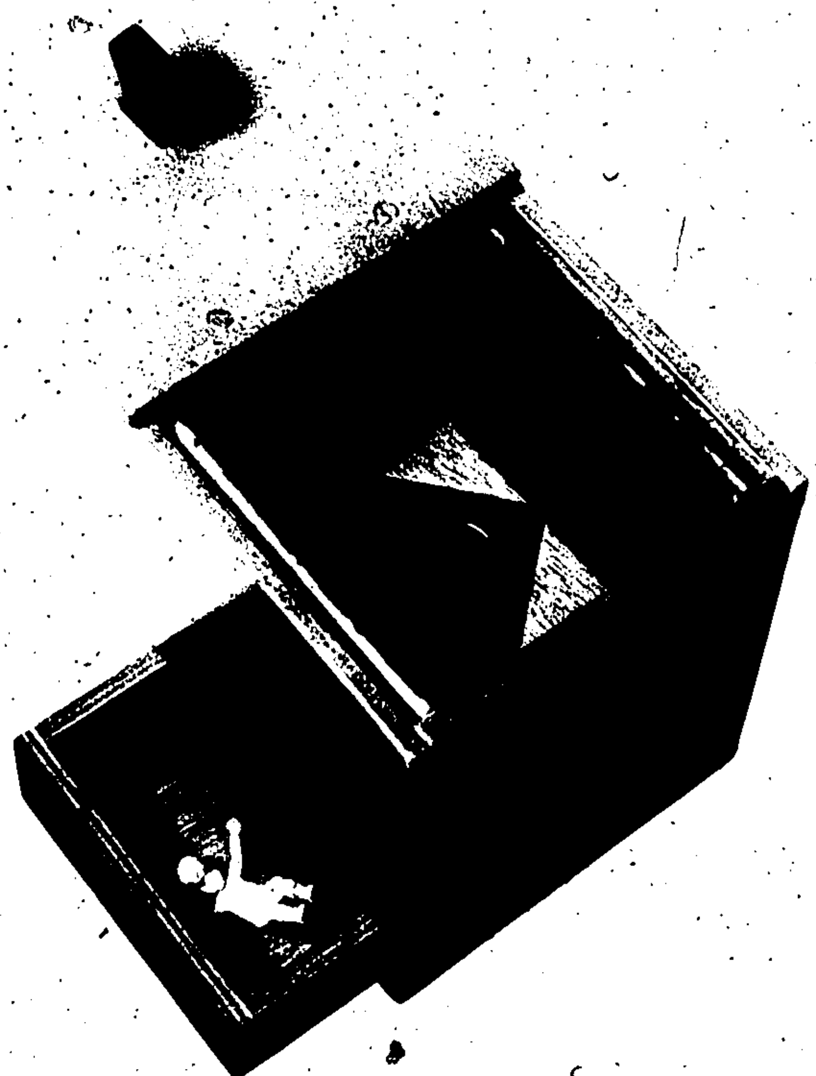

Plate 1   Archer Mystery Box

the hole, sitting approximately 3/4 inch from the top edge of the hole. When the button is pushed a small drawer at the front of the toy is opened in which a small toy doll is hidden.

Pilot tests were made with several children 18 to 48 months of age to determine the appropriate depth for the hole, vis à vis the length of the children's fingers, and the amount of resistance to be built into the lever and the button. In addition it was necessary to determine at what age children might be able to complete a task which required two actions to be performed in order.

Two actions performed in order were required to operate the toy. First, the lever must be pulled and second, the button must be located within the hole and pushed. One finger only can comfortably depress the button.

The operation of the toy was first demonstrated to the subject and then several practice trials (usually three or four) were conducted until it was clear that the subject could perform the actions as required. During the practice session a certain amount of experimentation and exploration of the toy was permitted and separate performance by each hand was not required.

For the test trials the subject was asked to hide one hand (i.e. in a pocket or behind her back) and then to pull the handle and push the button and get the baby that was hiding in the box. The time required to complete the two actions was recorded. Four test trials (two per hand) were conducted, alternating between the hands. Two scores were obtained for each hand and for comparison of the performance of the two hands the best right hand time and the best left hand time were used. For those analyses which required a single number measure of laterality the best right hand score and the best left hand score were put into the formula: LQ = R - L / R + L. Hand order was counterbalanced separately for the boys and the girls.

5. <u>Bead stringing</u>: Bead stringing is commonly used in developmental assessment. The task provided an additional and more complex measure of manual motor dexterity and motor planning. It was administered only at 30 months. Following a demonstration the subject was asked to thread three beads (dimensions: length = 5/8 inch, width = 5/8 inch, hole diameter = 3/8 inch) on to a 6 1/2" string. The beads and string were presented in the midline and the hand strategy adopted was recorded. The time required to thread all three beads was recorded. Two trials were conducted. The score was the best time of the two trials. A maximum time of 90 seconds was allowed for each trial.

3.2.2 Gross Motor Test

Gross motor function was evaluated using 29 items selected from the Bayley Psychomotor Inventory (PDI) (1969) (see Appendix). Items were chosen which could be easily administered in the home, and did not require any specialized equipment. Each item was administered and scored in the manner set out in the Bayley PDI manual. At 18 and 24 months 21 items were administered with a maximum possible score of 21. At 30 months 8 additional items were added, making a maximum possible score of 29, for the 30 month level.

3.2.3 Oral Motor Test

Measures of oral motor function are commonly used in studies of children with developmental language delay (Archer, 1980; Weiner, 1969; Yoss and Darley, 1974). There are few studies of this function in normally developing children and no studies were found using such tasks with children as young as those in this study. Therefore, pilot tests were done with children 18 to 30 months of age to select test items to represent a broad range of difficulty and also to determine appropriate gradations in scoring.

A two part inventory of oral motor function was developed. In Part 1 five tongue or lip actions were demonstrated and the subject was encouraged to "make funny faces" and do as the experimenter had done. No verbal labels for the actions were used during the demonstration, i.e. the child was asked to do as the experimenter had done; she was not asked to "blow" or "stick out her tongue". There was no limit to the number of demonstrations which were given although if the child had not imitated the examiner after two or three presentations the next item was presented, or the mother was asked to demonstrate the item. The subject was encouraged to imitate her mother. The mother was instructed that she was not to label the action which she was making.

The test items and scoring for Part 1 are as follows:

1) Blowing

Scoring: 0 -- not done

1 -- air expulsion <u>or</u> lip rounding

2 -- air expulsion and lip rounding

2) Tongue protrusion

Scoring: 0 -- not done

1 -- tongue protruded

3) Grin

Scoring: 0 -- not done

1 -- lips retracted to a grin

4) Tongue tip elevation

Scoring: 0 -- not done

1 -- tongue protruded

2 -- tongue protruded and elevated to nose

5) Tongue lateralization

Scoring: 0 -- not done

1 -- tongue protruded

2 -- tongue protruded and lateralized

Maximum score for Part 1 is 8.

For Part 2 all the stimuli used in Part 1 plus one additional stimulus (i.e. produce p^h sound) were combined into three items each consisting of two movements. The subject was instructed that she had to do two things and that she should watch carefully and wait until the experimenter had shown her both of them. Two trials were given for each test item and the mother was not permitted to demonstrate as in Part 1. The test items and scoring are as follows:

1) a) Blow

b) Protrude tongue

2) a) Elevate tongue

b) Grin

3) a) Produce p^h sound*

b) Lateralize tongue

(*Correct = lips together and air release)

Scoring: 0 -- no movements produced

1 -- two movements correct, reversed order, Trial #2

2 -- two movements correct, reversed order, Trial #1

3 -- two movements correct, correct order on Trial #2

4 -- two movements correct, correct order on Trial #1

Maximum score for Part 2 = 12.

Maximum score for Part 1 and Part 2 = 20.

3.3 Laterality Tests

Two types of tasks, preference and performance, were used to evaluate laterality. In preference measures the hand (or foot, eye or ear) which is "preferred" for performance of the task is recorded, whereas for performance measures each hand is required to perform the task and a separate score is taken for each hand.

3.3.1. Preference Tests

1) Hand Preference: An 11 item handedness inventory was developed. Pilot testing was done with children between 12 and 36 months of age, to aid in the selection of stimuli and plan of test administration. The items that were included in the inventory were selected primarily on the basis of two criteria: a) they should be interesting

to the children, and b) they should be well within the motor capabilities of children 18 to 30 months of age. When appropriate for this study items determined by Annett (1970b) to be most reliable in eliciting the preferred hand were chosen for the inventory, i.e. writing, banging with a hammer.

Seven of the items were unimanual items, requiring the use of only one hand, while the remaining four items were bimanual items and required the use of both hands. The unimanual items were: stir in a bowl with a spoon, comb hair, bang with a hammer, push a toy train, stack two blocks, draw with a crayon, put a small button in a small-mouthed bottle. The bimanual items were: place cap on a small plastic, easily tippable bottle, bang two plastic rods together, pull tape from a roll, push a plastic straw through a hole in a plastic block. Each item was demonstrated first, then the toy was presented to the child in the midline and the child was asked to do the same. As much as possible all actions performed with each item were recorded, i.e. the hand which touched the object first, transfers which occurred between hands. The hand which performed the action first was the hand which received credit for the item. For the bimanual items, the hand which assumed the manipulative role (as contrasted with the supportive role) was credited with the item. The score for the test was calculated in terms of the right hand (RH). Therefore, if the RH was credited with seven items and the left hand (LH) with four items, the handedness score would be 7/11. Because many of the children, particularly at the 18 month testing, did not do all 11 items the scores were converted to percentages.

2) Lateral Preference Inventory: Tasks to measure ear, eye and leg preference, modelled after Coren, Porac and Duncan (1981), were given to provide a more complete picture of lateral preference. The inventory consisted of six tasks, two for each aspect of preference being evaluated. Each task was demonstrated by the examiner (randomly alternating the ear, eye or leg used), then the object was placed in the midline and the child was encouraged to do as the examiner had done.

To evaluate ear preference the examiner demonstrated listening to a pocket watch and then a wrist watch, each of which were placed near one ear or other at random. Each watch was presented in the midline one at a time and the child was asked to put each by her ear and listen to it ticking. The ear the watch was placed beside first was recorded as the "preferred" ear.

For eye preference the child was asked to sight through a cone, peer into a small bottle to see a button and look into a kaleidoscope, after demonstration by the examiner. In each instance the child was encouraged to bring the object close to her eye and do as the examiner had done. The eye the object was brought to first was recorded as the "preferred" eye.

Leg preference was evaluated by having the child kick a ball and stamp on a small rubber foot. After demonstration the child was asked to kick the ball and stamp the foot as the examiner had done. The leg which performed the action first was recorded as the "preferred" leg.

The score for the test was calculated in terms of the right side. Therefore, if the right side was credited with five items and the left side with one, the lateral preference score would be 5/6. Because many of the children did not do all six items, particularly at the 18 month level, the scores were converted to percentages.

3.3.2 Performance Tests

Laterality scores were derived for the following tests:

1. Manual dexterity inventory
2. Bayley pegboard
3. Annett peg moving
4. Archer mystery box
5. Bayley formboard.

Tests 1, 2, 3 and 4 were described when the tests of motor function were described. The Bayley formboard will be described in the following section when control measures are discussed.

3.4 Control Measures

1. Bayley formboard (blue): The blue formboard is one of two formboards used in the Mental Developmental Inventory of the Bayley Scales of Infant Development (1969). It was included in the test battery to provide a marker of general cognitive maturation, and was administered in the prescribed manner at the 24 and 30 month sessions.

It is a nine piece formboard consisting of four circles and five squares. The shapes are presented one at a time and the child is requested to "Find a hole" for each of the shapes. Timing begins with presentation of the first shape. Special attention was paid to presenting the shapes in the midline in order that the hand which first reached for the shape could be recorded. This is not a requirement of the standardized administration. Two trials were conducted. Three scores were derived: 1) a score for accuracy, i.e. the number of shapes placed correctly, 2) a score for the time required to place the nine shapes and 3) a score for laterality. The accuracy score was not used because with the exception of three subjects at 18 months, all subjects obtained the maximum score of 9. The time score was used as the measure of proficiency, and the best time of the two trials was used for the statistical analysis.

The laterality of performance was determined by recording which hand first reached for each shape. The total number of shapes to be placed was 9 (shapes) x 2 (trials) = 18. The number of shapes taken by each hand was recorded. For some aspects of the statistical analysis a laterality quotient (LQ) was derived from the formula, LQ = R - L / R + L.

2) <u>Seguin formboard</u>: The Seguin formboard was administered only at the 30 month session. It was included in the test battery to provide an additional marker of general cognitive function; by 30 months of age a ceiling effect may be found with the Bayley formboard. The test requires the placement of 10 different geometric shapes in a time period of 212 seconds. The test was administered as suggested in the manual for the Merrill-Palmer Scale of Mental Tests (Stutsman, 1931), but only two trials (not three) were given and errors were not scored. Two scores were taken: the number of shapes correctly placed and, in the event that all 10 shapes were placed correctly, the time required to do so. With the exception of two subjects at 24 months all subjects were able to place all 10 shapes correctly; therefore, only the time scores were used in the statistical analysis.

3) <u>Height</u>: Height -- specifically supine length -- was measured at 24 and 30 months of age to provide a marker of physical maturation. The aim was a control measure for different maturation rates which might lead to some subjects demonstrating advanced performance on the language and motor measures. Height and IQ have been shown to be correlated (Tanner, 1978).

For children younger than 30 months it is suggested that supine length be measured and not standing height (Tanner, 1978). The supine length procedure as described by Cameron (1978) was followed as closely as possible with some modifications because the measurement was made at home. The measurement was taken by having the child lie on her back with her heels against a surface having a 90 degree angle. The mother was asked to keep the heels in place against the wall and to press the knees flat to the floor. The examiner was at the child's head and if necessary moved the child's chin upward until the eyes looked directly upward (Cameron, 1978). A large book was placed at the top of the head to make a 90 degree angle and a mark was made at the 90 degree point where the floor and book intersected. The measurement was made from the wall to the mark.

3.5 Measures to Describe the Sample

1. Familial Handedness: Familial handedness, in particular familial lefthandedness, has been used as a factor to explain the origins of handedness (Annett, 1978), the recovery of verbal functions after brain damage (Hécaen and Sauguet, 1971), and patterns of cognitive ability (Carter-Saltzman, 1979; Gilbert, 1977). Familial handedness was examined in this study to provide additional information about the laterality of the subjects, and as a possible explanatory factor for differences in language ability.

Parental handedness was measured by having each parent complete the Annett (1970b) handedness questionnaire in the manner suggested by Oldfield (1971), i.e. each of the 12 items are rated by the respondent as: always left, usually left, no preference, usually right, always right. These categories are scored, -2, -1, 0, +1, +2, respectively. Scores of -24 and +24 indicate strong lefthandedness and strong righthandedness, respectively. The criterion for familial lefthandedness (FLH) was a score of +19 or less.

Siblings 3 years of age and older were given a 10 item handedness inventory administered by the examiner. The child was asked to demonstrate: writing with a pencil, using a toothbrush, combing hair, cutting with scissors, eating with a spoon, throwing a ball, putting a button in a bottle, unscrewing the lid of a bottle, putting a straw through a hole, and pulling tape from a roll. For siblings who were 18 to 36 months of age the same hand preference inventory used for the subjects in the study was used. Siblings younger than 18 months of age were not tested. The criterion for righthandedness was eight or more items performed with the right hand. Those who performed fewer than eight items with the right hand were classed as non-righthanders. In total, 35 siblings were tested, 12 boys and 23 girls.

2. Parental Education: One of the criteria for including subjects in this study was a minimum of Grade 12 education for each parent. The level of parental education is said to be related to the child's verbal ability (Nelson, 1973; Schacter, 1979). The number of years of education beyond Grade 12 was recorded for each parent.

CHAPTER 3

RESULTS

The primary aim of this research was to study the acquisition of language in young children in relation to manual motor function and laterality. Some subsidiary aims were included in the study: sex differences in language, motor, and laterality behaviors; laterality in relation to increasing age. The results are presented in the following order:

1. Sex differences in language, motor, and laterality behaviors as well as control variables.
2. Laterality in motor performance tasks in relation to age.
3. Correlations between language and motor functions, language and laterality, language and control factors.
4. Multiple regression analyses for explanation and prediction of language production ability.

1. Sex Differences

Sex differences were examined in: a) language function, b) control factors, c) motor skill, and d) laterality. Girls performed significantly better than boys on a number of measures of language function. No differences were found between the sexes for control factors, motor skill or laterality.

T.1 Language Tests

A one-way analysis of variance (ANOVA) using Boys x Girls as a main effect in a repeated measures design (18, 24 and 30 months) was done for the two tests of language reception, the Reynell Developmental Language Scales (RDLS) and the Peabody Picture Vocabulary Test (PPVT), and one of the measures of language production, mean length of utterance (MLU). Birth order was entered as a covariate, because language ability in young children has been related to birth position (McCarthy, 1954) -- firstborns tend to be more precocious in language ability.

The girls performed significantly better than the boys at all ages on both the RDLS ($p = .009$) (Figure 1 and Table 3) and the PPVT ($p = .023$) (Figure 2 and Table 4). The birth order covariate was not significant for the PPVT, and just reached statistical significance with the RDLS ($p = .052$). For both tests, and both sexes, there was a significant main effect for age (RDLS: $p < .001$; PPVT: $p < .001$) indicating better performance with age. The interaction (Age x Sex) was not significant for either test.

A logarithmic transformation of the data was necessary to stabilize the variance in the MLU data because

Fig. 1 Reynell Language Scales (RDLS)

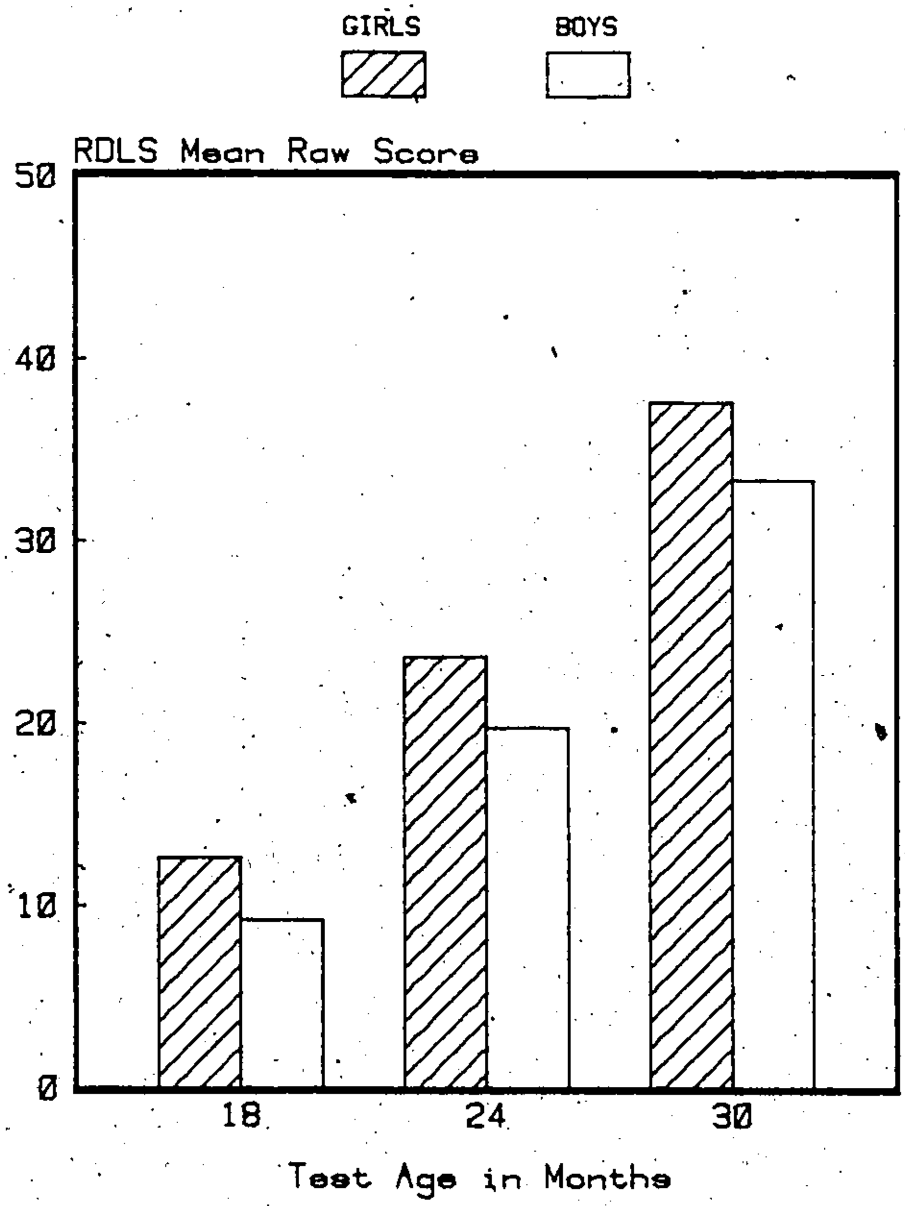

TABLE 3. Test of Language Reception. Means and standard deviations for the Reynell Developmental Language Scales (RDLS) at 18, 24 and 30 months.

TEST	AGE (months)	GIRLS (n = 22) $\overline{X}$	GIRLS (n = 22) S.D.	BOYS (n = 27) $\overline{X}$	BOYS (n = 27) S.D.
RDLS	18	12.6	5.5	9.2	3.6
(Max. Raw	24	23.6	6.7	19.7	5.9
Score = 62)	30	37.6	4.4	33.3	4.4

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	475.42	7.27**
Covariate (birth order)	1	261.26	4.00*
Error	46	65.37	
Age	2	7344.20	539.85***
Age x Sex	2	1.99	.15
Error	94	13.6	

* $p < .052$
** $p = .009$
*** $p = .001$

Fig. 2 Peabody Vocabulary Test (PPVT)

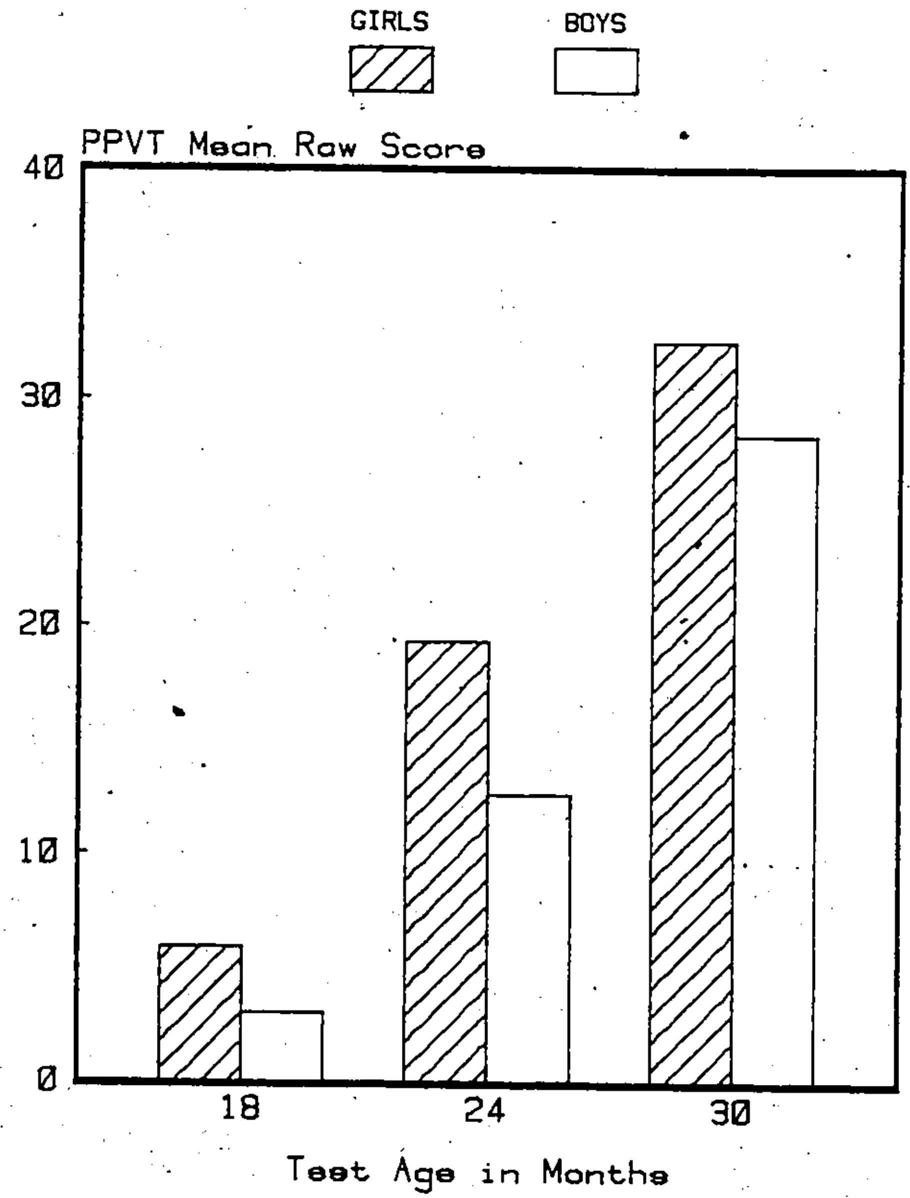

TABLE 4. Test of Language Reception. Means and standard deviations for the Peabody Picture Vocabulary Test (PPVT) at 18, 24 and 30 months.

TEST	AGE (months)	GIRLS (n = 22) $\bar{X}$	GIRLS (n = 22) S.D.	BOYS (n = 27) $\bar{X}$	BOYS (n = 27) S.D.
PPVT	18	5.9	4.9	3.0	3.2
(Raw Scores)	24	19.3	10.5	12.6	7.1
	30	32.5	10.2	28.4	10.4

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	662.52	5.54*
Covariate (birth order)	1	382.31	3.19
Error	46	119.68	
Age	2	8283.53	220.87**
Age x Sex	2	47.36	1.26
Error	94	37.50	

* $p = .023$
** $p < .001$

the assumption of homogeneity of variance was not met. Birth order was again used as a covariate and a one-way ANOVA, repeated measures design, was done on the transformed data. As shown in Figure 3 and Table 5, after accounting for birth order which was statistically significant ($p = .002$), the girls showed a significantly greater mean length of utterance ($p = .002$) at all ages. There was a significant main effect for age for both sexes ($p < .001$). The Age x Sex interaction was not significant.

A breakdown of the MLU data into Brown's (1973) stages is shown in Table 6. At 18 months all the boys and 18 (62%) of the girls are at Stage I. Chi-square analyses were done for the 24 and 30 month data to compare the number of girls versus boys who had moved beyond Stage 1. At 24 months, significantly ($p = .008$) more girls than boys had moved beyond Stage 1. However, by 30 months there was no difference between the groups.

There was no sex difference in the total number of utterances produced, as determined by a one-way ANOVA, repeated measures analysis (Table 7). There was a significant main effect for age ($p < .001$) and also a significant Age x Sex interaction ($p = .019$). The significant interaction reflects the cross-over at 24 months when the boys begin to produce more utterances than the girls. At 18 months the girls had produced more utterances.

Fig. 3 Mean Length of Utterance (MLU)

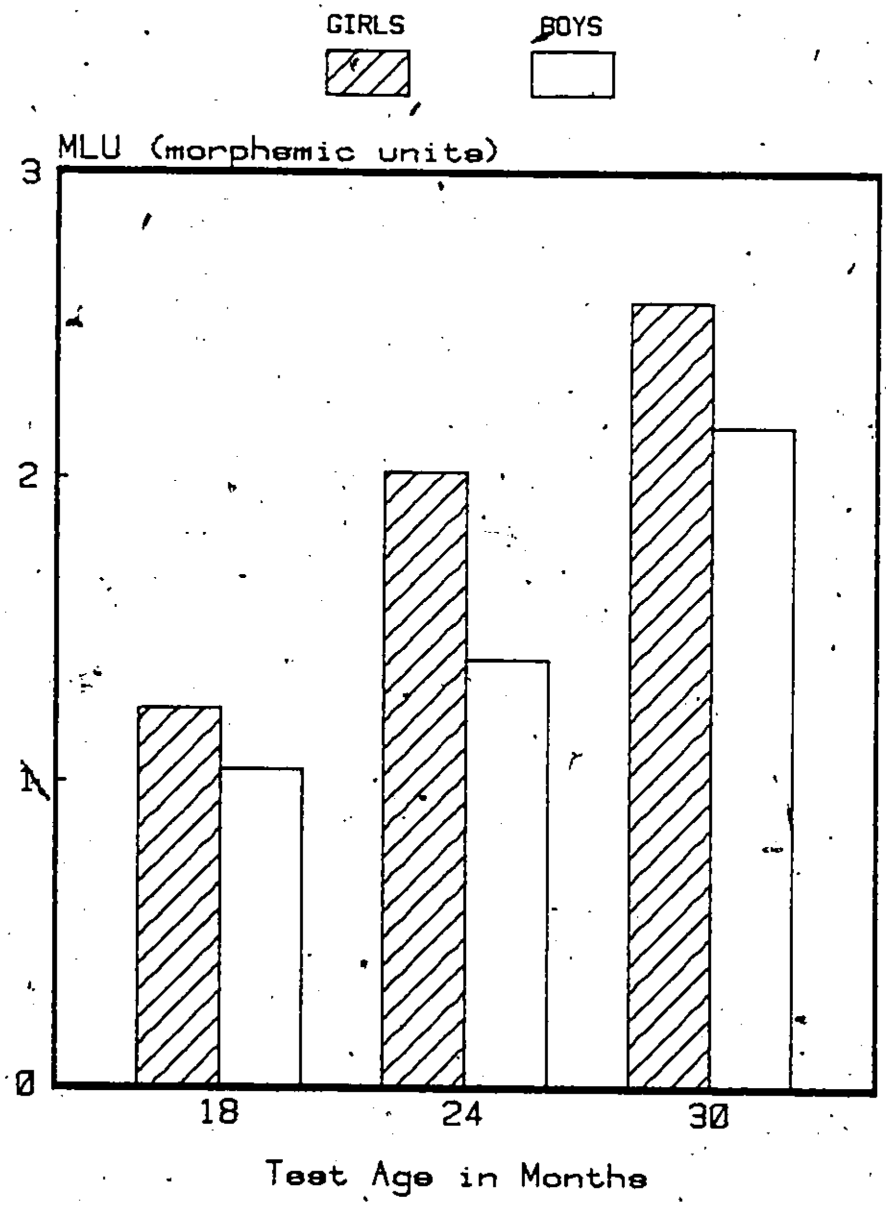

TABLE 5. Test of Language Production. Means and standard deviations for Mean Length of Utterance (MLU) at 18, 24 and 30 months.

TEST	AGE (months)	GIRLS (n = 22) $\overline{X}$	GIRLS S.D.	BOYS (n = 27) $\overline{X}$	BOYS S.D.
MLU[a] (Morphemic Units)	18	1.24	.28	1.04	.08
	24	2.02	.75	1.40	.40
	30	2.58	.81	2.17	.65

SUMMARY OF REPEATED MEASURES ANOVA:[b]

Source of Variation	df	Mean Square	F
Sex	1	1.18	10.78*
Covariate (birth order)	1	1.20	11.00*
Error	46	.11	
Age	2	5.25	147.58**
Age x Sex	2	.09	2.75
Error	94	.03	

a Raw data
b Logarithmic data
* $p = .002$
** $p < .001$

TABLE 6. Mean Length of Utterance (MLU). Proportion of girls (n = 22) and boys (n = 27) at 18, 24 and 30 months of age in Brown's (1973) Five MLU Stages.

BROWN'S MLU STAGES	18 MONTHS Girls	18 MONTHS Boys	24 MONTHS Girls	24 MONTHS Boys	30 MONTHS Girls	30 MONTHS Boys
Early Stage I [MLU = 1.01-1.49] [Age = 19.1-23.0 mos.]	18	27	8	18	1	4
Late Stage I [MLU = 1.50-1.99] [Age = 23.0-27.0 mos.]	4	0	3	5	5	7
Stage II [MLU = 2.00-2.49] [Age = 27.7-30.8 mos.]	0	0	6	4	5	9
Stage III [MLU = 2.50-2.99] [Age = 31.6-34.8 mos.]	0	0	4	0	5	4
Early Stage IV [MLU = 3.00-3.49] [Age = 35.6-38.7 mos.]	0	0	1	0	4	3
Late Stage IV-Stage V [MLU = > 3.49] [Age = 39.5-42.6 mos.]	0	0	0	0	2	0

† Chi-Square = 1.06, 1 df, p = .008

TABLE 7. Test of Language Production. Means and standard deviations for the Total Number of Utterances at 18, 24 and 30 months.

TEST	AGE (months)	GIRLS (n = 22)		BOYS (n = 27)	
		$\overline{X}$	S.D.	$\overline{X}$	S.D.
Total number of utterances	18	49.9	54.3	29.5	41.5
	24	125.5	54.4	137.6	63.4
	30	154.3	45.5	183.1	56.1

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	3010.18	.69
Covariate (birth order)	1	22834.79	5.20*
Error	46	4389.59	
Age	2		115.72***
Age x Sex	2		4.10**
Error	94		

* p = .03
** p = .019
*** p < .001

A count of the number of different utterances produced in a 20 minute time interval was made at 18 months only. An independent t-test showed no differences between the boys and the girls (Table 8).

The phonetic inventory task was given at 18, 24 and 30 months. At 18 months, 34 (66%) of the subjects, 12 (55%) of the girls and 22 (77%) of the boys refused to do the task. At 24 months, 16 (33%) subjects, 5 (23%) of the girls and 11 (41%) of the boys refused to do the task. There were so many missing values at 18 and 24 months that a comparison of the groups in terms of accuracy of performance was not done. However, the number of boys who refused was compared to the number of girls who refused. At 18 months (Table 9), significantly more boys than girls ($p = .04$) refused the test, but at 24 months there was no difference between the sexes in number of refusals. At 30 months the task was scored for the number of errors made (Table 10). An independent t-test showed no differences between the boys and the girls.

1.2 Control Measures

The Bayley formboard and Seguin formboard were included in the test battery as markers of general cognitive development. A one-way ANOVA for repeated measures showed a significant main effect for age ($p < .001$) but no significant sex differences for the Bayley formboard (Table 11).

TABLE 8. Test of Language Production. Means and standard deviations for Number of Different Utterances at 18 months.

		GIRLS (n = 22)		BOYS (n = 27)	
TEST	AGE (months)	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Number of different utterances	18	21.9	30.6	12.8	16.5

NS

TABLE 9. Test of Language Production. Phonetic Inventory Task -- proportion of girls and boys refusing task at 18 and 24 months.

18 MONTH TEST SESSION		SEX: GIRLS	SEX: BOYS
REFUSAL[†]	yes	12	22
	no	10	5
		n = 22	n = 27

† Chi-Square = 4.4, 1 df, p = .04

24 MONTH TEST SESSION		SEX: GIRLS	SEX: BOYS
REFUSAL	yes	5	11
	no	17	16
		n = 22	n = 27

NS

TABLE 10. Test of Language Production. Phonetic Inventory Task -- means and standard deviations for number of errors at 30 months.

SCORE	GIRLS (n = 22) $\overline{X}$	GIRLS (n = 22) S.D.	BOYS (n = 27) $\overline{X}$	BOYS (n = 27) S.D.
Raw score (Errors)	8.0	8.6	9.8	10.6

NS

TABLE 11. Control Measure. Bayley Formboard -- means and standard deviations for performance time at 24 and 30 months.

SCORE	AGE (months)	GIRLS (n = 22)		BOYS (n = 27)	
		$\overline{X}$	S.D.	$\overline{X}$	S.D.
Time (secs.)	24	47.6	18.0	52.2	17.0
	30	33.9	7.3	32.6	5.3

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	67.34	.32
Error	47	211.75	
Age	1	6751.51	51.13*
Age x Sex	1	215.72	1.63
Error	47	132.06	

* $p < .001$

The Age x Sex interation was not significant. The Seguin formboard was administered at the 30 month testing only. An independent t-test revealed no sex differences (Table 12).

Supine length was measured at 24 and 30 months to monitor physical maturation. A one-way ANOVA, repeated measures, showed no differences between the sexes (Table 13). There was not a significant main effect for age. The analysis was performed on the percentile ranks and not on the absolute values of supine length; the absence of a main effect for age indicates that while the children were growing in length they did not change their percentile rank from 24 to 30 months. The Age x Sex interaction was not significant.

Independent t-tests to test for differences between the boys and girls in the number of years of maternal and paternal education (Table 14) were not statistically significant.

1.3 Motor Tests

Several measures of motor skill were made. No differences were found between the boys and girls on any of these measures.

For the manual dexterity test (Table 15), the Bayley pegboard (Table 16) and the Bayley gross motor inventory (Table 17) a one-way ANOVA for repeated measures

TABLE 12. Control Measure. Seguin Formboard -- means and standard deviations for performance time at 30 months.

		GIRLS (n = 21)		BOYS (n = 26)	
SCORE	AGE (months)	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Time/secs. (Max. = 90 sec.)	30	74.7	36.0	67.1	18.2

NS

TABLE 13. Control Measure. Supine Length -- means and standard deviations for percentile ranks at 24 and 30 months.

SCORE	AGE (months)	GIRLS (n = 22) $\overline{X}$	GIRLS (n = 22) S.D.	BOYS (n = 27) $\overline{X}$	BOYS (n = 27) S.D.
Percentile rank	24	63.8	21.2	72.7	24.9
	30	68.9	19.4	73.5	25.3

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	1097.78	1.09
Error	47	1005.13	
Age	1	220.66	3.64
Age x Sex	1	113.64	1.88
Error	47	60.60	

TABLE 14. Control Measure. Parental Education -- means and standard deviations for number of years of education past Grade 12.

SCORE	PARENT	GIRLS (n = 22) $\overline{X}$	GIRLS (n = 22) S.D.	BOYS (n = 27) $\overline{X}$	BOYS (n = 27) S.D.
Yrs. of education past Grade 12	Mother[a]	4.2	3.0	2.8	2.1
	Father[b]	5.7	4.0	4.5	3.8

a,b NS

TABLE 15. Test of Manual Motor Skill. Manual Dexterity Inventory -- means and standard deviations for accuracy of performance at 18, 24 and 30 months.

SCORE	TEST AGE (months)	GIRLS (n = 22)		BOYS (n = 27)	
		$\bar{X}$	S.D.	$\bar{X}$	S.D.
Accuracy	18	5.9	2.5	5.7	2.5
(Max. raw	24	12.3	3.3	11.0	2.9
score = 24)	30	17.9	3.1	16.7	2.5

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	28.30	1.77
Error	47	15.94	
Age	2	1603.35	400.06*
Age x Sex	2	4.17	1.04
Error	94	4.01	

* $p < .001$

TABLE 16. Test of Manual Motor Skill. Bayley Pegboard -- means and standard deviations for performance time at 18, 24 and 30 months.

		GIRLS (n = 22)		BOYS (n = 27)	
SCORE	TEST AGE (months)	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Time (secs.)	18	31.6	9.8	34.8	11.2
	24	20.6	4.3	23.1	4.4
	30	18.2	3.2	19.7	4.8

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	215.73	3.39
Error	47	63.55	
Age	2	2753.50	65.98*
Age x Sex	2	8.80	.21
Error	94	41.73	

* $p < .001$

TABLE 17. Bayley Gross Motor Inventory. Means and standard deviations for accuracy of performance at 18, 24 and 30 months.

SCORE	TEST AGE (months)	GIRLS (n = 22) $\overline{X}$	GIRLS (n = 22) S.D.	BOYS (n = 27) $\overline{X}$	BOYS (n = 27) S.D.
Accuracy	18	7.3	2.1	7.0	1.9
(Max. raw	24	13.1	3.3	11.9	3.1
score = 29)	30	17.9	3.8	17.9	3.5

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	7.24	.38
Error	47	19.10	
Age	2	1393.45	324.34*
Age x Sex	2	4.43	1.03
Error	94	4.30	

* $p < .001$

showed no sex differences and no Age x Sex interactions. There was a significant main effect for age for each test (Manual dexterity, Bayley pegboard, Bayley gross motor: $p < .001$) indicating improved performance with age.

The Archer mystery box test (Table 18) and the Annett peg moving test (Table 19) were used at the 24 and 30 month test sessions only. These tasks required separate performance by each hand; two scores, a right hand score and a left hand score, were obtained. For this analysis, which is concerned with motor skill and not laterality of performance, the best score regardless of the hand which achieved it, was used. A one-way ANOVA for repeated measures revealed no sex differences (Tables 18 and 19) for either test.

The bead stringing test was administered at the 30 month level only (Table 20). An independent t-test revealed no differences between the boys and the girls.

The oral motor test was given at 18, 24 and 30 months. At 18 months 29% of the sample, 4 of the girls (18%) and 10 of the boys (37%), refused to do the test. There were too many missing values to permit a valid comparison of the groups in terms of accuracy of performance. The number of refusals made by the boys was compared to the number of refusals made by the girls. A chi-square (Table 21) showed no difference between the sexes in terms of the

TABLE 18. Test of Manual Motor Skill. Archer Mystery Box -- means and standard deviations for performance time at 24 and 30 months.

SCORE	TEST AGE (months)	GIRLS (n = 17) X̄	GIRLS (n = 17) S.D.	BOYS (n = 25) X̄	BOYS (n = 25) S.D.
Time (secs.)	[illegible]	3.3	.62	3.3	.68
	30	2.6	.50	2.6	.42

SUMMARY OF REPEATED MEASURES ANOVA

Source of Variation	df	Mean Square	F
Sex	1	.01	.01
Error	40	.41	
Age	1	8.20	35.76*
Age x Sex	1	.00	.00
Error	40	.23	

* $p < .001$

TABLE 19. Test of Manual Motor Skill. Annett Peg Moving Test -- means and standard deviations for performance time at 24 and 30 months.

		GIRLS (n = 20)		BOYS (n = 24)	
SCORE	TEST AGE (months)	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Time (secs.)	24	30.5	7.0	33.9	6.41
	30	21.9	3.1	22.9	3.48

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df.	Mean Square	F
Sex	1	108.09	3.64
Error	42	29.67	
Age	1	2095.42	81.06*
Age x Sex	1	36.87	1.43
Error	42		

* $p < .001$

TABLE 20. Test of Manual Motor Skill. Bead Stringing Task -- means and standard deviations for performance time at 30 months.

		GIRLS (n = 22)		BOYS (n = 27)	
SCORE	TEST AGE (months)	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Time/secs. (Max. = 90 secs.)	30	35.0	22.38	40.4	22.89

NS

TABLE 21. Oral Motor Test. Proportion of girls and boys refusing the task at 18 months.

		SEX	
		GIRLS	BOYS
REFUSAL	yes	4	17
	no	18	10
		n = 22	n = 27

NS

number of refusals at 18 months. At 24 and 30 months a score was taken (Table 22) for correct reproduction of the stimuli. A one-way ANOVA for repeated measures was done; no sex differences were found. There was a significant main effect for age ($p < .001$), indicating increasing accuracy with age. The Age x Sex interaction was not significant.

1.4 Laterality Measures

No differences were found between the sexes for any of the preference or performance measures.

1.4.1 Preference Tests

For the hand preference inventory no differences were found between the sexes as determined by a one-way ANOVA, repeated measures analysis (Table 23). There was not a significant main effect for age nor was the Age x Sex interaction significant. A breakdown of the hand preference data in terms of the number of subjects at each age who could be classified as right handed (RH) or non-right handed (NRH) and the mean strength of right handedness or non-right handedness is shown in Table 24. The criterion of RH is a score of 80% or more; the criterion of NRH is a score of 18% or less. Although a greater percentage of boys fall into the NRH category at all ages, chi-square analyses showed no sex differences at any age.

TABLE 22. Oral Motor Test. Means and standard deviations for accuracy of performance at 24 and 30 months.

SCORE	TEST AGE (months)	GIRLS (n = 18)		BOYS (n = 22)	
		$\overline{X}$	S.D.	$\overline{X}$	S.D.
Accuracy (Max. raw score = 20)	24	7.6	3.96	6.6	3.41
	30	11.8	4.64	10.6	4.10

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	23.17	1.07
Error	38	21.69	
Age	1	342.92	31.99*
Age x Sex	1	.27	.02
Error	38	10.72	

* $p < .001$

TABLE 23. Hand Preference. Means and standard deviations for degree of right handedness at 18, 24 and 30 months.

SCORE	TEST AGE (months)	GIRLS (n = 22) $\overline{X}$	GIRLS (n = 22) S.D.	BOYS (n = 27) $\overline{X}$	BOYS (n = 27) S.D.
Degree of right handedness (%)	18	78.7	14.4	70.5	29.3
	24	79.5	22.0	69.4	28.3
	30	74.6	27.0	70.8	29.4

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Sex	1	1984.29	1.16
Error	47	1714.00	
Age	2	54.77	.35
Age x Sex	2	129.37	.82
Error	94	158.47	

TABLE 24. Hand Preference. Mean strength of Right Handedness[a] (RH) and Non-Right Handedness (NRH) and number of subjects for each sex who are RH or NRH at 18, 24 and 30 months.

TEST AGE (months)	GIRLS (n = 22) STRENGTH OF HANDEDNESS (expressed in percent)		BOYS (n = 27) STRENGTH OF HANDEDNESS (expressed in percent)	
	$\bar{X}$ RH	$\bar{X}$ NRH	$\bar{X}$ RH	$\bar{X}$ NRH
18	85.4 (n = 16, 73%)	61 (n = 6, 27%)	90.1 (n = 16, 59%)	41.8 (n = 11, 41%)
24	90.6 (n = 16, 73%)	50 (n = 6, 27%)	91.4 (n = 13, 48%)	49.0 (n = 14, 52%)
30	89.2 (n = 15, 68%)	43.3 (n = 7, 32%)	94.4 (n = 17, 59%)	36.5 (n = 10, 41%)

NS

a Right handedness defined as a score of 80% or greater, all others non-right handedness.

In Table 25 the data are tabulated in terms of the number of subjects of each sex who demonstrated a clear hand preference (i.e. RH, > 80 or NRH, < 18). A chi-square analysis of the 24 month data was not statistically significant.

The data for handedness stability are given in Table 26. A change in handedness (i.e. unstable handedness) was recorded if the hand preference score changed sufficiently from one age to the next to move the subject from the right-handed category (Score > 80) to the non-right handed category (Score < 80) or vice versa. From 18 to 30 months of age 13 (59%) girls and 18 (67%) boys remained unchanged in their handedness category. A chi-square analysis showed no differences between the sexes. Similarly, chi-square analyses performed for the 18 to 24 month and 24 to 30 month time periods showed no sex differences in degree of handedness stability.

Separate chi-square analyses were done for each sex to determine if handedness stability differed for the three time intervals. None of these comparisons were significant for the girls (Table 27) or the boys.

Independent t-tests were done for each sex to compare the language abilities of children with stable handedness from 18 to 30 months to the language abilities of children with unstable handedness over the same time period. For

TABLE 25. Hand Preference. Number of subjects displaying clear hand preference, i.e. RH > 80% or LH < 18%.

	GIRLS (n = 22)	BOYS (n = 27)
TEST AGE (months)	n (%)	n (%)
18	16 (73)	19 (70)
24	17 (77)	16 (59)
30	17 (77)	20 (74)

NS

TABLE 26. Hand Preference Stability. Proportion of girls and boys who changed hand preference category over 18 to 30 month, 18 to 24 month and 24 to 30 month time intervals.

TIME INTERVAL		HANDEDNESS Unchanged	Changed
18-30 months	Girls	13 (59%)	9 (41%) (n = 22)
	Boys	18 (67%)	9 (33%) (n = 27)
18-24 months	Girls	16 (73%)	6 (27%) (n = 22)
	Boys	22 (81%)	5 (19%) (n = 27)
24-30 months	Girls	17 (77%)	5 (23%) (n = 22)
	Boys	19 (70%)	8 (30%) (n = 27)

NS

TABLE 27. Hand Preference Stability. Comparisons of hand stability at the three time intervals for each sex.

TIME INTERVAL (months)	GIRLS (n = 22) HANDEDNESS	
	Unchanged	Changed
18-30 months	13 (59)	9 (41)
18-24 months	16 (73)	6 (27)
24-30 months	17 (77)	5 (23)

NS

TIME INTERVAL (months)	BOYS (n = 27) HANDEDNESS	
	Unchanged	Changed
18-30 months	18 (67)	9 (33)
18-24 months	22 (81)	5 (19)
24-30 months	19 (70)	8 (30)

NS

both girls (Table 28) and boys (Table 29) there was no difference between the stable and unstable groups in language production (MLU) and language reception (RDLS) at any of the ages.

The lateral preference inventory was given at 18, 24 and 30 months of age, but only the 30 month data were analyzed because of a lot of missing data at the other ages. There were no differences between the sexes in the degree of right-sidedness (independent t-test), or in the number of subjects showing a clear right preference (chi-square) as shown in Table 30.

The familial left handedness (FLH) data are given in Table 31. A chi-square analysis showed no difference between the boys and girls in the number of subjects with FLH. The number of subjects with consistent NRH from 18 to 30 months was tabulated for each sex in terms of FLH, but the numbers were too small for formal statistical analysis. A comparison (across sexes) of language production ability (MLU) at 30 months in terms of the presence (FLH+) or absence (FLH-) of familial left handedness showed that subjects with FLH were more likely to have MLU scores in the top half of the scores (Table 32). This was statistically significant ($p = .03$).

TABLE 28. Handedness stability in girls in relation to Reynell Developmental Language Scales (RDLS) scores and Mean Length of Utterance (MLU) scores at 18, 24 and 30 months.

GIRLS (n = 22)

TEST AGE (months)	HANDEDNESS Stable (n = 13)		Unstable (n = 9)	
	RDLS SCORES			
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
18	12.76	5.54	12.44	5.79
24	23.69	6.82	23.55	7.00
30	38.15	7.44	36.77	8.10

NS

TEST AGE (months)	Stable (n = 13)		Unstable (n = 9)	
	MLU SCORES			
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
18	1.25	.28	1.22	.29
24	2.02	.83	2.01	.68
30	2.48	.85	2.72	.77

NS

TABLE 29. Handedness stability in boys in relation to Reynell Developmental Language Scales (RDLS) scores and Mean Length of Utterance (MLU) scores at 18, 24 and 30 months.

BOYS (n = 27)

TEST AGE (months)	HANDEDNESS Stable (n = 18)		Unstable (n = 9)	
	RDLS SCORES			
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
18	9.72	3.80	8.11	3.29
24	21.05	6.35	17.00	3.84
30	34.38	4.21	31.22	4.26

NS

TEST AGE (months)	Stable (n = 18)		Unstable (n = 9)	
	MLU SCORES			
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
18	1.05	.09	1.04	.06
24	1.50	.48	1.27	.31
30	2.27	.74	1.96	.39

NS

TABLE 30. Lateral preference inventory at 30 months.

	GIRLS (n = 22)		BOYS (n = 27)	
	$\bar{X}$	S.D.	$\bar{X}$	S.D.
Degree of right sidedness (%)	73.5	28.9	67.8	33.3

NS

	GIRLS	BOYS
Subjects showing clear right preference (i.e. > 80% items done on right)	12 (54%)	15 (56%)
Subjects showing clear left preference (i.e. < 33% items done on left)	4 (18%)	6 (22%)

NS

TABLE 31. Number of girls and boys with Familial Left Handedness (FLH).

	GIRLS (n = 20)[a]	BOYS (n = 27)
Subjects with FLH	11 (55%)	7 (25%)
Origins of FLH:		
Parent	8	5
Mother only	6	0
Father only	2	4
Both parents	0	1
Sibling only	3	2
Parent and sibling	0	2

NS

Subjects stable non-right handedness (NRH) from 18 to 30 months	3	8
Number of NRH'ers with FLH	1	4

NS

a Two subjects who were adopted not included.

TABLE 32. Familial lefthandedness in relation to language production (MLU) at 30 months, tabulated across sexes.

	FLH+*	FLH-
Subjects in top half of MLU scores	12	11
Subjects in bottom half of MLU scores	6	20

* Chi-Square = 4.44, 1 df, p = .03

1.4.2 Performance Tests

There were no differences between the boys and girls on several tasks of manual motor function which recorded separate scores for the right and left hand. The tasks were the Bayley pegboard, the Archer mystery box, the Bayley formboard and the Annett peg moving task. For the statistical analysis the right hand and left hand scores were transformed to one score using the Laterality Quotient: R - L / R + L which results in a score range of -1 to +1, to represent strong left handedness, through strong right handedness, respectively.

A one-way ANOVA, repeated measures design, was performed for all the preceding tasks. No sex differences in laterality were found (Tables 33, 34, 35, 36). The main effect for age was not significant for any of these tasks, nor was the Sex x Age interaction.

For the manual dexterity inventory (Table 37) the data are expressed as a percentage of right handedness. A one-way ANOVA for repeated measures revealed no sex differences. There was not a significant main effect for age nor was the Sex x Age interaction significant.

Correlation matrices for the different measures of laterality are given for the girls and boys in Tables 38 and 39, respectively. For the girls (Table 38) there is a positive, but weak association between the different indices at each of the ages; the actual number of correlations

TABLE 33. Performance Measure of Laterality -- Bayley Pegboard. Mean right hand and left hand scores and mean Laterality Quotient (LQ) for girls and boys at 18, 24 and 30 months.

SCORE	TEST AGE (mos.)	GIRLS (n = 22)			BOYS (n = 27)		
		HAND		LQ $(\frac{R-L}{R+L})$	HAND		LQ $(\frac{R-L}{R+L})$
Accuracy (Max. Raw Score R + L = 18)		$\bar{X}$ (R)	$\bar{X}$ (L)		$\bar{X}$ (R)	$\bar{X}$ (L)	
	18	11.9	6.1	.32	12.1	5.8	.34
	24	11.4	6.6	.27	9.8	8.2	.09
	30	11.8	6.8	.24	11.4	6.6	.26

SUMMARY OF REPEATED MEASURES ANOVA:[a]

Source of Variation	df	Mean Square	F
Sex	1	.06	.14
Error	47	.46	
Age	2	.29	2.30
Age x Sex	2	.17	1.32
Error	94	.13	

a ANOVA performed on LQ scores

TABLE 34. Performance Measure of Laterality -- Annett Peg Moving. Mean right hand and left hand scores and mean Laterality Quotient (LQ) for girls and boys at 24 and 30 months.

SCORE Time (secs.)	TEST AGE (mos.)	GIRLS (n = 20)			BOYS (n = 24)		
		HAND		LQ $\left(\frac{R-L}{R+L}\right)$	HAND		LQ $\left(\frac{R-L}{R+L}\right)$
		$\overline{X}$ (R)	X (L)		$\overline{X}$ (R)	X (L)	
	24	32.0	36.9	-.07	35.3	37.7	-.03
	30	23.5	26.2	-.04	24.4	26.6	-.04

SUMMARY OF REPEATED MEASURES ANOVA:[a]

Source of Variation	df	Mean Square	F
Sex	1	.008	.53
Error	42	.015	
Age	1	.001	.17
Age x Sex	1	.009	1.18
Error	42	.008	

a ANOVA performed on LQ scores

TABLE 35. Performance Measure of Laterality -- Archer Mystery Box. Mean right hand and left hand scores and mean Laterality Quotient (LQ) for girls and boys at 24 and 30 months.

SCORE Time (secs.)	TEST AGE (mos.)	GIRLS (n = 17)			BOYS (n = 25)		
		HAND		LQ $\left(\frac{R-L}{R+L}\right)$	HAND		LQ $\left(\frac{R-L}{R+L}\right)$
		$\bar{X}$ (R)	$\bar{X}$ (L)		$\bar{X}$ (R)	$\bar{X}$ (L)	
	24	3.5	4.3	-.08	3.7	4.0	-.03
	30	2.9	3.4	-.07	2.8	3.1	-.06

SUMMARY OF REPEATED MEASURES ANOVA:[a]

Source of Variation	df	Mean Square	F
Sex	1	.020	.65
Error	40	.031	
Age	1	.002	.10
Age x Sex	1	.014	.78
Error	40	.018	

a ANOVA performed on LQ scores

TABLE 36. Performance Measure of Laterality -- Bayley Formboard. Mean right hand and left hand scores and mean Laterality Quotient (LQ) for girls and boys at 24 and 30 months.

SCORE	TEST AGE (mos.)	GIRLS (n = 21)			BOYS (n = 24)		
Accuracy (Max. score R + L = 18)		HAND $\bar{X}$ (R)	HAND $\bar{X}$ (L)	LQ $\left(\frac{R-L}{R+L}\right)$	HAND $\bar{X}$ (R)	HAND $\bar{X}$ (L)	LQ $\left(\frac{R-L}{R+L}\right)$
	24	12.8	5.2	.42	11.4	6.6	.26
	30	13.4	4.6	.46	13.4	4.6	.53

SUMMARY OF REPEATED MEASURES ANOVA:[a]

Source of Variation	df	Mean Square	F
Sex	1	.04	.05
Error	43	.90	
Age	1	.52	1.94
Age x Sex	1	.30	1.13
Error	43	.27	

a ANOVA performed on LQ scores

TABLE 37. Performance Measure of Laterality -- Manual Dexterity Inventory. Means and standard deviations for scores expressed as percentage of right handedness (RH), for girls and boys at 18, 24 and 30 months.

		GIRLS (n = 22)		BOYS (n = 27)	
SCORE	TEST AGE (mos.)	$\overline{X}$	S.D.	$\overline{X}$	S.D.
Degree of	18	74	25	65	24
Right handedness	24	74	18	70	22
(%)	30	76	16	76	22

SUMMARY OF REPEATED MEASURES ANOVA:[a]

Source of Variation	df	Mean Square	F
Sex	1	765.18	.92
Error	47	831.58	
Age	2	487.85	1.80
Age x Sex	2	236.14	.87
Error	94	271.34	

a ANOVA performed on LQ scores

TABLE 38. Significant Pearson Correlations for Laterality Variables for Girls. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	HAND1	PEGSLAT1	DEXLAT1	HAND2	PEGSLAT2	DEXLAT2	MYSTLAT1	ANNLAT1	FMEDLAT1	HAND3	PEGSLAT3	DEXLAT3	MYSTLAT2	ANNLAT2	FMEDLAT2	LATPREF3
HAND1																
PEGSLAT1	.40 (.032)															
DEXLAT1	.36 (.051)															
HAND2																
PEGLAT2			.50 (.009)													
DEXLAT2	.54 (.004)			.43 (.022)												
MYSTLAT1					-.60 (.005)											
ANNLAT1																
FMEDLAT1																
HAND3	.64 (.001)		.44 (.021)	.72 (.000)		.57 (.003)										
PEGSLAT3			.44 (.021)		.49 (.01)				.38 (.044)							
DEXLAT3	.69 (.000)		.38 (.039)	.69 (.000)		.51 (.007)				.85 (.000)						
MYSTLAT2							.40 (.054)									
ANNLAT2			.46 (.015)								.37 (.044)					
FMEDLAT2			.47 (.013)													
LATPREF3	.55 (.004)			.77 (.000)		.46 (.014)				.67 (.000)		.53 (.006)				

Abbreviations Used:

HAND1, 2, 3 = Hand preference at 18, 24 and 30 months
PEGSLAT1, 2, 3 = Bayley Pegboard (laterality) at 18, 24 and 30 months
DEXLAT1, 2, 3 = Manual dexterity inventory (laterality) at 18, 24 and 30 months
MYSTLAT1, 2 = Archer mystery box (laterality) at 24 and 30 months
ANNLAT1, 2 = Annett Peg Moving (laterality) at 24 and 30 months
FMEDLAT1, 2 = Bayley formboard at 24 and 30 months
LATPREF3 = Lateral preference inventory at 30 months.

and many of the "r" values are small. There is a consistent positive association between hand preference (HAND 1, 2, 3) and laterality in the manual dexterity inventory (DEXLAT 1, 2, 3) at all three ages, i.e. HAND1/DEXLAT1, r = .36; HAND2/DEXLAT2, r = .43; HAND3/DEXLAT3, r = .85.

There is slightly more association between the different measures for the boys if the actual number of significant correlations are counted (Table 39). Again the most consistent finding is between hand preference and laterality in the manual dexterity inventory.

2. Laterality in Relation to Age

For the Bayley pegboard, Annett peg moving, Bayley formboard and Archer mystery box tasks there were separate scores for each hand. Statistical analyses were done to determine whether one hand performed better than the other and whether this was consistent over time. A one-way ANOVA for hand (Right Hand x Left Hand), repeated measures design, was done for all the tests. Separate analyses were done for each sex. Both sexes showed a right hand effect for the Bayley pegboard and the Annett peg moving tasks. For the Bayley formboard only the boys achieved a right hand effect, while for the Archer mystery box test a right hand effect was only obtained for the girls.

TABLE 39. Significant Pearson Correlations for Laterality Variables for Boys. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	HAND1	PEGSLAT1	DEXLAT1	HAND2	PEGSLAT2	DEXLAT2	MYSTLAT1	ANNLAT1	FMEDLAT1	HAND3	PEGSLAT3	DEXLAT3	MYSTLAT2	ANNLAT2	FMEDLAT2	LATPREF3
HAND1																
PEGSLAT1																
DEXLAT1	.57 (.001)															
HAND2	.92 (.000)		.60 (.000)													
PEGLAT2		.48 (.005)														
DEXLAT2	.51 (.003)		.53 (.002)	.53 (.002)	-.37 (.029)											
MYSTLAT1	.4[illegible] (.016)		.58 (.001)	.39 (.027)												
ANNLAT1		.45 (.014)			.36 (.041)											
FMEDLAT1																
HAND3	.84 (.000)		.59 (.001)	.82 (.000)	-.38 (.025)	.57 (.001)	.45 (.012)									
PEGSLAT3	.35 (.037)	.39 (.021)	.33 (.048)	.43 (.012)		.43 (.012)	.38 (.030)			.43 (.012)						
DEXLAT3	.43 (.013)		.42 (.015)		-.36 (.032)	.36 (.033)				.53 (.002)						
MYSTLAT2																
ANNLAT2		.32 (.05)									.51 (.003)					
FMEDLAT2			.38 (.025)	.39 (.022)		.32 (.052)				.39 (.022)		.43 (.013)				
LATPREF3	.55 (.001)		.36 (.031)	.60 (.000)		.53 (.002)				.65 (.000)		.36 (.034)			.50 (.004)	

Abbreviations Used:

HAND1, 2, 3 = Hand preference at 18, 24 and 30 months
PEGSLAT1, 2, 3 = Bayley Pegboard (laterality) at 18, 24 and 30 months
DEXLAT1, 2, 3 = Manual dexterity inventory (laterality) at 18, 24 and 30 months
MYSTLAT1, 2 = Archer mystery box (laterality) at 24 and 30 months
ANNLAT1, 2 = Annett Peg Moving (laterality) at 24 and 30 months
FMEDLAT1, 2 = Bayley formboard at 24 and 30 months
LATPREF3 = Lateral preference inventory at 30 months.

There was a significant right hand effect on the Bayley pegboard (Figure 4 and Tables 40, 41) for both sexes (Girls: $p = .003$; Boys: $p = .004$). The main effect for age was not significant for either sex because of a ceiling effect. All subjects got the maximum score for peg placement at all ages. The Hand x Age interaction was not significant for girls; however, it was significant for the boys ($p = .02$) because of the almost equal performance of the two hands at 24 months.

For the peg moving task (Figure 5 and Tables 42, 43) a significant right hand effect was found for both sexes (Girls: $p = .021$; Boys: $p = .004$). There was a significant main effect for age for both girls ($p < .001$) and boys ($p < .001$) because they both did the task more quickly at each successive age. The Hand x Age interaction was not significant for either sex meaning that the degree of laterality did not change from 24 to 30 months.

Analysis of the scores from the Archer mystery box task revealed a significant right hand effect for the girls ($p = .028$) but not for the boys (Figure 6 and Tables 44, 45). There was a significant main effect for age for both sexes (Girls $p < .001$; Boys $p < .001$), while the interaction (Hand x Age) was not significant for either sex.

For the Bayley formboard (Figure 7 and Tables 46, 47) the boys obtained a significant right hand effect

Fig. 4 Bayley Pegboard

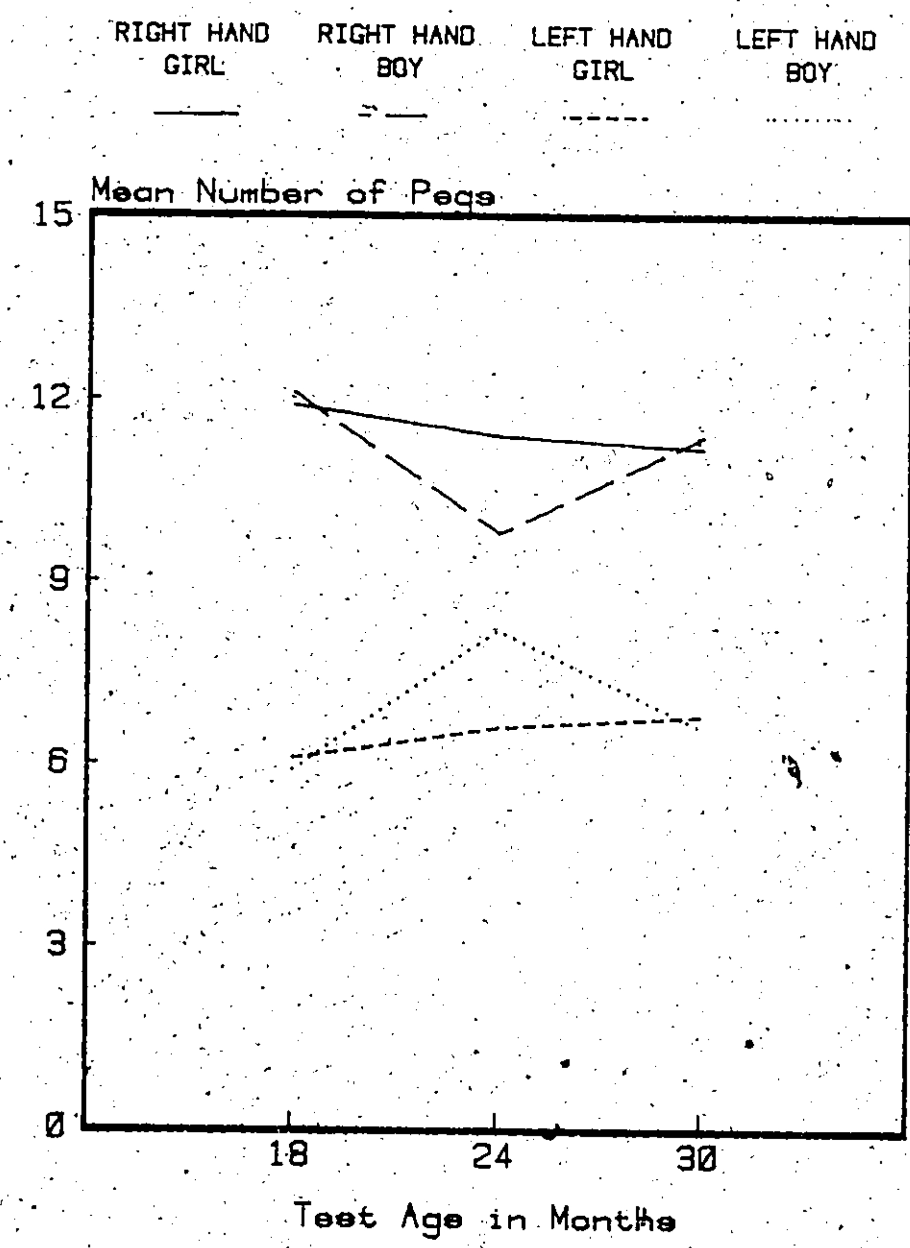

TABLE 40. Bayley Pegboard -- Girls (n = 22). Mean right hand and left hand scores at 18, 24 and 30 months.

Score	Test Age (mos.)	HAND $\bar{X}$ RIGHT	HAND $\bar{X}$ LEFT
Number of pegs placed by RH and LH (Total pegs = 18)	18	11.9	6.1
	24	11.4	6.6
	30	11.2	6.8

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Age	2	.00	.00
Error	42	.00	
Hand	1	815.03	11.25*
Error	21	72.43	
Hand x Age	2	5.30	.23
Error	42		

* p = .003

TABLE 41. Bayley Pegboard -- Boys (n = 27). Mean right hand and left hand scores at 18, 24 and 30 months.

Score	Test Age (mos.)	HAND $\bar{X}$ RIGHT	$\bar{X}$ LEFT
Number of pegs placed by RH and LH (Total pegs = 18)	18	12.1	5.9
	24	9.8	8.2
	30	11.4	6.6

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Age	2	.00	.00
Error	52	.00	
Hand	1	722.00	9.47**
Error	26	76.21	
Hand x Age	2	76.21	4.05*
Error	52	18.81	

* p = .02
** p = .005

Fig. 5 Annett Peg Moving

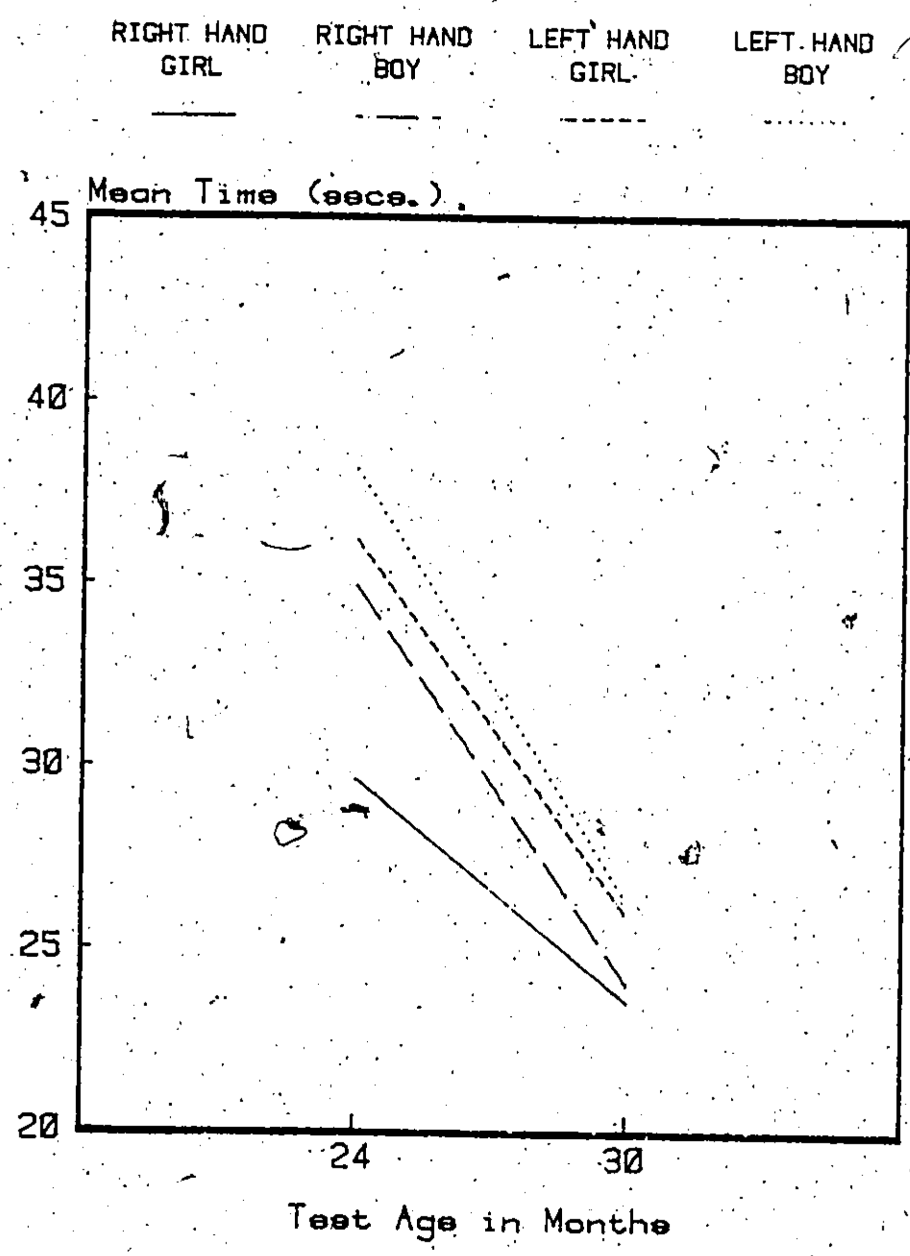

TABLE 42. Annett Peg Moving -- Girls (n = 17). Mean right hand and left hand scores at 24 and 30 months.

Score	Test Age (mos.)	HAND $\bar{X}$ RIGHT	$\bar{X}$ LEFT
Time (secs.)	24	29.62	36.19
	30	23.54	25.90

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Age	1	1138.98	50.40**
Error	16	22.60	
Hand	1	339.32	6.54*
Error	16	51.92	
Hand x Age	1	75.60	3.75
Error	16	20.17	

* $p = .02$
** $p < .001$

TABLE 43. Annett Peg Moving --- Boys (n = 22). Mean right hand and left hand scores at 24 and 30 months.

Score	Test Age (mos.)	HAND $\bar{X}$ RIGHT	HAND $\bar{X}$ LEFT
Time (secs.)	24	34.92	38.14
	30	24.03	26.33

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Age	1	2834.09	44.64**
Error	21	63.48	
Hand	1	167.48	10.48*
Error	21	15.98	
Hand x Age	1	4.64	.32
Error	21	14.56	

* $p = .004$
** $p < .001$

Fig. 6 Archer Mystery Box

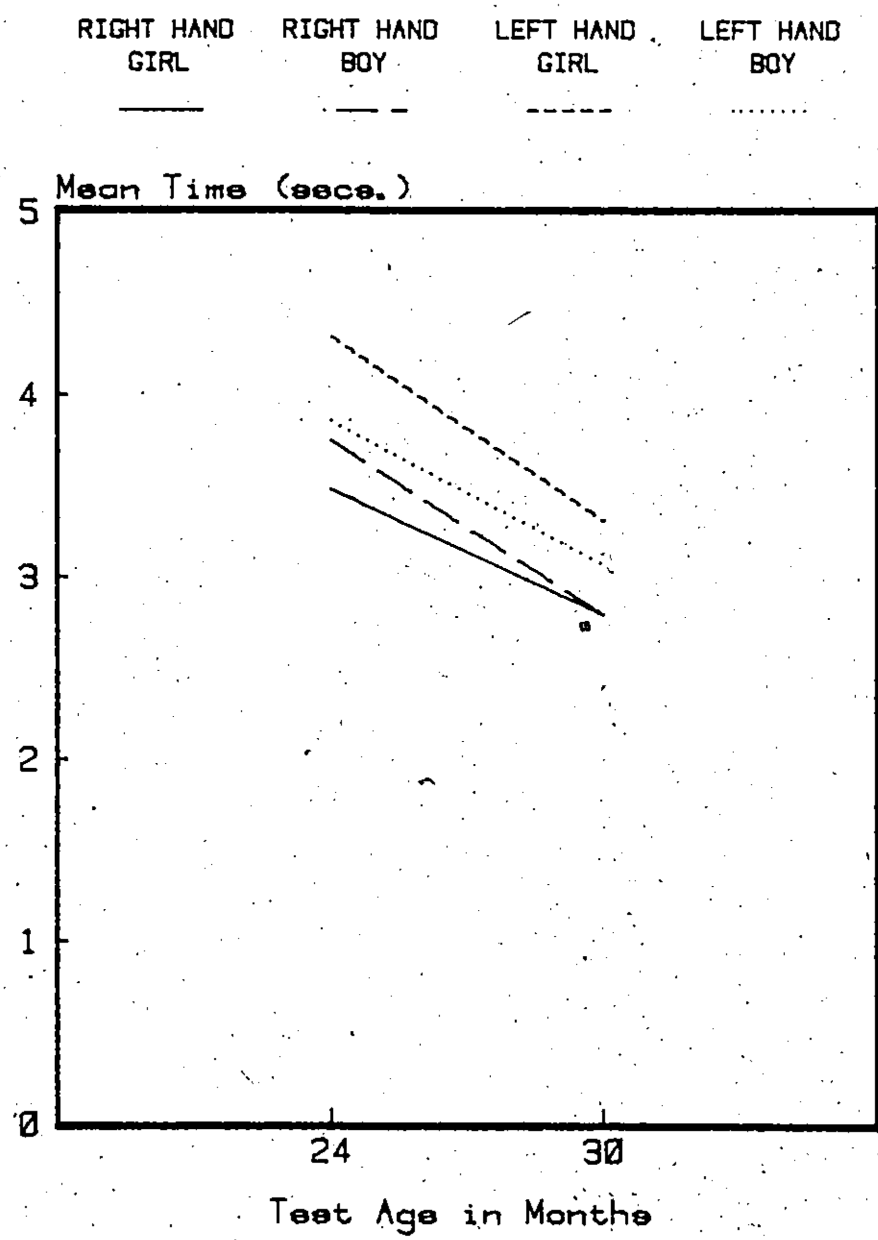

TABLE 44. Archer Mystery Box -- Girls (n = 17). Mean right hand and left hand scores at 24 and 30 months.

Score	Test Age (mos.)	HAND $\bar{X}$ RIGHT	$\bar{X}$ LEFT
Time (secs.)	24	3.48	4.32
	30	2.79	3.31

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Age	1	12.37	16.01**
Error	16	.77	
Hand	1	7.78	5.85*
Error	16	1.33	
Hand x Age	1	.46	.36
Error	16	.52	

* p = .03
** p = .001

TABLE 45. Archer Mystery Box -- Boys ($n = 22$). Mean right hand and left hand scores at 24 and 30 months.

Score	Test Age (mos.)	HAND $\bar{X}$ RIGHT	$\bar{X}$ LEFT
Time (secs.)	24	3.75	3.86
	30	2.79	3.07

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Age	1	16.76	20.68*
Error	21	.81	
Hand	1	.84	.74
Error	21	1.14	
Hand x Age	1	.15	.16
Error	21	.90	

* $p < .001$

Fig. 7 Bayley Formboard

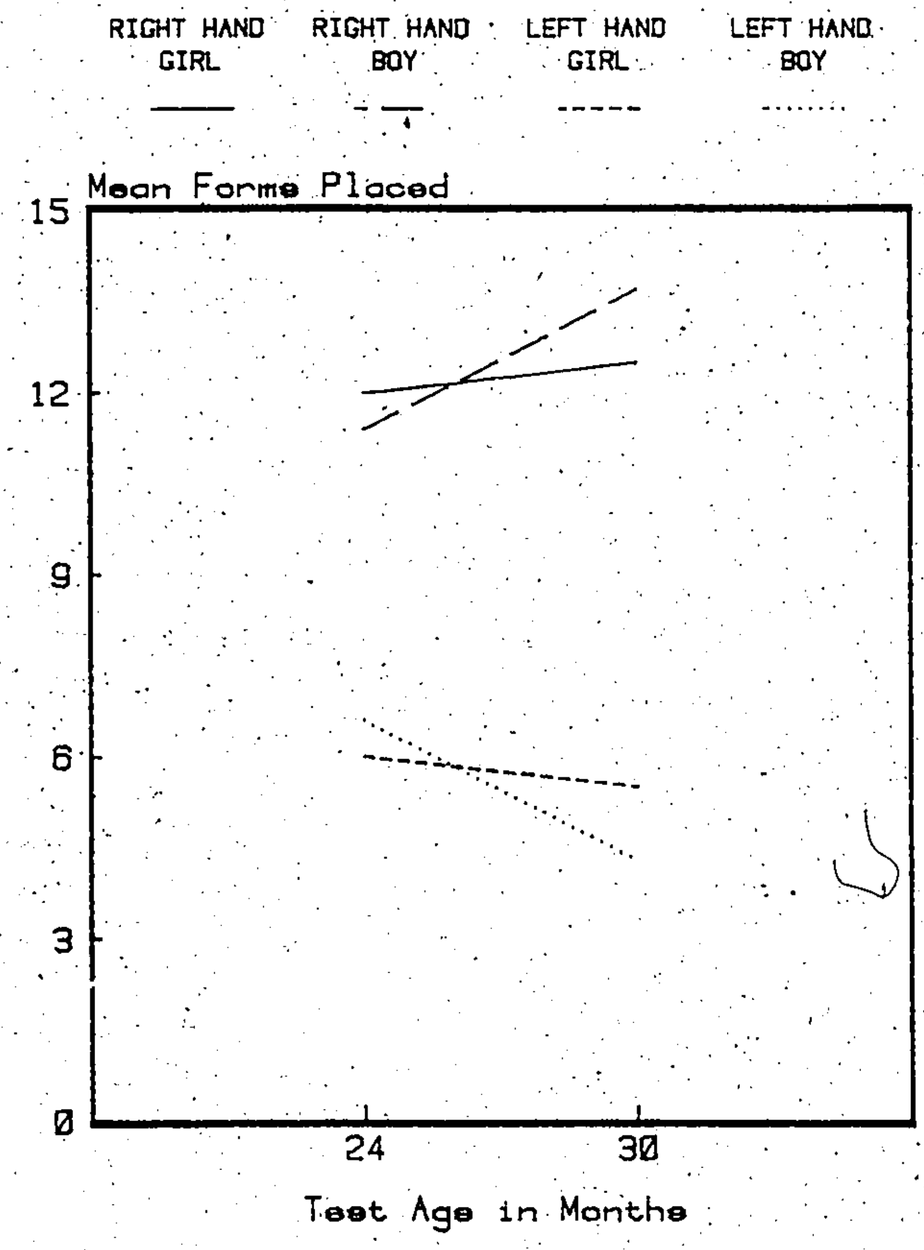

TABLE 46: Bayley FormBoard -- Girls (n = 17). Mean right hand and left hand scores at 24 and 30 months.

Score	Test Age (mos.)	HAND $\bar{X}$ RIGHT	$\bar{X}$ LEFT
Number of shapes placed by RH and LH (Total pegs = 18)	24	12.0	6.0
	30	12.5	5.5

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Age	1	.00	.00
Error	16	.00	
Hand	1	724.76	4.16
Error	16	174.14	
Hand x Age	1	4.76	.12
Error	16	40.64	

TABLE 47. Bayley Formboard -- Boys (n = 22). Mean right hand and left hand scores at 24 and 30 months.

Score	Test Age (mos.)	HAND $\bar{X}$ RIGHT	$\bar{X}$ LEFT
Number of shapes placed by RH and LH out of a total of 18	24	11.4	6.6
	30	13.7	4.3

SUMMARY OF REPEATED MEASURES ANOVA:

Source of Variation	df	Mean Square	F
Age	1	.00	.00
Error	21	.00	
Hand	1	1106.18	7.46*
Error	21	144.75	
Hand x Age	1	113.64	2.28
Error	21	49.73	

* p = .012

(p = .012), while a right hand effect for the girls approached but did not reach statistical significance (p = .058). There was not a main effect for age for either sex because all subjects obtained the maximum score for shape placement at both ages.

3. Relations Between Language Measures and Motor, Laterality and Control Measures

Pearson product-moment correlations were calculated separately for boys and girls to show the relations between:

a) Language reception and language production,
b) Language and motor skill,
c) Language and laterality,
d) Language and control variables.

In considering these correlations three types of questions were examined: 1) Do the variables in question correlate at a given age? 2) Do correlations found at 18 months persist at 24 and 30 months? 3) Is performance in one task at an early age related to performance in another task at a later age? For example: does manual motor ability at 18 months relate to language production at 24 months?

Part of the rationale for calculating the correlations, in addition to looking for significant relations between the scores, was to provide a basis for deciding the variables to be used in the regression analyses, which will be discussed in the next section. General patterns and trends will be attended to and less attention given to individual correlations.

3.1 Language Reception / Language Production Correlations

The girls' correlations (Table 48) show that language production and language comprehension are positively related at all three ages and that the "r" values are frequently high. AT 30 months there is an exception: total utterances (TOTUTT3) no longer correlates with PPVT and RDLS, although MLU continues to correlate with PPVT and RDLS.

The phonetic inventory (PHON30), a measure of speech articulatory ability, correlates only with measures of language production. Negative correlations are found in this instance because the phonetic inventory was scored for number of errors. Subjects who made fewer errors tended to obtain larger MLU's at 30 months, produce more utterances at 18 months (TOTUTT1) and 24 months (TOTUTT2) and more *different* utterances at 18 months (DIFFUTT1).

The majority of the 18 month measures, receptive and productive, correlate with the 24 and 30 month measures and the 24 month measures correlate with the 30 month variables.

TABLE 48. Significant Pearson Correlations for Language Variables for Girls. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	[illegible]	PPVT1	MLU1	TOTUTT1	DIFFUTT1	RDLS2	PPVT2	MLU2	TOTUTT2	RDLS3	PPVT3	MLU3	TOTUTT3	PHON30
[illegible]														
PPVT1	[illegible] (.000)													
MLU1	[illegible] (.023)	.49 (.01)												
TOTUTT1	.69 (.000)	.59 (.002)	.79 (.000)											
DIFFUTT1	.57 (.003)	.54 (.005)	.74 (.000)	.89 (.000)										
RDLS2	.84 (.000)	.78 (.000)	.42 (.025)	.62 (.001)	.51 (.007)									
PPVT2	.64 (.000)	.51 (.000)				.59 (.002)								
MLU2	.68 (.000)	.72 (.000)	.49 (.01)	.69 (.000)	.67 (.000)	.66 (.000)	.53 (.006)							
TOTUTT2	.65 (.001)	.65 (.001)	.44 (.02)	.54 (.005)	.52 (.006)	.65 (.001)	.70 (.000)	.67 (.000)						
RDLS3	.81 (.000)	.78 (.000)	.57 (.003)	.71 (.000)	.65 (.001)	.80 (.000)	.65 (.001)	.83 (.000)	.67 (.000)					
PPVT3	.74 (.000)	.65 (.000)	.46 (.015)	.59 (.002)	.54 (.005)	.74 (.000)	.60 (.002)	.76 (.000)	.47 (.013)	.86 (.000)				
MLU3	.68 (.000)	.70 (.000)	.39 (.035)	.61 (.001)	.48 (.01)	.61 (.001)	.63 (.001)	.81 (.000)	.74 (.000)	.72 (.000)	.69 (.000)			
TOTUTT3	.36 (.047)	.35 (.053)					.48 (.01)		.63 (.001)			-.46 (.016)		
PHON30				-.42 (.025)	-.37 (.044)				-.40 (.034)					

Abbreviations Used:

RDLS1, 2, 3 = Reynell Developmental Language Scales at 18, 24 and 30 months
PPVT1, 2, 3 = Peabody Picture Vocabulary Test at 18, 24 and 30 months
MLU1, 2, 3 = Mean length of utterance at 18, 24 and 30 months
TOTUTT1, 2, 3 = Number of total utterances at 18, 24 and 30 months
DIFFUTT1 = Number of different utterances at 18 months
PHON30 = Phonetic Inventory at 30 months

In contrast, for the boys (Table 49) there are fewer language production/language reception correlations within an age. At 18 months, TOTUTT1 and DIFFUTT1 correlate positively with RDLS1 and PPVT1. Mean length of utterance does not correlate with RDLS1 or PPVT1. This may be the result of limited variability in the MLU data at 18 months; at 18 months, 19 of the 27 boys had MLU's of 1.00. At 24 months, only one of four possible language production/language reception correlations is significant, i.e. MLU2/PPVT2, r = .45. Similarly, at 30 months the only significant correlation is TOTUTT3/RDLS3, r = .37.

Variables at one age are less likely to correlate with those at another age for the boys. Between 18 month variables and 24 and 30 month variables there are three significant correlations out of a possible forty-five; the "r" values are moderately low. There is more continuity between the 24 and 30 month variables -- seven significant correlations out of a possible sixteen.

The phonetic inventory (scored for number of errors) correlates negatively with mean length of utterance at 30 months (MLU3) and total number of utterances at 30 months (TOTUTT3). Performance on the PPVT at 24 months (PPVT2) also correlates negatively with the phonetic inventory.

TABLE 49. Significant Pearson Correlations for Language Variables for Boys. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	RDLS1	PPVT1	MLU1	TOTUTT1	DIFFUTT1	RDLS2	PPVT2	MLU2	TOTUTT2	RDLS3	PPVT3	MLU3	TOTUTT3	PHON30
RDLS1														
PPVT1	.33 (.045)													
MLU1														
TOTUTT1	.41 (.017)	.46 (.008)	.51 (.003)											
DIFFUTT1	.38 (.025)	.49 (.005)	.51 (.003)	.97 (.000)										
RDLS2		.51 (.003)												
PPVT2						.38 (.026)								
MLU2				.44 (.011)	.52 (.003)		.45 (.009)							
TOTUTT2														
RDLS3							.30 (.024)	.35 (.037)						
PPVT3		.54 (.002)				.38 (.025)	.51 (.003)			.66 (.000)				
MLU3				.33 (.045)	.41 (.018)	.38 (.024)	.48 (.006)	.62 (.000)						
TOTUTT3									.49 (.000)	-.37 (.027)				
PHON30							-.36 (.034)					-.46 (.008)	-.38 (.027)	

Abbreviations Used:

RDLS1, 2, 3	= Reynell Developmental Language Scales at 18, 24 and 30 months
PPVT1, 2, 3	= Peabody Picture Vocabulary Test at 18, 24 and 30 months
MLU1, 2, 3	= Mean length of utterance at 18, 24 and 30 months
TOTUTT1, 2, 3	= Number of total utterances at 18, 24 and 30 months
DIFFUTT1	= Number of different utterances at 18 months
PHON30	= Phonetic Inventory at 30 months.

3.2 Language/Motor Skill Correlations

There are four significant language/motor skill correlations for the girls at 18 months (Table 50). There is only one significant language production/manual motor skill correlation, i.e. MLU1/PEGS1, r = -.48. The negative correlation means that as MLU increases, performance time on the Bayley pegboard decreases. At 24 months, six significant language production/manual skill correlations are found; at 30 months there are significant correlations between the number of total utterances (TOTUTT3) and performance on the Bayley pegboard (PEGS3), and the Annett peg moving task (ANNETT2). There is no association at 30 months between mean length of utterance (MLU3) and manual motor skill.

Gross motor function correlates positively in a number of instances with language production and language reception, both within an age and across ages. Most correlations occur between language measures and gross motor function at 24 months (GROSS2).

The oral motor task at 30 months (ORAL30) correlates positively with language reception at 30 months (i.e. RDLS3 and PPVT3) but not with language production at 30 months.

All 18 month language measures correlate positively with the oral motor task at 30 months, at 24 months there is one significant correlation, i.e. RDLS2/ORAL30, r = .56.

TABLE 50. Significant Language/Motor Skill Pearson Correlations for Girls. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	RDLS1	PPVT1	MLU1	TOTUTT1	DIFFUTT1	RDLS2	PPVT2	MLU2	TOTUTT2	RDLS3	PPVT3	MLU3	TOTUTT3	PHON30
MANDEX1	.61 (.001)	.56 (.003)				.64 (.001)	.63 (.001)	.43 (.002)	.39 (.037)	.66 (.000)	.47 (.013)	.37 (.046)		
PEGS1			-.48 (.011)							-.40 (.03)				
GROSS1				.43 (.023)				.44 (.02)						
MANDEX2	.40 (.034)	.64 (.001)	.38 (.04)			.46 (.015)	.48 (.011)	.62 (.001)	.67 (.000)		.49 (.010)	.71 (.000)		
PEGS2		-.41 (.03)	-.43 (.02)		-.38 (.04)		-.47 (.014)		-.58 (.002)	-.40 (.033)		.40 (.034)	-.73 (.000)	
MYSTER1														.48 (.025)
ANNETT1	-.52 (.009)	-.51 (.011)		-.39 (.045)		-.60 (.002)	-.47 (.018)		-.58 (.004)	-.56 (.006)		-.47 (.018)	-.38 (.051)	
GROSS2	.38 (.04)			.38 (.043)			.62 (.001)	.55 (.004)	.47 (.014)	.51 (.007)		.54 (.005)	.48 (.012)	
ORAL24	.50 (.017)													
MANDEX3														
PEGS3	-.48 (.011)					-.35 (.05)	-.57 (.003)		-.65 (.001)	-.45 (.018)			-.62 (.001)	
MYSTER2									-.45 (.018)					.40 (.031)
ANNETT2									-.53 (.006)				-.44 (.019)	
GROSS3	.36 (.051)			.51 (.008)										
BEADS	-.45 (.017)	-.56 (.003)	-.38 (.041)			-.64 (.001)			-.36 (.048)	-.54 (.004)	-.43 (.023)			
ORAL30	.60 (.003)	.50 (.013)	.38 (.048)	.48 (.017)	.45 (.022)	.56 (.005)				.42 (.032)	.45 (.022)			

Abbreviations Used:

MANDEX1, 2, 3 = Manual dexterity inventory at 18, 24 and 30 months
PEGS1, 2, 3 = Bayley pegboard at 18, 24, and 30 months
GROSS1, 2, 3 = Bayley gross motor inventory at 18, 24 and 30 months
MYSTER1, 2 = Archer mystery box at 24 and 30 months
ANNETT1, 2 = Annett peg moving at 24 and 30 months
ORAL24, 30 = Oral motor test at 24 and 30 months
BEADS = Bead stringing task (given only at 30 months)

The relation between manual motor skill at an early age and later language performance was also examined. Manual dexterity at 18 months (MANDEX1) correlates moderately highly with all the language variables at 24 months and with three of the five variables at 30 months. Bayley pegboard performance at 18 months (PEGS1) correlates only with the RDLS at 30 months. There are a number of correlations between manual motor skill at 24 months and language performance at 30 months: manual dexterity (MANDEX2), Bayley pegs (PEGS2) and Annett peg moving (ANNETT2) correlate with mean length of utterance at 30 months and PEGS2 and ANNETT2 correlate with the total number of utterances at 30 months (TOTUTT3).

There are no significant language production/manual motor skill correlations for the boys (Table 51) at 18 months. There is a significant negative correlation between performance on the PPVT1 (a measure of language reception) and the Bayley pegs (PEGS1); boys who had higher scores on the PPVT1 tended to do the PEGS1 task more quickly.

At 24 months, there is only one significant language production/manual motor correlation out of a possible 12. Performance on the mystery box (MYSTER1) correlates positively with MLU2. Boys who took longer to do the mystery box had higher MLU's.

TABLE 51. Significant Language/Motor Skill Pearson Correlations for Boys. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	RDLS1	PPVT1	MLU1	TOTUTT1	DIFFUTT1	RDLS2	PPVT2	MLU2	TOTUTT2	RDLS3	PPVT3	MLU3	TOTUTT3	PHON30
MANDEX1										.34 (.043)				
PEGS1		-.41 (.018)												
GROSS1		.38 (.025)	.49 (.005)	.51 (.004)	.51 (.003)									
MANDEX2		.36 (.032)				.40 (.018)					-.34 (.041)			
PEGS2		-.35 (.035)								-.33 (.048)	-.35 (.035)		.33 (.045)	
MYSTER1	.39 (.027)				.39 (.027)		.42 (.019)	.69 (.000)				.35 (.042)		
ANNETT1													.42 (.022)	
GROSS2			.49 (.004)											
ORAL24														
MANDEX3					.32 (.052)					.44 (.016)				
PEGS3											-.40 (.020)			
MYSTER2							.35 (.036)	.38 (.026)				.55 (.002)		
ANNETT2									-.32 (.052)					
GROSS3			.54 (.002)		.34 (.04)			.38 (.024)		.36 (.03)				
BEADS										-.36 (.035)	-.33 (.046)			
ORAL30													-.34 (.046)	

Abbreviations Used:

MANDEX1, 2, 3 = Manual dexterity inventory at 18, 24 and 30 months
PEGS1, 2, 3 = Bayley pegboard at 18, 24, and 30 months
GROSS1, 2, 3 = Bayley gross motor inventory at 18, 24 and 30 months
MYSTER1, 2 = Archer mystery box at 24 and 30 months
ANNETT1, 2 = Annett peg moving at 24 and 30 months
ORAL24, 30 = Oral motor test at 24 and 30 months
BEADS = Bead stringing task (given only at 30 months)

At 30 months, again the only significant language production/manual motor skill correlation is the positive correlation between mystery box performance (MYSTER2) and MLU. There are 4 out of a possible 10 significant correlations between manual skill and language comprehension.

The oral motor task was scored at 24 and 30 months. There is only one significant correlation and tha is at 30 months, ORAL30/TOTUTT3, r = -.34.

For boys there is little relation between motor function measured at 18 months and language ability at 24 and 30 months; no significant correlations are found at 24 months and one only at 30 months (MANDEX1/RDLS3, r = .34). There are six significant correlations between tests of motor function at 24 months and tests of language ability at 30 months; in all cases the correlations are low and the highest (ANNETT1/TOTUTT3) was only r = .42.

Gross motor function correlates with measures of language production and language reception at all ages. In contrast to the girls the number of correlations are fewer and there is only one significant correlation with 24 month gross motor function.

3.3 Language/Laterality Correlations

Two scoring systems were used for the laterality measures. The hand preference, lateral preference and manual dexterity inventories were scored for percentage of right handedness. Lower scores mean weak right handedness, or strong left handedness. For all the other measures scores range from 0 to 1. Scores of 1 mean strong left or right handedness, while scores of 0 mean weak right or left handedness.

A total absence of significant correlations between language measures and laterality measures at 18 and 30 months is a striking feature of the girls' results (Table 52). At 24 months a small number of significant correlations are found; half are negative correlations (i.e. MLU2/MYSTLAT1; PPVT2/FMBDLAT1) and half are positive correlations (i.e. MLU2/PEGSLAT1; PPVT2/ANNLAT1). The negative correlations mean that language proficiency increases as the degree of laterality decreases (i.e. weak right or left preference) or vice versa; the positive correlations mean that language proficiency increases as the degree of laterality increases (i.e. strong right or left preference).

There is little relationship between measures of laterality at 18 months and language ability at 24 and 30 months, and little association between laterality at 24 months and language function at 30 months.

For the boys (Table 53), at 18 months a number of significant correlations, all negative, are found. The negative correlations with hand preference, lateral preference (LATPREF30) and manual dexterity (MANDEX) mean

TABLE 52. Significant Language/Laterality Pearson Correlations for Girls. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	RDLS1	PPVT1	MLU1	TOTUTT1	DIFFUTT1	RDLS2	PPVT2	MLU2	TOTUTT2	RDLS3	PPVT3	MLU3	TOTUTT3	PHON30
HAND1														
PEGSLAT1							.39 (.037)							
DEXLAT1														
HAND2			-.42 (.027)										-.36 (.05)	
PEGLAT2		.43 (.022)		.44 (.019)	.39 (.034)			.48 (.012)				.37 (.045)		-.37 (.035)
DEXLAT2			-.43 (.025)											
MYSTLAT1			-.47 (.03)	-.51 (.018)	-.47 (.027)			-.50 (.021)						
ANNLAT1			.38 (.049)					.45 (.023)			.45 (.022)			
FMEDLAT1							-.37 (.049)							
HAND3														
PEGSLAT3														
DEXLAT3														
MYSTLAT2														
ANNLAT2														
FMEDLAT2														
LATPREF3			-.36 (.047)											

Abbreviations Used:

HAND1, 2, 3	= Hand preference at 18, 24 and 30 months
PEGSLAT1, 2, 3	= Bayley Pegboard (laterality) at 18, 24 and 30 months
DEXLAT1, 2, 3	= Manual dexterity inventory (laterality) at 18, 24 and 30 months
MYSTLAT1, 2	= Archer mystery box (laterality) at 24 and 30 months
ANNLAT1, 2	= Annett Peg Moving (laterality) at 24 and 30 months
FMEDLAT1, 2	= Bayley formboard at 24 and 30 months
LATPREF3	= Lateral preference inventory at 30 months
RDLS1, 2, 3	= Reynell Developmental Language Scales at 18, 24 and 30 months
PPVT1, 2, 3	= Peabody Picture Vocabulary Test at 18, 24 and 30 months
MLU1, 2, 3	= Mean length of utterance at 18, 24 and 30 months
TOTTUT1, 2, 3	= Number of total utterances at 18, 24 and 30 months
DIFFUTT1	= Number of different utterances at 18 months
PHON30	= Phonetic inventory at 30 months

TABLE 53. Significant Language/Laterality Pearson Correlations for Boys. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	RDLS1	PPVT1	MLU1	TOTUTT1	DIFFUTT1	RDLS2	PPVT2	MLU2	TOTUTT2	RDLS3	PPVT3	MLU3	TOTUTT3	PHON30
HAND1			-.45 (.009)											
PEGSLAT1														
DEXLAT1		-.43 (.013)	-.47 (.006)	-.64 (.000)	-.65 (.000)									
HAND2		-.44 (.011)	-.36 (.034)	-.36 (.034)	-.35 (.037)	-.40 (.019)							-.35 (.035)	
PEGLAT2														
DEXLAT2		-.38 (.024)		-.74 (.000)	-.73 (.000)	-.45 (.009)	-.45 (.01)	-.61 (.000)		-.44 (.01)	-.55 (.002)	-.46 (.007)		
MYSTLAT1														
ANNLAT1														
FMBDLAT1								.40 (.028)						
HAND3			-.34 (.039)	-.48 (.006)	-.45 (.009)								-.34 (.043)	
PEGSLAT3						-.43 (.012)	-.46 (.007)							
DEXLAT3			-.39 (.022)	-.34 (.043)										
MYSTLAT2				-.34 (.042)										-.33 (.045)
ANNLAT2													-.37 (.029)	
FMBDLAT2			-.39 (.023)	-.49 (.005)	-.52 (.003)			-.33 (.046)						
LATPREF3		-.40 (.019)	-.36 (.031)	-.36 (.051)	-.36 (.051)									

Abbreviations Used:

HAND1, 2, 3	= Hand preference at 18, 24 and 30 months
PEGSLAT1, 2, 3	= Bayley Pegboard (laterality) at 18, 24 and 30 months
DEXLAT1, 2, 3	= Manual dexterity Inventory (laterality) at 18, 24 and 30 months
MYSTLAT1, 2	= Archer mystery box (laterality) at 24 and 30 months
ANNLAT1, 2	= Annett Peg Moving (laterality) at 24 and 30 months
FMBDLAT1, 2	= Bayley formboard at 24 and 30 months
LATPREF3	= Lateral preference Inventory at 30 months
RDLS1, 2, 3	= Reynell Developmental Language Scales at 18, 24 and 30 months
PPVT1, 2, 3	= Peabody Picture Vocabulary Test at 18, 24 and 30 months
MLU1, 2, 3	= Mean length of utterance at 18, 24 and 30 months
TOTUTT1, 2, 3	= Number of total utterances at 18, 24 and 30 months
DIFFUTT1	= Number of different utterances at 18 months
PHON30	= Phonetic Inventory at 30 months

that the boys who score higher on language tests have a mixed hand preference or are strongly left handed. The negative correlations with the other measures mean boys with high language scores have a mixed handedness but are not strongly left handed. There is a similar pattern at 24 and 30 months, but there are fewer correlations.

There is no relation between laterality at 18 months and language ability at 24 and 30 months, but there is some association (negative) between 24 month laterality and language ability at 30 months.

In summation, there is some evidence to suggest that laterality may be a factor in the language ability of boys.

3.4 Language/Descriptor and Control Variable Correlations

Birth order correlates positively with language function at all ages for the girls (Table 54). First born girls obtain higher language scores than girls who are not first born. Conversely, for the boys (Table 55) there is little relationship between birth order and language ability. There is one significant correlation at 18 months, and one at 30 months; both have very low "r" values.

Performance on the Bayley formboard at 30 months correlates negatively with language function at all ages for the girls (Table 54). Language performance improves as performance time on the formboard decreases. The Seguin

TABLE 54. Significant Language/Descriptor and Control Variables Pearson Correlations for Girls. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	RDLS1	PPVT1	MLU1	TOTUTT1	DIFFUTT1	RDLS2	PPVT2	MLU2	TOTUTT2	RDLS3	PPVT3	MLU3	TOTUTT3	PHON30
BIRTH ORDER	.52 (.066)	.39 (.037)	.59 (.002)	.59 (.002)	.44 (.019)		.37 (.046)	.44 (.021)	.54 (.005)	.39 (.037)	.36 (.048)	.50 (.008)	.53 (.006)	-.45 (.017)
FMBD1													-.66 (.000)	
FMBD2	-.39 (.037)	-.67 (.000)	-.43 (.024)	-.40 (.033)	-.45 (.017)	-.43 (.02[illegible]		-.38 (.039)	-.66 (.000)	-.45 (.017)		-.47 (.014)	-.52 (.007)	
SEGUIN		-.52 (.008)				-.45 (.001)	-.38 (.044)	-.47 (.016)	-.53 (.007)	-.47 (.017)	-.44 (.024)	-.62 (.001)		.42 (.03)
HT1														
HT2														
EDUCMOT	.40 (.033)	.40 (.034)	.56 (.003)	.51 (.008)					.35 (.053)			.36 (.051)		-.45 (.018)
EDUCFA			.37 (.044)	.42 (.026)		.36 (.050)								

Abbreviations Used:

FMBD1, 2 = Bayley formboard at 24 and 30 months
HT1, 2 = Height at 24 and 30 months
SEGUIN = Seguin formboard (given only at 30 months)
EDUCMOT = Maternal education
EDUCFA = Paternal education

TABLE 55. Significant Language/Descriptor and Control Variables Pearson Correlations for Boys. Significance levels in brackets; tests given at 18, 24 and 30 months represented by the numerals 1, 2 and 3, respectively, and by boundary markers.

	ROLS1	PPVT1	MLU1	TOTUTT1	DIFFUTT1	ROLS2	PPVT2	MLU2	TOTUTT2	ROLS3	PPVT3	MLU3	TOTUTT3	PHON30
BIRTH ORDER	.34 (.044)													-.36 (.032)
FMBD1														
FMBD2			.32 (.051)	.38 (.026)	.33 (.046)									
SEGUIN														
HT1										.33 (.046)	.37 (.03)			
HT2										.36 (.033)				
EDUCMOT		.38 (.027)	-.32 (.053)								.49 (.005)			
EDUCFA	.35 (.035)					.51 (.004)	.51 (.003)	.32 (.053)		.41 (.017)		.36 (.034)		

Abbreviations Used:

FMBD1, 2	= Bayley formboard at 24 and 30 months
HT1, 2	= Height at 24 and 30 months
SEGUIN	= Seguin formboard (given only at 30 months)
EDUCMOT	= Maternal education
EDUCFA	= Paternal education

formboard, administered only at 30 months, correlates negatively with language function at 24 and 30 months. For the boys there is no association between Seguin formboard performance and language ability, and very little association between language function and performance on the Bayley formboard (Table 55).

Height and language are not associated at any age for the girls (Table 54). For the boys height at 24 and 30 months correlates positively with language reception at 30 months. At 30 months, the taller boys score higher on measures of language reception (Table 55).

Maternal education relates positively to the girls' receptive and productive language function at 18 months and to language production at 30 months (Table 54). Thus, girls' skill in language function increases as the number of years of maternal education increases. Paternal education relates less strongly to verbal functions in girls. There is some correlation with the 18 month language measures, and the RDLS at 24 months, but no significant correlations at 30 months. Paternal education is the variable which correlates consistently with language ability in the boys at all ages (Table 55). The two are positively correlated -- with an increase in the number of years of paternal education there is an increase in language proficiency. There is a minimal relation between maternal education and language function in boys.

4. Explanation and Prediction of Language Production Ability

4.1 Introduction to Multiple Regression Analysis

In the preceding section the Pearson product-moment correlations were given. The correlation coefficient "r" describes the degree of association between two independent variables; it does not distinguish between an independent and dependent variable. The interpretations that can be made from the correlation coefficient and the potential for testing models of language acquisition is limited.

A more rigorous statistical procedure is the multiple regression analysis (Pedhazur, 1982). This statistic tests for the relationship of a single dependent variable (Y) to two or more independent variables (X_1, X_2 .... X_n). With a multiple regression analysis it is possible to control for the influence the independent variables may have on each other and how this in turn may influence the dependent variable. The multiple regression analysis generates a squared multiple correlation coefficient, R^2, which ". . . measures the strength of the linear relationship between X and Y" (Kleinbaum and Kupper, 1978, p. 76). The R^2 permits one to make statements about what percentage of the variance in the dependent variable can be attributed to the independent variable(s). Explanatory or predictive inferences can then be made (Pedhazur, 1982). However, it is important to note that causal inferences cannot be drawn (Kleinbaum and Kupper, 1978).

Various variable selection procedures are possible with a multiple regression analysis, the two main ones being the stepwise procedure and the hierarchical procedure (Cohen and Cohen, 1975; Pedhazur, 1982). With the stepwise procedure the order the independent variables are entered into the equation is determined by a computer program which selects the independent variables in order of decreasing relationship to the dependent variable. Cohen and Cohen (1975) discuss the various shortcomings of the stepwise procedure and stress that it only be used -- and with reserve -- to make predictive inferences. They note that the procedure fosters atheoretical statistical analysis in that the computer, and not the experimenter, decides the independent variables to be related to the dependent variables.

With the hierarchical procedure the order in which the independent variables are entered into the equation is determined by the experimenter, based on the hypotheses which are being tested. With this procedure the amount of the variance accounted for by each independent variable in the equation may be altered depending on the influence of the other independent variables. This procedure is recommended when the goal of the experiment is explanatory.

4.2 Explanation of Expressive Language Ability

Multiple regression analyses using a hierarchical design were done to examine how much of the variance of the dependent variable would be accounted for by three independent variables which related to the hypotheses of the study. Therefore, the independent variables manual dexterity (accuracy), manual dexterity (laterality) and the Reynell Developmental Language Scales -- representing manual motor skill, laterality and language reception, respectively, were regressed upon the dependent variable, mean length of utterance (MLU) which is a measure of expressive language ability.

Stepwise regressions were done first; using the results the hierarchical analyses were done. The independent variables were put into the equation in the reverse order to what had been generated with the stepwise regressions, i.e. the independent variable which accounted for most of the variation of the dependent variable (as determined by the stepwise procedure) was entered into the equation last. This procedure is designed to counteract multicollinearity (i.e. intercorrelation) between the independent variables which can lead to misleading results (Cohen, 1977). Separate regressions were done for each age and each sex.

Girls: The results are given in Figure 8 and Table 56. At 18 months, with all the variables in the equation, 29% of the total variance in MLU is accounted for. Receptive language ability (RDLS) accounts for 12% of the variance and this is statistically significant ($p = .05$). At 24 months, over half of the variance in MLU, 57%, is accounted for by the three variables in the equation. Examination of the change in R^2 reveals that manual dexterity skill accounts for 39% of the variance ($p = .01$) while language receptive ability accounts for 15% ($p = .01$). There is little change from 24 to 30 months in terms of the total amount of variance accounted for by the three variables. However, there is a major change in the breakdown of this variance with RDLS accounting for 48% of the variance; this is highly significant ($p = .0005$).

In summation from 18 to 30 months there is a steady increase in the amount of variance in language production which is accounted for. At 18 months 12% of the total variance is explained, at 24 months 54% is explained and at 30 months 48% is explained. With the exception of the 24 month analysis when manual motor skill was the main explanatory variable (although language reception still explained 15% of the variance), at 18 and 30 months language reception is the major explanatory variable.

Fig. 8 Regression Analysis (Girls)

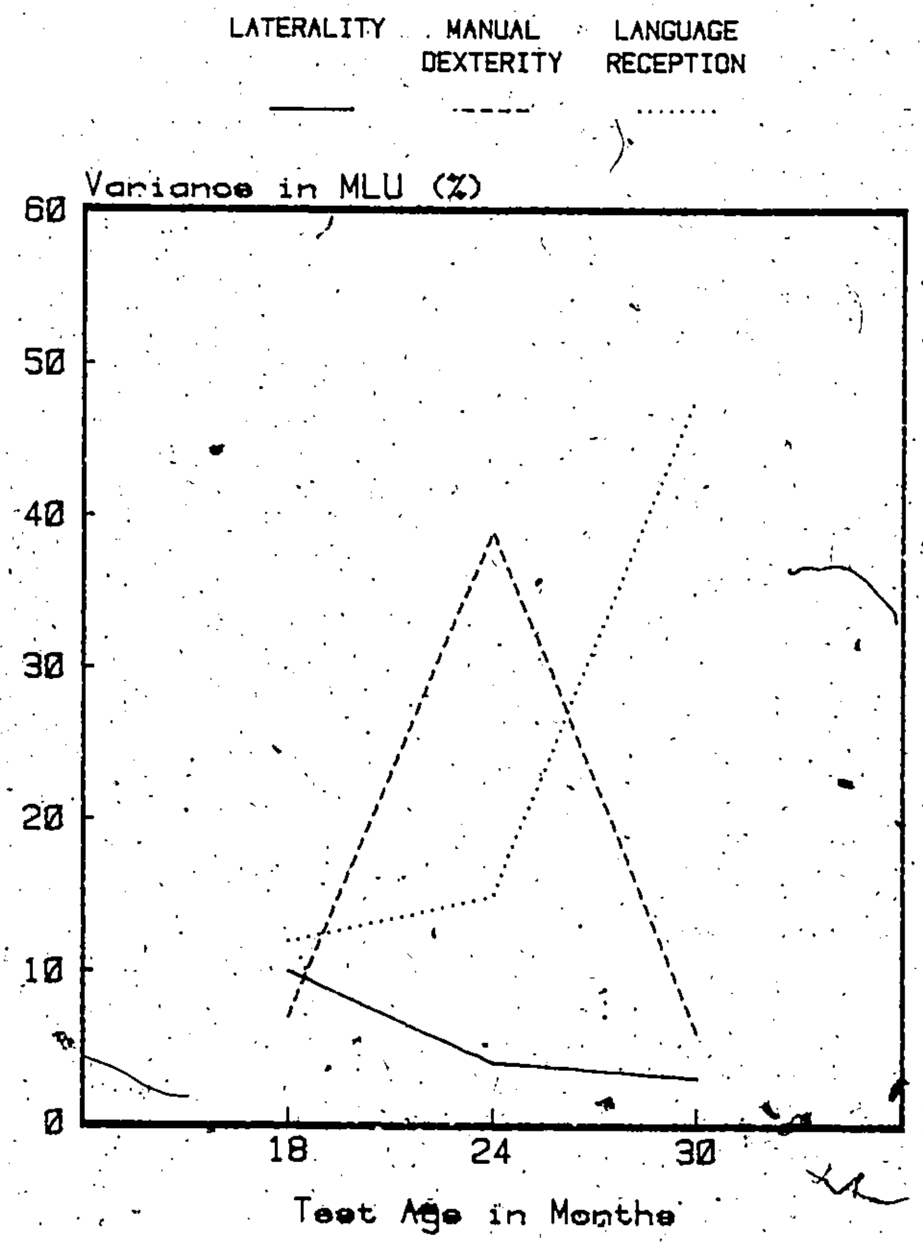

TABLE 56. Hierarchical regression analyses (girls) at 18, 24 and 30 months. Percent of variance in dependent variable, Mean Length of Utterance (MLU), accounted for by independent variables. Independent variables entered in order listed.

TEST AGE (mos.)	Independent Variables	R^2	R^2 Change
18	Manual motor skill	.065	.065
	Laterality	.165	.099
	Language reception	.287	.122*
24	Manual motor skill	.386	.386**[a]
	Laterality	.426	.040
	Language reception	.574	.147**[b]
30	Manual motor skill	.064	.064
	Laterality	.090	.026
	Language reception	.568	.478***

* $p = .05$ ($F(3,18) = 3.09$)
** $p = .01$ a($F(3,18) = 5.60$)
b($F(3,18) = 6.27$)
*** $p = .0005$ ($F(3,18) = 19.98$)

Boys: As with the girls, stepwise analyses were done first with the order for the hierarchical analyses determined by the results of the stepwise analysis. The results are in Figure 9 and Table 57. At 18 months 32% of the variance in MLU is accounted for by the three variables in the equation. The laterality variable accounts for 27% and this is highly significant ($p = .0005$). At 24 months of age there is a slight increase in the total variance accounted for, now 37%, and the laterality variable continues to be the significant variable ($p = .005$) in accounting for variability in MLU. At 30 months, while the total R^2 indicates that 13% of the variance is accounted for, none of the individual R^2 values are statistically significant.

In summation, 27% of the variance in MLU is explained at 18 months and 30% at 24 months. At both these ages laterality is the significant variable. At 30 months none of the variance in language production is explained by the model used here.

4.3 Prediction of Expressive Language Ability

Stepwise regression analyses were done to find predictors for expressive language ability. Analyses were done to determine what variables at 18 months might predict expressive language at 24 and 30 months and what variables at 24 months might predict expressive language at 30 months. Separate analyses were done for girls and

Fig. 9 Regression Analysis (Boys)

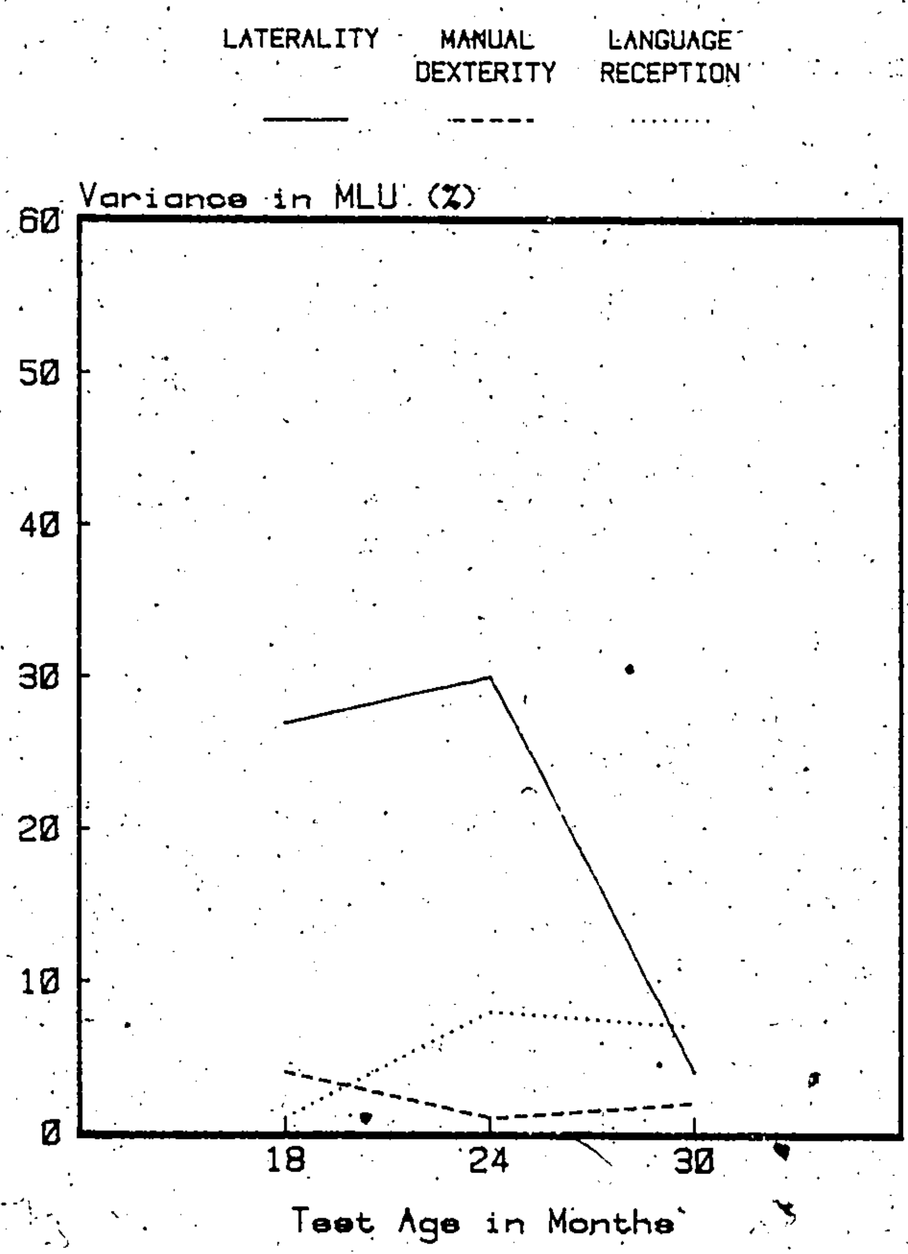

TABLE 57. Hierarchical regression analyses (boys) at 18, 24 and 30 months. Percent of variance in dependent variable, Mean Length of Utterance (MLU), accounted for by independent variables. Independent variables entered in order listed.

TEST AGE (mos.)	Independent Variables	R^2	R^2 Change
18	Manual motor skill	.041	.041
	Language reception	.046	.004
	Laterality	.315	.269*[a]
24	Manual motor skill	.003	.003
	Language reception	.078	.074
	Laterality	.374	.296*[b]
30	Manual motor skill	.018	.018
	Laterality	.060	.042
	Language reception	.131	.070

* $p = .0005$ a($F(3,18) = 9.05$), b($F(3,18) = 10.90$)

boys. Different independent variables were used for each sex based on the results from the correlation analyses.

Girls: The results are in Table 58. Seven independent variables were included in the equation to predict MLU at 24 and 30 months from 18 month measures. With all of the variables in the equation 70% of the variance in MLU at 24 months is predicted. The majority of the variance, 63%, is explained by the first three variables. Receptive language function at 18 months accounts for 46% of the variance ($p = .0005$) in MLU at 24 months, with gross motor accounting for 11% ($p = .0005$) and maternal education accounting for 5% ($p = .025$). From 18 to 30 months, with all seven variables in the equation, 55% of the variance in MLU at 30 months is accounted for. However, the only statistically significant variable is RDLS ($p = .01$). Receptive language ability at 18 months predicts 46% of the variance in expressive language ability at 30 months of age.

Turning to 24 month predictors, with all eight variables in the equation 81% of the variance in MLU at 30 months is accounted for. However, statistically significant contributions are derived only from manual dexterity skill ($p = .01$), RDLS ($p = .01$) and height ($p = .01$). These three variables explain 64% of the variance with respective contributions of 50%, 6%, 8%. Although statisti-

TABLE 58. Stepwise regression analyses (girls) to determine predictors for dependent variable, Mean Length of Utterance (MLU) at 24 and 30 month test ages.

Dependent Variable	Independent Variables	R^2	R^2 Change
MLU 24 months	Lang. Recept. -- RDLS 18 mos.	.459	.459***[a]
	Gross Motor -- 18 mos.	.579	.119***[b]
	Mother Education	.631	.051*
	Birth Order	.690	.059
	Laterality -- Man. Dext.	.700	.010
	Manual Skill -- Bayley Pegs	.701	.000
MLU 30 months	Lang. Recept. -- RDLS 18 mos.	.459	.459**[a]
	Gross Motor -- 18 mos.	.499	.040
	Birth Order	.526	.026
	Laterality -- Man. Dext. 18 mos.	.539	.013
	Manual Skill -- Man. Dext. 18 mos.	.545	.006
	Manual Skill -- Bayley Pegs 18 mos.	.547	.001
	Mother Education	.549	.001
MLU 30 months	Manual Skill -- Man. Dext. 24 mos.	.503	.503**[b]
	Birth Order	.617	.114
	Lang. Recept. -- RDLS 24 mos.	.681	.064**[c]
	Height -- 24 mos.	.761	.079**[d]
	Gross Motor -- 24 mos.	.804	.042
	Manual Skill -- Bayley Pegs 24 mos.	.809	.004
	Mother Education	.810	.000
	Laterality -- Man. Dext. 24 mos.	.810	.000

* $p < .025$ $(F(6,15) = 3.95)$
** $p = .01$ a$(F(7,14) = 4.61)$
b$(F(8,13) = 5.72)$
c$(F(8,13) = 6.06)$
d$(F(8,13) = 4.73)$
*** $p = .0005$ a$(F(6,15) = 11.10)$
b$(F(6,15) = 9.16)$

cally significant, the contributions of RDLS and height realistically are not remarkable.

Boys: Five independent variables were selected as possible predictors at 18 months for expressive language ability at 24 and 30 months. There were fewer potential predictors for the boys, in contrast to the girls, because the Pearson correlations showed fewer variables that correlated with the dependent variable MLU. At 24 months 25% of the variance in MLU is accounted for by all the 18 month variables (Table 59). However, only the 7% from the laterality variable is statistically significant ($p = .05$). Predicting from 18 to 30 months, education of the father predicts almost 13% of the variance in MLU at 30 months. This is statistically significant ($p = .025$).

From 24 to 30 months, while a total R^2 of almost 42% is obtained only the 8% derived from the manual dexterity measure is statistically significant ($p = .01$).

TABLE 59: Stepwise regression analyses (boys) to determine predictors for dependent variable, Mean Length of Utterance (MLU) at 24 and 30 Months.

Dependent Variable	Independent Variables	R^2	R^2 Change
MLU 24 months	Father Education	.100	.100
	Laterality -- Man. Dext. 18 mos.	.170	.070*
	Gross Motor -- 18 mos.	.230	.060
	Lang. Recept. -- RDLS 18 mos.	.245	.014
	Manual Skill -- Man. Dex. 18 mos.	.252	.007
MLU 30 months	Father Education	.127	.127
	Manual Skill -- Man. Dext. 18 mos.	.201	.074
	Laterality -- Man. Dext. 18 mos.	.268	.067
	Gross Motor -- 18 mos.	.270	.002
	Lang. Recept. -- RDLS 18 mos.	.271	.000
MLU 30 months	Laterality -- Man. Dext. 24 mos.	.215	.215
	Father Education	.286	.071
	Manual Skill -- Man. Dext. 24 mos.	.366	.079***
	Lang. Recept. -- RDLS 24 mos.	.405	.038
	Gross Motor -- 24 mos.	.418	.013

* $p = .05$ ($F(5,21) = 2.71$)
** $p = .025$ ($F(5,21) = 3.80$)
*** $p = .01$ ($F(5,21) = 4.37$)

CHAPTER FOUR

DISCUSSION

1. Outline

The main aim of this research was to study language development in young children in relation to manual motor function and laterality. Sex differences in language development and lateral behaviors in relation to age were also examined.

The major findings were as follows. Girls performed significantly better than boys on a number of measures of language function, but there were no sex differences for manual motor skill or laterality. Some association between language development and manual motor skill and laterality was found. Handedness was established at the earliest test age, 18 months, and did not change during the 18 to 30 month time interval. The results will be discussed under the following headings:

a) Sex differences in language development.

b) Handedness and language function in young children.

c) Language production in relation to manual motor skill.

d) Lateral behaviors in young children.

2. Sex Differences in Language Development

In the Introduction findings about the superiority of young girls on verbal measures were summarized; some of the controversy about the strength of these findings was described. The discussion of sex differences in language development will include a summary of the results from this research, a discussion of the design factors in this research which make the results particularly valid, and a presentation of three theories which try to explain why young girls are linguistically superior. The three theories will be preceded by some brief comments about sex differences in the representation of language in the adult brain, and functional cerebral asymmetry in young children regardless of sex. These topics are relevant for the theories of early female linguistic superiority.

2.1 Summary of Results

In planning this research the proposition was that girls would perform better than boys on measures of linguistic function. This prediction was unequivocally confirmed. The girls performed significantly better than boys on measures of language reception and language production. In addition, it was found that the factors which explained and predicted the variability in the girls' acquisition of language were not the same factors which accounted for the variability in the boys' language development.

The girls did better than the boys on measures of language reception and language production. Two measures of language comprehension (i.e. the RDLS and the PPVT) were given; girls performed better on both at all ages. The PPVT is a measure of single word comprehension; the RDLS measures the reception and retention of longer units which require the comprehension of different parts of speech such as nouns, prepositions, possessives, adverbs and abstract concepts such as color, position, size and number.

The girls had a longer mean length of utterance (MLU) than the boys at all ages. The MLU is a measure of maturation in syntactic and grammatical complexity for productive language. When the MLU data were tabulated in terms of the number of subjects who were at each of Brown's (1973) five stages of linguistic development, at 24 months it was found that whereas 50% of the girls had moved beyond Stage I to Stages II, III and IV, only 15% of the boys had done so. This difference was statistically significant ($p = .008$).

There was no difference between the boys and girls in the total number of utterances they produced or in the number of <u>different</u> utterances that were produced (measured at 18 months only). These measures may not have shown differences between boys and girls because they are gross measures of linguistic maturation and do not measure what is really changing in linguistic function from 18 to 30 months, i.e. grammar, syntax and semantics.

A similar argument may explain why no sex difference was found on the phonetic inventory task, a measure of speech articulation maturation. It was intended originally that a rather precise and complex scoring system would be used, which would have reflected subtle changes in speech articulation ability; however, this had to be rejected for a more crude scoring system because of the high refusal rate and problems with scoring the response from the tape recording. High quality tape recordings are required for accurate phonetic transcription. At 18 months significantly more boys than girls refused the task and one possible reason for the high refusal rate may have been inability to do the task. At 24 and 30 months there was no sex difference in refusal rate.

The multiple regression analyses showed that the factors which accounted for language production ability (i.e. MLU) in the girls were not the factors which explained language production ability in the boys. Language reception was the main factor which accounted for language production in the girls. Language reception never explained any of the variance in the boys' language production. At 24 months manual motor skill, in combination with language reception, explained a large part (54%) of the variance in the girls' language production. The laterality variable was the main factor to account for the boys' language production although it accounted for less of the variance (i.e. 30%) than did the language reception variable for the girls. By 30 months none of the variance in language production for boys was accounted for by any of the variables in the equation.

Multiple regression analyses were done to find predictors for language production. Girls' language at 30 months was more predictable. The reception of language at 18 months predicted 46% of the variability in the language production of the girls at 30 months. For the boys none of of the 18 month measures were significant in predicting language productivity at 30 months. Father's education accounted for 13% ($p = .025$) of the variability in language production at 30 months.

2.2. Factors in Research Design

Many of the studies which have reported verbal superiority for girls have been challenged on the ground that they were methodologically and/or statistically poor (Fairweather, 1977; Macaulay, 1978). It will be argued here that the results of this study indicate unequivocally that young girls are more linguistically adept than young boys -- and that a number of factors in the design and methodology of this study support the validity of these findings. These are:

1) Statistical analysis: hypothesis testing was done by formal statistical tests and the results were statistically significant.
2) Evidence from several tests: in many studies which reported sex difference only one measure of many measures of verbal functioning which had been given was statistically significant (e.g. Moore, 1967; Nelson, 1973); in this study a sex difference was found for a number of the tests and at all ages.
3) Standardized language tests: in this study standardized tests were used to measure linguistic function. Many researchers who have reported sex differences in language function have used non-standardized measures, subjective measures or tests that are poor measures of linguistic function (e.g. Gesell, 1940; Moore, 1967).
4) Sample size: the sample size necessary to establish the reliability of the results was statistically determined (Cohen, 1977).
5) Sample constitution and variability: the subjects were not randomly selected -- the optimum manner of subject selection. The sample was middle class; a Grade 12 minimum level of education was required for each parent. However, within that restriction there was considerable variation in paternal occupa-

tion, ranging from factory worker to medical doctor. It should be borne in mind that studies of child language development have been criticized for using only subjects from a middle class university community (Nelson, 1973).

A second factor which introduces variability into the sample is that no selection was made for firstborns. Only 22 (45%) of the children were firstborns.

6) Experimental design: the use of a longitudinal design controls for individual differences among subjects, thereby reducing the error term (Pedhazur, 1982). In addition it is the method of choice for studying development over time (McCall, 1977; Pedhazur, 1982).

This research was planned to avoid many of the criticisms which have been made of previous reports of female linguistic superiority (see Fairweather, 1977; and Macaulay, 1978 for critical reviews). The factors described in the preceding section suggest this was achieved.

2.3 Why Female Superiority in Linguistic Function?

Two questions arise: Why did the girls in this study perform better than the boys? Is this an idiosyncratic finding? Why in general do girls perform better than boys on verbal tasks?

It has been argued in the preceding section that in terms of the overall design and methodology of this study, the results are clearly defensible. However, it might still be argued that there is something unique about the girls -- or the boys -- in this study which would make it likely for a sex difference in verbal functioning to occur. Examination of the descriptive data and the performance of each group on some of the other variables in the test battery may address this issue.

In Table 1 it can be seen that a greater percentage of the girls were first born. This has been proposed as a factor in superior language ability (McCarthy, 1954). However, the significant language differences that were found here persisted after birth order had been removed as a covariate, and it is unlikely that the superior performance of the girls is related to birth order.

The number of years of parental education for both mother and father (Table 1) is somewhat higher for the girls. Children of highly educated parents tend to perform better on verbal measures (Harris, 1977; Nelson, 1973; Schacter, 1979). For both boys and girls all parents had at least grade 12 education. The mothers and fathers of the girls had a mean 1.4 years and 1.2 years more education, respectively, than did the mothers and fathers of the boys.

However, this difference was not found to be statistically significant and therefore, presumably is not a contributing factor to the superior verbal performance of the girls.

It might be argued that the girls in this sample are at the upper limits of linguistic and cognitive function and the boys are at the lower limits and that is why the girls are verbally advanced. If this were so one might expect to see differences between the sexes on some of the other measures in the test battery. This was not found. There were no differences between the sexes in gross motor function or in manual motor skill. Similarly on the control measures of general cognitive function (i.e. formboard performance) and maturational rate (i.e. supine length) there were no differences between the sexes.

The absence of a sex difference in supine length (height) suggests that the girls' superior linguistic ability is not merely a reflection of the well known more rapid maturational rate of girls (Hutt, 1972; Tanner, 1978). This conclusion however, warrants some qualification. Height is influenced by socioeconomic status and nutrition (Tanner, 1978), and it is not regarded as the definitive measure of physiological maturational rate (Tanner, 1978). Bone age is the measure of choice for assessing physiological maturational rate (Tanner, 1978). To assess bone age or skeletal maturity an x-ray of the hand and wrist bones is taken, although in principle any or all parts of the skeleton could be used. According to Tanner, "Skeletal maturity is a measure of how far the bones of an area have progressed towards maturity, not in size, but in shape and in their relative positions one to another, as visualized in a radiograph" (Tanner, 1978, p. 79). Measurement of bone age is a costly procedure which could not be used in this study.

Thus, it may be that the girls scored better on the language measures because of advanced maturational rate. However, if one accounts for the superior linguistic ability of the girls on this basis, why then did the girls not perform better than the boys on all the other measures in the test battery? This is an important issue which will be addressed in later discussion.

Some researchers (Cherry and Lewis, 1975; Lewis and Cherry, 1976; Moss, 1974) have suggested that the reason girls talk sooner and better than boys is because mothers and/or other caretakers talk to boys and girls differently.

Maternal speech was not analyzed and it remains possible that it may be an explanatory factor for the superior verbal ability of the girls. However, Bates, Bretherton, Beeghly-Smith and McNew (1982) made a critical analysis of the maternal speech literature and concluded that the importance of maternal speech to language acquisition -- regardless of sex -- was probably over-estimated. They write,

> Perhaps the amount and type of social input that is necessary for normal language development is a minimal threshold amount that every normal child receives. Increases in such input beyond the threshold amount may have no effect at all, so that correlational and experimental measures of input variation in the normal range yield largely nonsignificant results. (pp. 61-62)

To sum up, there is little direct evidence to support the proposition that the girls in this study performed better than the boys on verbal tasks due to an artefact of the subject sample. It appears that young girls have a special propensity to excel in verbal measures which has been unequivocally shown in this study, and consistently suggested in the literature for several decades. Theories for why this might be so will be considered at a later point.

2.4 Functional Cerebral Asymmetry in Relation to Sex and Age

Before presenting some theories which attempt to account for the verbal superiority of young girls, some introductory comments are warranted about: a) sex and the representation of language in the adult brain and, b) functional cerebral asymmetry in young children regardless of sex.

2.4.1 Sex and the Representation of Language in the Adult Brain

In 98% of right handed adults and 70% of left handed adults language is processed by the left cerebral hemisphere (Rasmussen and Milner, 1977). However, it is generally accepted that the sexes differ in the degree to which language is processed by the left hemisphere (Bryden, 1979; Lake and Bryden, 1976; McGlone, 1980; Segalowitz and Bryden, 1983). Males are described as being "more lateralized" for language functions, while females are described as being "less lateralized" for language. This means that in males language is mediated primarily by the left hemisphere, whereas for females there is some mediation of language in the right hemisphere as well as the left. This model of sex differences in brain organization for language has emerged from data about the recovery of language functions in males and females who have suffered left hemisphere brain damage (McGlone, 1977; Inglis and Lawson, 1981) and from comparisons of the performance of normal males and females on the dichotic listening task (Lake and Bryden, 1976; Segalowitz and Stewart, 1979). McGlone (1977, 1980) and others (Landsdell, 1964) have proposed that the poorer performance of males compared to females on tests of verbal function after unilateral left hemisphere lesions supports the notion of a more bilateral representation of language in females.

On the dichotic listening task males are more likely to show a right ear advantage for verbal material or a larger right ear effect (Lake and Bryden, 1976; Segalowitz and Stewart, 1979). Either a right ear superiority is not found for females or the difference between the right and left ear scores is much smaller for the females than for the males.

2.4.2 Functional Cerebral Asymmetry in Children, Regardless of Sex

Whether or not the brains of boys and girls differ in organization for language functions, it is important to consider what is known about functional cerebral asymmetry in the young child. It cannot be assumed that brain organization in children is simply a replica of adult brain organization.

Only those studies done with children three years of age and younger will be considered here. Segalowitz (1983b) has made a detailed review of studies with infants 12 months of age and younger. In this age range electroencephalographic (EEG) changes and event-related potentials (ERP's) have been the primary methods. The response of the cerebral hemispheres to speech and music or nonspeech stimuli has been measured in newborns, preterm infants and infants ranging in age from 2 days to 12 months. Of the thirteen studies reviewed by Segalowitz (1983b) ten reported left/right asymmetries comparable to those found in adults. A greater left hemisphere activation was recorded in response to speech stimuli and a greater right hemisphere activation in response to music or nonspeech stimuli such as clicks or white noise.

A gap occurs in the literature between age 12 months and 2 1/2 to 3 years. There are essentially no data regarding the response of the cerebral hemispheres to verbal stimuli in children who are 12 to 30 months of age. This is unfortunate because 12 to 36 months of age is the period when major speech/language advances occur. The lack of data for this time period seems largely due to methodological limitations. Electrophysiological recording is difficult with the toddler since she is likely to be too active to tolerate the procedure. The dichotic listening procedure has been used with children as young as 2 1/2 years of age; however, it is a cognitively demanding procedure which is not readily modifiable for the frequently active and non-compliant two year old.

In 1977 Witelson made a complete review of papers about dichotic listening in children. There were only two studies in which subjects younger than 3 years were tested (Bever, 1971; Gilbert and Climan, 1974). Bever and Gilbert and Climan were reported as having tested 2 1/2 year olds. Gilbert and Climan (1974) reported a right ear advantage for verbal stimuli. Bever's (1971) findings are not clear. In her summary of Bever's study, Witelson (1977, p. 226) says that children 2 1/2 to 5 years of age were tested and that ". . . about 65% chose more right ear than left ear stimuli". Bever says in the text of his paper (Bever, 1971, p. 247) that 2 1/2 year old children were tested; however, his tabulation of the data gives the youngest age as 3.11 years (p. 250). Moreover of 129 children tested, only 47 (37%) demonstrated a right ear preference.

There have been a number of studies in which 3 year old children are reported to have been given the dichotic listening test (Diana Ingram, 1975; Hiscock and Kinsbourne, 1978, 1980). In these studies the actual number of 3 year olds is usually small because they are part of a larger sample which encompasses a broad age range, i.e. 3 to 5 year olds. A right ear advantage for speech, suggesting left hemisphere representation of language has been found in the majority of these studies.

These results -- from infants less than 12 months of age and from children 2 1/2 to 3 years old -- indicate that even for children of this young age there exists functional cerebral asymmetry comparable to that of adults, i.e. the left hemisphere is preferred for processing speech stimuli and the right hemisphere is preferred for processing music and non-speech stimuli. The basis of this asymmetry in children is not clear. Segalowitz (1983b) and Molfese and Molfese (1983) note the stimuli used with young children and the manner in which the young child approaches the task are not the same as with an adult. Segalowitz (1980) proposes that, given cortical immaturity in the young child's brain, processing may be occurring at a subcortical level.

2.5 Theories to Explain Early Female Linguistic Superiority

Three theories which try to account for the linguistic superiority of young girls will be discussed. They are:

Theory One: Earlier left hemisphere maturation in girls.

Theory Two: Right hemisphere involvement in preverbal language functions in girls.

Theory Three: Different language acquisition strategies for boys and girls.

Theory One is the generally accepted theory (Harris, 1977; Taylor, 1969); Theories Two and Three which are new incorporate some of the data from this research as well as more recent concepts in the neuropsychological and developmental language literature.

2.5.1 THEORY ONE: Earlier Left Hemisphere Maturation in Girls

In this theory the earlier language acquisition of females is explained by the interaction of two factors -- the overall more rapid maturation of females and the presumed earlier maturation of the left cerebral hemisphere relative to the right. Therefore, left hemisphere mediation of language functions occurs sooner in females (Harris, 1977, 1978; Taylor, 1969). This is a logical proposition but the data which support it are limited. In the discussion which immediately follows, reports in the literature which support Theory One will be reviewed; some of the data from this research will be interpreted in the light of this theory.

A study by Taylor (1969) is frequently cited. Taylor examined a series of cases of temporal lobe epilepsy. He reported sex differences in the age of onset of the disorder and in the hemisphere of seizure activity. For girls left-sided lesions were common in the first year of life and rare after 2 years of age; the rate of occurrence dropped precipitously. For boys, the decline in left hemisphere seizure activity was more gradual spanning the first 4 years. Right hemisphere seizure activity was equally prevalent in both sexes during the first 4 years of life.

Because seizure activity is more likely to occur in tissue less functionally active Taylor interpreted his data to support a differential cerebral maturation rate between the sexes. The rapid decline in left hemisphere seizure activity for the girls was interpreted to mean earlier left hemisphere function for the girls. The tendency of boys to experience febrile convulsions over a longer time was regarded as further evidence to support a sex difference in cerebral maturation. Taylor attributed female linguistic superiority to their more rapid maturation which interacts with the differential maturation of the hemispheres -- the left maturing earlier.

In a careful reanalysis of Taylor's data Harris (1978) showed that Taylor's distribution of subjects was not converted to percentiles, as it should have been because the number of boys and girls were not equal. Harris did this and found that the difference between the sexes was no longer statistically significant, although a trend in favour of the girls persisted.

Studies of cerebral asymmetry for speech in children 0-3 years of age might provide the most relevant data about sex differences in hemispheric specialization in the young child. While the majority of these studies (Gilbert and Climan, 1974; see Segalowitz, 1983b for review), as noted earlier, reported left/right asymmetries for speech and nonspeech stimuli, many did not test for sex differences. Those that did (Entus, 1977; Molfese and Hess, 1978; Molfese and Molfese, 1979; Shucard, Shucard, Cummins and Campos, 1981), with the exception of the work in Molfese and Shucard found no differences between the sexes.

Those researchers who did find sex differences are not in agreement as to how those differences should be interpreted. Molfese (Molfese and Hess, 1978; Molfese and Molfese, 1979) found a difference between the sexes for an auditory evoked response task in infants 24 hours old and 3 to 4 months of age. They interpreted their data to mean that there was a difference in the maturational rate of the males and females, and not a difference in brain organization for language, since sex differences were not found in adults using similar tests.

Shucard, Shucard, Cummins and Campos (1981) used a "two-tone probe technique" whereby two-tone pips were presented against a verbal or music background. In 3 month old infants they reported that females produced higher amplitude left hemisphere responses, while males produced higher amplitude right hemisphere responses. They did not report a left/right asymmetry in response to speech and music stimuli respectively for either males or females. Shucard interpreted the findings to support sex differences in hemispheric specialization. Shucard also indicated that they did not find any sex differences in adults with whom a similar procedure had been used. It is interesting that Molfese chose not to interpret their data as evidence for sex differences in brain organization <u>because</u> they had not found sex differences in adults using similar tests.

In 3 to 5 year old children a sex difference on tests of laterality is no more evident than in younger children (Hiscock and Kinsbourne, 1980; Diana Ingram, 1975). Witelson (1977) reviewed this literature and concluded that the results of testing with the dichotic listening procedure provided no evidence to support greater left hemispheric specialization in girls. D. Gordon (1983) concurred with Witelson's (1977) conclusions. She (D. Gordon, 1983) studied the performance of 9 and 13 year olds on a dichotic listening test and reported that not until later childhood (i.e. 13 years of age) was a difference seen between boys and girls on the dichotic listening task. At that age the girls stopped showing a significant right ear effect for speech stimuli, suggesting less lateralization of language functions which is the pattern observed in adult females.

In this research cerebral asymmetry for speech was not tested; however, for all the measures of lateral motor function which were given no sex differences were found. This outcome buttresses the results from studies of sex differences in laterality which were just reviewed.

The finding, only for the girls, that the variance in language production at 24 months is largely explained by manual motor skill may be an indicator of left hemisphere maturation and ascendancy in the girls. This is very speculative. However, there is consistent evidence from adults that the production of language is exclusively mediated by the left hemisphere as are higher order manual motor functions, i.e. praxis (Geschwind, 1975, Kimura, 1977). That this language production/manual motor skill association occurredat 24 months may be important. Two years of age is regarded as the age when formal linguistic processing begins (E. Clark, 1977). It is at this age when children first begin to comprehend linguistically complex utterances and to produce two and three word utterances, requiring the generation of syntactical rules. The maturation of manual motor skill is less well documented. Certainly in this study not until the children were 24 months old did they begin to demonstrate an ability to perform the more complex tasks, i.e. bead threading, operation of the mystery box, cutting with scissors.

Summary

The theory that female linguistic superiority is a function of the more rapid maturation of females combined with a differential rate of maturation of the hemispheres (faster in the left), although a logical possibility, is still a matter of speculation. There are few data which soundly support the proposition.

The predominant role ascribed to the different maturational rates of the sexes may not be warranted. A more plausible position is that sex differences in brain organization, possibly due to genetic factors, may account for different cognitive abilities in the sexes. Maturational rate may be a contributing factor but it cannot be the sole explanatory factor. The results of the multiple regression analyses in this research suggest that not only are girls more advanced than boys in linguistic development, but that the manner in which they acquire language differs from the way in which boys acquire language. This speaks against the argument of differential maturational rates as the sole explanatory factor (but see Waber, 1976, 1977). This point will be taken up in some detail when Theory Three is discussed.

2.5.2 THEORY TWO: Right Hemisphere Involvement in Preverbal Language Functions in Girls

In adults, males are said to be highly lateralized for language functions, meaning that language is processed primarily in the left hemisphere. Females are said to be less lateralized for language functions in that there is greater involvement of the right hemisphere in language processing.

The brain is said to be preprogrammed (Witelson, 1977), the female is predisposed to a less lateralized state, and this lesser lateralization, may operate at a very young age. It is possible that in young girls the right hemisphere takes the lead role in the early stages of language acquisition. Recent work in developmental language acquisition supports the proposition that the reason girls acquire language earlier than boys is a function of greater right hemisphere involvement particularly during the preverbal and early verbal stages of language acquisition. Early involvement of the right hemisphere may provide girls with an advantage which results in early linguistic superiority (see below).

Witelson (1977) speculated that there may be some right hemisphere mediation of language functions in young children. Others (Brown and Jaffe, 1975; Moscovitch, 1977) have specified a role for the right hemisphere in the early, sometimes termed "prelinguistic" stages of language development, arguing that the stimuli which are to be processed during that time period may be particularly appropriate for right hemispheric processing. Brown and Jaffe (1975) write, "The right hemisphere can be considered dominant in infancy, 'for the type of visual and acoustic communication which is relevant to the prelinguistic child'" (p. 108).

Moscovitch (1977) proposed that more attention be given to recent theory and data in developmental psycholinguistics. The early sensorimotor, paralinguistic cognitive underpinnings to more sophisticated verbal processing, Moscovitch suggests, may be better mediated by the right cerebral hemisphere.

In the next sections studies of the linguistic capabilities of the right hemisphere and studies of the pre-verbal and early verbal stages of language acquisition will be summarized. These studies will be used to support Theory Two which states that young girls excel verbally because of the involvement of the right hemisphere in the earliest stages of language acquisition.

Linguistic Capabilities of the Right Hemisphere: The two cerebral hemispheres make use of different processing styles to process stimuli (Dimond and Beaumont, 1974; Zangwill, 1960). The left hemisphere uses a sequential, analytic processing style and processes stimuli or performs tasks which will be most effectively processed by such a strategy, i.e. verbal tasks and complex measures of manual motor skill. The right hemisphere uses a non-analytic, gestalt, holistic processing style and as a consequence is most proficient at processing nonlinguistic stimuli such as music or visuo-spatial material.

The linguistic capabilities of the right hemisphere have been studied in normal individuals (Moscovitch, 1976, 1983) but, particularly in individuals who have a left hemidecortication (Dennis and Whitaker, 1976, 1977), or right hemisphere brain damage (Gainotti, Caltagirone, Miceli and Masullo, 1981; Wapner, Hamby and Gardner, 1981). These studies consistently show that while the right hemisphere is able to comprehend language, when syntactically complex material is presented the performance of the right hemisphere is always inferior to the performance of the left hemisphere. In addition, except in cases of early hemidecortication, the right hemisphere is quite incapable of producing language. It is speculated that as long as the left hemisphere is present, regardless of the degree of damage it may have suffered itself, it is able to inhibit right hemisphere productive language ability (Gazzaniga, 1974; Moscovitch, 1976).

Zaidel (1978) summarized the linguistic capabilities of the right hemisphere as: "The right hemisphere can process grammatical or syntactic structures at both the word and phrase levels, but it fails to analyze correctly long, nonredundant sentences in which order is important or the context is not helpful" (p. 269).

The right hemisphere, however, appears to have a unique ability not shared by the left hemisphere for processing the paralinguistic components of language, i.e. voice intonation, prosody, gesture (Millar and Whitaker, 1983). Ross and Mesulam (1979) described the loss of speech prosody (i.e. speech intonation, melody and cadence) and emotional gesturing (i.e. facial, limb and body gestures which accompany emotional states) in two patients who suffered unilateral right hemisphere brain damage.

Wapner, Hamby and Gardner (1981) examined the ability of right-hemisphere brain damaged patients to appreciate humor, to integrate and order the elements of a story and to respond to the contextual demands of a story. They concluded that when right brain damaged patients are given complex linguistic tasks they,

> . . . exhibit clear and recurring difficulties, relating to the abilities to conceptualize the unit as a whole, to appreciate its purpose and its form, and to integrate specific elements appropriately within these forms. Correlatively, many of the patients seem insensitive to the context in which these linguistic entities are produced and utilized. Finally, they seem unable to honor the world of the fictive, the imaginary, the humorous. . . . (p. 31)

Millar and Whitaker (1983) reviewed the brain damage literature about the language abilities of the right hemisphere (RH) and concluded that,

> There is good evidence that the RH contributes to many factors of human behavior that play some role in communication. Affective behavior, especially as reflected in the appreciation of humor, imagery, visuospatial processing, and some aspects of attentional mechanisms, all have a RH contribution. (p. 110)

To sum up, it is clear that the RH can process linguistic material, although never to the level of the left hemisphere. However, it does appear that the RH by virtue of its processing style mediates the paralinguistic, pragmatic aspects of human language function. This is an aspect of human language/communicative function which has never been ascribed to the left hemisphere but appears unique to the right hemisphere.

Developmental Language Research: In the past two decades linguists and psychologists have become interested in the "preverbal" or "prelinguistic" stage of language development (Bates et al., 1979; Clark, Hutcheson and Van Buren, 1974; Dore, 1974, 1975; Kaplan and Kaplan, 1970). Efforts have been directed to identifying those factors which precede and may be necessary to the reception and production of verbal language. The typical age of subjects is between 9 and 15 months. The studies reviewed here will be divided into linguistic studies, social/interpersonal studies and studies of language comprehension. It will become apparent, however, that these divisions are somewhat artificial and they overlap.

i) Linguistic Studies: Linguistically oriented studies have stressed the pragmatic aspects of language function, i.e. the functions and uses of language (Bates, 1976). Research with the young child has tried to delineate what the very young child is able to communicate and how she achieves this. Both the verbal and nonverbal components of communication are recorded.

It is important to distinguish between "language" and "communication". Paivio and Begg (1981) define human language as ". . . a biological communication system that is specialized for the transmission of meaningful information between and within persons by means of linguistic signs" (p. 14). Communication refers to an exchange of information which may be verbally or nonverbally achieved. The young child may be unable to say the word "ball" but she may communicate her wishes to have her ball by babbling and pointing and looking toward her ball. She will likely be quite successful in getting her message across.

Greenfield and Smith (1976) write that children of this age ". . . are able to communicate because they are not solely dependent on words but use their words with gestures, action and intonation, within a context they share with their listener" (p. 221).

Dore (1974, 1975) developed the concept of "primitive speech act" (PSA) to describe the early language/communicative efforts of the young child. He operationally defined the PSA (Dore, 1974) as ". . . an utterance, consisting formally of a single word or a single prosodic pattern, with functions to convey the child's intention before he acquires sentences" (p. 345). Of relevance to the discussion here is the behavioral evidence Dore used to characterize the PSA's, i.e. "(1) the child's utterance; (2) his nonlinguistic behavior, e.g. gestures, and facial expressions; (3) the adult's response, both verbal and nonverbal; and (4) the relevant, salient aspects of the context of utterance, such as objects attended to, location of objects, and people" (p. 345).

ii) Social/Interpersonal Studies: Some researchers have proposed that the acquisition of language emerges out of and is fostered by social and dyadic interchanges (Bruner, 1977; Trevarthen, 1977; Stern, 1973). This is a burgeoning field of investigation and only the basic issues will be described here (see Bates, Bretherton, Beeghly-Smith and McNew, 1982 for a critical review).

Various maternal and infant social/interactive behaviors have been proposed as possible antecedents to the acquisition of verbal language function. The evolution of the pointing gesture in the preverbal child has been described in some detail and given a crucial role in the emergence of communication and language (Kinsbourne and Lempert, 1979; Murphy, 1978; Murphy and Messer, 1977). Murphy and Messer (1977), using frame-by-frame video-tape analysis, observed that ". . . the pointing gesture is not a simple process of the forefinger being extended towards an object but is rather composed of a number of behaviors each of which contributes to the 'pointing gestalt'" (p. 322). The other behaviors they refer to are: attraction of the mother's attention by the infant; attraction of the infant's attention by the mother; visual attention to the object being pointed to by the mother or infant; maternal verbalization when she or the infant is pointing.

The "give and take" or reciprocal interaction pattern that occurs between mothers and infants has also been proposed as a necessary antecedent to the development of verbal language (R. Clark, 1978; Lieven, 1981; Stern, 1973; Trevarthen, 1977). This refers to the back and forth interchange that occurs between even a very young infant and the caretaker, and is certainly an integral part of adult communication. As with the pointing gesture a constellation of behaviors have been identified in this back and forth game. These include: the infant's attention to the mother's face and facial gestures of smiling and making faces; visual attention to the toy the mother has and is talking about as well as attention to any pointing gestures the mother uses; an ability to participate in a back and forth exchange of an object with the mother or an action sequence.

iii) Studies of Language Comprehension: There are few studies of the comprehension of language in the early phases of language acquisition.

Clark, Hutcheson and Van Buren (1974) note that the receptive language abilities of the 9 to 15 month old are very much related to and assisted by contextual and para-linguistic clues. They make an important distinction between comprehension in the "narrow sense" and comprehension in the "broader sense". In the case of the former there is comprehension of the verbal message, the linguistic stimuli per se.

In the latter case successful comprehension is achieved through the use of contextual clues. Clark, Hutcheson and Van Buren (1974) discuss various factors, ". . . which make for adequate communication, or the appearance of it, between the child and adult in the absence of full understanding of the adult's utterance on the part of the child" (p. 44). These factors are: a) redundancy in the situation, b) consistencies in the way language is used, c) collusion on the part of the parent, d) paralinguistic cues, and e) redundancy in the language.

Huttenlocher (1974) described the role of attention in the comprehension of language by the child 10 to 13 months of age. She noted that there was a striking "inattention" to verbal stimuli and that it was difficult to get the children's attention at all. What is interesting, although Huttenlocher indicated that she did not test it out empirically, was her observation that she was most successful in getting the children's attention when she altered the intonation, volume or prosody of her voice.

For each of the areas of developmental language research just reviewed an important role is assigned to behaviors which appear similar to the prosodic and paralinguistic behaviors which were described in the discussion of right hemisphere linguistic functions. In the discussion of right hemisphere linguistic capabilities and in the discussion of preverbal behaviors an ability to attend to and comprehend situational factors, as well as an ability to receive and generate body and facial gestures was stressed. However, what appears to be the same behavior may not be processed in the same manner by the adult and the child.

Summary

The second theory proposes that while the right hemisphere of both sexes may be involved in the early stages of language acquisition -- given the nature of the stimuli involved in the preverbal language stage -- girls will have more right hemisphere involvement because they are preprogrammed for greater right hemispheric mediation of language. This may give them the lead in the early stages of language acquisition. If boys are preprogrammed to mediate language primarily by the left hemisphere, their right hemisphere will be less involved in the pre-linguistic stages of language development. The left hemisphere is specialized to process more clearly, linguistic syntactical and grammatical material. Thus boys will be slower in their acquisition of language until such time as their language function reaches a level of sophistication necessary to elicit left hemisphere processing. In addition it is widely accepted that males excel in spatial functions (Levy, 1969; Harris, 1978; Witelson, 1976). Some have argued that right hemisphere involvement in spatial processing occurs earlier in boys than in girls (Witelson, 1976). This would support the preceding suggestion that the right hemisphere of young boys is less likely to be involved in language processing.

When, for both sexes, the left hemisphere has assumed the major role in linguistic processing the sex difference in verbal functions will diminish or be eliminated. This concurs with Maccoby and Jacklin's (1974) comments that sex differences in verbal functioning are not observed from 3 to 11 years of age, and appear again at puberty.

The difficulty with Theory Two as with Theory One, is that there are no data which show sex differences in hemispheric function in the young child. While the female brain may be preprogrammed for greater right hemisphere involvement in language processing, the research to date suggests that this predisposition is not found until puberty (D. Gordan 1983; Witelson, 1977). Theory Two goes against the thinking that early female verbal precocity arises out of earlier left hemisphere maturation. Proponents of Theory One have not given credence to the early developmental language data, nor have they acknowledged the role of paralinguistic factors in language function or the role of the right hemisphere in processing paralinguistic behaviors.

2.5.3 THEORY THREE: Different Language Acquisition Strategies for Boys and Girls

Results from this Research

In the developmental language literature (Nelson, 1973; 1977; A. Peters, 1977) and the neuropsychological literature (Bryden, 1979; Lake and Bryden, 1976) strategy differences have been said to account for differences in how individuals (with and without regard to sex) perform on measures of verbal function. In this section it will be proposed that sex differences in the early acquisition of language may be related to the use of different cognitive strategies by boys and girls.

The multiple regression analyses described in the Results section showed that those factors which explained and predicted expressive language ability differed between the sexes. It may be that the female strategy facilitates more rapid language acquisiton.

Receptive language consistently accounted for a large part (as much as 48% at 30 months) of the variability in the girls' language production at all ages. It never explained any of the variability in the boys' production of language. The laterality variable was the sole and only variable which explained language production in the boys. At 18 months 27% of the variance was explained by the laterality variable and at 24 months it accounted for 30% of the variance. At 30 months none of the variance was explained. The association between language production and laterality was negative suggesting that better production of language was more likely for those boys who showed a mixed or strong left preference on the manual dexterity inventory.

There was a clear difference between boys and girls in predicting MLU. One will be more successful in predicting the girls who will be the better talkers than in predicting the boys who will be the better talkers. For the girls, 46% of the variance ($p = .01$) in MLU at 30 months is explained by language comprehension at 18 months. Nelson (1973) also found that language reception was the best predictor of language productive ability at a later age. However, her sample was too small to make a meaningful analysis of sex differences.

For the boys MLU at 30 months was best predicted by paternal education (which accounted for 13% of the variance). This was statistically significant ($p = .025$) but much less impressive than the girls' data.

Two points emerge from the regression analyses: a) the reception and production of language are related to each other in girls but not in boys and, b) laterality is the only factor which accounts for language production ability in boys. These points will be discussed in the next section.

Differences in Language Reception/Production Relationships Between the Sexes: Strategy Differences for Language Acquisition?

Some of the findings from this research may explain how early language acquisition differs in boys and girls and why young girls excel verbally. For the boys there was little correlation between reception and production of language; reception of language did not account for language production.

The relationship during development between the production and reception of language is not well understood (Bloom, 1974; Huttenlocher, 1974). Two positions are identifiable in the literature: 1) comprehension occurs first followed by production, and comprehension is necessary for production (D. Ingram, 1974; Lenneberg, 1967; Huttenlocher, 1974) or, 2) the maturation of the two is intertwined and comprehension is influenced by and/or mediated by production (Bloom, 1974; Clark, Hutcheson and Van Buren, 1974).

The difference between the boys and girls found in this research bears on the two views in the literature regarding the association between language production and language reception. Clark et al. (1974) argued that the <u>reception</u> of language is influenced by the production of language -- this may be the girls' strategy. The data from this research indicate the opposite, i.e. the <u>production</u> of language is influenced by language reception. However, this may not matter if the real issue is an interdependence of language production and reception. Others (D. Ingram 1974; Huttenlocher, 1974) have argued that the two processes are quite distinct, production following reception -- this may be the boys' strategy.

Nelson (1973, 1977) has suggested that some children may use a "comprehension strategy" while others may use a "production or hypothesis-testing strategy". Over the long term complete language mastery is achieved by both strategies. Children using a comprehension strategy listen but do not attempt to produce language. They do not begin talking until the end of the second year or early in the third year, at which time they may skip the one-word stage and begin talking in sentences. Children using a production strategy begin talking early and build large vocabularies quickly. They verify both their comprehension and production of language by saying words. Nelson does not consider that the two strategies might explain sex differences in language acquisition. However, they certainly offer a logical explanation for the data obtained in this study: girls use a production or hypothesistesting strategy, boys use a comprehension strategy.

The proposal that boys use a comprehension strategy is really reached by default and not on the basis of corroborative data. In fact laterality was found to be the major explanatory variable for the boys' language productive ability. However, interpretation of this finding is difficult. The correlation coefficients between language production and laterality were almost all negative for the boys. For the girls there was little association between language production and laterality. The inverse relationship between language production and laterality for the boys indicates that as language production scores get better, the degree of laterality decreases.

3. Handedness and Language Function in Children

3.1 Handedness and Language Ability in the Normal Child

The ideas that handedness and brain organization for language functions are related, and that handedness and language proficiency are related have a long history as described in the Introduction. Some of the results of this research and the discussion which immediately follows speak to the issue of the association of handedness and language proficiency in the normal child.

For this research it was hypothesized that hand preference would not be related to language ability. It was predicted that ambidexterity or left handedness would not be more prevalent in those subjects who scored at the lower limits (although still within normal limits) of the language measures, and that there would be no difference in the linguistic abilities of those who were ambidextrous and those who were not. These hypotheses were confirmed. Pearson correlation analyses showed no association between the strength or direction of handedness and language function (Table 52) for the girls. For the boys, out of 14 possible (within age) correlations only 3 significant correlations were obtained between hand preference and language function (Table 53). This does not suggest a strong relationship between handedness and language function. The clearest data are from the independent t-tests in which the language performance of those subjects who maintained the same handedness category (stable handedness) was compared to the language performance of those subjects who changed handedness category (i.e. unstable handedness) from 18 to 30 months of age. Left handers who maintained that category throughout the specified time period were included in the stable handedness category. Thus, the unstable handedness category was composed of mixed handers only. (Annett (1970a) and Swanson, Kinsbourne and Horn (1980) reported that left and right handers did not differ on measures of language and intellectual function, but that some decrement in ability was found for mixed handers.) In this research for both sexes no difference was found between the two groups (i.e. stable and unstable handedness) in either the production or reception of language at 18, 24 or 30 months.

Laterality in performance of the manual dexterity inventory, for the girls, neither accounted for variability in MLU within an age nor predicted future MLU, although it did for the boys. At 18 and 24 months, but not at 30 months, laterality accounted for a significant portion of the variance, approximately 30%, in the boys' language production. (Correlations were negative for the boys meaning that left handers or mixed handers obtained higher MLU's than right handers.) Laterality at 18 months predicted 7% of the variance in language production at 24 months. This was statistically significant (p = .05) but represents a very small portion of the total variance, and therefore cannot be given much weight.

The data from this study clearly suggest that for girls laterality as determined by the hand preference measure or laterality of performance on a manual dexterity inventory, is not a factor in the development of language. For the boys the data are less clear. When hand preference was used as the laterality measure no association was found with language function. For the regression analyses, laterality as taken from the manual dexterity inventory, assumed an explanatory and a predictive role for language production.

3.2 Handedness and Developmental Language Disability: A Critical Reexamination of the Clinical Literature

The results from this research do not represent a dramatic departure from traditional wisdom, but rather a more accurate assessment, than has been possible to date, of the relationship between language proficiency and handedness in the normal child. A critical reexamination of the clinical data will show that alternate interpretations of those data are also warranted.

It is in the clinical developmental literature, more than the normal developmental literature, that an association between language ability and handedness has been most strongly argued (Brain, 1945; Critchley, 1970; Orton, 1937; Subirana, 1969). However, attempts to isolate the actual data upon which this putative association rests are not overly fruitful.

There have been very few studies of the handedness of children with developmental language disorder. For the purposes of this discussion, some papers reporting on neuropsychological and neurological function in developmental dysphasics were selected to examine the handedness of these children. Papers with a neurological orientation were favored because it was felt that they would be more likely to report on handedness. Many studies with these children do not report handedness.

Ten studies were examined and the data in respect to handedness, sex and sample size are given in Table 60.

Only two of the ten studies indicated how handedness was determined. A study of handedness was not the professed goal of any of these studies. Nevertheless, it should be noted that the assessment of handedness, as both Annett (1970b) and Bryden (1982) have indicated, requires careful attention to the items which are used, the manner of assessment (i.e. questionnaire or demonstration) and the criteria for right, left or mixed handedness.

In the Goldstein, Landau and Kleffner (1960) and the Sato and Dreifuss (1973) papers the subject descriptive information shows that some of the children were epileptic or mentally retarded. A higher incidence of left handedness in these populations is well shown (Bingley, 1958; H. Gordan, 1920).

The higher incidence of boys with developmental language problems is well documented (Benton, 1964; T. T. S. Ingram, 1959). This is confirmed in the studies reviewed here; of the ten studies, eight gave the sex of the subjects. Of a total of 144 subjects, 100 (69%) were boys and 44 were girls. This is interesting since boys are more likely than girls to be left handed (Annett, 1970a). Thus, one might query whether the presumed greater prevalence of left handedness in developmental dysphasics reflects the higher percentage of boys in these studies.

TABLE 60. Handedness in Developmental Dysphasics.

Study	Sample Size/Sex	Age	Handedness	Handedness Method Given
Goldstein, Landau and Kleffner (1960)	n = 69/Male (M) = 46 /Female (F) = 23 - mentally retard (MR) - hard of hearing	4-14 yrs.	RH - 60 (86%) LH - 8 Ambi - 1	No
Landau, Goldstein and Kleffner (1960)	n = 1/M	10 yrs.	RH	No
Sato and Dreifuss (1973)	n = 1/M MR, seizures?	11 yrs.	LH	No
Sommers and Taylor (1972)	n = 10/not given	61-83 mos.	RH - 7 NRH - 3	Yes
Tallal and Piercy (1973)	n = 12/M = 9 /F = 3	6.9-9.3 yrs.	RH - 9 LH - 1 (boys) Mixed = 2	?
Witelson and Rabinovitch (1972)	n = 24/M = 21 /F = 3	8-13 yrs.	RH - 21 LH - 3 (boys)	No
Springer and Eisenson (1977)	n = 10/M = 6 /F = 4	8.7-12.10 yrs.	RH - 6 LH - 4 (M - 2; F - 2)	No
Rosenblum and Dorman (1978)	n = 20/M = 10 /F = 10	$\bar{X}$ 5.9 yrs.	all RH	Yes
Pettit and Helms (1979)	n = 20/sex?	6-9 yrs.	only RH selected	No
Maccario, Hefferen, Keblusek and Lipinksi (1982)	n = 7/M = 6 /F = 1	2.8-5.7 yrs.	RH - 4 LH - 2 Ambi - 1	No

Three factors confound the proposed association between handedness and developmental language problems: 1) the manner in which handedness is determined, 2) the tendency to include subjects who are at greater risk for aberrant handedness aside from a developmental language problem and, 3) the sex difference for developmental language problems, i.e. boys are more likely to have developmental language problems and to be left handed.

Applying some descriptive statistics to eight of the ten studies in Table 60, a total sample of 134 subjects is obtained. Of this 108 (81%) were reported to be right handed. This leaves 26 (19%) of the sample to be left handed. (The Pettit and Helms (1979) and the Rosenblum and Dorman (1978) studies were excluded from the calculations. Pettit and Helms indicated that they selected for right handedness. Rosenblum and Dorman did not say as much; however, all 20 of their subjects were reported to be right handed.)

The figure for percentage of left handedness obtained from these eight studies is higher than estimates of left handedness in the adult population which range from 5-10%; however, it is not overly high for a child population, and it may not be overly high given that 70% of the sample was male. Belmont and Birch (1963) measured handedness in seven age groups from 5 to 11 years of age. The percentage of right handers at each age was determined and varied from 60 to 87%. Eighty-seven per cent of 5 year olds were right handed and 83% of 11 year olds were right handed.

3.3 Summary

The proposition that the emergence of normal language functions and/or difficulties in language function are related to handedness behavior -- although long-standing -- does not derive from a sound data base. The data from this research do not support an association between handedness and language ability in the normally developing child, nor do the results from other studies. The most persistent arguments come from the clinical literature in which it has been consistently reported that children with developmental language problems are more likely to be ambidextrous or left handed. However, a careful examination of a number of these studies reveals major confounds in these data. How handedness was determined was rarely described and frequently inadequate. Subject selection was not always stringent and therefore samples of developmental dysphasics included epileptics or mentally retarded children, in whom the greater incidence of left handedness is well known. Lastly, the vast majority of subjects in these studies were male.

Kinsbourne (1975a) notes that we do not know if left handedness is more prevalent in children with developmental learning problems, since there has never been a large scale study to examine this question. If left handedness is more common in these children it may not be because handedness and language function/dysfunction are particularly related - but because brain function in these children is aberrant, and the occurrence of left handedness reflects this brain dysfunction (Bakan, 1971). The concept of pathological left handedness (Satz, 1972, 1973; Silva and Satz, 1979) has been introduced to distinguish between left handedness which occurs as a consequence of normal genetic variability and left handedness which occurs as a result of damage to the left hemisphere (i.e. pathological left handedness) producing mild dysfunction in the right hand and causing the child to switch preferred hand usage to the left hand. Left handedness may be the only marker of brain abnormality in developmental dysphasics; neurological examination (i.e. clinical neurological examination and electroencephalographic recording) is frequently negative (Benton, 1964; Ludlow, 1979).

4. Language Production in Relation to Manual Motor Skill

4.1 Summary of Results

The idea that hand function and language function have a special association has a long history (described in the Introduction). In this research it was expected that children who were more advanced in the production of language would also be more advanced in measures of manual motor skill. When sex is taken into account the data provide some support for this hypothesis. Manual motor skill and language production are related in girls but only minimally so in boys. For the girls at 24 months manual motor skill accounted for 39% of the variance (p = .01) in language production, i.e. mean length of utterance (MLU); however, at 18 and 30 months it did not explain a statistically significant portion of the variance in MLU. For the boys, at no time did manual motor skill explain any of the variance in MLU.

Manual motor skill at 24 months predicted 50% (p = .01) of the variability in the girls' MLU at 30 months. However, manual motor skill at 18 months was not a factor in predicting MLU at 24 or 30 months. For the boys, 8% (p = .01) of the variance in MLU at 30 months was predicted by the 24 month manual skill measure. While statistically significant this represents a very small portion of the total variance.

There is some evidence to suggest that manual motor skill is a factor in the development of language production when age and sex are taken into account. Manual motor skill at 24 months is a significant explanatory and predictive factor for language production in girls. Why manual motor skill might be more relevant to the development of productive language in girls and why this is observed only at 24 months will be considered next.

4.2 Manual Motor Skill and Language Production in Two Year Old Girls

Why manual motor skill (MMS) and language production are particularly related in the 2 year old girl is not immediately apparent. There has been very little research in the area. The few studies which were found, and described in the Introduction, are tangential in their relevance and were done with babies less than 1 year of age (Condon and Sander, 1974; Segalowitz and Chapman, 1980; Trevarthen, 1974, 1977) or with children 3 years of age and older (Diana Ingram, 1975; Jancovic, Devoe and Wiener, 1975). With the exception of the study by Diana Ingram (1975) none of the researchers analyzed their data for sex differences. Ingram found no sex differences in her data.

Given the state of research in this area, any attempt to explain the association between MMS and language production in the 2 year old girl must be speculative. The discussion will begin with a brief summary of the language and motor abilities of the 2 year old child as found in this research and reported in the literature. The two year old is moving out of the preverbal/prelinguistic stage and into the verbal stage (Bloom, 1973; Starr, 1975) At 24 months of age a child has a vocabulary of approximately 300 words (Smith, 1962). The mean length of utterance ranges from 1.50 to 1.99; this means that the child will be making use of different parts of speech such as nouns, verbs, prepositions and pronouns and will be consistently putting together two and three words.

In this research, at 18 and 24 months the MLU for the girls was 1.24 and 2.02, respectively. For the boys the MLU was 1.04 and 1.40 at 18 and 24 months. This indicates that at 24 months the girls have reached the two-element "true language" stage, whereas the boys are still at the earliest stage of verbal functioning in which single words predominate and two or three word combinations are relatively infrequent.

In the area of manual motor skill many 2 year olds are able to string beads, stack a number of blocks, screw a top on a bottle and operate a two element toy box (e.g. Archer mystery box). Each of these seemingly simple tasks requires a degree of fine motor coordination and motor planning organization not present at an earlier age. The Archer mystery box was not given at 18 months because pilot testing had shown that few children of that age were able to perform the task. A careful examination of the motor and cognitive demands of that task is insightful. To perform the task correctly sufficient eye-hand coordination is required to pull a lever and push a button. The lever and button were designed to be of a size that the actions could not be achieved by gross hand movements but required the use of one or two fingers in isolation. In addition it was required that the task be performed in a specified order, i.e. the lever pulled first and then the button pushed.

At 24 months an element of complexity in motor control, i.e. greater fine motor coordination and sequencing ability is beginning to emerge which has not been present up to this age. This is reflected in more sophisticated language and manual motor usage.

Although the girls in this study were better talkers than the boys they did not perform better than the boys on any of the measures of manual motor skill. However, it is generally held that girls do perform better than boys on tasks of fine motor skill such as repetitive finger tapping, successive finger movements and peg moving (Annett, 1970a; Denckla, 1973, 1974; Maccoby and Jacklin, 1974; McGuinness and Pribram, 1979). McGuinness (1981) has proposed, ". . . that in girls auditory-fine motor systems are integrated to produce greater linguistic ability: a 'communicative' mode of information acquisition; whereas in males visuo-gross-motor systems conjoin to produce greater aptitude in sport and in visuo-spatial problem solving: an 'action' mode of information acquisition" (p. 61).

Research with adults suggests that language functions and manual motor skill are both mediated by the left hemisphere (Kimura, 1974, 1977). Twenty-four months of age may be a turning point for girls in the establishment or emergence of this association. This may reflect the earlier maturation of the left hemisphere in girls referred to earlier. It may also reflect a maturation of cognitive processes, specifically motor, sequential and linguistic functions, thereby eliciting left hemispheric processing. The MLU of the girls at 24 months was 2.02, suggesting advancement to the two element stage of language production and thus the emergence of verbal/linguistic functions in the true sense of the word.

4.3 Summary

The hypothesis for this research was that manual motor skill and language production would be positively correlated in young children developing language. Some limited support was obtained for this idea. An association between the production of language and manual motor skill was found for the girls at 24 months. It is not possible to say whether a particular aspect of manual motor skill, i.e. fine motor coordination, temporal sequencing is related to language production or whether the two are related by virtue of the fact that both are higher order cognitive activities. The results suggest that sex may be a factor in the association between language and motor functions. This has not been implicated in the adult research, but does concur with McGuinness's (1981) proposal of auditory-motor superiority in girls. It is important to recognize that the language and praxis functions found in adults probably are not "cognitively" the same as those seen in children and therefore the association and the basis of the association between the two may not be the same in adults and in children. Further research with special attention to the cognitive components of the language and motor tasks is required.

5. Lateral Behaviors in Young Children

5.1 Summary of Results

Studying lateral behaviors in young children (while not measuring cerebral lateralization per se), can add to our understanding of whether specialization of the hemispheres develops with age or is present from birth. It was first held, as indicated in the Introduction, that specialization of the hemispheres developed with age reaching maturity at puberty (Lenneberg, 1967). As a result of critical reexamination of the early data (Kinsbourne, 1975b; Kinsbourne and Hiscock, 1981; Woods and Teuber, 1978) and recent investigations of lateral asymmetries in infants (Entus, 1977; Petrie and Peters, 1980; Ramsay, 1979) the notion of developing hemispheric specialization has been replaced by the concept of developmental invariance of hemispheric specialization.

In this research, two questions were asked about lateral behaviors in young children: 1) is functional asymmetry present in children as young as 18 months of age? and, 2) does the degree of asymmetry observed at 18 months remain constant or vary from 18 to 30 months? There has been no research with children of these ages.

It was hypothesized that left/right asymmetries in preference and motor performance measures would be observed at 18 months and that the degree of asymmetry would not change as the children grew older. Unequivocal support was obtained for both of these hypotheses. Clear preference and performance asymmetries were observed at 18 months and the degree of asymmetry did not change from 18 to 30 months. With the exception of some minor differences the same results were obtained for the girls and the boys. These results agree with reports in the literature for younger and older children. More important, they provide information about an age range for which there has been no research to date. These are also longitudinally derived data. Valsiner (1983) has commented upon the remarkable absence of longitudinal methodology in studies of the ontogeny of hemispheric specialization and has called for longitudinal design as the "only adequate research strategy" (p. 235) in this area.

In the following sections the data from the preference measures and the motor performance measures will be discussed in greater detail.

5.2 Preference Measures

5.2.1 Hand Preference

Disregarding the direction of handedness (i.e. left or right handedness) it was found that at 18 months, 73% of the girls and 70% of the boys displayed a clear hand preference (Table 25). Similar results were seen one year later, 77% of the girls and 74% of the boys displayed a clear hand preference. These data show that at 18 months, regardless of sex, three-quarters of children have established a preferred hand, be it the right or left hand. This situation persists one year later at 30 months of age.

If the data are broken down into left and right handedness, more boys than girls have mixed or left handedness. This concurs with reports in the literature (Annett, 1970a). Close to 70% of the girls displayed right handedness from 18 to 30 months, while only 50-60% of the boys were right handed across the same age span. Thus, for the girls approximately 70% are right handed, 5% are left handed and 25% are mixed in their handedness. For the boys, approximately 60% are right handed, 15% left handed and 25% mixed in their handedness.

These figures differ considerably from the adult figures which show 90% of adults to be right handed and 10% to be left handed. However, they are consistent with reports in the developmental literature. Liederman (1983) summarized recent reports of rightward head-turning bias in neonates and found that researchers consistently reported an incidence of approximately 75%. There was no breakdown in terms of sex. Belmont and Birch (1963) reported that the incidence of right handedness in children 5 to 12 years of age ranged from 60% for 6 year olds to 87% for 5 year olds. Eighty-three per cent of 11 year olds were right handed.

The data from this study are also consistent with Annett's (1967) trichotomous classification of handedness in adults. Annett used a very strict criterion for determining the preferred hand, i.e. all task items had to be done with the preferred hand or the subject was considered to be of "mixed" preference. Using these criteria, Annett obtained a handedness distribution of: right 65%, left 4% and mixed 31%. The number of subjects in the pure left group was greater for the males but this was not statistically significant.

The results from this study which are of particular interest, and obtainable only when a longitudinal design is used, are the data about the stability of hand preference. Three-quarters of the sample, as stated earlier, displayed a clear hand preference at 18 months which was maintained until 30 months. What is not known however is whether the same children or different children were involved. Additional analyses showed that while some children changed their handedness category (i.e. the same children did not contribute to the 75% figure) it was not statistically significant. From 18 to 30 months 9 (41%) of the girls and 9 (33%) of the boys changed their hand preference category; 59% of girls and 67% of boys remained unchanged in their handedness. The difference between the sexes was not statistically significant.

When handedness stability was examined over shorter time spans, i.e. 18 to 24 months and 24 to 30 months, there was little difference from the original 75% figure. From 18 to 24 months, 73% of girls and 81% of boys remained unchanged in their handedness, while from 24 to 30 months, 77% of girls and 70% of boys remained unchanged. Measuring over shorter time intervals, confirms the first set of data in which it was found that 75% of children 18 to 30 months of age showed a clear hand preference.

Bringing together the two types of analyses (i.e. the initial analysis which did not take account of handedness stability and the latter analysis which did) two conclusions can be drawn about handedness behavior in the child from 18 to 30 months of age: 1) at 18 months of age approximately 75% of children regardless of sex show a clear hand preference. This figure is upheld by the analyses of handedness stability from 18 to 24 months and from 24 to 30 months, 2) when the time interval of measurement is extended over one year, i.e.

from 18 to 30 months, some instability in handedness is reflected; only 59% of girls and 67% of boys display a clear and stable hand preference. While these data show less stability over the longer time interval, the difference between the different age spans was not statistically significant.

5.2.2 Interpretation of Hand Preference Data in the Young Child

It is frequently stated that establishment of the dominant hand is not consolidated until 8 to 10 years of age (Belmont and Birch, 1963; Gesell and Ames, 1947). The data from this study show that as early as 18 months and certainly by 30 months, two-thirds to three-quarters of children have a clear hand preference. While it may take until 8 to 10 years of age for 100% of children to establish handedness, the likelihood that two-thirds to three-quarters have done so by age 30 months and perhaps earlier, certainly seems likely. Moreover, if one accepts Annett's (1967) proposal for a trichotomous distribution of handedness in which 31% of the adult population never do achieve a clear hand preference, then there really is no difference between the adult and the child handedness data.

If the traditional left/right handedness dichotomy is accepted, one must then consider why approximately one third of young children remain undeclared or unstable in their handedness until 8 to 10 years of age. Methodological issues in measuring hand preference in the young child warrant some comment. For the most part adult models and methods for measuring hand preference, with some modifications, have been used with children. Handedness has been defined as the preferred use of one hand over another to do familiar, everyday activities. What is to be regarded as familiar everyday activity for an 18 or 24 month old: stacking blocks, eating with a spoon, rolling a ball? This is not a facile question. Is eating with a spoon done by a 30 year old, the same task as eating with a spoon done by an 18 month old? The items chosen for the hand preference inventory in this research were selected to be familiar and within the motor capabilities of the average 18 month old. However, 'familiarity' for an adult and familiarity for an 18 month old are not likely to be the same. Moreover, young children will be more variable in their motoric capabilities of simple motor tasks than adults will be.

When the hand preference test was given it was frequently observed that the hand which was first <u>preferred</u> for an item was not always the hand which successfully performed the item. In addition, it was not uncommon for the child to do the task with one hand and then with the other. Is this because the child is unsettled in her handedness, or because she is playing with and manipulating the toy in different ways? It seemed that at times part of a child's strategy in successfully mastering the task was to go back and forth between hands.

One solution to the selection of items is to present the same one, two or three objects several times over and observe which hand reaches for and/or grasps the object. This is a common procedure with infants 8 to 12 months of age. However, it is a reaching measure and does not fit the definition of hand preference given earlier. Liederman (1983) and M. Peters (1983) note that lateralized behaviors observed during infancy, such as reaching, may be less complex than adult measures of handedness, and that differences between the hands become more apparent as the task increases in complexity. Thus, the presentation of two or three objects repeatedly may not provide a valid measure of hand preference as defined earlier.

Two questions arise from the issue of handedness instability in the young child, they are:

1) Is the handedness instability of the young child more apparent than real?
2) Does unstable handedness in children matter? Do children who are unstable in their handedness display developmental problems?

Only if the same children are tested repeatedly over time can one comment on the stability of handedness behavior. That was done in this research and the results clearly indicate that almost three-quarters of children 18 to 30 months of age are stable in their hand preference. Most other research has been cross-sectional. With cross-sectional data one can only say that a certain percentage of children are right or left handed --at a fixed point in time -- but not whether the handedness of the subjects remains the same or changes over time. The finding that fewer infants and young children than adults demonstrate a right bias does not mean that they are more changeable and unstable in their handedness.

This issue is best exemplified in a recent review by Liederman (1983), entitled "Mechanisms underlying instability in the development of hand preference". Liederman purports to examine instability in the development of handedness but almost all of the studies she reviews are cross-sectional. They do not report development over time in the same subjects, but rather the percentage of subjects showing a right bias at one fixed point in time. Most studies with infants 0 to 12 months, Liederman concludes, report that approximately 75% of subjects have a right bias. She concludes that ". . . the low incidence of right-sidedness during infancy is a real phenomenon and requires explanation" (p. 76). However, this does not necessarily mean that there is instability in the development of handedness and the results from this research suggest the opposite.

It is questionable whether asymmetries in infant reflexive activity and asymmetries in volitional activity (i.e. handedness) should both be regarded as components of a continuum of asymmetry and therefore related, or whether they are independent of each other. This is currently a matter of discussion (Segalowitz, 1980, 1983a; Young, Corter, Segalowitz and Trehub, 1983).

A small number of researchers (Gesell and Ames, 1947; Goodwin, 1983) have looked for an association between the direction of neonatal reflexes (i.e. head turning bias) and hand preference at later ages. However, that is not the same as comparing hand preference at 12 to 18 months to hand preference at 24 months, 30 months and older -- in the same sample of children. Michel (1983) reviewed the literature on the development of handedness in infancy and concluded that, "The direction of the infant's early head orientation preference is virtually a perfect predictor of its hand use preference in reaching throughout the whole of its first 14 months" (p. 61). However, as indicated earlier, reaching behavior is not synonymous with established hand preference behavior.

In conclusion, the results from this research -- in which testing was longitudinal -- indicate that handedness in the young child is not particularly unstable and that the incidence of right sidedness is not lower than in adults. This finding contradicts most other data in the area, almost all of which has been cross-sectionally derived.

If children are more unstable in their handedness, does it matter? Is there a difference, on measures of cognitive function, between children who are stable in their handedness over time and children who are not? In this research no difference was found on measures of language production and reception between children who displayed stable handedness and children who did not.

Kaufman, Zelma and Kaufman (1978) reported that 2 1/2 to 4 1/2 year old children who had a clear hand preference obtained significantly higher scores on a general cognitive index and motor index than did children who did not have a clear hand preference. For children 5 1/2 to 8 1/2 years of age, there was no difference between the two handedness groups. However, these are cross-sectional data and ideally one would want to know whether the 2 1/2 year olds who were unstable in their handedness obtained lower cognitive indices at later ages.

5.2.3 Lateral Preference Inventory

Handedness is the index of lateral preference which has been studied the most (Coren and Porac, 1977; Coren, Porac and Duncan, 1981). However, there are three other paired organs -- the eye, ear and leg -- from which a measure of lateral preference can be taken. Researchers have been interested in how the four indices are related to each other (Porac, Coren, Steiger and Duncan, 1980) and whether eye, ear and leg lateralities are related to brain organization for language functions.

There has been little investigation of these issues in the young child. In the most thorough study to date Coren, Porac and Duncan (1981) examined lateral preference behavior in a large sample of preschool children 3 to 5 years of age and in high school students 15 to 19 years of age. They found that both the younger and the older children showed predominantly right-sided preference patterns for both limbs and sense organs. The older group, however, showed a higher degree of association between the different indices of laterality. In addition, they reported that 32% of the preschoolers and 53% of the adolescents showed a right bias on all four indices.

In this research eye, ear and leg preference was measured at 18, 24 and 30 months. Only the 30 month data were analyzed because of a lot of missing data at the earlier ages. At 18 and 24 months the leg items were refused by many of the children and many of the children did not seem to comprehend the task of bringing an object up to one eye and then sighting through it, even though considerable demonstration was given.

The eye, ear and leg measures were incorporated into one score of lateral preference. At 30 months, 12 (54%) of the girls and 15 (56%) of the boys showed a clear right sidedness, i.e. 5 of the 6 test items were performed with the right side.

Across all the girls a mean right sidedness of 74% was found, while for the boys a mean right sidedness of 68% was obtained. Correlation analyses showed that performance on the lateral preference inventory correlated positively with hand preference at all the test ages for both the boys and the girls.

It is difficult to compare the results of this research with those of Coren since Coren et al. (1981) tested each index more extensively than was done in this study and used a more stringent criteria of right preference for each index.

5.2.4 Familial Handedness

There has been increasing interest in patterns of familial handedness, in particular familial sinistrality, as a possible intervening and explanatory factor for: the determination of handedness (Annett, 1978), the degree of recovery from brain damage (Hécaen and Sauguet, 1971) and the pattern of performance on tests of cognitive function (Carter-Saltzman, 1979; Gilbert, 1977).

There has been no investigation of handedness behavior or language function in the young child in relation to patterns of familial handedness. The results obtained in this study suggest that familial left handedness (FLH) may be a factor in language acquisition. A comparison across sexes of high and low MLU scores in respect to the presence (FLH+) or absence (FLH-) of FLH showed that children who obtained higher MLU scores were more likely to have a left-handed family member. Thus, FLH may afford some advantage to the acquisition of language. In future researchers should consider variability in language development in relation to familial handedness patterns. In adults the prognosis for recovery of verbal functions after brain damage is better for individuals who have left-handed family members than for those who do not (Hécaen and Sauguet, 1971).

An analysis for sex differences showed no differences between boys and girls regarding the occurrence of FLH. Left handedness in the boys may be related to the presence of FLH but sample size was too small to permit formal statistical analysis. It has been reported that left-handed parents, in particular left-handed mothers, are more likely to have left-handed children (Annett, 1978).

5.3 Performance Measures

Two questions were of interest as regards the performance measures of laterality: would children as young as 18 months of age demonstrate a hand superiority in the predicted direction, and would this hand superiority be maintained until 30 months of age? Tests of lateral motor ability have been given to older children (youngest age 3 years, Diana Ingram, 1975; see Witelson, 1977 for a review of these studies), but no studies were found in which separate hand scores were obtained for children as young as 18 months. With the exception of the Annett peg moving task none of the tasks which were given have been used before as measures of lateral motor ability. A right hand preference was predicted for all the tasks. This prediction was made either on the basis of previous reports in the literature or on a theoretical basis, i.e. given the apparent motor/cognitive demand of the task and/or its similarity to a previously administered task, a right hand preference was expected. Annett (1970a) reported a right hand preference on the peg moving task for children 3 1/2 to 15 years of age. The Bayley formboard and pegboard tasks were regarded as pegboard variations and thus a right hand preference was predicted. For the mystery box task the child was required to pull a handle and push a button in a specified order. Since it was felt that there were some analytic and sequential components to the task a right hand preference was expected. Kimura (1977) used a similar, but more complex task, the "manual sequence box" with brain damaged adults and reported that subjects with a left hemisphere lesion performed more poorly than subjects with a right hemisphere lesion. Since Kimura did not actually use the task with normal subjects, the inference is made that with a left hemisphere mediated task, a right hand superiority will be obtained.

Scoring on the manual dexterity inventory differed from the other performance measures. The manual dexterity inventory is comprised of several items and because not all the children did the same items or the same number of items, for each child the data were represented as the percentage of items done with the right hand.

Predicting a right hand preference for the manual dexterity inventory may be somewhat questionable in that the task was comprised of several items which were likely to be within the motor capabilities of an 18 to 30 month old. Whether cutting with scissors and stacking blocks are tasks more likely to be performed by the right hand is a matter of conjecture. However, on the whole it was felt that the majority of the items would be more likely to require some analytic, sequential processing, fine motor skill and some degree of motor planning -- all likely to require left hemisphere mediation -- and therefore a right hand superiority.

A right hand preference was found for all the tests that were given. Both sexes showed a right hand effect for the Bayley pegboard and the Annett peg moving task at all the test ages. For the Bayley formboard only the boys achieved a right hand superiority, and on the Archer mystery box task only the girls showed a right hand effect. There was no difference between the sexes on the manual dexterity inventory; for both sexes the degree of right handedness was 70-75% across all the test ages.

These findings are important because they conclusively show laterality in the performance of manual motor tasks -- in children of an age for which there are no such data. These data show that children as young as 18 months clearly choose one hand over the other to perform tasks of manual motor skill. Moreover, the finding that the predicted right hand preference was obtained concurs with the handedness data in this study. The majority of the boys and girls were found to be right handed. This finding suggests continuity with the results from studies with adults.

In the "laterality invariance" hypothesis it is proposed that cerebral hemisphere specialization is present from birth and does not change with age (Kinsbourne, 1975b). The persistence of a right hand superiority across the total age period of testing supports a concept of invariance of lateral <u>behaviors</u>. Support for the concept of hemispheric invariance is secondary in that handedness is a poor marker of hemispheric specialization.

6. Concluding Remarks

In this thesis language development in young children was studied in relation to sex, manual motor skill and laterality. Lateral asymmetry in relation to age was also examined. The girls performed significantly better than the boys on almost all measures of language reception and language production. This confirms many previous reports of early female verbal superiority. Three theories were presented to account for the girls' verbal superiority. It is likely that female verbal superiority in the early years is a function of the girls' advanced maturational rate combined with a genetic predisposition to a more bilateral (relative to males) representation of language in the cerebral hemispheres. This is a synthesis of Theories One and Two. No differences were found between the sexes for measures of handedness, lateral motor performance, manual motor skill, gross motor function and general cognitive function.

These results provide supportive but not definitive evidence for the concept of developmental invariance of hemispheric specialization.

Language ability in relation to handedness strength and familial handedness patterns was also examined. Contrary to previous reports, language proficiency was not found to be related to the subject's strength of handedness; however, it was related to familial handedness patterns, a factor which has not previously been considered in the developmental language literature.

The results of this research contribute to our understanding of sex differences in language acquisition and to the relations, in children, between language ability, hand preference and familial handedness patterns. These factors may be relevant for the assessment and treatment of development language problems. In the future researchers should examine individual differences in language development in the light of familial handedness patterns. Since the sample was middle class it will also be important to determine if these findings hold for other social classes.

APPENDIX

GROSS MOTOR INVENTORY (Modified Bayley, PDI)

Name ____________ Date #1 ________ #2 ________ #3 ________
Birthdate ____________ Age #1 ________ #2 ________ #3 ________

Score: Pass = 1; Fail = 0.

Session/Score

PDI	ITEM	#1	#2	#3
47	1. Stands up: I			
49	2. Walks sideways			
50	3. Walks backward			
51	4. Stands on right foot with help			
52	5. Stands on left foot with help			
53	6. Walks up stairs with help			
54	7. Walks down stairs with help			
57	8. Stands up: II			
58	9. Stands on left foot alone			
59	10. Jumps off floor, both feet			
60	11. Stands on right foot alone			
61	12. Walks on line, general direction			
63	13. Jumps from bottom step			
64	14. Walks up stairs alone: both feet on each step			
65	15. Walks on tiptoe, few steps			
66	16. Walks down stairs alone: both feet on each step			
67	17. Walks backward, 10 feet			
69	18. Jumps from second step			
70	19. Distance jump: 4 to 14 inches (note distance)			
71	20. Stands up: III			
72	21. Walks up stairs: alternating forward foot			

Name ____________

Date ____________

Age ____________

PDI	ITEM	30 mos.
73	22. Walks on tiptoe 10 feet	
75	23. Keeps feet on line, 10 feet	
76	24. Distance jump: 14-24 inches	
77	25. Jumps over string 2 inches high	
78	26. Distance jump: 24-34 inches	
79	27. Hops on one foot, 2 or more hops	
80	28. Walks down stairs: alternating forward foot	
81	29. Jumps over string 8 inches high	

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PARENT CONSENT FORM

Study of the Relation Between Language Development and Motor Development in Young Children

The investigation in which my child is to be enrolled has been explained to me; I am signing on behalf of myself and the child. I understand that my child will be seen in my home on three occasions: at 18, 24 and 30 months of age. If my child objects to the investigation, or I do, we may withdraw from the study without jeopardy to any further treatment from our medical practitioner or from anyone at McMaster Medical Center.

On each of the occasions when my child will be seen the child will be given a variety of psychological tests intended to assess the child's language development and motor development; on each occasion the tests will take about 1 hour. I understand that the investigator and the tester will be Mrs. Lynda Archer; she undertakes to keep the results confidential so that they will be known only to her. However, she will undertake to provide me with any information about the child on the basis of the tests of which I may request or which she believes may be of interest to me.

There is no potential benefit to the child in these tests which are undertaken for research. I understand that I may be present if I wish throughout the tests and may interrupt them anytime.

Child's Name ______________________________

Parent ______________________________

Date ______________________________