11139

NATIONAL LIBRARY
OTTAWA

BIBLIOTHÈQUE NATIONALE
OTTAWA

CANADA

NAME OF AUTHOR...JAMES....WILLIAM...IRVINE......

TITLE OF THESIS..HANDEDNESS..PREFERENCE,........
...MANUAL..DEXTERITY,..EAR..ASYMMETRY
...IN...DICHOTIC..LISTENING..AND GRADE TWO
READING PROFICIENCY

UNIVERSITY.....UNI........OF........ALBERTA, EDMONTON.

DEGREE FOR WHICH THESIS WAS PRESENTED.......Ph.D.........

YEAR THIS DEGREE GRANTED........1972....................



(Signed)....J W Irvine.........

PERMANENT ADDRESS:

% Uni. of New England
Armidale. N.S.W.
Australia

DATED..February 3..1972

NL-91 (10-68)

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "Handedness Preference, Manual Dexterity, Ear Asymmetry in Dichotic Listening and Grade Two Reading Proficiency," submitted by James William Irvine, in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Supervisor

External Examiner

Date: January 19, 1972.

ABSTRACT

The present study examined some relationships pertaining to handedness preference, manual dexterity, ear asymmetry in dichotic listening and reading proficiency, for a sample of normal grade two children.

On the basis of reported handedness preferences, an initial sample was selected representing left, mixed and right preferent children. Manual dexterity tasks were administered to these 222 children (53 LH, 50 MH and 119 RH) and Gates-MacGinitie reading data were made available by cooperating schools.

Cerebral asymmetry for the processing and recall of serial, verbal information was measured by a dichotic listening task involving digit-pair-series. Dichotic listening data were obtained for 108 children, drawn from the initial sample to represent three levels of handedness preference, three levels of manual dexterity and two levels of familial handedness preference.

Planned comparisons indicated no differences in reading proficiency among handedness preference groups in the initial sample although dextrous children were clearly more proficient readers than nondextrous children. Similar results were obtained for children in the restricted sample of 108 Ss.

Children classified as right-ear-dominant (RE) and left-ear-dominant (LE) on the basis of dichotic listening performance were clearly more proficient readers than children with no demonstrated

recall asymmetry (nondominant; NE), particularly when this comparison was restricted to nondextrous Ss. The mean reading level of RE children was higher than that obtained by LE Ss. Under conservative analysis the difference was not significant.

Supplementary stepwise regression analyses suggested that ear asymmetry and manual dexterity variables provide significant, relatively independent information for the prediction of reading proficiency.

Although clearly defined handedness preference and ipsilateral ear asymmetry were modestly related, data were interpreted as equivocal with regard to handedness preference/ear asymmetry relationship.

The results seem to indicate that dichotic listening can provide a procedure for measuring functional asymmetry. Further investigations of ear asymmetry/handedness and ear-asymmetry/reading relationships were suggested.

ACKNOWLEDGEMENTS

The writer wishes to thank the principals, teachers and students involved in this investigation for their kind cooperation. Appreciation is also expressed to Vic Bauman, Glen Coward and Alan Yackulic for technical assistance in developing a dichotic tape, to Geoff Molloy and Paul Smith for assistance in data collection, and to the Division of Educational Research Services for assistance in data analyses.

A special word of thanks is due to Dr. J. Robertson, Dr. K. Gough, Dr. T. Maguire and Dr. J. Das for advice at various stages of the dissertation, and to Dr. D. Fitzgerald, whose insights and assistance are sincerely appreciated.

Finally, and with affection, the writer wishes to thank his wife Sue, and our boys Andrew and David, for their continual trust and support.

TABLE OF CONTENTS

LIST OF TABLES

| TABLE | | PAGE |
|---|---|---|
| 15 | Analysis of Variance Summary Table for Restricted Sample Reading Proficiency: Planned Comparisons Involving Handedness Preference, Manual Dexterity, Familial Handedness and Dichotic Listening Ear Asymmetry . . . . . . . . . . | 111 |
| 16 | Stepwise Regression: Manual Dexterity and Ear Asymmetry Variables With Reading . . | 122 |
| 17 | Correlation Matrix for Variables Entered in Stepwise Regression Analysis: Restricted Sample . . . . . . . . . . | 123 |
| 18 | Suggested Follow-up Studies . . . . . | 133 |
| 19 | Analysis of Variance Summary Table for Groups Drawn From Restricted Sample: Ear Asymmetry in Dichotic Listening and Reading . . . . . . . . | 158 |
| 20 | Ear Asymmetry Classifications and Reading: Restricted and Reduced-Restricted Samples . | 158 |

## LIST OF FIGURES

# CHAPTER I

## INTRODUCTION

Medical evidence suggests that the normal progression during early childhood from the prelanguage neonate to the fluently verbal preschooler is concomitant with cerebral maturation from a state of relative undifferentiation and hemispheric functional equipotentiality to progressively greater differentiation of cortical functioning and the lateralization of some functions (Basser, 1962; Lenneberg, 1967). Paralleling these developments, manual proficiency and more pronounced unimanual dominance develop, such that when formal schooling begins, most children have greater proficiency with, and preference for, the right hand (Hecaen & de Ajuriaguerra, 1964). A much smaller percentage are clearly sinistral (left) preferents, while an even smaller percentage have either not become proficient (dextrous) with either hand or can comfortably perform unimanual skill-demanding tasks with either hand.

Penfield and coworkers (1959) argued that the tendency for left-lateralization of speech functions to be more universal than right-handedness, suggests the independence of unimanual dominance and hemispheric functional asymmetry, except where hemispheric displacements occur in infancy due to cerebral pathology. In contrast, Benton (1965) and Hecaen & de Ajuriaguerra (1964) argued that displaced manual dominance <u>causes</u> an analogous displacement in "cerebral dominance." Right-lateralization and/or more diffuse representations of speech functions have been reported for some adult sinistrals among whom there was no reason to suspect infantile cerebral pathology (Carmon & Gombos, 1970; Conrad, 1949: Giannitrapani, 1967). Some evidence tangentially implies the greater likelihood of these functional differences among sinistral offspring of sinistral parents (Bryden, 1965; Weinstein & Sersen, 1961).

Of educational significance is the assumption that reading proficiency may be dependent upon what McFie (1952) described as the "neurophysiological organization corresponding to 'dominance' (p. 199)" being established in one hemisphere, a position espoused by Orton (1937), Silver & Hagin (1967), Zangwill (1962) and indirectly by Penn (1966). Harris (1957), Orton (1937) and Phelps (1965) further suggested that ambiguous hand preference is related to unestablished cerebral hemispheric "dominance" for verbal functioning, an assumption of central importance to the clinical programs of both Delacato (1963) and Phelps (1965).

By a series of inferences, linking unestablished unimanual dominance to unestablished cerebral functional asymmetry (allegedly due to mild neurological impairment or maturational "lag"), unestablished unimanual dominance has been assumed by some writers to be relevant to delayed speech or reading (Dreifuss, 1963; Harris, 1957; McFie, 1952; Naidoo, 1961; Orton, 1937; Phelps, 1965; Silver & Hagin, 1967).

It is interesting therefore, that studies involving non-clinical samples of children (Balow & Balow, 1964; Belmont & Birch, 1965; Capobianco, 1966, 1967; Coleman & Deutch, 1964; Stephens, Cunningham & Stigler, 1967; Treischmann, 1968) have consistently found little evidence to substantiate any relationship between unestablished unimanual dominance and reading proficiency. These studies did not, however, distinguish between handedness preference and manual proficiency (dexterity), yet this distinction may be important (Zangwill, 1962; Zurif & Carson, 1970). Additionally, when using children of elementary school age (Belmont & Birch, 1965; Capobianco, 1966, 1967; Coleman & Deutch, 1964; Treischmann, 1968), it is difficult to evaluate the importance of factors intervening between initial reading failures in primary classrooms and current performances (Koos, 1964). Available evidence neither adequately substantiates nor adequately refutes the suggested relationship between proficient unimanual dominance and reading proficiency. Although it has been possible for many years to systematically compare reading proficiencies of carefully delineated subgroups of manually proficient and nonproficient dextral, sinistral and ambilateral children, such comparisons do not appear to have been undertaken. The investigation of these relationships was of central concern in the present study.

The term "cerebral dominance" has also been widely used in relation to reading (McFie, 1952; Orton, 1937; Silver & Hagin, 1967; Zangwill, 1962). It must be stressed, however, that until the development of procedures for comparing left/right efficiencies in simultaneous bilateral viewing and simultaneous bilateral (dichotic) listening, the functional dominance of one cerebral hemisphere for the processing, storage and recall of "verbal" information (verbal left dominance or verbal right dominance), could be determined only by direct medical intervention (Penfield & Roberts, 1959; Serafetinides, et al, 1965; Wada & Rasmussen, 1960), or by comparing functional impairments with defined cortical lesions (Basser, 1962; Conrad, 1949; Luria, 1966).

Sufficient evidence now indicates the appropriateness of dichotic listening (DL) procedures for detecting cerebral functional dominance in processing series of "verbal" and "nonverbal" auditory stimuli (Curry, 1967; Kimura, 1964; Knox & Kimura, 1970; Satz et al., 1965). Using the DL technique, it is possible to compare subjects' performances under a variety of presentation and recall conditions and to compare such performances with handedness characteristics and reading criteria.

Ongoing clinical programs of Delacato (1963) and Phelps (1965) place heavy reliance on the necessary ontogenetic development of cerebral functional dominance and proficient unimanual dominance in children, despite the lack of substantive evidence supporting the underlying assumptions (Robbins & Glass, 1969). Additionally, many reading clinics continue to implicate laterality anomalies or inferred cerebral functional anomalies in cases of reading disability (Capobianco, 1967). Although less frequent today than some decades ago, the practice of requiring children to write with the right hand continues in some European educational settings (Glonig et al., 1969).

Such considerations suggest the importance of examining each of the variables; handedness, cerebral functional dominance and early reading proficiency, as well as some of their interrelationships. Accordingly, the primary purpose of the present investigation was to closely examine the relationships among variables pertaining to the concepts "handedness," "cerebral functional dominance" and "reading."

# CHAPTER 2

## REVIEW OF LITERATURE

### Laterality and Reading

One of the interesting developments in an infant's striving toward increased mobility and manipulation of the immediate environment is the gradual acquisition of manual proficiency. Unlike walking, however, manual coordination appears to become more efficient as the child learns to perform skill-demanding manual tasks primarily with one hand, with or without assistance from the other hand. Initial attempts, characterized as much by vacillation of preference as by minimal proficiency, become progressively more patterned (Kephart, 1964). Although most children develop consistency in manual preference during preschool years, it is a matter of conjecture why right-handed preference is most often developed. When formal schooling begins, most children have a consistently preferred dominant hand and a consistently preferred assisting hand for executing skilled bimanual tasks. Generally, the difference in proficiency between the skilled, dominant hand and the assisting hand is more readily apparent in childhood than in infancy.

Left-handedness (sinistrality) and ambilaterality are relatively uncommon in adult samples, with estimates of nondextrality ranging from 1-25%, depending upon the sample tested and the classificatory criteria employed (Hecaen & de Ajuriaguerra, 1964). Most studies concur with Brain's (1945) estimation that approximately 10% of any unselected adult population can be considered left-hand-preferent (LH).

In order to meaningfully compare research reports in which "handedness" is a relevant variable, it is imperative to know the criteria used for classifying subjects as left-hand-preferent, right-hand-preferent or mixed-hand-preferent. Available evidence clearly indicates that left-hand-preference is a matter of relative rather than absolute classification. Reported hand preference (Humphrey, 1951), more proficient hand (Treischmann, 1968), writing hand (Glonig et al., 1969), hand dominant in skilled manual tasks Harris (1958) arm extensibility (Hecaen & de Ajuriaguerra, 1964) and dominant hand observed over a period of weeks (Phelps, 1965) are clearly not synonymous classificatory criteria.

In the absence of any generally acceptable criterion of handedness against which measures of handedness can be validated, many writers have employed arbitrary procedures of dubious validity. The suggested handedness batteries of Bannatyne & Wichiarajote (1969), Cernacek (1964) and Luria (1966) contain items of questionable scientific merit.

Using a sample of Oxford University students, Humphrey (1951) examined the relationship between subjects' self-reported handedness, and handedness determined from responses to questionnaire items describing performance in some skilled manual activities. Right-handers were relatively consistent but some self-reported left-preferents were reclassified by Humphrey as ambilaterals or RH. The relative heterogeneity among self-classified LH has been noted elsewhere (Carmon & Gombos, 1970; Zurif & Bryden, 1969; Satz, Achenbach, Pattishall & Fennell, 1965).

Bannatyne's battery included some items alleged to measure "unlearned handedness" (viz: folding arms, clasping hands together with meshed fingers, and touching the left ear with a particular hand). It is difficult to accept the claim that these skills are unlearned.

Cernacek (1964) cited several studies suggesting the presence of laterality preferences among subhuman species. In attempting to account phylogenetically and ontogenetically for the development of laterality, Cernacek developed a battery of 17 tests which were administered to "100 persons." Subjects were arbitrarily classified, on the basis of test results, along a continuum from "very pronounced sinistrals" to "very pronounced dextrals." Partly due to the dubious validity of some of the subtests, few subjects were classified at either extreme, and the majority (77%) fell into dextral categories; viz: "slight dextrals" (18%); "moderate dextrals" (36%); "pronounced dextrals" (16%); very pronounced dextrals" (7%). Subtest inter-correlations and reliabilities were not reported.

The tendency for left-handedness to be more common in children having one or both parents left-handed (Hecaen & de Ajuriaguerra, 1964) has been interpreted by Penfield & Roberts (1959) as evidence of genetic factors in determining laterality. This interpretation is open to question. Recent studies by Bryden (1965), Curry (1967), Zurif & Bryden (1969) and by Weinstein & Sersen (1961) suggest that cerebral functioning of "left-familial/left-hand-preferents" (i.e., left-handers with left-handedness in members of immediate families and in particular, individuals with left-hand-preferent mothers) may be quite different from that of "nonfamilial/left-hand-preferents." The usefulness of distinguishing among left-hand-preferents on the bases of negative, suspected or verified infantile cerebral pathology, clarity of preference, manual dexterity, and presence or absence of left-handedness in immediate families, merits research consideration.

In their extensive but poorly documented review of relevant literature, Hecaen & de Ajuriaguerra (1964) reported unusually higher incidences of nondextrality for samples of retarded, epileptic and dyslexic adults. In each of these disabilities, the possibility exists that some form of childhood cerebral pathology, however mild, may be relevant (Dreifuss, 1963; Milner et al., 1964; Zangwill, 1962). Accordingly, a useful distinction between "shifted dextrals" (LH because of pathologically induced infantile displacement of hand control to the right cerebral hemisphere) and "natural sinistrals" (LH with no history of early cerebral pathology) was suggested by Dreifuss (1963). Dreifuss also suggested the importance of another handedness group which he called "shifted sinistrals" (natural LH forced by home or school to adopt dextral preference, especially in writing).

It is not surprising, therefore that consistently higher incidences of nondextrality have been reported among epileptic populations (Milner et al., 1964; Serafetinides et al., 1965), which could be expected to include both "shifted dextrals" and "natural sinistrals."

Higher incidences of non-right-handedness have also been reported among samples of children with serious reading difficulties (Harris, 1957; Ingram & Reid, 1956; Orton, 1937). Most commonly the reported nondextrality appeared to be characterized by inconsistent or poorly established manual preference. In this regard, an interesting recent study (Naidoo, 1961) has been reported by Zangwill (1962).

Naidoo administered ten conventional handedness measures to a random sample of 418 British school children (ages 4.9 - 5.11). On the basis of their performances on the handedness tests, 360 (86%) were classified as right-handed, 38 (9%) as left-handed and 20 (5%) as ambiguously handed. Each child in the ambiguously-handed group was matched, on age, sex and type of school, with one pronounced left-preferent and one pronounced right-preferent child. Group comparisons were then made. Zangwill commented:

> ...the children with ambiguous handedness were, as a group, significantly inferior to the other two groups in verbal intelligence-test level. They also tended to have a history of slow speech development and a higher incidence of complications at birth (p. 111).

Phelps (1965) and Dreifuss (1963) have also associated slow speech development with ambiguous hand preference.

Extensive research and some speculation concerning the etiology and remediation of reading problems was undertaken by Orton (1937). Having observed that many apparently normal children exhibited serious reading difficulties, Orton noted that reversal tendencies (e.g., reading "was" for "saw"), directional confusions and either left-handedness or poorly established manual dominance were often coexisting characteristics. Orton argued that confusion in the efficient directional processing of symbolic material was due to failure to establish a dominant hemisphere. Each hemisphere was assumed to be a mirror image of the other, the "minor" hemisphere being a "weakened copy."

Although current thinking does not support the global "dominance" assumption, some writers have suggested failure to establish a "dominant" hemisphere as a causal factor in dyslexia (McFie, 1952; Silver & Hagin, 1967; Zangwill, 1962). From observations of twelve adult dyslexics, McFie suggested that "the neurophysiological organization corresponding to "dominance" has not been established in either hemisphere (p. 199)."

Silver & Hagin (1960) noted abnormal Schilder Extension Test performances in 92% of a sample of 150 children between 8.6 and 14.0 years who were experiencing serious reading problems. A later study (1967) reported extension test abnormalities in 34 of 41 "underachieving readers" identified from a sample of 100 third and fourth grade children. Of the 41 exhibiting abnormalities on the extension test, 39 were rated as below average readers. The writers suggested that the extension test reflected "cerebral dominance" (or lack of dominance). This claim has not been substantiated empirically. As the criteria used for delineating "reading disability" and information concerning sampling procedures were not provided, meaningful interpretation of these data is difficult. The writer's experience

(Irvine, 1968) suggested that the Extension Test had limited inter-rater reliability.

Zangwill (1962) and Penn (1966) have reported high incidences of EEG abnormalities among samples of dyslexic children. Relevant studies reviewed by Penn consistently reported "parieto-occipital abnormalities...suggestive of immaturity and irregular cortical development (p. 245)," in approximately 75-80% of dyslexic children.

Some consistency is evident between the interpretations of Zangwill and Penn, and the "maturational lag" hypothesis of Bender (1957). Immaturity in development of cortical functions has been suggested by Harris (1957) and by Zurif & Carson (1970) as a plausible hypothesis accounting for delayed manual dominance concomitant with serious reading difficulties. Ingram & Reid (1956) studied 78 children having average intelligence test performances and severe reading and/or writing difficulties ("developmental aphasia") who had been referred to the Department of Psychological Medicine at Edinburgh. Some evidence of persisting articulation difficulties and histories of delayed speech development were evident in approximately 60% of these children. Sixty-five of the 78 were boys. Unestablished or vacillating hand dominance was noted in 71% of the sample, notwithstanding that the majority of the children were between six and nine years of age.

It must be emphasized that studies suggesting the relevance of laterality variables in delayed acquisition or speech or reading proficiency, have generally examined clinical samples. When nonclinical samples have been tested, most studies have failed to substantiate the relevance of laterality factors (Balow & Balow, 1964; Belmont & Birch, 1965; Capobianco, 1966, 1967; Coleman & Deutch, 1964; Stephens, Cunningham & Stigler, 1967; Treischmann, 1968).

Balow & Balow (1964) examined word reading and paragraph reading performances of 250 children randomly selected from grade two classes in Minneapolis. Comparisons were made among groups differentiated on the basis of hand dominance, hand/eye preference consistency and sighting dominance. No significant differences were noted between clearly established and unestablished manual preference groups, nor between groups differentiated on the basis of hand/eye consistency.

Coleman & Deutch (1964) compared laterality performances of matched groups of "normal" and "retarded" readers in upper elementary grades. No significant differences emerged. Similar findings were reported by Belmont & Birch (1965) for a random sample of 200 boys, 9-10 years of age, in Aberdeen, Scotland.

Capobianco's studies of mentally retarded (1966) and learning disability children (1967) found no differences in reading performance between groups with clear laterality preferences and those with unestablished laterality.

Koos (1964) questioned the validity of making retrospective inferences to causal factors among children tested after some years of reading failure. Factors responsible for initial failure need not be evident years later. Capobianco's learning disability sample of 41 children ranged from 7.7 to 16.7 years of age with a mean of 11.2. Yet Silver & Hagin (1964) seemed to imply that reading disability will persist whenever cerebral lateralization has not been established.

Stephens, Cunningham & Stigler (1967) noted negligible relationships between hand-eye combinations and "reading" performance (as measured by the Metropolitan Reading Readiness Test), for a sample of 89 grade one children. The MRRT is unfortunately not a highly successful predictor of later reading achievements, a finding which the researchers were cognizant of.

Treischmann (1968) compared normal and subaverage readers, in a sample of 60 boys from grades two and three, on some laterality and perceptual tasks. The incidence of undifferentiated handedness was the same in both groups. Hand proficiency was assessed for each hand on a series of fine-motor, unimanual tasks. However, since 47% of the boys were classified as having "undifferentiated handedness," meaningful comparisons with other studies are difficult.

Evidence concerning the relevance of laterality variables for proficiency in academic subjects is inconclusive. Some "clinical" studies have implied an underlying neurological "lag" or mild neurological abnormality in most cases of delayed development of unimanual proficiency. In contrast, studies of normal children have often been unable to establish relationships between laterality and academic variables. Undoubtedly some of this confusion results from the failure of most researchers to distinguish between manual dominance and manual competence or dexterity. There appears to be little a priori justification for expecting differences in academic achievements between proficient right-handed and either proficient left-handed or proficient ambilateral children.

## Clinical Considerations

Despite the confused state of information regarding handedness and lateralization of cerebral speech functions, some current clinical programs incorporate unilateral manual dominance training. One such program, advocated by Phelps (1965) is based on the assumption that:

> Normally, (manual) dominance becomes set at about 18 months, which is of course the age at which the child begins to talk. Delayed setting of dominance thus results in speech delay (p. 934).

In children presenting symptoms of delayed speech in conjunction with unestablished manual dominance, Phelps advocated intervention by means of restraining procedures for the hand/arm noted over several weeks of observation as "less dominant," while providing unimanual fine-motor and gross-motor activities for the "more dominant" hand. Phelps suggested that as manual dominance becomes established, speech facility improves and emotional lability declines. Successes have been claimed with 75-80% of children in the two to four years age range, who have been treated at his clinic. Phelps commented that the percentage of "successes" rapidly declines as adolescence approaches, so that the procedures are unlikely to benefit children over twelve years of age. While the latter claim is possibly consistent with neurological evidence of childhood plasticity (Basser, 1962; Lenneberg, 1967), Phelps has presented no evidence to support the efficacy of his intervention program, other than alleged successes in "over 25 years of clinical experience (p. 941)."

The program of Delacato and coworkers, centred at the Philadelphia Institute for the Achievement of Human Potential, received widespread publicity during the 1960's. In essence, their treatment program developed from an elaboration of the assumption that "ontogeny recapitulates phylogeny (1963, p. 6)." Thus, early intellectual development is assumed dependent upon an orderly progression through specific sensori-motor skills. When this assumed progression is impeded by physiological or neurological impairments, "patterning" (forced physical repetitions of prescribed exercises with the assistance of adults) is instituted. Such patterning continues on a daily basis, often over extensive periods so as to passively impose an appropriate "neurological organization" and thereby facilitate a child's progression to higher developmental levels.

The program is not without its critics. A scholarly and closely documented review (Robbins & Glass, 1969) of the assumptions, procedures and allegedly supporting evidence underlying the Delacato program, suggested that the validity of every aspect of the program has yet to be adequately established.

Although Phelps (1965) and Delacato (1963) have been primarily concerned with the rehabilitation of children with central nervous system impairments, the procedures have been suggested as appropriate for normal children. "Cerebral dominance" is a central concept in the rationale of both Phelps and Delacato and continues to be associated with laterality variables in the diagnostic programs of some reading clinics, despite the tenuous nature of supporting evidence (Capobianco, 1967).

The relationship between cerebral functioning and manual dominance, particularly during early childhood, is uncertain. An examination of some neurological evidence pertaining to these issues is thus of interest.

## Cerebral Functional Asymmetry: Neurophysiological Evidence

The interesting possibility that the two cerebral hemispheres in man might differ in function was suggested over one hundred years ago by Marc Dax and Paul Broca. Both surgeons had independently reported cases of speech impairments among dextral adults with left-hemispheric lesions (Penfield & Roberts, 1959). Broca also reported an instance of unimpaired speech in a right-hemiparetic, sinistral patient with an anatomically verified large lesion restricted to the left cerebral cortex.

Broca suggested that "speech dominance" (lateralization of speech functions) was directly related to motor dominance of the contralateral hand. This assumption gained some acceptance despite occasional reports of speech impairment following injuries to the hemisphere ipsilateral to the dominant (generally left) hand.

By the end of the nineteenth century, a sufficient number of exceptions had been reported to necessitate reconsideration of the assumed relationships between handedness and cerebral asymmetries. Some important postwar developments have added to our understanding of cerebral functioning.

One such development was the repatriation of large numbers of veterans who had sustained various types of cerebral injuries during combat. Samples of brain-injured veterans provided neurologists and psychologists with opportunities to more accurately compare structural damage with functional impairments. Additionally, it seemed reasonable to assume that most veterans had no background history of cerebral pathology during childhood. In the light of Basser's work (1962), it can be assumed that childhood cerebral pathologies may be associated with displacements of some functions, thus confounding attempts to relate functional impairments to specific lesions in cortical tissue. On the assumption that veterans had relatively normal structures and functions prior to sudden cerebral injury, it is of interest to examine figures derived from Conrad (1949, cited in Benton, 1965) concerning handedness and lateralization of speech functions.

It is important to note, however, that no attempt was made to match subjects on the basis of site of lesion or extensiveness of tissue destruction, factors clearly affecting the nature of functional impairments. Nevertheless, Conrad's figures suggest that the relationships between cerebral speech laterality and hand dominance were more complex than Broca had assumed.

TABLE 1

HEMISPHERIC LOCUS IN 203 APHASICS
WITH UNILATERAL LESIONS

| Locus of Lesion | Handedness Classification | | Total |
| --- | --- | --- | --- |
| | Right | Left | |
| Left hemisphere | 175 | 10 | 185 (92%) |
| Right hemisphere | 11 | 7 | 18 (8%) |
| | 186 | 17 | 203 |

The development of the technique of "cortical mapping", by Penfield and associates at the Montreal Neurological Institute added considerably to the understanding of cerebral functions. When excision of cortical tissue was contemplated in cases of severe epilepsy, it was important for the neurosurgeon to presurgically determine the likelihood of postoperative impairments. Accordingly, electrodes were systematically applied to exposed areas of cortical tissue while the conscious patient responded to oral demands of the neurosurgeon. Impairments of functions and unsolicited responses were recorded, thus enabling the neurosurgeon to preoperatively plan the surgical intervention. Over a period of years, considerable information accumulated concerning cortical speech localization (Penfield & Roberts, 1959). It is interesting, therefore, that the Montreal data were interpreted as indicating that:

> ...the left hemisphere is usually dominant for speech regardless of handedness....Brain function and handedness may be unrelated except by disease (p. 102).

In most right-handed and approximately two thirds of left-handed adults examined by Penfield and associates, interference with speech (in the form of total arrest, slurring, distortion, impaired counting or naming difficulty) was associated primarily with three interdependent areas of the left cerebral hemisphere, viz: Broca's area (anterior frontal), Wernicke's area (posterior temporal, the angular gyrus and area surrounding the temporo-parieto-occipital junction), and the supplementary motor area (superior, posterior frontal lobe).

Penfield & Roberts observed that spontaneous vocalizations (vowel-like sounds) were elicited from precentral and postcentral Rolandic gyri of both hemispheres during electrical stimulation. Perhaps best known of Penfield's contributions was the compilation of information concerning important functions involving primarily the "nonspeech" (usually right) hemisphere. Penfield (1959) commented:

> Access to the record of the past seems to be as readily available from the temporal cortex of one side as from that of the other. Auditory illusions...either side. The same is true of illusionary emotions such as fear and disgust. But on the contrary, visual illusions (interpretations of distance, dimension, erectness, tempo of things seen) are only produced by stimulation of the temporal cortex on the non-dominant (usually right) side of the brain (p. 1725).

The apparently predominant role of the right hemisphere in some nonlanguage functions (e.g., dressing, directional memory, facial recognition, memory for melodies) has now been reasonably well documented (Benton, 1965). Following Penfield's work, any descriptions of cortical functioning in terms of a "dominant" and a "minor" hemisphere (e.g. Orton, 1937) appear to require qualification.

As an alternative to surgical investigation of cerebral speech laterality, Wada & Rasmussen (1960) developed a procedure involving intracarotid injections of sodium amytal, whereby functions in each hemisphere were inhibited. As the anesthetic is administered, the conscious subject is asked to raise arms, flex legs, move fingers, name objects, count, and follow simple spoken commands. Contralateral sensory impairments, contralateral hemianopia and speech arrest normally followed injections into the left carotid arteries of most adults tested. If speech arrest did not accompany the other reactions to anesthesia, the neurosurgeon assumed that aphasia would be unlikely following ipsilateral cortical surgery.

Using Wada's procedure, Milner, Branch & Rasmussen (1964) compared manual dominance and cerebral speech laterality in 119 neurosurgical patients. Left-hand-preferents were subdivided into two groups on the basis of positive or negative infantile left-hemispheric pathology (Table 2). From Table 2 it can be observed that early cerebral pathology appears to be an important determinant of functional lateralization.

A refinement of Wada's procedure, developed by Serafetinides, Hoare & Driver (1965), employed intracarotid administrations of sodium amylobarbitone. Handedness and speech laterality figures were obtained from a group of 18 adult epileptics (Table 3).

TABLE 2

SPEECH INHIBITION FOLLOWING SODIUM AMYTAL INTRACAROTID ANESTHESIA

| Locus of Inhibition | Handedness Classification | | | Total |
|---|---|---|---|---|
| | Right | Left(-)[a] | Left (+)[b] | |
| Left hemisphere | 43 | 28 | 6 | 77 (65%) |
| Both hemispheres | -- | 7 | 3 | 10 (8%) |
| Right hemisphere | 5 | 9 | 18 | 32 (27%) |
| | 48 (40%) | 44 (37%) | 27 (23%) | 119 |

[a]Left (-) Sinistrals with negative infantile left cerebral pathology.

[b]Left (+) Sinistrals with positive infantile left cerebral pathology.

TABLE 3

SPEECH INHIBITION IN 18 ADULT EPILEPTICS FOLLOWING SODIUM AMYLOBARBITONE INTRACAROTID ANESTHESIA

| Locus of Inhibition | Handedness Classification | | | Total |
|---|---|---|---|---|
| | Right | Mixed | Left | |
| Left hemisphere | 8 | 2 | 2 | 12 (66%) |
| Both hemispheres | | 2 | 1 | 3 (17%) |
| Right hemisphere | | 3 | | 3 (17%) |
| | 8 | 7 | 3 | 18 |

The authors reported that in all cases of unilateral speech representation, unconsciousness followed administration of the anesthetic agent to the dominant (speech) side only. Confirmation in further studies using larger samples of nonpathological subjects has yet to be reported.

A recent study by Giannitrapani, Sorkin & Enenstein (1966) raises some interesting questions concerning handedness and speech laterality relationships. Intra-person comparisons were made for each pair of symmetrically placed EEG electrodes, to ascertain the percentage of "leading activity" of left or right lobes in both "asleep" and "awake" conditions. Ten normal children and ten normal adults (five pronounced right-hand-preferents and five pronounced left-hand-preferents in each group) were tested. Differences between hemispheres were apparent in both "asleep" and "awake" conditions, particularly for the adult subjects. As differentiation was most readily apparent in occipital and parietal lobes, the authors developed a "laterality index" [(P-O asleep) - (P-O awake)]. Interesting group differences emerged. All sinistral adults obtained negative scores, all dextrals obtained positive scores, and the index yielded a rank order correlation coefficient of 0.96 with the classificatory handedness measures. Replications with larger samples are awaited. However, apart from its heuristic value, the study suggests that speech and handedness may not be as independent as Penfield had suggested.

Further support for the suggestion of asymmetrical cerebral functioning derives from the recent work of Carmon & Gombos (1970) at Jerusalem. Systolic and diastolic pressure differences between the right and left ophthalmic arteries and between the right and left brachial arteries were obtained for a sample of 110 young adults (81 trainee nurses and occupational therapists and 29 young soldiers hospitalized for lower extremity fractures), ranging in age from 15-21 years. Comparisons of right-left pressure differences were made with self-classified handedness and with handedness classifications based on questionnaire responses. Handedness and brachial arterial pressure differences were not significantly related, yet diastolic differences were moderately related to classificatory handedness groupings (Kendall's Tau = 0.33). Comparisons of handedness and right-left systolic ophthalmodynamometric arterial pressure differences (Table 4) indicate support for the researchers claiming "the existence of a physiological correlate of handedness (p. 125)." The authors further suggested:

> As the pressure of the ophthalmic artery is considered to be a function of the pressure of the internal carotid artery, the correlate found can be regarded as the difference between the pressures of the right and left internal carotid arteries. As handedness reflects to a large degree cerebral dominance, the correlation observed could also be viewed as a correlation between inter-hemispheric differences in blood supply (p. 125).

Having established only that a relationship exists but not having distinguished between cause and effect, Carmon & Gombos draw the unwarranted conclusion that:

> Cerebral dominance and interhemispheric behavioral differences are determined, to some degree at least by the differences in the blood supplies of the two cerebral hemispheres (p. 119).

TABLE 4

OPHTHALMIC ARTERIAL SYSTOLIC PRESSURE DIFFERENCES[a]

| Handedness Classification (Questionnaire Responses) | R L %[b] | R = L % | L R % | Total |
|---|---|---|---|---|
| Extreme right-handed | 50 | 11 | 1 | 62 |
| Moderate right-handed | 11 | 4 | 3 | 18 |
| Ambidextrous | 2 | 5 | 1 | 8 |
| Left-handed | 2 | 3 | 7 | 12 |
| | 65 | 23 | 12 | 100 |

[a]Adapted from Carmon & Gombos (1970, p. 123).
[b]Percentages rounded to nearest integer.

Glonig, Glonig, Haupt & Quatember (1969) compared handedness and cerebral dysfunctions for a sample of 57 right-handed (RH) and 57 non-right-handed (NRH) adults with unilateral cerebral lesions. Matched pairs were generated on the basis of location, extent and type of lesions (anatomically verified by autopsy). All subjects chosen were without infantile cerebral pathology and all NRH subjects had been forced to write with the right hand during their Austrian elementary schooling. Seventeen of the 57 NRH adults had reported reverting to sinistral writing preference some time after completing formal schooling. Interestingly, 40 NRH adults continued to write with the right hand. Comparisons between RH and NRH groups were made in writing, reading comprehension, form and content of expressive language, calculation, verbal comprehension and object naming. Several interesting findings emerged. Transient aphasias, associated in most cases with right hemispheric lesions, were more often observed in NRH adults. Within the NRH group, those writing with the hand ipsilateral to the site of lesion were less impaired in reading, writing and calculation than those writing with the contralateral hand. From the larger pool of 209 dextrals with some form of aphasia, only five cases of unilateral, right hemispheric lesions were noted (three of these having histories of early left cerebral injuries).

The rarity of aphasias in dextrals having right hemispheric lesions has now been well documented (Conrad, 1949; Lenneberg, 1967; Penfield & Roberts, 1959).

From their closer examination of language impaired dextrals with right-sided cerebral lesions, Archibald & Wepman (1968) suggested that the aphasic symptoms reflected an underlying and pronounced intellectual deterioration. The authors suggested that patients in this category would probably exhibit symptoms of subcortical impairments in addition to right cortical lesions. This position is consistent with Penfield & Roberts (1959) who suggested that bilateral or right lateralized cortical speech "areas" were probably pathologically displaced. The proximity of expressive speech areas to the pre-Rolandic motor cortex appeared to provide Penfield with a reasonable explanation for impairments in speech often being accompanied by impairments in manual control following unilateral cerebral insult. Thus, pathologically induced speech displacements may or may not be accompanied by analogous displacements of manual dominance and vice versa. This interpretation clearly implies the assumption of early left cerebral pathology in most cases of bilateral or right lateralized speech functioning.

However, other evidence raises difficulties for the independence interpretation. Undoubtedly, very few normal left-hand-preferents have histories of early cerebral pathology. Nevertheless the greater likelihood of transient aphasias following any form of cerebral insult to children or to adult left-handers, allegedly attributable to more diffuse or unpredictable representation of speech functions, has been well documented (Giannitrapani, 1967; Glonig et al., 1969; Lenneberg, 1967; Zangwill, 1962). Together with the studies of Giannitrapani et al., (1966) Carmon & Gombos (1970), and Glonig et al., (1969), such evidence suggests that there are differences in cerebral functioning between dextrals and sinistrals, and further, that hand dominance and hemispheric functional asymmetry may not be unrelated. In fact, reviews by Benton (1965) and Hecaen & de Adjuriaguerra (1964) have suggested a <u>causal</u> relationship between manual dominance and cerebral language asymmetry. Benton commented:

> ...there is clinical evidence to support the idea that changes in hand usage forced by injury or disease (e.g. amputations of the right arm) can lead to changes in hemispheric cerebral dominance for language (1965, p. 339).

Benton did not cite the "clinical evidence" supporting his comment. In similar vein, Hecaen & de Ajuriaguerra suggested:

> ...manual superiority can be displaced from one side to the other for both pathological and social reasons, and we have seen that there is an analogous displacement in cerebral dominance (1964, p. 148).

Both statements might profitably be qualified by delineating the critical period for such displacements. Some clinical evidence of functional equipotentiality in neonates and cerebral plasticity in children is available (Basser, 1962; Dreifuss, 1963; Lenneberg, 1967). Basser's studies have indicated that onset of normal speech in infants need not be unduly delayed by left hemispherectomy nor by extensive unilateral insult. Dreifuss (1963) cited four cases in which delayed speech was accompanied by delayed or vacillating manual dominance, hyperactivity/distractibility, and neurological evidence of mild bilateral impairments. Dreifuss suggested that:

> ...whereas devastating unilateral brain disease of early onset does not significantly affect the development of hemisphere dominance, even a mild bilateral hemisphere deficit will seriously compromise the acquisition of speech and handedness (p. 514).

Four selected cases provide rather tenuous evidence, but the hypothesis is both interesting and testable. Although cortical functional asymmetry is by now well documented, there appear to be few reports suggesting that the cerebral hemispheres in adults may be morphologically different (Geschwind & Levitsky, 1968; Von Bonin, 1962).

Geschwind & Levitsky (1968) observed that compared to the corresponding area of the right temporal cortex, the left planum temporale was larger in 65 of 100 brains made available for post-mortem examinations. Eleven of the remaining brains had enlargements of the right planum temporale, while the remaining 24 appeared to have no observable differences between the left and right hemispheres. Handedness and medical histories were unavailable and therefore not reported. The nature of the sample suggests that any generalizations would be inadvisable. Replications with samples having well documented life histories of handedness, occupation, education and medical factors should be of great interest. Uncovering morphological differences between the hemispheres could suggest important questions concerning some "structural" changes postulated by Piaget (1963) and others.

From the foregoing review, some important considerations emerge. Available evidence suggests that most adults have developed functional and possibly morphological differences between the two cerebral hemispheres; differences thought not to be present in neonates. Whether causally or fortuitously related, both manual dominance and lateralization of some cortical functions appear to become more pronounced during childhood. For most adults, the dominance of one hand and lateralization of cortical speech functions can probably be assumed, with right-handedness and left cerebral dominance in speech functions being by far the most common combination. While manual dominance can be displaced pathologically or for social reasons, and cerebral speech representation may be partially or completely displaced for pathological reasons, it has not been satisfactorily established that cerebral displacements follow manual displacements as Benton (1965) and Hecaen & de Ajuriaguerra (1964) have suggested. Conversely, available evidence suggests that for some normal left-hand-preferents, speech functions may be more diffusely and more unpredictably represented, thereby posing some difficulties for Penfield & Roberts' independence interpretation.

Some of the issues pertaining to handedness speech relationships, particularly among younger children and left-hand-preferents, cannot yet be adequately resolved from extant neurological evidence (this evidence being most often obtained from subjects having known or suspected cerebral pathologies). Interpretations of such evidence are complicated by uncertainty concerning the extensiveness of cerebral lesions and the possibility of pathologically induced cerebral displacements during early childhood. With the possible exception of EEG techniques (Giannitrapani et al., 1966) and ophthalmodynamometry (Carmon & Gombos, 1970), available methods for medically measuring cerebral speech functioning are clearly inappropriate for comparing handedness-cerebral speech relationships in large samples of nonpathological children.

## Cerebral Functional Asymmetry: Dichotic Listening Evidence

The dichotic listening technique developed initially by Broadbent (1954) has been used in recent years to provide an alternative, nonmedical procedure for measuring functional asymmetries of the two cerebral hemispheres. In essence, dichotic listening (DL) studies compare left/right efficiency in recall or recognition of competing, simultaneous, bilateral auditory stimuli.

Although sensory inputs to visual receptors and to auditory receptors are transmitted via both contralateral and ipsilateral pathways, physiologists have demonstrated the dominance of contralateral projections from receptors to analyzers in both the visual (Hubel & Weisel, 1959) and the auditory (Rosenzweig, 1951) modalities. Dichotic stimuli (i.e., simultaneous auditory signal pairs) of nearly identical duration and intensity but which differ in informational content (e.g., the word "four" spoken to left ear, "nine" to right ear) are thus assumed to be transmitted predominantly to contralateral hemispheres for interpretation and temporary storage (Kimura, 1967; Satz, Achenbach, Pattishall & Fennell, 1965; Sparks & Geschwind, 1968). However, as medical evidence has indicated, the two cerebral hemispheres are not functionally identical in most if not all adults (Benton, 1965; Giannitrapani et al., 1966; Glonig et al., 1968; Penfield & Roberts, 1959). Competing verbal or nonverbal dichotic stimuli would not, therefore, be processed equally well by both cerebral hemispheres. On physiological grounds, it could be anticipated that verbal material arriving exclusively at the right ear or in the right visual field, might be more efficiently or more directly transmitted to the interpreting (normally left) hemisphere, than comparable stimuli arriving exclusively at the left ear or in the left visual field. Accordingly, when presentation rates are sufficiently rapid to preclude rehearsal of stimuli during presentation, recall of verbal material arriving at the right ear would be expected, over a series of counterbalanced trials, to be superior to recall of comparable verbal stimuli presented dichotically to the left ear.

Superior recall of information presented to the right ear has been demonstrated using, as stimuli, CV syllables (Shankweiler & Studdert-Kennedy, 1967), words (Bryden, 1969; Curry, 1967; Kimura, 1967; Knox & Kimura, 1970), digits (Bartz, 1968; Broadbent & Gregory, 1964; Bryden, 1962, 1963, 1965, 1966, 1969; Carr, 1969; Kimura, 1961, 1963, 1964, 1967; Knox & Kimura, 1970; Neufeldt, 1966; Satz et al., 1970; Schwartz & Bryden, 1969), distorted speech (Kimura, 1968); and nonsense phrases (Zurif & Sait, 1970).

To be consistent with Benton (1965) and Penfield & Roberts (1959), the apparently predominant role of the right hemisphere in processing some nonverbal stimuli should be demonstrable using the DL paradigm. Left ear superiority has been reported using dichotic environmental sounds (Curry, 1967; Knox & Kimura, 1970; Spreen et al., 1970), Dichotic musical phrases (Gordon, 1970; Kimura, 1964; Knox & Kimura, 1970; Shankweiler, 1966; Spreen et al., 1970), animal sounds (Knox & Kimura, 1970), hummed melodic patterns (King & Kimura, 1971) and vocal nonspeech sounds (e.g., laughing, crying, sighing) (King & Kimura, 1971).

In the visual modality, studies employing dichoptic verbal stimuli (simultaneous, bilateral, tachistoscopically presented visual pairs) have not yielded consistent laterality differences favoring the right visual field (White, 1969). When dichoptic stimuli are pairs of English words or letters, or paired Arabic numerals, the firmly entrenched visual habit of scanning from left to right confounds the measurement of differential processing efficiencies at the cortical level. Unilateral random presentations of digits (White, 1969), English words (Harcum & Finkel, 1963) and single letters (Bryden, 1966) have yielded right visual field recall superiority, under optimal tachistoscopic presentation conditions.

With younger children, the auditory modality appears to be more appropriate for examining laterality differences in cerebral hemispheric functioning, as performances in the listening tasks are not confounded by differential reading proficiencies when verbal stimuli are to be used.

Although most DL studies have employed normal, adult, dextral subjects, the DL technique has been successfully employed with mentally retarded children (Neufeldt, 1966; Urbano & Scott, 1967), left-handed adults (Satz et al., 1965), elementary and primary school children (Knox & Kimura, 1970; Zurif & Carson, 1970), adult stutterers (Curry & Gregory, 1969), and neurological patients (Kimura, 1961; Milner, Taylor & Sperry, 1968; Sparks & Geschwind, 1968).

By comparing medical and DL classifications, Kimura (1961) provided some evidence for the validity of the DL technique as an index of functional asymmetries of the two cerebral hemispheres. Additionally, by demonstrating superior recall from the right ear for "verbal" stimuli in the same groups of subjects for whom left ear superiority for "nonverbal" stimuli had been noted, the DL technique gains additional support as an index of functional cortical asymmetries (Curry, 1967; Kimura, 1964; Knox & Kimura, 1970).

Some attempts have been made to demonstrate laterality differences in auditory perception using monaural presentations. Bakker (1967) administered 18 series of 4, 5 and 6 digits, and 18 series of morse-like stimuli, to 120 Dutch children (10 boys and 10 girls at each age level from 6 through 11 years). Stimuli were input to left and right ears in a random order and the children were asked to repeat each series immediately following presentation. Right-ear minus left-ear comparisons revealed a significant left-ear superiority for nonverbal material and a nonsignificant trend for verbal material presented to the right ear to be better recalled. A later study (1969) compared right-left ear recall of six series of four letters and six series of five letters. Thirty grade-five right-hand-preferent girls were randomly assigned to a free recall (FR), serial recall (SR) or ordered recall (OR) condition (OR requiring location of the correct ordinal position of one letter which had been used in the immediately preceding series). Random alternation of letters to left and right ears was employed, using a presentation rate of approximately 50 per minute. Recall superiority for information presented to the right ear (right-ear effect) was observed in both SR and OR conditions. For the five letter series, under SR conditions, a rho of 0.56 was obtained between R-L ear scores and a test of "reading" ($n = 10$; $p < .05$, one tailed). The small group size, the relatively slow presentation rate and the use of letters which are more likely than digits to introduce acoustic confusability errors (Conrad, 1964), impede meaningfully generalizing from Bakker's findings. Bakker's interpretation in terms of cerebral functional laterality is somewhat tenuous as the design did not eliminate attentional nor acuity variables.

Assuming the dominance of contralateral auditory projections and assuming differences in functioning of the two hemispheres, lower right-ear speech intelligibility thresholds and lower left-ear pure tone acuity thresholds might be hypothesized for the majority of adults. Relevant evidence concerning this prediction appears to be equivocal (Palmer, 1964). Palmer employed a "step-down attenuation" of the Central Institute for the Deaf Auditory Test W-2, alternating words R-L-R-L etc., and reversing headphones for two of the four descents. Fifty-five Harvard undergraduate men with normal hearing were tested. A slight but nonsignificant lower right-ear threshold was demonstrated. Twenty-six subjects obtained more left-ear recall errors and 27 obtained more right-ear errors. Discrepancy scores (R-L errors) for right-ear superior subjects were larger than for left-ear superior subjects. Palmer interpreted his findings as indicating that:

> ...an auditory effect attributable to the dominance of the left hemisphere can in fact be demonstrated with monaural audiometric techniques...individuals manifesting right-ear superiority, and in whom language functions were conceivable more strongly lateralized, manifested greater asymmetry in auditory function (pp. 162-3).

The relatively restricted sample and four repetitions of the 36 basic W-2 words might suggest some caution in accepting Palmer's interpretation. A cerebral laterality interpretation would seem tenable only if significant right-ear superiority for recall of verbal material can be demonstrated in subjects having left-ear superiority or no differences between ears for pure-tone acuity through the speech frequencies. Pure-tone and speech intelligibility thresholds for each ear were not compared for each subject in Palmer's study.

Corso's report (1963) of pure-tone acuity changes in normal adults as a function of age, was based on data gathered between 1952 and 1962 in Pennsylvania. Some 912 randomly selected adults were closely examined (following exclusion from the study of subjects with histories of auditory ailments). Negligible between-ears differences were noted for the overwhelming majority of adults tested.

Bakker's limited evidence (1967, 1969, 1970) notwithstanding, it would seem most parsimonious, with present evidence, to suggest that competition is a facilitating condition for demonstrating laterality differences in efficient recall or recognition of dichotic stimuli. Other evidence (Bryden, 1969; Oxbury, Oxbury & Gardiner, 1967) supports this contention. Oxbury et al., asked adult subjects to shadow a continuous stream of random digits and to ignore occasional digit intrusions to the nonattended ear. Subjects were more often distracted by right ear intrusions, suggesting an attentional bias toward the right ear in a free recall situation.

Bryden (1969) was unable to show any recall superiority for left or right ear using monaurally presented words or "speeded-up" digits (computer-compressed), while significantly better recall of dichotic words presented to the right ear was noted for 18 of 32 dextral adults. Superior left-ear recall was obtained for five subjects. Right-channel intrusions were significantly more common than left-channel intrusions, supporting the contentions of Oxbury et al., (1967) and Treisman & Geffen (1968) that for most adults it is more difficult to attend to the left ear than to the right, in situations involving competing, binaural, verbal input.

Although neurological evidence might suggest that almost all dextrals should obtain superior right-ear recall scores, this prediction was not confirmed in Bryden's (1969) study. Under monaural presentation conditions, approximately 20% of the words were incorrectly recalled or omitted. Considerable error undoubtedly resulted from the combination of relatively slow presentation rates (1000 ms/pair) and CVC auditory stimuli. In earlier papers (1962, 1967) Bryden observed that slower rates were less likely to yield laterality effects, as more time was available for covert rehearsal of dichotic pairs. Six discrete CVC words may well have been near the upper limits of normal, limited capacity short-term-memory (STM) storage (Adams, 1967), while the possibility of acoustic confusability of CVC words (Baddely, 1966, 1968; Conrad, 1964) ought not to be discounted.

When dichotic stimulus pairs are nonverbal (e.g., musical passages, tonal patterns or animal sounds tested by binaural recognition series), or speech-like sequences of nonsense syllables (Spreen, Spellacy & Reid, 1970) or jumbled speech (Kimura, 1968), covert rehearsal and/or articulation would seem unlikely. Neurological evidence (Benton, 1965; Penfield & Roberts, 1959) and dichotic listening studies involving nonverbal stimuli (Curry, 1967; Gordon, 1970; Kimura, 1964; King & Kimura, 1971; Knox & Kimura, 1970; Shankweiler, 1966; Spreen et al., 1970) have suggested the dominance of the hemisphere not primarily involved in language functions (i.e., normally the dominance of the right hemisphere). Accordingly, it is of interest to ascertain whether ear asymmetries (normally favoring recognition of nonverbal stimuli presented to the left ear) are optimally revealed under recognition testing conditions.

Spreen, Spellacy & Reid (1970) examined the effects of delaying a recognition test by intervals of one, five and twelve seconds following offset of dichotic stimulus pairs. Recognition of brief musical passages and tonal patterns presented at approximately 50 db and also 70 db intensities was tested. Ear asymmetries (favoring superior left-ear stimuli recognition) for both types of stimuli were more clearly evident at the lower presentation intensity (50 db) and when recognition testing followed stimulus offset almost immediately. Ear asymmetries were least apparent for higher intensity presentations (70 db) with an interval exceeding five seconds between offset and recognition testing.

Thus, it would seem important to examine the rather global "verbal/nonverbal" stimulus distinction more closely. In this regard, interesting data have been reported by Sparks & Geschwind (1968) and Schwartz & Bryden (1969).

Sparks & Geschwind (1968) reported DL performances of a 52 year old dextral male with recently sectioned neocortical commissures. Using dichotic series of digit-pairs and dichotic series of familiar/unfamiliar word-pairs, 100% left-ear extinction (i.e., no correct responses of digits or words presented to the left ear) was observed. Yet, in monaural presentations, the subject recalled equally well from either side. Additionally, verbal stimuli presented to the left ear were satisfactorily recalled when right-ear competing stimuli were white noise or cocktail noises. Left-ear inhibition increased as right-ear competition became more similar in content. Confirmatory evidence of left-ear inhibition of verbal stimul in free recall DL among commissurally sectioned dextral adults, has been reported elsewhere (Milner, Taylor & Sperry, 1968).

In contrast, ear asymmetry (using free recall) was not found by Bryden & Zurif (1970) in their examination of a 15 year old dextral male with congenital agenesis of the corpus callosum. The possibility of undetected neurological involvement of other cortical areas makes interpretation of this one case tenuous.

Although there are obviously very few commissurally sectioned subjects available for study, they provide unique subjects for comparing the functioning of surgically independent hemispheres. From their small sample of three such cases, Gazzaniga & Sperry (1967) suggested that verbal expressive functions (speech and writing) were confined to the left hemisphere while comprehension of both written and spoken words appeared to be possible in either hemisphere. Recently reported clinical evidence (Luria et al., 1970) raises difficulties for this claim. While localized left-hemispheric lesions in some clinical subjects precluded letter-by-letter synthetic speech and written spelling, "kinesthetic stereotypes" (automatized writing skill, e.g. one's name, p. 15) remained intact. Thus, one of Luria's subjects, when asked to repeat the word "no" carefully, quickly replied: "No, doctor, I am unable to say 'no' (p. 13)." Luria and coworkers suggested that when numerous repetitions have facilitated relatively automatic responding on future occasions, a "stable structure" organized by a different system of cerebral control could be hypothesized (p. 14). Although Gazzaniga & Sperry's subjects provided some evidence of hemispheric functional independence on some specific tasks, the level of comprehension (object recognition or matching in response to visual or auditory stimuli) was relatively modest when exclusively right-hemispheric functioning was required.

Rather liberally interpreted, automatic "whole-word" spelling or reading of well known words and "synthetic" spelling or reading of less common or more complex words may involve different processing and retrieval mechanisms. Or, it could be hypothesized that words spoken and/or written earliest in a child's development of language, presumably at a time when hemispheric functional differentiation is at best incomplete (Basser, 1962; Lenneberg, 1967), may remain bilaterally represented. Taking into account the possibility of symmetrical/asymmetrical cortical representation of vowels and consonants respectively, suggested by Penfield & Roberts (1959), and by Shankweiler & Studdert-Kennedy (1967) these hypotheses merit empirical investigation.

The effects of different types of competing stimuli on recall in DL, were systematically examined by Schwartz & Bryden (1969). Three experimental groups were asked to recall twelve series of six random-digits presented in the presence of competing continuous music, a repeated (pre-cued) digit (e.g., 222222), or the numbers one to six in sequence. In each condition, the right-handed adult male subjects were pre-cued concerning the content and location of the irrelevant channel. Three control groups listened to series of dichotic random number pairs. Significant right-ear recall superiority was observed in all three control groups and in the random/serial digits condition but not when competing stimuli were music or repeated single digits. The right-ear effect observed in the random-serial digits condition was attributed by the researchers to similarity of competing input.

Few extant DL studies have systematically examined the effects of varying presentation rates on recall. Almost all studies reviewed by the writer have used a presentation rate of one pair per half second (i.e., 500 ms/pair). Discrete meaningful speech stimuli such as single consonants, single digits from 1-10 or CVC trigrams, when normally articulated, require approximately 100-300 milliseconds, thus providing an interval of approximately 200-400 msec for "trace consolidation" or "echoic" storage (Neisser, 1967). While Neisser's discussion of echoic memory offers some insights concerning the persistence of the trace, no direct indication of the lower limits or minimal signal-plus-interval duration is provided.[1] Kimura & King (1971) have recently suggested that "...the duration of speech required to activate left hemisphere mechanisms is in the range of a syllable length (p. 192)." With presentation rates of approximately 500 ms per dichotic pair, it has commonly been noted under free recall conditions that most adult subjects recall material from one channel prior to attempting recall of any stimuli presented to the other ear. This tendency to attempt recall in two half-series (i.e., ear-order of report) rather than in pairs (pair-order of report) was observed as early as 1954 by Broadbent. At slower presentation rates there appears to be sufficient time for covert rehearsal of dichotic verbal pairs and a greater likelihood of pair-order recall. Bryden's (1962) sample of university students most often attempted pair-order recall of a presentation rate of 1000 ms/pair (1 pair per second), whereas at 500 ms/pair, an ear-order of report was adopted.

Under free recall rapid presentation DL conditions, researchers have consistently observed a tendency for most subjects to begin serially recalling stimuli presented to the right ear, prior

---

[1]The procedures for making dichotic tapes (discussed in Appendix E) lend themselves readily to a systematic examination of this problem.

to attempting to report left-ear stimuli, thus subjecting left-ear half series to greater delay and interference prior to recall. However, as Bryden (1967) and Carr (1969) demonstrated, right-ear recall superiority appears to be more universal than the tendency to initially report stimuli presented to the right ear. Bryden noted instances of left-ear then right-ear order of report where superior recall was evident for stimuli presented to the right ear.

An important methodological objection to interpreting ear asymmetries in DL free recall tasks as indicating cortical processes, was raised by Inglis (1965). Inglis argued that ear asymmetry could be attributed to the interference of first half-series (normally right-ear) stimuli upon subsequent recall of delayed-channel stimuli. Thus by systematically controlling the order-of-report bias, ear asymmetry would in all likelihood disappear. This contention has not been supported empirically. Broadbent & Gregory (1964) demonstrated right-ear superiority under conditions requiring recognition of three-pair dichotic-digit series in four subsequent binaural recognition triads. Other researchers have systematically alternated recall order yet most subjects obtained superior right-ear recall scores (Bryden, 1963, 1967, 1969; Knox & Kimura, 1970; Satz et al., 1965, 1970; Zurif & Sait, 1970).

Kimura (1967) and Knox & Kimura (1970) demonstrated right-ear recall superiority when subjects were asked to attend to and report from the left or right channel only and to ignore completely the competing input to the nonattended ear. Kimura commented:

> The number of "words" reported under the dichotic condition for the two ears does not differ significantly....What does differentiate the scores for the left and right ears is the number of errors made...right-ear superiority...must reflect...a perceptual rivalry rather than a response rivalry (1967, p. 172).

Two recent studies (Mehlman, Satz & Tyson, 1969; Satz, Levy & Tyson, 1970) have suggested that right-ear first response bias and right-ear recall superiority may be due largely to reduced transmission time from receptor (ear) to processor (generally left temporal cortex), for verbal stimuli arriving at the right ear than for comparable left-ear input. To preclude any tendency to "response-set," Satz et al., (1970) compared groups of subjects randomly assigned to one channel-delay condition of 10, 20 or 30 msec. The fourteen subjects in each condition were further assigned to either an initial right-channel or initial left-channel delay condition. Thus six groups of seven subjects were generated from the sample of 42 RH, University of Florida undergraduates. Irrespective of delay condition, digits presented to the right ear were recalled more accurately. Unilateral channel delays longer than 30 msec were not tested. Empirical examinations of critical delay conditions at which ear asymmetries dissipate have yet to be undertaken. Such research for different CA, MA, IQ or specific disability samples offers promising information concerning some parameters of auditory perception.

Turning to the relationships between ear asymmetry and handedness, little definitive information is available for comparisons with neurological data.

Satz, Achenbach, Pattishall & Fennell (1965) compared DL performances of 52 RH and 41 LH adults (mean age 26.2 years) under stimulus overload conditions (2 blocks of 15 trials, each trial using six dichotic digit pairs presented at 500 msec/pair). Although both groups made significantly fewer errors on right-ear recall, the mean difference between left and right ear-recall for RH subjects was almost twice as large as that for LH subjects. Closer inspection, however, reveals that LH subjects with superior left channel recall had a much larger between-ears discrepancy than dextrals as a group. Assuming the dominant hemisphere (for speech functions) to be contralateral to the ear from which recall is more efficient, it is interesting to note the general consistency of Satz's figures (Table 5) with those obtained medically (Tables 1-4).

TABLE 5

HANDEDNESS AND INFERRED SPEECH LATERALITY

| Hemisphere Contralateral to Superior Recall Ear | Handedness Classification Right | Left |
|---|---|---|
| Right | 11.5% | 26.8% |
| Left | 88.5% | 73.2% |

Although 73.2% of the LH subjects obtained superior right-ear recall, a more clearly lateralized minority (26.8%) might profitably have been examined more closely for details of familial handedness,

education, pure-tone asymmetry, and infantile medical history. Unfortunately, these details, as well as information concerning classificatory criteria of "handedness" were not given in the report.

Dichotic listening performances of 40 undergraduates (10 RH and 10 LH males; 10 RH and 10 LH females) were examined by Bryden (1965). Subjects were instructed to attend to and report from one specified channel, before attempting to recall digits presented on the other channel. Ten lists of four dichotic digit-pairs (presented at 500 msec/pair) were used as stimuli, followed by ten further trials with earphones reversed. Bryden counterbalanced order of presentation over subjects. Thus it was possible to compare handedness groups on overall recall, initial half-series recall and delayed half-series recall. Information was obtained for all subjects concerning familial handedness. Only 4/20 LH subjects reported having a left-handed parent or sibling. These four left-familial/LH subjects recalled left-ear material more efficiently, while dextrals were superior on right-ear recall. Nonfamilial LH subjects as a group recalled equally well from both channels. It was not reported whether between-ears differences were more apparent for half-series recall in either the initial or the delayed channel position.

Bryden's study (1965) also employed tachistoscopically presented unilateral random letters to assess laterality differences. Exposure durations of both 25 and 20 msec/letter were used. Left-right differences were more apparent with the shorter exposure time and correlated 0.19 with between-ears differences in DL. A later study (Zurif & Bryden, 1969) using similar tasks and procedures yielded a correlation of 0.18 between DL (ordered recall) and bilateral viewing (ordered recall). Tachistoscopic random letters presented unilaterallty (5 msec above individually determined recognition threshold) were also used. This strategy may more adequately test differences in hemispheric processing if procedures ensure central fixation as each stimulus is presented, minimal exposure time per letter and exposure of stimuli in peripheral visual fields (to ensure initial reception by temporal hemiretina of ipsilateral eye and nasal hemiretina of contralateral eye). Although efforts were made to satisfy these conditions, the successive tachistoscopic (ST) condition was only modestly related to bilateral viewing (r = 0.45 with free recall; r = 0.29 with ordered recall). Comparisons of any one visual strategy with DL performances would seem difficult to interpret. Bilateral letter-pairs in series of four pairs, unilateral single letters to be recognized, and dichotic digit-pairs in four-pair series do not seem optimally comparable. Tachistoscopic recognition (between-eyes difference) was not related to ordered recall DL (r = 0.01). It appears premature, therefore, to accept Zurif & Bryden's suggestion that "there seems to be a dissociation of perceptual laterality effects in the auditory and visual modalities (1969, p. 185)."

Curry (1967) examined DL performances of 25 dextral and 25 LH adults using monosyllabic words, monosyllabic nonsense words and environmental sounds as dichotic stimuli. Earphones were reversed for half of the subjects to attempt "to counterbalance against effects of stimuli, equipment and recording inequalities between channels (p. 344)." Free recall of stimuli was used, but both order-of-report and within-subject counterbalance of stimuli were experimentally uncontrolled. One-tailed comparisons revealed more efficient recall of stimuli presented to the right ear on both verbal stimuli tasks, although between-ear comparisons for nonsense words were not statistically significant for the LH group. Modest left-channel recall superiority was obtained for both groups on environmental sounds. In this task, subjects were instructed to orally identify the sound presented to each ear immediately following presentation. Twenty-seven sets of one dichotic pair per trial were used. Nevertheless, although subjects were pre-experimentally familiarized with stimuli, the highest mean recall (dextrals left channel group) was 17.64 out of 27 and the lowest was 15.96 out of 27 (obtained by both groups: right channel). In the two verbal tasks having only three dichotic word-pairs per trial, maximum mean recall (dextrals right-channel) was 36.16 for meaningful words and 15.76 for nonsense words, out of a possible 60, indicating the difficulty of the task. Acoustic confusability may well be an important contributor to recall errors in such tasks involving CVC stimuli. Nevertheless, it is interesting that Curry's study identified a sub-group of approximately one-third of the LH subjects whose difference scores were the reverse of the LH group as a whole. Again it would seem important to assume considerable heterogeneity in cerebral functioning for adults loosely classified as "left-handed."

A recent report (McGlone, 1971) commented that "...in left handers at least, speech lateralization does not appear to be associated with increased skill of the contralateral hand (p. 195)." Yet, when Knox & Boone (1970) attempted to select a group of "strongly left-handed" from a sample of 80 Kansas undergraduates claiming to be "predominantly left-handed," only 11 subjects met the stringent criteria (clear sinistral preference for 80% of tasks in the Harris laterality battery). Dichotic listening ear asymmetries of the LH subjects were compared with those of 11 strongly RH subjects. Ipsilateral ear effects were observed for both groups ( L>R for LH; R>L for RH). Whether any subjects obtained ear effects opposite to those of their handedness group is not reported. Family handedness characteristics were also not reported.

Further evidence suggesting the desirability of distinguishing "familial" from "non-familial" sinistrals obtains from an investigation of tactile sensitivity (Weinstein & Sersen, 1961). The writers observed greater left-sided tactile sensitivity for 16/19 RH adults and for 26/29 nonfamilial LH adults. Subjects having a left-handed sibling or parent tended to have more acute tactile sensitivity on <u>right-sided</u> (nondominant) loci (18/27 following this pattern). Of heuristic value was the further observation that 7/8 subjects whose <u>mothers</u> were left-handed were tactually more pressure sensitive on the <u>right</u> side. Only four subjects reported having both parents left-handed and three of these followed the right-sensitive pattern.

The evidence from Satz et al., (1965), Bryden (1965), Curry (1967), and Zurif & Bryden (1969) lends some support to Zangwill's (1962) contention that speech functions may be less clearly lateralized among LH persons. Handedness skill, clarity of preference between hands, and handedness characteristics of immediate family members appear to need systematic examination. Although some neurological evidence implicates pathologically induced cerebral displacement as a likely determinant of left-handedness and/or right lateralization of speech, this explanation is incomplete. It is not clear what factors determine left-handedness, per se, nor what factors account for right lateralization or diffuse representation of verbal functions in a minority of subjects.

## Cerebral Functional Asymmetry: Educational Relevance

Some interesting DL studies have been undertaken by Kimura (1961, 1963, 1964, 1967), by Knox & Kimura (1970) and by Zurif & Carson (1970) to explore both the age at onset of ear asymmetries and the relevance of cerebral functional asymmetries to scholastic achievements.

Kimura (1963) examined DL ear-asymmetries for an age-stratified sample of 120 middle-class Montreal children from four through nine years of age. Superior recall of right-ear information was obtained for both sexes at each age level tested. However, the number of digits correctly recalled was higher for girls than for boys at each age level, particularly at ages four, five and six. A developmental trend reflecting higher mean recall scores at successive age levels was apparent for both sexes. It must be noted, however, that a maximum of three dichotic digit-pairs per trial was used. Perfect recall (all six digits) appears to have taken place on many trials, particularly at the nine-year-old level, thereby attenuating between-ears differences and resulting in less marked ear asymmetries. Other researchers (Satz et al., 1965) have demonstrated that ear asymmetries are more readily apparent under free recall conditions when the number of discrete stimuli to be recalled is roughly equivalent to, or even slightly exceeds, the assumed upper limits of short-term sequential storage (Adams, 1967).

Some evidence suggests that right-ear effects may be maturational indices. A study by Taylor (1962, cited in Kimura, 1967) noted an absence of right-ear DL recall superiority in a sample of "reading disability" boys from seven through eleven years of age. Kimura's 1963 study was later replicated in two school settings described as "low-to-middleclass socio-economic area (1967, p. 168)." Right-ear/left-ear recall comparisons were significant for the group of 18 five-year-old girls but not for the 20 five-year-old boys tested, even though the mean number correctly recalled (right + left combined) was similar for both groups. Significant right-ear superiority in recall was obtained for both sexes at each of the other age levels tested (ages 6, 7 and 8). Higher recall scores for right-ear stimuli were obtained by 11 of the boys while eight had higher left-ear scores. Information concerning assessed IQs or reading performances of these boys was not reported.

Some novel procedures and stimuli were used by Knox & Kimura (1970) in a series of studies designed to examine DL performances of five to eight-year-old children. A modification of Curry's dichotic environmental sounds test, and dichotic pairs of familiar animal sounds (one per trial for six trials and requiring oral identification responses) constituted the "nonverbal" stimuli. Dichotic digits, pointing-to-pictures and placing-objects-on-pictures were used to assess DL ear asymmetries for "verbal" stimuli. Seven trials at each of one, two and three dichotic digit-pair series were given. Pointing-to-pictures involved listening binaurally to a voice saying "point to the..." followed by a dichotic pair of monosyllabic common nouns (which shared the same vowel sound but differed in either the initial or final consonant sound). Children had only to point to one or two of four recognition pictures. Twelve dichotic noun-pairs were presented. Overall results indicated that nonverbal stimuli were more accurately identified from the left ear in the same groups of children exhibiting right-ear superiority for verbal stimuli (in recall and recognition tasks). It is noteworthy that all children tested were right-handed.

In contrast to studies implying the earlier development in girls of asymmetries in verbal DL tasks, Knox & Kimura commented:

"...total scores (left ear score plus right ear score) on the nonverbal tasks indicated that boys were superior to girls in identifying nonverbal sounds. The superior performances of boys...cannot be attributed to superior ability in labelling what was perceived, for what evidence there is suggests that girls of this age surpass boys in the use of expressive language (1970, p. 235)."

When 18 animal sounds (each of four seconds duration) were played binaurally through speakers to 27 preschool children (ages 2½ to 5 years), boys were superior to girls in naming the sounds heard.

Sex differences in age of onset of assumed hemispheric processing asymmetries are obliquely supported by the work of Ghent (1961). Ghent's study indicated the earlier emergence in girls of asymmetries in tactual pressure sensitivity favoring the nondominant hand.

Some of the variables suggested in the literature as relevant to "developmental dyslexia" were examined by Zurif & Carson (1970). Two groups of 14 grade four boys were selected from two Montreal schools. Groups were comparable in Henmon Nelson IQ scores, Stanford Arithmetic Test performances and age, but differed significantly in reading abilities as indicated by the Gates Reading Test. Since the subaverage readers did not have histories of brain trauma or auditory deficits, and since IQ scores and general academic performances other than reading fell within the normal range, the term "developmental dyslexia" was used to describe the boys. Dichotic listening, handedness, manual dexterity, auditory-visual crossmodal matching and temporal processing of both auditory and visual patterns were measured. Handedness was determined by mimed responses to a 14 item questionnaire, while manual dexterity testing compared preferred and nonpreferred hands in accuracy of cutting around a 5 cm circle. For the 30 pairs of auditory patterns, subjects were asked to respond "same" or "different" following each pair of patterns tapped out in quick succession. A similar procedure was used for the 10 visual pairs. In a procedure similar to that used by Birch & Belmont (1964), each subject was also asked to identify one of three visual dot patterns corresponding to a previously delivered auditory click pattern. Normal readers were significantly superior to dyslexics on all tasks although the handedness questionnaire did not differentiate between the two groups. Correlated t tests for right-left DL scores for each group did not indicate a significant right-ear superiority for either group (Table 6).

TABLE 6

DICHOTIC LISTENING EAR ASYMMETRIES AND READING

| Reading Classification | Mean DL Recall Score | |
|---|---|---|
| | Left Ear | Right Ear |
| Poor Readers (n = 14) | 38.5 | 36.9 |
| Normal Readers (n - 14) | 40.7 | 48.2 |

It is readily apparent however (Table 6) that normal readers as a group tended to recall more efficiently those digits presented to the right ear. Ten three-pair digit series (repeated with earphones reversed) were used as DL stimuli with a free-recall mode of

The possibility that left-hemispheric dominance may be indicative of a developmental stage in neurological maturation upon which reading proficiency depends, has not yet been specifically examined for comparable age and/or handedness samples of proficient and subaverage readers. Nevertheless, such comparisons might provide empirical tests of some controversial issues evident in literature pertaining to "cerebral dominance."

## Review of Literature: Summary

As manual proficiency develops during infancy and early childhood, it is generally accompanied by differentiation of function between the consistently preferred and the consistently nonpreferred hand. When children begin formal schooling, most have clearly established the dominance of one hand in the performance of skilled manual tasks. Further, most children are right-handed and the proportions of clearly left-preferent and mixed-preferent children are small.

Estimates of sinistrality among unselected adult populations suggest an incidence of approximately 10% (Brain, 1945; Hecaen & de Adjuriaguerra, 1964), with higher incidences of ambilaterality and/or sinistrality in some clinical populations such as retardates, elipeltics and dyslexics (Hecaen & de Ajuriaguerra, 1964), among whom displacements attributable to mild infantile cerebral pathology may be relevant (Dreifuss, 1963; Milner et al., 1964; Penfield & Roberts, 1959; Zangwill, 1962).

Although some studies have implied a mild neurological impairment or "lag" in cases of speech or reading difficulties concomitant characteristic plasticity declines progressively as adolescence approaches (Basser, 1962; Dreifuss, 1963; Lenneberg, 1967). During early childhood, unimanual preference and hemispheric functional asymmetry apparently become more clearly lateralized in most children. It has been suggested that unimanual dominance is discernible prior to the assumed lateralization of some cortical functions (Benton, 1965; Delacato, 1963; Hecaen & de Ajuriaguerra, 1964; Phels, 1965). These workers have thus argued that unimanual dominance and cerebral functional asymmetry are directly related. However, the tendency for left cerebral representation of speech functions to be more universal than right-handedness prompted Penfield & Roberts (1959) to suggest that handedness and cerebral functional asymmetry may be unrelated except in cases of displacements due to early cerebral pathology. Considerable medical evidence suggests that right-lateralization or diffuse representation of speech functions sometimes occurs, particularly in LH adults with no suspected histories of childhood cerebral pathology (Carmon & Gombos, 1970; Conrad, 1949; Giannitrapani, 1967).

Cerebral hemispheric functional differences have been suggested by many researchers, using one of several distinct investigatory techniques, viz:

(a) systematic examinations of functional impairments associated with defined cortical lesions (Archibald & Wepman, 1968; Basser, 1962; Benton, 1965; Conrad, 1949; Glonig et al., 1969; Lenneberg, 1967; Luria, 1966, 1970; Luria et al., 1970; Penfield & Roberts, 1959);

(b) cortical mapping (Penfield, 1959; Penfield & Roberts, 1959);

(c) intra-carotid intervention (Milner et al., 1964; Serafetinides et al., 1965; Wada & Rasmussen, 1960);

(d) EEG (Giannitrapani et al., 1966; Penn, 1966);

(e) ophthalmodynamometry (Carmon & Gombos, 1970).

Rather consistently, the above studies suggest that most left-handed (sinistral) adults and almost all right-handed (dextral) adults without histories of infantile cerebral pathology, depend primarily on the intact functioning of the _left_ cerebral hemisphere for processing "verbal" stimuli. In contrast, some perceptual and memory functions of a "nonverbal" nature appear to be more dependent on intact _right_ hemispheric functioning. Further, this asymmetry may possibly be reflected in subtle structural differences (Carmon & Gombos, 1970; Geschwind & Levitsky, 1968; Giannitrapani, 1967; Von Bonin, 1962).

The limitations of medical techniques for measuring cerebral functional asymmetries in large numbers of nonpathological children are readily apparent. However, bilateral tachistoscopic viewing and simultaneous bilateral (dichotic) listening have been successfully employed for nonmedically measuring functional asymmetries in simultaneous information processing. Basically, both techniques involve bilateral presentations, most often using discrete stimuli in series, ordered so as to directly induce competition between the left and right hemispheres. Processing efficiency is normally measured by comparing recognition or recall of material presented to the left or the right receptor, with recognition or recall of material presented to the contralateral receptor, over a series of counterbalanced trials.

Unfortunately, the interpretation of results from studies using visually presented verbal material is complicated by the firmly entrenched habit among literate subjects of scanning from left-to-right whenever stimuli are Arabic numerals or English words, as well as by inter-subject and intra-subject variability in word- and letter-recognition (Harcum & Finkel, 1963; White, 1969). Although stimuli other than words, letters or numbers have been used in bilateral viewing studies (White, 1969, 1971), auditory procedures may be preferable for determining asymmetries in functioning among young children.

For every subject tested by appropriate dichotic listening procedures, comparable acuity of the left and right receptors, and comparability of left and right signal inputs (with regard to onset, content, signal quality, intensity and duration) need to be assured. Assuming comparability of receptors and signal input characteristics, obtained ear effects (superiority in recognition or recall of material presented to the left or the right ear over a series of counterbalanced trials) are assumed reflective of an underlying asymmetry in processing efficiencies of the left and right hemispheric areas of interpretive cortex (Bryden, 1967(a), (b); Kimura, 1967; Satz et al., 1965). Furthermore, comparative physiological evidence has suggested the dominance of contralateral over ipsilateral projections from receptors to analyzers (Hubel & Weisel, 1959; Rosenzweig, 1951). Thus, a functional "dominance" in efficiency of stimuli processing is inferred for the hemisphere <u>contralateral</u> to the ear from which the stimuli were better recognized or recalled under comparable conditions.

Using bilateral auditory stimuli, a rather consistent picture of functional asymmetries has emerged.

(a) Superior <u>recall</u> of material presented to the <u>right ear</u> (inferring left cerebral functional dominance) has been reported using:

(i) monaural, randomly alternating digits (Bakker, 1967, 1970);

(ii) monaural, randomly alternating letters (Bakker, 1969);

(iii) shadowing of continuous prose (Treisman & Geffen, 1968);

(iv) shadowing of continuous digits (Oxbury, Oxbury & Gardiner, 1967);

(v) dichotic word-pair series (Bryden, 1969; Curry, 1967; Kimura, 1967; Knox & Kimura, 1970);

(vi) dichotic digit-pair series (Bartz, 1968; Bryden, 1962, 1963, 1965, 1966; Carr, 1969; Kimura, 1961, 1963, 1964, 1967; Knox &

Kimura, 1970; Mehlman, Satz & Tyson, 1969; Neufeldt, 1966; Satz et al., 1965, 1970; Schwartz & Bryden, 1969);

(vii) dichotic nonsense-word-pair series (Curry, 1967);

(viii) dichotic consonant-vowel-pair series (Shankweiler & Studdert-Kennedy, 1967).

(b) Superior recognition of material presented to the right ear has been reported (generally using binaural recognition testing) with:

(i) dichotic digit-pair series (Broadbent & Gregory, 1964);

(ii) dichotic "backwards speech" (Kimura & Folb, 1968);

(iii) picture recognition of dichotic word-pairs (Knox & Kimura, 1970);

(iv) dichotic nonmeaningful phrases (Zurif & Sait, 1970).

(c) Superior recall or recognition of stimuli presented to the left ear (inferring right cerebral functional dominance) has been reported for:

(i) dichotic environmental sounds (Curry, 1967; Knox & Kimura, 1970);

(ii) dichotic animal sounds (Knox & Kimura, 1970);

(iii) dichotic tonal patterns (Spreen, Spellacy & Reid, 1970);

(iv) dichotic musical phrases (Gordon, 1970; Kimura, 1964; Shankweiler, 1966; Spreen et al., 1970);

(v) vocal, nonverbal sounds (King & Kimura, 1971).

If it is acceptable to subsume words, nonsense words, letters, digits, speech-like phrases, continuous prose and backwards-speech under the general classification of "verbal" stimuli, while assigning the label "nonverbal" to such stimuli as environmental sounds, animal sounds, tonal patterns and musical phrases, the overall picture with regard to inferred hemispheric functional asymmetries is consistent with relevant medical evidence (Archibald & Wepman, 1968; Benton, 1965; Conrad, 1949; Gazzaniga & Sperry, 1967; Hecaen & de Ajuriaguerra, 1964; Luria et al., 1970; Milner, 1962; Penfield & Roberts, 1959; Zangwill, 1962). The assumption that ear asymmetries in dichotic listening reflect hemispheric functional asymmetries obtains further support from Kimura's (1961) demonstration of comparable medical and DL determinations of cerebral functioning in a group of neurosurgical patients. Other studies have noted right-ear recall superiority for verbal stimuli in the same group of subjects who were superior in recognition of "nonverbal" stimuli presented to the left ear (Bakker, 1970; Curry, 1967; Kimura, 1964; Knox & Kimura, 1970). Additionally, while admitting the nonrepresentativeness of some pathological samples, it is interesting that medical and DL approaches have reported comparable proportions of handedness subgroups classified as left-dominant, bilateral or right-dominant with regard to hemispheric processing of verbal material (Carmon & Gombos, 1970; Conrad, 1949; Glonig et al., 1969; Kimura, 1964; Milner et al., 1964; Satz et al., 1965; Serafetinides et al., 1965).

Under optimal conditions, the DL technique thus appears to be an adequate nonmedical procedure for determining hemispheric functional asymmetries.

Several conditions facilitate the demonstration of asymmetries in functioning using DL procedures:

(a) Stimuli

(i) Comparability of content in each dichotic pair (Bryden, 1969; Schwartz & Bryden, 1969; Sparks & Geschwind, 1968);

(ii) a sufficient amount of material in each series to approach upper limits of individual abilities to recall or recognize a series of discrete stimuli (Kimura, 1963; Satz et al., 1965);

(iii) minimal acoustic confusability of stimuli to be recalled or recognized in each trial; digit pairs thereby being preferable to letter- or word-pairs (Bryden, 1969; Curry, 1967; Shankweiler & Studdert-Kennedy, 1967).

(b) Presentation Conditions

(i) A rate sufficient rapid (most often one pair per 500 msec has been used) to preclude pair-wise rehearsal (Bryden, 1962);

(ii) simultaneity of left and right channel signals (Oxbury et al., 1967; Palmer, 1964; Schwartz & Bryden, 1969; Sparks & Geschwind, 1968): Bakker (1967, 1969, 1970) disagrees;

(iii) minimal intensities (possibly) (Spreen et al., 1970).

(c) Recall Conditions

(i) immediate recall following offset of last stimulus-pair in each series (Spreen et al., 1970);

(ii) although most DL studies have used free-recall, it has been argued (Inglis, 1965) that this procedure does not adequately test cerebral processing efficiencies. Asymmetries have been demonstrated using counterbalanced half-series serial recall (Bryden, 1963, 1967(a), (b), 1969; Knox & Kimura, 1970; Satz et al., 1965, 1970; Zurif & Sait, 1970) and using counterbalanced recall of one channel only per trial (Kimura, 1967, Knox & Kimura, 1970).

(d) Scoring

(i) Bakker (1969, 1970) has suggested that by scoring only those half-series recalled in correct order of presentation, some control over guessing is likely.

(e) Subjects

(i) Asymmetries are more clearly demonstrated with homogeneous age and handedness subjects (Bryden, 1965; Curry, 1967; Satz et al., 1965; Zurif & Bryden, 1969).

Evidence concerning the relevance of laterality variables (handedness, eye preference, hand-eye consistency, visual acuity, auditory acuity and ear asymmetries in DL) to the development of proficiency in speech and reading is characterized as much by methodological shortcomings as by conflicting findings. Some studies (Kimura, 1963, 1967; Knox & Kimura, 1970; Zurif & Carson, 1970) suggested that verbal left dominance may not be evident in some primary school children. These studies thus raise the interesting possibility that many children not characterized by verbal-left-cerebral-dominance (i.e., verbal-right-ear-dominance) on the DL tasks may be minimally proficient readers. Assuming that appropriate dichotic listening techniques can measure asymmetries in cerebral functioning, it would appear possible to allow the study of the relationships between handedness and cerebral asymmetry on the one hand, and the relevance of functional asymmetries to child development on the other. The systematic examination of ear asymmetries in recall of dichotically presented digit series, reading proficiency, handedness preferences and manual dexterity, for a sample of normal primary school children, would appear timely. To this end, the present investigation was developed.

# CHAPTER 3

# RATIONALE AND HYPOTHESES

## Rationale

Important controversies have emerged concerning both the relevance of manual dominance to the development of cerebral functional asymmetries, and the consequences of delayed or impeded development of functional asymmetries for the acquisition of linguistic and reading proficiency.

Several writers (Dreifuss, 1963; Harris, 1957; McFie, 1952; Naidoo, 1961; Orton, 1937) have suggested that school age children exhibiting unestablished or vacillating handedness preference are more likely to be nonproficient readers than clearly lateralized age-peers. Other studies, undertaken primarily with elementary school children, have failed to support this hypothesis (Balow & Balow, 1964; Belmont & Birch, 1965; Capobianco, 1966, 1967; Coleman & Deutch, 1964; Stephens, Cunningham & Stigler, 1967; Treischmann, 1968). Although the latter studies have generally been more rigorous than the former, definitive information is not yet available concerning handedness/ reading relationships for a sample of children having had at least one year's formal reading instruction and whose reading performances are least likely to have been depressed by neurological impairment, special class placement or prolonged experience of reading failure.

Further, the quality of manual performance, as distinct from the asymmetry or direction of handedness preference, may be related to reading proficiency (Zurif & Carson, 1970). Zangwill (1962) suggested that ambiguous-hand-preferent children were more likely to exhibit reading difficulties than clearly lateralized hand-preferent children. Quite apart from speculations concerning inferred neurological states, vacillating hand preference associated with minimal manual proficiency might be considered representative of the pattern exhibited by children of a much younger age. For the purposes of the present study, the inclusion of dexterity and preference measures of handedness thus seemed warranted.

Considerable neurophysiological evidence attests to the relationship between cerebral functional asymmetry and handedness, particularly with regard to right-handed adults (Archibald & Wepman, 1968; Benton, 1965; Carmon & Gombos, 1970; Conrad, 1949; Giannitrapani et al., 1966; Glonig et al., 1969; Lenneberg, 1967; Luria, 1966, 1970; Luria et al., 1970; Milner et al., 1964; Serafetinides et al., 1965). However, handedness preference is less clearly related to cerebral functional asymmetry among left-handed adults or young children. Reports discussing "left-handedness" are difficult to compare because widely divergent classificatory criteria have been used (Bannatyne & Wichiarajote, 1969; Cernacek, 1964; Glonig et al., 1969; Harris, 1958; Hecaen & de Ajuriaguerra, 1964; Humphrey, 1951; Knox & Boone, 1971; Luria, 1966; Phelps, 1965). Further, the factors influencing the <u>development</u> of clearly left-handed manual preference have not been satisfactorily examined (Hecaen & de Ajuriaguerra, 1964). While it is clear that left-handedness is characteristic of only a small percentage of manually proficient adults (Brain, 1945; Hecaen & de Ajuriaguerra, 1964), it is not certain why this is so. Some evidence implicates pathologically induced cerebral displacements (Dreifuss, 1963; Milner et al., 1964; Penfield & Roberts, 1959; Zangwill, 1962), while other evidence suggests pronounced sinistrality in immediate family members (Bryden, 1965; Weinstein & Sersen, 1961) or pronounced, consistent left-hand preference, (Knox & Boone, 1971) as possible determinants of right-cerebral lateralization, consistently reported for a minority of nominally left-hand-preferent adults (Bryden, 1965; Carmon & Gombos, 1970; Conrad, 1949; Curry, 1967; Glonig et al., 1969; Giannitrapani et al., 1966; Kimura, 1964; Lenneberg, 1967; Milner et al., 1964; Penfield & Roberts, 1959, Satz et al., 1965; Serafetinides et al., 1965). However, cerebral asymmetries appear to be less pronounced and more difficult to measure in young children (Basser, 1962; Giannitrapani et al., 1966; Lenneberg, 1967), and relevant evidence has accrued primarily from clinical samples. Thus, it has been difficult to definitively relate cerebral and manual laterality characteristics for normal populations, especially children, and thereby suggest whether these functions are independent (Penfield & Roberts, 1959) or directly related (Benton, 1965; Delacato, 1963; Hecaen & de Ajuriaguerra, 1964; Phelps, 1965).

Although the evidence relating early reading proficiency to manual dominance is inconclusive, several writers (Bender, 1957; Delacato, 1963; McFie, 1952; Orton, 1937; Silver & Hagin, 1967) have implicated cerebral dominance anomalies in some instances of delayed or impaired reading proficiency, despite the tenuous nature of procedures used to determine interhemispheric functioning. Dichotic listening techniques have demonstrated asymmetries in processing both "verbal" and "nonverbal" stimuli in children (Kimura, 1963, 1967; Knox & Kimura, 1970; Zurif & Carson, 1970) thus paving the way for further examining relationships among indices of laterality and early reading proficiency. Assuming that school age children can readily recognize and distinguish all of the digits from one through nine when presented auditorily, and that recall of digit series should result in minimal acoustic confusability of stimuli (Bryden, 1969; Curry, 1967; Shankweiler & Studdert-Kennedy, 1967), it seemed that ear asymmetries in DL could be demonstrated optimally in primary school children by a counterbalanced graded sequence of digit-pairs in series, presented so as to ensure comparability of left and right channel inputs, left and right input intensity at receptors and other relevant presentation conditions. Left/right ear-recall differences thus obtained would be assumed to reflect asymmetries in processing efficiencies of the contralateral hemispheres (Bryden, 1967(a), (b); Kimura, 1967; Satz et al., 1965).

It has been suggested (Koos, 1964) that attempts to measure correlates of early reading proficiency need to circumvent complications associated with prolonged failure to read. Yet consideration must also be given to the amount of prior reading instruction. Some children begin grade one without any prior formal instruction in reading while others have had some instruction during preschool or kindergarten years. By grade two, however, it can generally be assumed that most children have had at least one year of formal instruction in reading.

Taking these considerations into account, a study was planned to compare reading proficiencies of a sample of grade two children representing RH, MH and LH classifications. Within each handedness preference classification, an effort was made to select manually proficient and manually nonproficient children and to further classify children according to familial-handedness-preference classifications (Table 7).

TABLE 7

HANDEDNESS CHARACTERISTICS OF PROPOSED SAMPLE

| Preference | RH[a] | | | | MH | | | | LH | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dexterity | D[b] | | ND | | D | | ND | | D | | ND | |
| Familial-Preference | RF[c] | Lf | RF | LF | RF | LF | RF | LF | RF | LF | RF | LF |

[a]RH - Right-hand-preferent; MH - Mixed-hand-preferent; LH - Left-hand-preferent.

[b]D - Manually dextrous; ND - Manually nondextrous.

[c]RF - Right-Familial Handedness Preference; LF - Left-Familial Handedness Preference.

The present study was thus designed to provide empirical information relative to three general questions, viz:

1. Is handedness related to reading proficiency?
2. Are ear asymmetries in dichotic listening related to reading proficiency?
3. Are ear asymmetries in dichotic listening related to handedness?

## Derivation of General Hypotheses

Question 1: Is handedness related to reading proficiency?

Studies involving samples of normal elementary school children suggest that reading proficiency and handedness preference are probably unrelated (Balow & Balow, 1964; Belmont & Birch, 1965; Coleman & Deutch, 1964; Stephens, Cunningham & Stigler, 1967; Treischmann, 1968). Nevertheless, it has been argued that ambiguous hand preference may reflect delayed cerebral functional lateralization (Ingram & Reid, 1956; Naidoo, 1961; Zangwill, 1962). But ambiguous hand preference, characterized either by alternation of hands during performance on a given task, or by inconsistent hand preference for performing the same task on separate occasions, is clearly not synonymous with consistent unilateral preference which differs across tasks (e.g., consistent left-handed usage for writing, in combination with consistent right-handed usage for scissor manipulation). Thus, the category "mixed-hand-preferent," used for the present study, is somewhat heterogeneous. Since manual proficiency undoubtedly improves from preschool through primary school, and in the light of some recent evidence (Zurif & Carson, 1970), it is likely that manually dextrous children of primary school age will be superior readers to manually nondextrous age peers. Additionally, Naidoo's work (1961) would suggest that nondextrous ambiguous-hand-preferent children will be less proficient readers than children of any other handedness preference classification.

General Hypotheses

1A. Mixed-hand-preferent (MH) children will be less proficient readers than either left-hand-preferent (LH) or right-hand-preferent (RH) children.

1B. Nondextrous (ND) children will be less proficient readers than dextrous (D) children.

1C. Nondextrous mixed-hand-preferent (MH/ND) children will be less proficient readers than children of any other handedness preference/dexterity classification.

Question 2: Are ear asymmetries in dichotic listening related to reading proficiency?

If *left* cerebral representation of verbal functions is the normal adult state, as Penfield & Roberts (1959) have suggested, and if cerebral asymmetries are less pronounced and more difficult to measure among children (Basser, 1962; Giannitrapani et al., 1966; Kimura, 1967; Lenneberg, 1967), it is quite likely that right-ear effects may not be demonstrable in some primary school children. Recent evidence from bilateral auditory perceptual studies (Bakker, 1969; Kimura, 1963, 1967; Knox & Kimura, 1970) suggests that DL recall symmetry (i.e., an absence of ear-dominance) is more likely to be characteristic of subaverage than proficiently reading children. Zurif & Carson's study (1970) suggests that children exhibiting right-ear dominance on the DL digit series will be more proficient readers than either nondominant or left-ear-dominant children. In the present study, however, an attempt was made to obtain approximately equal numbers of right, mixed and left-hand-preferent children, and to locate as many children as possible from families where important models might be left-handed, thus resulting in a sample not representative of the population generally (Hecaen & de Ajuriaguerra, 1964) with regard to handedness preference. From previous research suggesting the likelihood of ipsilateral ear/hand dominance among many left-handed subjects, particularly left-familial/left-hand-preferents (Bryden, 1965; Curry, 1967; Satz et al., 1965; Zurif & Bryden, 1969), it is likely that left-familial-handedness-preference and left-hand-preference may attenuate the magnitude of right-ear-effects anticipated for proficient readers. Ear dominance, handedness preference and familial-handedness preference might therefore be expected to interact, in view of the composition of the sample used in the present investigation.

Assuming manual dexterity and demonstrable ear asymmetry to be maturational indices, it is anticipated that dextrous children with demonstrable ear asymmetries will be more proficient readers than nondextrous children classified as nondominant with respect to ear asymmetries in dichotic listening.

General Hypotheses

2A. Children classified as "non-dominant" (NE) in the recall of dichotic digit-pair-series will be less proficient readers than children classified as either "right-ear-dominant" or left-ear-dominant" (LE).

2B. Children classified as "left-ear-dominant" (LE) in the recall of dichotic digit-pair series will be less proficient readers than children classified as "right-ear-dominant" (RE).

2C. Dextrous children classified as "right-ear-dominant" (D/RE) or "left-ear-dominant (D/LE) in the recall of dichotic digit-pair-series will be more proficient readers than nondextrous children classified as "nondominant" (ND/NE).

2D. Left-familial/left-hand-preferent children classified as "left-ear-dominant" (LH/LF/LE) in the recall of dichotic digit-pair-series and right-familial/right-hand-preferent children classified as "right-ear-dominant (RH/RF/RE) will be more proficient readers than children of other handedness-preference/familial handedness preference classifications.

Question 3: Are ear asymmetries in dichotic listening related to handedness variables?

Available research has consistently noted that a substantial proportion of "left-handed" adults have right-lateralized verbal functioning (Bryden, 1965; Carmon & Gombos, 1970; Conrad, 1949; Curry, 1967; Giannitrapani, 1967; Glonig et al., 1969; Kimura, 1964; Satz et al., 1965), and that this tendency is more pronounced among left-familial/left-hand-preferent adults (Bryden, 1965; Weinstein & Sersen, 1961; Zurif & Bryden, 1969) and strongly left-handed subjects (Knox & Boone, 1971). Yet, Penfield & Roberts (1959) have argued that handedness and cerebral functional asymmetries may be unrelated except in cases of displacements due to cerebral pathology. A further complication arises in relating handedness/cerebral asymmetries in functioning, when young children are used as subjects, particularly if such children are subaverage in manual dexterity (Zurif & Carson, 1970) or reading proficiency (Kimura, 1967; Knox & Kimura, 1970).

If, as Penfield & Roberts have argued, handedness preference and ear asymmetry are independent, there should be a negligible incidence of left-ear-dominant subjects in any handedness subgroup. If Bryden's interpretations are correct, left-ear-effects may be obtained for some left-familial/left-hand-preferent subjects. Likewise, if strength of handedness preference and ear asymmetries in DL are related, as Knox & Boone have suggested, left-ear-dominance is most likely for strongly left-hand-preferents, while right-ear-dominance is most likely for strongly right-hand-preferent children.

It was earlier suggested that manual performance is characterized by increased proficiency from preschool through early primary grades. A similar developmental trend toward more pronounced right-ear-effects among older children (Bakker, 1967; Kimura, 1963, 1967; Knox & Kimura, 1970) suggests that the magnitude of right-ear-effects will be attenuated by manual nondexterity. Thus dextrous children are more likely to demonstrate right-ear-dominance than nondextrous children.

General Hypotheses

3A. The proportion of right-familial/right-hand-preferent children classified as "right-ear-dominant" (RH/RF/RE) in recall of dichotic digit-pair series will be greater than the proportion of left-familial/left-hand-preferent children classified as "right-ear-dominant" (LH/LF/RE).

3B. The proportion of strongly right-hand-preferent children classified as "right-ear-dominant" (RH/RE) in recall of dichotic digit-pair series will be greater than the proportion of strongly left-hand-preferent children classified as "right-ear-dominant" (LH/RE).

3C. The proportion of "dextrous" children classified as "right-ear-dominant" (D/RE) in recall of dichotic digit-pair series will be greater than the proportion of "nondextrous" children classified as "right-ear-dominant" (ND/RE).

# CHAPTER 4

# PROCEDURES

## Sample

The sample for the present investigation was drawn from the population of grade two children attending regular classes within the jurisdiction of the Edmonton Public School Board (EPSB) during the spring semester of 1971.

To obtain adequate representation of "left-familial" subjects (cf. p. 72), it seemed advisable to initially screen approximately 1,000 children. Following consultations with the E.P.S.B. and cooperating schools, access was granted to children from 45 regular grade two classrooms located in 11 schools.

Each cooperating teacher was asked to identify all left-hand-preferent children, all children having mixed or vacillating handedness preference, and a subgroup of right-hand-preferent children representing a reasonable cross-section of handwriting abilities of children currently enrolled in his/her class.

A letter, containing both a brief comment about the purpose of the study, and a short checklist pertaining to handedness preferences of the grade two child, his/her siblings and parents,[1] was sent home with those children identified by teachers as potential subjects. From the 307 usable returns, an intended initial sample was drawn, including all "left-familial" children and a sample of "right-familial"

---

[1] Appendix A.

children from each handedness preference category as reported by parents, ensuring where possible that each classroom was represented in each right-familial-handedness-preference classification (Table 8). Following handedness testing, all children were reclassified and data analyzed on the basis of observed handedness preferences.[1] The initial sample thus consisted of 222 children for whom complete handedness preference, manual dexterity, and reading data were available.

Anticipating approximately fifty minutes of further testing to obtain dichotic listening data for each child, it was necessary to select a restricted sample. Accordingly, 115 children (66 right-familials and all 49 available left-familials) were tested. Complete data[2] were obtained for 108 children (Table 8).

An inspection of Table 8 indicates that the restricted sample is not proportionately representative of a normal grade two population with regard to handedness preferences. Indeed, a conscious effort was made to locate and test children most likely to exhibit <u>left-dominant</u> or nondominant ear-effects, normally expected for less than 20% of unselected adult populations (Satz et al., 1965). However, with regard to the average levels and distributions of reading performances

---

[1]The correlation between "observed" and "reported" handedness preference classifications of children in the initial sample was 0.865.

[2]Handedness preference, manual dexterity, dichotic listening and reading tasks.

TABLE 8

DISTRIBUTION OF SUBJECTS: INITIAL AND RESTRICTED SAMPLE

| A. Initial Sample<br>Intended numbers in parentheses | Handedness Classification: Observed Preference | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | LH | | MH | | RH | | |
| | RF | LF | RF | LF | RF | LF | |
| | 39(45)[a] | 14(15) | 41(45) | 9(10) | 96(90)[b] | 23(24) | 222(229)[c] |

| B. Restricted Sample<br>Intended numbers in parentheses | Handedness Classification: Observed Preference | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | LH | | MH | | RH | | |
| Dexterity Classification | RF | LF | RF | LF | RF | LF | |
| Dextrous | 10(11) | 6(7) | 11(11) | 5(6) | 11(11) | 10(11) | |
| Nondextrous | 11(11) | 7(8) | 10(11) | 4(4) | 11(11) | 12(13) | |
| | 21(22) | 13(15) | 21(22) | 9(10) | 22(22) | 22(24) | 108(115)[d] |

[a]RF - Right-familial handedness preference: LF - Left-familial handedness preference:

[b]Six children originally classified as MH or LH according to reported-handedness preference were reclassified as RH for observed-handedness-preference.

[c]Criteria data were subsequently unavailable for five subjects intended for both initial and restricted samples. Two children from intended initial sample were absent during testing.

[d]Unsatisfactory DL testing conditions necessitated omitting one RH/LF and one LH/LF subject from analyses involving the restricted sample.

(Table 9), both the initial and the restricted samples appear to be reasonably representative of normal grade two children.

TABLE 9

INITIAL AND RESTRICTED SAMPLES:
GATES-MacGINITIE READING DATA

| | Subtest | Mean[a] | S.D.[a] | N | Subtest Correlation |
|---|---|---|---|---|---|
| A. Norming Sample[b] | | | | | |
| | Vocabulary | 50.00 | 10.00 | 1.270 | |
| | Comprehension | 50.00 | 10.00 | 1,270 | 0.78 |
| B. Initial Sample | | | | | |
| | Vocabulary | 54.19 | 8.70 | 222 | |
| | Comprehension | 51.28 | 10.13 | 222 | 0.80 |
| C. Restricted Sample | | | | | |
| | Vocabulary | 52.89 | 9.32 | 108 | |
| | Comprehension | 50.50 | 11.23 | 108 | 0.84 |

[a] In standard score units (Mean = 50: S.D. - 10).

[b] From Technical Manual (Gates & MacGinitie, 1965).

## Testing Procedures, Stimulus Materials and Apparatus

All testing was carried out in the cooperating schools during April, May and June of 1971. Gates-MacGinitie Reading Tests were administered and scored by class teachers. Complete reading data were not available until mid-June 1971.

Handedness testing in schools was conducted by the investigator and two assistants experienced in teaching elementary school children. All dichotic listening testing (restricted sample only) was carried out by the investigator during May 1971, normally in the quietest room available at each cooperating school. Although measures were undertaken to minimize background noise, some variability in the attendant noise levels across schools and testing sessions was inevitable.

## Handedness Preference and Manual Dexterity Tasks

Pilot studies conducted by the investigator in 1970 indicated that handedness preference and dexterity might be readily assessed by three tasks, performed once by the preferred hand and once by the nonpreferred hand of each subject. Combined testing time for these tasks was approximately five minutes.

(i) Writing Name

Each child was asked to print quickly and carefully his first and last names, in the space indicated on the test-blank by the examiner.[1] The initial attempt was assumed to have been performed by the preferred hand. The procedure was then repeated for the non-preferred writing hand and the time taken by the subject for each attempt was recorded.

(ii) Drawing the Rungs of a Ladder

Each "ladder" stimulus consisted of a pair of vertical lines 11 cm in length and 3 cm apart, with inward facing horizontal marks

---

[1]A test-blank for handedness tasks is appended (Appendix B).

2 mm in length, spaced 10 mm apart along each vertical side (Appendix B). Three line-pairs were printed but only two were normally used, one for the preferred hand and one for the nonpreferred hand, the third being available for use in cases of minor administrative aberrations. Children were preinstructed to complete each trial quickly and carefully within the 10 second time-limit.

(iii) Scissor Cutting of a Paper Circle

Subjects were instructed to cut-out a paper circle of 5 cm diameter,[1] as quickly and carefully as possible using the preferred hand. The time taken was recorded and the procedure repeated for the nonpreferred hand. Children's stub-nosed, metal paper-cutting scissors were provided.

## Dichotic Listening Tasks

In the preparation of the dichotic listening test tape, procedures were adopted to maximize the comparability of both channels with regard to stimulus quality, intensity, duration and phasing.[2] However, unless testing procedures can ensure comparability of input intensity at the left and right ears for the dichotic digit sequences, obtained recall asymmetries cannot be assumed to reflect differential processing efficiencies at the cortical level. The

---

[1]Appendix D contains a stimulus, hypothetical performance and scoring template for this task.

[2]Appendix E includes a detailed description of the stimuli, equipment and procedures used in the preparation of the dichotic tape.

present study therefore employed step-attenuation to determine signal intelligibility thresholds of each subject. Having determined this level for each channel when presented monaurally to each ear, the experimenter can ensure a playback intensity of threshold plus a constant for all subjects.

Although it has been suggested (Spreen et al., 1970) that reduced playback intensities may facilitate the demonstration of ear asymmetries in recall of dichotic stimuli, field testing of children imposes the restriction that playback intensity must be sufficient to compensate for distracting background noises. A playback intensity level of threshold plus 40 dB for all subjects seemed appropriate for present purposes.

Matched Grason-Stadler Step Attenuators were interposed between playback recorder outputs and the subject's earphones (Figure 1) so that the intelligibility threshold could be found for each channel played to each ear in turn. Channel one of the trial series of digits (Appendix E) was played monaurally to one ear with signal intensity being progressively attenuated until the subject could detect and recall correctly only one digit in four. The attenuation procedure was then repeated for channel two played to the other ear. Earphones were then reversed and the above procedure repeated. Approximately five minutes per subject were required for the entire attenuation procedure. At a playback-intensity of threshold-plus-40 dB, each subject heard tape-recorded instructions to listen and

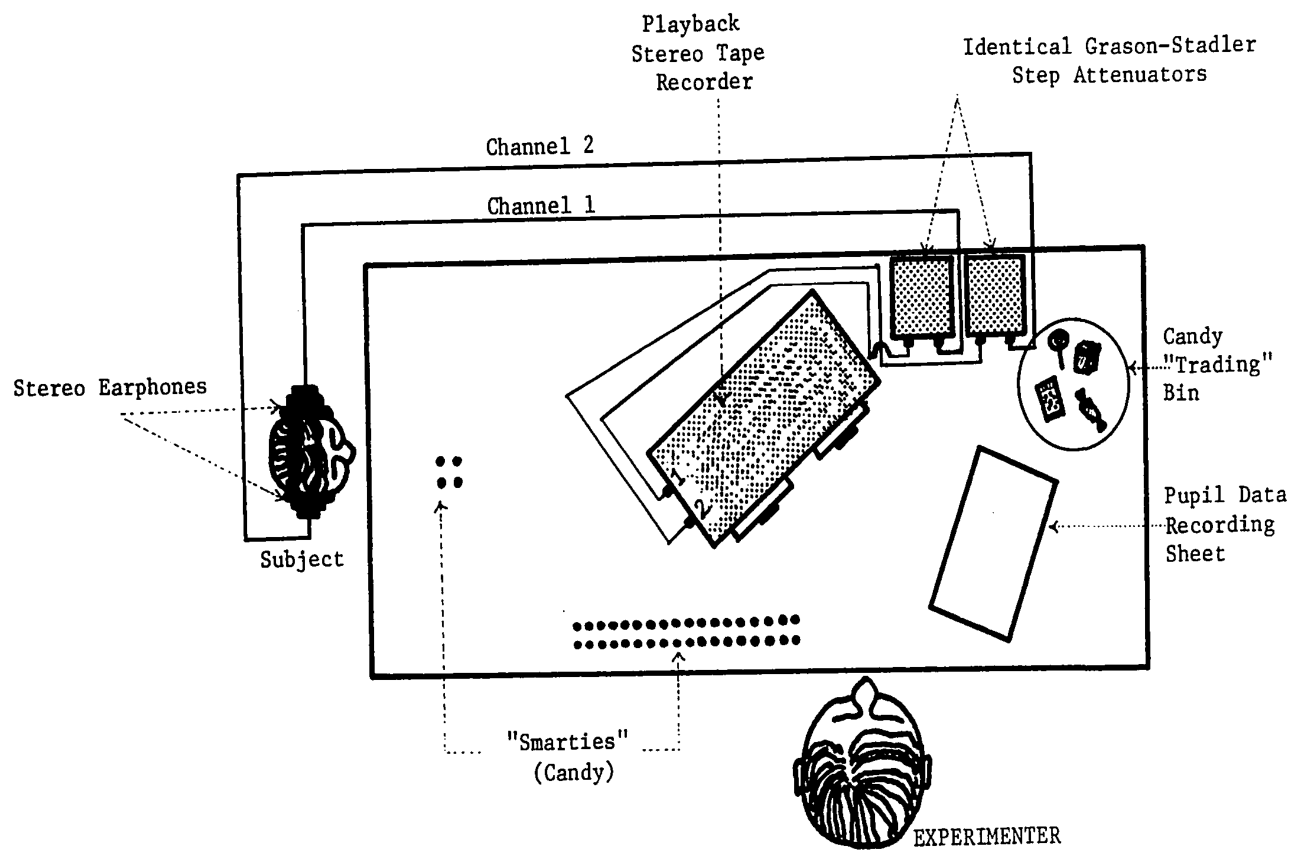



FIGURE 1

SCHEMATIC DIAGRAM OF DICHOTIC TESTING APPARATUS AS USED IN FIELD TESTING recall dichotically-presented digit-pair-series.[1] Each series was preceded by a binaural 1000 Hz pure-tone cue-signal of 500 msec duration. The free-recall practice sequence consisted of five single dichotic-digit-pair trials, four trials with two digit-pairs per trial and four three-pair trials.[2] Half of the subjects in the intended restricted sample listened initially to channel-one with the right ear and channel-two with the left ear (Position A), then, with earphones reversed and attenuator levels readjusted, the stimuli were repeated (Position B: channel-one to left ear, channel-two to right ear), The other half sample was tested using a Position B then Position A sequence. The practice sequences provided subjects with an opportunity to become familiar with the presentation rate, the intensity level, the interval between cue-signal and stimulus onset and the time available between trials for oral recall.

The dichotic digit test sequence consisted of two single-pair practice trials followed by six trials with two-pairs per trial, four three-pair trials and four four-pair trials,[3] following the same presentation order for each subject used in the free-recall series. However, unlike the free-recall practice sequence, the test sequence required an ordered recall of stimuli, wherein the subject

---

[1]Details of stimuli, instructions and scoring are provided in Appendix E.

[2]Appendix E.

[3]Appendix E.

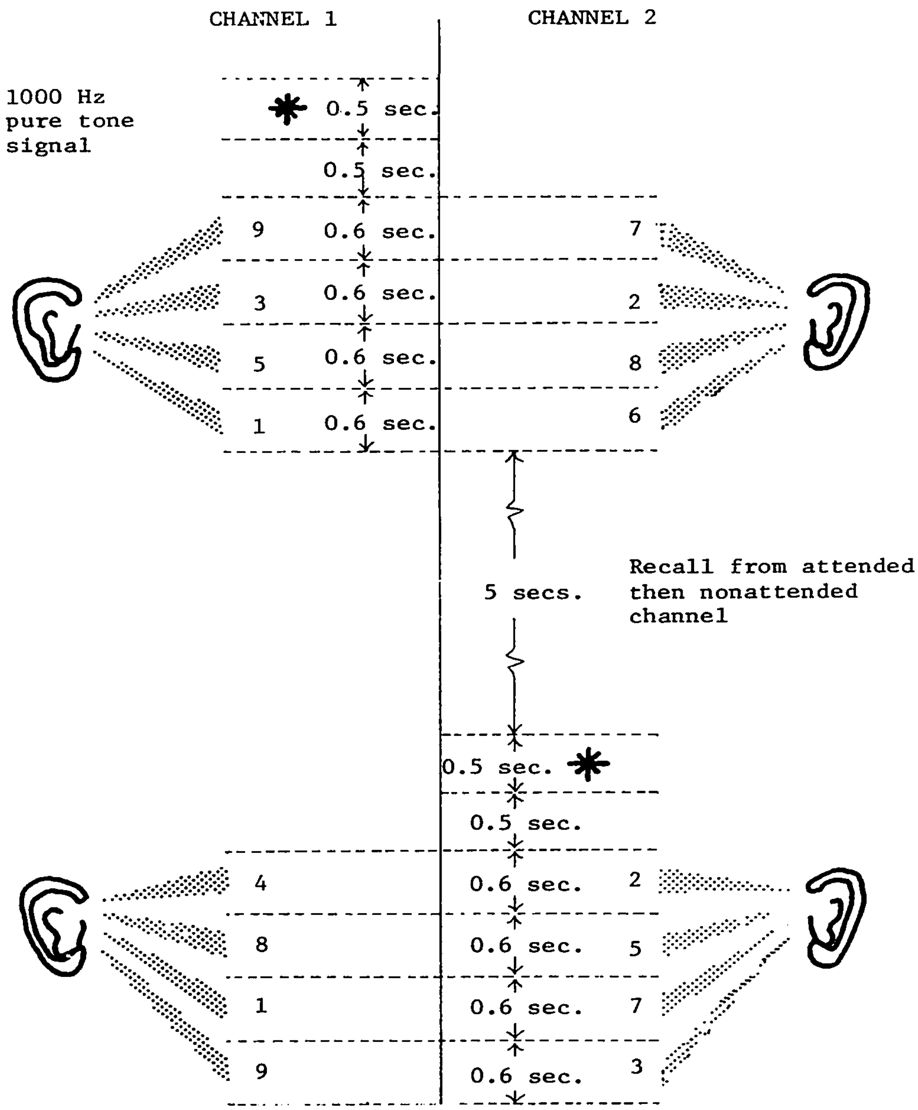



FIGURE 2

DIAGRAMMATIC REPRESENTATION OF TWO FOUR-PAIR DIGIT SERIES

(Diagrammatic format adopted from Gordon, 1971) was cued by a monaurally presented pure-tone "beep" signal to attend to one channel only and to begin recall from this channel prior to recalling any other digits heard on the nonattended channel (Figure 2). Subjects were thus instructed to adopt an ear-order of recall. As noted earlier (pp. 42-43), at a rapid presentation rate, subjects almost invariably attempt to recall two "strings" or half-series of numbers, rather than attempt to recall numbers in pairs. Requiring subjects to adopt the salient ear-order of recall (Table 10) and systematically alternating the cue-channel signal from one channel to the other over trials (Appendix E) ought therefore to minimize any systematic bias in initial-half-channel-recall and delayed-half-channel-recall.

TABLE 10

EXAMPLES OF RECALL STRATEGIES USED IN
A TWO-PAIR DICHOTIC-DIGIT TRIAL

| Dichotic Stimuli | | Recall Strategy | |
|---|---|---|---|
| Ch. 1 | Ch. 2 | (a) Ear-Order | (b) Pair-Order |
| 6 -------- | 9 | 6 3 9 1<br>or | 6 9 3 1 |
| 3 -------- | 1 | 9 1 6 3 | 3 1 6 9 |

The ordered-recall test sequence was preceded by two practice trials each having a monaural cue-signal and one pair of dichotic digits. Following the recorded instructions, the first practice-pair was presented. The subject responded and was given one M & M ("Smarties") candy if he/she repeated the cued-channel number first, and a second candy if the number presented to the noncued ear was also recalled. The examiner briefly explained why one or two candies were given and reminded the subject to listen to the signalled channel and repeat the number(s) from that channel prior to attempting to recall any other numbers heard. The second test-sequence practice-pair was then presented and responses appropriately reinforced. This procedure was repeated until both trials were correctly recalled. The test sequence was then presented and one or two candies given without comment following each digit-pair-series, the second candy being awarded for either complete or partial recall of numbers in the delayed-half-series. After the entire test sequence had been administered once, the subject was given an opportunity to exchange ten Smarties for one small sealed packet of raisins, peanuts or candies (Figure 1). Earphones were then reversed, attenuators were adjusted and the test-sequence procedures were repeated. Approximately twenty minutes of testing time beyond step-attenuation threshold measurement was required for each subject.

In the production of the dichotic tape, the equivalence of repeated presentations of the same digit was controlled by dubbing all digits from a single source tape containing the digits one through nine recorded under optimal conditions.[1] In the presentation of the

---

[1]Appendix E.

tape, inequalities in input intensity were minimized by step attenuation, while the repeated presentation of the entire test-sequence was assumed to control for any inequalities between channel-one and channel-two signals which might affect recall. For the ordered-recall test-sequence, optimal attention was sustained by a monaural cue-signal preceding each series, and by the use of post-recall candy reinforcers on each trial. Initial half-series recall was alternated between channels.

Given the inevitable variability in attendant noise levels during field testing, it is nevertheless suggested that the task and procedures employed in the present study represent, across subjects, a feasible means of measuring right/left asymmetry in simultaneous processing and recall of dichotically presented digit-series, and further, that the procedures outlined are relatively free from any systematic bias favoring left or right-sided recall superiority.[1]

## Scoring Procedures

### Handedness Preference

On the basis of the child's demonstrated preference and the examiner's observations of right/left performance differences, a rating from one to five was assigned for each of the tasks "Writing

---

[1]DL data for eight subjects were not used when, in the investigator's opinion, adequate rapport could not be re-established following interruption, or when background noise levels were excessively high or variable and caused attentional lapses during testing.

Name," "Drawing the Rungs of a Ladder," and "Scissor Cutting of a Paper Circle." This rating was intended to indicate the clarity or strength of preference for the preferred hand relative to the non-preferred hand of each child. Ratings were assigned as follows:

1 - Pronounced left-hand-preferent (LH), having negligible facility with the right-hand;

2 - Left-hand-preferent (LH), having some facility with the right hand;

3 - Equal preference for either hand (MH), having equal facility with either hand;

4 - Right-hand-preferent (RH), having some facility with the left hand;

5 - Pronounced right-hand-preferent (RH), having negligible facility with the left hand.

A rating of 3 was assigned only when the subject indicated that he/she could perform the task comfortably with either hand, and when the performances of both the right and the left hand were equivalent with respect to manipulation of the pencil or scissors, quality of performance and time taken to complete the task.[1] For each task, most children demonstrated a preference for, and greater facility with one hand. Ratings of 1 or 5 were given only when the

---

[1]In ladder drawing, an equal number of lines drawn and an equal quality score (Appendix C) for both hands was classified as "equal facility" (classification 3).

subject did not complete the task with the nonpreferred hand, used a completely inappropriate pencil or scissor grip, or when task performance for the nonpreferred hand was negligible relative to the preferred hand. Ratings were then averaged for the three tasks as a basis for classifying from 1 to 5 the handedness preference of each child (Tables 11 and 12).

TABLE 11

HANDEDNESS PREFERENCE: PERCENTAGE DISTRIBUTION OF SUBJECTS IN INITIAL SAMPLE

| | L.H. | | MH | R.H. | | |
|---|---|---|---|---|---|---|
| A. Handedness Preference as Reported by Parents | 1 | 2 | 3 | 4 | 5 | Combined |
| 1. Writing Name | 43 | 1 | 0 | 3 | 53 | 100 |
| 2. Scissor Cutting | 25 | 3 | 5 | 8 | 59 | 100 |
| 3. Throwing a Ball | 26 | 5 | 8 | 11 | 50 | 100 |
| 4. Brushing Teeth | 35 | 3 | 6 | 6 | 50 | 100 |
| 5. Tasks $A_1$-$A_4$ combined | 21 | 13 | 10 | 6 | 50 | 100 |
| B. Handed Preference as Observed by Examiner | | | | | | |
| 1. Writing Name | 15 | 27 | 5 | 22 | 31 | 100 |
| 2. Drawing Rungs of Ladder | 5 | 37 | 5 | 39 | 15 | 100 |
| 3. Scissor Cutting | 2 | 18 | 5 | 57 | 18 | 100 |
| 4. Tasks $B_1$-$B_3$ combined | 4 | 20 | 23 | 32 | 21 | 100 |

## Familial Handedness Preference

In view of comments by Bryden (1965), Weinstein & Sersen (1961) and Zurif & Bryden (1969), familial preference was based on questionnaire reports (Appendix A). Left-familial children were defined as those having a left-handed mother, or left-handed father and sibling, or two or more left-handed siblings. Classifications were:

1 - Left-familial hand-preferent (LF).

2 - Right-familial hand-preferent (RF).

TABLE 12

HANDEDNESS PREFERENCE CORRELATIONS:[1]
INITIAL SAMPLE

| Handedness Task | | Variable | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A. Reported Preference | | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Writing Name | 1 | 76 | 80 | 89 | 93 | 90 | 88 | 63 | 84 |
| Scissor Cutting | 2 | | 76 | 74 | 89 | 73 | 71 | 78 | 79 |
| Throwing a Ball | 3 | | | 80 | 91 | 76 | 72 | 67 | 76 |
| Brushing Teeth | 4 | | | | 92 | 84 | 83 | 65 | 81 |
| Reported Handedness Classification | 5 | | | | | 87 | 84 | 75 | 86 |
| B. Observed Preference | | | | | | | | | |
| Writing Name | 6 | | | | | | 91 | 68 | 92 |
| Drawing Ladder | 7 | | | | | | | 65 | 92 |
| Scissor Cutting | 8 | | | | | | | | 83 |
| Observed Handedness Classification | 9 | | | | | | | | |

[1]Decimals omitted.

From Table 11B it is apparent that the majority of children classified as left-preferent (classifications 1 or 2) or right-preferent (classifications 4 or 5) have some facility with the nondominant hand. The relative proficiency with the nondominant hand appears to be greater for left-hand-preferents than right-hand-preferents. Additionally, although only 5% of children demonstrated equal hand preference and proficiency on any one of the three observed tasks, 23% (50 children) were ultimately classified as "mixed-preferents." Most of these children were nominal left-hand-preferents who demonstrated a clear preference for, and greater dexterity with the <u>right</u> hand for scissor cutting (Table 11B).

Although the correlation between observed and reported handedness classifications is 0.86, parents were asked to rate on the basis of frequency of preference, whereas the observed classification attempted to compare the preference and proficiency of one hand relative to the other. Inasmuch as some children were clearly incorrectly classified by parents, it was decided to use only the "observed preference" classification for the present investigation.

Manual Dexterity

Proficiency of performance on two tasks, viz: "Drawing the Rungs of a Ladder" and "Scissor Cutting of a Paper Circle" was used to assess the manual dexterity of each child relative to other children in the initial sample. Although "Writing Name" performances of both hands were available for each child, it was found difficult to develop a reasonably objective scoring rationale for assessing the child's manual proficiency independent of manual preference and spelling proficiency. It also seemed unjustified to consider as "nondextrous" those children who were permitted to adopt an unconventional but legible letter-shape format in writing their names.

In allowing only ten seconds per hand for each attempt at the ladder-drawing task, it was assumed that time and accuracy of performance are both relevant dimensions of dexterity. However, the scissor-cutting task imposed no time restraints other than a direction to children to work as quickly and carefully as possible. It seemed reasonable therefore to give credit to performances completed more quickly than those of peers in the initial sample, and to mildly penalize children who took considerably longer than most of their peers. These considerations suggested the adoption of the following scoring and classification procedures:

(i) Drawing the Rungs of a Ladder

Time being fixed (ten seconds per trial), it was necessary to score only proficiency of performance. The dexterity score was thus the number of acceptable lines drawn with the better hand, an acceptable line being defined as one which began and finished within 2 mm of the indicated marks and which did not deviate more than ± 1 mm from the most direct path between paired marks throughout its length, as indicated by a specially made cardboard scoring template.[1]

(ii) Scissor Cutting of a Paper Circle

The circle cut out by each hand was lightly tacked to the sheet containing the child's name-writing and ladder-drawing attempts. Proficiency on this task was determined by the number of centimetres on target, (possible 16) allowing the cut edge to deviate no more than ± 1 mm from the circle outline, as indicated by a specially made transparent scoring template.[2]

The distribution of time taken using the preferred hand was

---

[1]The printed stimulus (Appendix B); and the performance of a hypothetical child, the scoring of this performance and the scoring template are diagrammatically depicted in Appendix C.

[2]The circle stimulus as presented, the performance of a hypothetical child, the scoring of this performance and an opaque replica of the scoring template are diagrammatically depicted in Appendix D.

transformed to stanine scores. For each stanine below stanine-five (thus indicating faster performance relative to other children in the initial sample), one bonus point was added to the obtained cutting-proficiency score to obtain the adjusted proficiency score. One score point was likewise deducted for each stanine above stanine-five.

(iii) Dexterity Classification

The distribution of raw scores for ladder-drawing proficiency and the distribution of adjusted raw scores for scissor-cutting proficiency were transformed to standard scores (Mean 50; S.D. 10). The ladder-drawing standard score for the better hand of each child and his/her scissor-cutting standard score, were averaged and entered as a stanine figure for each child. For statistical analyses, this distribution of manual dexterity was collapsed to three levels,[1] viz: "Dextrous" (Stanines 6, 7, 8 and 9); "Marginally-Dextrous" (Stanine 5); and "Nondextrous" (Stanines 1, 2, 3 and 4):

1 - Nondextrous (ND)

2 - Marginally-dextrous (MD)

3 - Dextrous (D)

## Dichotic Listening Test Sequence

To measure ear-asymmetries in recall of dichotic digit-pair-series, most researchers have employed difference-scores (right-ear

---

[1]Although the intended restricted sample was drawn so as to obtain approximately equal numbers of "Dextrous" and "Nondextrous" children as dichotomized above and below the combined dexterity mean, statistical analyses employed three levels of dexterity and not two.

minus left-ear summed over n trials). When a test sequence consists of relatively few trials, it is possible under pre-instructed alternating-channel ordered-recall conditions that a R-L difference score of $\pm 1$ for each of four trials can be nullified in one trial, should a R-L score of -4 be obtained due to a temporary lapse in concentration. Although it could be expected that attentional lapses, guessing or recall difficulties due to extraneous distracting stimuli would exert no systematic bias favoring left or right, it seemed useful to score each half-series as correct or incorrect (1/0) and thus provide an additional scoring procedure, based on serial recall of ear-half series. It is interesting to recall that Bakker (1969) found serial-recall to be a more sensitive index of ear-asymmetries in recall, than free-recall without regard to seriation.

The superiority of the right-ear in "grabbing the system" in dichotic listening or shadowing tasks (Bryden, 1969; Oxbury et al., 1967; Treisman & Geffen, 1968), suggests that a R/L comparison of <u>intrusions</u> might also reveal recall asymmetries. The test sequence in the present study instructed subjects to recall all digits presented to the cued channel before attempting to report any digits presented to the nonattended, delayed-recall channel. Thus, digits from the nonattended channel reported prior to recall of the last digit in the cued-channel half-series were scored as intrusions (Table 13).

TABLE 13

DICHOTIC LISTENING: SCORING EXAMPLES FOR ONE FOUR-PAIR DICHOTIC-DIGIT SERIES

| Dichotic Stimuli Right Ear | Dichotic Stimuli Left Ear | Subject | Report | Scoring: Digits R | Digits L | ½ Series R | ½ Series L | Intrusions R | Intrusions L |
|---|---|---|---|---|---|---|---|---|---|
| * (pure-tone) | | A | 9351726 | 4 | 3 | 1 | 0 | – | 0 |
| | 9--7 | B | 928751 | 3 | 3 | 0 | 0 | – | 3 |
| | 3--2 | C | 735186 | 3 | 3 | 0 | 0 | – | 1 |
| | 5--8 | D | 93516 | 4 | 1 | 0 | 0 | – | 0 |
| | 1--6 | E | 9728651 | 3 | 4 | 0 | 1 | – | 4 |

Right-minus-left (R-L) score over the 14 trials of the test sequence were summed in all three scoring procedures; i.e., R-L digits; R-L ½ series; R-L intrusions. Ear asymmetries were then defined as the direction of R/L difference for all three scoring procedures combined, viz:

1 - Left-ear-dominant (LE): L > R for 3/3 or 2/3 scoring procedures;

2 - Nondominant (NE): R = L for 3/3 or 2/3 scoring procedures; or R > L, R = L and L > R for the three procedures;

3 - Right-ear-dominant (RE): R > L for 3/3 or 2/3 scoring procedures.

Reading Tasks

Reading Comprehension and Vocabulary scores obtained during the May-June 1971 administration of the Gates-MacGinitie Reading Tests, Primary B (1965), were made available for most children tested in the present investigation. After transformation to standard scores (Mean 50; S.D. 10), it was decided to combine the two parts, Vocabulary and Comprehension as one dependent Variable for statistical analyses. Thus, for the purposes of the present study, reading proficiency was defined as the mean of Gates-MacGinitie Vocabulary and Comprehension subtests combined, expressed in standard scores. For the initial sample, the combined score correlated 0.938 and 0.953 with Vocabulary and Comprehension respectively, while for the restricted sample, the respective coefficients were 0.952 and 0.967.

## Experimental Variables and Statistical Procedures

### Independent Variables

(i) Observed Handedness Preference:

(a) Initial Sample: (5 levels)

1 - Pronounced-left-hand-preferent (LH);

2 - Left-hand-preferent (LH);

3 - Mixed-hand-preferent (MH);

4 - Right-hand-preferent (RH);

5 - Pronounced-right-hand-preferent (RH).

(b) Restricted Sample: (3 levels)

1 - Left-hand-preferent (LH);

2 - Mixed-hand-preferent (MH);

3 - Right-hand-preferent (RH).

(ii) Manual Dexterity: (3 levels)

1 - Nondextrous (ND);

2 - Marginally dextrous (MD);

3 - Dextrous (D).

(iii) Familial Handedness Preference: (2 levels)

1 - Left-familial-preferent (LF);

2 - Right-familial-preference (RF).

(iv) Dichotic Listening Ear Asymmetry: (3 levels)

1 - Left-ear-dominant (LE);

2 - Non-dominant (NE);

3 - Right-ear-dominant (RE).

Dependent Variable

Reading proficiency - Mean Vocabulary/Comprehension standard score from the Gates-MacGinitie Reading Tests (Primary B, 1965).

Statistical Procedures

(i) Hypotheses 1A, 1B, 1C

(a) Sample:

Initial sample; n = 222.

(b) Dependent Variable:

Reading proficiency (Vocabulary/Comprehension combined).

(c) Independent Variables:

Factor A - Observed handedness preference (5 levels);

Factor B - Manual dexterity (3 levels).

(d) Statistical Analyses:

Four planned comparisons were analyzed.[1]

---

[1]Comparisons preceded by the symbol † provided tests of hypotheses 1A, 1B, 1C.

CA1 The mean of levels 1 and 2 of factor A with the mean of levels 4 and 5 of factor A;

i.e., $M_{(\underline{LH},LH)}$: $M_{(RH,\underline{RH})}$

*CA2 The mean of levels 1, 2, 4 and 5 of factor A with the mean of level 3 of factor A;

i.e., $M_{(\underline{LH},LH,RH,\underline{RH})}$: $M_{MH}$

*CB1 The mean of level 1 of factor B with the mean of level 3 of factor B;

i.e., $M_{ND}$: $M_{D}$

*CA2/B1 level 2 The mean of nondominant/left and right-hand-preferents with the mean of non-dominant/mixed-hand-preferents;

i.e., $M_{(\underline{LH},LH,RH,\underline{RH})/ND}$: $M_{MH/ND}$

(ii) <u>Hypotheses 2A, 2B, 2C, 2D</u>

(a) Sample:

Restricted sample; n = 108.

(b) Dependent Variable:

Reading proficiency (Vocabulary/Comprehension combined).

(c) Independent Variables:

Factor A - Observed handedness preference (3 levels);

Factor B - Manual dexterity (3 levels);

Factor C - Familial handedness preference (2 levels);

Factor D - Dichotic listening ear asymmetry (3 levels);

Factor E - Sex (2 levels).[1]

(d) Statistical Analysis:

Eight planned comparisons were analyzed.[2]

$C_{A1}$ The mean of level 1 of factor A with the mean of level 3 of factor A;

i.e., $M_{LH}$: $M_{RH}$

$C_{A2}$ The mean of levels 1 and 3 of factor A with the mean of level 2 of factor A;

i.e., $M_{(LH,RH)}$: $M_{MH}$

$C_{B1}$ The mean of level 1 of factor B with the mean of level 3 of factor B;

i.e., $M_{ND}$: $M_D$

$C_{C1}$ The mean of level 1 of factor C with the mean of level 2 of factor C;

i.e., $M_{LF}$: $M_{RF}$

†$C_{D1}$ The mean of levels 1 and 3 of factor D with the mean of level 2 of factor D;

i.e., $M_{(LE,RE)}$: $M_{NE}$

---

[1] Sex was included as a factor in the analysis to reduce the within-cell error term but was not otherwise used to test hypotheses.

[2] Comparisons preceded by the symbol † provided tests of hypotheses 2A, 2B, 2C, 2D.

*!$C_{D2}$ The mean of level 1 of factor D with the mean of level 3 of factor D;

i.e., $M_{LE}$: $M_{RE}$

*!$C_{B1/D1}$ (restricted) The mean of factor B level 3 Ss classified as either LE or RE (levels 1 and 3 of factor D) with the mean of factor B level 1 Ss classified as NE (level 2 of factor D);

i.e., $M_{D(LE,RE)}$: $M_{\overline{N}D/NE}$

*!$C_{A1/C1/D2}$ (restricted) The mean of Ss classified as either LH/LF/LE or RH/RF/RE with the mean of Ss in all other classifications involving factors A, C and D combined.

Although equal numbers of subjects per cell are desirable for multifactor analyses of variance in the present study, 58 of the possible 108 cells (3x3x2x3x2) were empty, largely due to the distribution of Ss on factor D (DL ear asymmetry).[1] As a check on the multifactor analysis, planned comparisons for factor D were analyzed using 30 subjects, randomly drawn from the restricted sample so as to have 10 Ss in each level of factor D.[2]

---

[1]Of the 108 children in the restricted sample, 33 were classified as LE (level 1), 10 as NE (level 2), and 65 as RE (level 3) on factor D.

[2]Tables 19 and 20 of Appendix F provide descriptive information re this reduced sample.

(iii) Hypotheses 3A. 3B, 3C

(a) Sample:

Restricted sample; n = 108.

(b) Variables:

Observed handedness preference (5 levels);

Manual dexterity (3 levels);

Familial handedness preference (2 levels);

Dichotic listening ear asymmetry (3 levels).

(c) Statistical Analyses:

Each of hypotheses 3A, 3B and 3C was analyzed using a one-tailed z test of significance of the difference between two independent proportions (Ferguson, 1966, pp. 176-178).

(iv) Supplementary Analyses

The extent to which reading proficiency might be predicted from dichotic listening and handedness data was of interest to the researcher. Seven variables selected as potentially useful predictors were combined for stepwise regression analyses, using the restricted sample then a randomly chosen half of the restricted sample. The remaining half of the restricted sample was used for cross-validation, by applying regression weights obtained for the first half sample to relevant data for the remaining 54 Ss. Optimally, cross validation should be undertaken with a different sample of children, inasmuch as 54 Ss are far fewer than desirable for multiple regression analysis (Nunnally, 1967).

(a) Dependent Variable:

Reading proficiency (Vocabulary/Comprehension combined).

(b) Predictor Variables:

1. Scissor cutting of a circle: raw score (adjusted) for the better hand;
2. Drawing the rungs of a ladder: raw score for the better hand;
3. Mean dexterity: standard score mean of (1) and (2);
4. Number of half-series recalled in serial order over all DL ordered-recall trials: raw score for the better ear;
5. Number of digits correctly recalled over all DL ordered-recall trials: raw score for the better ear;
6. Highest number of digits recalled in correct serial order (cued + noncued half-series) on any one of the DL ordered-recall trials;
7. Ear-asymmetry classification (restructured as NE = 1, LE = 2 and RE = 3).[1]

---

[1] In accordance with earlier discussion relevant to hypotheses 2A and 2B.

# CHAPTER 5

# RESULTS AND DISCUSSION

## Handednes Preference, Manual Dexterity and Reading: Hypotheses 1A, 1B, 1C

Tests of planned comparisons involving children in the initial sample are presented in Table 14. No significant differences emerged among handedness-preference groups, ($M_{LH}$ = 52.43, $M_{MH}$ = 54.04, $M_{RH}$ = 52.79). Thus comparison $C_{A1}$ and comparison $C_{A2}$ were not significant (Table 14). Although dextrous children were more proficient readers than nondextrous children; $C_{B1}$ ($M_{ND}$ = 48.86, $M_D$ = 55.51, F = 26,371, df = 1/208, $p < .0001$), mixed-hand-preferent children were not less proficient readers than right or left-preferent children, even when the comparison was restricted to nondextrous Ss (Figure 3). These data thus failed to support hypotheses 1A and 1C but offered strong support for hypothesis 1B.

Mixed-hand-preferent children in the present study were not less proficient readers than their unimanual-preferent peers, a finding which is consistent with other recent studies of normal, elementary school children (Balow & Balow, 1964; Belmont & Birch, 1965; Coleman & Deutch, 1964; Stephens et al., 1967; Treischmann, 1968). However, the mixed-hand-preferent children in the present study had consistent unimanual preference for specific tasks, combined with inconsistent hand preferences across tasks. Many left-preferents in writing were clearly right-preferents in scissor

TABLE 14

ANALYSIS OF VARIANCE SUMMARY TABLE FOR INITIAL SAMPLE READING PROFICIENCY: PLANNED COMPARISONS INVOLVING HANDEDNESS PREFERENCE AND MANUAL DEXTERITY

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Planned Comparison[a] | | | | |
| $C_{A1}$ $M_{(\underline{LH},LH)}$ : $M_{(RH,\underline{RH})}$ | 70.802 | 1 | 70.802 | 0.994 |
| *!$C_{A2}$ $M_{(\underline{LH},LH,RH,\underline{RH})}$ : $M_{MH}$ | 2.289 | 1 | 2.289 | 0.032 |
| *!$C_{B1}$ $M_{ND}$ : $M_{D}$ | 1,878 641 | 1 | 1,878.641 | 26.371*** |
| *!$C_{A2}$ at b1 | | | | |
| $M_{(\underline{LH},LH,RH,RH)/ND}$ : $M_{MH/ND}$ | 162.352 | 1 | 162.352 | 2.279 |
| Residual | 585.861 | 9 | | |
| Between Groups | 2,699.945 | 13 | | |
| Within Cell | 14,818.016 | 208 | 71.240 | |
| | 17,517.961 | 221 | | |

***$p < .001$.

*! Comparisons providing tests of hypotheses.

[a] cf. p. 102 for description of planned comparisons

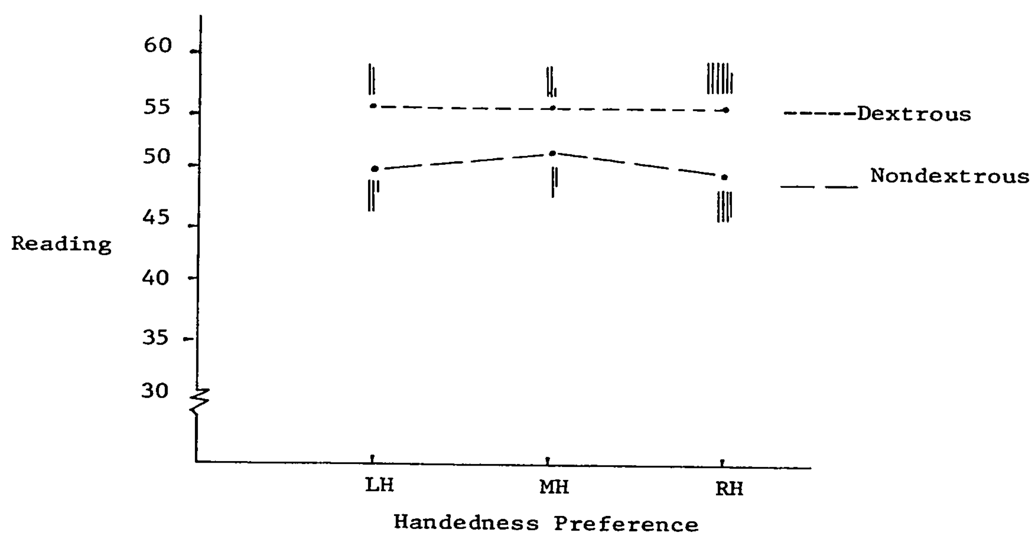



FIGURE 3

READING PROFICIENCY FOR INITIAL SAMPLE:
HANDEDNESS PREFERENCE X MANUAL DEXTERITY:
BARS REPRESENT SUBJECTS,
1 BAR of 5 mm LENGTH=10 Ss

manipulation. Assuming that this pattern was indicative of preferences for other nontested manual tasks, these children were generally classified as mixed-hand-preferents. Only seven students exhibited ambidexterity on two of the three observed tasks and not one was classified as nondextrous. The present study, therefore, does not constitute a reasonable test of reading proficiencies of nondextrous ambiguous hand-preferent-children (Zangwill, 1962).

Consistent with Zurif & Carson (1970), data from the present study indicated that dexterity and reading proficiency were related. Zurif & Carson reported a correlation of 0.36 between scissor cutting proficiency and reading (Gates Reading: grade four level), whereas the correlations were 0.30 and 0.30 for the initial and restricted samples in the present study. Ladder drawing correlations with reading were 0.36 and 0.40.

## Handedness Preference, Manual Dexterity, Familial Handedness Preference, Ear Asymmetry in Dichotic Listening and Reading: Hypotheses 2A, 2B, 2C, 2D

For the restricted sample (Table 15), handedness-preference groups were again not significantly different in reading proficiency, as indicated by the two planned comparisons on factor A, $C_{A1}$ ($M_{LH}$ = 51.47, $M_{RH}$ = 51.18; $F = 0.48$, df = 1/58, n.s.), and $C_{A2}$ ($M_{(LH,RH)}$ = 51.31, $M_{MH}$ = 53.57; $F = 0.613$; df = 1/58, n.s.). As in the initial dextrous children were more proficient readers than nondextrous children; as indicated by comparison $C_{B1}$ ($M_{ND}$ = 47.70, $M_D$ = 55.89; $F = 20.248$, df = 1/58, $p < .0001$). Both comparisons on factor D

TABLE 15

ANALYSIS OF VARIANCE SUMMARY TABLE FOR RESTRICTED SAMPLE READING PROFICIENCY: PLANNED COMPARISONS INVOLVING HANDEDNESS PREFERENCE, MANUAL DEXTERITY, FAMILIAL HANDEDNESS AND DICHOTIC LISTENING EAR ASYMMETRY

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Planned Comparison[a] | | | | |
| $C_{A1}$ $M_{LH}$: $M_{RH}$ | 27.255 | 1 | 27.255 | 0.476 |
| $C_{A2}$ $M_{(LH,RH)}$: $M_{MH}$ | 35.076 | 1 | 35.076 | 0.613 |
| $C_{B1}$ $M_{ND}$: $M_{D}$ | 1,158.542 | 1 | 1,158.542 | 20.248*** |
| $C_{C1}$ $M_{LF}$: $M_{RF}$ | 1,063 | 1 | 1,063 | 0.019 |
| ***!$C_{D1}$ $M_{(LE,RE)}$: $M_{NE}$ | 1,095.403 | 1 | 1,095.403 | 19.145*** |
| *!$C_{D2}$ $M_{LE}$: $M_{RE}$ | 314.107 | 1 | 314.107 | 5.490 |
| *!$CB_{1/D1}$ (restricted) $M_{D/(LE,RE)}$: $M_{ND/NE}$ | 1,478.837 | 1 | 1,478.837 | 25.847*** |
| *!$C_{A1/C1/D2}$ (restricted) $M_{(LH/LF/LE,RH/RF/RE)}$: $M_{(others)}$ | 139.724 | 1 | 139.724 | 2.442 |
| Residual | 2,767.194 | 41 | 67.512 | 1.180 |
| Between Groups | 7,018.001 | 49 | | |
| Within Cell | 3,318.545 | 58 | 57.216 | |
| | 10,336.546 | 107 | | |

*$p < .05$; **$p < .01$; ***$p < .001$. *! Comparisons providing tests of hypotheses.

[a]cf. p.103 for description of planned comparisons.

(Figure 4) were significant, least proficient readers being those children classified as nondominant with regard to DL ear asymmetry, and most proficient being right-ear-dominant children; $C_{D1}$ ($M_{(LE,RE)}$ = 52.86, $M_{NE}$ = 42.8; $F = 19.145$, df = 1/58, $p < .0001$), and $C_{D2}$ ($M_{LE}$ = 50.30, $M_{RE}$ = 54.17; $F = 5.49$; df = 1/58, $p < .05$). It was earlier noted, however, that comparisons $C_{D1}$ and $C_{D2}$ were also re-tested using 10 Ss at each level of factor D (Appendix F). In this latter analysis, the difference in reading proficiency between left-ear-dominant and right-ear-dominant children was not significant; $C_{D2}$ ($M_{LE}$ = 50.1, $M_{RE}$ = 58.3; $F = 2.89$, df = 1/27, n.s.), while left and right-ear-dominant children were again significantly more proficient readers than nondominant children; $C_{D1}$ ($M_{LE,RE}$) = 54.2, $M_{NE}$ = 42.8; $F = 7.44$, df = 1/27, $p < .05$).

Hypothesis 2A is thus convincingly supported but hypothesis 2B obtains only tentative support from these data.

However, the combination of ear asymmetry and dexterity is rather important (Figure 5). Increments in reading proficiency from NE through LE to RE classifications of ear asymmetry are apparent only for the least proficient level (ND) of manual dexterity. The planned comparison of dextrous/ear dominant with nondextrous/nondominant children is highly significant; $C_{B1/D1(restricted)}$ ($M_{D/(LE,RE)}$ = 55.93, $M_{ND/NE}$ = 35.75, $F = 25.847$, df = 1/58, $p < .0001$), thus providing strong support for hypothesis 2C.

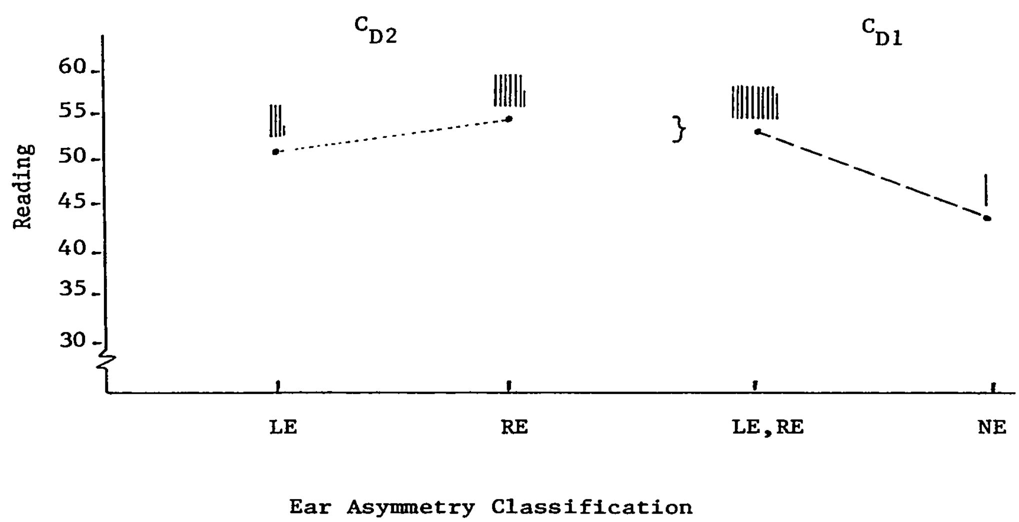



FIGURE 4

READING PROFICIENCY FOR RESTRICTED
SAMPLE: EAR ASYMMETRY IN DL:
BARS REPRESENT SUBJECTS
1 BAR OF 5 mm
LENGTH=10 Ss

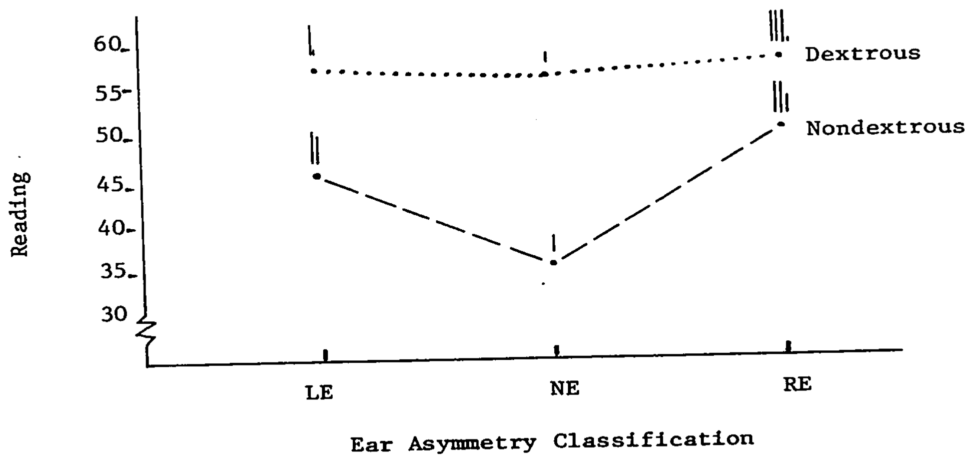
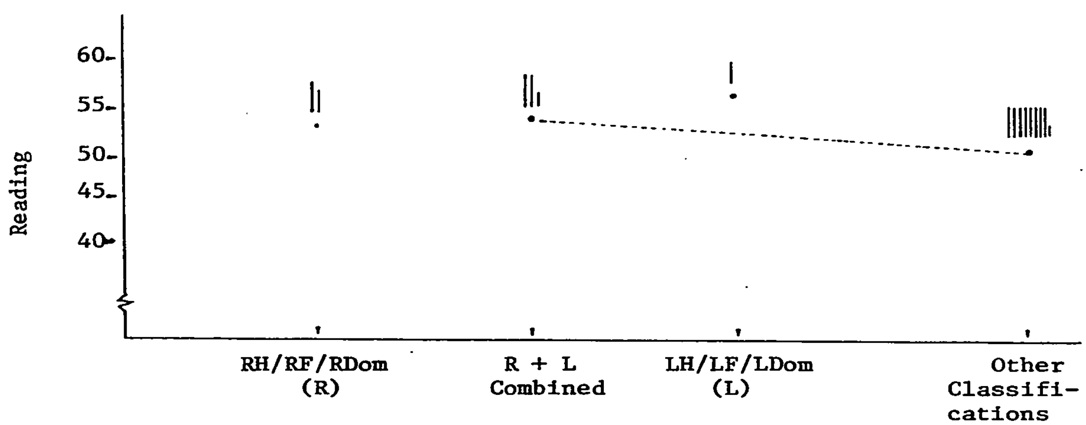



FIGURE 5

READING PROFICIENCY FOR RESTRICTED SAMPLE:
DEXTERITY X EAR ASYMMETRY IN DL:
BARS REPRESENT SUBJECTS:
1 BAR OF 5 mm
LENGTH=10 Ss

The comparison of clearly left and right-dominant Ss with those of other handedness-preference/familial-handedness/ear-asymmetry classifications (Figure 6) was not significant; $C_{A1/C1/D2(restricted)}$ ($M_{(LH/LF/LE,RH/RF/RE)}$ = 53.24. $M_{(others)}$ = 51.38; F = 2.442, df = 1/58, n.s.).




Handedness Preference X Familial Handedness X Ear Asymmetry Classification

FIGURE 6

READING PROFICIENCY FOR RESTRICTED SAMPLE: HANDEDNESS PREFERENCE X FAMILIAL HANDEDNESS X EAR ASYMMETRY IN DL: BARS REPRESENT SUBJECTS; 1 BAR OF 5 mm LENGTH=10 Ss

From these data, hypotheses 2A and 2C are convincingly supported, hypothesis 2B obtains limited support and hypothesis 2D failed to obtain support.

These findings suggest that manual dexterity and cerebral functional asymmetry are characteristic of most proficiently reading, grade two children. Inasmuch as cerebral functional asymmetry and equipotentiality in infancy give way to cerebral lateralization of verbal expressive functions during childhood (Basser, 1962; Lenneberg, 1967), the present study suggests that delayed development of cerebral asymmetry may be accompanied by sub-average reading proficiency. Although an attempt was made in selecting the sample for ear-asymmetry testing, to locate children likely to demonstrate _left_-ear-dominance, _right_-ear-dominance was demonstrated for the majority of children, irrespective of handedness preference, and tended to be associated with greater proficiency in reading than either left-ear-dominance or nondominance. The predicted order from nondominance through left-ear-dominance to right-ear-dominance, associated with more proficient reading is demonstrated for non-dextrous but not for dextrous children.

Assuming manual dexterity and ear asymmetry to be maturational indices (Zurif & Carson, 1970), a rather interesting developmental issue emerges. Consistent with previous research, the present findings suggest that children who are poor readers or who are in the initial stages of learning to read, are likely to be nondominant or left-ear-dominant (Bakker, 1969; Kimura, 1963; Knox & Kimura, 1970;

Zurif & Carson, 1970) in the recall of dichotic verbal information. Infantile cerebral asymmetry and equipotentiality implies, however, that right lateralization may represent an intermediate stage between uncommitted functional representation in infancy and left-lateralized representation of some verbal functions in the mature brain. Oblique support for this position obtains from Zurif & Carson's recent study. If appropriate studies can reveal a clear developmental trend through three such stages, the possibility exists that some correspondence may be found to the prelanguage/sensori-motor, the pre-operational and the concrete-operational stages suggested by Piaget. Although these issues are beyond the scope of the present study, the present data suggest that reconsideration of the cerebral asymmetry/reading question may be timely. The limited evidence from the present study may not constitute support for the arguments of Bateman (1969), Bender (1958), Delacato (1963), McFie (1952), Phelps (1965) or Silver & Hagin (1967) but it does suggest that cerebral asymmetry can be measured, and appears relevant to reading proficiency in primary school children.

## Handedness Preference, Manual Dexterity, Familial Handedness Preference and Ear Asymmetry in Dichotic Listening: Hypotheses 3A, 3B, 3C

The proportion of right-hand-preferent/right-familial children who were right-ear-dominant was significantly larger than the proportion of left-hand-preferent/left-familial children who were classified as right-ear-dominant ($P_{RH/RF/RE} = {}^{17}/_{22}$, $P_{LH/LF/RE} = {}^{6}/_{13}$; z = 1,874,

$p < .05$ (one tailed)), thus providing modest support for hypothesis 3A.

Similarly, the proportion of pronounced-right-hand-preferent children classified as right-ear-dominant was significantly larger than the proportion of pronounced-left-hand-preferent children who were classified as right-ear-dominant ($P_{\underline{RH}/RE} = {}^{17}/_{23}$, $P_{\underline{LH}/RE} = {}^{2}/_{6}$; $z = 1.862$, $p < .05$ (one tailed)). Modest support was thus obtained for hypothesis 3B.

The proportion of dextrous children classified as right-ear-dominant was not significantly different from the proportion of non-dextrous children who were classified as right-ear-dominant ($P_{D/RE} = {}^{31}/_{44}$, $P_{ND/RE} = 25/_{47}$; $z = 1.69$, n.s.). Hypothesis 3C was thus not supported in the present investigation.

Evidence pertaining to handedness/ear-asymmetry relationships is equivocal. On the one hand, clearly defined dextral and sinistral groups are characterized by ipsilateral ear-dominance. The more restricted the classification, the more readily this tendency becomes apparent. Pronounced-left-preferents and left-familial/left-preferents tended to demonstrate left-ear-dominance. A posteriori it seemed useful to make a comparison between pronounced-left-preferent/left-familial/left-eye-preferents[1] and their dextral counterparts.

---

[1]The eye preferred for peeping through a hole, aiming a toy pistol, and looking through a simulated telescope was noted.

Only two left-preferents could be included in this most restricted classification and both were left-ear-dominant, as opposed to 12 of 15 right-preferent peers who were right-ear-dominant ($P_{\underline{LH}/LF/L\ Eye/LE} = {}^{0}/_{2}$, $P_{\underline{RH}/RF/R\ Eye/RE} = {}^{12}/_{15}$; $z = 2.33$, $p < .05$ (two tailed)).

On the other hand, very few subjects were available in the present study who could be confidently classified as left-preferents or right-preferents. Further, hypothesis 3C which compared proportions of dextrous and nondextrous right-ear-dominant children was not significant and the correlation between dexterity and reordered ear-asymmetry classification was 0.12, suggesting the relative independence of these two assumed maturational indices. Further support for this latter claim can be found by inspection of Tables 16 and 17, and Figure 7. Data from the present study demonstrated that there is not a clear tendency for clarity of handedness-preference to be reflected in ear-asymmetry classification, at least for children of primary school age.

While confirmation of hypotheses 3A and 3B appears to lend some support to findings reported by Curry (1967), Knox & Boone (1971) and Zurif & Bryden (1969), handedness/ear asymmetry data would seem most parsimoniously interpreted as failing to provide definitive evidence for either dependence or independence. Consistent with earlier studies (Bryden, 1965; Curry, 1967; Satz et al., 1965; Zurif & Bryden, 1969) this study identified a small but important subgroup of children who were both proficient readers and clearly

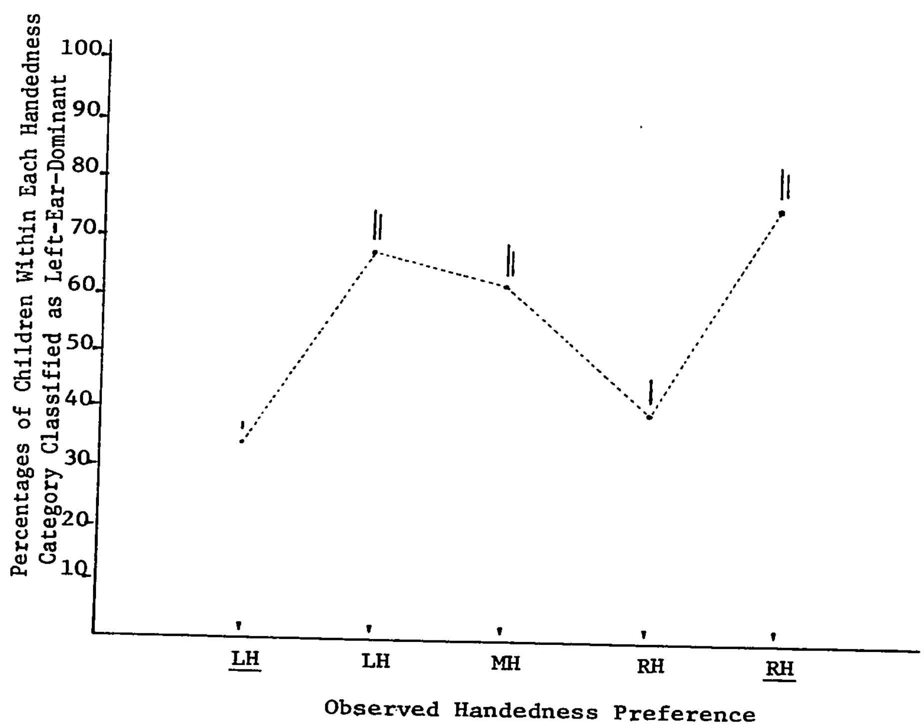



FIGURE 7

PERCENTAGE OF CHILDREN IN HANDEDNESS CATEGORIES WHO ARE CLASSIFIED AS LEFT-EAR-DOMINANT: BARS REPRESENT SUBJECTS, 1 BAR OF 5 mm LENGTH=10 Ss left dominant in both manual preference and ear-asymmetry classification. Assuming these characteristics reflect a stable neurological pattern of right-cerebral-dominance for both motor control and serial information processing, it is difficult to accept Penfield & Roberts' (1959) suggestion that right-cerebral-dominance for speech functions most likely results from displacements due to left-cerebral pathology. It seems most unlikely that the subgroup of efficiently reading left-preferents classified as left-ear-dominant would include children with histories of early cerebral pathology.

On the other hand, when one inspects Tables 16 and 17 and Figure 7, it is even more difficult to find support for a causal relationship between handedness preference and cerebral functional asymmetry, as suggested by Benton (1965) and Hecaen & de Ajuriaguerra (1964). This issue can best be resolved by ear-asymmetry studies of rigorously defined handedness-preferents and possibly by examining ear asymmetries of unimanual amputees who have been forced since infancy to perform all manual activities with one hand only.

An interesting supplementary finding from the present study emerged from ear-asymmetry classifications of a pair of identical-appearing twin boys, one of whom wrote with his left-hand and the other of whom was strongly right-preferent. Ipsilateral hand-ear dominance was demonstrated in both cases but reading data were not available, thus necessitating their exclusion from the intended restricted sample.

Should ear-asymmetry and handedness classifications be shown

TABLE 16

STEPWISE REGRESSION: MANUAL DEXTERITY AND EAR ASYMMETRY VARIABLES WITH READING

| Predictor Variable No.[a] | Description[a] | Zero-Order r | R[b] | F[c] |
|---|---|---|---|---|
| A. | Restricted Sample: n = 108 | | | |
| 5. | Σdigits recalled (better ear) | .533 | .533 | 42.11*** |
| 2. | Draw ladder-rungs (better hand) | .404 | .640 | 22.24*** |
| 6. | Digit span (best OR trial) | .497 | .668 | 6.87** |
| 7. | DL classification (reordered) | .346 | .684 | 4.27* |
| | Variance % = | | 46.804 | Fd=22.67*** |
| B. | Random Half of Restricted Sample: n = 54 | | | |
| 5. | Σdigits recalled (better ear) | .611 | .611 | 30.91*** |
| 2. | Draw latter-rungs (better hand) | .446 | .711 | 13.66*** |
| 6 | # digits serially recalled (best trial) | .454 | .733 | 3.41 |
| | Variance % = | | 53.695 | F[d]=19.327*** |

C. Cross-Validation Half of Restricted Sample: n = 54

| Predictor Variable No. | Regression Weight | Zero-Order r | R | F |
|---|---|---|---|---|
| 5. | 2.100819 | .449 | | |
| 2. | 0.605513 | .355 | | |
| 6. | 2.276888 | .555 | | |
| | Constant = −2.615 | | .533 | 20.65*** |
| | Variance % = | | 28.424 | 20.65*** |

*$p < .05$; **$p < .01$; ***$p < .001$

[a]As presented on p.106

[b]Cumulative multiple correlation coefficient

[c]F for significance of variance added to R by variable entering

[d]F for significance of multiple R.

TABLE 17

CORRELATION MATRIX FOR VARIABLES
ENTERED IN STEPWISE REGRESSION
ANALYSIS: RESTRICTED SAMPLE

| Variable | | Variable Number | | | | | | |
|---|---|---|---|---|---|---|---|---|
| No.[a] | Description[a] | 2.[b] | 3. | 4. | 5. | 6. | 7. | 8. |
| 1. | Θ cutting (better hand) | 46 | 86 | 12 | 16 | 11 | 05 | 29 |
| 2. | Draw ladder-rungs (b.h.) | | 85 | 09 | 10 | 11 | 14 | 40 |
| 3. | Mean of 1,2 (in SS) | | | 12 | 15 | 12 | 11 | 41 |
| 4. | Σ DL ½ series (better ear) | | | | 61 | 57 | 20 | 47 |
| 5. | Σ DL digits (better ear) | | | | | 62 | 32 | 53 |
| 6. | Digit span (best OR trial) | | | | | | 19 | 50 |
| 7. | DL classification (reordered) | | | | | | | 35 |
| 8. | Reading proficiency | | | | | | | |

[a]As presented on p. 106

[b]Decimals omitted

to be strongly related (Ø > .75 or so) in future research, the suggested progression from non-dominance through left-ear-dominance to a stable state of right-ear dominance would be untenable unless reading proficiency and handedness preference per se were as clearly related. Yet available evidence and results from the present investigation indicate that handedness preference and reading proficiency are negligibly related in samples of normal children.

## Stepwise-Regression Analyses

Results from stepwise regression analyses involving manual-dexterity and ear-asymmetry variables are presented in Tables 16 and 17. A multiple R was first obtained from the performances of all 108 subjects in the restricted sample ($R = .684$; $F = 22.67$, $df = 4/103$, $p < .0001$). A random sample of 54 children was then drawn and these data analyzed ($R = .733$; $F = 19.327$, $df = 3/50$, $p < .0001$). Regression weights obtained from this latter analysis were then applied to the data for the other 54 children to obtain a cross-validated multiple R. Fifty-four subjects is fewer than optimal for multiple regression analysis and the variables used in the predictor set were obtained from relatively new tasks administered under variable conditions. These qualifications notwithstanding, the cross-validated-sample multiple R was significant ($R = .533$; $F = 20.65$, $df = 1/52$, $p < .0001$).

These results clearly indicate that manual dexterity and ear-asymmetry tasks can provide useful information for predicting reading proficiency in grade two children.

Only two tasks, ladder-drawing and circle-cutting were used to assess manual dexterity. Children enjoyed doing both tasks and their performances were readily scored without recourse to subjective judgments. The provision of a practice trial on each task and the averaging of two attempts with each hand might have provided a more sensitive measurement of dexterity.

It is interesting that manual dexterity and dichotic listening tasks accounted for a significant percentage of variance in reading proficiency. No measures of visual perception were used in the present investigation yet early reading proficiency obviously depends upon a prerequisite level of visual perceptual efficiency (Bateman, 1964; Gibson, 1965). The relatedness of cerebral asymmetry and serial recall efficiency to reading proficiency tends to suggest that proficiency in serial information processing and recall, itself possibly dependent upon cerebral "specialization" of functions, may also faciliate reading proficiency.

CHAPTER 6

# INTEGRATION

## Summary of Results

Based on data gathered from the 222 grade two children included in the initial sample, no significant differences in reading proficiency were apparent for groups classified according to handedness preferences, even when comparisons were restricted to nondextrous subjects. Manually dextrous subjects were significantly more proficient readers than non-dextrous peers. These findings were again noted for data obtained from the restricted sample of 108 children.

Data for the restricted sample indicated that children having demonstrable ear asymmetry in recall of dichotic digit-pair sequences were more proficient readers than the group of ten children classified as non-dominant. Although less convincing, the data also suggested a higher level of reading proficiency for right-ear-dominant children when compared to left-ear-dominant peers. This difference was more readily apparent when restricted to nondextrous subjects. Right-hand-preferent/right-familial/right-ear-dominant and left-hand-preferent/left-familial/left-ear-dominant subjects considered together, were not significantly more proficient readers than the other children in the restricted sample.

When ear-asymmetry classifications were restricted to clearly defined handedness-preference groups, the data tended to support the hypothesized relationships between clear hand preference and ipsilateral ear dominance in recall of dichotic digits. However, the proportion of manually dextrous children classified as right-ear-dominant was not significantly different from the proportion of nondextrous peers classified as right-ear-dominant. Furthermore, it appeared that ear asymmetries were much more clearly related to reading proficiency than to handedness-preference. The present data were thus interpreted as being inconclusive with regard to handedness/cerebral functional asymmetry relationships.

Supplementary findings from multiple regression analyses suggested that ear asymmetry and manual dexterity variables provide useful and relatively independent measures for predicting reading performances of grade two children.

## Limitations of the Present Study

In selecting a sample for the present study, an effort was made to include many children from left-hand-preferent families and to compare approximately equal numbers of children in each handedness preference category, so as to provide an adequate sample for examining some issues relevant to handedness/ear-asymmetry relationships. The restricted sample (Table 8) used for ear-asymmetry data collection was not representative of the population of grade two children with regard to handedness characteristics. Accordingly, inferences concerning proportions of grade two children likely to exhibit particular ear-asymmetry characteristics are not possible from the present data. Further, the selection of only grade-two children imposes limitations on any attempt to locate developmental patterns or trends in variables under consideration.

The dichotic listening tape-making procedures evolved over approximately eighteen months. While several useful controls can be introduced by the system employed in tape-making and the procedures used in testing, the test tape was not without imperfections. To overcome the loss in voice quality and intensity when dubbing from the source tape to the dichotic tape, further experimentation is necessay to ensure impedance matching of equipment, instant activation, acceleration and stopping of the recording tape recorder, and improved signal quality feedback from the tape-loop or continuous tape-spool of the delayed feedback recorder. The precise balancing of each channel's recording intensity by volume control adjustments to a continuous, pure-tone signal, is also desirable and was not undertaken in the construction of the present dichotic test-tape.

The variability in background noise levels during DL field testing undoubtedly added some error to the obtained DL data. The use of a sound-proofed travelling unit or the testing of children under controlled laboratory conditions might facilitate more precise DL ear-asymmetry data collection.

Handedness tasks in the present study were economical for screening a large number of children and for providing both preference and proficiency information. However, a brief practice period for each hand, to familiarize children with apparatus and stimuli, the addition of a simple learning task (eg. pursuit rotor or finger tracing through a wooden maze) and a further simple dexterity task (eg. time-limited tower building using 1/2" wooden cubes), might provide a more sensitive basis for handedness/dexterity classification.

The classification of children according to familial-handedness-preferences followed obliquely from literature, but lacked a sound, theoretical basis. Unfortunately, parents of children in the present study were not asked to indicate the ages of subjects' siblings, yet this information might have been useful for a tentative examination of an "early modelling" hypothesis for the acquisition of handedness preference. It may well be that the mother and/or slightly older siblings, are the most important figures in the infant's early learning, thus providing models and acting as reinforcing agents for early manual performances. Some attention might also be given to the inclusion of manual preference and proficiency tasks which were likely to have been initially mastered during clearly defined periods of early childhood. These considerations were not incorporated in the present investigation.

Although there is considerable literature to indicate sex differences inearly reading proficiency (Bakker, 1969, Irvine, 1968; Kimura, 1967; Knox & Kimura, 1970), sex differences were not analyzed in the present investigation. The small proportion of children in some of the classifications of interest suggested that a further constraint in sampling of children would have resulted in very small numbers within planned cells (p. 72). It is interesting, however that the mean reading level of girls in the present study was 53.81 while that of boys was 49.18.

A major limitation of the present study is associated with statistical analyses. Two central variables, handedness preference and ear asymmetry in dichotic listening are known not to be normally distributed, right-handedness and right-ear-dominance being characteristic of the majority of adults. The present sample consisted of approximately equal numbers of children in each handedness-preference category and contained approximately equal numbers of boys and girls. However, manual dexterity, familial handedness and ear asymmetry classifications all had unequal numbers of children in each classificatory level, so that when these three factors as well as handedness preference and sex were combined in a 3 x 3 x 2 x 3 x 2 design (handedness-preference x manual dexterity x familial handedness x ear asymmetry x sex), for a sample of 108 subjects, 58 of the 108 cells were empty and preliminary analyses suggested that the assumption of homogeneity of within-cell variance was not tenable.[1]

Given these difficulties in conjunction with the problems associated with the use of relatively novel tasks, perhaps more conservative statistical procedures may have been appropriate. However the primary purpose of the present study was to explore some of the relationships among variables which have in some cases been minimally examined in previous research. The findings of the present study are indeed tentative and in need of validation in more precisely defined contexts.

## Implications for Education

The present study supports a consistent finding in previous research with normal children, that non-right-handedness is not indicative of an inferior maturational state nor should non-right-handedness be considered a symptom of mild cerebral pathology unless accompanied by other signs (Boder, 1966). The practice of requiring

---

[1] Appendix E.

left-preferent children to write with the right hand (Glonig et al., 1969) has no justifiable basis in the present study. Nor does it appear in any way "undesirable" to allow a child to execute some manual tasks with one hand and some primarily with the other hand. However, as this investigation did not examine hand/eye preference consistency, left/right awareness or other indices of functional lateralization, it would seem premature to endorse Capobianco's suggestion (1967) that reading clinics should no longer collect laterality data. Present findings would in fact suggest that such data may be useful if combined with procedures for objectively scoring proficiency of performances.

Inasmuch as dichotic listening appears to provide a valuable index of cerebral asymmetries in both verbal and nonverbal functioning, and in addition makes available other information relevant to reading proficiency, its use in reading clinics and in early pediatric or preschool screening programs appears warranted. If the findings of the present study with regard to ear asymmetry/reading relationships are supported in future work, heavy commitment to a phonic approach in the early teaching of reading would seem undesirable for children noted in DL testing as both nondominant in ear asymmetry classification and limited in serial recall efficiency.

Many elementary schools undoubtedly have limited access to audiological personnel, particularly for purposes of routine auditory screening of children beginning grade one. It is therefore suggested that a preliminary assessment of hearing for every child entering grade one could be accomplished, in the absence of pure-tone sweep-test screening with a reliably calibrated audiometer, by using reasonably standardized step-attenuation procedures and a tape containing both digit and word-pairs. A reasonable assessment of intelligibility thresholds takes approximately five minutes and can be readily administered by any teacher with experience in testing young children. While step-attenuation of monaurally presented words does not assess hearing across as broad a range of frequencies as pure-tone audiometry, it can provide an adequate assessment across the speech range. Having determined intelligibility thresholds for each ear, a quick assessment of auditory perception of words, digits and/or sounds could follow, by asking the child to repeat stimuli presented binaurally at threshold plus a constant level of intensity.

It is thus suggested that dichotic listening procedures can provide an indication of auditory acuity, functional asymmetry at the cortical level, task persistence, unrehearsed recall span and auditory perceptual efficiency. Assuming this information to be useful to teachers, particularly those teaching early primary grades, it is suggested that dichotic listening tasks could be developed specifically for inclusion in preschool screening or psychological assessment programs and that the inclusion of such tasks could provide unique, useful information.

## Suggestions for Further Research

Some previous discussion has been devoted to suggesting some of the directions which follow-up studies could take. Inasmuch as the present study was exploratory in its use of relatively untried tasks and procedures, further refinements were earlier suggested.

Several possiblities for follow-up studies are listed in Table 18.

TABLE 18
SUGGESTED FOLLOW-UP STUDIES

| | Variables | Sample | Purpose |
|---|---|---|---|
| 1. | H'ness preference, manual dexterity, ear asymmetry, sex, reading and other academic subjects | Normal children; grades 1, 2, 3 | Cross-validation of present study with wider range of ages, abilities |
| 2. | Ear asymmetry under free recall/ordered recall/ pair-wise recall, reading and other academic subjects | Any | Examination of ear asymmetry/ academic performance; and follow-up (in intramodality integration context), work of Beery (1967), Senf et al.,(1969) |
| 3. | Handedness preference, dexterity, verbal/ spatial abilities, occupation, sex, reading, ear asymmetry | (a) Normal adult, (b) Normal left-ear dominant adults | Examination of correlates of ear asymmetry in dichotic listening |
| 4. | Ear asymmetry, manual dexterity, academic skills | Pathologically-forced unimanual preferents since infancy (preferably restrict to adolescents/adults) | Examination of handedness preference/ear asymmetry relationships |
| 5. | Dichotic listening, academic performances, verbal & performance IQ, and for (b), Piaget conservation classification | (a) Stratified sample from 3-9 years of age; equal sex distribution at each age (b) Children 5-8 years of age, classified on conservation status | Developmental trends and correlates of ear asymmetry in children |

## REFERENCES


Adams, J. Human memory. New York: McGraw-Hill, 1967.

Ajuriaguerra, J.de., & Hecaen, H. Left-handedness manual superiority and cerebral dominance. New York: Grune & Stratton, 1964.

Archibald, Y., & Wepman, J. Language disturbance and nonverbal cognitive performance in eight patients following injury to the right hemisphere. Brain, 1968, 91, 117-130.

Archibald, Y., Wepman, J., & Jones, L. Nonverbal cognitive performance in brain damaged patients. Cortex, 1967, 3, 275-294.

Baddeley, A. The influence of acoustic and semantic similarity on long-term memory for word sentences. Quarterly Journal of Experimental Psychology, 1966, 18, 302-309.

Baddeley, A. How does acoustic similarity influence short-term memory? Quarterly Journal of Experimental Psychology, 1968, 20, 249-264.

Bakker, D. Left-right differences in auditory perception of verbal and non-verbal material by children. Quarterly Journal of Experimental Psychology, 1967, 19, 334-336.

Bakker, D. Ear-asymmetry with monaural stimulation: Task influences. Cortex, 1969, 5, 36-42.

Bakker, D. Ear-asymmetry with monaural stimulation: Relations to lateral dominance and lateral awareness. Neuropsychologia, 1970, 8, 103-117.

Balow, I., & Balow, B. Lateral dominance and reading achievement in the second grade. American Educational Research Journal, 1964, 1, 139-143.

Bannatyne, A., & Wichiarajote, P. Hemispheric dominance, handedness, mirror imaging, and auditory sequencing. Exceptional Children, 1969, 36, 27-36.

Bartz, W. Serial position effects in dichotic listening. Perceptual and Motor Skills, 1968, 27(3), Part I, p. 1014.

Bartz, W. Satz, P., & Fennell, E. Grouping strategies in dichotic listening: The effects of instructions, rate and ear asymmetry. Journal of Experimental Psychology, 1967, 74, 132-136.

Bartz, W., Satz, P., Fennell, E., & Lally, R. Meaningfulness and laterality in dichotic listening. Journal of Experimental Psychology, 1967, 73, 204-210.

Basser, L. Hemiplegia of early onset and the faculty of speech with special reference to the problems of hemispherectomy. Brain, 1962, 85, 427-460.

Bateman, B. Learning disorders. Review of Educational Research, 1966, 36, 93-119.

Bateman, B. Reading: A controversial view: Research and rationale. In L. Tarnapol (Ed.) Learning disabilities: Introduction to medical and educational management. Springfield, Ill.: Thomas, 1969, Pp. 289-304.

Beery, J. Matching of auditory and visual stimuli by average and retarded readers. Child Development, 1967, 38, 827-833.

Belmont, L., & Birch, H. Lateral dominance, lateral awareness and reading ability. Child Development, 1965, 36, 57-71.

Bender, L. Specific reading disability as a maturational lag. Bulletin of the Orton Society, 1957, 7, 9-18.

Benton, A. The problem of cerebral dominance. Canadian Psychologist, 1965, 6, 332-348.

Birch, H., & Belmont, L. Auditory-visual integration in normal and retarded readers. American Journal of Orthopsychiatry, 1964, 34, 852-861.

Birch, H., & Belmont, L. Audio-visual integration, intelligence, and reading ability in school children. Perceptual & Motor Skills, 1965, 20, 295-305.

Blau, A. The master hand: a study of the origin and meaning of right and left sidedness and its relation to personality and language. Research Monograph No. 5, New York: American Orthopsychiatric Association, 1946, p. 206.

Boder, E. A neuropediatric approach to the diagnosis & management of school behavioral and learning disorders. In J. Hellmuth (Ed.) Learning disorders, Vol. 2. Seattle: Special Child Publications, 1966, Pp. 15-44.

Brain, R. Speech and handedness. Lancet, 1945, 11, 837-842.

Branch, C., Milner, B., & Rasmussen, T. Intracarotid sodium amytal for the lateralization of cerebral speech dominance. Journal of Neurosurgery, 1964, 21, 399-405.

Broadbent, D. The role of auditory localization in attention and memory span. Journal of Experimental Psychology, 1954, 47, 191-196.

Broadbent, D., & Gregory, M. Accuracy of recognition for speech presented to the right and left ears. Quarterly Journal of Experimental Psychology, 1964, 16, 359-360.

Broca, P. Sur la faculte du language articule. Bulletin de la Societe d'Anthropologie (Paris), Vol. 6, 1865. Cited by A. Benton, The problem of cerebral dominance. Canadian Psychologist, 1965, 6, P. 333.

Bryden, M. Tachistoscopic recognition of non-alphabetical material. Canadian Journal of Psychology, 1960, 14, 78-86.

Bryden, M. Order of report in dichotic listening. Canadian Journal of Psychology, 1962, 16, 291-299.

Bryden, M. Ear preference in auditory perception. Journal of Experimental Psychology, 1963, 65, 103-105.

Bryden, M. The manipulation of strategies of report in dichotic listening. Canadian Journal of Psychology, 1964, 18, 126-138.

Bryden, M. Tachistoscopic recognition, handedness, and cerebral dominance. Neuropsychologia, 1965, 3, 1-8.

Bryden, M. Short-term memory for unbalanced dichotic lists. Psychonomic Science, 1966, 6, 379-380.

Bryden, M. A model for the sequential organization of behavior. Canadian Journal of Psychology, 1967(a), 21, 37-56.

Bryden, M. An evaluation of some models of laterality effects in dichotic listening. Acta Otolaryngologica, 1967(b), 63, 594-604.

Bryden, M. Binaural competition and division of attention as determinants of the laterality effect in dichotic listening. Canadian Journal of Psychology, 1969, 23, 101-113.

Bryden, M. Left-right differences in tachistoscopic recognition as a function of familiarity and pattern orientation. Journal of Experimental Psychology, 1970, 84, 120-122.

Capobianco, R. Ocular-manual laterality and reading in adolescent mental retardates. American Journal of Mental Deficiency, 1966, 70, 781-785.

Capobianco, R. Ocular-manual laterality and reading achievement in children with special learning disabilities. American Educational Research Journal, 1967, 4, 133-138.

armon, A., & Gombos, G. A physiological vascular correlate of hand preference: Possible implications with respect to hemispheric cerebral dominance. Neuropsychologia, 1970, 8, 119-128.

Carr, B. Ear effect variables and order of report in dichotic listening. Cortex, 1969, 5, 63-68.

Cernacek, J. Handedness as a quantitative estimate. Journal of the Neurological Sciences, 1964, 1, 152-159.

Coleman, R., & Deutch, C. Lateral dominance and right left discrimination: A comparison of normal and retarded readers. Perceptual and Motor Skills, 1964, 19, 43-50.

Conrad, K. Ueber aphasische sprachstoerungen dei hirnverletzten linkshaendern. Nervenarzt, 1949, 20, 148-154. In A. Benton. The problem of cerebral dominance. Canadian Psychologist, 1965, 6, P. 337.

Corso, J. Age and sex differences in pure-tone thresholds. Archives of Otolaryngology, 1963, 77, 385-405.

Critchley, M. Speech and speech-loss in relation to the duality of the brain. In V. Mountcastle (Ed.), Interhemispheric relations and cerebral dominance. Baltimore: John Hopkins Press, 1962, Pp. 208-213.

Curry, F. A comparison of left-handed and right-handed subjects on verbal and non-verbal dichotic listening tasks. Cortex, 1967, 3, 343-352.

Curry, F., & Gregory, H. The performance of stutterers on dichotic listening tasks thought to reflect cerebral dominance. Journal of Speech and Hearing Research, 1969, 12, 73-82.

Delacato, C. The diagnosis and treatment of speech and reading problems. Springfield, Ill.: Thomas, 1963.

Dreifuss, F. Delayed development of hemispheric dominance. Archives of Neurology, 1963, 8, 510-514.

Eames, T. The anatomical basis of lateral dominance anomalies. American Journal of Orthopsychiatry, 1934, 4, 524-528.

Egeth, H. Selective attention. Psychological Bulletin, 1967, 67, 41-57.

Ferguson, G. A. Statistical Analysis in psychology and education. (2nd Ed.) N.Y.: McGraw-Hill, 1966.

Gazzaniga, M., & Sperry, R. Language after section of the cerebal commissures. Brain, 1967, 90, 131-148.

Geschwind, N., & Levitzky, W. Human brain: Left-right asymmetries in the temporal speech regions. Science, 1968, 161, 186-187.

Ghent, L. Developmental changes in tactual thresholds on dominant and nondominant sides. Journal of Comparative and Physiological Psychology, 1961, 54, 670-673.

Giannitrapani, D. Electroencephalographic differences between resting and mental multiplication. Perceptual and Motor Skills, 1966, 22, 399-405.

Giannitrapani, D. Developing concepts of lateralization of cerebral functions. Cortex, 1967, 3, 353-370.

Giannitrapani, D., Sorkin, A., & Enenstein, J. Laterality preference of children and adults as related to inter-hemispheric phase activity. Journal of the Neurological Sciences, 1966, 3, 139-150.

Gibson, E. Learning to read. Science, 1965, 148, 1066-1072.

Glonig, I., Glonig, K., Haub, G., & Quatember, R. Comparison of verbal behavior in right-handed and non right-handed patients with anatomically verified lesion of one hemisphere. Cortex, 1969, 5, 43-52.

Goodglass, H. Dichotic listening and early lateral brain damage. Cortex, 1967, 3, 295-306.

Goodglass, H., & Quadfasel, F. Language laterality in left-handed aphasics. Brain, 1954, 78, 521-548.

Gordon, H.W. Hemispheric asymmetries in the perception of music, Cortex, 1970, 6, 387-398.

Haber, R. How we remember what we see. Scientific American, 1970, 222(5), 104-112.

Harcum, E., & Finkel, M. Explanation of Mishkin and Forgays' result as a directional-reading conflict. Canadian Journal of Psychology, 1963, 17, 224-234.

Harris, A. Lateral dominance, directional confusion and reading disability. Journal of Psychology, 1957, 44, 283-294.

Harris, A. The Harris tests of lateral dominance. New York: Psychological Corporation, 1958.

Hecaen, H., & Ajuriaguerra, J. de. Left handedness manual superiority and cerebral dominance. New York: Grune & Stratton, 1964.

Hubel, D., & Wiesel, T. Receptive fields of neurons in the cat's striate cortex. Journal of Physiology, 1959, 148, 574-591.

Humphrey, M. Consistency of hand usage. British Journal of Educational Psychology, 1951, 21, 214-225.

Inglis, J. Dichotic listening and cerebral dominance. Acta Otolaryngologica, 1965, 60, 231-238.

Ingram, T., & Reid, J. Developmental aphasia observed in a department of child psychiatry. Archives of Disease in Childhood, 1956, 31, 161-172.

Irvine, J. Correlates of grade one achievement. Unpublished master's thesis. University of Alberta, 1968.

Jensen, A. Individual differences in learning: Interference factor. Washington: Department of Health, Education & Welfare, Cooperative Research Report No. 1867, 1964.

Kephart, N.C. Perceptual-motor aspects of learning disabilities. Exceptional Children, 1964, 31, 201-206.

Kimura, D. Cerebral dominance and the perception of verbal stimuli. Canadian Journal of Psychology, 1961, 15, 166-171.

Kimura, D. Speech lateralization in young children as determined by an auditory test. Journal of Comparative and Physiological Psychology, 1963, 56, 899-902.

Kimura, D. Left-right differences in the perception of melodies. Quarterly Journal of Experimental Psychology, 1964, 16, 355-358.

Kimura, D. Dual functional asymmetry of the brain in visual perception. Neuropsychologia, 1966, 4, 275-285.

Kimura, D. Functional asymmetry in the brain in dichotic listening. Cortex, 1967, 3, 157-178.

Kimura, D., & Folb, S. Neural processing of backwards-speech sounds. Science, 1968, 161, 395-396.

Kimura, D. & King, L. Length of speech segment associated with right-ear superiority in dochotic listening. Canadian Psychologist, 1971, 12, Supplement No. 2, 192.

King, L. & Kimura, D. Left-ear superiority associated with dichotic perception of vocal nonverbal sounds. Canadian Psychologist, 1971,12, Supplement No. 2, 192.

Knox, A.W., & Boone, D.R. Auditory laterality and tested handedness. Cortex, 1970, 6, 164-173.

Knox, C., & Kimura, D. Cerebral processing of verbal sounds in boys and girls. Neuropsychologia, 1970, 8, 227-237.

Koos, E. Manisfestations of cerebral dominance in reading retardation in primary grade children. Journal of Genetic Psychology, 1964, 104, 155-165.

Krippner, S., & Herald, C. Reading disability among the academically talented. Gifted Child Quarterly, 1964, 8, 12-20.

Lenneberg, E. Biological foundations of language. New York: Wiley, 1967.

Luria, A.R. Higher cortical functions in man. New York: Basic Books, 1966.

Luria, A. The functional organization of the brain. Scientific American, 1970, 222(3), 66-78.

Luria, A., Simernitskaya, E., & Tubylevich, B. The structure of psychological processes in relation to cerebral organization. Neuropsychologia, 1970, 8, 13-19.

Madsen, M., Rollins, H., & Senf, G. Variables affecting immediate memory for bisensory stimuli: Eye-ear analogue studies of dichotic listening. Journal of Experimental Psychology, Monograph Supplement, 1970, 83(3) (Whole, Part 2).

McFie, J. Cerebral dominance in cases of reading disability. Journal of Neurology, Neurosurgery and Psychiatry, 1952, 15, 194-199.

McGlone, J. The relation between hand preferences, cerebral dominance for speech, and motor skills of left and right hands. Canadian Psychologist, 1971, 12, Supplement #2, 195.

Mehlman, A., Satz, P., & Tyson, M. Ear-asymmetry as a function of delayed stimulus presentation. Reprinted from the Proceedings, 77th Annual Convention, American Psychological Association, 1969.

Milner, B. Laterality effects in audition. In V. Mountcastle (Ed.), Interhemispheric relations and cerebral dominance. Baltimore: John Hopkins Press, 1962, Pp. 177-195.

Milner, B., Branch, C., & Rasmussen, T. Observations on cerebral dominance. In A. de Reuck & M. O'Connor (Eds.), Ciba Foundation symposium: Disorders of language. London: Churchill, 1964, Pp. 200-214.

Milner, B., Taylor, L., & Sperry, R. Lateralized suppression of dichotically presented digits after commissural section in man. Science, 1968, 161, 184-186.

Money, J. On learning and not learning to read. In J. Money (Ed.), The disabled reader: Education of the dyslexic child. Baltimore: John Hopkins Press, 1966, Pp. 21-40.

Mountcastle, V. (Ed.), Interhemispheric relations and cerebral dominance. Baltimore: John Hopkins Press, 1962.

Naidoo, S. An investigation into some aspects of ambiguous handedness. Unpublished M.A. thesis. University of London, 1961.

Neisser, U. Cognitive psychology. New York: Appleton-Century-Crofts, 1967.

Neufeldt, A. Short-term memory in the mentally retarded: An application of the dichotic listening technique. Psychological Monographs, 1966, 80, (12, Whole No. 620).

Neville, D. A comparison of the WISC patterns of male retarded and non-retarded readers. Journal of Educational Research, 1961, 54, 195-197.

Nunnally, J. Psychometric theory. N.Y.: McGraw-Hill, 1967.

Orton, S. Reading, writing and speech problems in children. New York: Norton, 1937.

Osbury, S., Oxbury, J., & Gardiner, J. Laterality effects in dichotic listening. Nature, 1967, 214, 742-743.

Palmer, R. Cerebral dominance and auditory asymmetry. Journal of Psychology, 1964, 58, 157-167.

Penfield, W., & Roberts, L. Speech and brain mechanisms. Princeton, N.J.: Princeton University Press, 1959.

Penfield, W. The interpretive cortex. Science, 1959, 1719-1725.

Penn, J. Reading disability: A neurological deficit? Exceptional Children, 1966, 33, 243-248.

Phelps, W. The mixed dominant child. In C. Carter (Ed.), Medical aspects of mental retardation. Springfield: Ill.: Thomas, 1965, Pp. 930-941.

Piaget, J. Judgment and reasoning in the child. London: Routledge & Kegan Paul, 1951.

Piaget, J. The thought of the young child. Lecture given at the Institute of Education, University of London (1963). In D. Elkind (Ed.) Six psychological studies, N.Y.: Random House, 1967, Pp. 77-86.

Rabinovitch, R., & Ingram, W. Neuropsychiatric considerations in reading retardation. Reading Teacher, 1962, 15, 433-438.

Robbins, M., & Glass, G. The Doman-Delacato rationale: A critical analysis. In J. Hellmuth (Ed.), Educational Therapy (Vol. 2) Seattle: Special Child Publications, 1969, Pp. 321-377.

Rosenzweig, M. Representation of the two ears at the auditory cortex. American Journal of Physiology, 1951, 167, 147-158.

Sampson, H. Immediate memory and simultaneous visual stimulation. Quarterly Journal of Experimental Pscyhology, 1964, 16, 1-10.

Sampson, H., & Spong, P. Handedness, eye dominance and immediate memory. Quarterly Journal of Experimental Psychology, 1961, 13, 173-181.

Satz, P., Achenbach, E., Pattishall, E., & Fennell, E. Order of report, ear asymmetry and handedness in dichotic listening. Cortex,1965, 1, 377-396.

Satz, P., Levy, C., & Tyson, M. The effects of temporal delays on the ear asymmetry in dichotic listening. Journal of Experimental Psychology, 1970, 84, 372-374.

Schwartz, M., & Bryden, M. Dichotic listening competition and the production of perceptual asymmetries. Paper read at meeting of Canadian Psychological Association, Toronto, 1969.

Scott, K., & Scott, M.S. Research and theory in short term memory. In N. Ellis (Ed.), International review of research in mental retardation (Vol. 3). New York: Academic Press, 1968, Pp. 135-162.

Senf, G. Development of immediate memory for bisensory stimuli in normal children and children with learning disorders. Developmental Psychology Monograph, 1969, 1 (6) (Whole Part 2).

Serafetinides, E., Hoare, R., & Driver, M. Intracarotid sodium amylobarbitone and cerebral dominance for speech and consciousness. Brain, 1965, 88, 107-130.

Shankweiler, D. Effects of temporal lobe damage on perception of dichotically presented melodies. Journal of Comparative and Physiological Psychology, 1966, 62, 115-119.

Shankweiler, D., & Studdert-Kennedy, M. Identification of consonants and vowels presented to left and right ears. Quarterly Journal of Experimental Psychology, 1967, 19, 59-63.

Silver, A., & Hagin, R. Specific reading disability: Delineation of the syndrome and relationship to cerebral dominance. Comprehensive Psychiatry, 1960, 126-134.

Silver, A., & Hagin, R. Specific reading disability: Follow-up studies. American Journal of Orthopsychiatry, 1964, 34, 95-102.

Silver, A., & Hagin, R. Specific reading disability: An approach to diagnosis and treatment. Journal of Special Education, 1967, 1, 109-118.

Sparks, R., & Geschwind, N. Dichotic listening in man after section of neocortical commissures. Cortex, 1968, 4, 3-16.

Spellacy, F., & Blumstein, S. Language set in phoneme recognition. Cortex, 1970, 6, 430-439.

Spreen, O., Spellacy, F., & Reid, J. The effect of interstimulus interval and intensity on ear asymmetry for nonverbal stimuli in dichotic listening. Neuropsychologia, 1970, 8, 245-250.

Stephens, W., Cunningham, E., & Stigler, B. Reading readiness and eye-hand preference patterns in first grade children. Exceptional Children, 1967, 33, 481-488.

Sutcliffe, J.P. A general method of analysis of frequency data for multiple classification designs. Psychological Bulletin, 1957, 54 (2), 134-137.

Tarnapol, L. (Ed.) Learning disabilities: Introduction to medical and educational management. Springfield, Ill.: Thomas, 1969.

Teuber, H. Effects of brain wounds implicating the right or left hemisphere in man. In V. Mountcastle (Ed.), Interhemispheric relations and cerebral dominance. Baltimore: John Hopkins Press, 1962, Pp. 131-157.

Treischmann, R. Undifferentiated handedness and perceptual development in children with reading problems. Perceptual and Motor Skills, 1968, 27, 1123-1134.

Treisman, A., & Geffen, G. Selective attention and cerebral dominance in perceiving and responding to speech messages. Quarterly Journal of Experimental Psychology, 1968, 20, 139-150.

Urbano, R., & Scott, K. Digit span, practice and dichotic listening performance in the mentally retarded. Journal of Experimental Child Psychology, 1969, 8, 432-442.

Von Bonin, G. Anatomical asymmetries of the cerebral hemispheres. In V. Mountcastle (Ed.), Interhemispheric relations and cerebral dominance. Baltimore: John Hopkins Press, 1962, Pp. 1-6.

Wada, J. & Rasmussen, T. Intracarotid injection of sodium amytal for the lateralization of cerebral speech dominance. Experimental and clinical observations. Journal of Neurosurgery, 1960, 17, 266-282.

Wechsler, D. Manual: The Wechsler intelligence scale for children. New York: Psychological Corporation, 1949.

Weinstein, S., & Sersen, E. Tactual sensitivity as a function of handedness and laterality. Journal of Comparative and Physiological Psychology, 1961, 54, 665-669.

Weinstein, S. Differences in effects of brain wounds implicating the right or left hemisphere: Differential effects on certain intellectual and complex perceptual functions. In V. Mountcastle (Ed.), Interhemisheric relations and cerebral dominance. Baltimore: John Hopkins Press, 1962, Pp. 159-176.

Wepman, Auditory discrimination test. Chicago: Language Research Associates, 1958.

White, M.J. Laterality differences in perception: A review. Psychological Bulletin, 1969, 72, 387-405.

White, M.J. Visual hemifield differences in the perception of letters and contour orientation. Canadian Journal of Psychology, 1971, 25 (3), 207-212.

Zangwill, O. Dyslexia in relation to cerebral dominance. In J. Money (Ed.), Reading disability: Progress and research needs in dyslexia. Baltimore: John Hopkins, 1962, Pp. 103-113.

Zaslow, R.W. Reversals in children as a function of midline body orientation. Journal of Educational Psychology, 1966, 57, 133-139.

Zurif, E., & Bryden, M. Familial handedness and left-right differences in auditory and visual perception. Neuropsychologia, 1969, 7, 179-187.

Zurif, E., & Carson, G. Dyslexia in relation to cerebral dominance and temporal analysis. Neuropsychologia, 1970, 8, 351-361.

Zurif, E., & Sait, P. The role of syntax in dichotic listening. Neuropsychologia, 1970, 8, 239-244.

# APPENDIX A

## LETTER TO PARENTS

## and

## FAMILIAL HANDEDNESS QUESTIONNAIRE

FACULTY OF EDUCATION
DEPARTMENT OF EDUCATIONAL
PSYCHOLOGY

THE UNIVERSITY OF ALBERTA
EDMONTON 7, CANADA

Dear

We are conducting a research study at the university concerning handedness characteristics of grade two children and are at the stage where we would like to gather more detailed information.

Could we ask your help in commenting on the handedness preferences of members of family? On the back of this letter are a few questions which will only take a couple of minutes to answer. The information provided will be confidential and used only for statistical purposes. We would appreciate your placing the completed information in the envelope and asking to return it to at school.

When all relevant information is analyzed, we hope to know more about the interesting phenomenon of handedness. Your assistance in the project is greatly appreciated.

Yours sincerely,

J. W. Irvine

J. W. Irvine
Department of Educational Psychology

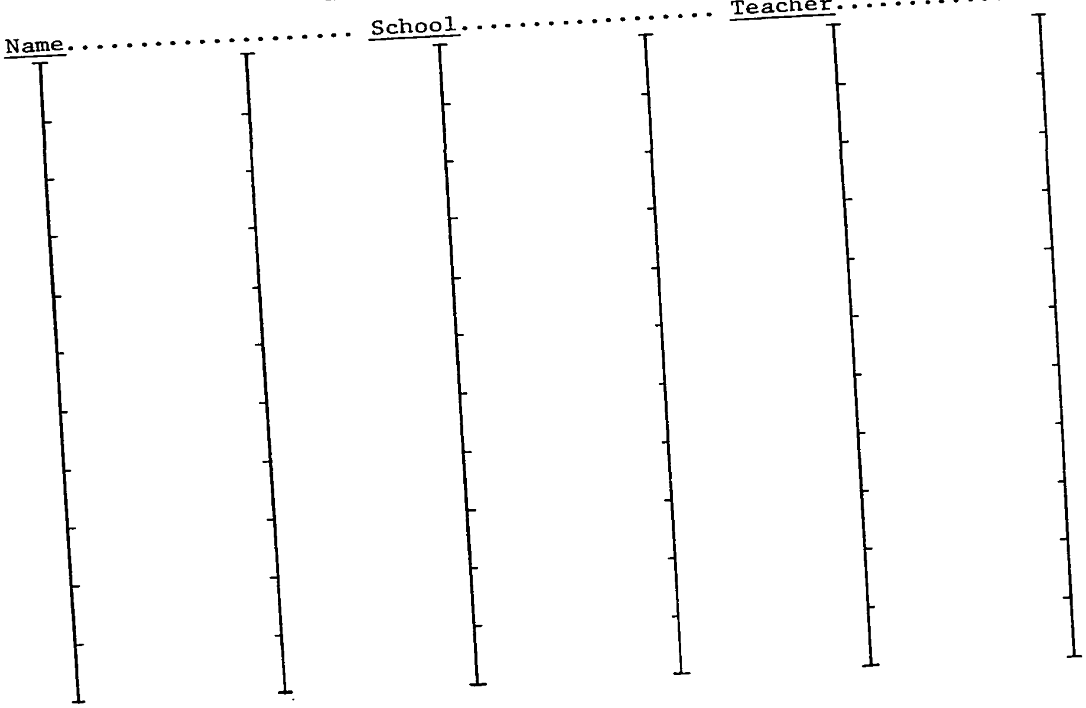
# APPENDIX B

## HANDEDNESS/DEXTERITY FORM

FIGURE 8

HANDEDNESS/DEXTERITY FORM

Name.................. School................. Teacher..............



Circle: Scissor Cutting Attempts

My name is ......................................................

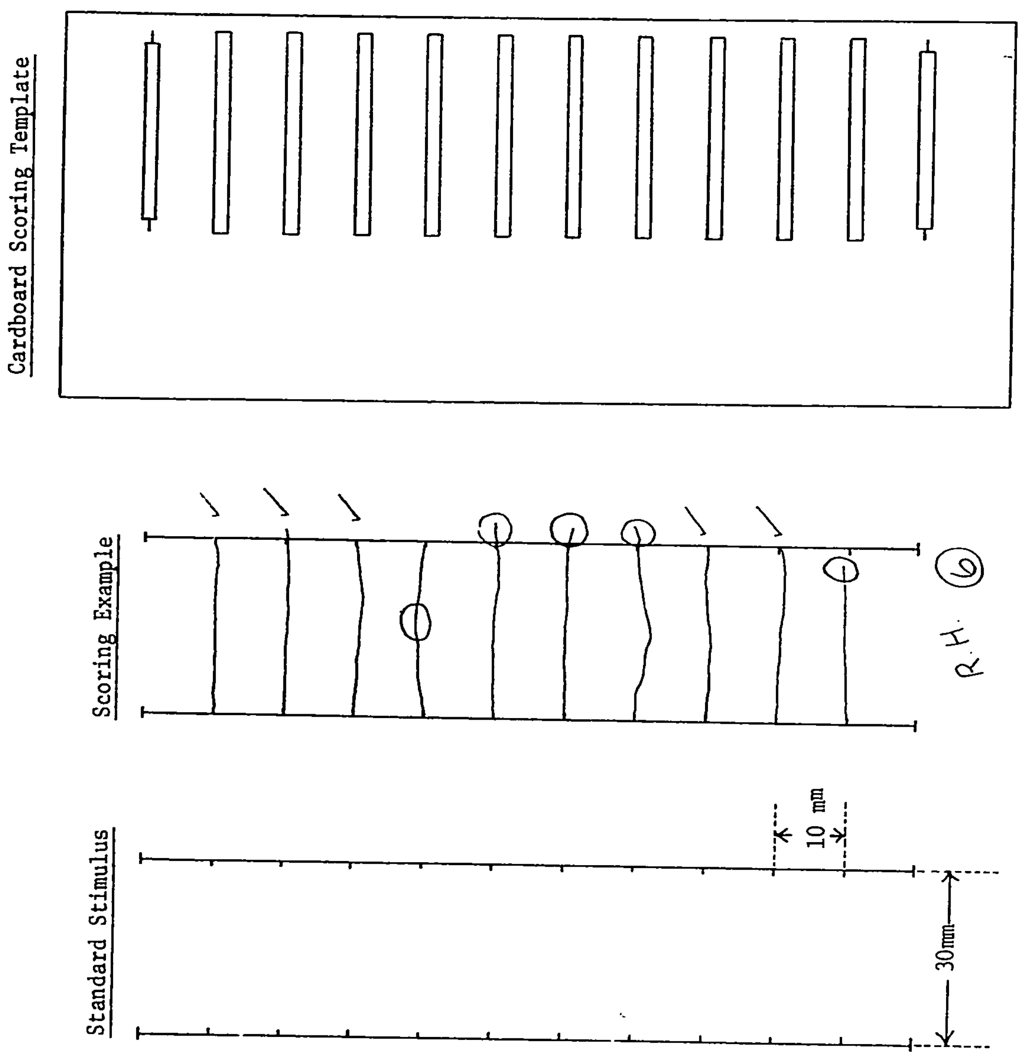
My name is ......................................................

APPENDIX C

DRAWING THE RUNGS OF A LADDER
STIMULUS, SCORING EXAMPLE
AND SCORING TEMPLATE

FIGURE 9

DRAWING THE RUNGS OF A LADDER: STIMULUS:
SCORING EXAMPLE AND SCORING TEMPLATE



APPENDIX D

SCISSOR CUTTING OF A PAPER
CIRCLE OUTLINE: STIMULUS,
SCORING EXAMPLE AND
SCORING TEMPLATE

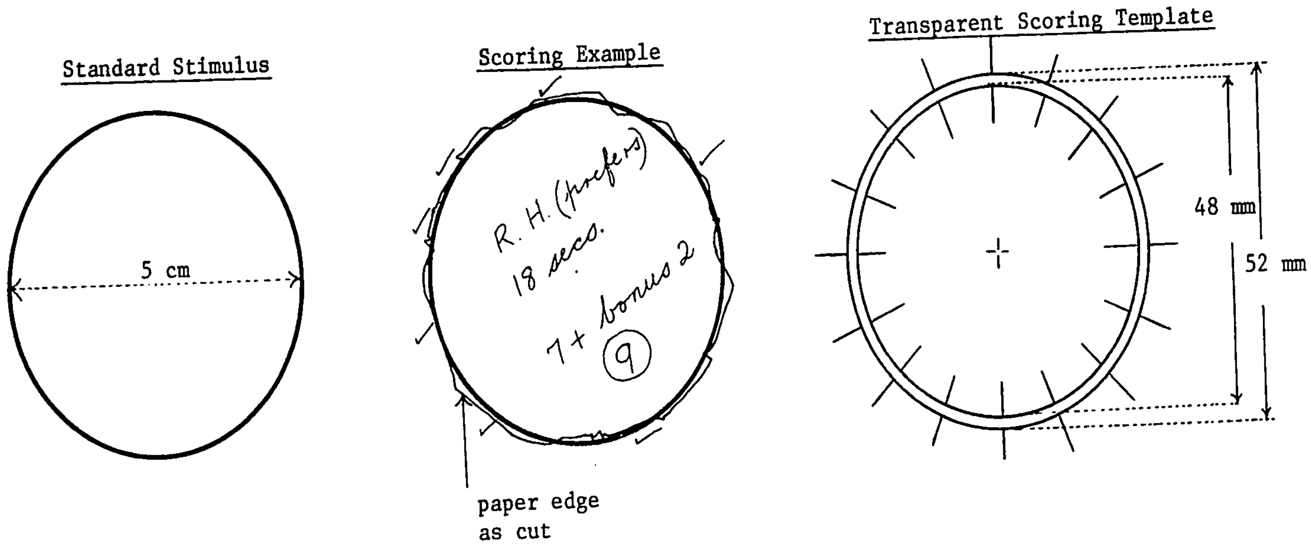



FIGURE 10

SCISSOR CUTTING OF A PAPER CIRCLE OUTLINE: STIMULUS,
SCORING EXAMPLE AND SCORING TEMPLATE

# APPENDIX E

# PREPARATION OF THE DICHOTIC TAPE

Source Tape

Instructions to students and the digits one through nine were recorded on both channels of the source tape[1] using a Sony 777 Tape Recorder and matching microphones. All recording was done in sound-treated auditory-testing rooms of the Department of Speech Pathology & Audiology, University of Alberta, using the voice of a Western Canadian male, experienced in public speaking.

A half-second (500 msec) segment of a continuous 1000 Hz pure tone (recorded at 70 dB) was manually spliced into the source tape.

Experimental Tape

Using the apparatus indicated in Figures 11 and 12, and the intervals indicated in Figure 2, digits were recorded onto the experimental tape from the same source-tape sequence of the digits one through nine. The following procedures were adopted:

(a) Apparatus and Settings

(i) Sony Tape Deck (TC-355): Line output from each channel of source tape (unaffected by settings).

(ii) All-Tronics Delayed Feedback Apparatus (Model DLF/5): For present purposes the tape-spool was removed and a continuous tape loop substituted to ensure no variability in tape speed. Settings were: Speed: fast (15" per second); Delay: 0.2 seconds; Auxiliary amplification : setting 10.

(iii) Hunter Decade Interval Timer. Setting: 0.6 seconds.

---

[1]To ensure high quality reproduction, a new 1.5 mil polyester-backed Scotch brand tape was used.

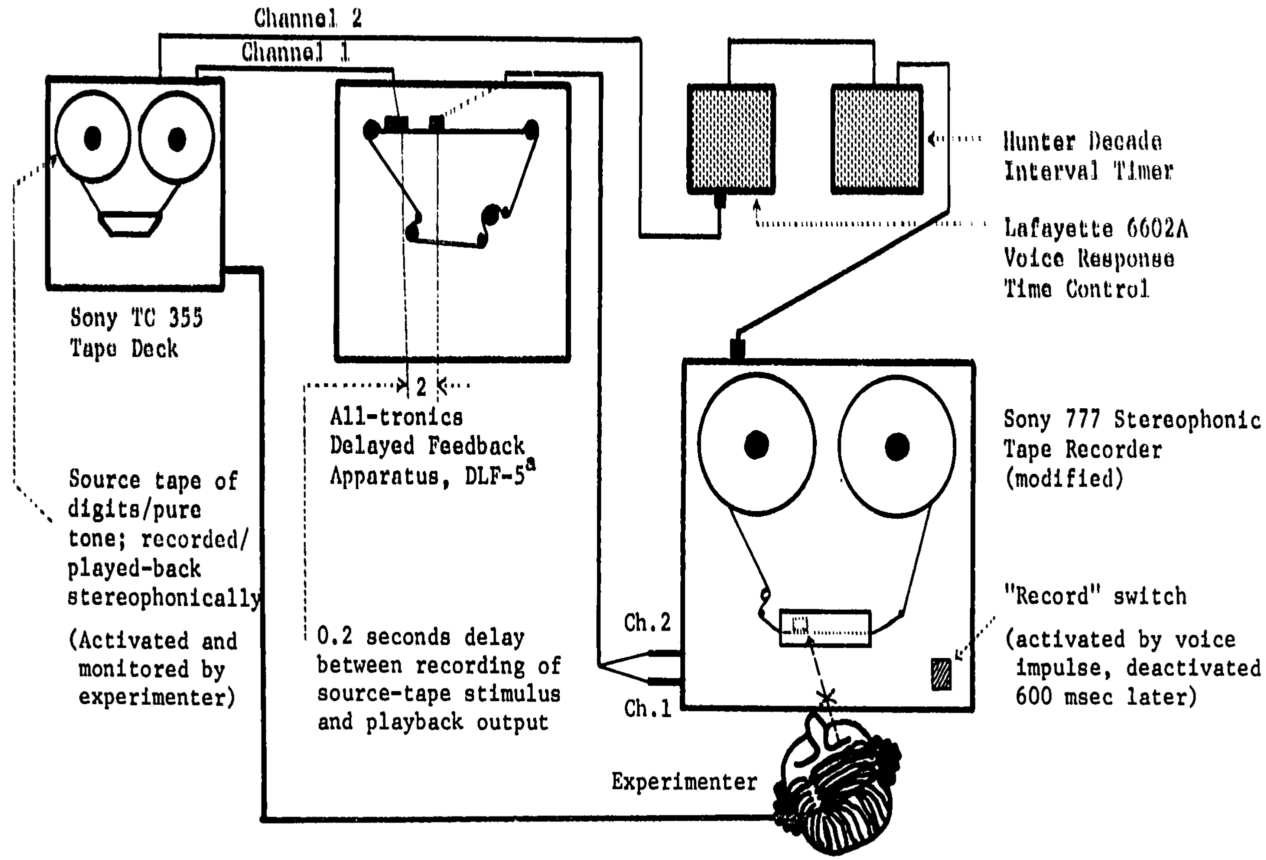



FIGURE 11

SCHEMATIC DIAGRAM OF APPARATUS USED FOR PREPARATION OF THE DICHOTIC-DIGIT TAPE

[a]The Delayed Feedback Recorder is pictured on p. 152

ALL-TRONICS DELAYED FEEDBACK APPARATUS:
(DLF/5) MODIFIED[b]

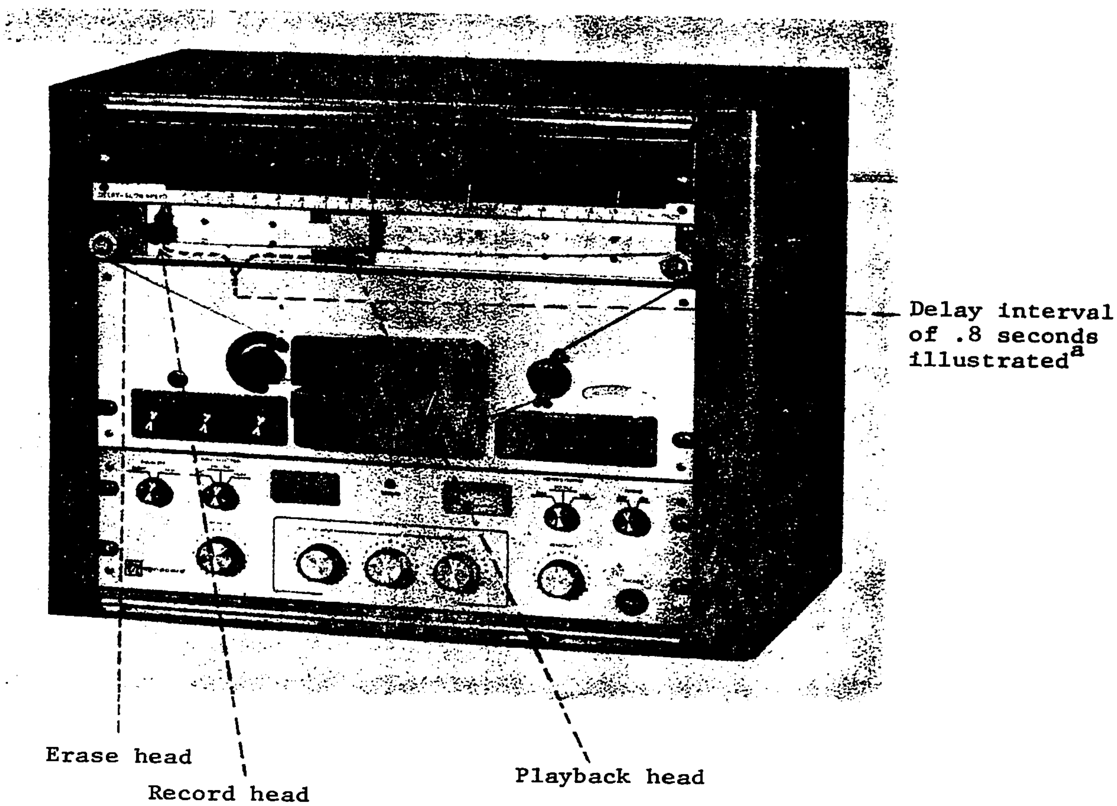



FIGURE 12

[a]A delay interval of 0.2 seconds (200 msec) at fast speed (15" per second) was used in the present study.

[b]The present study used a tape loop and not continuous tape reel as illustrated.

ALL-TRONICS DELAYED FEEDBACK APPARATUS:
(DLF/5) MODIFIED[b]

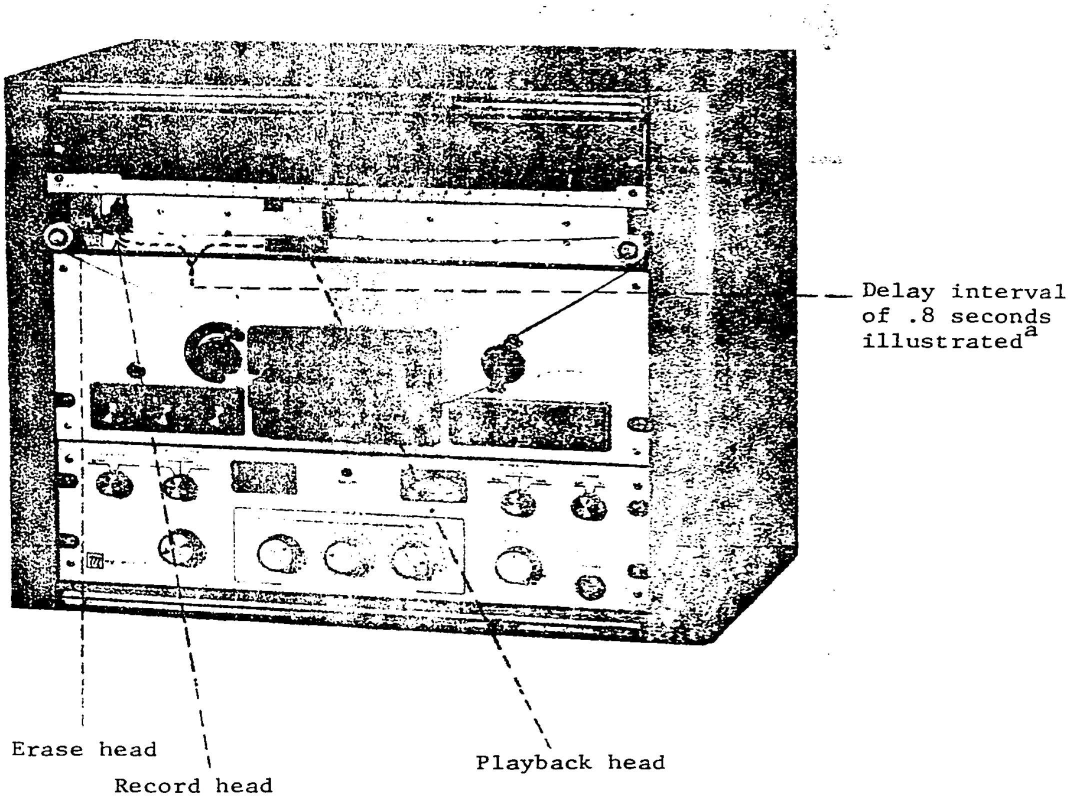



FIGURE 12

[a]A delay interval of 0.2 seconds (200 msec) at fast speed (15" per second) was used in the present study.

[b]The present study used a tape loop and not continuous tape reel as illustrated.

(iv) Lafayette 6602A Voice Response Time Control: Sensitivity setting "2" to activate experimental-stimulus tape drive, by voice from source tape.

(v) Sony 777 Stereophonic Tape Recorder: Channels one and two were both set at level 4 volume (optimal level for source-tape stimuli replayed through delayed feedback recorder). Tape speed: 7½" per second.

(b) Recording of Stimuli

Procedures used in recording the series $\begin{smallmatrix}*6 & 3\\ 9 & 1\end{smallmatrix}$ are discussed.

A new 1.5 mil polyester-backed Scotch Brand tape was installed on the Sony 777 Tape Recorder. A 1/4" square of off-white splicing tape was carefully affixed to the non-recording surface of the tape and its leading vertical edge visually aligned with both the right vertical edge of the recording head and a point marked on the surface of the tape recorder (Figure 11). Care was taken to maintain consistent tape tension between spools.

When the recording of "6" was located by the experimenter's monitoring of the source tape (Figure 11), the "Record" switch of the Sony 777 was activated. However, this recorder had been modified to remain inactive until an impulse released the "Instant Stop" control. Thus the "6" was recorded on the experimental tape, 200 msec after activation of the tape drive by an impulse from the voice control unit. This delay enabled the tape to be fully accelerated before accepting the "6" for recording. At 600 msec after activation, the experimental tape stopped, the "Instant Stop" having been activated. By having the signal from the delayed feedback recorder fed into line inputs of both channels (Figure 11), the signal could thus be directed to either or both channels. The "6" was recorded on channel-one of the dichotic tape.

Thus, the "6" on channel-one of the source tape electronically activated the tape drive via the voice response control unit and the timer, while the "6" located on channel-two of the source tape was recorded 200 msec after the tape was activated. Since the tape stopped 600 msec after voice activation, the signal had to be completely recorded before the tape decelerated, to avoid distortion and/or clipping of the signal. This consideration suggested the use of 600 msec per digit rather than the more usual 500 msec.

Having recorded "6" on channel-one of the dichotic tape, the procedure was repeated without any realignment of the tape for the digit "3". After recording "6, 3" on channel-one, the tape was realigned at the marker, recording signal directed now to channel-two and a similar procedure followed for the digits "9" and "1". Once 6 3 (Ch. 1) / 9 1 (Ch. 2) had been recorded, the tape was moved back nine inches (9") from the original marker[1] and the 1000 Hz pure-tone (beep) signal recorded on channel-one.

---

[1]At 7½" per second recording speed, 9" was needed: 1½" (200 msec) for delay following tape-drive activation, 3-3/4" (500 msec) for signal, leaving 3-3/4" (500 msec) trace consolidation time prior to onset of digit stimulus.

The same pure-tone signal, the same sequence of source-tape digits, the same recording levels and the same recording procedures were used for all other dichotic-digit series. Instructions were then manually spliced into the experimental tape as needed. When completed, the experimental tape was duplicated to minimize any likelihood of tape-stretching or audible clicks associated with tape markers and splices. The duplicated tape was then used for dichotic testing in the present investigation.

(c) Instructions and Test Stimuli

(i) Attenuation and Free-Recall Stimuli/Instructions

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ch. 1: | *2 | *8 | *3 | *5 | *6 | *63 | *42 | *17 | *28 |
| Ch. 2: | *8 | *1 | *9 | *7 | *2 | *91 | *83 | *94 | *35 |

| | | | | |
|---|---|---|---|---|
| Ch. 1: | *158 | *385 | *624 | *832 |
| Ch. 2: | *297 | *746 | *817 | *916 |

Ch. 1: This time you will hear the numbers in pairs.

Ch. 2: This time you will hear the numbers in pairs.

Ch. 1: One in this ear

Ch. 2: and one in this ear at the same time.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ch. 1: | Let's try some. | *2 | *8 | *3 | *5 | *6 | *63 | *42 |
| Ch. 2: | Let's try some. | *8 | *1 | *9 | *7 | *2 | *91 | *83 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ch. 1: | *17 | *28 | *158 | *385 | *624 | *832 |
| Ch. 2: | *94 | *35 | *297 | *746 | *817 | *916 |

(ii) Ordered-Recall Test Sequence/Instructions

1: This time, when you hear a beep, tell me the

2: This time, when you hear a beep, tell me the

1: numbers in that ear before you tell me the others.

2: numbers in that ear before you tell me the others.

1: The beep tells you to listen to that ear and

2: The beep tells you to listen to that ear and

1: say those numbers first. Ready *8 3

2: say those numbers first. Ready 1 *5

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1: | 14 | *61 | *63 | 42 | 17 | *28 | 158 | *385 |
| 2: | *89 | 87 | 91 | *83 | *94 | 35 | *297 | 746 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1: | *624 | 832 | *9351 | 4819 | 7249 | *3928 |
| 2: | 817 | *916 | 7286 | *2573 | *8516 | 4175 |

# APPENDIX F

# SUPPLEMENTARY STATISTICAL INFORMATION

Cochran's Test for Homogeneity of Variance

1. Initial Sample (n = 222)

Of 15 possible cells (5 x 3), 1 was empty.

$$F_{max} = \frac{S^2 \text{ largest}}{MS \text{ error}} = \frac{(11.75735)^2}{71.24046} = 1.940404$$

$$F_{critical} = F_{.95}\ (14,208) = .0889$$

$$F_{max} > F_{critical} \qquad (p < .0001)$$

The homogeneity of variance assumption is thus untenable for these data.

2. Restricted Sample (n = 108)

Of 108 possible cells (3 x 3 x 2 x 3 x 2), 58 were empty.

$$F_{max} = \frac{S^2 \text{ largest}}{MS \text{ error}} = \frac{(18,38477)^2}{57.216293} = 5.907$$

$$F_{critical} = F_{.95(50/58)} = 0.0328$$

$$F_{max} > F_{critical}. \qquad (p. < .0001)$$

Homogeneity of variance cannot thus be assumed for these data. Although the F test is robust with respect to moderate departures from homogeneity of variance (Winer, 1962, pp.92-93), the marked departures indicated above, together with the non-normality of distribution in populations classified according to handedness preference and/or ear asymmetry in dichotic listening (cf. pp. 129-130), suggest a conservative interpretation of findings. More conservative analysis (Table 19) does not provide support for hypothesis 2B; viz: $C_{D2}$ ($M_{LE}$ = 50.1, $M_{RE}$ = 58.3; F = 2.89, df = 1/27, n.s.).

TABLE 19

ANALYSIS OF VARIANCE SUMMARY FOR GROUPS DRAWN FROM RESTRICTED SAMPLE: EAR ASYMMETRY IN DICHOTIC LISTENING AND READING

| Source | SS | df | MS | F |
|---|---|---|---|---|
| Planned Comparison[a] | | | | |
| $C_{D1}$ $M_{(LE,RE)}: M_{NE}$ | 866.40 | 1 | 866.40 | 7.44* |
| $C_{D2}$ $M_{LE}: M_{RE}$ | 336.20 | 1 | 336.20 | 2.89 |
| Between Group | 1202.60 | 2 | | |
| Within Cell | 3148.60 | 27 | 116.61 | |
| Total | 4351.20 | 29 | | |

*$p < .05$

[a]cf. p. 103 for description of planned comparisons

TABLE 20

EAR ASYMMETRY CLASSIFICATIONS AND READING: RESTRICTED AND REDUCED-RESTRICTED SAMPLES

| Sample | DL Ear Asymmetry Level | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 (LE) | | | 2 (NE) | | | 3 (RE) | | | Combined | | |
| | n | M | SD | n | M | SD | n | M | SD | n | M | SD |
| Restricted | 33 | 50.3 | 10.2 | 10 | 42.8 | 10.5 | 65 | 54.2 | 8.6 | 108 | 51.9 | 9.8 |
| Restricted(2)[a] | 10 | 50.1 | 10.8 | 10 | 42.8 | 10.5 | 10 | 58.3 | 11.0 | 30 | 50.4 | 12.2 |

[a]Randomly drawn from restricted sample to have an equal number of Ss at each level