1991

Handedness and achievement of young beginner pianists on elementary performance tasks

Robert A. Smith

University of Wollongong

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Handedness and Achievement of Young Beginner Pianists on Elementary Performance Tasks

A thesis submitted in partial fulfilment of the requirements for the award of the degree

Master of Arts (Honours)

from

Graduate School
Faculty of Education
University of Wollongong

by

Robert A. Smith, B.Mus.Ed.

February, 1991
Declaration

I hereby certify that this work is a result of my own personal effort and as such has not been submitted to any other university or institution for the award of a degree.

(R. Smith)
Dedication

To my twins,
Joshua and Jasmine,
who are not only quite different
by being brother and sister
each having a very different personality,
but who have individually turned out to be:
the one a right-hander
and the other a left-hander!

Acknowledgements

I would like to thank firstly the mums and dads of the children used in my study for allowing the extra intrusion into their already busy lives, and secondly those members of the N.S.W. Music Teachers' Association (Wollongong Branch) who assisted initially by providing access to their pupils as subjects.

Special thanks go to the children themselves, who formed such an important part of the research study upon which this thesis is based, and who, even in the face of the combined excitement and duress of being assessed, seemed to regard it as just a bit of extra work that was expected of them.

Thanks also to two personal colleagues, Dr John Patterson and Dr Barry Watkin, for their help and guidance in research design, and support with one of the computer programs used to analyse the data.

I would also like to thank my two Co-supervisors: Jim Powell, retired Director of the Conservatorium of Music, University of Wollongong for his musical stimulus and listening ear; and Professor Carla Fasano, ex-Head of School of Policy and Technology Studies in Education, University of Wollongong for her professional skills and insights.

Also I would like to register my deepest thanks to Professor Russell Linke, Dean of Faculty of Education, University of Wollongong, for his competence, expertise and guidance as the project was brought to fruition.

Lastly, and most importantly, to Patricia for her moral support and understanding through the long years when midnight oil was being burnt.
Abstract

The primary objective of this study is to synthesise from the literature and prior research studies the background to the determinants and assessment of handedness, especially left-handedness as applied to music and musicians, and particularly left-handedness as it affects beginner pianists.

The writer, in private practice, has noticed that left-handed children in the early stages of learning to play the piano, exhibit, when reading notation, some confusion in directing the appropriate left or right hands as indicated by the music. This appears to be a confusion as to which direction, on the horizontal keyboard (to the left or to the right), is expected by the written vertical movement of notes on the staff (either up or down). This same confusion seems to be rarely and/or only slightly exhibited by right-handed children. So for the purposes of this study two hypotheses were put. Namely:

- a left-handed child in the early stages of learning to play a musical keyboard instrument will exhibit (when reading notation) more misdirection of the appropriate left or right hand as indicated by the music, than a right-handed child; and
- a left-handed child, even after a period of early tuition, consolidation and practice on a musical keyboard instrument, will still exhibit (when reading notation) greater misdirection of the appropriate left or right hand as indicated by the music, than a right-handed child.

The secondary objective of this study is to provide a pertinent and new contribution to this area, and so this study attempts, with a small random sample of young left-handed and right-handed beginners at the piano, to test empirically, through a series of specially designed basic exercises, the two hypotheses.

Having provided specific information on the nature, complications and disadvantages of left-handedness from the synthesis of the literature on the topic, and the confirmed evidence of misdirectioning of hands from the experimental study, this research then makes recommendations for further studies on the topic which would lead to the formulation of appropriate teaching strategies and methods, construction of remedial exercises at the keyboard and support pedagogy to be used by the piano teacher of the problem beginner left-hander.
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Introduction

Rationale for investigation

Pooh looked at his two paws.
He knew that one of them was the right,
and he knew that when you had decided which one of them was the right,
then the other one was the left,
but he never could remember how to begin.
"Well — " he said slowly . . .

(Milne, 1960:118)

Research objectives

The primary objective of this study is to synthesise the background to and prior research studies into the many determinants and possible assessments of handedness, especially left-handedness as applied to music and musicians, and particularly left-handedness as it affects beginner pianists. The secondary objective of this study is to provide a pertinent and new contribution to this area, and so this study attempts, with a small random sample of young left-handed and right-handed beginners at the piano, to test empirically, through a series of specially designed basic exercises, two relevant hypotheses which will be discussed in the next few pages.

Having provided specific information on the nature and possible disadvantages of left-handedness from the synthesis of the literature on the topic and the experimental study, this research then makes recommendations for further studies which would lead to the formulation of appropriate teaching strategies and methods, construction of remedial exercises at the keyboard, and other support pedagogy to be used by the piano teacher of the problem beginner left-hander.
Hypotheses

Through subjective observation over more than twenty years as a music educator and piano teacher, the writer has noticed that some left-handed children in the early stages of learning to play the piano (or other musical keyboard instrument) exhibit, when reading notation, a degree of confusion in directing the appropriate left or right hand as indicated on the music. It appears to be an obfuscation of orientation, i.e. which direction, on the horizontal keyboard (to the left or to the right), is expected by the written vertical movement of notes on the staff (either up or down). This misorientation seems to be rarely exhibited by right-handed children.

The times when this misdirection of hands and fingers is most evident in the left-handers seem to be:

• when the hands are put together for the first time(s); and
• when the hands have to play something similar — but quite independent of each other; i.e. the confusion seems to be less evident when the hands are performing in contrary motion.

Other evidence of this temporary obfuscation, however, seems often to persist well past the beginner stage, and seems often to pervade the player's sight-reading attempts and learning routines many years later.

The question is then raised: Is a left-handed child in the early stages of learning to play a musical keyboard instrument more confused than a right-handed child in his attempts at directing and/or directioning the appropriate left or right hand, as indicated by the music? In other words, can it be empirically shown that a confusion of directing/directioning of hands does exist in the left-handed child, to a much greater degree than in the right-handed child? From the available literature and research studies, it appears that these questions have not been asked before, or at least they appear not to have been the basis of empirical investigation.
In an attempt to answer this questioning, and for the purposes of the research project, two hypotheses are tested in the present study. The first is:

**A left-handed child in the early stages of learning to play a musical keyboard instrument will exhibit (when reading notation) more misdirection of the appropriate left or right hand as indicated by the music, than a right-handed child.**

There is a further subjective observation which the writer has made, and that is that after a fairly short period (say six or eight months) of normal instruction and practice on the keyboard, left-handers who initially exhibited a misdirecting of hands, are still likely to make errors in this respect, although not as frequently. The second hypothesis, based on this observation, is:

**A left-handed child, even after a period of early tuition, consolidation and practice on a musical keyboard instrument, will still exhibit (when reading notation) greater misdirection of the appropriate left or right hand as indicated by the music, than a right-handed child.**

The time base of the major study was extended in order to test this hypothesis, with the students being re-assessed after such a period of time in order to gather data from a further observation.
Justification of Literature Survey

There have been very little research or writings published on the specific topic of left-handedness as it applies to the beginner piano player. There are therefore several areas and issues directly connected with left-handedness and the present experimental study which need to be clarified in order to provide a strong foundation for this work.

The first chapter attempts to show to what extent differences between types of manual laterality do occur in the population, and whether as a type left-handedness is normally a problem with executant skills. By hypothesising that there is a problem for the left-hander, this study looks to the causes and origins of left-handedness in order to understand what the problem is so that it can be addressed.

If the overall problem of left-handedness were to be only social and experiential, then remediation would easily be able to be applied and the problem lessened, but if it were found to be genetic, then there would be much less that could be done in the face of a strong genetic predisposition. Research shows that such a genetic predetermination is not the case and that among other possible influences social and environmental pressures are very important factors in the child's own particular predilection to being right- or left-handed.

The first chapter of this study then addresses the various issues directly connected with left-handedness and the ensuing experimental study. Namely:

- a discussion of the language and customs of "right" and "left";
- investigations of the development of right-left awareness and discrimination in the child;
- a brief survey of the multi-faceted phenomenon of handedness and its classification and assessment (amplified in Appendix A); and
- a survey of the research in the area of handedness related to musicians, and in particular to beginner pianists.

The justification for inclusion of these areas is as follows:
Language and customs of "right" and "left"

It is possibly interesting to trace the philology and semantics and cultural and social customs of right and left. But it is more important to see how the associated stigma of left-handedness and left-sidedness has evolved and how this influence has remained in our interpretation and thinking even to the present day.

Right-left awareness/discrimination in the child

When addressing the topic of handedness as applied to young children it is imperative to ascertain whether they are able to discriminate critically between right and left. An investigation into the development of right-left awareness and discrimination in the child must therefore be pursued in order to suggest safely that misdirecting of hands was not caused by the child’s immaturity with the concepts of right and left, and to be able to say with any surety that the child is consistent in his/her choice of hand.

Handedness

Although handedness is a highly complex trait, for the purposes of the empirical study it is not necessary to investigate all of its multiple aspects, so a summary of the most prominent features and general outcomes of research is presented through three sections: • Cerebral Laterality; • Incidence; and • Classification and Assessment.

Nevertheless it is useful in interpreting the results and outcomes of this study to provide a more detailed analysis of the context in which this study has been set. So in order to create a more complete picture of left-handedness and the left-handed child, a detailed review of the aetiology of human laterality (specifically manual laterality and handedness) is included in Appendix A under the more specific headings of: • Cerebral Laterality; • Cerebral Dominance; • Physiology; • Heredity; • Necessity; • Developmental progression; • Forced change; • Incidence; and • Classification and Assessment.
It will be shown that over the past three decades knowledge of the processing within the brain has increased dramatically. The concept of duality of brain function was not new, but hard empirical evidence to support the concept of cerebral laterality was possible from patients who underwent the new surgery of commissurotomy. Educators are now better able to explain and understand the types of processing required for various intellectual tasks and can better understand and effectively teach those with creative and artistic temperaments, although the research is currently unable to show absolute links between cerebral dominance and physical laterality.

Following the new light shed on cerebral laterality, there were attempts made to explain handedness as being dictated by whichever hemisphere was dominant in the brain. Postural symmetry, physical and constitutional predispositions and even social custom have all been held to be determining factors in handedness. Geneticists have long held a hereditary basis for handedness but most recent research indicates that a number of nongenetic and even random factors contribute to the formation of handedness within families. Nature's economy can be seen in the training of a dominant hand its specialisation of function. After about two years of vacillation in infants, lateral dominance and preference can be seen to become stronger and more definite with age. Forced change of handedness was often blamed for confusion and speech disturbances. The incidence of left-handedness in the population has been shown to vary greatly. A great deal of this conflicting evidence is due to the method of classification and assessment.

Handedness as it relates to musicians, and in particular to beginner pianists

Having presented the various complex facets of handedness, and being in a better position to interpret differences in performance, the chapter will then present the few research studies which relate to handedness in music and musicians, and then even fewer which specifically relate to the topic of handedness as it applies to beginner piano players. The chapter will then close with some statements about the pertinent new contribution which the present study will make to the understanding of handedness in Musicians.
Comment

The above areas are not provided in any order of importance, but are each regarded by most educational researchers as being important in providing a complete understanding of left-handedness and its affect on the child who lives with his or her physical differences and sometimes questions "why me?" It will also be shown that empirical research on these issues appears to have followed a periodic pattern with varying concentrations of work done throughout certain periods of this century. Occasionally more or less was done in a particular decade and so therefore the literature survey reflects this pattern of eclectic research.
Chapter 1
Literature survey

1.1 Introducing "right" and "left"

I often think it's comical -
Fal la lal Fal la lal, la!
How Nature does contrive -
Fal la lal Fal la lal, la!
That ev'ry boy and ev'ry gal
That's born into this world alive,
Is either a little Liberal,
Or else a little Conservative!

(Gilbert and Sullivan, 1956:127)

Permeating our language throughout history are words and phrases concerning the concepts and attributes of right and left.

The Latin word for "left" is sinister (derived from sinus or "pocket" of the toga i.e. left-hand = pocket-hand) which is also used to translate words such as "bad", "ominous", "sinister"; whereas the Latin word for "right" is dexter from which comes our English word "dexterity", meaning "skill" or "adroitness".

The French word for "left" is gauche which we take into English to mean "awkward" and from which comes our slang word "gawky". The French word for "right" is droit, also meaning "good", "just" and "proper" and from which we get the word "adroitness".

Our English word "left" comes from the Anglo-Saxon lyft, also meaning "weak", "infirm", "broken" (as in "lopt/lopped" and the German licht or English "light/fragile") or "worthless" and "lacking in moral strength"; whereas the Anglo-Saxon word for "right" is reht or
riht meaning "straight" and "just". From reht and its Latin cognate rectus we have derived the English words "correct" and "rectitude" etc.

Meanings and synonyms for "left-handed" are quoted in Delbridge (1985) as being:

"ambiguous or doubtful" (as in "a left-handed compliment"),
"clumsy or awkward" (as in "having two left feet" to dance with),
"morganatic (from the bridegroom's giving the bride his left hand instead of his right as was the custom at morganatic weddings)" (1985:989)
and others which come to mind are "insincere" and "malicious".

However, synonyms for "right-handed" are:

"normal", "customary", "correct", "indispensable" and "reliable"
and include the meaning of "right-hand" being

"most efficient or useful as a helper" (as in "one's right-hand man") (1985:1465)

As our language shows, the right hand has been strongly associated with what is good, just, moral and proper – it represents permanence, force, power, strength, grace, dexterity, dispatch, godliness, rectitude, truth, goodness, and sanctity. Whereas the left represents the opposite, the reverse, the lack, the negation of all those traits and characteristics (Blau, 1946:63). It has long been associated with concepts describing bad, immoral, ill-natured, discreditable, dangerous, and anarchic – in fact often with feelings that are out of conscious control. These attributes are not confined to simple objective orientation but have taken on moral, ethical and religious values. The right has become a synonym for goodness, brightness and clearness; the left for badness, dullness and clumsiness. Whereas one's "right-hand man" is a person to be highly depended upon, a "left-handed friend" is an enemy:

*The stranger greets thy hand with proffered left?*

*Accept not: 'tis of loyalty bereft.*

*Left-handed friends are underhanded foes;*

*True openness a swordless right hand shows.* (Harvey, copy not dated:l.98)
The left was the unlucky side in the interpretations of omens in Roman augury, and has pervaded English superstitions, although little notice is taken of them today. e.g.:

*If left-hand fortune gave thee left-hand chances,*

*Be wisely patient.* (Quarles, 1886:209);

and one is admonished to:

*throw a pinch of salt over your left shoulder, for there the Devil is standing; your guardian angel stands at your right.* (Burt, 1958:314)

But at the turn of this century Browne (ed. Sayle, 1912) launched a three-pronged attack on slavish beliefs in the superstitions about right and left (and quotes some quaint remedies) in:

*And therefore what admission we ow unto many conceptions concerning right and left, requireth circumspection. That is, how far ought we to rely upon the remedy in Kiranides, that is, the left eye of an Hedgehog fried in oyl to procure sleep, and the right foot of a Frog in a Dears skin for the Gout; or that to dream of the loss of right or left tooth, presageth the death of male or female kindred, according to the doctrine of Artemidorus. What verity there is in that numeral conceit in the lateral division of Man by even and odd, ascribing the odd unto the right side, and even unto the left; and so by parity or imparity of letters in Mens names to determine misfortunes on either sides of their bodies; by which account in Greek numeration, Hephrestus or Vulcan was lame in the right foot, and Anibal lost his right eye. And lastly, what substance is there in that Auspicial principle, and fundamental doctrine of Ariolation, that the left hand is ominous, and that good things do pass sinistrously upon us, because the left hand of man respected the right hand of the Gods, which handed their favours unto us.* (1912:133)

As far as our cultural customs go, it is interesting to note that:

- the place of honour at a formal dinner is on the host's right-hand side;
- we are told the Son in Heaven is "seated at the right hand of God";
- the groom stands on the right in the marriage ceremony – the bride on the left (a somewhat non-verbal message about the status of the two participants?);
- we shake hands with our right hands (it seems somehow wrong to shake with the left).

Some everyday machines and instruments require the operator to be ambilevous or
ambidextrous (or even "ambisinistral" as the case may be). The typewriter, word-processor, most musical instruments (harp, piano, violin etc.) require as much speed and "dexterity" in the left hand as in the right. Also, although civilisation is rigid in some of its right/left customs, world-wide it seems not to have decided upon others. e.g. buttons on men's clothing are to the right, and on women's to the left, yet no-one seems to want to change it; in Australia and Great Britain traffic drives on the left of the roadway, whilst in Europe and U.S.A. on the right – it seems that no-one has decided internationally on which side the driver should sit, or on which side the gear lever should be (yet the accelerator pedal is always to the right of the brake!)

An interesting area of research into one aspect of handedness was commenced in the early sixties by Salk (1961, 1962) and Weiland (1964), and continued by Weiland and Sperber (1970). It was observed that 80% of all mothers exhibit a natural preference for holding their baby on the left side of their chest irrespective of whether they performed their household chores as right-handers or left-handers!); and Salk (1973:24) showed by various experimental studies that there is reason to believe that the sound of the adult heart has a soothing effect on the infant. Could it then be that "Close to a mother's heart" is more than just an expression?

There can be no doubt at all that in a great many ways our world favours the right-handed. The fact that most of the current range of tools and instruments have a right-handed bias may come as a surprise to the right-hander, but is probably well known to the frustrated left-hander. These include scissors, potato peelers, can openers and corkscrews, fountain pens, firearms, and most musical instruments. Two examples may suffice to reinforce this bias:

• The famous silent-movie actor Charlie Chaplin, a self-confessed left-hander, used to play the violin – left-handed! This required shifting the bass bar and soundpost, re-stringing the instrument, and playing it "in reverse" to the accepted tradition. In his autobiography (Chaplin, 1964) he says that from the age of sixteen he used to take lessons and practice from four to six
hours a day, with the idea of becoming a concert artist, or failing that, to be able to use his playing in a vaudeville act (1964:131). However, he concludes this particular chapter by saying that as time went on he realised that he could never achieve excellence on the instrument, and so gave it up!; and

- Barsley (1970), also a left-hander, chronicles the success at the opening in London in 1968 of "Anything Left-Handed" – the first shop in the world to cater exclusively for left-handers, with "left-handed" stock including (in addition to those mentioned above): carpenters benches, T-squares, artist's palettes, etc., and some things that could be more correctly labelled as ambidextral devices, such as a saucepan with a lip on each side – so it could be used equally well to pour by using either hand (1970:178).

Had the above shop been a music shop, it could only have sold French Horns, for these instruments are the only orchestral instruments which have been set up with a left hand bias. It has been observed that in the playing of most musical instruments (as with nearly any bi-manual tasks) the dominant hand will perform the executant skill whilst the non-dominant hand takes a subservient rôle in supporting the instrument (or tool as the case may be) (Oldfield, 1969:95). In the case of the French Horn, the player supports the instrument and stops the bell with the right hand, and articulates the valves with the left hand – essentially a left-handed performance task.

There are only about four known exceptional cases of right-handed instruments which can be converted to left-handed playing. They include the complicated reversal of strings and soundpost on violins (and others of the bowed strings) as mentioned in the Chaplin case previously; the well-known case of mostly simple reversal of guitars for left-handers (as well as instances of specially made instruments for players such as Paul McCartney and Jimi Hendrix); the case of the slide trombone (assuming that it is not provided with an F register key) where it is possible without any mechanical modification to reverse the angle and position of the bell and thus play it over the right shoulder – non-traditionally or left-handedly; and the ability to
reverse the hand positions on the recorder group of instruments (although strictly not exactly perfect intonation results if the instrument has unequal sized holes for low C# F# in the foot joint). It is not known of other instruments which could either be termed left-handed, or be able to accommodate naturally a player with left-hand dominance.

It is obvious to all aspiring brass players that their instruments have been designed for most skilful use by a right-hander. Although a player may attempt to hold and/or support the instrument in or with the non-traditional (right) hand and further attempt to articulate the valves with the fingers of the other (left) hand, the result is less than satisfactory, being not only most uncomfortable, but not conducive to technical facility because of the greater bulk of the instrument on the left hand side. Most brass instruments were quite obviously not designed to be played in this reversed or left-handed fashion.

The situation with woodwind instruments is much the same as that for the brasses, in that the keys and or holes have been designed to be operated with left hand uppermost and the right hand on the lower section. Even though these instruments are also bi-manual in performance, one would expect that they should be regarded as requiring equal degrees of skill for both hands, and that is possibly so. But for reasons of personal comfort (or anything else for that matter) if a player did wish to reverse hands, the fingers would plainly not be able to play some or all of the keys or keyholes.

Percussionists if working with untuned percussion have very few difficulties with the left- or right-handedness of most instruments. Drummers can reverse the position of drums within their kit with little or no real difficulty, and can reverse the hand held uppermost for sticking (as did Ringo Starr – another of the Beatles). But when working with tuned instruments (except for the harp – as the left-handed Harpo Marx played resting on his left shoulder, with no need for any further alteration) they are certainly not be able to reverse the instrument's predicated and inherent arrangement of notes from left to right.
One would expect at first glance the piano to be non-handed, equally-handed or ambi-lateral. In reality it has a lateral bias where notes are named from left to right. It is perfectly feasible to expect that the orientation of a musical keyboard, with its pitch represented horizontally and moving up to the right (rather than up to the left), was conceived by a right-handed person for use by right-handed people (although we also would expect that it was not designed with this exclusivity in mind). It would be expected that as it was being conceived originally, the dominant hand would have been used to play it in single note melodic fashion. The speculative point being made is that most probably it was not an arbitrary choice of the original constructor to have pitch represented up and away to the right, but that this concept was reinforced by the use of the dominant hand and so the orientation of the keys was based on what would have suited most people (i.e. right-handers) at the time.

It would also appear to be no co-incidence that melody, being the most ear-catching part of music, has been notionally taken on the keyboard (set up in this right-handed fashion) by the right hand – the dominant or leading hand for most people.

These two observations about the keyboard raise several fairly obvious questions:

• Would left-handers feel (if not persuaded otherwise by convention) that upwards in pitch and away from the body would be to the left (a total mirror reversal of the keyboard concept as we know it today)?

• Would left-handers feel (if not persuaded otherwise by convention) that a melodic line should be carried in the left hand?

• Where is the feeling for a strong melodic line for the left-hander? Is it naturally in the left hand? (Could this then be the reason why it appears that left-handed children – more so than right-handers – exhibit confusion when playing sections of music and misdirect their hands?)

• Could it then be concluded that musical keyboards ( pianos, organs, synthesisers etc.) should, in order to support left-handers best, be also constructed with a reversed direction of keys? !!

• Do left-handers have to conform once again to what appears to be a right-handed tradition,
when their strong/leading/preferred hand is the left?

[It should be noted here however, that in all of the above observations the music would not need to be written any differently, because it is oriented vertically – and so correctly – with low notes at the bottom and high notes at the top.]

Although feasible from the point of view of engineering, it would be too much to expect manufacturers to make purpose-built left-handed instruments, for (as will be amplified later) the incidence of left-handers in the community is only approximately one in 10, and the cost of specially tooling up to make such low volume numbers would be prohibitive. It would not be thought commercially viable to have to produce double stocks of instruments in such an already small section of the market.

If this argument is taken to the extreme, and if it were possible for the left-handed pianist to learn to play "left-handedly" on a reversed (i.e. left-handed) keyboard, s/he would then be greatly limited in performance away from the teaching/learning instrument(s), unless the community as a whole accepted this radical concept and had "left-handed" pianos (and organs) on stage, in the theatre, in the school hall, in the church etc. just for the case of the one-in-ten player!

Alas then the left-handed beginner piano player, who is going to be disadvantaged by having to play on the instrument as it exists with its right-handed bias!

It is to be expected therefore that some left-handed children will have difficulty in learning to play a keyboard. The left-handed piano player (as with any left-handed musician) has to accept the right-handedness of his or her instrument and work to overcome the personal difficulties and disadvantages that may thereby exist.
1.2 Right-left Awareness/Discrimination and Finger-Localisation

I do not know whether it is obvious to other people which is their own or others' right and left. In my case in my early years I had to think which was my right; no organic feeling told me. To make sure which was my right hand I used quickly to make a few writing movements.

(Freud, 1954:243)

As was mentioned briefly in the Introduction, it is imperative if one is going to make certain assumptions about a child's misdirectioning of hands, that one considers the developmental nature of the child's awareness and discrimination of right and left. This particular area of literature search in this study is given importance because it is necessary for the researcher to have a thorough understanding of the background influences which may create in the beginner piano student any element(s) of confusion or obfuscation which would result in possible misdirection or misdirecting of hands.

The following review therefore provides a synthesis of the developmental progression within the child of the awareness of and discrimination between right and left, and then shows that the literature also attaches this awareness to a parallel capacity to localise or locate correctly the activity of the fingers of individual hands (Belmont & Birch, 1963; Benton, 1955; Benton, 1959; Binet & Simon, 1908; Head, 1926; Piaget, 1928; Strauss & Werner, 1938; Swanson & Benton, 1955; Terman, 1919). The section then closes with a review of recognised Tests and Assessments of Right-left Awareness/Discrimination and of Finger Localisation Capacity.
1.2.1 Development of Right-left Awareness/Discrimination

This gradient, which is sensorimotor in nature, underlies the consistent discrimination of the lateral parts of one's body without reference to the verbal concepts of right and left. It is also reflected in unilateral hand preference.

(Benton, 1959:144)

The ability of a person to discriminate between right and left and its clinical dysfunction strephosymbolia has long been the subject of interest to psychologists, neurologists and educators. Since the turn of the century psychologists have viewed right-left discrimination as an index of general development – with two Frenchmen (Alfred Binet, a psychologist in collaboration with Theodore Simon, a physician) being the pioneers of psychometric measurement in this area. They proposed a task of right-left discrimination in the original battery of tests for classification of children against a scale of maturational norms by using their Measuring Scale of Intelligence – 1908/1911 (Binet & Simon, 1980:275). This test was included in various revisions of the Binet Scale developed by other researchers for specific use in various countries such as Belgium, Italy, Germany, Britain and America (1980:viii) and in the translations into Turkish and Russian (Wolf,1961:247). The first English translation by Terman & Childs (1912) was quickly revised and became the 1916 edition known as the Stanford Revision and Extension of the Binet-Simon Scale for Measuring Intelligence (Terman, 1916/1919, 1917). It has since been popular in schools in the English speaking world especially through the first half of this century, having been altered little, and is still being used in the psychiatric profession today in its most recent (third) revision as the Terman-Merrill (1972).

Gerstmann from 1924 through to 1930 reported frequent association of right-left disorientation with cerebral pathology and finger agnosia (inability to localise/identify correctly one's own fingers), acalculia (inability to perform calculatory – arithmetic – problems), and agraphia (inability to write). He reports on further observations (1940:398), and after corroboration of his work by other researchers and observers, this tetrad of symptoms has
become known as "Gerstmann's syndrome" (Critchley, 1953; Swanson & Benton, 1955:123; and Gerstmann, 1957:866).

Piaget (1928) analysed the child's ability to make reliable right-left discriminations, both with reference to his/her own body and to the surrounding environment, and empirically showed that this awareness and resultant ability to discriminate, follows a recognizable developmental course. He notes that most children can pass a simple test of right-left discrimination at the age of six, but are unable to achieve the same performance level with respect to another person, until after the age of eight. He regarded this phenomenon as a reflection of a normal process in the growth of thought, in which the child's thinking becomes gradually less egocentric.

In discussing the findings of their study into Dextrality Quotients for seven-year-olds in terms of hand usage, Johnson and Davis (1937) found that in general the seven-year-old does not use the left hand now and then in a random manner, but uses it to a certain quite definite degree and for quite well designated activities. They found that the seven-year-old is practically one hundred per cent right-handed for certain activities, and practically one hundred per cent left-handed for others (1937:354).

In 1938, Strauss and Werner reported that performance on a test battery, covering both right-left discrimination and finger localisation ability, correlated positively with arithmetic ability, in a group of high grade defective boys. While these writers interpreted their results as demonstrating an obvious relationship, subsequent analysis of their data, and further investigation of these relationships by Benton, Hutcheon and Seymour (1951), found no support for the original hypothesis. The latter writers did however find a significant positive correlation between finger localisation ability and right-left discrimination with respect to one's own body in the group of defective children.

Swanson and Benton, (1955:131) were able to show that growth in this type of
discriminative skill begins at about the age of five years, and that there is then a progressive development through to the age of nine years. They also showed that the rate of growth is fairly rapid between the sixth and seventh years, but decreases between the seventh and ninth years. Therefore they suggest that the growth curve could be fairly accurately described as being negatively accelerated, and point out (1955:132) that it appears that full maturation of these discriminative abilities of a third person does not occur until late childhood, perhaps at about the age of 12 years. Benton (1959) suggests that the growing awareness and discrimination during the fifth and sixth year of a child's life is a further differentiation of the body schema in the form of a right-left gradient – where the two sides of the body are felt as being different from each other, although he says that it is difficult for most children to verbalise the specific nature of this feeling (1959:141).

Harris (1957) has pointed to disturbance in the area of right-left discrimination being related to developmental dysfunctions, and Benton and Menefee (1957) indicate a small positive correlation between this discriminative function and handedness.

Belmont and Birch (1963) attempt to specify within a given sample, the ages where lateral usage (of hand, eye and foot) and right-left discrimination become established, and the relationship between these two functions in normal school age children. In discussing the results of this larger study to test the correlation between "lateral dominance and right-left awareness in normal children", the authors pointed out that at ages of five and six, there was rarely complete failure to distinguish left from right but rather an occasional confusion; and that 95% of children above seven years of age make correct responses in relation to the lateralisation of their own body parts, compared with 69% below the age of seven (1963:266). They conclude this observation by suggesting that after this age and up to the age of 12, since there is then little significant room for improvement in this ability, little takes place, and that within their study all the children from the age of 10 years and upward passed all the questions asked. (1963:268)
In discussing the main point of their study – the comparison of right-left awareness with observed motor laterality – Belmont & Birch (1963) say that it is of interest to note that the accuracy of right-left awareness of a child's own body parts

*antedates the clear-cut establishment of hand preference by 2 years...* (1963:266)

Along with other findings, their main conclusion (1963:269) is that it is highly improbable that the development of right-left awareness (which develops earlier) is dependent upon consistent lateralisation of hand usage (which occurs some two years later).
1.2.2 Development of Finger-Localisation Capacity

Specific developmental deficit in finger-localization can occur, and it shows some degree of association with developmental deficit in right-left discrimination.

(Benton, 1959:64)

Finger-localisation ability, unlike right-left discrimination, is not a perceptual skill which carries any great cultural interest. Whereas children from an early age are encouraged to label correctly right and left, there is little or no attention given to the correct localisation of fingers, except perhaps in play with the "This little piggy went to market" game. Finger-localisation – or the appreciation of the finger schema as Strauss & Werner (1938) labelled it – is a development in body awareness which begins at about the age of four years and shows a continuous growth throughout school childhood. Benton (1959) says that by the age of six years, the normal child is able to identify and localise tactile stimulation of the individual fingers with only an occasional error (1959:145), and that there are no consistent differences of accuracy discernible between either of the hands, whether the child is right- or left-handed (1959:146).

In a large study of a normal population Benton (1959), reports using the test battery described herewith (see Benton, 1955). Not only specifically for that study, but in general he recognises three aspects of finger-localisation, namely:

• tactual-visual localisation;

• tactual localisation; and

• tactual localisation of pairs of fingers (1959:67).

He goes on to point out that when young children are having difficulty in localising fingers, it is always greatest with the fourth, then third fingers, and least with the thumb then fifth/little finger, a point which shows obviously that the "borders" of a "finger schema" are gradually becoming defined, even if the the inner components are not (1959:70).
1.2.3 Tests of Right-left Awareness/Discrimination and Finger Schema

*Rarely were these children characterized by complete failure to distinguish right from left but rather by an occasional confusion.*

*(Belmont & Birch, 1963:266)*

The simplest form of right/left discrimination is called into play when a subject is asked merely to show a single lateral part of his/her own body, e.g. right hand, left eye etc. A more advanced and relational level of left-right discrimination is assessed when the subject is requested to identify the lateral body parts of either a person facing him, or on a picture showing a frontal view of a person. The following literature survey of right/left discrimination tests are in chronological order from the earliest found, and have been grouped under:

- tests of a child's awareness of the basic concepts of right and left initially as related to parts of his/her own body but also to those of a third party;
- tests of a child's ability to discriminate between right and left parts of his/her own body and again those of a third party; and
- basic tests of a child's recognition of finger localisation — usually referred to as the finger schema.

The early Binet-Simon Measuring Scale of Intelligence (1908/1911) with its 54 test items (Binet & Simon, 1980:vii), and its later American revision as the Stanford Binet-Simon with 90 items (Terman, 1917:16) appear to be the first psychometric tests to use right-left discrimination as tests of intelligence. These are not tests of right-left discrimination as such, but one of them is typically a test of right-left awareness used to classify a child against an empirical scale of maturational norms.

After exhaustive preliminary observations and testing, Binet and Simon in 1905 constructed a battery of tests which they continually monitored and developed. In 1908 they proposed a revision and suggested that among another five verbal items the following is a test of a "normal" six-year-old:

*Ask the child, "Show me your right hand," and then "Show me your left ear." This is almost a*
'catch' question, for by asking the child to show his right hand, he has a tendency to show his right ear. . .

At four no child shows his left ear. At five years half the children commit errors. At six years there are no mistakes. It is, therefore, a test which is of great value for classification. (1911/1980:201)

The scale was finally revised and shortened slightly in 1911. In this modification Binet and Simon accept the above test (along with four others) as a definite classification for a seven-year-old (1911/1980:276). However Terman's Stanford American/English revision (Terman, 1916, 1917, 1919) still justifies its use for a six-year-old (1919:175).

Head (1926) used a series of left-right discrimination tests (amongst others which assessed one or another aspect of language) in the study of aphasic patients. They were as follows (in rough order of increasing difficulty):

- naming the right and left hands as they are raised by the examiner, and raising the right and left hands on oral command;
- responding to double uncrossed and crossed oral commands;
- imitation of double uncrossed and crossed movements made by the examiner who is standing beside the subject and whose movements are reflected in a mirror;
- imitation of double uncrossed and crossed movements depicted in schematic front-view representations (of a man) which are placed beside the subject and reflected in a mirror;
- imitation of double uncrossed and crossed movements made by the examiner who is facing the subject; and
- imitation of double uncrossed and crossed movements depicted in schematic front-view representations (of a man) which are presented to the subject (1926:82).

Piaget (1928) created a set of twelve "Tests of Judgement and Reasoning in the Child". The full battery consisted of:

- six items which tested the child's ability to handle the concepts of brothers and sisters; and
- another six on the ability to discriminate between right and left on own body parts, the body
parts of the examiner facing the child, and other objects in the room. These latter six (pertinent to the present study) are:

7. Show me your right hand. Your left. Show me your right leg. Now your left.

8. Show me my right hand. Now my left. Show me my right leg, now my left. [During these questions the experimenter must sit opposite the child].

9. [A coin is placed on the table to the left of a pencil in relation to the child.] Is the pencil to the right or to the left? And the penny?

10. [The child is opposite the experimenter, who has a coin in his right hand and a bracelet on his left arm.] You see this penny. Have I got it in my right hand or my left? And the bracelet?

11. [The child is opposite these three objects in a row: a pencil to the left, a key in the middle, and a coin to the right]. Is the pencil to the left or to the right of the key? And of the penny? Is the pencil to the left or to the right of the penny? And of the pencil? Is the penny to the left or to the right of the pencil? And of the key? [Six answers altogether.]

12. [The same questions as before with three objects in a row opposite the child, a key to the left, a piece of paper in the middle, and a pencil to the right. But the objects are only shown for half a minute and are then covered over with a copy-book, and the answers are taken down. The child is told:] Now listen, I am going to show you three things only for a tiny moment. You must look very carefully, and then afterwards tell me by heart how the things are arranged. Look out . . . (the experiment) . . . Well now, is the key left or right of the piece of paper? And of the pencil? Etc. (1969:99)

In discussion of the findings on 240 children aged between four and 12, he shows that the relative notion of right and left passes through three successive stages which correspond to:

three successive points in the desubjectification or socialization of thought: the first stage (5-8) in which the left and right are considered only from the child's point of view; the second (8-11) in which they are also considered from that of the other person, of the person who is speaking to him; finally, the third stage (11-12), which marks the moment when right and left are also considered from the point of view of the things themselves. (1969:107)

He shows that not until age eight is the child able to interpret correctly the Experimenter's right and left [in summarising he labels this point in the child's maturational development as diminution of ego-centrism (1969:113)] but confirms the Binet and Simon results in finding that by age six a child is able to identify his left and his right (1969:108).
Strauss and Werner (1938) set up a battery of 13 items which would show deficiencies in the finger schema, on the basis that when one considers the normal functioning of the finger schema, one assumes an ability to articulate the fingers of the hand and to single out one or two fingers (1938:724). The items were constructed as follows:

1. **Body orientation; showing on command left or right hand, ear, eye, etc.** Copying crossed movements of Examiner (e.g. left hand on right ear, etc.)

2. **Pointing with open eyes at one finger of the left (right) hand on command; show me finger 1, 3, 5, etc.**

3. **Same as Number 2 with eyes closed.**

4. **Same as Number 3 with 2 fingers called in each trial.**

5. **Examiner touches one finger of S. S. (having the eyes closed) points at the finger touched. Left (right) hand.**

6. **Same as Number 5 with two fingers, touched successively in each trial.**

7. **Examiner touches one finger of S. (eyes closed). S. calls the number of finger touched. Left (right) hand.**

8. **Same as Number 7 with two fingers.**

9. **Examiner's and S's right (left) hand lie opposite each other. S. has eyes closed. Examiner touches one of S's fingers. S. opens eyes and indicates on Examiner's hand the finger touched.**

10. **Same with two fingers successively touched.**

11. **Right (left) hand picture drawn on the blackboard. Examiner touches one of S's fingers. S. has eyes closed. S. opens eyes, indicating in the picture the finger touched.**

12. **Same with two fingers.**

13. **Counting by fingers with closed eyes.** (1938:721)

Thurstone (1938) used a *Hands* test (no. 53 in a battery of 60 sub-sets of tests designed by the author to test Primary Mental Abilities) specifically to study visualising. He quotes its original purpose as:

> to involve visualising and kinæsthesia in nongeometrical and nonmechanical form.

(1938:54)

In the test the subject is shown a series of 49 pictures of hands – some right, some left – and is
asked to identify them as being right or left by putting a check mark (✓) in the square to the right if it is a right hand, and in the one to the left left if a left hand (1938:55). Taken in isolation it provides an examiner with an empirical measure of a subject's discrimination/awareness of right and left on a third person.

Benton, Hutcheon and Seymour (1951) constructed a battery of tests as part of a preliminary comparative investigation of finger-localisation and right-left discrimination in normal and defective children. The right-left discrimination battery consisted of a series of 18 items as follows:

- **Items 1-6** "Show me your left hand (right leg, left eye, right ear, left leg, right hand)."
- **Items 7-10** "Point to the doll's right leg (left ear, right eye, left hand)."
- **Items 11-12** "Touch your right ear with your left hand (left foot with right hand)."
- **Item 13** "Cross your left leg over your right knee."
- **Item 14** "Touch your right knee with your left hand and at the same time touch your left elbow with your right hand."
- **Items 15-18** Identification of "hands" number 4, 11, 19 and 7 in the "Hands Test" of Thurstone (1938, p.55). (1951:757)

The finger-localisation test battery was much larger by comparison and consisted of 60 items, as follows:

- **Items 1-20** With his hand visible to him, subject names fingers touched as examiner touches them in predetermined random order (ten trials each hand).
- **Items 21-40** With his hand visible to him, subject names and points to corresponding finger on a model as examiner touches them in predetermined random order (ten trials each hand).
- **Items 41-50** With his hand visible to him, subject names and points to corresponding finger on a model in the order touched as examiner touches two fingers in succession in predetermined random order (five trials each hand).
- **Items 51-60** With his hand visible to him, subject names and points to corresponding finger on a model as examiner touches two fingers simultaneously in predetermined random order (five trials each hand). (1951:758)
In a normative age-specific study on Right-left Discrimination, Swanson and Benton (1955) used a battery of twenty tests, which, after specifying them individually, were summed up as follows:

1. Six commands for identifying body parts with the eyes open.
2. Four commands for identifying body parts on a front view picture of a boy.
3. Four "crossed commands" with the eyes open (e.g. "Touch your right ear with your left hand").
4. Four commands for identifying body parts with the eyes closed.
5. Two "crossed commands" with the eyes closed. (1955:125)

In scoring the test, they found advantage in not only considering the Verbal Symbol score, (simply the number of correct responses made), but also used a Discrimination score, which was the number of consistent discriminations, disregarding the correctness of the labelling of "right" and "left". They noted, that using the Discrimination scoring method, there is a consistent growth in a child's discriminative capacity with increasing age level, for each performance; and that using the Verbal Symbol score, the result was nearly the same except for two minor reversals in the score between adjacent age levels (1955:128).

They also note that of the three types of tasks (discrimination of parts of one's own body with the aid of vision, discrimination of parts of one's own body without the aid of vision, and identification of body parts of a representation), the performances indicate little difference in difficulty between the two "own body" tasks; and so suggest that, since this present battery is shown to be heterogeneous, a revised battery might well be restricted to "own body" items, and a separate normative investigation might consider the "other person in space" in its own right (1955:132).

For the Right-left discrimination part of a study of 110 defective children, Benton (1955) used this same 20 item test. But in addition, for this study of defective children, he added a battery of tests to measure Finger Localisation. This battery of 50 items is a slightly abridged form of the one used by Benton, Hutcheon and Seymour (1951) and is as follows:

Items 1-20: With his hand visible to him, the patient names (or points to) single fingers which
have been tactually stimulated with the end of a pencil in predetermined random order; 10 trials each hand.

Items 21-40: With his hand hidden from his view, the patient names (or points to) single fingers which have been tactually stimulated; 10 trials each hand.

Items 41-50: With his hand hidden from his view, the patient names (or points to) pairs of fingers which have been subjected to simultaneous tactual stimulation; 5 trials each hand. (1955:584)

In order to test the child's ability to make right-left discriminations on own body parts, Belmont and Birch (1963) used two tests. One contained three items:

1. Raise your right hand.
2. Touch your left ear.
3. Point to your right eye. (1963:260)

and the other contained four items from the Piaget (1928) schedule:

1. Show me your right hand.
2. Now show me your left hand.
3. Show me your right leg.
4. Now show me your left leg. (1963:260)

In addition, each subject was asked to respond to a series of other questions derived from Piaget, concerning the awareness of right-left relations on other than their own body.
1.3 Major aspects of Handedness

Lack of knowledge concerning left-handedness springs rather from the multiplicity of studies and contradictory nature of the findings on the various aspects of laterality, than from any insufficiency of material on the subject. The absence of any single authoritative work and the extensiveness of existing material make a more prolonged study...than the average interested person is willing or able to make.

(Clark, 1957:v)

Koch (1933), in summarising a study of hand preference which used an exhaustive, questionnaire and battery of tests on a randomised group of college students, was only prepared to say:

...hand preference is a trait influenced by many variables among which are probably: instruction, example, convenience, obviousness of choice, previous habits, specific nature and familiarity of the tasks to be performed, hand strength, and genetic factors. (1933:217)

Palmer (1964) posits a differentiated perspective of handedness, and opens his paper with:

Research in the area of hand laterality too often has failed to contribute as fully and consistently as it might to the systematic, cumulative growth of knowledge. This failure can be attributed in large degree to limited theoretical perspectives involving (a) an excessive reliance upon empirical and pragmatic distinctions, and (b) a compartmentalized view of handedness which fails to recognize that handedness is rooted in more general aspects of motor and psychological development. (1964:257)

He further suggests that expressions of handedness and hand differentiation and lateralisation, are very probably multiply and complexly determined in their origins (1964:269).

Humankind seems to have become right-handed, and to have acquired speech and
language, at about the same time in evolutionary history (Blau, 1946; Cunningham, 1902; Wile, 1934; Wilson, 1876 & 1891). Penfield and Roberts (1974) go one step further and suggest that perhaps the reason why the human race is right-handed is one of chance which was then developed into custom and became further reinforced by laziness (1974:102). The literature is not able to reach a consensus on the various factors which determine the phenomenon of handedness, but certainly cerebral laterality (see 1.3.1 and Appendix A.2) presents some argument (though still not empirically proven) for cerebral dominance having an effect on physical laterality (see Appendix A.3). Also as presented in greater detail in Appendix A, the literature suggests that handedness is certainly determined by at least one if not all of:

- hereditary and familial similarities (see Appendix A.4);
- social and environmental pressures (see Appendix A.5);
- maturational development (see Appendix A.6).

In addition, the remainder of this section of the chapter will summarise the incidence of (see also Appendix A.8) and types of assessment for (see also Appendix A.9) handedness.

In the given allocation of both space and time for this part of the study, neither the summary of the literature presented in this chapter, nor the expanded review presented in Appendix A, attempts to synthesise the whole body of literature on the topic. Nevertheless the remainder of this chapter is an attempt to present as clearly as possible from within the topic of handedness, all that is specific and relevant to the experimental study which follows.
1.3.1 Cerebral Laterality: A Clinical Diversion and an Educator’s Perspective

Much I owe to the lands that grew -
More to the lives that fed -
But most to the Allah Who gave me Two
Separate sides to my head.

Much I reflect on the Good and the True
In the faiths beneath the sun
But most upon Allah Who gave me Two
Sides to my head, not one.

I would go without shirt or shoe,
Friend, tobacco or bread,
Sooner than lose for a minute or two
Separate sides of my head!

(Kipling, 1966:587- abridged)

The human brain can be seen to be divided quite obviously into two hemispheres. It has long been known that the body’s nervous system is connected to the brain in a contra-lateral fashion; i.e. the left hemisphere controls the right side of the body (right hand, leg, eye etc.) and the right hemisphere controls the left side (left hand etc.) Most clinical research indicates that in the brains of animals, the cerebral hemispheres are essentially symmetrical in purpose and function; but in humans it has been shown that there is a large asymmetry of function (although not so much of size, mass or volume).

Critchley (1961) says as far back as the early observations of Dax (in 1830) and Broca and Bouillaud (in 1860), scientists, in observing the effects of brain injuries or disorders in patients, have recognised the lateralisation of certain cerebral functions to one hemisphere only. It had become apparent that if a patient had suffered a stroke or an injury to the left side of the brain, this was more likely to cause an impairment or loss of speech, than if equal damage was done to the right side. The relationship between right-handedness and what was to be later called left cerebral dominance, was first established at that time.
In 1910, Aurobindo, a yogic philosopher (handedness apparently unknown) wrote:

The intellect is an organ composed of several groups of functions, divisible into two important classes: the functions and faculties of the right-hand; the functions and faculties of the left-hand. The faculties of the right-hand are comprehensive, creative and synthetic; the faculties of the left-hand critical and analytic . . . the left-hand limits itself to ascertained truth, the right-hand grasps that which is still elusive or unascertained. (Aurobindo, 1971:207)

Evidence found by Levy in her doctoral studies (1970) showed that the mode of processing used by the right hemisphere is rapid, complex, whole-pattern, spatial, and perceptual. She showed that its processing is not only different from but comparable in complexity to the left brain's verbal, analytic mode (Levy, 1970, in Edwards, 1979:30). Two years later she (Levy, 1972) quoted Broca (1960), Critchley (1962), and Hécaen (1962) as having shown that language resides in the logical, analytical and normally dominant left hemisphere, and Patterson & Zangwill (1944), Piercy & Smyth (1962), and Bogen & Gazzaniga (1965) as having shown the right, mute minor hemisphere was specialised in Gestalt perception, synthesis and creativity (1972:160). She (Levy, 1974) finally explains quite succinctly that the left hemisphere analyses over time, whereas the right hemisphere synthesises over space (1974: 167).

In reviewing the milestones in our knowledge and understanding of cerebral laterality and cerebral dominance, Edwards (1979) writes that as a result of the extraordinary findings through the late 1960's and 1970's:

. . . we know now that despite our normal feeling that we are one person - a single being - our brains are double, each half with its own way of knowing, its own way of perceiving external reality. In a manner of speaking, each of us has two minds, two consciousnesses, mediated and integrated by the connecting cable of nerve fibres between the hemispheres. (1979:31)

She helps to bring point to this observation, by summing up and giving examples. She says that the left hemisphere analyses, abstracts, counts, marks time, plans step-by-step procedures, verbalises, and makes rational statements based on logic - that a fairly typical
example of the use of left-brain thinking would be:

• Given the numbers a, b and c, we can say, that if $a > b$, and $b > c$, then necessarily $a > c$.

She goes on to say however, that we have a second way of "knowing" — that it is through the right hemisphere mode of thinking that:

• we "see" things that may be imaginary, that exist only in the mind's eye;
• we recall things that may be real;
• we see how things exist in space, and how the parts go together to make up the whole;
• we understand metaphors, we dream, we create new combinations of ideas;
• when something is too complex to describe, we make gestures that communicate (1979:35).

Dean (1982) quotes recent research which questions the longstanding assumption of an absolute link between overt left- or right-handedness and contra-lateral cerebral dominance, and even calls into question the whole idea of dominance of either one of the cerebral hemispheres. Satz (1973), Bakan (1978), and Ross, Lipper & Auld (1987) showed that birth complications lead to minor brain damage which may alter a child's hand preference and affect his/her mental and motor development (1987:615). Zarske (1987), in a wide-ranging review of cerebral laterality, says that although differences in cortical processing between the two hemispheres is acknowledged, in the light of today's understanding it is now considered less likely to be able to highly specify the localisation of functions within the brain (1987:298).

From our earliest days, we Westerners are fed an academic diet of the three R's and straightforward analysis, with just a sprinkle of art, music and literature; and when it comes to having scholastic development evaluated, we depend almost exclusively on written tests designed to measure verbal, rational on-time left-brained thinking. Nevertheless, there is another and oftentimes more effective way of thinking which calls upon the idiosyncracies by which the right hemisphere is now recognised. This style of thinking is intuitive, subjective, relational, holistic and time-free. Edwards (1979:35) writes about it thus:

*In the right-hemisphere mode of processing, we use intuition and have leaps of insight — moments when 'everything seems to fall into place' without figuring things out in logical order.*
Unfortunately this right-brained thinking is also the disdained mode, which in our culture has been generally neglected, ignored, or even despised by some, because

- you can't reason with it,

- it is at sequencing (it may start anywhere, or even take the whole lot on at once),

- it doesn't know about time-wasting,

- it sees things just as they are, and

- it is not any good at analysing and abstracting salient characteristics.

In fact, it is metaphorically "left-handed" with all the ancient connotations of that characteristic.

Aurobindo (1971), mentioned earlier, continues with his proposition of the dichotomy of intellect and its "two important classes" with:

Both are essential to the completeness of the human reason. These important functions of the machine have all to be raised to their highest and finest working-power, if the education of the child is not to be imperfect and one-sided. (Aurobindo, 1971:207)

Bogen (1975) puts that:

If our society has overemphasized propositionality at the expense of appositionality . . . it means that the entire student body is being educated lopsidedly. (1975:29)

It does seem that, although educators are increasingly aware of the need to encourage intuitive, perceptive, inventive and creative thought, the right brain – the dreamer, the artificer, the artist – is still virtually lost in our school system and remains largely untaught. Perhaps we should heed Thoreau (1941) when he wrote:

If a man does not keep pace with his companions, perhaps it is because he hears a different drummer. Let him step to the music which he hears, however measured or far away. (1941:287)
1.3.2 Incidence of Left-handedness

*But when the children of Israel cried unto the Lord,*  
*the Lord raised them up a deliverer,*  
*Ehud the son of Gera, a Benjamite,*  
*a man left-handed – shut of his right hand.*

*(Judges 3:15)*

Blau (1946), after an extensive review of the research on left preference to that date concluded that there was too much variety in the figures reported by different investigators (1946:32), and that in dealing with figures on the incidence of sinistrality, he was not able to find a single one which he considered to be authoritative (1946:85). There have been quite a number of surveys taken at different times through this century to establish empirically the incidence of left preference in general, and left-handedness in particular, as it occurs in either school children or certain parts of the adult population. It could be expected because of the widely differing types of samples taken in the reports of studies, that the incidence found could be fairly easily related to the population at large. Research shows that the incidence of left-handedness varies with sex, race, mental maturity and age; and although a review of the reports of left-handedness show many discrepant findings (see Appendix A.8), an attempt is made towards the end of that section to point out several possible reasons for this wide disagreement.

Recent studies have been consistent in identifying the incidence of left-handedness and its criterion for assessment lies within the limited range of 10% to 14% as the following three examples show. From a sample of 5,147 people (2,391 females and 2,756 males) drawn from a broad range of socio-economic categories from the United States and Canada, Porac and Coren (1981) found 88.2% (90.1% females and 86.5% males) were right-handed (1981:36). In the control group of four-year-olds in a study mentioned in Appendix A, Ross, Lipper & Auld (1987) found the incidence of right-handers to be 80%, mixed-handers 9%, and left-handers 11% (1987:618). Strauss and Goldsmith (1987) discovered the incidence of dextrals in their small sample of 51 undergraduates to be 86.3% (1987:498).
1.3.3 Handedness: Classification and Assessment

"A red Rod is held in the median plane, and the child is encouraged to make repeated efforts to grasp it."

With the shy...

... a sweet wrapped in coloured paper is sometimes more effective.

(Burt, 1958:272)

There have been many tests of handedness proposed and pursued over the past hundred years or so. In attempting to measure a person's own particular predilection for the use of one side or another, they have set out to examine amongst other things the steadiness of aiming, speed of tapping, strength of gripping, ability at throwing, writing, paper cutting, peg-board manipulating, balancing, mirror tracing, and other like skills. In most tests, the differentiation or measurement of dominant laterality (i.e. overt right- or left-sidedness) is usually based on either accuracy, speed, or strength, or a combination of two or even all of these three factors.

Van Riper (1935) queried the validity of previous sidedness tests which attempted to measure the preference of right- from left-sidedness. He showed that since they involve factors of accuracy, strength and speed, which are all subject to training, the tests really measure a learned skill rather than a natural disposition (1935:372).

Durost (1934) says that handedness tests should meet certain established criteria:

- be as objective to score as a good intelligence test;
- be simple and efficient to administer and quick to mark;
- have known reliability; and
- be valid as a comparison of achievement of the hands (1934:276).

Hildreth (1950) refines these parameters further and suggests that laterality tests must:
discriminate between extreme right- and left-handed groups;

have high reliability; and

show degrees of laterality if such exist. She also suggests that in clinical testing a battery of tests should be used, but nevertheless in all cases, two phases of laterality should be tested and observed. Namely:

(a) preference or choice of hand for unimanual acts, or the hand chosen for the dominant rôle in bimanual acts;

(b) the relative dexterity of the two hands determined by testing each hand in the same skills.

(1950a:90)

The number of variations encountered in the types of tasks expected, seems to suggest the need to select test tasks or measurements in terms of specific components based on analyses of the nature of the activity. i.e. the extent to which a particular test would mean that the subject had to plan, coordinate and control several actions at once. Bruml (1972) points out that the greater this demand on multiplicity of concept and function, the slower should be the developmental rise of a consistent behavioural pattern of preference, regardless of whether a task is attempting to measure "preference" or "skill" (1972:12).

As recently as 1970, Ammons and Ammons (1970:214) point out that there seem to be no well-validated or even conceptually adequate laterality scales – a point which is supported by Berman (1973) in his summary, when he suggests the reason why many studies are inconclusive and the total picture is still unclear may be the lack of a widely accepted, reliable series of laterality measurements (1973:604). As could be expected, he states that his particular piece of research, while not yet definitive, is an attempt to remedy that situation.

Appendix A (A.9) provides a comprehensive review of the more substantial studies of methods of assessment of hand preference (or dominant laterality or handedness) pursued throughout this century – some of the more recent of these attaining a high degree of reliability. In most tests, the measurement of overt right- or left-sidedness has usually been
based on either accuracy, speed, or strength, or some combination of these factors. All significant clinical studies have concentrated on the subject's preference in unimanual acts, and the degree of dexterity found by comparing the operation of each hand, whereas studies requiring a notional indication of the handedness of subjects were satisfied by the use of often a small battery of tests, which were either conducted by observation or by questionnaire, most of which still carried high reliability.

It is apparent that assessment batteries attempting to measure preference or skill can be and have been tailored to suit the purpose(s) of particular studies. As was earlier pointed out, Durost (1934) explained that a good laterality test should be time-efficient in being simple to administer and quick to mark, should be thoroughly objective and have known reliability and validity (1934:276). Although some carried sophisticated formulae for delivering a Handedness Score, the literature seems to support the simpler formulae as providing a most satisfactory result when assessing handedness under all but the strictest parameters.

The following section of this study focuses on studies which have been connected with music and musicians and briefly describes them in an effort to provide a more specific and pertinent background on the way handedness and left-handedness in particular effects practising and performing musicians.
1.4 Handedness in Music and Musicians

Many modern machines – the typewriter, for example – and several ancient instruments – like the harp, the piano, the violin – require as much speed or dexterity in the left hand as in the right: and, in everyday life, though civilization is rigid enough about some one-sided activities - for example, shaking hands - its practice is arbitrary in regard to others.

(Burt, 1958:316)

Only a very small number of articles correlating "left-handedness" and "music or musicians" are available in the literature and most of these seem to be concentrated on addressing handedness as it applies to music "achievement" and/or music "aptitude". However, some of the most recent studies look more specifically at the effects of various "laterality" or "cerebral dominance" characteristics and their relationship to musicians and musical abilities.

Including those already mentioned in the preceding sections of this chapter, the following nine research studies would appear to sum up all research connected with handedness as it applies broadly to music and musicians. They are presented in order in of publication starting from the first few in the 1920's and jumping to the larger group from ten to twenty-five years ago. In the light of current knowledge and research the earlier studies have a quaintness which can be easily identified with early attempts to understand the topic of handedness and musicians better. The more recent studies can be seen to make a more pertinent and realistic contribution to our understanding of the area.

Several of the studies are essentially concerned with hemispheric representation of music in the brain, and as such are only tenuously linked to the present experimental study, but are included for reasons of supporting the body of other medical and clinical knowledge already presented. Some others have direct references to musical performers, but unfortunately cannot be linked directly to the present experimental work. Nevertheless they again present a
supportive view of the questioning attitudes prevalent about left-handedness in musical performance.

1.4.1 Quinnan (1922) set up a study of a hundred each of musicians, iron workers and others. He had found that from a group of private patients, of the *sinistral* musicians (he used the words *sinistral* and sinistrality to designate partial rather than complete left-sidedness, e.g. left eye dominance and right or left handedness, and vice versa), some admitted to a tendency to bump into things, others admitted to a faulty sense of rhythm and finding sight-reading an embarrassment, and still others thought of abandoning their study because of their inability to make headway. He states that the observations of the patients initially seem to show:

(1) that sinistrals are especially prone to various forms of muscle incoordination, and

(2) that in some of these persons both the sense of equilibrium and the sense of rhythm are defective. (1922:352)

He used a simple peg-board test to grade the subjects' handedness, and invariably found (understandably) that right-handed people scored more with the right hand than with the left, and conversely left-handed people scored more with the left hand than with the right. He also showed that awkwardness was more characteristic of sinistrals, and pointed out that the results show that it is possible to diagnose established left-handedness by means of a simple test i.e. the pegging-board (1922:356).

Of the 100 musicians which Quinnan tested, 64 were string players, 18 played piano or organ, 10 played flute or oboe, and eight played trombone. He states that twice throughout the testing, he heard left-handed musicians remark that they "had to work hard" for their music, and from other conversations on the subject got the impression that they felt they had to overcome greater physical odds in acquiring technique than did dextrals. In support of this, he points to the fact that in the performance test, the average sinistral score is lower than the average dextral score, and says that such as it is, therefore, the evidence goes to show that muscle coordination is more highly organised in right-handed players (1922:357); and that left-handedness is a physical handicap (1922:358).

Quinan (1922) then pre-empts the findings of the 1960's when he says that there is
an intimate relation which appears to exist between left laterality and a type of mental organisation prevalent in musicians. He also makes an unfortunate statement for the world of left-handers that both left-handedness and sinistrality are indicative of the *psychopathic constitution* (1922:358) and that:

*a high proportion of left-handedness in any population is at least suggestive . . . of a peculiar susceptibility to the influence of music. Hence sinistrals feel drawn to the musician's vocation in spite of the fact that it is a vocation for which in many instances they are not well adapted.*

(1922:358)

He substantiates this with his findings that some of the subjects with left-sided dominance showed an inability to solve problems in rhythm, and four of those subjects could not play in perfect tempo. He says that they constitute a class of *square pegs* whose mental difficulties would merely be aggravated by *psych-analysis* (1922:359).

In summing up his findings, Quinan concluded that left-handed and sinistral musicians (which he found to be 32% of the total), unfortunately for the skills required in the execution of their chosen field of endeavour, were prone to various forms of muscle co-ordination (which he saw as difficulties) and also often exhibited a defective sense of rhythm (1922:360).

1.4.2 Henschen (1926) emphasises the role of the left hemisphere which he says mostly dominates in music, but indicates that a basic exception exists in some forms of instrumental music which require the use of both hands (as in the piano), or almost exclusively the left hand (as in the violin and cello), where he suggests that both hemispheres interact, or where even the right might predominate (1926:117).

Although music is only one small feature of this study, he finds time in summing up to make two interesting points about the psychopathic origins of music:

- First, the faculty of music is phylogenetically older than speech – in other words, in the evolutionary process, some lower forms of animals (i.e. than humans), have a musical faculty, e.g. birds to a high degree (1926:118).
- Second, the faculty of music is ontogenetically older than speech, i.e. a child begins to sing before s/he speaks (1926:119).
1.4.3 Quinan (1930), in reviewing his earlier testing, felt that he could show that sinistrals seemed in many ways to be more sensitive than dextrals, and that they were more idealistic in temperament (1930:35).

He then decided to note the relative numbers of dextrals and sinistrals to be found:

* in control groups of normal people;
* among persons engaged in certain vocations; and
* among persons with mental diseases (1930:36).

In fact he was able to show that nearly 13% of the art students in his experimental group were left-handed (as against 4% to 6% in the normal population, as other studies of that time showed), and that not only do many sinistrals become musicians, but more of them strive to become *artists*, or to become *ministers of the gospel*, than would be expected from the proportion of sinistrals in the population (1930:42).

He also conducted a follow-up investigation which attempted to find:

* the number of persons in the population at large who possess musical talent; and
* the H-E (handed and eyed) peculiarities of such persons (1930:42).

From a sample consisting of 590 dextrals and 225 sinistrals (making a total of 815 students in all), Quinan found that 28.7% of the sample played some sort of instrumental music, and that 23.8% of dextrals, and 41.3% of sinistrals could play the piano, which data he believed justified the conclusion that sinistrals have a quicker sense of harmony than dextrals, and that sinistrals therefore, more commonly than dextrals, try to express themselves through the medium of a musical instrument (1930:43). He further points out that:

* sinistrals are more musical in their tastes than dextrals;
* sinistrals, compared with dextrals, are more delicately constituted; and
* the perceptive faculties of sinistrals are perhaps more sensitive and impressionable than that of dextrals, and in some way this factor seems to determine the vocational trend to which attention has been drawn (1930:43).

In summing up the accumulated evidence drawn from this study, Quinan says that:

* about one quarter of the people who make up the general public are sinistrals (note again that Quinan's definition of sinistral refers to partial or mixed-handers as well as pure left-handers);
• under normal conditions, sinistrals tend to concentrate in certain (aesthetic) vocations; and
• among persons with mental disease, sinistrals are most numerous in the classes of patients known as psychopathic personalities (1930:46).

1.4.4 Farnsworth (1938), in a study of nearly 1200 children from first to fourth grades, reported in accord with Quinan that there is an appreciable tendency for the ability in music to be related to ability in art, and for both of these to be associated with better than average amounts of effort and adjustment to school and schoolwork; but reported in conflict to the findings of Quinan that these children showed more right-handedness (1938:91). Farnsworth does however question the significance of some of the handedness scores in his own testing, but dispels this by saying (again contrary to the findings of Quinan), that even here the differences are in what he suggests is the "proper" direction i.e. of aesthetic ability associated with right-handedness (1938:93).

In conclusion he states that the data give no support to the contention that children rated high in aesthetic abilities are more abnormal, sinistral or defective in speech than their less aesthetic peers (1938:94).

1.4.5 Wertheim (1963 and 1969), after extensive investigation of individual patients and a synthesis of the clinical literature relating to amusia (anything from a disturbance to full disintegration of the musical functions), makes valuable observations, not addressed to handedness specifically, but to cerebral laterality. He starts (1963) by pointing out that the musical function is a very complex one, that musical aptitude or the receptivity towards music is an inborn capacity of the human brain, that the development of musical ability is subject to wide variations amongst different people, and that this musical aptitude can be studied by reducing it to its:

five components:

(1) The ability to turn musical perception into emotion
(2) The rhythmic sense
(3) The sense of sounds (particularly "relative hearing" and "absolute pitch")
(4) The sense of musical intervals

(5) The agogical (variations of tempo) and dynamic sense. (1963:178)

He uses this outline as a basis for clinical analysis of patients, and further suggests that the prosodic (rhythmic/melodic) quality of speech seems to be a sort of intermediate transition between musical function and speech function (1963:179).

He administered a battery of 45 tests, which he divided notionally into two groups. viz:
• to test the receptive component he conducted 11 tests on the tonal, melodic and harmony elements, five on rhythm, and five on reading; and
• to test the expressive component, ten on singing/whistling, nine on instrumental performance, and two on music writing (1969:201).

From his own clinical observations and comparisons made from other researchers, Wertheim suggests that receptive (or sensory or agnosic) amusia corresponds to a lesion in the dominant hemisphere, while a lesion in the minor hemisphere may cause some forms of expressive (or productive or apraxic) instrumental and vocal amusia (1963:178). Thus, his findings accord with those of Henschen, when he considers that musical functions seem to have specific bilateral hemispheric representation (1963:179, 1969:203).

1.4.6 Oldfield (1969) found no dearth of decisively sinistral musicians, but found only one out of his sample of 129 who was clearly mixed-handed. However contrary to the findings of Quinan (1930) quoted above, he concluded that the occurrence of left-handedness among musicians is in similar proportion to the general population, and also that non-beginner left-handed musicians had no particular problem in acquiring executant skills. (More detail is presented on this aspect in section 1.5.2.)


Having defined mixed-handers as having to have Laterality Quotients between ±50
inclusive, Byrne, in accord with the earlier findings of Quinan (1930) and contrary to the earlier findings of Oldfield (1969), found an excess of mixed-handers amongst the 108 instrumentalists (right-handers: 66.5%; mixed-handers: 30.5%; and left-handers: 3.0%), but found that the proportion of mixed-handed singers was not significantly different from that of the mixed-handers of the unselected sample of university students (from 134 singers – right-handers: 76.0%; mixed-handers: 19.0%; and left-handers: 5.0%; from 864 unselected students: right-handers: 74.0%; mixed-handers: 21.5%; left-handers: 4.5%; comparing right- and mixed-handers amongst singers versus controls yielded $\chi^2 = 0.522, p > 0.10$).

In a second approach, Byrne tested all right-handed and mixed-handed subjects on the Seashore (1960) Timbre and Tonal Memory Tests (Timbre: 40.8 and 40.1 – maximum 50; and Tonal Memory: 18.7 and 17.9 – maximum 30), subjected these means to a t-test, found none of the differences proved significant, and concluded that the data supported a case for the independence of musical abilities and handedness (1974:280).

Apart from making a obtuse passing reference to woodwinds and keyboards (1974:279), Byrne does not specify what the instrumentalists in the study played. He actually uses this study to draw conclusions about bilateral language representation in the brain occurring at the expense of some right hemisphere functions (spatial operations) but not others (music) (1974:281).

1.4.8 Gates and Bradshaw (1975), in an investigation of hand coordination and brain hemisphere dominance of organists, suggest that left-right differences in bi-manual music performance may be more difficult to demonstrate than left hemisphere speech domination.

But in follow-up work done less than two years later (1977), in examining the cerebral control of musical behaviours in both clinical and normal populations the writers state that an investigation of mental abilities common to music and language points to left hemisphere control for certain aspects of temporal order, duration, simultaneity, rhythm, effector motor control, and categorical perception (1977:403). However they emphasise that there is ample evidence to demonstrate varying degrees of asymmetry for pitch, harmony, timbre, intensity and rhythm (1977:403). They further point out that each of us has a predisposition to
differential laterality effects i.e. we use more or less of a certain hemisphere for a given task, and that this might not be the same as the use by someone else, given that each of us has been trained differently or has adopted a different strategy for processing information. However they do point out that the way musical information is processed may be an important determinant of an individual's own hemispheric mediation, and that one hemisphere should not be regarded as dominant for music, but rather that each interacts with the other and operates according to its own specialisation (1977:403).

They further state:

Thus, the left hemisphere may take a greater role when the sequential and analytic aspects of music are more important; the right hemisphere may be superior when the sound gestalt is emphasised. (1977:404)

In substantiating this claim, the writers quote many clinical cases which show that left hemisphere dominance is proven, and is a direct result of speech, which arises from a basic specialisation for analytic processing or sequencing operations in the left brain (1977:408). They quote Krashen (1973) and suggest that since music and speech share the same kind or mode of processing, then the left hemisphere may be important for musical abilities which share properties with speech, such as temporal order, duration, simultaneity and rhythm. They further point out that:

Hemispheric control of such motor movements involved in music perception may depend not only on the left hemisphere (if articulation is controlled there for playing of brass and woodwind instruments) but also on the right (if the left hand articulation of pitch is controlled there for playing string instruments such as violin and cello). (1977:412)

1.4.9 Schleuter (1978), in outlining the reasons for his research, suggests that it might be possible that limb and eye dominance in combination with music aptitude levels have an effect on functional music achievement, particularly at the beginning levels of instrumental instruction. Apart from stating the obvious, that learning to play a musical instrument could be facilitated or hampered by physical characteristics and music aptitude, he also says that:

An exploration of the many possible combinations of certain lateral dominance variables and music aptitude levels with music achievement could yield important insights. (1978:23)
However, with his small sample of 104 students (from grades four, five, and six – learning flutes, clarinets, trumpets, french horns, trombones, percussion, violins, and 'cellos), he was not able to show conclusively that there was any correlation between these variables (1978:29). As a result he suggests that before definite conclusions are made the study should be replicated with other groups of students; that in future studies the sample should include a larger number of left-dominant subjects; and that a graded scale of hand dominance could be used (1978:30).

Schleuter does say that his results may be interpreted as showing that musical achievement, exhibited in initial stages of instrumental training, is more influenced by the music aptitude level of the student, than by handedness (1978:30).

1.4.10 Summary

By way of conclusion then, we have seen how Henschen (1926) was mainly interested in the dominant role of the left hemisphere for music processing. Wertheim (1963 & 1969) showed within studies of patients with musical dysfunction that music seems to be bilaterally represented in the brain, a point which Gates & Bradshaw (1975) confirmed and expanded to suggest that hemispheric mediation associated with music varies from person to person.

Quinan (1922) showed that in his sample of 100 the left-handers had a more difficult task in musical performance than did the right-handers, but later (1930) that the left-handers from his sample of 815 students were more musically sensitive, chose more aesthetic vocations and were more idealistic in temperament than their right-handed counterparts. Farnsworth (1938) reported positively on the strong correlation between musical and artistic ability in 1200 first to fourth grade pupils, but in conflict with Quinan's earlier findings on there being also a strong association with left-handedness.

Oldfield (1969) suggested that from his sample of 129 musicians he could not support the theory that accomplished left-handed musicians had any greater difficulty with execution on their instruments than their right-handed fellows. However Byrne (1974) found in accord with
Quinan earlier, but against Oldfield, that from his 108 instrumentalists there was a large proportion of mixed- and left-handers. And finally Schleuter (1978) suggested that the results from his 104 primary pupils may be interpreted to indicate that achievement in the early stages of musical training is more influenced by musical aptitude than handedness.

As suggested earlier, few research studies seem to have been written on the topic of handedness as applied to musicians, and although none of these studies seems to throw a specific light on the present experimental study, there are two that appear to be closely enough related to warrant a more detailed analysis.
1.5 Handedness and Misdirected Hands in Beginner Pianists

\[ \ldots \] the piano is the social instrument \textit{par excellence}. It is drawing-room furniture, a sign of bourgeois prosperity, the most massive of devices by which the young are tortured in the name of education and the grown-up in the name of entertainment. (Barzun, \textit{in Loesser}, 1954:viii)

The study by Bruml (1972), earlier mentioned in section 1.3.3 and appraised in Appendix A.9) comments in reporting on the peg-board task that, although the children (aged from six to ten) were allowed to start from anywhere on the board, two main patterns were popular:

1. on all four trials, regardless of hand, the child moves from left to right, with no reversals; and
2. the child starts from the right with his right hand, and from the left with his left (1972:8).

She then meticulously describes that:

• the two patterns occurred equally in kindergarten (average age six) with 36% : 38%;
• pattern one is more popular in second grade (average age eight) probably because of the emphasis on left-to-right movement in writing – 43% : 29%; and
• pattern two is overwhelmingly more frequent in grade four (ten year olds) with 23% : 55% (1972:8). She says the data seem to show that the two directions of movement seem to be progressing towards equivalence, with changing age, and that it is obvious then that any confusion of directioning of hands in young children becomes ameliorated with age and experience (1972:9).

The nearest piece of research which touches on the specific topic of relating handedness to a music keyboard was done in Edinburgh by Oldfield (1969) by means of a \textit{Questionnaire} (and a \textit{Handedness Inventory}) which looked at the prevalence of left-handedness among musicians (129 students and staff – 57 males, 72 females – in two university schools of music – no specific instruments listed, but reference is made to \textit{recorder, violin, keyboard, percussion and conducting}), and the difficulties experienced by the players in
acquiring executant skills (1969:91). It was found that left-handedness was neither less nor more common in the group of musicians studied than in a population of psychology undergraduates, and it seemed that left-handedness did not, in general, occasion any special difficulty, i.e. that the left-handers adapted successfully to the "right-handedness" of their instruments, the only substantial connexion in which left-handed practices were retained being in conducting (1969:91).

Oldfield suggested on the basis of these findings that:

"right-handedness" is less a matter of superior inherent "dexterity" or the capacity for agility, precision and speed in the right hand than of closer, more immediate availability of the right hand as the instrument of the individual's conceptions and intentions. (1969:91)

He also stated, in general discussion of the findings, that keyboard instruments represent a special case inasmuch as right-handed players must deliberately exercise the left hand to ensure adequate facility and control of power (1969:95) – but he did not suggest or include the reverse argument about left-handers. He further said that since the rôle of the left hand is usually a subordinate one of accompaniment, and since greater agility is required of the right by most composers, to this extent left-handedness does entail a handicap – as one or two of the strongly sinistral subjects had remarked (1969:95).

He also pointed out that his findings showed there is no proportional shortage of left-handers among musicians and said (interestingly enough for the present study) that he felt this implied that there was no great or widespread difficulty experienced in reversing the "dominant" for "non-dominant" hands in musical execution (1969:94).

This could possibly be the case with advanced/accomplished musicians as the above study had used, but it is not to say that the beginner piano player will not experience some or great difficulty in elementary execution. Oldfield (1969) had earlier made the point that left-handedness in musical performance is a handicap, but had qualified that statement by
suggesting that the piano was a special case which required special exercise of the left (non-dominant) hand for effective performance (1969:95).

Apart from the lack of direct relevance to beginner left-handed piano players (as the present study requires), the Oldfield study contains a weakness, in that in order to assess the handedness and difficulties in performance skills on their instruments, subjects were tested only on the basis of a questionnaire. It is not valid to assess practical skills by a self-report questionnaire, so for the purposes required in the Oldfield study, the self-reporting procedure must carry doubtful validity, in that the skills (or difficulties encountered in acquiring executant skills) were not actually observed and tested by an examiner.

However more can certainly be learnt and explored about the difficulties experienced by the beginner, particularly the left-hander, at the keyboard.
1.6 Pertinent new contribution

Nevertheless, anyone who has puzzled at all deeply over the personal aspects of his art knows the rich complexity of the problems he encounters and the relative uselessness of broad distinctions. If one's own intuitions do not rebel, then the facts of history afford proof against too facile thinking. (Schultz, 1936:vii)

As the previous section indicated there is a paucity of studies which address the area of handedness as applied to practising musicians, and it possibly comes as no great surprise that since piano playing is seen as a bi-manual task, i.e. that the two hands perform in essentially the same fashion, the bias of handedness is not expected to interfere too strongly — if at all. However a search through available research studies reveals none that are directed at the beginner piano player from the perspective of his or her handedness.

Returning to the starting point of this study, it is highly likely (because of the incidence figures purported in the literature for those times) that the keyboard was originally designed by a right-handed person, and that the resultant representation of upward pitch movement to the right in the horizontal plane favours the right-handed player and disadvantages the left-hander. It then goes without saying that if this right-handed bias of the keyboard has any effect at all on a left-hander it will be at the beginner level rather than after several years of practice, and since this is at the conceptual level rather than the physiological level it may be less readily observed and will be a lot more difficult to measure than a simple test of handedness. However an attempt is made in this study to start investigations into this area.

The literature on piano playing pedagogies in particular seldom presents more than a paragraph or two devoted to the specialised area of remediation for the left-hander (Schultz, 1936; Terwilliger, 1965; M.E.N.C., 1967; Gerig, 1985; Bailie, 1988). A great deal of treatises have been written about the dexterity expected of the right and left hands, and the balance which must be created between them for expressive control and interpretation
(Brée/Leschetizky, 1902; Matthay, 1903; Breithaupt, 1909; Matthay, 1911; Ortmann, 1925; Whiteside, 1929; Schultz, 1936; Whiteside, 1955; Ortmann, 1981; Maier, 1963; Sienczynska, 1976; Newman, 1984). But apart from an occasional passing comment recognising that a left-handed piano player might need to exercise his right hand more to match the more inherent finger facility of the right-hander, it has not been possible to locate any study which addresses specifically the left-hander's possible confusion and resultant misdirectioning of hands. This finding comes as no great surprise since social awareness of Left-handedness during the genesis of the Fortepiano and the subsequent rise of the Pianoforte through until the turn of this century was almost nil and even when recognised, Left-handedness was not regarded as being socially acceptable – full social acceptance not coming until the latter part of this century.

This present study could then be seen as taking a first step to remedy this void, and makes recommendations as to further studies which could be pursued on this topic. As Clark (1976) puts it when summing up Teaching Left-handed Children:

Left-handedness has its disadvantages in a right-handed world, but even some of these disadvantages are slowly being rectified as machines are being produced with adjustments for use by left-handed operators, and as even scissors, potato peelers and tin openers have become available for left- as well as right-hand use. (1976:45)

Unfortunately for the left-hander, the reversal of a piano keyboard is never going to be a reality for the number of valid reasons already presented. We cannot hope to look forward to the sorts of changes in the construction of piano/organ/synthesiser keyboards that Clark has cited above for adjustments to various mechanical devices. Piano-teachers will have to keep correcting, drilling and setting supportive "remedial" exercises for those left-handed children who come their way, because the acceptance of our present day musical keyboard is another prime example of the minority group of left-handers in our society having once again to conform to the majority, with the associated traumas or otherwise of bending their minds to accept right-handed concepts and constructs. It is therefore the music educator's rôle to ensure that the left-hander is accommodated and settled as successfully as possible into the right-handedness of one of the most beautifully expressive of all instruments.
Chapter 2

Description of Investigation

Symmetry is a human concept, because with all our irregularities we are more or less symmetrical and the balance of a mantelpiece by Adam or a phrase by Mozart reflects our satisfaction with our two eyes, two arms and two legs.

(Clarke, 1969:202)

2.1 Sample

The purpose of this study is to focus more closely on the beginner piano player and the misdirectioning of hands which may be exhibited to a greater or lesser degree by the left-hander.

Several points, specifically to do with selection and availability of subjects for deciding sample size and the inclusion/exclusion of control groups, had to be borne in mind when deciding upon a viable research design. They were:

• limitation of choice of subjects to finding left-handers; and
• availability of beginner piano players.
2.1.1 Selection of Subjects

In order to test for left-handedness, only one simple handedness test was used in the present study – writing. Notwithstanding the variety of previous studies on left-handedness and its assessment the writer chose the exclusive use of this quick and simple test upon two grounds:

• its importance *per se*; and

• it is the most reliable single measure.

The importance of the hand used in writing as a criterion for dividing populations accords well with the conclusions of Annett (1970), when she says:

*Writing discriminates as effectively as any other action...* (1970:316).

Also Deutsch (1978) corroborates this point when she states:

*The present criterion for dividing populations into right-handed and left-handed groups correlates highly with the hand used in writing.* (1978:560).

It might be anticipated that the subjects in this experiment would be more naturally left-handed in comparison with subjects of studies conducted several decades ago, or with those carried out on an older age-group of the population, because of the more tolerant attitude in today’s society towards left-handedness, i.e. the resultant absence of teacher/parent/social pressure on the hand used in writing, and the little or no social stigma currently attached to a person’s writing with the left-hand, and so it is expected that the results of this study would give a stronger indication of difficulties from left-handedness than would have been possible several decades ago.

Most of the recent empirical studies indicate that left-handers represent about 10% of the total population of school children (Bruml, 1972; Enstrom, 1962; Ross, Lipper & Auld, 1987; Schleuter, 1978; Strauss & Goldsmith, 1987). With this incidence figure in mind, the selection of a topic which called upon a sample of left-handers from the population was recognised as already narrowing the potential pool of subjects by a factor of approximately ten.

However there was no specific population study to give an indication of how much the
second parameter of beginner piano player status would be expected to narrow the potential pool of subjects. From personal experience as a teacher of piano for more than twenty years the proportion seemed to be more in the order of tens than units.

Normal piano instruction begins with the hands being treated separately and the fingers of the separate hands being played individually. Within the first few weeks of learning and practice the student is encouraged to read the elementary notation and to practise playing with separate hands only. This stage corresponds to the first few pages of tunes or exercises in most current piano instruction methods (Baker, 1984; Bastien, 1985; Brandman, 1982; Brimhall, 1977; Burnam, 1974; Fletcher, 1950; Hyde & Thompson, 1978; Kaschau, 1969; Stecher, Horowitz & Gordon, 1957; Thompson, 1954).

The next elementary stage is the use of both hands to play in similar and contrary motion, within the traditional “five finger position”. This stage of learning can continue for the next six months and is largely dependent upon the pupil's motivation and amount of progress.

Having conducted a small pilot study using a small sample of only eight subjects (four left-handers and four right-handers from a pool of 38 children), the writer found that the time when the confusion of misdirecting or misdirectioning of hands was most noticeable was when the hands were put together for the very first time. So for the purposes of this study, the most appropriate time to test a subject for an observable confusion seemed to be within the first six to eight weeks of instruction and practice. It was expected that in that short period of time the pupil would have started to come to grips with pitch and rhythm notation and so would not have to be taught every simple step, yet would still be in a naive and elementary stage of skill development and understanding, and as such would still be exhibiting true “beginner” tendencies.

Notwithstanding the potential difficulties in finding an adequate number of subjects, a further attempt was made to limit the variations in the characteristics of the subjects, and so to more accurately test the hypotheses, by imposing a further criterion for selection, in that they
should be aged approximately eight years. This age was decided upon for two reasons:

- a normal child at this age is able to competently identify left and right on his/her own body. Binet and Simon (1908) showed that mostly at age six and conclusively at age seven a child is able to identify right and left on his/her own body; Piaget (1928) confirms that most children at age six can pass a simple test of right-left discrimination on their own body parts; and Belmont & Birch (1963) showed that 95% of children above the age of seven years make correct responses in identifying the lateralisation of their own body parts; and
- the most popular age of children starting to learn to play piano seems from personal experience to be around seven to eight years.

There was a minor deviation from this general guideline in selection of the sample of subjects. Although every attempt was made to select eight year olds, the final selection of Left-handers contained a beginner ten year old and a seven year old, because as was earlier mentioned in detail the time-scale and geographical base over which this study was undertaken barely allowed sufficient latitude in the sense of finding potential subjects who fitted the two parameters of being both eight year olds and beginners at the piano. Even in the light of this small change, however, there was never any question about including these subjects as part of the sample for the experimental part of the study, because as Benton and Menefee (1957) found, from a study of the association between right-left discrimination and the degree of unilateral hand preference in five to nine year olds:

*Variations in chronological and mental age did not affect the size of the relationship...*  
(1957:241)

On the basis of this finding, it seemed unlikely that the slight age difference in the subjects would have any substantial effect on the validity of the data or results.

Inevitably the task of searching for ten left-handed beginner piano players at approximately age eight was a matter of some concern, but the goal was eventually realised. Fortunately, the nature of the experimental study was individual-subject based, which meant the search for a subject could be conducted over as broad a period of time as was necessary until the ten left-handed beginner piano playing subjects were found.
2.1.2 Sample size

In a study of this nature, it would be customary to select two random samples of subjects from each group type, i.e. one randomly sampled "experimental" group (for treatment) and another randomly selected "control" group (no treatment) for each of the types to be tested (in this case for each of the left-handed and right-handed types).

A limiting factor in both issues about selection (sample size and randomness of selection), was the potential difficulty of finding sufficient left-handed beginner piano players at approximately age eight. Finding right-handers, because they were anticipated to be found in the approximate ratio of somewhere between 14:1 and 10:1 compared with left-handers, was expected to pose much less of a problem.

However the selection of two samples of each of left- and right-handed groups of even the recommended minimal size of 10 presented an enormous problem when considering the potential difficulty of finding 20 left-handed beginner piano students. Since this meant gaining ready access to somewhere around 200 beginner piano player subjects, it was considered a task of unnecessary magnitude in its demands of time allocation, geographical scope and associated resources, to meet the needs and scope of the current study.

With all the above constraints being taken into account, a minimal sample size of a group of 10 left-handers and another of 10 randomly selected right-handers was used for this experimental study, and was considered to be adequate to show the process of the research.

In real terms the difficulty of locating somewhere near 100 beginner piano students in the local population of school children was great. It was possible through the support of the Wollongong Branch of the N.S.W. Music Teachers' Association to gain direct access to piano playing beginners from a large number of private piano teachers within the Greater Wollongong area and the southern part of the Campbelltown district of Sydney, N.S.W. Even from this large population of more than 250,000 it was necessary to test 96 potential beginner piano playing subjects for handedness before finding the tenth left-hander, in the period of just over a year and a half in which the data for this study was being collected.
2.1.3 Randomness of selection of groups

As suggested above, it was not possible, within the time and resources allocated to this study and because of the limited availability of subjects, to take a random sample (in an experimentally controlled sense) of Left-handed beginner piano players. However the selection of Left-handers for the group was random to the extent that it contained the chance allocation of the first ten left-handed beginner piano students available by accident of timing from within a geographical radius of 50 kilometres.

The limitation of a control group to a comparison between left-handed and right-handed subjects without a second non-treatment group does not necessarily undermine the validity or usefulness of the study. Tuckman (1978), for example, argues that the absence of a control group gives minimal concession to validity (1978:135). This study is then presented as a comparison of the observable confusion of directioning and misdirectioning hands anticipated to be evident in left-handers but not in right-handers, without the sophistication of a control group for each of the two groups of left- and right-handers.

As the search for ten left-handed beginner-piano-playing subjects was being made, at the same time from the remaining pool, a list of potential right-handed subjects was being compiled. This list was essentially time-based, in that subjects were not sorted for example into an alphabetical list of surnames, but were simply listed as found in time. The eventual group of ten right-handers was then selected on the basis of a table of random numbers. Of all 86 right-handed beginner piano players found in the search for the ten left-handers, the ten right-handers randomly selected by this process were numbers: 17, 19, 22, 27, 36, 46, 59, 65, 68, and 84 of those considered.
2.2 Research Design

This study predominantly uses as its basis the "Pre-test Post-test Control Group Design" (Campbell & Stanley, 1967; Sax, 1968; Tuckman, 1978), which can be represented as:

Experimental group(s): \[ R \quad O_1 \quad X \quad O_2 \]
Control group(s): \[ R \quad O_3 \quad O_4 \]

where: for the Experimental group R indicates the group is randomly selected, \( O_1 \) represents the scores on the Pre-test or First Observation, \( X \) is the treatment applied, and \( O_2 \) represents the Post-test or Second Observation; and for the Control group R indicates the group is randomly selected, \( O_3 \) represents the scores on the Pre-test or First Observation, there is no treatment \( (X) \) to be given, and \( O_4 \) represents the Post-test or Second Observation. Tuckman (1978) says that this design, by the utilisation of of a control group, controls for all the simple sources of invalidity (e.g. history, maturation, and regression), and by its random selection of Subjects controls for selection and mortality (1978:132). He warns that by using a Pre-test, that there is no control for a testing effect (a gain on the Post-test due to the experience on the Pre-test) which may reduce internal validity; nor is there any control for the possible sensitisation to the treatment that a subject might gain by having the Pre-test experience, thus affecting external validity (1978:132). It therefore controls many threats to validity or sources of bias, but by virtue of its use of a pre-test it does not control for the testing sources of invalidity (both simple and interactive) that may have some effect on a study (1978:132).

However, as Tuckman (1978) says:

*The real educational world, i.e., that world confronting the educational researcher, is fraught with real limitations upon the researcher's ability to assign subjects or manipulate conditions.*

(1978:137)

He further says that in order to present a workable solution researchers find they can but:

*carry experimental control to its reasonable limit within the realities of a particular situation.*
As pointed out in 2.1.2, the difficulties in selection of subjects were limited by not using a "non-treatment" control group and by thus using a simpler form of this design, namely the "One Group Pre-test Post-test Design" (Campbell & Stanley, 1967; Sax, 1968; Tuckman, 1978), for the Right-handed sample. Although as Tuckman (1978) says, this design falls short of handling sources of internal validity, it nevertheless provides some information about selection because the pre-test describes the initial state of the selected subjects (1978:129). Also, in this present study the concerns raised about testing effect and sensitisation are negated by the fact that the treatment ($X$) is an exercise routine which embodies those tasks set in both the Pre-test and Post-test.

The paradigm for the design of the Right-handed group is therefore:

Right-handers: $R \ \ O_{1R} \ \ X \ \ O_{2R}$

where it can be seen that the group is randomly selected ($R$); is given a pre-test ($O_{1R}$); receives the treatment ($X$); and is given a post-test ($O_{2R}$). (More detail will be given later on the design of the pre-test, treatment and post-test.)

For left-handed beginner piano players the same design was used except that the group was not randomly sampled in an experimentally controlled sense. However, the selection was random to the extent that it contained the chance allocation of the first ten left-handed beginner piano students available from within a geographical radius of 50 kilometres.

The design for the left-handed group therefore became:

Left-handers: $[R] \ \ O_{1L} \ \ X \ \ O_{2L}$

where as can be seen the group is formed by "qualified" random selection i.e. self-selection by accident of timing [$R$]; given a pre-test ($O_{1L}$); receives the treatment ($X$); and is given a post-test ($O_{2L}$).
So in order to test the first hypothesis, namely:

A left-handed child in the early stages of learning to play a musical keyboard instrument will exhibit (when reading notation) more misdirection of the appropriate left or right hand as indicated by the music, than a right-handed child;

and expressed as a combined study, the paradigm for this stage of the research design then becomes:

<table>
<thead>
<tr>
<th>Left-handers:</th>
<th>[R]</th>
<th>$O_{IL}$</th>
<th>$X$</th>
<th>$O_{2L}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right-handers:</td>
<td>R</td>
<td>$O_{1R}$</td>
<td>$X$</td>
<td>$O_{2R}$</td>
</tr>
</tbody>
</table>

where the two groups are recognised as being not strictly equivalent as shown by the dashed line between them (Tuckman, 1978:138); both groups are observed in a pre-test ($O_{1L}$ and $O_{1R}$ for Left- and Right-handers respectively); both receive the same treatment ($X$); and both are again observed in a post-test ($O_{2L}$ and $O_{2R}$).

From the information gained in the pilot study, the writer decided to include a further and later observation into the design by extending the time base for the major study in order to test the first hypothesis further over time. This decision was arrived at because of another personal observation that after a fairly short period (typically six months to a year) of fairly normal instruction and coaching on the keyboard, left-handers who initially exhibit a confusion with directing of hands, although they are less likely to make obvious errors in this respect, nevertheless still seem to make a larger number of mistakes than right-handers.

So it was considered worthwhile to re-test after such a period of time in an effort to collect data relating to the second hypothesis, namely that:

A left-handed child, even after a period of early tuition, consolidation and practice on a musical keyboard instrument, will still exhibit (when reading notation) greater misdirection of the appropriate left or right hand as indicated by the music, than a right-handed child.

This on-going period of tuition and practice was expected to extend over a teaching period of some six to eight months and is expressed as $P$ in the extended research design.
With this third observation adopted and integrated into the study, the paradigm for the final research design then becomes:

**Left-handed group:**

\[ \text{[R]} \quad O_{1L} \quad X \quad O_{2L} \quad P \quad O_{3L} \]

**Right-handed group:**

\[ \quad R \quad O_{1R} \quad X \quad O_{2R} \quad P \quad O_{3R} \]

Both groups are observed in the same Pre-test \((O_{1L} \text{ and } O_{1R})\); receive the same first structured treatment \((X)\); are each observed in the same First Post-test \((O_{2L} \text{ and } O_{2R})\); then continue with their ongoing normal tuition and practice \((P)\); and are observed again on the same Second Post-test \((O_{3L} \text{ and } O_{3R})\).
2.3 Construction of Tasks

Traditional elementary piano method courses (Baker, 1984; Bastien, 1985; Brandman, 1982; Brimhall, 1977; Burnam, 1974; Fletcher, 1950; Hyde & Thompson, 1978; Kaschau, 1969; Stecher, Horowitz & Gordon, 1957; Thompson, 1954) use two sets of parameters as part of basic piano instruction, namely:

• similar and contrary motion/direction; and
• hands separately and together.

The four variations possible using a matrix of these directional parameters are:

• separate hands playing in a contrary direction;
• separate hands playing in a similar direction;
• hands together in contrary motion; and
• hands together in similar motion.

As part of a smaller pilot study to investigate the feasibility of this larger work, the writer constructed a set of eight simple exercises to highlight the confusion or misdirection of hands—using the above matrix and based on his experience with piano teaching pedagogies and the experience of other respected teachers of piano. The eight individual tasks designed for a 6-week beginner, have been altered slightly from those used in the pilot study in order to focus more clearly on the particular parameters set for each particular task, and as finally constructed, allowed for the comprehensive testing required from this inquiry. The following is the resultant test instrument (see Appendix D for music notation), from which was gathered the data which constituted each complete observation for each subject:

• Task 1: A separate right hand phrase then left hand phrase in contrary direction;
• Task 2: A separate left hand phrase then right hand phrase in contrary direction;
• Task 3: A separate right hand phrase then left hand phrase in similar direction;
• Task 4: A separate left hand phrase then right hand phrase in similar direction;
• Task 5: Two hands initially together in contrary motion then separating to right hand then left
• Task 6: Two hands initially together in contrary motion then separating to left hand then right hand phrases (still in contrary direction);

• Task 7: Two hands initially together in similar motion then separating to right hand then left hand phrases (still in similar direction);

• Task 8: Two hands initially together in similar motion then separating to left hand then right hand phrases (still in similar direction).

In devising the eight tasks, it can be seen that the writer used each of the four variations of the directional parameters twice – the first task of the pair being initially taken with the right hand and the second with the left. The writer considered randomising this right/left occurrence of the tasks but felt that the support given by the regularity of right then left would lessen the effect of any chance extraneous right/left confusion, and so allowed the testing instrument to remain in that regular order to measure more exactly the specific confusion addressed in the topic.

It will also be noticed that each pair of right/left contrary direction/motion tasks (whether hands separately or hands together), is followed by a balancing pair of right/left tasks in similar direction/motion. Two principles were set in the design of these tasks, in that a conscious attempt was made to ensure that:

• all tasks used hand movements that were as similar as possible in structure (in the contrary direction/motion tasks they were mirror reverse; and in similar direction/motion they were played by the same note-names at the octave); and

• the handed pairs (right/left) of tasks and the directionally different (contrary/similar) tasks were as near as possible to equivalent difficulty. It was not felt necessary (nor was it feasible) to make the four hands separately tasks equivalent in difficulty to the four hands together tasks, since attempting to make this equivalence would weaken the challenge of those tasks and give a false impression of the coordination difficulties normally encountered when hands are put together.
2.4 Testing Procedure

Since the children tested were beginner piano students of only a few weeks, and some of them were not completely conversant with the position that their hands should be placed in at the keyboard, a need was apparent from the pilot study for the subjects to be provided with a hand placement diagram (see Appendix E) for each of the two different positions (left hand only) covered in the eight tasks. These diagrams (the actual page of the relevant beginner piano book was used during the assessment procedure) were only used if the subject suggested s/he was unsure of the correct position for the hands. They were found to be of genuine assistance to those subjects requesting their support, and eliminated one possible area of initial confusion because of ignorance or poor acquaintance with the keyboard layout. This had a direct and precise impact on the collection of data for the study in that the left/right directioning confusion was tested more accurately.

Another small difficulty which occurred with only some of the very beginner subjects was their insecurity and unfamiliarity with musical notation. The importance of this as far as this study was concerned was only slight, but those subjects experienced some small difficulty with pitch notation on the staff. It was very evident that in their learning of piano up until this point of time (i.e. the testing for this study), the written music had always carried the support of fingering above all or at least some of the notes. The writer found that with those subjects therefore, he had to write in some fingering, in order to help them feel more comfortable with the tasks.

Apart from the above, no other form of assistance was given to any of the subjects whilst being assessed.

The assessment of each individual subject was conducted:
• without any attempt from the examiner at correction or corrective comment;
• at a different time in the week from, and in addition to, the subject's normal lesson time, to preclude any additional chance learning of the tasks; and
• in isolation from any other potential subjects, to guard against vicarious learning.
For the purposes of this study only errors or mistakes of pitch or pitch direction were recognised i.e. rhythmic errors and other mistakes considered superfluous to the study were not counted. This had the effect of isolating and focusing on the immediate problem – the confusion of the directing or directioning of hands – and of excluding extraneous mistakes. Two separate sets of scores were recorded for each task by each subject as a result of any errors made (each error or mistake being given a score of one). The two categories (one a sub-set of the other) for the purpose of scoring were:

- All (non-rhythmic) Errors – any non-rhythmic error occasioned in any hand (whether incorrect notes or then corrected); and
- Incorrect Hands mistakes – only mistakes of confusion or misdirectioning of hands – where the wrong hand attempts/continues to play in any direction (but not where the correct hand plays in the wrong direction). These mistakes, by virtue of their type, are a sub-set of All Errors and are also non-rhythmic. The joint term errors/mistakes is used from here on to indicate the above differentiation between All (non-rhythmic) Errors (which are simply referred to as errors), and Incorrect Hands Mistakes (which, by representing a different kind of incorrect response, are more commonly referred to as mistakes).

From the experience gained from the pilot study, observation and recording of the scores on assessment tasks was found to be best accomplished by making notations on copies of the written musical score sheets. These sheets became the assessment/observation schedule and allowed quicker, easier, more exact recording of errors/mistakes being made by the subjects. The use of such a schedule simplified the assessment of a subject's performance and was an additional attempt to ensure the correct testing of the specified task(s).

For the Pre-test ($O_{1L}$ or $O_{1R}$ – representing the First Observation for Left-handers and Right-handers respectively) each subject was required to play through the battery of eight tasks, and the assessor noted the errors/mistakes being made, and made special note of the mistakes of misdirection of hands.
For the following three days, each subject was allowed the same one practice effort at the tasks (X), and no attempt was made by the assessor to correct obvious mistakes in the child's misdirectioning of hands. (This "treatment" was timed at fifteen minutes and occurred on three successive days to enable the subject to feel s/he had some sort of acquaintance with, or mastery of, the music – so that any errors/ mistakes which were made in the testing on following observations could not be attributable to "sight-reading" errors.) Then on the fifth day the child was again tested on the battery of tasks and another record kept of errors/mistakes made (O_{2L} or O_{2R} – representing the Second Observation for the Left-handers and the Second Observation for the Right-handers respectively).

After both the Pre-test (O_{1L}/O_{1R}) and the Post-test 1 (O_{2L}/O_{2R}) observations were made, a period of some six to eight months was allowed to elapse. During this time the student's own piano teacher taught the student as usual and used technical studies and tasks as necessary for his/her development, and incorporated into the normal course of teaching (as is usual), any remediation thought necessary at the particular time (P representing practice). After this amount of time, the Post-test 2 (O_{3L} or O_{3R} – representing the Third Observation for the Left-handers and the Right-handers respectively) of the students' performance was made.
Chapter 3

Analysis of Test Results

Poor little sucker, how will it learn
When it is climbing, which way to turn.
Right – left – what a disgrace
Or it may go straight up and fall flat on its face!

(Flanders, in Gardner, 1979:53)

3.1 General issues involved in Analysis

3.1.1 Categories of Errors/Mistakes

As was mentioned in the previous chapter, raw data (errors/mistakes of pitch or pitch direction only) were collected under the two categories of:

- All (non-rhythmic) Errors; and
- Incorrect Hands mistakes.

The choice was made to ignore rhythmic inaccuracies in all performances and to consider only errors/mistakes of pitch and pitch direction, in an attempt to restrict the number of variables, and so to isolate and focus on the immediate problem – the confusion of the directing or directioning of the Subjects' hands. So because rhythmic correctness or incorrectness of Tasks and the ensuing musicality of the performances was not assessed, these features are not evident from the results presented. However, the assessor did note on the individual assessment schedules (when possible) these inaccuracies.

By way of comment on these notations, a fairly common rhythmic error and one not in
any direct way related to the purpose of the tasks occurred in the \( \frac{3}{4} \) tasks (Tasks 3, 4, and 5, which involved hands playing separately in similar direction, and hands together in contrary motion then separately). Some subjects would invariably pause at the end of each bar, and by holding on to those note(s), would turn a crotchet (1-beat note) into a minim (2-beat note) etc., and so in effect played those tasks in \( \frac{4}{4} \) time! This apparent increase in rhythmic confusion, especially in the Left-handers, occurred mainly when the hands were being played together. Therefore because there is no indication that they are mistakes tied to a hand, they were not considered specific or relevant to this study. In addition there were some other unrelated rhythmic inaccuracies (only some of which were noted on the assessment form) which seemed to occur more often in performances by Left-handed subjects. (However, from the information available, had it been the purpose of this study to recognise these types of errors as real data for assessments, the scores from seven of the Left-handed and three of the Right-handed subjects would have been much higher i.e. their performances much poorer).

3.1.2 Groupings of Tasks

All data collected on errors/mistakes is analysed throughout this chapter on a standard range of nine different groupings of Tasks. These groupings present a variety of individual and composite combinations of the four possible variations of the basic directional parameters mentioned in the previous chapter (hands playing separately and/or together in contrary and/or similar direction/motion) and one summative grouping, and are intended to highlight the particular qualities of certain tasks rather than taking each of the tasks for analysis individually.

The results of the data are presented throughout this chapter in table form (Tables 1 – 6b), and for this purpose each of the nine groupings of Tasks is referred to by a two-letter abbreviation given here as the Key at the commencement of each line. (At all other times both the abbreviation and full description are given.)
The first four groupings of Tasks are the prime groupings of the above four possible variations of the directional parameters. They are:

- CS – contrary direction tasks when the hands are playing separately (which sums the scores from Tasks 1 & 2);
- SS – similar direction tasks when the hands are playing separately (which sums the scores from Tasks 3 & 4);
- CT – contrary motion tasks with the hands playing together (which sums the scores from Tasks 5 & 6); and
- ST – similar motion tasks with the hands playing together (which sums the scores from Tasks 7 & 8).

The last five groupings of Tasks are referred to as secondary or composite groupings of the above four variations of the directional parameters. Four are included as an extension of the prime groupings and the fifth uses the total score. These secondary groupings of Tasks indicate whether significance is reached in aggregate scores and are:

- CB – contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together (the sum of the scores from Tasks 1, 2, 5 & 6);
- SB – similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (the sum of the scores from Tasks 3, 4, 7 & 8);
- BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar (the sum of the scores from Tasks 1, 2, 3 & 4);
- BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (the sum of the scores from Tasks 5, 6, 7 & 8); and
- BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (the sum of the scores from all Tasks).
3.1.3 Methods of Analysis

The initial analysis of results was made on a simple comparative basis which examined the relative numbers and proportion of errors/mistakes made by the Left-handed and the Right-handed groups. From these simple comparisons appeared patterns which tended to support the previously defined propositions based on casual observations.

In order to test the underlying significance of the observed differential pattern of errors/mistakes made, these patterns became framed into propositions which were subjected to formal statistical analysis, and because of an uncertainty about the assumption of normality of some of the data, and the presence of some zero scores, nonparametric statistical analysis was used.

The two data sets (formed from each of the All (non-rhythmic) Errors and Incorrect Hands Mistakes categories) were subjected to nonparametric statistical analysis using the Mann-Whitney U test which is a comparison of two independent samples. The U statistic was computed each time using StatView 512+ and then compared with tables of the distribution function of the Mann-Whitney U statistic in order to find the associated probability value. When analysing data from the first two observations the distribution tables for both sample sizes being equal to ten ($n_1 = n_2 = 10$) were used, but because of the unavailability of one of the subjects for the final observation, when analysing data from the third observation the distribution tables for one sample size being equal to nine and the other to ten ($n_1 = 9, n_2 = 10$) were used.

The Mann-Whitney U test was used in two ways:

• on the raw error/mistake scores to compare the mean error/mistake scores of the Left-handers ($\bar{X}_L$) with those of the Right-handers ($\bar{X}_R$) on each observation – specifically on the Pre-test ($\bar{X}_{1L}$ and $\bar{X}_{1R}$ respectively), Post-test 1 ($\bar{X}_{2L}$ and $\bar{X}_{2R}$ respectively), and Post-test 2 ($\bar{X}_{3L}$ and $\bar{X}_{3R}$ respectively); and
• on the negative gain scores indicating reduction in errors/mistakes from the relevant Left-handers' or Right-handers' Pre-test/First Observation scores ($O_{1L}$ or $O_{1R}$ respectively) and their corresponding other two observations – specifically the Post-test 1/Second Observation scores ($O_{2L}$ or $O_{2R}$ respectively) in a comparison of the mean difference in errors/mistakes made by the Left-handers ($\bar{X}_{2L}$) with those made by the Right-handers ($\bar{X}_{2R}$), and also the Post-test 2/Third Observation scores ($O_{3L}$ or $O_{3R}$ respectively) in a comparison of the mean difference in errors/mistakes made by the Left-handers ($\bar{X}_{3L}$) with those made by the Right-handers ($\bar{X}_{3R}$).

In analysing the results of the groupings of Tasks, the critical level at which results are said to be statistically significant, designated alpha ($\alpha$), was set at .05, although a large number of results were significant at the more stringent $\alpha$ level of .01. This means in effect that when conclusions are being drawn about possible differences between the Left-handers and the Right-handers and generalised to the whole population, there is no more than a 5% chance that the conclusion could be incorrect, or if $\alpha$ is .01 then there is no more than a 1% chance that it could be incorrect.

In order to test the results of this study for statistical significance, a probability value was calculated for the U statistic (Mann-Whitney), indicating the likelihood that the difference observed could have arisen by chance variation alone. The difference between the means is regarded as significant if this probability is less than or equal to the critical value of $\alpha$ set for the test (e.g. if $\alpha$ is set at .05 then $p \leq .05$, or if $\alpha$ is .01 then $p \leq .01$). Throughout this study the critical level for significance was set at .05. There were, however, some results of the groupings of Tasks which failed to reach this critical level of significance (i.e. where $p$ was greater than .05), but in which the result was only slightly greater – in this case in the range of $.05 < p \leq .10$. If consideration is taken of the small sample size (Left-handers = Right-handers = 10), which has weakened the statistical power of the test (the ability to reject the Null Hypothesis when it is false), then the $p$-value obtained could be interpreted as being sufficiently close to the critical value of .05 such that with larger samples (and hence greater
power) some of the results could become significant at the .05 level. On these results the most appropriate conclusion is not to accept the Null Hypothesis without reservation, but rather to suspend judgement on the outcome of the test. i.e. the Alternate Hypothesis is not proved to be true, but at the same time the Null Hypothesis is sufficiently doubtful to have judgement reserved. Finally in all cases if \( p > .10 \) the Null Hypothesis is accepted and the Alternate Hypothesis rejected.

Also, occasionally in analysing the results of one or more groupings of Tasks, the difference between the means was in a direction opposite to that posed by the Alternate Hypothesis. In those cases the value of \( U \) and the probability value were much larger in comparison with values from groupings of Tasks when the mean scores were in the direction anticipated. The results show that the apparent shift in direction was only a small amount relative to the standard deviation of scores within each respective group of subjects, and so could easily be due to random variation.
3.2 Comparative observations on All (non-rhythmic) Errors data

3.2.1 Initial Numbers of All (non-rhythmic) Errors - First Observations (Pre-test)

Table 1: Numbers of All (non-rhythmic) Errors - First Observation (Pre-test)

<table>
<thead>
<tr>
<th>Subject Number:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right-handers:</td>
<td>20</td>
<td>32</td>
<td>24</td>
<td>3</td>
<td>15</td>
<td>22</td>
<td>18</td>
<td>19</td>
<td>5</td>
<td>17</td>
<td>175</td>
<td>17.5</td>
<td>8.528</td>
</tr>
</tbody>
</table>

As Table 1 shows, initially on the Pre-test, All (non-rhythmic) Errors were made by:

• 10 Left-handers; and

• 10 Right-handers.

In other words, all Subjects made All (non-rhythmic) Errors.

Figure 1 shows the proportion of the 217 mistakes made by the Left-handers and the 175 made by the Right-handers as a percentage of the combined Total (392) for this observation.

Figure 1: Distribution of All (non-rhythmic) Errors - First Observation (Pre-test)
3.2.2 Effects of Treatment (X) – Second Observations (Post-test 1)

Table 2: Numbers of All (non-rhythmic) Errors – Second Observation (Post-test 1)

<table>
<thead>
<tr>
<th>Subject Number:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left-handers:</td>
<td>7</td>
<td>2</td>
<td>18</td>
<td>9</td>
<td>11</td>
<td>13</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>89</td>
<td>8.9</td>
<td>4.383</td>
</tr>
<tr>
<td>Right-handers:</td>
<td>4</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>37</td>
<td>3.7</td>
<td>3.199</td>
</tr>
</tbody>
</table>

As Table 2 shows, after the short period of Treatment, All (non-rhythmic) Errors were made by:

- 10 Left-handers; and
- 9 Right-handers.

In other words, of those 19 who made All (non-rhythmic) Errors:

- 53% were Left-handers; and
- 47% were Right-handers.

Figure 2 shows the proportion of the 89 mistakes made by the Left-handers and the 37 made by the Right-handers as a percentage of the combined Total (126) for this observation.

Figure 2: Distribution of All (non-rhythmic) Errors – Second Observation (Post-test 1)
3.2.3 Effects of Practice (P) – Third Observations (Post-test 2)

Table 3: Numbers of All (non-rhythmic) Errors – Third Observation (Post-test 2)

<table>
<thead>
<tr>
<th>Subject Number:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left-handers:</td>
<td>4</td>
<td>1</td>
<td>9</td>
<td>5</td>
<td>9</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>49</td>
<td>4.900</td>
<td>2.807</td>
</tr>
<tr>
<td>Right-handers:</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>n/a</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>21</td>
<td>2.333</td>
<td>2.000</td>
</tr>
</tbody>
</table>

Table 3 shows that after a prolonged period of Practice, All (non-rhythmic) Errors were made by:

• 10 Left-handers; and
• 8 Right-handers.

In other words, of those 18 who made All (non-rhythmic) Errors;

• 56% were Left-handers; and
• 44% were Right-handers.

Figure 3 shows the proportion of the 49 mistakes made by the Left-handers and the 21 made by the Right-handers as a percentage of the combined Total (70) for this observation.

Figure 3: Distribution of All (non-rhythmic) Errors– Third Observation (Post-test 2)
3.2.4 Left-handers made more All (non-rhythmic) Errors than did Right-handers

Table 4: Total numbers (and percentage) of All (non-rhythmic) Errors

<table>
<thead>
<tr>
<th>First Observation</th>
<th>Second Observation</th>
<th>Third Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Errors (% of Total)</td>
<td>No. of Errors (% of Total)</td>
</tr>
<tr>
<td>from Left-handed group:</td>
<td>217 (55)</td>
<td>89 (71)</td>
</tr>
<tr>
<td>from Right-handed group:</td>
<td>175 (45)</td>
<td>37 (29)</td>
</tr>
<tr>
<td>Total:</td>
<td>392 (100)</td>
<td>126 (100)</td>
</tr>
</tbody>
</table>

(The percentage calculated indicates the proportion of the Total of any All (non-rhythmic) Errors made on that particular observation.)

As can be seen in Table 4 and Figure 4, which show a comparison of the Left-handed and Right-handed groups in all observations, the Left-handers not only started out making more All (non-rhythmic) Errors than the Right-handers in the Pre-test, but made a proportionately greater number of All (non-rhythmic) Errors after Treatment, and a greater number again after Practice.

Figure 4: Total distribution of All (non-rhythmic) Errors

![Figure 4: Total distribution of All (non-rhythmic) Errors](image)

- **Left-handers**
- **Right-handers**
3.2.5 All (non-rhythmic) Errors were made by more Left-handers than Right-handers

Table 5: Numbers (and percentage) of Subjects with All (non-rhythmic) Errors

<table>
<thead>
<tr>
<th></th>
<th>First Observation</th>
<th>Second Observation</th>
<th>Third Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Errors (% of Total)</td>
<td>No. of Errors (% of Total)</td>
<td>No. of Errors (% of Total)</td>
</tr>
<tr>
<td>from Left-handed group:</td>
<td>10 (50)</td>
<td>10 (53)</td>
<td>10 (56)</td>
</tr>
<tr>
<td>from Right-handed group:</td>
<td>10 (50)</td>
<td>9 (47)</td>
<td>8 (44)</td>
</tr>
<tr>
<td>Total:</td>
<td>20 (100)</td>
<td>19 (100)</td>
<td>18 (100)</td>
</tr>
</tbody>
</table>

(The percentage calculated indicates the proportion of the Total of any All (non-rhythmic) Errors made on that particular observation.)

Table 5 and Figure 5 compare the Left-handed and Right-handed groups in all observations but count only the numbers of Subjects who made any All (non-rhythmic) Errors — the figure clearly indicating over successive Observations, that as the number of Right-handers making All (non-rhythmic) Errors was falling, all Left-handers were continuing to make All (non-rhythmic) Errors.

Figure 5: Distribution of Subjects with All (non-rhythmic) Errors
3.3 Comparative observations on Incorrect Hands data

3.3.1 Initial Numbers of Incorrect Hands Mistakes – First Observations (Pre-test)

Table 6: Numbers of Incorrect Hands Mistakes – First Observation (Pre-test)

<table>
<thead>
<tr>
<th>Subject Number:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left-handers:</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>17</td>
<td>1.7</td>
<td>1.252</td>
</tr>
<tr>
<td>Right-handers:</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>0.6</td>
<td>0.843</td>
</tr>
</tbody>
</table>

As Table 6 shows, initially on the Pre-test, Incorrect Hands mistakes were made by:

- 8 Left-handers; and
- 4 Right-handers.

In other words, of those 12 who made Incorrect Hands mistakes;

- 67% were Left-handers; and
- 33% were Right-handers.

Figure 6 shows the proportion of the 17 mistakes made by the Left-handers and the 6 made by the Right-handers as a percentage of the combined Total (23) for this observation.

Figure 6: Distribution of Incorrect Hands Mistakes – First Observation (Pre-test)
3.3.2 Effects of Treatment (X) – Second Observations (Post-test 1)

Table 7: Numbers of Incorrect Hands Mistakes – Second Observation (Post-test 1)

<table>
<thead>
<tr>
<th>Subject Number:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left-handers:</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>10</td>
<td>1.0</td>
<td>1.054</td>
</tr>
<tr>
<td>Right-handers:</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0.2</td>
<td>0.422</td>
</tr>
</tbody>
</table>

Table 7 shows that after the short period of Treatment, Incorrect Hands mistakes were made by:

- 6 Left-handers; and
- 2 Right-handers.

In other words, of those who made Incorrect Hands mistakes:

- 75% were Left-handers; and
- 25% were Right-handers.

Figure 7 shows the proportion of the 10 mistakes made by the Left-handers and the 2 made by the Right-handers as a percentage of the combined Total (12) for this observation.

Figure 7: Distribution of Incorrect Hands Mistakes – Second Observation (Post-test 1)
3.3.3 Effects of Practice ($P$) – Third Observations (Post-test 2)

Table 8 shows that after a prolonged period of Practice, Incorrect Hands mistakes were made by:

- 5 Left-handers: but
- no Right-handers.

Following through from the previous sections with the illustration of proportioning of mistakes, Figure 8 graphically shows that of those who made Incorrect Hands mistakes all were Left-handers.

Figure 8: Distribution of Incorrect Hands Mistakes – Third Observation (Post-test 2)
3.3.4 Left-handers made more Incorrect Hands Mistakes than did Right-handers

Table 9: Total numbers (and percentage) of Incorrect Hands Mistakes

<table>
<thead>
<tr>
<th></th>
<th>First Observation</th>
<th>Second Observation</th>
<th>Third Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Errors (% of Total)</td>
<td>No. of Errors (% of Total)</td>
<td>No. of Errors (% of Total)</td>
</tr>
<tr>
<td>from Left-handed group:</td>
<td>17 (74)</td>
<td>10 (83)</td>
<td>6 (100)</td>
</tr>
<tr>
<td>from Right-handed group:</td>
<td>6 (26)</td>
<td>2 (17)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Total:</td>
<td>23 (100)</td>
<td>12 (100)</td>
<td>6 (100)</td>
</tr>
</tbody>
</table>

(The percentage calculated indicates the proportion of the Total of any All (non-rhythmic) Errors made on that particular observation.)

From Table 9 and Figure 9 it can be seen that:

- Incorrect Hands mistakes were made by subjects in both the Left-handed and Right-handed groups, but by noticeably more Left-handers; and
- the number of Incorrect Hands mistakes made by both Left-handers and Right-handers decreased across the three observations.

Also, when a comparison is made of the responses:

- the proportion of Incorrect Hands mistakes made was always greater from Left-handers compared with Right-handers, and increased dramatically across the three observations.

Figure 9: Total distribution of Incorrect Hands Mistakes
3.3.5 Incorrect Hands Mistakes were made by more Left-handers than Right-handers

Table 10: Numbers (and percentage) of Subjects with Incorrect Hands Mistakes

<table>
<thead>
<tr>
<th></th>
<th>First Observation</th>
<th></th>
<th>Second Observation</th>
<th></th>
<th>Third Observation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Errors</td>
<td>(% of Total)</td>
<td>No. of Errors</td>
<td>(% of Total)</td>
<td>No. of Errors</td>
<td>(% of Total)</td>
</tr>
<tr>
<td>from Left-handed group:</td>
<td>8 (67)</td>
<td></td>
<td>6 (75)</td>
<td></td>
<td>5 (100)</td>
<td></td>
</tr>
<tr>
<td>from Right-handed group:</td>
<td>4 (33)</td>
<td></td>
<td>2 (25)</td>
<td></td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td>12 (100)</td>
<td></td>
<td>8 (100)</td>
<td></td>
<td>5 (100)</td>
<td></td>
</tr>
</tbody>
</table>

(The percentage calculated indicates the proportion of the Total of any All (non-rhythmic) Errors made on that particular observation.)

Table 10 and Figure 10 show that confusion in directing the appropriate left or right hands was not evident in all Left-handed or all Right-handed Subjects, but was consistently exhibited by a larger number of Left-handers. Namely:

- in the First Observation by eight Left-handers and four Right-handers;
- in the Second Observation by six Left-handers and only two Right-handers; and
- in the Third Observation by five Left-handers and no Right-handers.

Figure 10: Distribution of Subjects with Incorrect Hands Mistakes
3.4 Analysis of All (non-rhythmic) Errors

3.4.1 Proposition 1 (First Observations – Pre-test)

The proposition "left-handers make more non-rhythmic errors than right-handers - initially" was represented by the two statistical hypotheses

\[ H_0 : \mu_{1L} \leq \mu_{1R} \]

\[ H_A : \mu_{1L} > \mu_{1R} \]

(where \( H_0 \) represents the Null Hypothesis, \( H_A \) the Alternate Hypothesis, \( \mu_{1L} \) the mean error score for left-handers, and \( \mu_{1R} \) the mean error score for right-handers).

Data were analysed using the Mann-Whitney U test (one-tailed) to compare the mean error scores of the Left-handers (\( \bar{X}_{1L} \)) with those of the Right-handers (\( \bar{X}_{1R} \)).

Table 11: All (non-rhythmic) Errors, First Observations (Pre-test)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>( \bar{X}_{1L} ) (S.D.)</th>
<th>( \bar{X}_{1R} ) (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>3.9 (1.729)</td>
<td>2.2 (1.932)</td>
<td>21.5</td>
<td>.0160</td>
</tr>
<tr>
<td>SS:</td>
<td>4.3 (2.263)</td>
<td>3.0 (1.826)</td>
<td>34.5</td>
<td>.1315</td>
</tr>
<tr>
<td>CT:</td>
<td>5.4 (1.578)</td>
<td>5.5 (3.951)</td>
<td>61.0</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>ST:</td>
<td>8.1 (2.767)</td>
<td>6.8 (2.936)</td>
<td>34.5</td>
<td>.1315</td>
</tr>
<tr>
<td>CB:</td>
<td>9.3 (2.830)</td>
<td>7.7 (5.229)</td>
<td>31.5</td>
<td>.0887</td>
</tr>
<tr>
<td>SB:</td>
<td>12.4 (4.671)</td>
<td>9.8 (4.566)</td>
<td>33.0</td>
<td>.1088</td>
</tr>
<tr>
<td>BS:</td>
<td>8.2 (3.425)</td>
<td>5.2 (2.936)</td>
<td>28.0</td>
<td>.0526</td>
</tr>
<tr>
<td>BT:</td>
<td>13.5 (3.837)</td>
<td>12.3 (6.075)</td>
<td>40.0</td>
<td>.2406</td>
</tr>
<tr>
<td>BB:</td>
<td>21.7 (7.025)</td>
<td>17.5 (8.528)</td>
<td>35.0</td>
<td>.1399</td>
</tr>
</tbody>
</table>

[where \( \bar{X}_{1L} \) (S.D.) represents the mean error score of All (non-rhythmic) Errors for the left-handers with the Standard Deviation from the mean in parenthesis, \( \bar{X}_{1R} \) (S.D.) represents the mean error score of All (non-rhythmic) Errors for the right-handers with the Standard Deviation from the mean in parenthesis, Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.]
As Table 11 shows, the groupings of Tasks which clearly achieved statistical significance (p ≤ .05) and for which the Null Hypothesis was rejected and the Alternate Hypothesis ("left-handers make more non-rhythmic errors than right-handers – initially") was accepted, were:

- CS – in contrary direction tasks when the hands are playing separately (p = .02); and
- BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar (p = .05).

These two groupings of Tasks which reached significance (one a prime and the other its composite secondary grouping) each featured the simplest use of separate hands. However another grouping:

- CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together (p = .09),

could be considered as being amongst those groupings alluded to previously, where it was suggested that if consideration is taken of the power of the tests, with larger samples the probability obtained might possibly reach the critical level for statistical significance.

From these results it could be inferred that, when using hands separately and in a contrary and combination of contrary and similar directions, and possibly in contrary motion with a combination of separate and together hands, left-handers will tend to make more non-rhythmic errors of pitch and pitch direction than right-handers.

Six other groupings of Tasks failed to achieve statistical significance at the .05 level; five because the difference between the means was not large enough, although the mean error scores for the Left-handers were still greater than those for the Right-handers. In these cases the Null Hypothesis that "left-handers do not make more errors than right-handers – initially" was accepted. These groupings of Tasks were:

- SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (p = .11);
- SS – in similar direction tasks when the hands are playing separately (p = .13);
- ST – in similar motion tasks with the hands playing together (p = .13);
• BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p = .14); and

• BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p = .24).

The non-significance of these six groupings of tasks indicates that from the data available in this study, there was insufficient evidence to indicate a significant difference between the expected performance ability of left-handers compared with right-handers on all other non-rhythmic errors.

One final grouping of Tasks was:

• CT – in contrary motion tasks with the hands playing together (p > .50).

In this grouping of Tasks the mean error score for the Left-handers was not greater than that for the Right-handers, so without evidence to support the Alternate Hypothesis as specified, the Null Hypothesis was accepted. However because of the unexpected direction of the difference between the means, a modified proposition was tested in relation to this grouping of Tasks. This modified proposition allowed the possibility of a difference in error scores favouring either the Left-handers or the Right-handers.

**Modified proposition 1 (First Observations – Pre-test)**

The proposition that "there is a significant difference in the number of non-rhythmic errors made by left-handers and right-handers – initially" was represented by the two statistical hypotheses

\[ H_0 : \mu_{1L} = \mu_{1R} \]

\[ H_A : \mu_{1R} > \mu_{1L} > \mu_{1R} \]

(where \( H_0 \) represents the Null Hypothesis, \( H_A \) the Alternate Hypothesis, \( \mu_{1L} \) the mean error score for left-handers, and \( \mu_{1R} \) the mean error score for right-handers).

Data were analysed using the Mann-Whitney U test (two-tailed) to compare the mean error scores of the Left-handers (\( \bar{X}_{1L} \)) with those of the Right-handers (\( \bar{X}_{1R} \)) on the one grouping of Tasks "CT". This analysis was based on the same information gained in the
previous directional form of this proposition. The analysis of those results could be interpreted as suggesting no other groupings of Tasks need to be subjected to this broader non-directional analysis.

Table 12: All (non-rhythmic) Errors, First Observations (Pre-test) – modified proposition

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>$\bar{X}_{1L}$ (S.D.)</th>
<th>$\bar{X}_{1R}$ (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT:</td>
<td>5.4 (1.578)</td>
<td>5.5 (3.951)</td>
<td>39.0</td>
<td>.4358</td>
</tr>
</tbody>
</table>

(where $\bar{X}_{1L}$ (S.D.) represents the mean error score of All (non-rhythmic Errors for the left-handers with the Standard Deviation from the mean in parenthesis, $\bar{X}_{1R}$ (S.D.) represents the mean error score of All (non-rhythmic) Errors for the right-handers with the Standard Deviation from the mean in parenthesis, Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.)

As Table 12 shows, this grouping of Tasks:

- CT – in contrary motion tasks with the hands playing together – failed to achieve statistical significance at the .05 level (p = .44) although the mean error score for the Left-handers was less than that for the Right-handers. So the Null Hypothesis, that left-handers do not make significantly greater or fewer non-rhythmic errors than right-handers – initially, was accepted.

The non-significance of this result indicates that from the data available in this study, that when measuring all non-rhythmic errors on tasks of hands together in contrary motion, there was insufficient evidence to indicate a significant difference between the expected performance ability of left-handers and right-handers in favour of either group.

3.4.2 Proposition 2a (Second Observations – Post-test 1)

The proposition "left-handers make more non-rhythmic errors than right-handers – after a short period of Treatment" was represented by the two statistical hypotheses:
$H_0 : \mu_{2L} \leq \mu_{2R}$

$H_A : \mu_{2L} > \mu_{2R}$

(where $H_0$ represents the Null Hypothesis, $H_A$ the Alternate Hypothesis, $\mu_{2L}$ the mean error score for left-handers, and $\mu_{2R}$ the mean error score for right-handers).

Data were analysed using the Mann-Whitney U test (one-tailed) to compare the mean error scores of the Left-handers ($\bar{X}_{2L}$) with those of the Right-handers ($\bar{X}_{2R}$).

Table 13: All (non-rhythmic) Errors, Second Observations (Post-test 1)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>$\bar{X}_{2L}$ (S.D.)</th>
<th>$\bar{X}_{2R}$ (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>1.6 (1.430)</td>
<td>0.4 (0.516)</td>
<td>25.0</td>
<td>.0315</td>
</tr>
<tr>
<td>SS:</td>
<td>1.1 (0.876)</td>
<td>0.3 (0.483)</td>
<td>24.0</td>
<td>.0262</td>
</tr>
<tr>
<td>CT:</td>
<td>2.2 (0.919)</td>
<td>0.9 (1.197)</td>
<td>19.0</td>
<td>.0093</td>
</tr>
<tr>
<td>ST:</td>
<td>4.0 (2.582)</td>
<td>2.1 (1.595)</td>
<td>26.0</td>
<td>.0376</td>
</tr>
<tr>
<td>CB:</td>
<td>3.8 (2.098)</td>
<td>1.3 (1.337)</td>
<td>13.5</td>
<td>.0022</td>
</tr>
<tr>
<td>SB:</td>
<td>5.1 (2.558)</td>
<td>2.4 (2.011)</td>
<td>20.5</td>
<td>.0130</td>
</tr>
<tr>
<td>BS:</td>
<td>2.7 (1.767)</td>
<td>0.7 (0.675)</td>
<td>16.0</td>
<td>.0045</td>
</tr>
<tr>
<td>BT:</td>
<td>6.2 (3.293)</td>
<td>3.0 (2.625)</td>
<td>19.5</td>
<td>.0104</td>
</tr>
<tr>
<td>BB:</td>
<td>8.9 (4.383)</td>
<td>3.7 (3.199)</td>
<td>16.0</td>
<td>.0045</td>
</tr>
</tbody>
</table>

[where $\bar{X}_{2L}$ (S.D.) represents the mean error score of All (non-rhythmic) Errors for the left-handers with the Standard Deviation from the mean in parenthesis, $\bar{X}_{2R}$ (S.D.) represents the mean error score of All (non-rhythmic) Errors for the right-handers with the Standard Deviation from the mean in parenthesis, Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.]

As Table 13 shows, all groupings of Tasks achieved statistical significance, and in all cases the Null Hypothesis was rejected and the Alternate Hypothesis ("left-handers make more non-rhythmic errors than right-handers – after a short period of Treatment") was accepted.
The six groupings of Tasks reaching significance at $\alpha = .01$ ($p \leq .01$) were:

- CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together ($p = .002$);
- BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar ($p = .005$);
- BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together ($p = .005$);
- CT – in contrary motion tasks with the hands playing together ($p = .01$);
- BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar ($p = .01$); and
- SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together ($p = .01$).

The remaining three groupings reached significance at $\alpha = .05$ ($p \leq .05$) as follows:

- SS – in similar direction tasks when the hands are playing separately ($p = .03$);
- CS – in contrary direction tasks when the hands are playing separately ($p = .03$); and
- ST – in similar motion tasks with the hands playing together ($p = .04$).

Since all groupings of Tasks reached statistical significance we can infer to the general population that left-handers, after a short period of treatment, will make more non-rhythmic errors of hands playing separately and/or together in contrary and/or similar direction or motion than right-handers.

3.4.3 Proposition 2b (Second Observations – Post-test 1) – to show improvement

In addition to comparing the precision of performance of Subjects in this study, as was shown in Propositions 1 and 2, it was considered valuable also to compare their improvement in performance.

As a result the proposition that "left-handers are likely to make less improvement than right-handers – after a short period of Treatment" was put. At this stage "improvement" was
simply construed as a reduction in non-rhythmic errors, and so the proposition was represented by the two statistical hypotheses $H_0: \mu_{1L} - 2L \geq \mu_{1R} - 2R$

$H_A: \mu_{1L} - 2L < \mu_{1R} - 2R$

(where $H_0$ represents the Null Hypothesis, $H_A$ the Alternate Hypothesis, $\mu_{1L} - 2L$ the mean difference in error scores for left-handers, and $\mu_{1R} - 2R$ the mean difference in error scores for right-handers).

Data were analysed using the Mann-Whitney U test (one-tailed) on the negative gain scores (reduction in error scores) from the relevant Left-handers' or Right-handers' Pre-test/First Observation scores ($O_{1L}$ or $O_{1R}$ respectively) and their corresponding Post-test 1/Second Observation scores ($O_{2L}$ or $O_{2R}$ respectively), in a comparison of the mean difference of the Left-handers ($X_{1L} - 2L$) with that of the Right-handers ($X_{1R} - 2R$).

Table 14: All (non-rhythmic) Errors, Second Observations (Post-test 1) – Improvement (with reduction scores)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>$\bar{X}_{1L} - 2L$ (S.D.)</th>
<th>$\bar{X}_{1R} - 2R$ (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>2.3 (0.675)</td>
<td>1.8 (1.619)</td>
<td>68.0</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>SS:</td>
<td>3.2 (2.098)</td>
<td>2.7 (1.767)</td>
<td>58.0</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>CT:</td>
<td>3.2 (1.229)</td>
<td>4.6 (3.098)</td>
<td>30.5</td>
<td>.0770</td>
</tr>
<tr>
<td>ST:</td>
<td>4.1 (2.558)</td>
<td>4.7 (2.058)</td>
<td>46.0</td>
<td>.3980</td>
</tr>
<tr>
<td>CB:</td>
<td>5.5 (1.434)</td>
<td>6.4 (4.169)</td>
<td>42.0</td>
<td>.2894</td>
</tr>
<tr>
<td>SB:</td>
<td>7.3 (3.302)</td>
<td>7.4 (3.534)</td>
<td>47.0</td>
<td>.4267</td>
</tr>
<tr>
<td>BS:</td>
<td>5.5 (2.593)</td>
<td>4.5 (2.506)</td>
<td>61.5</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>BT:</td>
<td>7.3 (2.869)</td>
<td>9.3 (3.860)</td>
<td>31.5</td>
<td>.0887</td>
</tr>
<tr>
<td>BB:</td>
<td>12.8 (4.341)</td>
<td>13.8 (6.033)</td>
<td>38.5</td>
<td>.2070</td>
</tr>
</tbody>
</table>

[where $\bar{X}_{1L} - 2L$ (S.D.) represents the mean difference of All (non-rhythmic) Errors for the left-handers with the Standard Deviation from the mean in parenthesis, $\bar{X}_{1R} - 2R$ (S.D.) represents the mean difference of All (non-rhythmic) Errors for the right-handers with the Standard Deviation from the mean in parenthesis,
Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.

It can be seen from Table 14 that when the data were analysed using reduction in error scores from the Pre-test to this same First Post-test, the mean difference in error scores for the Left-handers was less than that for the Right-handers for six groupings of Tasks. The first two of these:

- CT – in contrary motion tasks with the hands playing together (p = .08); and
- BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p = .09);

could be considered as being amongst those groupings alluded to previously, where it was suggested that if consideration is taken of the power of the tests, with larger samples the probability obtained might possibly reach the critical level for statistical significance, whereas the other four failed to reach statistical significance at the critical level, as follows:

- BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p = .21);
- CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together (p = .29);
- ST – in similar motion tasks with the hands playing together (p = .40); and
- SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (p = .43).

For the remaining three groupings, the mean difference in error scores for the Left-handers was greater than that for the Right-handers, as follows:

- CS – in contrary direction tasks when the hands are playing separately (p > .50);
- SS – in similar direction tasks when the hands are playing separately (p > .50); and
- BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar (p > .50).
In seven groupings therefore, the Alternate Hypothesis was rejected and the Null Hypothesis, that left-handers are likely to make no less improvement (reductions in non-rhythmic errors) than right-handers – after a short period of Treatment, was accepted.

The results for those groupings of Tasks with negative differences between the means (as proposed) indicate that there is not a statistically significant difference in the reduction of non-rhythmic errors between the two groups of Left-handers and Right-handers after a short period of treatment. The groupings of Tasks where the mean difference for the Left-handers was greater than that for the Right-handers indicates that there was not sufficient evidence to support the Alternate Hypothesis. So for all groupings we cannot infer that left-handers are likely in general to show less improvement (reductions in non-rhythmic errors) than right-handers after a week of treatment.

Even when subjecting the data to the modified proposition ("there is a significant difference between the number of reductions in non-rhythmic errors made by left-handers or right-handers – after a short period of Treatment") in the same way that was done earlier, none of the groupings where the mean difference scores for the Left-handers was greater than the Right-handers achieved statistical significance at the .05 level. These results can be summarised briefly as:

- CS – in contrary direction tasks when the hands are playing separately – value of U: 32 (p = .19);
- SS – in similar direction tasks when the hands are playing separately – value of U: 38.5 (p = .41); and
- BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar – value of U: 42.0 (p > .50).

These results indicate that there was not a statistically significant difference in the improvement of the Left-handers compared with the Right-handers when improvement is measured by the reduction in error scores, and so we are left to infer that left-handers are
likely to make no greater or fewer reductions in non-rhythmic errors than right-handers – after a short period of Treatment.

The non-significance of so many of the above results gives some cause for concern in the light of the literature and the comparative observations to the contrary. The proposition tests for improvement in performance, so it is important to attempt to define improvement in numerical terms. The simplest definition, as used in the above analysis, is based on an absolute reduction in errors:

\[
(number\ of\ errors)_1 - (number\ of\ errors)_2 = \text{reduction\ in\ errors\ score}
\]

(i.e. a numerical improvement score)

This is certainly a measure of improvement which yields valid insights, but if we are to subject varying amounts of improvement to statistical analysis (which typically compares the means of scores of two groups of samples) then we have to be sure that such absolute reduction scores correctly represent the effect or the type of improvement we expect to be testing.

In this respect it is important to note that comparison of absolute error scores cannot be applied in a meaningful way in some extreme cases. The following hypothetical example helps to explain.

If subject S\textsubscript{X} (handedness inconsequential) made 40 errors on the Pre-test and subsequently reduced them to 20 on the Post-test 1, then his/her reduction in error score would be 20. If at the same times subject S\textsubscript{Y} made 10 errors and reduced them to none, his/her reduction in error score would be 10. In this example, it can be seen that S\textsubscript{X} made a greater reduction in errors than did S\textsubscript{Y}, and if reduction in errors is equated with improvement, then it would be interpreted that S\textsubscript{X} made greater improvement than did S\textsubscript{Y}. This is not necessarily the case, since although S\textsubscript{X} has certainly improved his/her performance by halving the number of errors, S\textsubscript{Y} has improved his/her performance to the maximum by reaching a perfect score of no errors. This is not to suggest of course that the playing of S\textsubscript{Y} is in the general sense...
perfect, but rather that this particular method of testing chooses not to discriminate in
quality of performance beyond the specified range of non-rhythmic errors.

So although the use of reduction in error scores can give a valuable perspective on the data
and can be used to make valid statistical inferences (provided it is regarded as just that –
reductions in errors), nevertheless it becomes apparent that in order to have an unequivocal
measure of improvement, the data must also be examined in another way.

The limitation in the above analysis lies in using a simple (or absolute) reduction in
errors to describe improvement. In the case of a subject $S_Z$ who makes no, or very few, errors
at the outset (on the Pre-test), the numerical score indicates that s/he cannot improve to the
same extent (does not have as many errors to reduce) on that particular task as another
subject $S_a$ who makes numerous errors initially, although it is known that if subject $S_Z$ attains a
zero score (i.e. no errors) s/he still can certainly improve by playing: faster (and still error free);
with (more) expression; with (better) dynamics; with improved phrasing etc.

This study specifically did not take into account rhythm (or tempo, expression etc.) as
was earlier mentioned, but sought only to measure precision in performance. Unlike the
affective nuances just cited, precision has a finite end-point i.e. when all the notes are correct
then that correctness cannot be made any more correct. An associated problem with this end-
point of correctness, is that as it is being approached the task of reducing errors seems to
become harder – that is, the difference in being able to reduce from, say, ten errors to nine in a
simple performance task is probably much easier than reducing from the last one down to
none.

Given that improvement attempts to measure this decreasing error rate in
performance, a more appropriate way for it to be described may be in relative terms – i.e. there
is a change in the difficulty associated with reducing errors as the level of performance
precision approaches perfection or a score of zero errors.
This relative way of looking at improvement is best reflected by the proportional change in error scores between two observations. In mathematical terms it can be represented by $\frac{O_1 - O_2}{O_1}$. i.e. this function, the Relative Improvement Score (RIS), measures the proportional reduction in errors relative to the original error score, rather than just the absolute reduction in errors. It is a good indicator of the "realised potential" of a subject's subsequent performance, in that the improvement is comparative — it is compared with the performer's initially displayed inherent performance potential — and it is educationally sound in that it makes allowance for individual differences between subjects — by comparing each subject with him/herself.

3.4.4 Proposition 2c (Second Observations - Post-test 1) – relative improvement scores

The proposition "left-handers are likely to make less improvement than right-handers — after a short period of Treatment" was therefore newly represented by the two statistical hypotheses:

$H_0 : \mu_{RIS1-2(L)} \geq \mu_{RIS1-2(R)}$

$H_A : \mu_{RIS1-2(L)} < \mu_{RIS1-2(R)}$

[where $H_0$ represents the Null Hypothesis, $H_A$ the Alternate Hypothesis, $\mu_{RIS1-2(L)}$ the mean Relative Improvement Scores (relative error reduction scores) from the First Observation (Pre-test) to the Second Observation (Post-test 1) for left-handers, and $\mu_{RIS1-2(R)}$ the mean Relative Improvement Scores (relative error reduction scores) from the First Observation (Pre-test) to the Second Observation (Post-test 1) for right-handers]

Data were analysed using the Mann-Whitney U test (one-tailed) on the Relative Improvement Scores (proportional reduction in error scores) from the relevant Left-handers' or Right-handers' Pre-test/First Observation scores and their corresponding Post-test 1/Second Observation scores ($O_{1L}$ or $O_{1R}$ respectively, and $O_{2L}$ or $O_{2R}$ respectively; and where each respective Relative Improvement Score $x_{RIS1-2(L)} = \frac{O_{1L} - O_{2L}}{O_{1L}}$ and $x_{RIS1-2(R)} = \frac{O_{1R} - O_{2R}}{O_{1R}}$ in a comparison of the mean difference of the Left-handers ($\bar{x}_{RIS1-2(L)}$) with that of the Right-handers ($\bar{x}_{RIS1-2(R)}$).
Table 15: All (non-rhythmic) Errors, Second Observations (Post-test 1), – Improvement (with relative improvement scores)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>( \bar{x}_{\text{RIS1-2(L)}} ) (S.D.) and ( n_L )</th>
<th>( \bar{x}_{\text{RIS1-2(R)}} ) (S.D.) and ( n_R )</th>
<th>Value of ( U )</th>
<th>Probability (( p ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>( .6596 (.2591) ; 10 )</td>
<td>( .8111 (.3274) ; 9 )</td>
<td>27.5</td>
<td>.0845</td>
</tr>
<tr>
<td>SS:</td>
<td>( .7052 (.3048) ; 10 )</td>
<td>( .8959 (.1460) ; 8 )</td>
<td>22.0</td>
<td>.0610</td>
</tr>
<tr>
<td>CT:</td>
<td>( .5874 (.1400) ; 10 )</td>
<td>( .8067 (.3086) ; 10 )</td>
<td>14.0</td>
<td>.0026</td>
</tr>
<tr>
<td>ST:</td>
<td>( .5022 (.2362) ; 10 )</td>
<td>( .7120 (.1731) ; 9 )</td>
<td>20.5</td>
<td>.0241</td>
</tr>
<tr>
<td>CB:</td>
<td>( .6119 (.1367) ; 10 )</td>
<td>( .7859 (.2937) ; 10 )</td>
<td>16.0</td>
<td>.0045</td>
</tr>
<tr>
<td>SB:</td>
<td>( .5909 (.1219) ; 10 )</td>
<td>( .7753 (.1521) ; 9 )</td>
<td>14.5</td>
<td>.0058</td>
</tr>
<tr>
<td>BS:</td>
<td>( .6761 (.2202) ; 10 )</td>
<td>( .8790 (.0994) ; 9 )</td>
<td>17.5</td>
<td>.0124</td>
</tr>
<tr>
<td>BT:</td>
<td>( .5522 (.1574) ; 10 )</td>
<td>( .7960 (.1140) ; 10 )</td>
<td>9.0</td>
<td>.0005</td>
</tr>
<tr>
<td>BB:</td>
<td>( .6028 (.1149) ; 10 )</td>
<td>( .8191 (.1069) ; 10 )</td>
<td>6.0</td>
<td>.0002</td>
</tr>
</tbody>
</table>

[where \( \bar{x}_{\text{RIS(L)}} \) (S.D.) and \( n_L \) represents the mean Relative Improvement Scores, with the Standard Deviation from the mean in parenthesis, of All (non-rhythmic) Errors for the relevant number of Left-handers with meaningful (non zero) initial scores, \( \bar{x}_{\text{RIS(R)}} \) (S.D.) and \( n_R \) represents the mean Relative Improvement Scores, with the Standard Deviation from the mean in parenthesis, of All (non-rhythmic) Errors for the relevant number of Left-handers with meaningful (non zero) initial scores, Value of \( U \) is the test statistic produced by the Mann-Whitney \( U \) test, and Probability (\( p \)) represents the probability of obtaining a value of \( U \) at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.]

For the purpose of this analysis individual cases with original perfect (zero error) scores are treated as special cases, in that the original perfect score leaves no opportunity for improvement (relative or absolute). For this reason, and because in these circumstances RIS is a meaningless value, the relevant data are excluded from the analysis. This has the effect of reducing the number of cases, and constraining the probability value, but ensures that all the scores used in the analysis are meaningful.
It can be seen from Table 15 that when the data were analysed using Relative Improvement Scores (proportional reduction in error scores) from the Pre-test to this same First Post-test, the mean RIS for the Left-handers was less than that for the Right-handers for all groupings of Tasks, and seven of these groupings achieved statistical significance (six at the $\alpha \leq .01$ level, and another at $\alpha \leq .02$) as follows:

- BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together ($p < .001$);
- BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar ($p = .001$);
- CT – in contrary motion tasks with the hands playing together ($p = .003$);
- CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together ($p = .005$);
- SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together ($p = .006$);
- BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar ($p = .01$); and
- ST – in similar motion tasks with the hands playing together ($p = .02$).

For these seven groupings the Null Hypothesis was rejected, and the Alternate Hypothesis, that left-handers are likely to make less relative improvement (relative reductions in non-rhythmic errors) than right-handers – after a short period of Treatment, was accepted.

The two following groupings failed to achieve significance at the .05 level:

- SS – in similar direction tasks when the hands are playing separately ($p = .06$); and
- CS – in contrary direction tasks when the hands are playing separately ($p = .08$).

However, certainly the first of these two (SS), with possibly the addition of the second (CS), could be considered as being amongst those groupings alluded to previously, where it was suggested that if consideration is taken of the power of the tests, with larger samples the probability obtained might possibly reach the critical level for statistical significance.
The results indicate that we can infer that left-handers, when all non-rhythmic errors are measured (possibly except for specific tasks of separate hands contrary direction, and separate hands similar direction), are likely to show less relative improvement than right-handers after a week of treatment.

3.4.5 Proposition 3a (Third Observations – Post-test 2)

The proposition "left-handers make more non-rhythmic errors than right-handers – after a long period of tuition and Practice" was represented by the two statistical hypotheses:

\[ H_0 : \mu_{3L} \leq \mu_{3R} \]

\[ H_A : \mu_{3L} > \mu_{3R} \]

(where \( H_0 \) represents the Null Hypothesis, \( H_A \) the Alternate Hypothesis, \( \mu_{3L} \) the mean error score for left-handers, and \( \mu_{3R} \) the mean error score for right-handers).

Data were analysed using the Mann-Whitney U test to compare the mean error scores of the Left-handers (\( \bar{X}_{3L} \)) with those of the Right-handers (\( \bar{X}_{3R} \)).

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>( \bar{X}_{3L} ) (S.D.)</th>
<th>( \bar{X}_{3R} ) (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS</td>
<td>0.4 (0.516)</td>
<td>0.0 (0.000)</td>
<td>27.0</td>
<td>.0782</td>
</tr>
<tr>
<td>SS</td>
<td>0.4 (0.516)</td>
<td>0.2 (0.441)</td>
<td>37.0</td>
<td>.2745</td>
</tr>
<tr>
<td>CT</td>
<td>1.3 (0.949)</td>
<td>0.4 (0.882)</td>
<td>22.0</td>
<td>.0326</td>
</tr>
<tr>
<td>ST</td>
<td>2.8 (1.229)</td>
<td>1.7 (1.000)</td>
<td>22.5</td>
<td>.0360</td>
</tr>
<tr>
<td>CB</td>
<td>1.7 (1.418)</td>
<td>0.4 (0.843)</td>
<td>19.0</td>
<td>.0175</td>
</tr>
<tr>
<td>SB</td>
<td>3.2 (1.687)</td>
<td>1.7 (1.337)</td>
<td>25.0</td>
<td>.0564</td>
</tr>
<tr>
<td>BS</td>
<td>0.8 (0.919)</td>
<td>0.2 (0.422)</td>
<td>29.5</td>
<td>.1133</td>
</tr>
<tr>
<td>BT</td>
<td>4.1 (1.969)</td>
<td>1.9 (1.663)</td>
<td>19.5</td>
<td>.0195</td>
</tr>
<tr>
<td>BB</td>
<td>4.9 (2.807)</td>
<td>2.1 (2.025)</td>
<td>19.5</td>
<td>.0195</td>
</tr>
</tbody>
</table>
As Table 16 shows, on the Second Post-test five out of nine groupings of Tasks achieved statistical significance at the .05 level, and so for these the Null Hypothesis was rejected and the Alternate Hypothesis, that left-handers make more non-rhythmic errors than right-handers – after a long period of tuition and Practice, was accepted. Two were from the four prime groupings of Tasks and three were from the composite secondary groupings as follows:

- **BB** – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p = .02).
- **BT** – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p = .02).
- **CB** – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together (p = .02);
- **CT** – in contrary motion tasks with the hands playing together (p = .03); and
- **ST** – in similar motion tasks with the hands playing together (p = .04).

Another secondary grouping near to achieving statistical significance at the .05 level was:

- **SB** – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (p = .06). In addition a prime grouping:
- **CS** – in contrary direction tasks when the hands are playing separately (p = .08), was also within this broader range of .10 ≥ p > .05.
These two cases could be considered as being amongst those also alluded to previously, where it was suggested that if consideration is taken of the power of the tests, with larger samples the probability obtained might possibly reach the critical level for statistical significance.

The remaining two groupings of Tasks which did not achieve statistical significance were:

• SS – in similar direction tasks when the hands are playing separately ($p = .27$); and

• BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar ($p = .11$).

For these two groupings the Alternate Hypothesis was rejected and the Null Hypothesis, that left-handers do not make more non-rhythmic errors than right-handers – after a long period of tuition and Practice, was accepted.

It should come as no surprise that the last two "separate hands" results (SS and its composite BS) did not achieve significance and yet the "hands together" results (CT, ST and composite BT) did. Behaviourally these results support the fact that separate hand playing is easier than playing with both hands together, and that left-handers after an extended period of instruction and practice are able to compare favourably with their right-handed counterparts in the simplest of tasks – separate hands – but make more non-rhythmic errors in the more difficult tasks – when the hands are playing together – and in the overall picture (BB).

These results allow us to predict that in the general population left-handers will tend to make more non-rhythmic errors than right-handers after a prolonged period of practice, in all situations except for the simplest (when the hands are playing separately) when it seems that there should be no difference between the achievement of left-handers compared with that of right-handers.
3.4.6 Proposition 3b (Third Observations – Post-test 2) with reduction in error scores

The specific proposition "left-handers are likely to make fewer reductions in non-rhythmic errors than right-handers – after a long period of tuition and Practice" was represented by the two statistical hypotheses

\[ H_0 : \mu_{1L - 3L} \geq \mu_{1R - 3R} \]
\[ H_A : \mu_{1L - 3L} < \mu_{1R - 3R} \]

(where \( H_0 \) represents the Null Hypothesis, \( H_A \) the Alternate Hypothesis, \( \mu_{1L - 3L} \) the mean difference in error scores for left-handers, and \( \mu_{1R - 3R} \) the mean difference in error scores for right-handers).

Data were analysed using the Mann-Whitney U test on the negative gain scores (reduction in error scores) from the relevant Left-handers' or Right-handers' Pre-test/First Observation scores (\( O_{1L} \) or \( O_{1R} \) respectively) and their corresponding Post-test 2/Third Observation scores (\( O_{3L} \) or \( O_{3R} \) respectively), in a comparison of the mean difference of the Left-handers (\( \bar{X}_{1L - 3L} \)) with that of the Right-handers (\( \bar{X}_{1R - 3R} \)).

Table 17: All (non-rhythmic) Errors, Third Observations (Post-test 2)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>( \bar{X}_{1L - 3L} ) (S.D.)</th>
<th>( \bar{X}_{1R - 3R} ) (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>4.300 (2.111)</td>
<td>2.333 (2.000)</td>
<td>70.5</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>SS:</td>
<td>4.700 (2.541)</td>
<td>3.556 (1.740)</td>
<td>56.0</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>CT:</td>
<td>6.700 (2.406)</td>
<td>6.333 (4.770)</td>
<td>54.0</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>ST:</td>
<td>10.900 (3.843)</td>
<td>9.222 (2.635)</td>
<td>60.0</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>CB:</td>
<td>11.000 (4.110)</td>
<td>8.667 (5.937)</td>
<td>62.5</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>SB:</td>
<td>15.600 (6.077)</td>
<td>12.778 (4.086)</td>
<td>61.0</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>BS:</td>
<td>9.000 (4.163)</td>
<td>5.889 (2.848)</td>
<td>63.5</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>BT:</td>
<td>17.600 (5.661)</td>
<td>15.556 (6.729)</td>
<td>57.5</td>
<td>&gt; .5000</td>
</tr>
<tr>
<td>BB:</td>
<td>26.600 (9.582)</td>
<td>21.444 (9.029)</td>
<td>61.5</td>
<td>&gt; .5000</td>
</tr>
</tbody>
</table>

(where \( \bar{X}_{3L} \) (S.D.) represents the mean difference of All (non-rhythmic) Errors for the left-handers with the Standard Deviation from the mean in parenthesis, \( \bar{X}_{3R} \) (S.D.) represents the mean difference of All (non-rhythmic) Errors for the right-handers with the Standard Deviation from the mean in parenthesis, Value of
U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70. Also, because of the unavailability of one of the subjects for testing, the above p-values were gained from distribution tables for one sample size equal to nine and the other to ten.

As Table 17 shows, when the data were analysed using reduction in error scores from the Pre-test to this same Second Post-test, no groupings of Tasks achieved statistical significance, and the mean reduction in errors for the Left-handers was greater than that for the Right-handers. This was in the direction contrary to that proposed. So for all groupings the Alternate Hypothesis was rejected and the Null Hypothesis, that left-handers are likely to make no fewer reductions in non-rhythmic errors than right-handers – after a long period of Practice, was accepted. So although when examined comparatively the data appears to show otherwise, the non-significance of these results indicates that we must infer to the normal population that left-handers, after a six or eight month period of tuition and practice, would be likely to show no fewer reductions in errors than right-handers when all (non-rhythmic) errors are measured.

The modified non-directional proposition ("there is a significant difference between the number of reductions in non-rhythmic errors made by left-handers or right-handers – after a long period of tuition and Practice") was subjected to analysis, and one grouping reached significance at the .05 level. It was:

- CS – in contrary direction tasks when the hands are playing separately – Value of U: 19.5 (p = .04).

The remaining eight groupings failed to reach this critical level. A brief summary of the results shows:

- BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar – Value of U: 26.5 (p = .14);
- CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together – Value of U: 27.5 (p = .17);
• BB - when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together – Value of U: 28.5 (p = .20);
• SB - in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together – Value of U: 29.0 (p = .21);
• ST - in similar motion tasks with the hands playing together – Value of U: 30.0 (p = .24);
• BT - when the hands are playing together with no differentiation as to whether the motion is contrary or similar – Value of U: 32.5 (p = .34);
• SS - in similar direction tasks when the hands are playing separately – Value of U: 34.0 (p = .40); and
• CT - in contrary motion tasks with the hands playing together – Value of U: 36.0 (p = .50).

From these results we must infer that left-handers, after a six or eight month period of tuition and practice, would be likely to show no more reductions in errors than right-handers when all (non-rhythmic) errors are measured – except when the hands are playing separately in contrary directions.

3.4.7 Proposition 3c (Third Observations – Post-test 2) with relative improvement scores

As put for Proposition 2b previously, the data gathered from this Third Observation was subjected to analysis using Relative Improvement Scores and a modified proposition. The proposition “left-handers are likely to make less relative improvement than right-handers - after a long period of tuition and Practice” was therefore represented by the two statistical hypotheses $H_0 : \mu_{RIS1-3(L)} \geq \mu_{RIS1-3(R)}$

\[ H_A : \mu_{RIS1-3(L)} < \mu_{RIS1-3(R)} \]

[where $H_0$ represents the Null Hypothesis, $H_A$ the Alternate Hypothesis, $\mu_{RIS1-3(L)}$ the mean Relative Improvement Scores (relative error reduction scores) from the First Observation (Pre-test) to the Second Observation (Post-test 1) for left-handers, and $\mu_{RIS1-3(R)}$ the mean Relative Improvement Scores (relative error reduction scores) from the First Observation (Pre-test) to the Second Observation (Post-test 1) for right-handers]

Data were analysed using the Mann-Whitney U test (one-tailed) on the Relative Improvement Scores (proportional reduction in error scores) from the relevant Left-handers' or
Right-handers' Pre-test/First Observation scores and their corresponding Post-test 2/Third Observation scores ($O_{1L}$ or $O_{1R}$ respectively, and $O_{3L}$ or $O_{3R}$ respectively; and where each respective Relative Improvement Score $x_{RIS1-3(L)} = \frac{O_{1L} - O_{3L}}{O_{1L}}$ and $x_{RIS1-3(R)} = \frac{O_{1R} - O_{3R}}{O_{1R}}$) in a comparison of the mean difference of the Left-handers ($\bar{x}_{RIS1-3(L)}$) with that of the Right-handers ($\bar{x}_{RIS1-3(R)}$).

Table 18: All (non-rhythmic) Errors, Third Observations (Post-test 2), – Improvement (with relative improvement scores)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>$\bar{x}_{RIS1-3(L)}$ (S.D.) and $n_L$</th>
<th>$\bar{x}_{RIS1-3(R)}$ (S.D.) and $n_R$</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>.9157 (.1193) 10</td>
<td>1.0000 (.0000) 9</td>
<td>27.0</td>
<td>.0782</td>
</tr>
<tr>
<td>SS:</td>
<td>.9181 (.1177) 10</td>
<td>.9375 (.1157) 8</td>
<td>36.0</td>
<td>.3809</td>
</tr>
<tr>
<td>CT:</td>
<td>.7799 (.1417) 10</td>
<td>.9645 (.7772) 10</td>
<td>15.0</td>
<td>.0034</td>
</tr>
<tr>
<td>ST:</td>
<td>.6467 (.0894) 10</td>
<td>.7943 (.1150) 9</td>
<td>14.0</td>
<td>.0051</td>
</tr>
<tr>
<td>CB:</td>
<td>.8368 (.1131) 10</td>
<td>.9700 (.0675) 10</td>
<td>16.0</td>
<td>.0045</td>
</tr>
<tr>
<td>SB:</td>
<td>.7402 (.0749) 10</td>
<td>.8399 (.1029) 9</td>
<td>22.0</td>
<td>.0326</td>
</tr>
<tr>
<td>BS:</td>
<td>.9187 (.0976) 10</td>
<td>.9654 (.0720) 9</td>
<td>32.0</td>
<td>.1577</td>
</tr>
<tr>
<td>BT:</td>
<td>.7094 (.0796) 10</td>
<td>.8781 (.0823) 10</td>
<td>6.5</td>
<td>.0002</td>
</tr>
<tr>
<td>BB:</td>
<td>.7876 (.0703) 10</td>
<td>.9067 (.0734) 10</td>
<td>12.0</td>
<td>.0028</td>
</tr>
</tbody>
</table>

[where $\bar{x}_{RIS1-3(L)}$ (S.D.) and $n_L$ represents the mean Relative Improvement Scores, with the Standard Deviation from the mean in parenthesis, of All (non-rhythmic) Errors for the relevant number of Left-handers with meaningful (non zero) initial scores, $\bar{x}_{RIS1-3(R)}$ (S.D.) and $n_R$ represents the mean Relative Improvement Scores, with the Standard Deviation from the mean in parenthesis, of All (non-rhythmic) Errors for the relevant number of Left-handers with meaningful (non zero) initial scores, Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed, when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70. As for a comparable earlier analysis, individual cases with original perfect (zero error) scores are treated as special cases, and the relevant data are]
excluded from the analysis, thus reducing the number of cases and constraining the probability value, but ensuring that all the scores used in the analysis are meaningful.

As Table 18 shows, when the data were analysed using reduction in error scores from the Pre-test to this same Second Post-test, six out of nine groupings of Tasks achieved statistical significance (five at the .01, and one at the .05 level of significance) as follows:

- **BB** – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together ($p < .001$);
- **BT** – when the hands are playing together with no differentiation as to whether the motion is contrary or similar ($p < .001$);
- **CT** – in contrary motion tasks with the hands playing together ($p = .003$);
- **CB** – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together ($p = .005$);
- **ST** – in similar motion tasks with the hands playing together ($p = .005$); and
- **SB** – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together ($p = .03$).

For these groupings the Null Hypothesis was rejected and the Alternate Hypothesis, that left-handers are likely to make less relative improvement in non-rhythmic errors than right-handers – after a long period of tuition and Practice, was accepted.

One further case:

- **CS** – in contrary direction tasks when the hands are playing separately ($p = .08$), was outside the .05 critical level, but within the broader range of $0.10 \geq p > 0.05$, where it was suggested earlier that if due consideration is taken of the power of the tests, with larger samples the probability obtained might possibly reach the critical level for statistical significance.

The remaining two groupings of Tasks failed to achieve statistical significance even though in each case, as before, the mean RIS for the Left-handers was still less than that for the Right-handers. For these groupings the Alternate Hypothesis was rejected and the Null
Hypothesis, that left-handers are likely to make no less relative improvement in non-rhythmic errors than right-handers – after a long period of tuition and Practice, was accepted. They were:

• BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar ($p = .16$); and

• SS – in similar direction tasks when the hands are playing separately ($p = .38$).

The significance and non-significance of these results indicates that we can infer to the normal population that left-handers, after a six or eight month period of tuition and practice, would be likely to show less relative improvement than right-handers when all non-rhythmic errors are measured – except in tasks when the hands are playing separately.
3.5 Analysis of Incorrect Hands Mistakes

3.5.1 Proposition 1 (First Observations – Pre-test)

The proposition "left-handers make more mistakes of misdirection of hands than right-handers – initially" was represented by the two statistical hypotheses

\[ H_0 : \mu_{1L} \leq \mu_{1R} \]
\[ H_A : \mu_{1L} > \mu_{1R} \]

(where \(H_0\) represents the Null Hypothesis, \(H_A\) the Alternate Hypothesis, \(\mu_{1L}\) the mean mistake score for left-handers, and \(\mu_{1R}\) the mean mistake score for right-handers).

Data were analysed using the Mann-Whitney U test to compare the mean mistake scores of the Left-handers (\(\bar{X}_{1L}\)) with those of the Right-handers (\(\bar{X}_{1R}\)).

Table 19: Incorrect Hands Mistakes, First Observations (Pre-test)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>(\bar{X}_{1L}) (S.D.)</th>
<th>(\bar{X}_{1R}) (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>0.3 (0.483)</td>
<td>0.0 (0.000)</td>
<td>35.0</td>
<td>.1399</td>
</tr>
<tr>
<td>SS:</td>
<td>0.0 (0.000)</td>
<td>0.0 (0.000)</td>
<td>50.0</td>
<td>.5147</td>
</tr>
<tr>
<td>CT:</td>
<td>0.1 (0.316)</td>
<td>0.1 (0.316)</td>
<td>50.0</td>
<td>.5147</td>
</tr>
<tr>
<td>ST:</td>
<td>1.3 (0.949)</td>
<td>0.5 (0.707)</td>
<td>25.5</td>
<td>.0344</td>
</tr>
<tr>
<td>CB:</td>
<td>0.4 (0.516)</td>
<td>0.1 (0.316)</td>
<td>35.0</td>
<td>.1399</td>
</tr>
<tr>
<td>SB:</td>
<td>1.3 (0.949)</td>
<td>0.5 (0.707)</td>
<td>25.5</td>
<td>.0344</td>
</tr>
<tr>
<td>BS:</td>
<td>0.3 (0.483)</td>
<td>0.0 (0.000)</td>
<td>35.0</td>
<td>.1399</td>
</tr>
<tr>
<td>BT:</td>
<td>1.4 (0.966)</td>
<td>0.6 (0.843)</td>
<td>27.0</td>
<td>.0446</td>
</tr>
<tr>
<td>BB:</td>
<td>1.7 (1.252)</td>
<td>0.6 (0.843)</td>
<td>24.0</td>
<td>.0262</td>
</tr>
</tbody>
</table>

[where \(\bar{X}_{1L}\) (S.D.) represents the mean mistake score of Incorrect Hands mistakes for the left-handers with the Standard Deviation from the mean in parenthesis, \(\bar{X}_{1R}\) (S.D.) represents the mean mistake score of Incorrect Hands mistakes for the right-handers with the Standard Deviation from the mean in parenthesis, Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.]
As Table 19 shows, four groupings of Tasks achieved statistical significance at the .05 level and for these the Null Hypothesis was rejected and the Alternate Hypothesis ("left-handers make more mistakes of misdirection of hands than right-handers – initially") was accepted. They were:

- BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p = .03);
- ST – in similar motion tasks with the hands playing together (p = .03);
- SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (p = .03); and
- BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p < .05).

The other five groupings of Tasks failed to achieve statistical significance at the .05 level, and so for them the Alternate Hypothesis was rejected and the Null Hypothesis ("left-handers make no more mistakes of misdirection of hands than right-handers – initially") was accepted. They were:

- CS – in contrary direction tasks when the hands are playing separately (p = .14);
- CB – in the contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together (p = .14);
- BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar (p = .14).
- SS – in similar direction tasks when the hands are playing separately (p = .51); and
- CT – in contrary motion tasks with the hands playing together (p = .51).

In the overall view (BB), and from one of the four prime groupings (ST) and two of the composites (SB and BT), there is support therefore for the inference that in the general population left-handers will initially be making more mistakes of misdirection of hands than right-handers.
However, it will be noticed that these groupings are the only four which include the similar together tasks, and so the results further suggest that we can infer that, when measuring mistakes of misdirection of hands, left-handers have more difficulty than right-handers with playing hands together in similar motion.

3.5.2 Proposition 2a (Second Observations – Post-test 1)

The proposition "left-handers make more mistakes of misdirection of hands than right-handers – after a short period of Treatment" was put, and then represented by the two statistical hypotheses $H_0: \mu_{2L} \leq \mu_{2R}$

$H_A: \mu_{2L} > \mu_{2R}$

(where $H_0$ represents the Null Hypothesis, $H_A$ the Alternate Hypothesis, $\mu_{2L}$ the mean mistake score for left-handers, and $\mu_{2R}$ the mean mistake score for right-handers).

Data were analysed using the Mann-Whitney U test to compare the mean mistake scores of the Left-handers ($\bar{X}_{2L}$) with those of the Right-handers ($\bar{X}_{2R}$).

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>$\bar{X}_{2L}$ (S.D.)</th>
<th>$\bar{X}_{2R}$ (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS</td>
<td>0.2 (0.422)</td>
<td>0.0 (0.000)</td>
<td>40.0</td>
<td>.2406</td>
</tr>
<tr>
<td>SS</td>
<td>0.0 (0.000)</td>
<td>0.0 (0.000)</td>
<td>50.0</td>
<td>.5147</td>
</tr>
<tr>
<td>CT</td>
<td>0.1 (0.316)</td>
<td>0.0 (0.000)</td>
<td>45.0</td>
<td>.3697</td>
</tr>
<tr>
<td>ST</td>
<td>0.7 (0.675)</td>
<td>0.2 (0.422)</td>
<td>29.0</td>
<td>.0615</td>
</tr>
<tr>
<td>CB</td>
<td>0.3 (0.483)</td>
<td>0.0 (0.000)</td>
<td>35.0</td>
<td>.1399</td>
</tr>
<tr>
<td>SB</td>
<td>0.7 (0.675)</td>
<td>0.2 (0.422)</td>
<td>29.0</td>
<td>.0615</td>
</tr>
<tr>
<td>BS</td>
<td>0.2 (0.422)</td>
<td>0.0 (0.000)</td>
<td>40.0</td>
<td>.2406</td>
</tr>
<tr>
<td>BT</td>
<td>0.8 (0.789)</td>
<td>0.2 (0.422)</td>
<td>28.0</td>
<td>.0526</td>
</tr>
<tr>
<td>BB</td>
<td>1.0 (1.054)</td>
<td>0.2 (0.422)</td>
<td>27.0</td>
<td>.0446</td>
</tr>
</tbody>
</table>

[where $\bar{X}_{2L}$ (S.D.) represents the mean mistake score of Incorrect Hands mistakes for the left-handers]
with the Standard Deviation from the mean in parenthesis, \( \bar{X}_{2r} \) (S.D.) represents the mean mistake score of Incorrect Hands mistakes for the right-handers with the Standard Deviation from the mean in parenthesis, Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.]

As Table 20 shows, two of the nine groupings of Tasks achieved statistical significance at the .05 level, and another two could be considered as being amongst those referred to previously, where it was suggested that if consideration is taken of the power of the tests, with larger samples the probability obtained might possibly reach this critical level. These four groupings were:

- BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p < .05);
- BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p = .05).
- ST – in similar motion tasks with the hands playing together (p = .06); and
- SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (p = .06).

In these cases the Null Hypothesis was rejected and the Alternate Hypothesis ("left-handers make more mistakes of misdirection of hands than right-handers – after a short period of Treatment") was accepted as follows:

The results of the other five groupings of Tasks which failed to reach statistical significance at the .05 level and for which the Alternate Hypothesis was rejected and the Null Hypothesis ("left-handers make no more mistakes of misdirection of hands than right-handers – after a short period of Treatment") accepted were:

- CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together (p = .14);
- CS – in contrary direction tasks when the hands are playing separately (p = .24);
• BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar (p = .24);
• CT – in the contrary motion tasks with the hands playing together (p = .37); and
• SS – in the similar direction tasks when the hands are playing separately (p = .51).

From this complex set of nine results, it can be seen that the groupings which reached (or nearly reached) statistical significance are the same as in the previous set of results from the Pre-test (BB: the overall view; ST: one of the four prime groupings; and SB and BT: two of the composites) and as can be seen, are the only four groupings of Tasks which include the tasks of hands playing together in similar motion. The problem that so few Incorrect Hands mistakes were being made by subjects after Treatment means that it became increasingly difficult for the tests to differentiate between the level of performance of the Left- and Right-handers. To the extent that any distinction is possible, the results suggest that after a short period of treatment, in the population at large, left-handers will still be making more mistakes of misdirection of hands than right-handers when putting hands together in similar motion.

3.5.3 Proposition 2b (Second Observations – Post-test 1) reduction in mistake scores

The proposition "left-handers are likely to make fewer reductions in mistakes than right-handers – after a short period of Treatment" was represented by the two statistical hypotheses $H_0: \mu_{1L} - 2L \geq \mu_{1R} - 2R$

$H_A: \mu_{1L} - 2L < \mu_{1R} - 2R$

(where $H_0$ represents the Null Hypothesis, $H_A$ the Alternate Hypothesis, $\mu_{1L} - 2L$ the mean difference in mistake scores for left-handers, and $\mu_{1R} - 2R$ the mean difference in mistake scores for right-handers).

Data were analysed using the Mann-Whitney U test on the negative gain scores (reduction in mistake scores) from the relevant Left-handers' or Right-handers' Pre-test/First Observation scores ($O_{1L}$ or $O_{1R}$ respectively) and their corresponding Post-test 1/Second
Observation scores (O_{2L} or O_{2R} respectively), in a comparison of the mean difference of the Left-handers (\bar{X}_{1L} - 2L) with that of the Right-handers (\bar{X}_{1R} - 2R).

Table 21: Incorrect Hands Mistakes, 2nd Observations (Post-test 1)
- Improvement (with reduction scores)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>(\bar{X}_{1L} - 2L) (S.D.)</th>
<th>(\bar{X}_{1R} - 2R) (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>0.1 (0.316)</td>
<td>0.0 (0.000)</td>
<td>55.0</td>
<td>&gt;.5147</td>
</tr>
<tr>
<td>SS:</td>
<td>0.0 (0.000)</td>
<td>0.0 (0.000)</td>
<td>50.0</td>
<td>.5147</td>
</tr>
<tr>
<td>CT:</td>
<td>0.0 (0.471)</td>
<td>0.1 (0.316)</td>
<td>45.5</td>
<td>.3838</td>
</tr>
<tr>
<td>ST:</td>
<td>0.6 (0.516)</td>
<td>0.3 (0.675)</td>
<td>67.0</td>
<td>&gt;.5147</td>
</tr>
<tr>
<td>CB:</td>
<td>0.1 (0.568)</td>
<td>0.1 (0.316)</td>
<td>50.5</td>
<td>&gt;.5147</td>
</tr>
<tr>
<td>SB:</td>
<td>0.6 (0.516)</td>
<td>0.3 (0.675)</td>
<td>67.0</td>
<td>&gt;.5147</td>
</tr>
<tr>
<td>BS:</td>
<td>0.1 (0.316)</td>
<td>0.0 (0.000)</td>
<td>55.0</td>
<td>&gt;.5147</td>
</tr>
<tr>
<td>BT:</td>
<td>0.6 (0.516)</td>
<td>0.4 (0.699)</td>
<td>62.0</td>
<td>&gt;.5147</td>
</tr>
<tr>
<td>BB:</td>
<td>0.7 (0.675)</td>
<td>0.4 (0.699)</td>
<td>63.5</td>
<td>&gt;.5147</td>
</tr>
</tbody>
</table>

(where \(\bar{X}_{1L} - 2L\) (S.D.) represents the mean difference of Incorrect Hands mistakes for the left-handers with the Standard Deviation from the mean in parenthesis, \(\bar{X}_{1R} - 2R\) (S.D.) represents the mean difference of Incorrect Hands mistakes for the right-handers with the Standard Deviation from the mean in parenthesis, Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.]

It can be seen from Table 21 that when the data were analysed using reduction in mistake scores from the Pre-test to this same First Post-test, no groupings of Tasks achieved statistical significance because, in all but one case, the mean reduction in mistakes for the Left-handers was greater than that for the Right-handers. In all nine cases the Alternate Hypothesis was therefore rejected and the Null Hypothesis ("left-handers are likely to make no
fewer reductions in mistakes than right-handers – after a short period of Treatment”) was accepted. The groupings, with results in parenthesis, are as follows:

- **CT** – in contrary motion tasks with the hands playing together (p = .38); and
- **SS** – in similar direction tasks when the hands are playing separately (p = .51).
- **CB** – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together (p > .51);
- **CS** – in contrary direction tasks when the hands are playing separately (p > .51);
- **BS** – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar (p > .51);
- **BT** – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p > .51);
- **BB** – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p > .51);
- **ST** – in similar motion tasks with the hands playing together (p > .51); and
- **SB** – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (p > .51).

In respect of the seven groupings where the mean reduction in mistakes for the Left-handers was not greater than that for the Right-handers, a modified non-directional proposition (“there is a significant difference between the reductions in mistakes between left-handers and right-handers – after a short period of Treatment”) was advanced. A brief summary of results follows:

- **ST** – in similar motion tasks with the hands playing together – value of U: 33.0; (p = .22);
- **SB** – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together – value of U: 33.0; (p = .22);
- **BB** – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together – value of U: 36.5; (p = .33);
- **BT** – when the hands are playing together with no differentiation as to whether the motion is contrary or similar – value of U: 38.0; (p ≈ .39);
• CS – in contrary direction tasks when the hands are playing separately – value of U: 45.0; (p > .51);

• BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar – value of U: 45.0; (p > .51); and

• CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together – value of U: 49.5; (p > .51).

Since these results are not statistically significant at the .05 level, the Alternate Hypothesis was therefore rejected and the Null Hypothesis, that there is not a significant difference between the reductions in mistakes between left-handers and right-handers – after a short period of Treatment, was accepted.

The statistical non-significance of all these results suggests that Treatment does not have any greater or less effect upon left-handers or right-handers, when reduction in numbers of mistakes of misdirection of hands is measured.

We are left to infer that, allowing for the fact that a left‐hander initially exhibits more qualified mistakes of misdirection of hands (ST: similar together; SB: combinations of similar together and similar separately; BT: combinations of similar together and contrary together; and BB: all types of playing involving hands separately and/or together in contrary and/or similar direction or motion) as was shown by the results of the Pre-test (3.5.1), after a short period of treatment, even though s/he will still exhibit more of the same qualified mistakes of misdirection of hands at that time as was shown by the results of Post-test 1 (3.5.2), s/he will not reduce the number of mistakes made by any more or less than a right‐hander.

3.5.4 Proposition 2c (Second Observations – Post-test 1) relative improvement scores

The proposition for relative improvement was also put on the same First Observation data. The proposition "left-handers are likely to make less relative improvement than right-handers – after a short period of Treatment" was therefore represented by the two statistical
hypotheses \( H_0 : \mu_{\text{RIS1-2}(L)} \geq \mu_{\text{RIS1-2}(R)} \)

\( H_A : \mu_{\text{RIS1-2}(L)} < \mu_{\text{RIS1-2}(R)} \)

(\text{where } H_0 \text{ represents the Null Hypothesis, } H_A \text{ the Alternate Hypothesis, } \mu_{\text{RIS1-2}(L)} \text{ the mean Relative Improvement Scores (relative mistake reduction scores) from the First Observation (Pre-test) to the Second Observation (Post-test 1) for left-handers, and } \mu_{\text{RIS1-2}(R)} \text{ the mean Relative Improvement Scores (relative mistake reduction scores) from the First Observation (Pre-test) to the Second Observation (Post-test 1) for right-handers.)}

Data were analysed using the Mann-Whitney U test (one-tailed) on the Relative Improvement Scores (proportional reduction in error scores) from the relevant Left-handers’ or Right-handers’ Pre-test/First Observation scores and their corresponding Post-test 1/Second Observation scores (\( O_{1L} \) or \( O_{1R} \) respectively, and \( O_{2L} \) or \( O_{2R} \) respectively; and where each respective Relative Improvement Score \( x_{\text{RIS1-2}(L)} = \frac{O_{1L} - O_{2L}}{O_{1L}} \) and \( x_{\text{RIS1-2}(R)} = \frac{O_{1R} - O_{2R}}{O_{1R}} \)) in a comparison of the mean difference of the Left-handers (\( \bar{x}_{\text{RIS1-2}(L)} \)) with that of the Right-handers (\( \bar{x}_{\text{RIS1-2}(R)} \)).

Table 22: Incorrect Hands Mistakes, Second Observations (Post-test 1),
− Improvement (with relative improvement scores)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>( \bar{x}_{\text{RIS1-2}(L)} ) (S.D.) and ( n_L )</th>
<th>( \bar{x}_{\text{RIS1-2}(R)} ) (S.D.) and ( n_R )</th>
<th>Value of ( U )</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS</td>
<td>.3333 (.3333)</td>
<td>3 no values (n/a)</td>
<td>0 n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>SS</td>
<td>no values (n/a)</td>
<td>0 no values (n/a)</td>
<td>0 n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>CT</td>
<td>1.0000 (n/a)</td>
<td>1 1.0000 (n/a)</td>
<td>1 0.5</td>
<td>&gt; .6000</td>
</tr>
<tr>
<td>ST</td>
<td>.4791 (.3825)</td>
<td>8 .5000 (.5774)</td>
<td>4 16.0</td>
<td>.5333</td>
</tr>
<tr>
<td>CB</td>
<td>.5000 (.5774)</td>
<td>4 1.0000 (n/a)</td>
<td>1 3.0</td>
<td>&gt; .6000</td>
</tr>
<tr>
<td>SB</td>
<td>.4791 (.3825)</td>
<td>8 .5000 (.5774)</td>
<td>4 16.0</td>
<td>.5333</td>
</tr>
<tr>
<td>BS</td>
<td>.3333 (.3333)</td>
<td>3 no values (n/a)</td>
<td>0 n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>BT</td>
<td>.4791 (.3825)</td>
<td>8 .6250 (.4787)</td>
<td>4 19.5</td>
<td>&gt; .6000</td>
</tr>
<tr>
<td>BB</td>
<td>.4479 (.3907)</td>
<td>8 .6250 (.4787)</td>
<td>4 20.0</td>
<td>&gt; .6000</td>
</tr>
</tbody>
</table>
[where $\bar{XRIS}(L)$ (S.D.) and $n_L$ represents the mean Relative Improvement Scores, with the Standard Deviation from the mean in parenthesis, of All (non-rhythmic) Mistakes for the relevant number of Left-handers with meaningful (non zero) initial scores, $\bar{XRIS}(R)$ (S.D.) and $n_R$ represents the mean Relative Improvement Scores, with the Standard Deviation from the mean in parenthesis, of All (non-rhythmic) Mistakes for the relevant number of Left-handers with meaningful (non zero) initial scores, Value of $U$ is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of $U$ at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70. As for comparable earlier analyses, individual cases with original perfect (zero mistake) scores are treated as special cases, and the relevant data are excluded from the analysis, thus reducing the number of cases and constraining the probability value, but ensuring that all the scores used in the analysis are meaningful.]

It can be seen from Table 22 that the decision to treat data containing zero scores as special cases and exclude it from the analysis constrained the results to the extent that no data were present in one or both of some groupings, and other groupings contained very small numbers of scores. The effect of this constraint was that the critical level of statistical significance became impossible to attain with so few effective scores available.

When data were analysed using Relative Improvement Scores (proportional reduction in mistake scores) from the Pre-test to this same First Post-test, the mean RIS for the Left-handers was less than that for the Right-handers for five out of six groupings of Tasks with effective data, and in the sixth case the means were equal. However, none of the five groupings achieved statistical significance at the .05 level, and so for them the Alternate Hypothesis was rejected and the Null Hypothesis, that left-handers are likely to make no less relative improvement than right-handers – after a short period of Treatment, was accepted. Those groupings were:

• ST – in similar motion tasks with the hands playing together ($p = .53$);
• SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together ($p = .53$);
• CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together ($p > .60$);
BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p > .60); and

BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p > .60);

Because of the equivalence of the means in respect to the sixth grouping (CT) and the unavailability of effective data in the other three groupings (CS, SS, and BS) of the total nine, there was not convincing or sufficient evidence to support the Alternative Hypothesis, and so for these also the Null Hypothesis, that left-handers are likely to make no less relative improvement than right-handers – after a short period of Treatment, was accepted.

The results indicate that we cannot infer that left-handers, when misdirectioning of hands is measured, are likely to show less relative improvement than right-handers after a week of treatment.

3.5.5 Proposition 3a (Third Observations – Post-test 2)

Table 23: Incorrect Hands Mistakes, Third Observations (Post-test 2)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>$\bar{x}_{3L}$ (S.D.)</th>
<th>$\bar{x}_{3R}$ (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>0.0 (0.000)</td>
<td>0.0 (0.000)</td>
<td>45.0</td>
<td>.5159</td>
</tr>
<tr>
<td>SS:</td>
<td>0.0 (0.000)</td>
<td>0.0 (0.000)</td>
<td>45.0</td>
<td>.5159</td>
</tr>
<tr>
<td>CT:</td>
<td>0.0 (0.000)</td>
<td>0.0 (0.000)</td>
<td>45.0</td>
<td>.5159</td>
</tr>
<tr>
<td>ST:</td>
<td>0.6 (0.699)</td>
<td>0.0 (0.000)</td>
<td>22.5</td>
<td>.0360</td>
</tr>
<tr>
<td>CB:</td>
<td>0.0 (0.000)</td>
<td>0.0 (0.000)</td>
<td>45.0</td>
<td>.5159</td>
</tr>
<tr>
<td>SB:</td>
<td>0.6 (0.699)</td>
<td>0.0 (0.000)</td>
<td>22.5</td>
<td>.0360</td>
</tr>
<tr>
<td>BS:</td>
<td>0.0 (0.000)</td>
<td>0.0 (0.000)</td>
<td>45.0</td>
<td>.5159</td>
</tr>
<tr>
<td>BT:</td>
<td>0.6 (0.699)</td>
<td>0.0 (0.000)</td>
<td>22.5</td>
<td>.0360</td>
</tr>
<tr>
<td>BB:</td>
<td>0.6 (0.699)</td>
<td>0.0 (0.000)</td>
<td>22.5</td>
<td>.0360</td>
</tr>
</tbody>
</table>
[where $\bar{X}_{3L}$ (S.D.) represents the mean mistake score of Incorrect Hands mistakes for the left-handers with the Standard Deviation from the mean in parenthesis, $\bar{X}_{3R}$ (S.D.) represents the mean mistake score of Incorrect Hands mistakes for the right-handers with the Standard Deviation from the mean in parenthesis, Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.]

The proposition "left-handers make more mistakes of misdirection of hands than right-handers - after a long period of tuition and Practice" was represented by the two statistical hypotheses $H_0: \mu_{3L} \leq \mu_{3R}$

$H_A: \mu_{3L} > \mu_{3R}$

(where $H_0$ represents the Null Hypothesis, $H_A$ the Alternate Hypothesis, $\mu_{3L}$ the mean mistake score for left-handers, and $\mu_{3R}$ the mean mistake score for right-handers).

Data were analysed using the Mann-Whitney U test to compare the mean mistake scores of the Left-handers ($\bar{X}_{3L}$) with those of the Right-handers ($\bar{X}_{3R}$).

As Table 23 shows, on the Second Post-test the Incorrect Hands mistakes scores were so low that the values calculated for the standard deviations on groupings of Tasks were often greater than the values for the means, making great difficulty for the analysis to find significant differences between groups. However, four results out of the nine groupings of Tasks achieved statistical significance at the .05 level, and so for these the Null Hypothesis was rejected and the Alternate Hypothesis ("left-handers make more mistakes of misdirection of hands than right-handers - after a long period of tuition and Practice") was accepted as follows:

- ST – in similar motion tasks with the hands playing together (p = .04);
- SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (p = .04);
- BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p = .04); and
• BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p = .04).

The other five groupings of Tasks failed to reach significance at the .05 level, and so for them the Alternate Hypothesis was rejected and the Null Hypothesis ("left-handers make more mistakes of misdirection of hands than right-handers – after a long period of tuition and Practice") was accepted. These groupings were:

• CS – in contrary direction tasks when the hands are playing separately (p = .51);
• SS – in similar direction tasks when the hands are playing separately (p = .51);
• CT – in contrary motion tasks with the hands playing together (p = .51);
• CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together (p = .51); and
• BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar (p = .51).

The four groupings of Tasks which achieved statistical significance (p = .04) are the same four which also achieved significance in the Pre-test (3.5.1) and Post-test 1 (3.5.2) – ST: similar together; SB: combinations of similar together and similar separately; BT: combinations of similar together and contrary together; and BB: all types of playing involving hands separately and/or together in contrary and/or similar direction or motion.

Following the same line of reasoning already expressed in discussing those earlier results, there is support from the total scores (BB), for the inference that in the general population left-handers will be making more qualified mistakes of misdirection of hands (after a period of six to eight months tuition and practice) than will right-handers, and from one of the prime groupings of Tasks (ST) that left-handers at that time still find that hands together in similar motion is a more difficult style of playing than do right-handers.
3.5.6 Proposition 3b (Third Observations – Post-test 2) reduction scores

The proposition "left-handers are likely to make fewer reductions in mistakes of direction than right-handers – after a long period of tuition and Practice" was represented by the two statistical hypotheses

\[ H_0: \mu_{1L-3L} \geq \mu_{1R-3R} \]
\[ H_A: \mu_{1L-3L} < \mu_{1R-3R} \]

(where \( H_0 \) represents the Null Hypothesis, \( H_A \) the Alternate Hypothesis, \( \mu_{1L-3L} \) the mean difference in mistake scores for left-handers, and \( \mu_{1R-3R} \) the mean difference in mistake scores for right-handers).

Data were analysed using the Mann-Whitney U test on the negative gain scores (reduction in mistake scores) from the relevant Left-handers' or Right-handers' Pre-test/First Observation scores (\( O_{1L} \) or \( O_{1R} \) respectively) and their corresponding Post-test 2/Third Observation scores (\( O_{3L} \) or \( O_{3R} \) respectively), in a comparison of the mean difference of the Left-handers (\( \bar{X}_{1L-3L} \)) with that of the Right-handers (\( \bar{X}_{1R-3R} \)).

Table 24: Incorrect Hands Mistakes, 3rd Observations (Post-test 2) – Improvement (with reduction scores)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>( \bar{X}_{1L-3L} ) (S.D.)</th>
<th>( \bar{X}_{1R-3R} ) (S.D.)</th>
<th>Value of U</th>
<th>Probability (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>0.300 (0.483)</td>
<td>0.000 (0.000)</td>
<td>58.5</td>
<td>&gt; .5159</td>
</tr>
<tr>
<td>SS:</td>
<td>0.000 (0.000)</td>
<td>0.000 (0.000)</td>
<td>45.0</td>
<td>.5159</td>
</tr>
<tr>
<td>CT:</td>
<td>0.100 (0.316)</td>
<td>0.111 (0.333)</td>
<td>44.5</td>
<td>.5000</td>
</tr>
<tr>
<td>ST:</td>
<td>1.900 (1.370)</td>
<td>0.556 (0.726)</td>
<td>71.0</td>
<td>&gt; .5159</td>
</tr>
<tr>
<td>CB:</td>
<td>0.400 (0.516)</td>
<td>0.111 (0.333)</td>
<td>58.0</td>
<td>&gt; .5159</td>
</tr>
<tr>
<td>SB:</td>
<td>1.900 (1.370)</td>
<td>0.556 (0.726)</td>
<td>71.0</td>
<td>&gt; .5159</td>
</tr>
<tr>
<td>BS:</td>
<td>0.300 (0.483)</td>
<td>0.000 (0.000)</td>
<td>58.5</td>
<td>&gt; .5159</td>
</tr>
<tr>
<td>BT:</td>
<td>2.000 (1.491)</td>
<td>0.667 (0.866)</td>
<td>69.0</td>
<td>&gt; .5159</td>
</tr>
<tr>
<td>BB:</td>
<td>2.300 (1.703)</td>
<td>0.667 (0.866)</td>
<td>71.0</td>
<td>&gt; .5159</td>
</tr>
</tbody>
</table>
[where \( \bar{X}_{3L} \) (S.D.) represents the mean difference of Incorrect Hands mistakes for the left-handers with the Standard Deviation from the mean in parenthesis, \( \bar{X}_{3R} \) (S.D.) represents the mean difference of Incorrect Hands mistakes for the right-handers with the Standard Deviation from the mean in parenthesis, Value of \( U \) is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of \( U \) at least as extreme as that actually observed when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70.]

As Table 24 shows, when the data were analysed using reduction in mistake scores from the Pre-test to this same Second Post-test, no groupings of Tasks achieved statistical significance at the .05 level, and in eight of them the mean reduction in mistakes for the Left-handers was not less than that for the Right-handers. For all groupings therefore, the Alternate Hypothesis was rejected and the Null Hypothesis ("left-handers are likely to make no fewer reductions in mistakes of direction than right-handers - after a long period of tuition and Practice") was accepted. The results were:

- CT – in contrary motion tasks with the hands playing together (p = .50);
- SS – in similar direction tasks when the hands are playing separately (p = .52);
- CB – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together (p > .52);
- CS – in contrary direction tasks when the hands are playing separately (p > .52);
- BS – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar (p > .52);
- BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p > .52);
- SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (p > .52);
- ST – in similar motion tasks with the hands playing together (p > .52); and
- BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p > .52).
With respect to the eight groupings where the mean reduction in mistakes for the Left-handers was not less than that for the Right-handers, when the modified non-directional proposition ("there is a significant difference between the reduction in mistakes of left-handers compared with right-handers – after a long period of tuition and Practice") was applied, as was done to some similar results in previous propositions, a summary of the test results indicate that four achieved significance at the .05 level, as follows:

- **ST** – in similar motion tasks with the hands playing together – value of \( U = 19.0 \) \((p < .04)\);
- **SB** – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together – value of \( U = 19.0 \) \((p < .04)\);
- **BB** – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together – value of \( U = 19.0 \) \((p < .04)\); and
- **BT** – when the hands are playing together with no differentiation as to whether the motion is contrary or similar – value of \( U = 21.0 \) \((p = .05)\).

For these groupings the Null Hypothesis was rejected and the Alternate Hypothesis, ("there is a significant difference in the reduction of mistakes between left-handers and right-handers – after a long period of tuition and Practice"), was accepted.

The remaining five results were not statistically significant at the .05 level and so for them the Alternate Hypothesis was rejected and the Null Hypothesis, that there is no significant difference in the reduction of mistakes between left-handers and right-handers – after a long period of tuition and Practice, was accepted. Those results were:

- **CS** – in contrary direction tasks when the hands are playing separately – value of \( U = 31.5 \) \((p = .30)\);
- **BS** – when the hands are playing separately with no differentiation as to whether the direction is contrary or similar – value of \( U = 31.5 \) \((p = .30)\);
- **CB** – in contrary direction or contrary motion tasks with no differentiation as to whether the hands are playing separately or together – value of \( U = 32.0 \) \((p = .32)\);
• CT – in contrary motion tasks with the hands playing together – value of $U = 44.5$ ($p = .50$); and
• SS – in similar direction tasks when the hands are playing separately – value of $U = 45.0$ ($p = .52$).

Again the four groupings of Tasks to achieve statistical significance were the same four which also achieved significance in the Pre-test (3.5.1), Post-test 1 (3.5.2) and Post-test 2 (3.5.5). From these we can infer that a prolonged period of six or eight months of tuition and practice is going to have a more beneficial effect (in terms of improvement in correctness of performance) upon left-handers than on right-handers when measuring qualified mistakes of misdirection of hands.

We are left to infer in much the same way as before that, allowing for the facts that a left-hander initially exhibits more qualified mistakes of misdirection of hands (ST, SB, BT and BB) as was shown in the analysis of results of the Pre-test (3.5.1) and s/he will still exhibit more of the same qualified mistakes after a period of six or eight months of tuition and practice as was shown in the analysis of the results of Post-test 2 (3.5.5), then his/her ability to have a reduced number of these qualified mistakes in performance at that time will be correspondingly better than that of a right-hander.

3.5.7 Proposition 3c (Third Observations – Post-test 2) relative improvement scores

As put previously for Proposition 2b, the data gathered from this Third Observation was subjected to analysis using Relative Improvement Scores and a modified proposition. The proposition "left-handers are likely to make less relative improvement than right-handers – after a long period of tuition and Practice" was therefore represented by the two statistical hypotheses $H_0 : \mu_{RIS1-3(L)} \geq \mu_{RIS1-3(R)}$

$H_A : \mu_{RIS1-3(L)} < \mu_{RIS1-3(R)}$

[where $H_0$ represents the Null Hypothesis, $H_A$ the Alternate Hypothesis, $\mu_{RIS1-3(L)}$ the mean Relative
Improvement Scores (relative mistake reduction scores) from the First Observation (Pre-test) to the Second Observation (Post-test 1) for left-handers, and $\mu_{RIS1-3(R)}$ the mean Relative Improvement Scores (relative mistake reduction scores) from the First Observation (Pre-test) to the Second Observation (Post-test 1) for right-handers.

Data were analysed using the Mann-Whitney U test (one-tailed) on the Relative Improvement Scores (proportional reduction in error scores) from the relevant Left-handers' or Right-handers' Pre-test/First Observation scores and their corresponding Post-test 2/Third Observation scores ($O_{1L}$ or $O_{1R}$ respectively, and $O_{3L}$ or $O_{3R}$ respectively; and where each respective Relative Improvement Score $x_{RIS1-3(L)} = \frac{O_{1L} - O_{3L}}{O_{1L}}$ and $x_{RIS1-3(R)} = \frac{O_{1R} - O_{3R}}{O_{1R}}$) in a comparison of the mean difference of the Left-handers ($\bar{x}_{RIS1-3(L)}$) with that of the Right-handers ($\bar{x}_{RIS1-3(R)}$).

Table 25: Incorrect Hands Mistakes, Third Observations (Post-test 2),
   Improvement (with relative improvement scores)

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>$\bar{x}_{RIS1-3(L)}$ (S.D.) and n$_L$</th>
<th>$\bar{x}_{RIS1-3(R)}$ (S.D.) and n$_R$</th>
<th>Value of $U$</th>
<th>Probability ($p$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS:</td>
<td>1.0000 (.0000) 3 no values (n/a)</td>
<td>0 n/a</td>
<td></td>
<td>n/a</td>
</tr>
<tr>
<td>SS:</td>
<td>no values (n/a) 0 no values (n/a)</td>
<td>0 n/a</td>
<td></td>
<td>n/a</td>
</tr>
<tr>
<td>CT:</td>
<td>1.0000 (n/a) 1 1.0000 (n/a)</td>
<td>1 0.5</td>
<td>&gt;.5000</td>
<td></td>
</tr>
<tr>
<td>ST:</td>
<td>.4584 (.6829) 8 1.0000 (.0000)</td>
<td>4 6.0</td>
<td>.0545</td>
<td></td>
</tr>
<tr>
<td>CB:</td>
<td>1.0000 (.0000) 4 1.0000 (n/a)</td>
<td>1 2.0</td>
<td>&gt;.5000</td>
<td></td>
</tr>
<tr>
<td>SB:</td>
<td>.4584 (.6829) 8 1.0000 (.0000)</td>
<td>4 6.0</td>
<td>.0545</td>
<td></td>
</tr>
<tr>
<td>BS:</td>
<td>1.0000 (.0000) 3 no values (n/a)</td>
<td>0 n/a</td>
<td></td>
<td>n/a</td>
</tr>
<tr>
<td>BT:</td>
<td>.5834 (.4179) 8 1.0000 (.0000)</td>
<td>4 6.0</td>
<td>.0545</td>
<td></td>
</tr>
<tr>
<td>BB:</td>
<td>.6146 (.4201) 9 1.0000 (.0000)</td>
<td>4 6.0</td>
<td>.0545</td>
<td></td>
</tr>
</tbody>
</table>

[where $\bar{x}_{RIS1-3(L)}$ (S.D.) and n$_L$ represents the mean Relative Improvement Scores, with the Standard Deviation from the mean in parenthesis, of All (non-rhythmic) Mistakes for the relevant number of Left-handers with meaningful (non zero) initial scores, $\bar{x}_{RIS1-3(R)}$ (S.D.) and n$_R$ represents the mean Relative Improvement Scores, with the Standard Deviation from the mean in parenthesis, of All (non-rhythmic)
Mistakes for the relevant number of Left-handers with meaningful (non zero) initial scores, Value of U is the test statistic produced by the Mann-Whitney U test, and Probability (p) represents the probability of obtaining a value of U at least as extreme as that actually observed, when the Null Hypothesis is true. The Key to the groupings of Tasks appears on p. 70. As for a comparable earlier analysis, individual cases with original perfect (zero mistake) scores are treated as special cases, and the relevant data are excluded from the analysis, thus reducing the number of cases and constraining the probability value, but ensuring that all the scores used in the analysis are meaningful.

It can be seen from Table 25 that the decision to treat data containing zero scores as special cases and exclude it from the analysis again constrained the results to the extent that no data were present in one or both of some groupings, and other groupings contained very small numbers of scores. Again the critical level of statistical significance became virtually impossible to attain with so low a base error rate especially in the scores of the Right-handers, and overall so few effective scores available.

When data were analysed using Relative Improvement Scores (proportional reduction in mistake scores) from the Pre-test to this same Second Post-test, the mean RIS for the Left-handers was less than that for the Right-handers for four out of six groupings of Tasks with effective data, and in the other two cases the means were equal. All four groupings achieved statistical significance at the .05 level, and so for them the Null Hypothesis was rejected and the Alternate Hypothesis, that left-handers are likely to make less relative improvement than right-handers – after a long period of tuition and Practice, was accepted. These groupings were:

• ST – in similar motion tasks with the hands playing together (p = .05); and

• SB – in similar direction or similar motion tasks with no differentiation as to whether the hands are playing separately or together (p = .05);

• BT – when the hands are playing together with no differentiation as to whether the motion is contrary or similar (p = .05); and

• BB – when no differentiation is made as to whether the direction or motion is contrary or similar or whether the hands are playing separately or together (p = .05);
Because of the equivalence of the means in respect to two groupings (CT and CB) and the unavailability of effective data in the other three groupings (CS, SS, and BS), there was not convincing or sufficient evidence to support the Alternative Hypothesis, and so for these the Null Hypothesis, that left-handers are likely to make no less relative improvement than right-handers – after a long period of tuition and Practice, was accepted.

The significance and non-significance of these results indicates that we can infer to the normal population that left-handers, after a six or eight month period of tuition and practice, would be likely to show less relative improvement than right-handers when misdirectioning of hands is measured, in certain specified tasks of hands playing separately and together in similar and combination of similar and contrary motion.
Chapter 4
Discussion of Results

Every man did what was right in his own eyes.
Some handled their tools and drew with their left hand.
A larger number used the right hand, but as yet no rule prevailed.
In this, as in certain other respects, the arts and habits of that period
belonged to a chapter in the infancy of the race, when the law of dexterity,
as well as other laws, begot by habit, convenience or more prescriptive conventionality,
had not yet found their place in that code
to which prompter obedience is rendered than to the most absolute of royal or imperial decrees.

(Wilson, 1876:53)

Having examined in detail the individual propositions and results of testing each of them, it is appropriate to bring together the various components of the analyses and look at the overall trends.

4.1 Comparative Analyses

Tables 1, 2 and 3 showed the individual scores of errors made on successive Observations. (For more detail see Appendix B). Table 4 summarised the totals of the three observations, and with Table 5 showed that not only did the Left-handers start out making more All (non-rhythmic) Errors than the Right-handers in the Pre-test, but they further made a proportionately greater number of All (non-rhythmic) Errors after Treatment, and greater again after Practice. Tables 6 and 7 clearly indicate that over successive Observations, as the number of the Right-handers making All (non-rhythmic) Errors was falling, all Left-handers were continuing to make All (non-rhythmic) Errors.
Tables 8, 9 and 10 specifically showed mistakes of misdirection of hands (Incorrect Hands Mistakes), and a comparison is made of the responses in Tables 11 and 12 showing that the mistakes made by Left-handers were always greater than those made by Right-handers, and that this unbalanced proportion increased dramatically across the three observations. Tables 13 and 14 showed that the confusion in directing the appropriate left or right hands was not evident in all Left-handed or all Right-handed Subjects, but was consistently exhibited by a larger number of Left-handers.

There are no immediate answers as to why the expected confusion was also exhibited (although to a lesser extent) by some of the Right-handed sample. Nor is there any need for argument or explanation for the converse – as to why only two of the Left-handers (along with six Right-handers) showed no evidence of confusion of hands in any observation. The phenomenon of a left-hander not exhibiting this confusion might be able to be explained simply as having adjusted well to the right-handedness of the keyboard, or might be better explained not just as not exhibiting confusion, but of exhibiting a right-handed trait, and vice versa.

But in an attempt in some way to answer why the confusion existed in some Right-handers and did not exist in two of the Left-handers, there appear to be at least two possible explanations, viz:

- those subjects could have been latent left-handers or mixed-handers respectively (as referred to by: Annett, 1967; Annett, 1970; Belmont & Birch, 1963; Benton, Myers & Polder, 1962; Berman, 1973; Bruml, 1972; Dean, 1978; Harris, 1979; Oldfield, 1969; Oldfield, 1971; Ross, Lipper & Auld, 1987; Schleuter, 1978). In Chapter 5 (under 5.2 Suggestions for Further Studies) is provided a detailed discussion of the ways in which a more stringent measure of handedness could be assessed in order to allow a more significant differentiation not only between right-handedness and left-handedness, but especially within the area of mixed-handedness; or
those subjects may, because of their physiological and mental maturation, still have been confused with the labelling or direction of left and right as a general practice – although this is a less likely argument given that most normative studies have shown that a child's ability to discriminate successfully between right and left has developed by the age of six or seven (Belmont & Birch, 1963; Benton, 1959; Binet & Simon, 1908/1911; Piaget, 1928; Swanson & Benton, 1955; Terman, 1916/1919; Teman et al., 1972). A test measuring each Subject's right-left directional discrimination as part of this current study was initially considered, but was thought unnecessary on the basis of the normative studies quoted above and on the findings of Benton and Menefee (1957), who found from a study of the association between right-left discrimination and the degree of unilateral hand preference that they were related (1957:241).

Whatever the reason for apparently uncharacteristic behaviour of some individual subjects, the general but overwhelming trend in results points to the Left-handers under-achieving in comparison to the Right-handers.
### 4.2 Statistical Analyses

The following table provides a summary of the statistical significance achieved when applying Mann-Whitney U tests on the various groupings of Tasks across the three Observations and seven Propositions posed on each of All (non-rhythmic) Errors and Incorrect Hands mistakes.

**Table 26: Summary of statistical significance of the comparison in achievement between the Left-handers and the Right-handers on groupings of Tasks**

<table>
<thead>
<tr>
<th>Groupings of Tasks</th>
<th>All (non-rhythmic) Errors</th>
<th>Incorrect Hands Mistakes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2a</td>
</tr>
<tr>
<td>CS:</td>
<td>.02</td>
<td>.03</td>
</tr>
<tr>
<td>SS:</td>
<td>.03</td>
<td>(.06)</td>
</tr>
<tr>
<td>CT:</td>
<td>.01</td>
<td>(.08)</td>
</tr>
<tr>
<td>ST:</td>
<td>.04</td>
<td>(.06)</td>
</tr>
<tr>
<td>CB:</td>
<td>(.09)</td>
<td>.01</td>
</tr>
<tr>
<td>SB:</td>
<td>.01</td>
<td>(.06)</td>
</tr>
<tr>
<td>BS:</td>
<td>.05</td>
<td>.01</td>
</tr>
<tr>
<td>BT:</td>
<td>.01</td>
<td>(.09)</td>
</tr>
<tr>
<td>BB:</td>
<td>.01</td>
<td>(.09)</td>
</tr>
</tbody>
</table>

[where: the value quoted indicates statistical significance at that appropriate $\alpha$ level; parentheses around the value, e.g. (.06), indicate values of $0.1 \geq \alpha > 0.05$; a value followed by m in parenthesis, e.g. .04(m), indicates that significance was found with a modified proposition; and . indicates that significance was not found at $\alpha \leq 0.10$]

In discussing the results of the empirical tests presented in the previous chapter, some strong trends will be seen emerging. It will be observed that consistent patterns
emerge within each of the categories, but that consistency does not necessarily carry over between the categories, that is to say except for the fact that where significance is found in the narrower category of Incorrect Hands mistakes, it nearly always is found in the broader All (non-rhythmic) Errors. In essence the latter encompasses the mistakes which were made by the subjects' misdirectioning of hands, so these results really come as no surprise.

It is important then to realise that the confusion of hands which was hypothesised at the outset of this study is most clearly measured by the Incorrect Hands scores, and hence will be proven by those results specifically. The All (non-rhythmic) Errors category serves to support the observations that left-handers generally seem to make more errors and show less improvement than most right-handers.

4.2.1 All (non-rhythmic) Errors

Table 26 shows that within All (non-rhythmic) Errors, when the raw scores on each observation (Propositions 1, 2a and 3a) are considered:
• initially – on the First Observation (Pre-test) – only two of the three groupings of tasks calling for the use of separate hands reached statistical significance at the $\alpha < .05$ level, and the combined separate and together contrary motion tasks achieved significance at a level of $\alpha < .09$;
• after treatment – on the Second Observation (Post-test 1) – all groupings of Tasks reached statistical significance at $\alpha < .05$; and
• the overall result after six to eight months of tuition and practice – on the Third Observation (Post-test 2) – allows the inference that generally in the population left-handers will make more errors of pitch and pitch direction than right-handers.

Table 26 also shows that within All (non-rhythmic) Errors, when applying the absolute reduction (negative gain) scores from two different sets of observations:
• the results after treatment \((O_{1L} - O_{2L} \text{ or } O_{1R} - O_{2R}) - \text{Proposition 2b}\) indicate that we should not infer that left-handers are predisposed to make fewer errors of pitch and pitch direction or less absolute improvement than right-handers (with maybe the exception of hands together in contrary or combinations of contrary and similar motion); and
• the results after a six or eight month period of tuition and practice \((O_{1L} - O_{2L} \text{ or } O_{1R} - O_{3R}) - \text{Proposition 3b}\), also caution any inference to the normal population that left-handers, when expected to play all but contrary direction with separate hands, will be predisposed to less absolute improvement (reduction in errors) than right-handers in tasks involving pitch and pitch direction.

Table 26 further shows that within All (non-rhythmic) Errors, when using the relative improvement scores (RIS) from the same two sets of observations:
• after treatment – \(x_{\text{RIS1-2}(L)} \text{ or } x_{\text{RIS1-2}(R)}\) (Proposition 2c) – there is mostly very strong support from the full variety of types and combinations of tasks, that left-handers will make less relative improvement than right-handers; and
• after a six or eight month period of tuition and practice – \(x_{\text{RIS1-3}(L)} \text{ or } x_{\text{RIS1-3}(R)}\) (Proposition 3c) – there is again nearly full support, except for separate hands in similar motion or similar and contrary motion, for the inference that left-handers will make less relative improvement than right-handers.

It is fair to comment further that after both the Second and Third Observations, in both raw score (Propositions 2a and 3a) and relative improvement terms (Propositions 2c and 3c), the sum-of-all-scores grouping (BB) always reached significance. The importance of this result cannot be stressed too much because these summative scores represent the total picture – that which was portrayed throughout the previous comparative section, and that which the teacher of the beginner left-handed piano player would notice.

Other observations could be made in similar ways, such as the BT grouping (both contrary and similar motion with hands always played together) which also, with those same propositions, always achieved significance. But not so the BS grouping (both contrary and
similar motion with hands always played separately) which only achieved significance after the Second Observation and not the Third. The main reason for the non-significance on the latter is possibly that since separate handed playing is easier than hands together, then the difference which was able to be noticed on the Post-test 1 between left- and right-handers on the overall and more difficult groupings (including BS) was not evident on the Post-test 2 BS grouping because of its comparative ease and given that the subjects had by then progressed in their playing as a result of the six or eight months spent in tuition and practice.

Two of the prime groupings of Tasks (CT and ST – contrary motion with hands together, and similar motion with hands together) were just as consistent. This again indicated in comparative terms a more difficult set of tasks than the other two prime groupings (CS and SS – contrary motion with hands playing separately, and similar motion with hands playing separately) although they each and together at times achieved significance.

Mostly when each of the above contrary and similar motion tasks (whether hands separately or together) were combined (as CB and SB) significance was also found, serving to further reinforce the prime groupings.

The SS grouping failed to achieve significance on the final observation in any of the three ways of analysing the scores (Propositions 3a, 3b and 3c). This could have been for either of the reasons that the tasks were easy or difficult, but most probably the former, because of the comparative ease of the separate hands component. When the hands are expected to play separately in a similar direction, there is a degree of support gained from the directional similarity of movement which is not completely allayed even though a reversed order of fingers must be applied.

### 4.2.2 Incorrect Hands mistakes

When interpreting the Incorrect Hands results of the statistical analysis on the raw scores of all Observations, the results from four out of nine groupings of Tasks (ST – similar motion tasks with the hands playing together; SB – combination of similar direction separately and similar motion together tasks; BT – both contrary motion together and similar motion
together tasks; and BB – sum of all scores of the four prime tasks, namely hands playing separately in contrary and similar direction, and hands playing together in contrary and similar motion) consistently support the inference that in the general population left-handers will make more mistakes of misdirection of hands than right-handers:

- initially (Proposition 1);
- after a short period of treatment (Proposition 2a); and
- after a long period of six to eight months of tuition and practice (Proposition 3a).

Interpreting the results of the analysis of the reduction (absolute improvement) scores from Incorrect Hands mistakes:

- after treatment – on the Second Observation (Post-test 1) – none of the nine groupings of Tasks reached statistical significance at the .05 level \( (p \leq .05) \) even when Proposition 2b was modified to non-directional, so we are left to infer that the reduction in mistakes of misdirecting hands will not be statistically different when comparing left-handers with right-handers, at this particular point of progress in their learning; but
- after a long period of six to eight months of tuition and practice – on the Third Observation (Post-test 2) – the four groupings of Tasks which had consistently supported significant \( (p \leq .06) \) results from the raw scores in the three observations above, were again significant here at the .05 level when Proposition 3b was modified to indicate a significant difference but of no qualified direction. We are able then to infer that after a period of six to eight months of tuition and practice the reduction in mistakes of misdirecting hands within those qualified tasks, will be significantly different between left-handers and right-handers.

Finally, interpreting the results of the analysis of the relative improvement scores (RIS) from Incorrect Hands mistakes:

- no inference can be drawn from the results after treatment – on the Second Observation (Post-test 1) from the respective RIS1-2 scores; but
- after a long period of six to eight months of tuition and practice – on the Third Observation (Post-test 2) from the respective RIS1-3 scores – the four groupings of Tasks which had
consistently supported significant \( (p \leq .06) \) results from the raw scores in the three observations (Propositions 1, 2a and 3a) and from the reduction scores on modified Proposition 3b, were again significant here at the .05 level with Proposition 3c. We are left to infer that, after a period of six to eight months of tuition and practice, the relative improvement (when measuring mistakes of misdirecting hands within the qualified tasks) of left-handers will be worse than that of right-handers.

The importance of these four groupings consistently finding statistical significance suggests that they alone are the successful indicators of a difference in achievement between left- and right-handers in measuring mistakes of misdirection or confusion of hands. As with the results of All (non-rhythmic) Errors discussed earlier, of those results from Incorrect Hands mistakes which achieved the critical level of significance, the sum of all scores result (BB) is present; along with the composite scores of similar motion by hands playing separately or together (SB); also one of the prime groupings – similar motion with hands playing together (ST); and the composite involving both similar and contrary with hands playing together (BT).

None of the prime or composite groupings of contrary motion played separately, together, or separately and together, nor the similar direction with hands played separately found significance. Since the previous four groupings of Tasks (BB, SB, ST and BT) had achieved significance (i.e. there is a difference between the performance achievement of left-and right-handers) then the non-significance of these latter groupings of Tasks (CS, CT, CB, and CS) and a final composite of both similar and contrary direction with hands played separately (BS) indicates that the performance of left-handers is not different from that of right-handers on these tasks. In other words, these tasks seem to occasion left-handers less difficulty than those on which significance was reached, and so could be said to be intrinsically easier by comparison.

The question of degree of difficulty of the testing instrument will be raised in detail in the next chapter, but it bears noting here that when measuring mistakes of Incorrect Hands, so few mistakes were being made towards the last Observation that it became increasingly
difficult for the tests to identify the differences in performance when the overall number of mistakes made by both groups was so small (sometimes nil). However to increase the difficulty of the tests overall would have caused serious problems at the start for the real beginners. In retrospect it might have been better to have used tests of differential difficulty.

As a closing point, it should be recognised that within each of the two major categories (All non-rhythmic Errors and Incorrect Hands mistakes) there was mostly consistency over time from the groupings which achieved significance and from those which did not. Perspectives have already been presented for the comparative ease or difficulty of some of the tasks, and they must be the main reasons for any significant discrepancy.

Attention is drawn to the writer's prior (and obviously not altogether subjective) observations that left-handers have initially more difficulty coping with the early stages of learning the piano keyboard. Since it is pointless to speculate whether there could be such a thing as a left-handed piano (which of course the left-handed subjects would be expected to use appropriately for them, i.e. in the mirror-reverse of the normal directions which we are accustomed to seeing), we must address the practical question arising from these results of how to help left-handers overcome what will continue to be their greater difficulty in initial adjustment to the conventional keyboard and traditional musical notation. This issue is discussed in Chapter 5.
Chapter 5
Conclusion, Suggestions and Recommendations

But since the bread-and-butter of the average piano teacher is not to produce world-beaters (although one or two might not come amiss),
the most important factor in technical teaching today is just trouble-shooting,
as when one tries to discover the causes of, and cure for,
more basic technical failures . . .

(Reeves, 1986:13)

5.1 Conclusion

It should be stressed that because of the paucity of prior research on this topic, this investigation was necessarily exploratory in nature, and that before definite conclusions can be made, it may be necessary to replicate the study with larger groups of students.

Nevertheless, as was measured by the tasks set in the study and discussed in detail in Chapter 4, the confusion of directing the appropriate left or right hands (as anticipated by the hypothesis) was exhibited to smaller or larger degrees in All (non-rhythmic) Errors and Incorrect Hands mistakes. Table 10 and Figure 10 showed clearly that the confusion, measured by Incorrect Hands mistakes, was exhibited:

- in the First Observation by eight Left-handers and four Right-handers;
- in the Second Observation by six Left-handers and only two Right-handers; and
- in the Third Observation by five Left-handers and no Right-handers.
It is reasonable to conclude from foregoing analyses that:

*A left-handed child in the early stages of learning to play a musical keyboard instrument will exhibit (when reading notation) more misdirection of the appropriate left or right hand as indicated by the music, than a right-handed child.*

At the same time, it can be assumed that left-handers generally will make more errors or mistakes than right-handers in the earliest stages of learning.

In addition, it has also been shown that:

*A left-handed child, even after a period of early tuition, consolidation and practice on a musical keyboard instrument, will still exhibit (when reading notation) greater misdirection of the appropriate left or right hand as indicated by the music, than a right-handed child.*

Also, whilst left-handers will exhibit more mistakes of misdirection of hands (and other non-rhythmic errors for that matter) than right-handers, the results of this study indicate that they will also be given to *less* relative improvement (when taken to mean a proportionate reduction in errors or mistakes) within the first half year or so of learning.
5.2 Remedial treatment of exhibited confusion

Mention was made in the previous chapter of groupings of Tasks which did not find significance when measuring Incorrect Hands mistakes or confusion of direction. These four groupings of tasks were:

* contrary motion played separately (CS);
* contrary motion played together (CT);
* composite of contrary motion played both separately and together (CB); and
* similar direction with separate hands (SS).

The results showed that the difference between the performances of the Left- and Right-handers was not statistically significant by comparison on these four groupings. In other words, these groupings were found by comparison to occasion the Left-handers less difficulty than the other groupings where statistical significance was reached. The statistical non-significance of these four groupings of the Tasks is nevertheless behaviourally significant, because the non-significance suggests that they are easier types of tasks, and so in terms of remediation for a problem left-hander, tasks of this nature could be used to advantage. They could be explained as being "passively" remedial, and could be used beneficially to instil confidence in a non-threatening, positively achieving way, before the student progressed to types of tasks which would be clearly more challenging but nevertheless constructive and classed as being "actively" remedial.

The groupings found to be the successful indicators of confusion of hands were:

* the sum of all scores (BB);
* the composite scores of similar motion by hands playing separately or together (SB);
* similar motion with hands playing together (ST); and
* the composite involving similar motion but with both hands playing separately and together (SB).

From these groupings, the one prime grouping of Tasks which could potentially be considered to be actively remedial was the grouping of similar motion tasks with hands playing together
The results indicate that since this grouping of ST tasks was consistently significant in showing a difference in achievement between the Left- and Right-handers, it (from the four prime groupings used) would be the best indicator of confusion of misdirectioning of hands. It then follows that in the hands of the piano teacher this type of task would be the one most valuable for correction of a problem left-hander's confusion of misdirectioning of hands.

The results (both the statistically significant and non-significant) can be interpreted to suggest strongly that a handedness-specific remediation program could now be designed for the beginner left-hander to enable him immediately to begin to correct any inherent confusion of misdirection of hands. Exercises which feature the use of one or more of the newly found actively and/or passively remedial tasks could be constructed and designed into a tailor-made balanced remediation program, which would provide the piano teacher with an empirically based corrective tool for use with problem left-handers.
5.3 Suggestions for further studies

As the writer has already mentioned, since there is so little information available on this particular topic, the current study has been an attempt to explore the subject area and define where possible the confusion of directioning of hands. In an effort to establish this even further and to broaden the knowledge on this particular topic, several options are available for further research – not the least replicating this study on a larger scale.

It became obvious when subjecting the scores from the Third Observation (Post-test2) to analysis, that the absence of one subject's scores had a severe effect on the outcome of the significance of the results – especially on the probability obtained. The following examples should amplify this:

Let us say for example the Value of U from a particular grouping was found to be 19.5. The tables of the distribution of the function of U for each group size being ten (n₁ = n₂ = 10) show a probability value of \( p = .01 \), whereas with the same value of U (19.5) for one group size being nine and the other ten (n₁ = 9, n₂ = 10) the probability is shown as \( p = .0195 = .02 \).

This effect of nearly doubling the probability factor when one sample group contains nine subjects instead of the customary ten, is consistent throughout the entire range as the next two summarised examples show:

- With a Value of U = 28.0:
  for n₁ = n₂ = 10: \( p = .05 \);
  whereas for n₁ = 9, n₂ = 10: \( p = .0912 \approx .09 \).

- With a Value of U = 32.5:
  for n₁ = n₂ = 10: \( p = .10 \);
  whereas for n₁ = 9, n₂ = 10: \( p = 1678 = .17 \).

It can be seen that the loss of one subject from a sample group has a rather devastating effect upon the probability value and the associated ability of that particular result to reach the critical level for statistical significance. It is then highly recommended, that in a similar future study, the sample sizes for groups should be large enough (12 or 15 would suffice) to attempt to
avoid the problem of loss of a subject to the experiment should this occur and to make the critical level of significance fall more easily within the reach of the outcome of the results.

If a larger study was to be considered, the present writer offers some further constructive points for such a major study.

5.3.1 Subjects' Handedness vs. Directional Confusion

The writer has already pointed out in Chapter 4, that in relation to both left-handers and right-handers sharing (although in very unbalanced proportion) the absence or presence of a confusion of hands in the testing, on the basis of his reading in this area he believes there are several explanations possible: either, that

* some subjects should have been classed as latent left-handers or mixed-handers; or that
* their right-left discrimination is not fully mature.

So in order to test the existing hypotheses further, and in an attempt to shed further light on the topic of the present study and on the observations already taken, a more comprehensive Handedness Rating and Measures of Pre-existing Left-Right Confusion could be addressed on a larger scale, or in greater depth.

Annett (1970) found from her testing of 2321 students, a different single criterion for assessing handedness from the one step writing test of Annett (1970), Clark (1957), Dean (1978), Deutsch (1978) and others. Annett (1970), in accord with Burt (1958), found that the one test which would differentiate a genuine left-hander from others was scissor-cutting, as she expressed in outlining her results:

\dots cutting with scissors, the test thought most valuable by Burt (1958), is the most stringent criterion. (1970:308)

A future study could look at further testing the discreteness or otherwise of the handedness of the subjects (who might ordinarily have been chosen solely on the basis of left-
or right-handed writing) by a simple two-step test which combines the writing and scissor-cutting tests, namely:

To each subject, give a sheet of paper, and ask him/her
• to write his/her name. Then hand the subject a pair of scissors and ask him/her
• to cut off the bottom section of the sheet.

By observation of the hand(s) used in these two simple activities, the initially obvious handedness of the subject could be first confirmed (from writing), and then doubly and more stringently established or questioned (from scissor cutting).

The results of this additional test would clearly establish, from the subjects in the left-handed group, those who could be classed as "discrete left-handers" or "mixed-handers". It would then be interesting to look for any correlation between this so-defined "mixed-handedness" and the numbers of non-rhythmic errors/mistakes made by those subjects, in comparison to the same performance from the "absolute left-handers".

However, it appears from the attention recently being given to the differentiality of handedness that it should not be classed dichotomously as simply left-handedness or right-handedness, and in this respect, it is often the intermediate type of hander (the mixed-hander, the ambidextrous or ambilevous, the inconsistent or indeterminate hander), and not the discrete or absolute left-hander who appears to have the greater problems with his or her own laterality (Annett, 1967; Annett, 1970; Belmont & Birch, 1963; Benton, Myers & Polder, 1962; Berman, 1973; Bruml, 1972; Dean, 1978; Harris, 1979; Oldfield, 1969; Oldfield, 1971; Ross, Lipper & Auld, 1987; Schleuter, 1978).

So in order to obtain a more accurate indication of a subject's handedness, it might be suggested that one of the more comprehensive measures of handedness could be administered, and the subjects given a handedness rating such as the Oldfield Laterality Quotient (Oldfield, 1969/1971) which rates handedness on a scale from +100 to -100 (from extremely right-handed to extremely left-handed). The only decision then to be made would be where to make the arbitrary cut-off for a "proper" left- or right-hander, viz:
• whether to use +100 to +90 and -90 to -100 (the narrowest part of the scale) to include only those exhibiting all one-handed traits; or
• whether to use +100 to +60 and -60 to -100 (the moderately narrow part of the scale) to include only those exhibiting all or almost all one-handed traits; or
• whether to use +100 to +30 and -30 to -100 (a broader, but still possibly as useful band) which includes those exhibiting all to most of the one-handed traits (Humphrey, 1951; Oldfield, 1969). Having then made the decision about a cut-off point there could be no further discussion about mixed-handedness or latent left- or right-handedness.

If there is a concern that a pre-existing left/right confusion in the subject(s) could and should be measured to improve the validity of a further or more in-depth study of this type, then some sort of test(s) of Right-Left Discrimination (Belmont & Birch, 1963; Benton, 1959; Benton, Hutcheon & Seymour, 1951; Binet & Simon, 1908/1911; Piaget, 1928/1969; Swanson & Benton, 1955; Terman, 1916/1919; Teman et al., 1972) would need to be administered to the subjects at the outset of any specific testing of the main handedness-related topic, and having measured for it, the experimenter would be in a position to decide whether to disqualify a particular subject or subjects from further selection on the basis of maturational development.

5.3.2 Construction of the Testing Instrument

It was evident throughout the testing of All (non-rhythmic) Errors in this study that the testing instrument was appropriate and successful and gave sufficient latitude for effective scoring of this category of errors. However, the reader is reminded of the perfect (zero) scores in some of the Incorrect Hands results. It appeared that a confusion of hands was not evident in most of the Right-handers and in a couple of the Left-handers, and so it seemed easy for those subjects to turn in zero Incorrect Hands mistake scores on all tasks. Educationally this would normally be construed as a commendable situation – for students to play without mistakes, whether they be of this kind or not. However, notwithstanding that this feat would
normally be applauded by the teacher of the beginner piano students, it nevertheless created a headache for the researcher, whose statistical analyses did not easily contend with such a low spread of scores, and with so many of those being zeros.

If a larger study of this same topic were to be contemplated, or even if a further effort were to be made to isolate more exactly and to measure more precisely the observed confusion of hands, and in order to allow for greater latitude for calculations and computations within the statistical analyses, a new testing instrument containing tests of differential difficulty could possibly be designed, or maybe two separate instruments could be used when specifically measuring either the All (non-rhythmic) Errors or the Incorrect Hands mistakes. Additionally, a separate and more rigorous instrument might be designed for assessing the performances after the prolonged period of tuition and practice. Further advantage might also be gained by enlarging and building more rigour into the existing testing instrument, by, for example doubling the length of each task, and adding rhythmic difficulty. These valid extensions of the current testing instrument could all possibly yield further insights.

At least in the existing design of the present study, the degree of difficulty of the tasks was sufficient to isolate mistakes of misdirection of hands for all but a couple of the highest achieving Left-handers, but this could be seen as being less than completely satisfactory from the point of statistical analysis when comparisons were made with almost zero (and at times zero) scores from Right-handers.

Although rhythmic accuracies were not being measured in this study (only errors/mistakes of pitch and pitch direction), nevertheless in a more extensive study, if more tasks with disparate rhythmic functions in the hands were included, then the degree of difficulty of the tasks would be increased and this would possibly create a broader band of errors/mistakes data for use in analyses. Rhythmic difficulties which could be built into the tests could include: e.g. semibreves and/or minims in one hand, being played against crotchets in the other, and vice versa.
The error made by some of the subjects in playing the $\frac{3}{4}$ tasks in $\frac{4}{4}$ time, could be avoided by changing those existing $\frac{3}{4}$ ones and devising similar tasks in $\frac{4}{4}$. However the writer feels that the aesthetic should not be disregarded just because of experimental testing, and so would recommend they be left as they are, since this change of time signature is probably the only major attempt possible to provide rhythmic variety and interest at a beginner level, and as has just been mentioned several times, no attempt was made to measure rhythmic inaccuracies – only errors/mistakes of pitch and pitch direction were counted.

5.3.3 Other perspectives

In respect to a child's physiological and mental development or maturation and ability to discriminate between left and right, the writer raises the question whether any advantage or insight would be gained by attempting to conduct this same type of experimental testing on a group of older subjects who were still beginners at the piano. Of course the decision to choose older subjects would create even greater problems in availability of selection of subjects for the samples, because the age of seven or eight years old is generally accepted to be the age when traditional notation-reading beginners are started on the piano.

However, on the basis of his experience, the writer is undecided whether, even if this testing were possible, it would yield any different insights, and whether there could be any further relevance gained, or further helpful information drawn. Nevertheless it remains a premise which could be tested.

Any further study which addressed the formulation of appropriate remedial exercises for the left-handed player could be extended with value across a longer period of time to measure at say the end of a two-year or five-year period any confusion or difficulties which still may be exhibited by left-handers, and could attempt to show what sort of practice best helps to overcome the left-handers' initial difficulties.
5.4 Justification for other further studies

Overall, the results justify the assertions made in the hypotheses, and nothing short of a much larger study would be able to clarify further any of the unanswered questions. The study, although demanding in its execution and successful in terms of results, could nevertheless be somewhat analagous to being on the "tip of the iceberg".

Since the hypotheses have been proven, the next obvious question which springs to mind is whether there is any remediation possible, or could an intervention programme be constructed to create a greater reduction in the incidence of non-rhythmic errors and mistakes of misdirection of hands made by left-handers in the early stages of their skill development at the keyboard? In other words, are there any ways in which the left-handed piano student can more quickly be helped to overcome any problem(s) which might be connected to a confusion of directing/directioning of hands?

Having from this study a synthesis of the background reading in the area, there is available to the researcher a foundation for worthwhile further studies, in the preparation and formulation of appropriate strategies and teaching methods that would lead to the construction of remedial exercises for the keyboard player and the necessary support pedagogy to be used by the piano teacher of the beginner left-hander.
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* * * *
Appendix A

The multiple facets of Handedness

As was mentioned in Chapter 1 (1.3) the literature is not able to reach a consensus on the various factors which determine the phenomenon of handedness, but reaches agreement that it is determined by at least one if not all of:

- psychological predispositions – both normal and abnormal (see A.2);
- physiological dispositions which favour one hand above the other (see A.3);
- hereditary and familial similarities (see A.4);
- social and environmental pressures (see A.5);
- maturational development (see A.6).

The literature also warns against:

- forced change of handedness (see A.7),

and presents:

- incidence of handedness (see A.8); and
- types of assessment for handedness (see A.9).

The following review (amplified from the main text of the present study) does not attempt to synthesise the whole body of literature on the topic, but attempts to present as clearly as possible the variety of dimensions of handedness.
A.1 Cerebral Laterality: A Weighty Clinical Diversion

A great amount of research has been done this century on cerebral dominance and cerebral laterality and the functions taken by each half of the brain. Most research has focussed on hemispheric dominance or mediation in relationship to – at worst – the possible inabilities, or – more frequently – the difficulties/disabilities/impairments in reading (alexia or dyslexia), writing (agraphia or dysgraphia – including mirror-writing) and speech (aphasia or dysphasia – including stuttering).

Apart from the use of gestures, there are two ways by which we can express our thoughts and feelings: language and music.

- Language is an expression in words of our intelligence as well as of our feelings (which are specially adapted to express our emotional life, and have not the clear form of language).
- Our musical faculty has forms analagous to language, and also analagous pathological forms.

The literature on verbal dysfunctions etc. frequently contains references to amusia (the inability to comprehend music as music), musical alexia, musical agraphia, musical aphasia, and musical apraxia (the inability to perform or execute music). Comparisons between language and music have been made with increasingly more regard to general capability, as well as to the more particular aspects of reading, writing, articulation, time sense, and prosody (the metric patterning or versification of speech) (Wertheim, 1963:167; Wertheim, 1969:199).

In fact, the area of music came to be featured in some of the clinical testing for the new research into the cerebral location of various thought functions and processes. The Seashore Measures of Musical Talents (Seashore, 1960), although originally designed to test potential musical talent as a battery of six sub-tests of sensory capacity (viz: Time, Loudness, Pitch, Rhythm, Timbre and Tonal Memory) was found by Milner (1962) to be effective (especially the Timbre and Tonal Memory tests) for recognising patients who were affected by right temporal lesions.
In clinical investigations of hemispheric asymmetry, Milner was able to show the fundamental nature of the processing differences between the two sides of the brain – namely that the left hemisphere is specialised for propositional, analytic, and serial/sequential processing of incoming information i.e. speech and logical thinking, while the right hemisphere is more adapted for the perception of appositional, holistic, Gestalt and synthetic relations i.e. non-verbal reasoning and music. Throwing a new light on cerebral dominance at that point in time, she (Milner, 1962) was able to show that there may be bilateral representation of speech in some individuals, with one hemisphere relatively, rather than absolutely, dominant; and says that:

... in man an asymmetry renders one hemisphere dominant for the perception and learning of verbal material, leaving it less important than the other hemisphere for the perception and learning of some nonverbal, visual and auditory patterns. (1962:195)

A great deal of attention and research has been given to the function of the interaction between the two hemispheres and in particular to the corpus callosum (the massive interconnecting nerve cable between the two). Studies done in the 1950's on animals provided the all-important information that the connection was there to allow communication between the two hemispheres and to allow transmission of memory and learning. Then in the early 1960's, extensions of these same studies, now known as the "split-brain" studies, were conducted on human subjects. They provided further information, and caused scientists to revise their views on the relative capabilities of the two hemispheres of the brain.

This remarkable work was done by Nobel-prizewinner Roger Sperry and his colleagues at the California Institute of Technology. Working on epileptics who had undergone surgery (by Vogel and Bogen) labelled commissuotomy [where the corpus collusum and related commissures (cross-connections) were separated (to dampen the life-threatening discharges of epileptic seizure crossing from one hemisphere to another)], Sperry and his team found that the patients' seizures were controlled and their health was regained, that their outward appearance, manner, and coordination were little affected, and to casual observation their ordinary daily behaviour seemed little changed.
Subsequent investigation and tests on both these patients and normal subjects provided new evidence that each hemisphere in a sense perceives reality in its own way:

\[
\ldots \text{each hemisphere seems to have its own separate and private sensations; its own perceptions; its own concepts; and its own impulses to act, with related volitional, cognitive, and learning experiences. (Sperry, 1968:724)}
\]

He points out that research on his split-brain subjects has shown that the left hemisphere in the right-handed patients is equipped with the expressive mechanisms for speech and writing, and with the main centres for the comprehension and organisation of language. He says this "major" hemisphere can communicate its experiences verbally and in an essentially normal manner, but that on the other side lies the mute aphasic and agraphic right hemisphere, which although it cannot express itself verbally, is not agnostic. The verbal (left) half, he says, dominates most of the time in nearly all individuals, whether split-brain or intact (1968:728).

Evidence had been gradually accumulating to show that the mode of the left is verbal and analytic, while that of the right is nonverbal and global. The non-speaking (right) half was said to act:

\[
\ldots \text{like a deaf mute or like some aphasics, (and) cannot talk about a perceived object and, worse still, cannot write about it either. (1968:725)}
\]

Yet it experiences, responds with feelings, and processes information on its own. It may be animal-like in not being able to talk or write, but it shows mental capacities that are definitely human. (1968:731)

New evidence found by one of Sperry's colleagues (Levy) in her doctoral studies showed that the mode of processing used by the right hemisphere is rapid, complex, whole-pattern, spatial, and perceptual. She showed that its processing is not only different from but comparable in complexity to the left brain's verbal, analytic mode (Levy, 1970, in Edwards, 1979:30). Sperry and his team were able to demonstrate that each side is responsible for a different set of functions and reactions, and that both hemispheres use high-level cognitive modes which – although different – involve thinking, reasoning, and
complex mental functioning.

In a joint paper presented at the 1968 National Academy of Science, Levy expressed this division of cerebral functioning as:

*The data indicate that the mute, minor hemisphere is specialized for Gestalt perception, being primarily a synthesist in dealing with information input. The speaking, major hemisphere, in contrast, seems to operate in a more logical, analytic computer-like fashion. Its language is inadequate for the rapid complex syntheses achieved by the minor hemisphere.* (Levy & Sperry, 1968:1151)

Sperry (1968) in summing up his paper and outlining possible future directions for his research, says that there was no indication at that time that the dominant mental system of the left hemisphere is concerned about, or even aware of, the presence of the subordinate minor system (1968:732). Certainly for the split-brain patients it had been shown conclusively that there was real substance in the expression that "the left hand did not know what the right hand was doing".

Levy (1972) in an address to the 32nd Biology Colloquium at Oregon State University said that the specific nature of right and left hemispheric function in man was not entirely clear, and quoted Broca (1960), Critchley (1962), and Hécaen (1962) as having shown language to reside in the left hemisphere, and Patterson & Zangwill (1944), Piercy & Smyth (1962), and Bogen & Gazzaniga (1965) as having shown constructional praxis in the right (1972:160). She said that of that time, our knowledge of this specialised part of the subject was like relating those descriptions to the output of what seems to be "two black boxes" (1972:161).

Through further research, Sperry (1973) was also able to show that the seemingly mute right hemisphere (the so-called artistic, emotional brain) can process data and communicate its results to us through dreams, symbols, gestures and sudden insights. He begins his discussion paper by stating that the main theme to emerge was that there appear to be two modes of thinking, verbal and nonverbal, represented rather separately in left and right
hemispheres (respectively); and goes on to point out that our educational system, as well as science in general, tends to neglect the nonverbal form of intellect – in fact that modern society discriminates against the right hemisphere (1973:209).

Levy (1974) finally explains quite succinctly that the left hemisphere analyses over time, whereas the right hemisphere synthesises over space, and that because of the disparate nature of these two functions, the two halves of the brain may be logically incompatible (1974: 167).

Bogen (1975), the surgeon who assisted in the first experimental human commissurotomies, addresses the ancient problem addressed by students of the mind: the dichotomous nature of "knowing", or the fact that we typically employ two different "kinds of intelligence" or more scientifically two different "sets of information-processing rules". He attempts to come to grips with this duality of brain function by citing scholars who have offered their own favourite dichotomy, and lists a whole table of these parallel "ways of knowing"/"types of intelligence"/"cognitive styles" from which the present author has selected the following:

(Parallel Ways of Knowing)

<table>
<thead>
<tr>
<th>intellect</th>
<th>intuition</th>
</tr>
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<tbody>
<tr>
<td>convergent</td>
<td>divergent</td>
</tr>
<tr>
<td>digital</td>
<td>analogic</td>
</tr>
<tr>
<td>deductive</td>
<td>imaginative</td>
</tr>
<tr>
<td>active</td>
<td>receptive</td>
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<tr>
<td>secondary</td>
<td>primary</td>
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<tr>
<td>abstract</td>
<td>concrete</td>
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<tr>
<td>directed</td>
<td>free</td>
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<tr>
<td>propositional</td>
<td>imaginative</td>
</tr>
<tr>
<td>analytic</td>
<td>relational</td>
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<td>rational</td>
<td>intuitive</td>
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<td>multiple</td>
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<tr>
<td>analytic</td>
<td>holistic</td>
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<tr>
<td>explicative</td>
<td>ampliative</td>
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<tr>
<td>explicit</td>
<td>tacit</td>
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<tr>
<td>objective</td>
<td>subjective</td>
</tr>
<tr>
<td>constrained</td>
<td>creative</td>
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</table>

(1975:25)
Bogen takes pains to point out that the suggested dichotomies are not intended to represent opposite ends of a continuum, but two different dimensions which are independent (1975:26), and says further that Levy (1972) had hypothesised that the two modes of thought were mutually inhibitory, and that their evolutionary lateralisation to different hemispheres was to prevent them from interacting detrimentally (Bogen 1975:30). Neisser (1966) calls one mode of thought "sequential processing"; the other he calls "multiple processing" – carrying out many actions simultaneously or at least independently (1966:297).

The point was made earlier that Edwards (1979) sums up the research of the 1960's and 1970's by saying that the left hemisphere analyses, abstracts, counts, marks time, plans step-by-step procedures, verbalises, and makes rational statements based on logic (1979:35), and that through the right hemisphere without figuring things out in logical order we "see" things that may be imaginary, we recall things that may be real, we use intuition and have leaps of insight, we see how things exist in space, and how the parts go together to make up the whole, we understand metaphors, we dream and create new combinations of ideas (1979:35).
A.2 Handedness and Cerebral Dominance

The phenomena of handedness and hand specialization could well be multiply and complexly determined; it would be easy, in the absence of a comprehensive body of theory and findings, to err on the side of oversimplification in explanation.

(Palmer, 1963:458)

Throughout the nineteenth century and into the start of the twentieth, with new light being shed on cerebral laterality and dominance, the scientific view was held that because most of the population at that time seemed to be classed as right-handers, and because speech and language, along with thinking and reasoning, were observed to be located in the left hemisphere, that the left hemisphere be labelled as the major or dominant hemisphere. The converse of this reasoning was that because it was observed that the right hemisphere did not handle speech or reading and writing, and did not control our leading hand or other dominant limbs, it was therefore less advanced and less evolved than the left, and so was called the subordinate, non-dominant or minor hemisphere.

Gaupp (quoted in Henschen, 1926:121) emphasises the fact that the characteristic of right-handedness has been present in all nations of the world from oldest times to the present day, and that in no nation is left-handedness predominant. Henschen (1926) goes on to state that in the new-born child there is no predominance of one hand over the other (i.e. his findings are that the young child is bi-lateral or ambi-dextrous), and states further that in the tenth month, however, most children become definitely right-handed. In an attempt to explain the reason for this obvious display of "dexterity" (right-handedness), he again quotes that Gaupp prefers the theory that the primary cause of right-handedness lies in the higher development of the left brain (1926:122).
Research studies done on animals earlier this century show mostly that in quadrupeds both cerebral hemispheres probably have equal and similar functions and are developed to the same degree. According to Henschen (1926) it is only in man and perhaps in the erect walking anthropods that the right arm is developed to a special organ for more complicated acts (1926:119). He uses this evidence to support the notion of left-cerebral dominance, and further observes that it can be shown that:

... bilaterally gifted animals attain a higher degree of development of the one side only at the cost of reduced faculties of the other side. (1926:119)

There has therefore been quite a deal of research done, especially since the earliest part of this century, on handedness, left-handedness, lateral dominance, lateral preference, crossed laterality etc. especially as applied to cerebral dominance and cerebral laterality.

The early interest in cerebral dominance quickly exposed the inherent complexities of this once apparently simple topic.

From the earliest observations on cerebral laterality and dominance, it was concluded that language and similarly related functions are located in the left hemisphere of the brain in most individuals.

At that time scientists thought that left-handed individuals were the converse of the right-handed in terms of brain organisation, i.e. that the verbal functions of speech (reading, writing etc.) were contained in the right hemisphere of the left-handed, and spatial concepts in the left etc.

Critchley (1961), in reviewing the discoveries made in this area, says that subsequent to the research from the early decades of this century, left-handedness and right-brain dominance were no longer to be regarded as a mirror-opposite variant of the normal state of affairs. He says that topics such as degrees of cerebral dominance; cross-laterality; correlation of inadequate dominance with cerebral immaturity; ambidexterity as a state of bisinistrality – all now come up for discussion (1961:210).
Recent research indicates that most left-handers are like right-handers and have verbal etc. functions located in the left hemisphere. In an empirical approach to this topic, Knox and Boone (1970) conducted tests of dichotic word and noise presentations on strongly right- and left-handed subjects (1970:165). Their findings indicated that under difficult listening conditions the right-handed subjects showed a significant right-ear effect (as could be expected from the concept of left-hemisphere processing of verbal information being the norm) but interestingly the left-handers showed an ipsilateral effect also i.e. they were strongly left-eared, pointing in their case to right-hemisphere processing of verbal stimuli (1970:172).

Lefevre, Starck, Lambert and Genesee (1977) took the hemispheric representation of handedness and listening and a step further by studying the lateral eye movements of right-handers during verbal and non-verbal dichotic listening (1977:1115). They showed that the subjects, when given a verbal dichotic listening test, made significantly more rightward than leftward eye movements and confirmed previous findings by noting that the subjects showed more accuracy and speed in processing information presented to the left ear rather than the right. Conversely when given a non-verbal test, they made significantly more leftward than rightward eye movements, and processed non-verbal information better when presented to the right ear (1977:1120).

Fairly recent evidence, according to Edwards (1979), sets this "norm" of left hemisphere dominance for speech etc. as occurring in approximately 98% of right-handers and two thirds of left-handers (1979:27). This indicates that only one-fiftieth of all right-handers and a third of all left-handers have reversed cerebral hemisphere processing, and are the exception to the rule. Edwards (1979) interestingly reports that for most of those individuals exhibiting right-brain dominance – as shown by the location of verbal functions there – their mothers were (also) left-handed (1979:43).

Dean (1979) in a paper presented at the Annual Meeting of the American Psychological Association, recognises that a longstanding implicit assumption about cerebral
laterality is that observable patterns of left- or right-handed preference would be reflected in the lateralisation of functions in the cerebral hemispheres. It was mentioned earlier in Chapter 1 (1.3.1) that he further (1982) quotes recent research which question(s) this absolute link between handedness and cerebral dominance, and even calls into question the idea of dominance of either one of the cerebral hemispheres. He also surveys (1985), the development and findings of research on this topic over the past century and especially the last several decades and shows that the relationship between atypical patterns of lateral preference and cortical functioning has been, and still is, one of the most studied and controversial issues in the neurosciences.

Again, mentioned in less detail earlier (1.3.1), an interesting study of four-year-old children who had been born prematurely with a very low birth-weight was conducted by Ross, Lipper and Auld (1987). Their findings support the the previously held theory (Satz, 1973; Bakan, 1978) that birth complications lead to cerebral insult or damage which may alter a child's hand preference and affect his/her mental and motor development (1987:615), and they suggest that in the near future it may be possible to examine brain scans to determine whether there is a documentable relationship between early brain asymmetries and later laterality (1987:620).

Finally, Zarske (1987), in a most recent and wide-ranging review of cerebral laterality, is prepared to say:

*It is generally established now that a patient's early medical and developmental history, as well as individual differences in brain chemistry and structure, make the entire enterprise of specific structural localization of functions a questionable endeavour.* (1987:298)

He continues by saying that although differences in cortical processing between the two hemispheres is acknowledged, in the light of today's understanding it is now considered less likely to be able to highly specify the localisation of functions within the brain (1987:298).
A.3 Handedness: The Physiological Evidence of Determinants

Having looked briefly at the clinical reasonings and findings on cerebral dominance and cerebral laterality which surround and in some ways support the concept of lateral manual dominance, it is now an appropriate time to leave as it were the "deeper fissures and convolutions" of cerebral laterality and under the next few headings turn to the more obvious possible physical determinants and social occurrences and implications of manual dominance specifically as exhibited in left-handedness.

Throughout the early decades of this century there was considerable effort made to determine whether or not there are physical and constitutional factors that predispose an individual toward dominant handedness and laterality (Gould 1908; Stier 1911; Whipple 1915; Jones 1918; Parson 1924; Woo & Pearson 1927; Chamberlain 1928; Wile 1934; and Rife 1940).

In a lengthy series of five articles on the development and training of hand dominance, Hildreth (1949c) attempted to put to rest once and for all the discussion of physical and/or constitutional determinants by stating that:

Any bodily anatomical or postural symmetry shown in infancy tends to be right- or left-sided in equal proportion in the population. No preponderance of right asymmetry has been found at birth or in early infancy that would be sufficient to account for right-handedness. (1949c:256)

However, all efforts to identify some bias in anatomical structure that would account for lateral dominance have failed, for as soon as some seemingly confirmatory data are presented, other contradictory data are produced (Bakan et al. 1973; Coren & Porac 1977; and Ardila et al. 1987).

Bishop (1980) took the ingenious and unorthodox approach of looking at the performance of a child's non-preferred hand, rather than concentrating on the performance of the dominant hand. She hypothesised and successfully showed that there were more children
who were particularly clumsy with the non-preferred hand amongst the left-handers than in the remainder of the sample. In finding that there was a higher incidence of neurological disorder and significant cognitive impairment amongst these left-handers, she said it was nevertheless a very indirect index of the likelihood of neurological abnormality (1980:577). Furthermore, Bax (1980), in an editorial discussing whether or not to alarm parents of left-handed children, says that the clinician must emphasise that usually sinistrality is of no significance, and that most left-handers do as well as right-handers, but admonishes that:

... perhaps one should keep the caution in one's own mind to examine the left-handed child a little more carefully than his right-handed brother or sister. (1980:568)
A.4 Handedness: A Hereditary Characteristic?

Parson (1924), after summarising the reports of many previous researchers who offered evidence to support the view that handedness was a hereditary characteristic, concluded that there were two types of handedness:

• congenital or native; and
• handedness acquired through corrective educational measures or as a result of injury or disease (1924, in Hildreth 1949c:263).

Chamberlain (1928) offered data which he suggested supported hereditary influences and reported that when both parents are right-handed only 2.1% of their offspring are left-handed, but that when both parents are left-handed the incidence of left-handedness rises to 17.34%. (1928, in Hildreth 1949c:263).

Scheidemann (1931) observed the independence of training and heredity on handedness, and Orton (1937) reported that the findings suggested that handedness was a result of both. Later Hildreth (1949) summarises further by quoting that Beeley (1918), Gordon (1920), Rife (1922), Ojemann (1930), Wile (1934) and Orton (1937) all agreed that handedness was inherited for they believed that only in that way could the tendency be explained – also that Koch (1933), Durost (1934), Freeman (1942) and Brain (1945) agreed with these findings to more or less the same extent.

Burt (1937) however states that psychologists had become much more wary of admitting heredity as an explanation of the principle of handedness. In addressing this possibility, and after a great amount of circuitous discussion and citing of clinical findings both for and against, he sums up by saying that although the inherited bias must in most instances be only very slight (otherwise it would not be so difficult to substantiate), yet those numerous instances which cannot be explained by hereditary effects must be classed as more or less exceptional. He posits:
... a tendency to use the one hand rather than the other is, in a greater or lesser degree, congenital. Opportunity, exercise, social influence and suggestion, however, are needed to call out this tendency and ultimately to fix it. (1937/1958:306)

Blau (1946), however goes even further and in a very substantial study of hand dominance reviewed a large literature, including twin studies, and concluded that handedness is not inherited.

O'Leary (1962) questions this assertion by asking that if not genetically encoded, then how else could handedness be registered (1962:41). This point is dealt with in some biological detail by Annett (1964 and 1970). She (1964) opens by saying that there were still several differences of opinion as to the handedness characteristic found in left-handers and ambidexters, and expounds a biological model based on two alleles (hereditary units/genes): D (which manifests handedness, and is usually dominant) and R (which manifests left handedness, and is usually recessive). She illustrates that assuming 80% of D and 20% of R in a population, then the proportions of the genotypes would be 64% of DD, 32% of DR and 4% of RR, and says that in this population the lowest possible incidence of left-handedness would be 4% (1964:59). She points out that her current model accounts for the finding that many people who regard themselves as left-handed, are in fact less consistent users of the left hand than the majority of right-handers are of the right, and says that these people should in fact be classed as mixed-handers. She also says that the model accounts for the fact that some left-handers (i.e. "true" left-handers) will use the left consistently (1964:60).

Annett (1970) takes up further the explanation of handedness as being biologically attributable to hereditary genes and suggests that since Blau (1945) had only differentiated between right-handers and left-handers in his study, and not between right-handers, left-handers, and mixed-handers, that his conclusion was invalid. She supports her argument by saying that the possibility that mixed-handedness arose from a partial expression of the recessive gene in the heterozygote could not be examined until both parental and filial data were also classified into the same three groups (1970:318). Still within this study, and calling
on the model proposed in her earlier paper (1964), Annett states that the issue of a genetic basis to handedness has remained clouded and no completely satisfactory account has been offered to date, because of three main reasons:

First . . . the inherited determinants of preference are so weak in comparison with those operating in the course of constitutional and social development that they can be discounted...

second . . . that preference depends on some relatively simple genetic mechanism involving only a few alleles whose expression is systematically distorted by developmental factors . . .

that handedness is basically discrete but blurred in growth . . .

third . . . that hand preference involves many genetic factors. . . (i.e. that it) has a polygenic foundation. (1970:318)

Levy (1972) states that handedness in humans is clearly correlated with hemispheric dominance for speech, and that the asymmetry which results from this lateral specialisation can be shown biologically to be linked to genetic factors in that there can be no doubt that there is a large genetic component in the determinants of human hand usage. She shows that at most, a two gene, two allele per gene model is sufficient to account for handedness ratios in various types of matings (1972:160).

In the largest and most definitive study to date, McGee and Cozad (1980) collected hand preference data from 2,818 subjects in 616 families, added these into data from previous population studies, and analysed the resultant data from an aggregation of 38,505 subjects from 8,572 families (1980:263). Their results showed evidence for generation differences (a lower incidence of left hand preference in parent than off-spring), familial resemblance (higher incidence of left hand preference among off-spring when one or both parents are left-handed), and maternal effects (higher incidence of left hand preference among off-spring when the mother is left- and the father right-handed, than when the father is left- and the mother right-handed) (1980:274).

Porac & Coren (1981) were then able to review all this available literature and showed
that it could be divided into either the one gene or the polygenic approach. They also showed that these approaches alone were not sufficient to indicate an exclusive hereditary component as the determinant of handedness, and conclude by citing Hicks & Kinsbourne (1976), Annett (1978) and Corballis (1980) who have all shown that although genetic mechanisms may give rise to differences in handedness between families, a number of nongenetic and even random factors contribute to the formation of handedness patterns within families (1981:80).

It therefore becomes apparent that the tests and observation methods which were used earlier were insufficiently refined to detect the existence or otherwise of hereditary effects on human laterality.

The most that can at the moment be safely said is that heredity furnishes the normal infant with two hands and two arms that are about equally responsive to training, and also with an active mind that is capable of making complex motor adjustments.
A.5 Handedness and Dominant Laterality: A Necessity?

Probably the oldest known written reference to left-handedness dates from about 1406 B.C. where in the Old Testament we can read that from the 26,000 "men who drew sword" from the children of Benjamin and the inhabitants of Gibeah, there were 700 chosen men – left-handed – and that every one of them could sling stones at a hair's breadth and not miss (Judges, 20:16). [But even their exceptional skill did not help the whole army against the opposition of only 4,000 men of war, for it is further recorded that the Lord smote Benjamin before Israel (Judges, 20:35)]. There is another reference to the descendants of the same tribe (Saul's brethren of Benjamin) some 350 years later (c.1055 B.C.). It is recorded that these men were armed with bows, and could use both the right hand and the left in hurling stones and shooting arrows from a bow (I Chronicles, 12: 2).

Stier (1911), in attempting to give an historical justification for left-handedness as an evolutionary process suggests that since from the earliest times the heart was known to be on the left side, that warriors held the shield in their left hand for protection, and therefore, fought with the spear or sword in the right hand (1911:272). Although this view has been attacked as being simplistic because it does not take into consideration the role of the non-warring female in the evolution of handedness, there had nevertheless been very little else upon which to base the phenomenon.

Most other researchers however can agree (Blau, 1946; Burt, 1937; Coren & Porac, 1977; Hildreth, 1949; Subirana, 1969; and Wile,1934) that from the evidence of historical writings, drawings, paintings, palæolithic implements, methods of working flints, etc. from previous cultures and civilisations, early historical and prehistorical humans were still (although probably less than today) characteristically right-handed people.

In a study of the nature, measurement and determination of hand preference, Koch (1933) recognises a great variety of determinants of a person's hand preference(s) – left or
right such as instruction, example, convenience, obviousness of choice, previous habits, specific nature and familiarity of task, hand strength, and genetic factors.

Wile (1934) proposed a unique but highly speculative theory as to the origin of right-handedness. According to his theory of heliotropism and heliocentrism persons in the northern hemisphere turning towards the sun and following the sun all day would describe a circle to the right. He puts that since civilisation first developed in the northern hemisphere, the tool makers and highly skilled tool users originated in the north temperate zone, and so the right-handed custom became prevalent as civilization spread over the globe and man made specialised use of tools (1934:190).

Burt (1937) provides an excellent discourse on handedness which still stands today. He explains that the functions of the hands are complementary; one hand being used for the more lively movements and finer more skilled actions; and the other for steady postures and coarser more mechanical actions. He observes that with most human beings the more delicate tasks are regularly allotted to the right, and continues with the following summary:

The left hand grasps the shield, the right hand wields the sword or the spear; the left hand grips the rifle, the right hand pulls the trigger; the left supports the book, the right remains free to turn over the pages; the left steadies the dress material or the writing paper, the right manipulates the needle or the pen. And, generally, whether in striking, cutting, sawing, painting, drawing, playing the violin, or lighting a match, the left hand takes the bulkier portion of the thing to be used, and holds it firm and still, the right hand picks up the smaller object or the more mobile part — the knife, the saw, the brush, the pencil, the bow, or the matchstick — and carries out the activity and nicely adapted movements controlled by the fingers or the wrist. (1937/1958:291)

He continues by saying that this allotment of duties clearly avoids the hesitation and brain effort in decision-making, which is often observed in crossed-laterals, left-handers and some ambidexters, and further points out that in a lot of cases he has studied, the exhibited handedness for a given task could only be described as behavioural, social, or acquired, since the task was often performed with the non-dominant hand. He then puts that the most powerful influences on handedness will, after all, be habit and custom (1958:315) — a point
which was corroborated much later by Penfield and Roberts (1974), in a complete chapter on "Handedness and Cerebral Dominance" (1974:102).

Hildreth (1949a) supports Burt and points out that Nature's economy is shown in the "specialization of function". She says:

*The skilled use of the hands is but one illustration of this trait, and the attainment of dextrous manual dominance represents an even higher degree of specialization of motor functioning.*

_Effective motor adjustments require an active hand and an auxiliary hand._ (1949a:199)

She continues by saying that not only has uneven (i.e. normal/traditional) handedness certainly become a test of civilization and a social symbol, but that the person with the more dominant and consistent manual dexterity becomes the more expert artisan in using tools involving delicate adjustments and operations. She points out that individuals who have not achieved manual dominance are less effective at certain skills and may even be handicapped in motor performance (1949a:199). (Interestingly enough, this seems to be in direct opposition to the skills requirement of a piano player, who must learn to use and control each of his hands just as delicately as the other!)

Humphrey (1951) subjected 70 known left-handed and/or ambidextrous males (aged 17-46, average ages between 20 and 30), and 35 known right-handed males, to a twenty-point questionnaire, and found that the left-handers were less consistent than the right-handers in the use of their preferred hand. He also found that the left-handed subjects more frequently reported a preference for the left hand in certain spontaneous acts (such as throwing), than in others which he noted were more susceptible to training and social influences (such as batting).

Clark (1957) found, in her study of handedness in Scottish school children, that there was no apparent or essential difference between the overall performances of left-handers and right-handers (except for their use of a different hand). In making this point in summarising her study, she says that it was no empty statement, but that it was a finding which required to be
emphasised in view of the then current attitudes to the phenomenon of left-handedness (1957:201).

Annett (1970) conducted a survey of 2,321 subjects, made up from Psychology students, servicemen in training, and other university entrants. She found that among those who showed tendencies toward left-handedness yet wrote with the right hand, measures of skill revealed greater dextrality than sinistrality – a point which supports the hand used in writing as being a strong indicator of true handedness or dextrousness (1970:318). [This point is used as the basic premise for handedness in the present experimental testing.] Annett pointed out that her findings suggest handedness is not basically discrete, bi-polar, or dichotomous, but should be recognised as varying continuously. She claimed that her findings demonstrated a continuum of preference which could be coordinated with a continuum of skill (1970:319).
A.6 Handedness: A Developmental Progression

It has already been noted that Henschen (1926) found the new-born child to be bi-lateral or ambi-dextrous, and held further that in the tenth month most children have become definitely right-handed (1926:122).

Gesell and Ames (1947) in summarising their study of the development of handedness in young children state that:

_Handedness is not a simple trait, but must be regarded as a focal symptom of the current status of an ever changing action system – which system, nevertheless, displays consistent symmetry and asymmetry trends over a long reach of growth. (1947:174)_

Their study was based on periodic observations of a group of normal infants and children up to 10 years old with a special emphasis on the infants in the first year of life. The infants showed an amazing lack of consistency in the use of the preferred or dominant hand over the first few months and years of life, but showed a trend to stability from age four onwards. The researchers summarised their findings by stating that as a general rule the handedness of a right-handed infant/child can be expected to develop as follows:

- contact of object unilateral and with the left hand, 16-20 weeks;
- bilateral contact at 24 weeks;
- unilateral, usually right hand at 28 weeks;
- bilateral at 32;
- unilateral through the rest of the first year with now right, now left predominating;
- right hand dominance 52-56 weeks;
- marked interchangeability with considerable use of both hands or of left hand at 80 weeks;
- right hand at two years;
- considerable bilaterality from 2 1/2 to 3 1/2 years;
- right handedness in general predominating from 4 to 10 years. (1947:173)

Clark (1957) in discussing the developmental aspects of handedness says there is ample evidence to show that both hand and eye preferences are established in almost all
children prior to school age, which she says discounts a view which was held at that time, that the school writing situation is the first indication of right-handedness in the majority. She also strongly refutes another currently fashionable opinion of the time that some form of rebellion against school authority is an explanation of left-handedness (1957:23).

Bruml (1972), in looking at changes in preference with age in 6-10 year olds, found the performance of Kindergarten, 2nd Grade and 4th Grade boys and girls showed no significant differences, and no consistent direction of difference. But she was able to note (in accord with the findings of Annett, 1964) that at each grade level, children writing with their left hand gave more variable performances than right-handed writers – i.e. they more often used different hands from task to task and within a task, from trial to trial. She completes her observations by noting, but without drawing any definite conclusions, that although there was no significant variability from grade to grade, the inconsistencies in performance from trial to trial were higher for the left-handed writers in the highest grade, than for those in the earlier grades (1972:8).

Porac and Coren (1981) showed that although infants appear to exhibit inherent hand preferences at an early age, there is a gradual shift towards right-handedness with increasing age. They not only confirmed the previous findings on infants by showing that laterality may not be clearly established until a child has reached pre-school age, but also quoted recent studies (Fleminger, Dalton & Standage, 1977; Coren & Porac, 1979; and Porac, Coren & Duncan, 1980) that show this age-related right-handed trend continues into adulthood (1981:40).
A.7 Results of forced change of Handedness

In the 1930's a lot of research was directed towards the observation of the forced conversion of handedness in the early school years. Koch (1933), Durost (1934), Burt (1937) and others since have been able to show that it may cause confusion, slowness, indecision, or motor fatigue, with nervous disorders.

However, because of the pressure and implications of social factors, Hildreth (1950b) suggests that where left-handedness is observed in the nursery years, parents should endeavour to encourage and strengthen any evidence of right-handedness in the child, especially in the areas of eating, writing, sewing, and using household tools and equipment. She reports studies which support the claim of minimum or no maladjustment in the child if the attempted conversion to right-handedness occurs before the age of three, i.e. before the child has developed far in speech (1950b:104 and 111). She warns that there should be no forcing if the child resists, but that training should be attempted on a day-to-day basis, and should be in the spirit of a game, and never associated with punishment (1950b:106). She then points to the fact that physicians agree that it is desirable for children to develop both sides of the body symmetrically, and that there is little danger that training in right-handed eating or writing will cause bodily lop-sidedness because young children tend to be ambilateral in the vigorous play activities which occupy most of their time. She then sums up by providing some prognostic signs of the ability to shift a child's handedness without permanent speech disturbance, motor upset and confusion, further points where certain difficulties may arise, and a copious list of suggestions to facilitate the shift of handedness (1950b:113-115).

Burt (1958) suggests that before deciding whether to attempt to retrain the left-hander, the crucial questions to be answered are: Which of the two hands is the more trainable for skilled movements; and, How great is the difference between them (1958:273)? He reported that it was far easier to acquire habits with the unfavoured hand than is commonly supposed, and suggests that what trouble there is springs less from a lack of capacity than from
the presence of irritating conflicts i.e. the learner has not only to overcome and tolerate the clumsiness or inexperience of the unaccustomed hand, but has also to resist the temptation to use the habitual and hence more dextrous hand (1958:316).

In a study of hand differentiation and psychological functioning Palmer (1963) found that those subjects with poorly differentiated handedness (i.e. quite ambilaterial, or ambilevous) were poorly integrated both psychologically and motorically (1963:447), and explained that this was possibly a manifestation of a general failure by those persons to realise full developmental growth potential. He found conversely that those with a strongly lateralised or differentiated pattern of skill (whether right- or left-handed) showed greater ego-strength and less physical maladjustment or awkwardness or clumsiness (1963:460).

Harris (1979), when discussing the relationship between lateral dominance and reading disabilities, confirms a positive attitude to conversion, because in those subjects whose handedness had been changed from left to right by the use of force, punishment, or ridicule, he found that it was not the fact of change, but the method of doing it that produced an emotional blocking that disrupted learning (1979:58).

These findings serve as a warning against forceful attempts to convert a strong left-hander; so much that today, most experts in the field of child psychology and development are opposed to attempting to shift over the strongly left-handed child above the nursery years, especially for fear of confusion and speech disturbance.
A.8 Incidence of Left-handedness

De Moragas and Subirana (in Subirana 1969), studied the manual preferences by the men represented in the rupestrial paintings of Spain. They found that the number of left handers, even in Neolithic times, was greater than at present. In certain places as in "La gruta de la vieja" (Alpera, province of Albacete) four out of the seven men held the arrow with their left hand (1964:250).

In a survey of more than 5,000 years of art works, encompassing 1,180 scorable instances of unimanual tool or weapon usage, Coren and Porac (1977) found no systematic trends in hand usage, but found that the right hand was used in 93% of cases regardless of which historical era or geographic region was being assessed (1977:631).

Without putting too much emphasis on the validity of the numbers or randomness of sample, of the 26,000 men that drew sword in the army of Benjamin quoted earlier (Judges 20:16), 700 men chosen because of their slingshot ability were left-handers (2.7%). Among soldiers, Stier (1911) found that the percentage of left-handers varied greatly (from 2.32% to 6.5%) in different provinces (1911:302).

Moutier (in Henschen, 1926) found that about 10% of hospital patients were left-handed (1926:121). [Henschen (1926) even makes the point that ambidexterity is more common than right-handedness in idiots (1926:121).]

Wile (1934), in an extensive monograph on handedness, tabulated the following findings of percentages of sinistrality from 26 authorities, reported between 1871 and 1933:

<table>
<thead>
<tr>
<th>Reference</th>
<th>Date</th>
<th>%</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hasse and Denhur</td>
<td>1914</td>
<td>1.00</td>
<td>(5141 soldiers)</td>
</tr>
<tr>
<td>Baldwin</td>
<td>1911</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>Hyrtl</td>
<td>1871</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>Brinton</td>
<td>1896</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>Ballard</td>
<td>1911</td>
<td>2.70</td>
<td></td>
</tr>
<tr>
<td>Mason</td>
<td>1896</td>
<td>3.00</td>
<td>(Based on 100 throwing sticks)</td>
</tr>
<tr>
<td>Researcher</td>
<td>Year</td>
<td>Rate (Left-Handedness)</td>
<td>Notes</td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Kapustin</td>
<td>1933</td>
<td>3.80</td>
<td></td>
</tr>
<tr>
<td>Lombroso</td>
<td>1903</td>
<td>4.00</td>
<td></td>
</tr>
<tr>
<td>Stier</td>
<td>1909</td>
<td>4.00</td>
<td>(German army)</td>
</tr>
<tr>
<td>Wisely</td>
<td>1930</td>
<td>4.00</td>
<td>(18,560 pupils)</td>
</tr>
<tr>
<td>Ogle</td>
<td>1871</td>
<td>4.50</td>
<td></td>
</tr>
<tr>
<td>Schaefer</td>
<td>1933</td>
<td>4.60</td>
<td>(Berlin School Children)</td>
</tr>
<tr>
<td>Smith</td>
<td>1917</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td>Burt</td>
<td>1921</td>
<td>5.10</td>
<td>(Pupils of ordinary schools of London)</td>
</tr>
<tr>
<td>Maro</td>
<td>1887</td>
<td>6.20</td>
<td>(81 &quot;normal&quot; and 190 working men)</td>
</tr>
<tr>
<td>Pyle and Drouin</td>
<td>1932</td>
<td>6.40</td>
<td>(Based on 862 left-hand writers among 13,438 elementary pupils)</td>
</tr>
<tr>
<td>Schiller</td>
<td>1932</td>
<td>7.77</td>
<td>(10,108 school children of Stuttgart)</td>
</tr>
<tr>
<td>Schwerz</td>
<td>1914</td>
<td>7.90</td>
<td>(1,072 school children in District of Schaffhausen-Bern)</td>
</tr>
<tr>
<td>Arnstein</td>
<td>1933</td>
<td>11.07</td>
<td>(2256 Palestinian children)</td>
</tr>
<tr>
<td>Schott-Esslinger</td>
<td>1933</td>
<td>11.49</td>
<td></td>
</tr>
<tr>
<td>Ramaley</td>
<td>(no date given)</td>
<td>15.70</td>
<td>(1130 cases)</td>
</tr>
<tr>
<td>Van Biervliet</td>
<td>1897</td>
<td>22.00</td>
<td></td>
</tr>
<tr>
<td>Quinan</td>
<td>1930</td>
<td>26.10</td>
<td>(1,000 university students, 317 Chinese school children nearly the same)</td>
</tr>
<tr>
<td>Woo and Pearson</td>
<td>1927</td>
<td>28.80</td>
<td>(7,000 cases)</td>
</tr>
<tr>
<td>Parson</td>
<td>1924</td>
<td>29.70</td>
<td>(865 cases based on eyedness)</td>
</tr>
<tr>
<td>Wile</td>
<td>1932</td>
<td>25.00-30.00</td>
<td>(Based upon natural carrying practices) (1934:68)</td>
</tr>
</tbody>
</table>

Wile found this incidence of from 1% to 30% sinistrality a rather wide distribution which was said to reflect a variety of methods and basic principles of identification (1934:68).

Selzer (1933) reports only one to two percent of pupils using their left hand for writing (in Enstrom 1962:235), but also reports a range from 2% to 28.79% for other left-handedness tests (in Blau, 1946:32).

Palmer (1943) reports that about 6% of all people are left-handed writers (1943:45).

Brackenridge (1981) in a study of handedness over a period of ninety years from 1880 to 1970, found that left-handed writers of high socio-economic status in Australia and New Zealand had increased from being only 2% of the population in 1880, to 13.2% shortly before 1970, and offers that "cultural relaxation of the right hand being used for writing" could be a reason for the results (1981:461).

Of about 600 school children systematically tested on a battery of specifically devised tests, Burt (1936/1958) found that 5.2% were left-handed. However in a wider survey of about 5,000 children in London schools he was able to show 6.1% of boys, 3.9% of girls, and an average of 5.1% who could be classed as left-handers (1958:281).
Carrothers (1947), in a survey of 225,000 pupils in Michigan state found that 8.2% were left-handed writers, and with reference to previous findings is prepared to say that this incidence had not only risen within the decade but was still increasing (1947:18).

Rife (1951) states that of children in his study: 50% were left-handed when both parents were left-handed; 16.7% were left-handed when one of the parents was left-handed; and 6.3% were left-handed when neither parent was left-handed. He pointed out that such percentages may be due to either heredity or environment. Additionally, pooled data from other experimenters show that in identical twins: 78% of the pairs are right-handed; 2% are left-handed; and 20% have one right-handed and one left-handed – an almost perfect random distribution in which approximately 12% of the individuals are left-handed (1951:188).

Clark (1976) reports that studies conducted over a ten-year period (1953-1963) by the Scottish Council for Research in Education (1963, 1968) show not only an increase in the incidence of left-handedness, but a greater incidence of left-handedness amongst boys. The incidence of left-handed writers amongst ten-year-old boys was found to have increased from 6.8% to 8.2%, and amongst girls 5.1% to 6.7%. She goes on to point out that as well as this higher incidence of left-handedness occurring in boys, there is a higher incidence of left-handedness in twins – though she says it is rare to find both twins left-handed (1976:28).

In another large-scale survey of handedness over eight years across four states of America, 92,656 school children (48,009 boys and 44,647 girls) from grades one through to six were surveyed. Enstrom (1962), showed there was a slightly greater proportion of boys who were left-handers, viz.: 12.5% boys, and 9.7% girls (1962:234). He stresses that these figures were taken from a geographic region where schools subscribed to a handwriting program that has for many years discouraged the forcing of children with strong left preference to write with the right hand. He suggests that the figures stabilise at an average statistical proportion of 11.1% of the school population in this area being left-handers (1962:235), and goes further to point out nine factors why the results of various findings up to date may have
shown such disagreement. He says:

*Disagreement in the findings may be the result of one or more of these factors:*

1. *In testing method employed, as for example, use of the left hand in various activities,*
   strength of grip, dexterity, measurement of bones, carrying hand, throwing hand, writing hand, hand clasping, tapping.
2. *In phase of sidedness tested — handedness, eyedness, leg and foot preference, ear preference, various combinations.*
3. *In the group tested — normal, abnormal, subnormal, delinquent, epileptic, special population group such as army.*
4. *In the age group tested — pre-school, primary, intermediate, advanced, high school, university, general adult.*
5. *In the degree of accuracy in testing procedure.*
6. *In the validity of the test used.*
7. *In the size of the group tested.*
8. *In birth status — single born, twin, identical twin, mirror-image twin.*
9. *In sex.* (1962:234)

In their study of lateral dominance and right-left awareness of normal children, Belmont and Birch (1963) tested a sample of 148 children from a suburban elementary school in New York, ranging from just over five to twelve and a half years old, found the incidence of left-handers as 10%, right-handers as 76%, and mixed-handers as 14% (1963:261); but if the stringency of the criterion is lowered to accept one slight inconsistency of hand preference within one-handed dominance, then the findings show the incidence of left-handers as 13%, right-handers as 84%, and mixed-handers as 3% (1963:262).

In a study of the handedness of musicians, Oldfield (1969) found their tendency to left-handedness was in a proportion statistically indistinguishable from that found from a control group of 1128 Psychology undergraduates (1969:94). He found that from the control group, although 19.9% said they had had a tendency to left-handedness, the final proportion resulted in 14% of males and 7% of females who were definitely left-handed (according to the criterion
established for this study). He devised a Laterality Quotient (individual scores for which had to be computed), and showed that more than two-thirds of all the subjects tested returned LOs of between +90 and +100 (1969:93).

Annett (1970) in her survey of 2321 subjects, (mentioned earlier) says that estimates of the left-handedness of this sample could vary between 3% and 30%, depending on whether complete consistency of left preference, or any left preference is the criterion (1970:319). She picks up the point [of which Travis (1931) many years earlier was aware, and was either missed, forgotten, or ignored by most researchers in the intervening period of time], that handedness is not dichotic, discrete or definitely polarised into two simple groups of right and left, but is spread across a continuum ranging from extreme or complete right-handedness through all variants and degrees of mixed-handedness and ambidexterity into the other extreme of complete left-handedness. This flexibility of criterion reinforces and accounts for the widely discrepant incidences and relative proportions that have been reported in all the foregoing literature on handedness.

Bruml (1972) made a study of changes of preference with age and validity of handedness measures, and found the incidence of left-handed writers across 60 children in each of three sets of classes to be: kindergarten 22%, second grade 8%, and fourth grade 15%, making the average for the whole sample 15% (1972:5). Ingram (1975) observed 103 three- to five-year-old children on a series of tasks in the Oldfield Questionnaire (Oldfield 1971) and found 84 (81.5%) of them to be right-handed in accordance with the definition of the questionnaire (1975:96).

Schleuter (1978) found in a small sample of 104 fourth, fifth and sixth grade beginner instrumentalists, that the proportion of subjects in the handedness levels are similar to those reported elsewhere in literature on handedness. The figures actually quoted are: ninety (86.5%) right-handers, eight (7.7%) mixed-handers, and six (5.8%) left-handers (1978:25). [It is of interest to note here that some of the previous literature would have grouped the
mixed-handers and left-handers together to give a left-hander or "sinistral" count of fourteen or 13.5%.

As was mentioned in the main body of this study (1.3.2) recent studies have been consistent in identifying the incidence of left-handedness and its criterion for assessment within the limited range of 10% to 14% as the following final three examples show.

From a sample of 5,147 people (2,391 females and 2,756 males) drawn from a broad range of socio-economic categories from the United States and Canada, Porac and Coren (1981) found 88.2% (90.1% females and 86.5% males) were right-handed (1981:36).

In the control group of four-year-olds in a study mentioned earlier, Ross, Lipper & Auld (1987) found the incidence of right-handers to be 80%, mixed-handers 9%, and left-handers 11%, (1987:618).

Strauss and Goldsmith (1987) discovered the incidence of dextrals in their small sample of 51 undergraduates to be 86.3% (1987:498).

It has been argued that the relaxation of social and parental pressure on the expectation that all children will be right-handers has created an increase in incidence of left-handedness over the past decades. However, empirical evidence for the increase in incidence is not clear cut, and as a complicating factor there is as yet no clear definition of what is meant by left-handedness, and whether any amount of the more recently recognised mixed-handedness or ambi-laterality should be allowed when describing or assessing "true" left-handedness. We cannot say conclusively then that there has been an increase in left-handedness and cannot say conclusively what its causes are. But we can say however that social attitudes and behaviour are important factors in forming the character and expression of left-handedness.
A.9 Handedness: Classification and Assessment

One of the earliest documented tests relating to handedness was labelled a Test of Preferred Hand (Hall and Hartwell, 1884), and not only shows the attempt being made at that time to define a handed preference, but actually seems more relevant to piano playing than many of the other tests found. A ruler six feet long was fastened to the edge of the table. The Subject, seated in front of the middle of the ruler, was asked to place the index finger of each hand on each side of a centre pin and move both fingers along suddenly and simultaneously in opposite directions. The preferred hand was found to make the wider excursion (1884:103).

Quinan (1922) and subsequently many others used The ordinary "primary pegging-board". This consisted of a thin piece of board, 10 inches square, one side of which presented 100 shallow holes arranged in ten parallel rows. Wooden pegs were provided with this board, and in one minute, as many pegs as possible had to be set up first by the right hand always moving to the right, then by the left hand always moving to the left (1922:354). According to whichever hand had the higher score, the subject was classed as being right-handed or left-handed (1922:356).

Rife (1922) attempted to break the myth that handedness should only be seen dichotomously, and proposed six Types of Dextrality, as a classification of handedness which was later adopted by Downey (1927). She did not attempt any assessment of handedness but made the point that any scientific investigation of handedness should always be accompanied by determination and analysis of the types (1922:480). According to her classification RRR represents a person who is right-handed for both unimanual and bimanual activities, RLL is a person who is right-handed for unimanual and left-handed for bimanual skills; and RLR denotes a person who is right-handed for unimanual skills but divided between right- and left-handed for bimanual skills (1922:478).

Quinan (1930) was satisfied in the context of his piece of research to use only a Test
of throwing a soft rubber ball – with “great force” (1930:37) to define overt handedness (in addition to using another test to measure eyedness). On the basis of whichever hand the subject used in attempting to throw the ball, s/he was given the label of so being right-handed or left-handed (1930:43).

The following Tests for preferential handedness were used by Updegraff (1932) with children aged from two to six years: picking up small articles; spinning a top; pushing a toy; spooning sand; picking up a spoon from floor; tossing a ring; writing; shaking a rattle; tearing paper; sweeping; and hammering a block. The four most reliable tests with this age group were found to be: spinning; spooning; shaking; and hammering (1932:136).

Koch and others from the University of Texas (1933) carried out an extremely comprehensive Study of the Nature, Measurement, and Determination of Hand Preference. The measurement containing over a hundred items was administered to 201 university students to determine the correlation between observed lateral behaviour and a questionnaire paralleling these observations (1933:213). The study comprised: • a preliminary questionnaire (Part A) of 12 questions (some further subdivided) on hereditary and known physical traits; in addition • a barrage of performance items noting the hand used for performing a hundred or more different tasks (the sort with which people have daily contact); and • a questionnaire which accorded with the same tasks as found in the performance tests. These test/questionnaire items were notionally divided into five parts and designated: Part I "bimanual untaught" (10 items); Part II "bimanual taught" (10 items); Part III "unimanual taught" (20 items); Part IVA "unimanual untaught" – equal opportunity (25 items); Part IVB "unimanual untaught" – handicap offered (25 items); which were then followed by a final questionnaire labelled Part V "side preference" (10 items) (1933:126). Koch noted the manual choices of her subjects, and demonstrated the feasibility of substituting a questionnaire for performance tasks when attempting to measure hand preference. The scoring scheme finally decided upon was expressed by the formula \( \frac{R - L}{R + L} \) which gives an indication of right- and left-handed choices of total usage; with +1.00 signifying absolute right-handedness, and -1.00 signifying
absolute left-handedness (1933:156).

Witty and Kopel (1936) arranged twenty-two items from these 105 used by Koch (1933) into a new Degree of Dextrality Questionnaire for elementary-school children. The questionnaire was scored in terms of the percentage of dextral responses. On the assumption that dextrality ranges from 0 to 100 degrees, handedness indices reflecting the percentage or degree of right-handedness were computed. The following formula, similar to the one used by Van Riper (1934), was employed:

$$\text{Handedness Index} = \frac{R + E}{2} \times 100$$

where $R$ and $E$ refer to the number of questions answered "right" and "either" hand respectively; and $N$ refers to the total number of questions answered. Thus a subject who indicated all Left answers would earn an index of zero, while one with all Rights would have an index of 100 (1936:124).

Johnson and Duke (1936) also designed a battery of twenty-seven simple observations/tests of Hand usage along the same lines and proceeded to devise a series of Dextrality Quotients for fifty six-year-olds (1936:33). Johnson next proceeded to devise a series of Dextrality Quotient norms for seven-year-olds (Johnson and Davis, 1937) and this time tested 50 boys and 50 girls with a variety of forty activities – thirty-two of which were found to be statistically reliable (1937:351) – namely: pulling down a curtain (twice); taking articles out of a desk; tearing a sheet of paper (from a pad); turning a piece of paper over; sharpening a pencil (hand that does the turning); writing name; erasing name; writing name again; putting pencil in the desk; taking out crayons (twice); colouring a picture; placing crayon(s) in a box (twice); closing box (twice); picking up scissors for cutting; putting scissors back; pointing (twice); picking up blocks; placing blocks; picking up cards (twice); laying down cards (twice); folding paper; sharpening pencil (again); turning pages; drawing; picking up scissors (again); putting scissors away; picking up pen; taking top off pen (hand doing turning); taking top off ink bottle; filling pen; writing name (again); putting top back on pen; erasing name (again); folding paper; picking up pen (again); taking top off pen (again); taking top off ink bottle (again); filling pen (again); writing name (again); picking up chalk; writing name (on chalkboard); picking up chalk (again); and printing name (on chalkboard) (1937:349). Johnson and Davis used the same Dextrality Quotient
Johnson and Duke (1940) then developed the *Iowa Scale for Measuring Hand Preference*. There are 64 items in this scale — some repeated twice. The test makes use of situations expected to be found in the ordinary office or schoolroom e.g. pulling down the shade; taking an article from the desk; writing with chalk; etc. The tests have the advantage of being easy to give and do not call the child's attention to his/her handedness. The authors use a dextrality quotient in nearly the same way as before, but quote it as: 

\[
\text{Total } R + .5B \\
\text{No. of test items tried}
\]

where \( R \) represents right-handed responses, and \( B \) both hands (1940:47). The quotients therefore range from 0.00 (extreme left-handedness) to 1.00 (extreme right-handedness) (1940:48).

In order to determine very simply the handedness of a small sample of young instrumentalists, Schleuter (1978) used a brief interview, where each student was observed in only six of the most reliable of the above tests, namely: writing; holding spoon; throwing ball; holding toothbrush; hammering nail; and cutting with scissors (1978:24). If all tasks were performed solely with the right hand or the left hand, the student was categorised as right-handed or left-handed, but if some task or tasks were performed by one hand and other task(s) by another, then those students were classed as mixed-handers (1978:25).

Selzer (1933) created a set of *Tests of Lateral Dominance and Visual Fusion* in order to determine the relative dexterity of the two hands. It includes the following tests: dynamometer; tapping; tracing; throwing darts; throwing bean bag; shot tube; steadiness; peg board; brachiometer; action current; drawing; vertical lines (in Hildreth 1950a:94).

After considerable experimentation Durost (1934) constructed a battery of four *Group Tests of Manual Laterality*, with a fifth being added later for another study. They were: pin test (puncturing as many small holes printed on cardboard in the one minute given, then repeating with the other hand); target test (3 shots with each hand); and line, square and circle tests (testing the steadiness of each hand holding a pencil which had to draw in between converging
lines that continually changed direction).

The scoring scheme finally decided upon was expressed by the formula \( \frac{R - L}{R + L} \) which was used by Koch et al. (1933). In reporting on his tests, Durost recommended the omission of decimal points (in fact the indicator becomes multiplied by 100) and so the ratios are expressed as whole numbers ranging from -100 to +100 (1934:250).

Durost (1934) also put forward a 10 item L-E-R Criterion Questionnaire as a less labour-intensive form of assessing a large number of subjects. Eight of the questions concern habitual unimanual tasks, whilst the other two involve the Subject's own judgement of strength and reaching. The 10 questions were specifically about: holding a jack-knife or paring-knife; writing; throwing a ball; erasing a blackboard; shooting marbles; brushing teeth; drawing or painting; reaching higher/highest; holding glass or cup (when drinking); and the stronger hand (1934:278). Subjects were instructed to answer L, or E, or R to the list of questions where: L denoted left-handed usage; E either hand; and R right-handed. He suggests that the formula used on the test battery would not work with the questionnaire, so proposed the slightly modified formula: \( \frac{R - L}{\text{No. of questions}} \) (1934:279). The correlation between the results of the test battery and the questionnaire was found to be quite high, which allowed Durost to recommend it highly for the purposes for which it was designed (1934:280).

Van Riper (1934 & 1935) devised a The Test of Laterality for which he designed the Critical Angle Board. The first, the laterality test (1934), employed the simultaneous drawing of various types of patterns (a kinesthetic, a visual, and a script/word) on opposite sides of a vertical board. It was shown to differentiate between groups of extremely right-handed, left-handed and ambidextrous individuals (1934:313). The second, the test using the Critical Angle Board, was intended to be a more quantitative test of laterality, and employed the simultaneous drawing of the same (above) three types of patterns on two writing boards, which could be converged through 90° from a position parallel to the subject's chest to a position perpendicular to his/her chest.

The angle of convergence at which one hand produced mirrored patterning was shown to
differentiate quantitatively between thoroughly right and left handed groups and an ambidextrous group, while a group of less thoroughly right handed subjects mirrored at angles approximately midway between the angles of the former groups. (1935:382)

An interesting (but expected) point made from the observations of the tests, was that when mirrored patterns did occur, they were drawn by the non-dominant hand (as indicated by a verbally professed handedness preference). These tests were scored according to the formula

\[ \text{Laterality Index} = \frac{R + E/2}{N} \]

where \( R \) and \( E \) refer to the number of questions answered "right" and "either" respectively; and \( N \) refers to the total number of questions answered. So a subject who indicated all Left answers would earn an index of 0.00 while one with all Rights would have an index of 1.00 (1934:306).

[These laterality tests themselves were two decades later subjected to further critical empirical testing by Clark (1957), who asserts that she found the use of the Van Riper Critical Angle Board was not justified as a diagnostic instrument for measuring left-handedness (1957:200).]

Roos (1935) tested the handedness of kindergarten, sixth grade and college students with the tapping test (1935/4:260), and groups of college students on strength of grip; and number marking tests (1935/4:267). She claimed that her Logarithmic Handedness Index (\( \log R/L \)) is ideal (1935/4:263), and found that it was distributed normally, and did not form a bi-modal curve (1935/2:91 and 1935/4:266). She also showed that 75% of people with native left-handed ability, developed a preferential use of their right hand, (probably because they live in a right-handed world) and found that she could label 19% of her sample as left-handers on the tapping test – more than double the percentage of those who wrote with their left hand (1935a:263).

Beck (1936) initiated a study to consider the merits of certain tests of Motor Skills and their relationship to handedness (1936:259). He used five tests: single plate tapping, triple plate tapping, Miles motility rotor, Brown spool packer, and Koerth pursuit rotor tests. Single plate tapping calls for the tapping with a stylus on a single metal plate, while triple plate tapping
involves the successive striking of three plates arranged in a triangular pattern. The Miles motility rotor measures the speed with which the handle of a manual drill can be turned, the Brown spool packer involves continual serial movements of picking up spools one at a time and placing them in a tray, and the Koerth pursuit rotor calls for a high degree of precision of manual movement in following a rotating metal target with a flexible pointer. The tapping tests had been previously outlined by McCollom (1932:82), and the Miles, Brown and Koerth tests were part of the Stanford Motor Skills Battery described in detail by Seashore (1928:56). Beck found the motility rotor, the triple plate tapping, and the pursuit rotor tests to be more discriminative as measures of handedness, but did not attempt to define a formula for laterality or handedness.

Buxton (1937) compared three of these manual-skill measures of handedness as proposed by Beck (1936) above (the pursuit rotor, triple plate tapping, and motility rotor tests) with a battery of his own preference tests to determine whether laterality (or dominance) was tested by each type of test. His choice was for five activities. The first three (tested ten times each) were: throwing; reaching (for objects – near and far); and brushing (lint from clothing). To these he added: a peg-board test; and a dynamometer test. He found the reliabilities of the three motor-skills ratios relatively satisfactory; the brushing and the dynamometer tests not so satisfactory; and the throwing, reaching, and peg-board activities very high (1937:466). In summing up he suggests that the motor-skills did not correlate closely enough either with each other, or with the preference tests, to indicate significant communality. He further suggests that this level of correlation failed to indicate that either battery of tests could be substituted one for the other (1937:469).

Hull (1936) conducted a study of Laterality Test Items to assess the validity of a self-administered questionnaire. Two questionnaires (the same 40 items were included in each – but jumbled) and two performance tests (using the same items and order of the questionnaires) were given at least four weeks apart. In the performance tests, 21 of the items yielded a better than 90% reliability across the four test periods, whereas over both questionnaires, 14 yielded those same reliability figures. On test-retest of performance and
questionnaire 12 items were answered identically in over 90% of cases which Hull suggests permits the use of those items in a sidedness questionnaire. They are: hammering; cutting (with scissors); dealing cards; spinning (a top); winding (a watch); holding (a toothbrush); sharpening (a pencil); writing; cutting (with the knife when eating); drawing; throwing; holding (a tennis racquet) (1936:290).

With twenty of the above original items, Humphrey (1951) set out to test the observation that not only are left-handers a minority, but that they tend to be less strongly unilateral in their hand dominance and preference than a normal right-hander (1951:214). He set up a questionnaire on the assumption that hand dominance is manifested in the tendency to use one hand rather than the other in a number of skilled acts which are common to most educated people (1951:214), and notes that some activities are especially susceptible to training and social influences, as well as being the subjects' natural inclinations. He had hoped to evolve a new "laterality index" but found it to be outside the scope of his study and so adapted the formula of Witty and Kopel (1936) (1951:219) to create his own version of their Handedness Index with a Dextrality Index (D.I.) and a Sinistrality Index (S.I.) thus:

\[
\text{D.I.} = \frac{R + E}{2} \times 100 \quad \text{and} \quad \text{S.I.} = \frac{L + E}{2} \times 100
\]

where \( R, L, \) and \( E \) refer to the number of questions answered "right", "left" and "either" respectively (1951:215). The twenty item questionnaire, adapted from Hull (1936) invited an answer for the hand(s) used for: throwing; writing; drawing; wielding a racket; cutting with scissors; using a razor; combing; brushing with toothbrush; cutting with a knife (but not eating); using spoon (for eating); hammering; screw-driving; cutting with knife (for eating - with fork); swinging a cricket bat; sweeping with broom (top hand); raking (top hand); unscrewing jar; striking a match; dealing cards; and threading a needle (1951:217). He found that from all twenty activites used in questioning, the strongly left-handed persons were always identified by just three: throwing; wielding a racket; and writing - or having shown early tendencies to write with the left-hand (1951:221).

In investigating the incidence of handedness in musicians, Oldfield (1969) initially makes the point that this Inventory of Handedness Activities is derived from, though not
identical with, the above as used by Humphrey (1951), and that it is substantially the same as
that used by himself in a larger scale survey of handedness in an undergraduate population
(1969:92), which is reported later. Subjects were asked to indicate their hand preference in
the use of twenty-four activities by putting a "+" in the columns marked "R" and "L". Further,
where the preference was so strong that they would never try to use the other hand unless
absolutely forced to, they were instructed to put ++, and if in any case they were really
indifferent about which to use, they were asked to put + in both columns (1969:99). The first
twenty-two activities listed were: writing; drawing; throwing; cutting with scissors; using a
razor; using a comb; using a toothbrush; cutting (with knife); using a spoon; hammering;
screwdriving; wielding a tennis racket; using a fishing rod; cutting with knife (and fork); wielding
cricket bat (lower hand); swinging golf club (lower hand); sweeping with broom (upper hand);
raking (upper hand); striking match (match); opening box (lid); dealing cards (card being
dealt); and threading needle (whichever is moved). The final two questions were about which
foot the subject preferred to kick with, and the eye used when using only one (1969:99).
(Other questions were asked, but were related specifically to the topic of handedness as it
applies to musical activities and/or musical instruments, and these will be addressed by the
present writer in a later, more specific section.) The first twenty-two responses were
scored as follows:

<table>
<thead>
<tr>
<th>R</th>
<th>L</th>
<th>x_i</th>
</tr>
</thead>
<tbody>
<tr>
<td>++</td>
<td></td>
<td>+2</td>
</tr>
<tr>
<td>+</td>
<td></td>
<td>+1</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
<td>-1</td>
</tr>
<tr>
<td>++</td>
<td></td>
<td>-2</td>
</tr>
</tbody>
</table>

From these scores a "Laterality Quotient" (LQ) was computed for each subject using the
formula \( LQ = 100 \cdot \frac{\sum_{i=1}^{22} x_i}{\sum_{i=1}^{22} |x_i|} \) which asked for the algebraic sum of the individual scores to be
divided by the sum of their absolute values regardless of sign, and the quotient multiplied by
100 (1969:92). It will be seen that the LQ takes values from +100 to -100 which then allows the
researcher a useful tool for expressing handednesses on an extended scale rather than as
simply left or right, or even left, mixed and right.

Oldfield (1971) designed the Edinburgh Handedness Inventory for use in a large scale survey of handedness in an undergraduate population, and based it on his previously successful inventory, only this time reducing it marginally by leaving out using razor and using fishing rod, to a battery of 20 handedness indicators; and again adds the same additional two questions (which foot the subject preferred to kick with, and the eye used when using only one) (1971:112). Having conducted the investigation, Oldfield shows that a shorter form of the inventory would yield as good a Laterality Quotient, and so suggests "a short form of only 10 questions", viz: writing; drawing; throwing; cutting with scissors; using a toothbrush; cutting with a knife (without fork); using a spoon; sweeping with a broom (upper hand); striking a match (match); and opening the lid of a box (1971:111). In either of these forms, subjects are asked to indicate their hand preference in the use of the activities in the same way as for the previous inventory. He also concedes that, instead of using the previously ponderous equation for finding the LQ, all that has to be done is to add all the +'s for each hand, subtract the sum for the left from that for the right, divide by the sum of both and multiply by 100 (1971:99). This is the same sort of formula as the formula for Hand Dominance put forward by Koch (1933), Durost (1934) and others who followed suit, but with a slight change in that it should be multiplied by 100 to obtain a "Laterality Quotient".

Ingram (1975) observed 103 three- to five-year-olds in a series of uni-manual activities similar to those in the Oldfield Questionnaire above. Subjects were asked to demonstrate the use of twelve objects such as a spoon, hammer, comb, shovel, etc. A subject was arbitrarily classified as right- or left-handed if he used the same hand for at least eight of these activities (1975:96).

Ross, Lipper and Auld (1987) used a modification of the Oldfield Questionnaire (above) specifically for four-year-olds in that parents were asked to observe their child's hand preference(s) over a period of a few days and then report on the 10 items listed. The first seven were: writing; drawing a picture; throwing a ball; holding scissors to cut paper; holding toothbrush; holding fork while eating; and opening lid of box (hand(s) actually pulling lid). The final three were considered to be more appropriate for young children than those used
previously, and were: *combing* hair; *brushing/painting* picture; and *holding* (top of) shovel to move sand (1987:616). The items were scored according to a system developed by Bryden (1977) where: $AR$ always right $= 1$; $UR$ usually right $= 2$; $E$ either hand $= 3$; $UL$ usually left $= 4$; and $AL$ always left $= 5$. Thus the total score for the 10 items ranged from 10 (extremely right-handed) to 50 (extremely left-handed), and for the purposes of the study children scoring 10-20 were considered to prefer the right hand; those between 21 and 39 to have mixed hand preference; and those scoring 40-50 to prefer the left (1987:616).

Burt (1937/1958) suggests that if a quantitative measurement of a child's manual dexterity and preference for hand is required, then a teacher could merely observe the child's customary mode of *using the pencil or pen*. He goes on to say that other simple indicators are:

- *his* power to *throw* a ball or *pick up* a weight, to *hammer* or *bore*, to *sort* marbles, *deal* cards, *cut* with a *knife* or *scissors*, *stir* with a *teaspoon* in a *cup*, *turn* a *handle* or *wind* cotton round a *reel*, *more easily with the one hand than with the other*. Probably the best single test for rapid use is to ask the child to *cut paper with loose-riveted scissors*. (1958:271)

However, he adds that for more empirical individual testing, the following ten questions would pick out most children with left-handed tendencies, when asked to reply "right", "left", or "either" hand to: *writing; drawing/painting; throwing* (ball); *striking* (with racket/stick/bat); *holding* penknife; *cutting* (with scissors); *carrying / lifting* (cup of water/glass in drinking); *brushing* teeth; *winding* (clock/watch/musical box); and *reaching* (for a book/plate on a high shelf). He further suggests that for group testing the simpler tests of manual speed and dexterity can be applied, viz: *tapping; aiming; and tracing* tests, and refers the reader to Durost (1934) *Group Tests of Manual Laterality* (Burt, 1958:280). He puts toward a simple formula for an "Index of Left-Handedness" as being: \[ \frac{L}{R} \times 100 \] where $L$ and $R$ denote the number of points scored with each hand respectively, and also provides what he calls a somewhat better "Measure of Right-Handedness" with: \[ \frac{R - L}{R + L} \] (1958:272).

Gesell had in 1925 devised a number of tests for infants to measure motor skills and prehension (seizing/grasping/taking hold). In the 1938 monograph (a manual of revised
tests) there is listed under "Prehension" the observations which form the basis of the infant's developing handedness. These include the infant's exploitation of materials such as: rattle; cup; cup and spoon; ball; pellet; ring dangling from a string; and form board (1938:172).

Gesell and Ames (1947) report the Tonic neck-reflex is an asymmetric posturing behaviour found in the unborn foetus and the young infant, and can be observed as a condition of muscular contraction in which the head is turned to the right (or left) side, the arm and leg on the same side are extended, and the arm and leg on the other side flexed, or vice-versa (1947:171). Gesell and Ames made a study of the asymmetric hand, arm and leg movements developing out of this tonic neck-reflex, and the parallel development of handedness in the infant, and found that in fourteen out of nineteen cases investigated, the tonic neck-reflex was predictive of handedness, and showed that the handedness of all four left-handers was correctly predicted in this way. However they noted that their observations could in some situations be unstable and were sometimes submerged by other movements (1947:172). They also noted in conclusion that from their extensive studies, perfect ambidexterity (if it exists at all) would be seen to be an abnormality, i.e. that all normal children grow up to be either right- or left-handed (1947:175).

Hildreth & Scheidemann (1950) suggested that the following informal tests would provide objective data on a child's handedness: watch test (setting the hands of a large watch or alarm clock); lock test (unlocking and locking a padlock); cutting test (with scissors along an irregular line); winding test (winding unspooled cord onto an existing ball); throwing test (with a soft ball); receiving test (presenting the child with a ball, pencil, paper, etc.); and energetic reaching (for a ball, just out of normal reach). They explain that the tests should be conducted three times each, with the child unaware of the purpose of the testing; as consciousness of its purpose often interferes with natural preference (1950:521). They suggest a Hand Dominance Score and use the same formula as put forward by Durost (1934), viz: Hand Dominance Score = \( \frac{R-L}{R+L} \) giving an indication of right- and left-handed choices of total usage; with +1.00 signifying absolute right-handedness, and -1.00 signifying absolute
left-handedness (1950:521).

Clark (1957) used a series of Tests of hand preference, and relative ability with hands as part of a larger battery for testing body laterality preferences and dominance. Three tests of hand preference were used, namely tests of: throwing; reaching; and screwing / unscrewing. Also two tests to measure the relative ability of the two hands were employed: a speed comparison test, and a test of simultaneous writing. In addition two other tests were used which do not fit exactly into either of the two above-mentioned categories: a test of 'fine' movement showing hand skill, and one of alternating movement showing which hand had the greater facility in actions – quite apart from skill (1957:115). She used Burt's (1937) idea for an Index of Handedness being: \[ \frac{L}{R} \times 100 \] or more simply \[ \frac{L}{R} \] (1957:115).

Harris (1947) set up a series of tests of lateral dominance, and subsequently after ten years of clinical trials, modified them slightly (1956) and as well as using them separately (1957) presented them in a 3rd edition monograph form as the Harris Tests of Lateral Dominance (1958). They include a test of knowledge of left and right; five tests of hand dominance; two tests of eye dominance; and a test (later augmented to two tests) of foot dominance (1957:283). By using the revised form of the tests, Harris (1957) conclusively showed that consistency of hand usage across tasks, and lessening of mixed-handedness (giving way to right-handedness), increase with age (1957:285). He did not use or attempt to formulate a laterality index but hypothesises that the tests are a more "sensitive indicator of directional confusion" than those conducted previously, because of the statistical significance reached (1956:258).

As part of a total study of lateral dominance and right-left awareness in normal children (mentioned earlier in A.3), Belmont and Birch (1963) used four of the simple basic tests of handedness: ball throwing, door-knob turning, scissor cutting and writing (1963:259). They found specifically that by nine years of age the children in their sample had developed a high level of consistency in preferential hand usage, and suggested that this age could be used as
an indicator for the existence of reliably established preferential hand usage (1963:264). From the observations in their study, they found a critical break (at the age of nine) in the number of children who exhibited mixed-handedness. They then make the point that they would differentiate between the ambilaterality in observed handedness which occurs between these two groups of children. Namely: the ambilaterality which is shown to occur in children before the age of nine; and that which can be demonstrated as occurring after that age (1963:268).

Annett (1970) used a questionnaire in a study of the Classification of hand preference by association analysis. The following twelve activities were presented: writing; throwing ball; wielding racket; striking match; cutting with scissors; threading needle; sweeping; shovelling; dealing playing cards; hammering; using toothbrush; and unscrewing jar (1970:321). Annett makes three important points in discussing her findings:

* cutting with scissors, the test thought most valuable by Burt (1958), she found to be the most stringent criterion (1970:308);
* as a general rule, if only a single test is to be employed, she shows that:
  
  ... writing discriminates as effectively as any other action ... (1970:316); and
* if distinctions must be made within the dextral and sinistral groups, the criterion of consistency or inconsistency in the six primary actions can be used. These six were: writing, throwing a ball, using a racket, striking a match, hammering, and using a toothbrush (1970:317).

Bruml (1972) designed a series of Preference and Skill Measures of Handedness primarily to highlight the changes evident in the development of a child with age (with specific reference to six-, eight- and ten-year-olds). In addition she used them to point to several ways in which tasks can differ from one another; and to point to the general importance of considering the growth of skill in both hands, and the associated development of divisions of labour between the hands (1972:3). Bruml attempted to provide data which would allow for a more informed choice of measures for diagnostic or research purposes, for she says that although each type of task has a long history of use, few measures have separated unimanual from bimanual tasks, which she says is a very important feature in effectively testing laterality.
The 21 measures fall into three groups – three bimanual tasks, thirteen unimanual preference tasks, and five tasks for differential skill. They are respectively: threading beads; winding a thread (on spool); applauding; drawing a circle; placing beads in a bottle; touching nose; clapping the experimenter’s palm with one hand; reaching for ceiling; snapping fingers; clapping hands twice, and then one knee; clasping hands together; pointing; picking up a ball; throwing a ball; eating (actually pretending to eat with a spoon); and building a tower of blocks; squeezing a dynamometer; filling a peg-board; turning screws; simple tapping (without aim); and tapping/visual-aiming (1972:5). Three important points arose from the findings:

• with few exceptions the unimanual tasks agree well with one another and the results show they are well developed by the time a child reaches kindergarten age (1972:7);

• the most promising measure of true handedness seemed to be the bimanual task of clasping hands – whichever thumb is uppermost (1972:8); and

• only the two tapping tasks showed that differences between the hands become more marked with age (1972:12). In summing up Bruml (1972) says:

Grouping measures of handedness into ‘preference’ and ‘skill’ tasks may be misleadingly gross. The first distinction needed is between unimanual and bimanual tasks. . . both are scored for the pattern of use rather than for speed or accuracy, bimanual measures show a much slower rise toward consistent behaviour (across time) than unimanual measures do . . .

The next distinction needed is among skill tasks . . . (which should be) scored for differential accuracy or speed. (1972:12)

Berman (1971 & 1973) attempted to address the serious questions already raised in the literature about the reliability and validity of existing measures. He published both an Index of Cerebral Dominance and an Index of Perceptual-motor Laterality which are essentially the same very extensive battery of laterality measures. Fifty-four tasks have the Examiner noting not just an initial preference of hand, eye or leg/foot, but asking for a repeat of the activity with the other hand etc., and then sometimes both, and also noting the skill and/or accuracy and/or speed of the various performance(s). The tasks were randomised and observed as follows: folding arms; drawing a circle (first with one hand, then another, then both); hopping; looking
with one eye closed (at a pencil); putting pegs in a peg-board (with right hand, left hand and both together); listening at a wall (either ear); holding arms straight out in front with eyes closed; throwing a ball; stepping up and down; pushing with both hands; (Examiner noting) tilt of the head whilst writing; kicking a ball; cutting with scissors; drawing a square (first with one hand, then another, then both); kneeling on one knee; looking through a tube; stepping forward and backward; aiming a rifle; threading beads; lining up a pencil with the wall, with one eye closed; writing (first with one hand, then another, then both); sighting a spot on wall through a hole in paper (the hand and eye used); listening to a watch ticking; stamping on a paper cup; winding a watch; hammering; and swinging a bat (for boys) or sweeping with broom (for girls) (1973:600). Berman noted that of the 54 tests, only nine were insignificantly related to the total laterality scores: the two tests of folding arms, the two tests of stepping forward and the kneeling on one knee, and the four listening to the wall and listening to the stopwatch tests. He then suggests that these nine should be left out of the battery in order to increase internal consistency and validity (1973:602).

Dean (1978) designed his Lateraljty Preference Schedule as a five-page self-report, which can be completed and scored within 15 minutes. It is a broadly based 33 or 49 (or even 59) item self-administered questionnaire which queries the respondent’s laterality for tasks involving hands, legs, feet, ears, and eyes. The 49 items are presented according to the following categories: Visual activities; Auditory activities; Foot use; Strength; General laterality; and Visually guided activity. An additional 10 items that focus on Maternal and Paternal preferences are also included (1978a:5). The responses are asked for on a weighted 5-point scale along the lines of those proposed by Bryden (1977) mentioned earlier. Dean’s 5-point scale was: LA, left always = 5; LM, left mostly = 4; E, left and right equally = 3; RM, right mostly = 2; and RA, right always =1. With the multiplication of the weighted factor on each of the responses and the addition of all these weighted response-scores, an overall laterality score is formed. Thus the normal (49-point) laterality scores vary from 49 (where right is indicated for all items) to 245 (left for all). This score allows placement of the individual on a continuum which indicates overall right-left orientation (1978b:1345). Dean provides validity and reliability
studies that show his schedule is a highly sensitive instrument for clinical and research studies (1978b:1345).

In summary then, and as was pointed out earlier in the main body of this study (1.3.3), there have been substantial studies pursued throughout this century on the various ways of assessing hand preference or dominant laterality or handedness – some of the more recent of these attaining a high degree of reliability. In most tests, the measurement of overt right- or left-sidedness has usually been based on either accuracy, speed, or strength, or some combination of these factors. All significant clinical studies have concentrated on the subject's preference in unimanual acts, and the degree of dexterity found by comparing the operation of each hand, whereas studies requiring a notional indication of the handedness of subjects were satisfied often by the use of a small battery of tests, which were either conducted by observation or by questionnaire, most of which still carried high reliability. Although some have carried sophisticated formulae for delivering a Handedness Score, the literature seems to support the simpler formulae as providing a most satisfactory result when assessing handedness under all but the strictest parameters.
# Appendix B

## Individual Subject Data

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**Total All (non-rhythmic) Errors:** 20 7 4

**Total Incorrect Hands Mistakes:** 2 0 0

[In the above table: $L_1$ represents the first Left-hander tested; and $O_{1L}$, $O_{2L}$ and $O_{3L}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
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[In the above table: \( L_2 \) represents the second Left-hander tested; and \( O_{1L}, O_{2L} \) and \( O_{3L} \) represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
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**Total All (non-rhythmic) Errors:**
30 18 9

**Total Incorrect Hands Mistakes:**
2 1 2

[In the above table: \( L_3 \) represents the third Left-hander tested; and \( O_{1L}, O_{2L} \) and \( O_{3L} \) represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
Subject L₄

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**Total All (non-rhythmic) Errors:** 19 9 5

**Total Incorrect Hands Mistakes:** 2 2 1

[In the above table: \(L_4\) represents the fourth Left-hander tested; and \(O_{1L}, O_{2L}, O_{3L}\) represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
## Subject L₅

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**Total All (non-rhythmic) Errors:** 31 11 9

**Total Incorrect Hands Mistakes:** 3 2 1

[In the above table: L₅ represents the fifth Left-hander tested; and O₁₅, O₂₅ and O₃₅ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
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**Total All (non-rhythmic) Errors:** 28 13 8

**Total Incorrect Hands Mistakes:** 4 3 1

[In the above table: \( L_6 \) represents the sixth Left-hander tested; and \( O_{1L} \), \( O_{2L} \) and \( O_{3L} \) represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
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**Total All (non-rhythmic) Errors:** 19 9 3

**Total Incorrect Hands Mistakes:** 1 1 0

[In the above table: \( L_7 \) represents the seventh Left-hander tested; and \( O_{1L}, O_{2L} \) and \( O_{3L} \) represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
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[In the above table, $L_8$ represents the eighth Left-hander tested; and $O_{1L}$, $O_{2L}$ and $O_{3L}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
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</tr>
<tr>
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<td>All (non-rhythmic) Errors:</td>
<td>3</td>
<td>1</td>
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</tr>
<tr>
<td></td>
<td>Incorrect Hands Mistakes:</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Task 7:</td>
<td>All (non-rhythmic) Errors:</td>
<td>4</td>
<td>2</td>
<td>1</td>
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<tr>
<td></td>
<td>Incorrect Hands Mistakes:</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Task 8:</td>
<td>All (non-rhythmic) Errors:</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Incorrect Hands Mistakes:</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Total All (non-rhythmic) Errors: 22 8 4
Total Incorrect Hands Mistakes: 2 1 0

[In the above table: \( L_9 \) represents the ninth Left-hander tested; and \( O_{1L}, O_{2L} \) and \( O_{3L} \) represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
<table>
<thead>
<tr>
<th>Task</th>
<th>All (non-rhythmic) Errors:</th>
<th>Incorrect Hands Mistakes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>3</td>
<td>2</td>
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<tr>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
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<td>6</td>
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<tr>
<td>7</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

| Total All (non-rhythmic) Errors: | 25 | 6 | 3 |
| Total Incorrect Hands Mistakes: | 1  | 0 | 1 |

(In the above table: \(L_{10}\) represents the tenth Left-hander tested; and \(O_{1L}, O_{2L}\) and \(O_{3L}\) represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.)
<table>
<thead>
<tr>
<th>Task</th>
<th>All (non-rhythmic) Errors</th>
<th>Incorrect Hands Mistakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
<td>3</td>
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<td>4</td>
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</tr>
<tr>
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<td>1</td>
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<td>7</td>
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<td>0</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

**Total All (non-rhythmic) Errors:** 20

**Total Incorrect Hands Mistakes:** 0

In the above table: $R_1$ represents the first Right-hander tested; and $O_1R$, $O_2R$ and $O_3R$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.
<table>
<thead>
<tr>
<th>Task</th>
<th></th>
<th>All (non-rhythmic) Errors:</th>
<th></th>
<th>Incorrect Hands Mistakes:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
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<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

| Total All (non-rhythmic) Errors: | 32 | 10 | 6 |

| Total Incorrect Hands Mistakes: | 2 | 1 | 0 |

In the above table: $R_2$ represents the second Right-hander tested; and $O_{1R}$, $O_{2R}$ and $O_{3R}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.
<table>
<thead>
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<th>$R_3$</th>
<th>$O_{1R}$</th>
<th>$O_{2R}$</th>
<th>$O_{3R}$</th>
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</thead>
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</tr>
<tr>
<td>All (non-rhythmic) Errors:</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 2:</strong></td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Incorrect Hands Mistakes:</td>
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<td>0</td>
<td>0</td>
<td>0</td>
</tr>
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<td><strong>Task 3:</strong></td>
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<td>1</td>
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<td>All (non-rhythmic) Errors:</td>
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<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Incorrect Hands Mistakes:</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 5:</strong></td>
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<td>Incorrect Hands Mistakes:</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 6:</strong></td>
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<td>1</td>
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<tr>
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<td>0</td>
<td>0</td>
</tr>
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<td><strong>Task 7:</strong></td>
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<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 8:</strong></td>
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<td>1</td>
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<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
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<td><strong>Total All (non-rhythmic) Errors:</strong></td>
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<td></td>
</tr>
</tbody>
</table>

[In the above table: $R_3$ represents the third Right-hander tested; and $O_{1R}$, $O_{2R}$ and $O_{3R}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
Subject $R_4$

<table>
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<tr>
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<th>All (non-rhythmic) Errors:</th>
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<th>$O_{3R}$</th>
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<tr>
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<td>n/a</td>
</tr>
<tr>
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<td>0</td>
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</tr>
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<td>2</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
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</tr>
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<td>0</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Incorrect Hands Mistakes:</td>
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<td>0</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Total All (non-rhythmic) Errors: 3
Total Incorrect Hands Mistakes: 0

[In the above table: $R_4$ represents the fourth Right-hander tested; and $O_{1R}$, $O_{2R}$ and $O_{3R}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
Subject $R_5$ | $O_{1R}$ | $O_{2R}$ | $O_{3R}$
---|---|---|---
Task 1: All (non-rhythmic) Errors: | 1 | 0 | 0 |
Incorrect Hands Mistakes: | 0 | 0 | 0 |
Task 2: All (non-rhythmic) Errors: | 1 | 0 | 0 |
Incorrect Hands Mistakes: | 0 | 0 | 0 |
Task 3: All (non-rhythmic) Errors: | 1 | 0 | 0 |
Incorrect Hands Mistakes: | 0 | 0 | 0 |
Task 4: All (non-rhythmic) Errors: | 2 | 0 | 0 |
Incorrect Hands Mistakes: | 0 | 0 | 0 |
Task 5: All (non-rhythmic) Errors: | 2 | 0 | 0 |
Incorrect Hands Mistakes: | 0 | 0 | 0 |
Task 6: All (non-rhythmic) Errors: | 2 | 0 | 0 |
Incorrect Hands Mistakes: | 0 | 0 | 0 |
Task 7: All (non-rhythmic) Errors: | 3 | 1 | 0 |
Incorrect Hands Mistakes: | 0 | 0 | 0 |
Task 8: All (non-rhythmic) Errors: | 3 | 1 | 1 |
Incorrect Hands Mistakes: | 0 | 0 | 0 |

Total All (non-rhythmic) Errors: | 15 | 2 | 1 |
Total Incorrect Hands Mistakes: | 0 | 0 | 0 |

In the above table: $R_5$ represents the fifth Right-hander tested; and $O_{1R}$, $O_{2R}$ and $O_{3R}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.
<table>
<thead>
<tr>
<th>Subject $R_6$</th>
<th>$O_{1R}$</th>
<th>$O_{2R}$</th>
<th>$O_{3R}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task 1:</strong></td>
<td>All (non-rhythmic) Errors: 1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 2:</strong></td>
<td>All (non-rhythmic) Errors: 2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 3:</strong></td>
<td>All (non-rhythmic) Errors: 2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 4:</strong></td>
<td>All (non-rhythmic) Errors: 3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 5:</strong></td>
<td>All (non-rhythmic) Errors: 2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 6:</strong></td>
<td>All (non-rhythmic) Errors: 3</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Incorrect Hands Mistakes:</td>
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<td>0</td>
</tr>
<tr>
<td><strong>Task 7:</strong></td>
<td>All (non-rhythmic) Errors: 5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Task 8:</strong></td>
<td>All (non-rhythmic) Errors: 4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect Hands Mistakes:</td>
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<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Total All (non-rhythmic) Errors:** 22 3 2

**Total Incorrect Hands Mistakes:** 1 1 0

[In the above table: $R_6$ represents the sixth Right-hander tested; and $O_{1R}$, $O_{2R}$ and $O_{3R}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
### Task 1:
- All (non-rhythmic) Errors: 0
- Incorrect Hands Mistakes: 0

### Task 2:
- All (non-rhythmic) Errors: 1
- Incorrect Hands Mistakes: 0

### Task 3:
- All (non-rhythmic) Errors: 1
- Incorrect Hands Mistakes: 0

### Task 4:
- All (non-rhythmic) Errors: 2
- Incorrect Hands Mistakes: 0

### Task 5:
- All (non-rhythmic) Errors: 3
- Incorrect Hands Mistakes: 0

### Task 6:
- All (non-rhythmic) Errors: 2
- Incorrect Hands Mistakes: 0

### Task 7:
- All (non-rhythmic) Errors: 4
- Incorrect Hands Mistakes: 0

### Task 8:
- All (non-rhythmic) Errors: 5
- Incorrect Hands Mistakes: 0

---

<table>
<thead>
<tr>
<th>Subject $R_7$</th>
<th>$O_{1R}$</th>
<th>$O_{2R}$</th>
<th>$O_{3R}$</th>
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<tbody>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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<tr>
<td><strong>Task 7</strong></td>
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<td>1</td>
</tr>
<tr>
<td><strong>Task 8</strong></td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Total All (non-rhythmic) Errors:**
- 18
- 5
- 3

**Total Incorrect Hands Mistakes:**
- 0
- 0
- 0

---

In the above table, $R_7$ represents the seventh Right-hander tested; and $O_{1R}$, $O_{2R}$ and $O_{3R}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.
<table>
<thead>
<tr>
<th>Subject</th>
<th>Task 1</th>
<th>Task 2</th>
<th>Task 3</th>
<th>Task 4</th>
<th>Task 5</th>
<th>Task 6</th>
<th>Task 7</th>
<th>Task 8</th>
</tr>
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<td>4 1 1</td>
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</tr>
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<tr>
<td>Task 4</td>
<td>2 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
</tr>
<tr>
<td>Task 5</td>
<td>2 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
</tr>
<tr>
<td>Task 6</td>
<td>3 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
</tr>
<tr>
<td>Task 7</td>
<td>4 1 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
</tr>
<tr>
<td>Task 8</td>
<td>4 1 1</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
<td>0 0 0</td>
</tr>
</tbody>
</table>

**Total All (non-rhythmic) Errors:**

19 3 1

**Total Incorrect Hands Mistakes:**

0 0 0

**In the above table:** $R_8$ represents the eighth Right-hander tested; and $O_{1R}$, $O_{2R}$ and $O_{3R}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.
<table>
<thead>
<tr>
<th>Subject $R_9$</th>
<th>$O_{1R}$</th>
<th>$O_{2R}$</th>
<th>$O_{3R}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Task 1:</strong></td>
<td>All (non-rhythmic) Errors: 0 0 0</td>
<td>Incorrect Hands Mistakes: 0 0 0</td>
<td></td>
</tr>
<tr>
<td><strong>Task 2:</strong></td>
<td>All (non-rhythmic) Errors: 0 0 0</td>
<td>Incorrect Hands Mistakes: 0 0 0</td>
<td></td>
</tr>
<tr>
<td><strong>Task 3:</strong></td>
<td>All (non-rhythmic) Errors: 0 0 0</td>
<td>Incorrect Hands Mistakes: 0 0 0</td>
<td></td>
</tr>
<tr>
<td><strong>Task 4:</strong></td>
<td>All (non-rhythmic) Errors: 0 0 0</td>
<td>Incorrect Hands Mistakes: 0 0 0</td>
<td></td>
</tr>
<tr>
<td><strong>Task 5:</strong></td>
<td>All (non-rhythmic) Errors: 0 1 0</td>
<td>Incorrect Hands Mistakes: 0 0 0</td>
<td></td>
</tr>
<tr>
<td><strong>Task 6:</strong></td>
<td>All (non-rhythmic) Errors: 1 0 0</td>
<td>Incorrect Hands Mistakes: 0 0 0</td>
<td></td>
</tr>
<tr>
<td><strong>Task 7:</strong></td>
<td>All (non-rhythmic) Errors: 2 0 0</td>
<td>Incorrect Hands Mistakes: 0 0 0</td>
<td></td>
</tr>
<tr>
<td><strong>Task 8:</strong></td>
<td>All (non-rhythmic) Errors: 2 0 0</td>
<td>Incorrect Hands Mistakes: 0 0 0</td>
<td></td>
</tr>
</tbody>
</table>

**Total All (non-rhythmic) Errors:** 5 1 0

**Total Incorrect Hands Mistakes:** 0 0 0

[In the above table: $R_9$ represents the ninth Right-hander tested; and $O_{1R}$, $O_{2R}$ and $O_{3R}$ represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
### Task 1:
- **All (non-rhythmic) Errors:** 1
- **Incorrect Hands Mistakes:** 0

### Task 2:
- **All (non-rhythmic) Errors:** 1
- **Incorrect Hands Mistakes:** 0

### Task 3:
- **All (non-rhythmic) Errors:** 2
- **Incorrect Hands Mistakes:** 0

### Task 4:
- **All (non-rhythmic) Errors:** 2
- **Incorrect Hands Mistakes:** 0

### Task 5:
- **All (non-rhythmic) Errors:** 2
- **Incorrect Hands Mistakes:** 0

### Task 6:
- **All (non-rhythmic) Errors:** 2
- **Incorrect Hands Mistakes:** 0

### Task 7:
- **All (non-rhythmic) Errors:** 3
- **Incorrect Hands Mistakes:** 0

### Task 8:
- **All (non-rhythmic) Errors:** 4
- **Incorrect Hands Mistakes:** 1

**Total All (non-rhythmic) Errors:** 17
**Total Incorrect Hands Mistakes:** 1

---

[In the above table, \(R_{10}\) represents the tenth Right-hander tested; and \(O_{1R}, O_{2R}\) and \(O_{3R}\) represent the First Observation (Pre-test), Second Observation (Post-test 1) and Third Observation (Post-test 2) respectively.]
# Appendix C

## Summary Tables

### Table 27: Numbers of All (non-rhythmic) Errors for Left-handed Subjects

<table>
<thead>
<tr>
<th>Subjects:</th>
<th>L₁</th>
<th>L₂</th>
<th>L₃</th>
<th>L₄</th>
<th>L₅</th>
<th>L₆</th>
<th>L₇</th>
<th>L₈</th>
<th>L₉</th>
<th>L₁₀</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (non-rhythmic) Errors in O₁L:</td>
<td>20</td>
<td>9</td>
<td>30</td>
<td>19</td>
<td>31</td>
<td>28</td>
<td>19</td>
<td>14</td>
<td>22</td>
<td>25</td>
<td>217</td>
</tr>
<tr>
<td>All (non-rhythmic) Errors in O₂L:</td>
<td>7</td>
<td>2</td>
<td>18</td>
<td>9</td>
<td>11</td>
<td>13</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>89</td>
</tr>
<tr>
<td>All (non-rhythmic) Errors in O₃L:</td>
<td>4</td>
<td>1</td>
<td>9</td>
<td>5</td>
<td>9</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>49</td>
</tr>
<tr>
<td>Total All (non-rhythmic) Errors:</td>
<td>31</td>
<td>12</td>
<td>57</td>
<td>33</td>
<td>51</td>
<td>49</td>
<td>31</td>
<td>23</td>
<td>34</td>
<td>34</td>
<td>355</td>
</tr>
</tbody>
</table>

### Table 28: Numbers of All (non-rhythmic) Errors for Right-handed Subjects

<table>
<thead>
<tr>
<th>Subjects:</th>
<th>R₁</th>
<th>R₂</th>
<th>R₃</th>
<th>R₄</th>
<th>R₅</th>
<th>R₆</th>
<th>R₇</th>
<th>R₈</th>
<th>R₉</th>
<th>R₁₀</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (non-rhythmic) Errors in O₁R:</td>
<td>20</td>
<td>32</td>
<td>24</td>
<td>3</td>
<td>15</td>
<td>22</td>
<td>18</td>
<td>19</td>
<td>5</td>
<td>17</td>
<td>175</td>
</tr>
<tr>
<td>All (non-rhythmic) Errors in O₂R:</td>
<td>4</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>All (non-rhythmic) Errors in O₃R:</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>n/a</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>Total All (non-rhythmic) Errors:</td>
<td>26</td>
<td>48</td>
<td>37</td>
<td>(3)</td>
<td>18</td>
<td>27</td>
<td>26</td>
<td>23</td>
<td>6</td>
<td>19</td>
<td>233</td>
</tr>
</tbody>
</table>
Table 29: Numbers of Incorrect Hands Mistakes for Left-handed Subjects

<table>
<thead>
<tr>
<th>Subjects:</th>
<th>L₁</th>
<th>L₂</th>
<th>L₃</th>
<th>L₄</th>
<th>L₅</th>
<th>L₆</th>
<th>L₇</th>
<th>L₈</th>
<th>L₉</th>
<th>L₁₀</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect Hand(s) in $O₁L$:</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>Incorrect Hand(s) in $O₂L$:</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Incorrect Hand(s) in $O₃L$:</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Total Incorrect Hand(s):</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>33</td>
</tr>
</tbody>
</table>

Table 30: Numbers of Incorrect Hands Mistakes for Right-handed Subjects

<table>
<thead>
<tr>
<th>Subjects:</th>
<th>R₁</th>
<th>R₂</th>
<th>R₃</th>
<th>R₄</th>
<th>R₅</th>
<th>R₆</th>
<th>R₇</th>
<th>R₈</th>
<th>R₉</th>
<th>R₁₀</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect Hand(s) in $O₁R$:</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Incorrect Hand(s) in $O₂R$:</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Incorrect Hand(s) in $O₃R$:</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total Incorrect Hand(s):</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>(0)</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>
### Table 31: Numbers of Errors and Mistakes for Left-handed Subjects

<table>
<thead>
<tr>
<th>Subjects:</th>
<th>L₁</th>
<th>L₂</th>
<th>L₃</th>
<th>L₄</th>
<th>L₅</th>
<th>L₆</th>
<th>L₇</th>
<th>L₈</th>
<th>L₉</th>
<th>L₁₀</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (non-rhythmic) Errors in O₁L:</td>
<td>20</td>
<td>9</td>
<td>30</td>
<td>19</td>
<td>31</td>
<td>26</td>
<td>19</td>
<td>14</td>
<td>22</td>
<td>25</td>
<td>217</td>
</tr>
<tr>
<td>Incorrect Hand(s) in O₁R:</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>All (non-rhythmic) Errors in O₂L:</td>
<td>7</td>
<td>2</td>
<td>18</td>
<td>9</td>
<td>11</td>
<td>13</td>
<td>9</td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>89</td>
</tr>
<tr>
<td>Incorrect Hand(s) in O₂R:</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>All (non-rhythmic) Errors in O₃L:</td>
<td>4</td>
<td>1</td>
<td>9</td>
<td>5</td>
<td>9</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>49</td>
</tr>
<tr>
<td>Incorrect Hand(s) in O₃R:</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Total All (non-rhythmic) Errors:</td>
<td>31</td>
<td>12</td>
<td>57</td>
<td>33</td>
<td>51</td>
<td>49</td>
<td>31</td>
<td>23</td>
<td>34</td>
<td>34</td>
<td>355</td>
</tr>
<tr>
<td>Total Incorrect Hand(s):</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>33</td>
</tr>
</tbody>
</table>

### Table 32: Numbers of Errors and Mistakes for Right-handed Subjects

<table>
<thead>
<tr>
<th>Subjects:</th>
<th>R₁</th>
<th>R₂</th>
<th>R₃</th>
<th>R₄</th>
<th>R₅</th>
<th>R₆</th>
<th>R₇</th>
<th>R₈</th>
<th>R₉</th>
<th>R₁₀</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (non-rhythmic) Errors in O₁L:</td>
<td>20</td>
<td>32</td>
<td>24</td>
<td>3</td>
<td>15</td>
<td>22</td>
<td>18</td>
<td>19</td>
<td>5</td>
<td>17</td>
<td>175</td>
</tr>
<tr>
<td>Incorrect Hand(s) in O₁R:</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>All (non-rhythmic) Errors in O₂L:</td>
<td>4</td>
<td>10</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>Incorrect Hand(s) in O₂R:</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>All (non-rhythmic) Errors in O₃L:</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>n/a</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>21</td>
</tr>
<tr>
<td>Incorrect Hand(s) in O₃R:</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n/a</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total All (non-rhythmic) Errors:</td>
<td>26</td>
<td>48</td>
<td>37</td>
<td>(3)</td>
<td>18</td>
<td>27</td>
<td>26</td>
<td>23</td>
<td>6</td>
<td>19</td>
<td>233</td>
</tr>
<tr>
<td>Total Incorrect Hand(s):</td>
<td>0</td>
<td>3</td>
<td>2</td>
<td>(0)</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>
Appendix D

Notation of Experimental Tasks

Task 1:

Task 2:
Appendix E

Hand Placement Diagrams

For Tasks 1, 3 & 5:

For Tasks 2, 4, 6, 7 & 8: