THE INFLUENCE OF LATERAL DOMINANCE ON ACCURACY AND DIRECTIONAL ERRORS WHEN THROWING AT A TARGET

Thesis for the Degree of M. A.

MICHIGAN STATE UNIVERSITY

EMMA JEAN McCONKIE

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ABSTRACT

THE INFLUENCE OF LATERAL DOMINANCE ON
ACCURACY AND DIRECTIONAL ERRORS
WHEN THROWING AT A TARGET

By

Emma Jean McConkie

The purpose of the present study was to determine the influence of hand dominance, eye dominance, and combinations of hand and eye dominance on the accuracy of throwing at a target, and on the direction of errors made when throwing at a target. The directions considered were the right and left halves of the target and the upper and lower halves of the target.

Eleven subjects were randomly selected from each of four laterality strata (right-handed and right-eyed; right-handed and left-eyed; left-handed and right-eyed; left-handed and left-eyed) which had been obtained from a population of 238 high school girls at Eastern High School, Lansing, Michigan. They ranged in age from 15 years to 19 years. The mean age was 16.2 years. Approximately 82 percent of the sample were Sophomore girls enrolled in a required physical education program. The remaining 18 percent were Junior or Senior girls enrolled in an elective physical education program.

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Each subject was given 30 trials of dart throwing during each of two class periods. The first five throws of each session were allowed for practice and the last twenty-five throws were scored for accuracy, right-left directional error (horizontal), and above-below directional error (vertical). Darts were thrown in sets of five trials each and scores by sets were used in the analyses.

Analysis of variance was used to statistically test the obtained data. The results indicated hand dominance, eye dominance, and combinations of hand and eye dominance failed to significantly influence the accuracy of throwing at a target and the direction of throwing errors. A priori comparisons tests of ipsilateral and contralateral-dominant groups also failed to detect a significant effect of dominance on throwing performance.

THE INFLUENCE OF LATERAL DOMINANCE ON
ACCURACY AND DIRECTIONAL ERRORS
WHEN THROWING AT A TARGET

By

Emma Jean McConkie

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Physical Education

1974

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ACKNOWLEDGMENTS

I would like to express my gratitude to the members of my Guidance Committee, who greatly aided me in the preparation of this thesis. I extend special thanks to Dr. John Haubenstricker, who guided me throughout all stages of the work; to Dr. Vern Seefeldt, who advised me on the proposal and on the final draft; and to Dr. William Heusner, who gave so willingly of his time to provide invaluable statistical assistance. Each of these men made worth-while suggestions which resulted in improvements.

I would also like to acknowledge the cooperation of Mr. Don Johnson, Principal of Eastern High School; Miss Jean Robinson, Miss Candy Whitmore, and Miss Gloria Miller, Physical Education Instructors at Eastern High School; and the girl's Physical Education classes at Eastern High School for their respective roles in the collection of the data. Sincere appreciation is expressed to the women students at Michigan State University, who volunteered as subjects for the pilot study.

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CHAPTER I

THE PROBLEM

One important aspect of the psychometric trend in skills research is the study of individual variations in performance and the factors that contribute to skilled performances. Investigators continue to delve into the identification of differences between individuals as one source of variation. Once identified, the question becomes that of determining the effect these differences have on subsequent behavior or performance.

Many of the existing differences between the sexes that affect motor ability are obvious. Other differences that exist between and within individuals of the same sex are not apparent. Some of these include: (a) dominance of eye, hand, or foot (Irwin, 1938); (b) movement time between preferred and non-preferred limbs, and between arms and legs (Lotter, 1960; Bartee, 1971); (c) kinesthetic perceptivity between preferred and non-preferred arms (Phillips and Summers, 1954); and (d) a more perfect eye-moving apparatus in champion atheletes than in non-athletes (Graybiel, Jokl, and Trapp, 1955).

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The problem of individual differences in lateral dominance and how these differences influence performance of motor skills has not been conclusively documented. Are there activities in which it is an advantage to have ipsilateral dominance of hand and eye? Similarly, are there activities in which contralateral dominance is a disadvantage? Perhaps only certain skills are significantly influenced by dominance. If so, they should be identified and the physical education teacher made aware of them. The effect of lateral dominance on the performance of a target throwing task was selected as the focus of the present study.

Lateral Dominance

The relationship of various lateral dominance patterns to the performance of motor skills has received increasing attention since the mid-1950's. As revealed in the review of literature, Chapter II, results of completed studies are confusing and often conflicting. Several authors have reached conclusions which indicate the unilaterally dominant individual is superior in motor ability (Poindexter, 1965; Robinson, 1965; Kisler, 1971). In 1958, Way claimed the superiority of mixed-dominant subjects on motor ability tests and in selected skills. The right-eyed, left-handed men in Roth's study (1942) outperformed all other laterality combinations of hand and eye. In a study of baseball players, Baughman (1968) found con

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Only one study of gross motor skills specifically investigated the relationship of hand-eye dominance to directional errors. Shick (1971) reported that contralaterals made more errors toward the side of their dominant eye in basketball free throw shooting than to the other side. Does this phenomenon occur in other activities where accuracy of direction is important?

Although the majority of the literature has not revealed specific lateralities to be a factor in performance of skills (Sinclair and Smith, 1957; Fox, 1957; Frahm, 1967; Adams, 1965; Cooke, 1969), all activities may not be similarly affected. Thus, the issue remains a viable one for investigation.

Need for the Study

The reasons for the development of a particular dominance pattern in an individual remain a mystery. It appears to be similar to the issue of I.Q. in that heredity is a factor, but the role of environment and the changes that result from experiences affect its development.

The practical significance of dominance in eyedness differs considerably from that in handedness. Binocular vision is obviously the most common, while in many activities unimanual hand usage is more prevalent than the simultane

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simultaneous use of both hands. It is generally agreed that eye dominance is established early in life and does not change. The non-dominant eye cannot be trained to become the dominant eye (Clark, 1957). On the other hand, invariability in handedness is the exception and not the rule. Hand usage depends on the action being performed and the skill or precision of the movement required.

The hand which is chosen for use in a particular activity may or may not be on the same side of the body as the dominant eye. Little is known as to what effect this may have on hitting or missing the target in hand-eye coordination activities requiring accuracy of direction. Clark (1957) has summarized the situation well:

> Although it has been established that crossed laterality is common, this does not exclude the view that unilateral dominance is the ideal. It has frequently been asserted that it is an advantage to have the preferred hand and eye on the same side . . . At present no decision can be given on this issue since it is not known in what activities crossed laterality may be a disadvantage. Its effect may be limited to certain situations, for example, monocular sighting in such activities as rifle shooting. Whether it is important in binocular situations is not established. (p. 75)

Several questions that need answers have been suggested. In tasks requiring accuracy of direction toward a target: (a) are left handed individuals more accurate than right handed individuals, or vice versa; (b) does hand dominance or eye dominance have the greatest influence on the direction in which errors are made; or

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(c) is it the combination of hand-eye dominance which is most influencial on the direction of misses?

If a direct and measurable connection can be established between hand-eye dominance patterns and accuracy of direction when throwing at a target, the physical education teacher or coach may use this information to help students select focal points which will result in more successful performances.

Purpose of the Study

The purpose of the investigation was to study the effects of hand dominance, eye dominance, and hand-eye dominance combinations on accuracy and direction of errors made when throwing at a target. Specifically, the study was designed to:

1. Explore the influence of hand dominance on three dependent variables: (a) overall accuracy of throwing at a target; (b) directional errors in the right and left halves of the target; and (c) directional errors in the upper and lower halves of the target.
2. Explore the influence of eye dominance on the same three dependent variables.
3. Explore the influence of the four hand-eye dominance combinations (RH-RE, RH-LE, LH-RE, LH-LE) on each of the three dependent variables.

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4. Explore the influence of ipsilateral and contralateral dominance of hand and eye on each of the three dependent variables.

Research Hypotheses

The review of literature suggested the following hypotheses would be supported by the findings of the study:

1. Hand dominance (R or L) has a significant influence on accuracy and/or directional errors in the performance of a target throwing task.

2. Eye dominance (R or L) significantly affects accuracy and/or the direction of errors made in the performance of a target throwing task.

3. Combinations of hand-eye dominance (RH-RE, RH-LE, LH-RE, LH-LE) significantly influence accuracy and/or directional errors in the performance of a target throwing task.

4. Ipsilateral (RH-RE and LH-LE) and contralateral (RH-LE and LH-RE) dominance of hand and eye significantly affects accuracy and/or the direction of errors made in the performance of a target throwing task.

Scope of the Study

Sophomore high school girls, enrolled in a required physical education program, were potential subjects for the study. The potential subject population was stratified with respect to eye dominance and preferred hand for dart throwing. Experimental subjects were randomly selected using disproportionate sampling from each of the four strata o

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strata obtained. Dart throwing was used to obtain the data on the three dependent variables. Each experimental subject attended two measurement sessions in which 30 trials of dart throwing were administered. The first five trials of each session were allowed for practice with the last 25 trials being scored for the dependent variables. Measurement sessions were separated by a period of seven days. Results of the 50 scored trials were compared to categories and combinations of the independent variables (lateral dominance of hand and eye) using parametric statistics.

Limitations of the Study

Results of the investigation were limited in respect to the following:

1. The sample selected was a stratified random sample of female Sophomore students attending Eastern High School, Lansing, Michigan, and included three Juniors and five Seniors who were selected to fill the left-handed categories when these strata did not contain sufficient Sophomore students. The resulting sample had a mean age of 16.2 years. Generalizations must therefore be limited to the population from which the subjects were selected.

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2. Generalizations regarding accuracy and/or directional errors and dominance patterns are limited to the skill of dart throwing.

Significance of the Study

Positive conclusions relating hand and eye dominance patterns to measurable accuracy deviations may be of value to the teacher or coach of activities where accuracy of direction toward a target is important. Results of the study may serve to guide future research on the role of lateral dominance in the performance of motor skills.

Definitions

Lateral Dominance.--A preference for one eye, hand, or foot over the opposite member in unimanual activities. In bilateral tasks, dominance is exhibited by the member which performs the more complex maneuvers.

Unilateral or Ipsilateral Dominance.--The pattern where hand and eye, or hand, eye, and foot are dominant on the same side.

Contralateral Dominance.--The pattern where two of the three members are dominant on one side, and the third is dominant on the opposite side. When only hand and eye are involved, one is dominant on one side while the other is dominant on the opposite side. It may also be referred to as crossed-dominance.

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Mixed Dominance.--The pattern where one member is dominant on one side, one is dominant on the opposite side, and the third does not exhibit dominance. It may also be referred to as mixed-lateral.

Ambidextrous or Ambilateral.--Dominance is not exhibited by either side. Both sides are equally proficient. (True ambidexterity is rarely found.)

Directional Errors.--The direction of throws that miss the bull's eye. They may be in the right or left halves of the target, or in the upper or lower halves of the target. A miss may have both a right-left component and an up-down component.

R-L Directional Error.--A throw that is to the right or left of a vertical line drawn through target center.

A-B Directional Error.--A throw that is above or below a horizontal line drawn through target center.

RH-RE.--Right-handed and right-eyed.

RH-LE.--Right-handed and left eyed.

LH-RE.--Left-handed and right-eyed.

LH-LE.--Left-handed and left-eyed.

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CHAPTER II

RELATED LITERATURE

The purpose of this study was to determine the effect of lateral dominance patterns on accuracy and direction of errors when throwing at a target. The primary emphasis of this review was to investigate the relationship of lateral dominance to motor proficiency. The theories pertaining to the development of dominance, the incidence and characteristics of dominance, and the measurement of dominance were included as a necessary foundation for the present study.

Theories of Dominance Development

Numerous theories have been proposed to explain the observations of preferred laterality or handedness in the population. Any theory, to be tenable, must take into consideration most of the empirical evidence. The early theories were concerned with accounting for the right-hand preference of the majority and were inadequate when applied to left-handedness. Attempts to explain left-handedness did not occur until the nineteenth century.

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At present, the development of dominance continues to be a mystery to physiologists and psychologists alike. Theories that have been advanced may be classified as: anatomical, hereditary, or social in nature.

Anatomical

Theories of structural differences date back to Aristotle and Plato. Aristotle contended that the organs were more powerful on the right side of the body and this caused a right-sidedness. Left-sidedness could not be accommodated by his theory.

Many of the early anatomical theories postulated asymmetries within the fetus as the cause of dominance. Some of the ideas were: (a) the unequal development of the two sides of the brain before birth, with a greater mass on the left side (Jackson, 1905); (b) the position of the fetus in intrauterine life where its left arm lies posteriorly, thus giving the right arm greater facility of movement (Hildreth, 1949, II); (c) the arrangement of the blood supply from the heart favoring the right arm by providing better nutrition to the left cerebral hemisphere (Blau, 1946, citing H. E. Jordan, 1911); and (d) the displacement of the center of gravity to the right of the medial plane due to the greater weight of the liver and lungs on that side, which in time developed stronger muscles on the right side (Jackson, 1905, citing Professor Alexander Buchanan of the University of Glasgow). These theor

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theories have since been disproved because: (a) any postural asymmetry in infancy tends to be equally distributed in the population; and (b) persons with transposition of heart position are not reversed in handedness.

Parson (1924) advocated that handedness originates from eyedness, and that the right hand was guided by the right eye. His theory is refuted by the fact that in binocular vision it is not possible to detect the field of vision of one eye from the other. Also, handedness in the blind population does not differ appreciably from that in the normal population.

An asymmetrical neurological functioning of the two hemispheres has been claimed to be the basis of dominance development. However, complete cortical dominance has not been proven and the left hemisphere cannot be considered dominant for all nervous functions (Hildreth, 1949, III; Dimond, 1970).

All attempts to identify a structural basis which can explain lateral dominance have been unsuccessful. If handedness arises from some structural difference, then genetic factors should transmit it from generation to generation. This has not occurred.

Hereditary

The need to explain the consistent minority of left-handed individuals within a population brought the geneticists into the field at the beginning of this

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century. Their investigations were hampered by the fact that no society permitted the normal development of the left hand.

There is little reason to doubt that handedness is to some extent hereditary (Wile, 1934). Wile regarded left-handedness as a Mendelian recessive, and suggested that handedness is probably not a single gene but arises from a combination of factors. Subsequent observations have shown, however, that left-handedness does not follow known laws of heredity. Empirical evidence to support the inheritance theory of dominance development has been offered by Ojemann (1930), Brain (1945), and Tuttle and Travis (1935).

Observations of the incidence of handedness in identical twins and studies of palm patterns were used by Rife (1951) to propose a hypothesis of hereditary involvement. According to his scheme, genetically ambidextrous persons (Rr) are easily shifted by training and other environmental influences, whereas persons who are genetically right-handed (RR) or left-handed (rr) are not readily susceptible to training. As our society is a right-handed society, the naturally ambidextrous individuals become functionally right-handed. Rife concluded that the influence of environment on handedness depended to some degree on one's heredity.

Several authors have expressed opposition to heredity as a theory of dominance development (Jackson,

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1905; Downey, 1933; Blau, 1946). They consider the theory to be contrary to experience and unsupported by facts. Downey and Blau believed dominance to be a product of social cultivation and learning influences. Hildreth (1949, III), who believed that handedness should be trained and not left to chance, stated that if handedness were hereditary then attempts to change it would be futile.

Social

The social conditioning view of dominance development is currently the most widely accepted. It emphasizes man's adaptability and conformity to group pressure. The theory suggests the social demands of today are more significant than natural physical inclinations in the development of hand dominance.

Most individuals, at birth, do not have a hand preference and are therefore amenable to education (Jackson, 1905; Hildreth, 1949, I). Both hands are responsive to training. Blau (1946) advocated that laterality was acquired through training and education, and became a habitual response by social conditioning. He believed that left-handedness reflected a sociological deviation of the individual due to an inherent deficiency, faulty education, or emotional negativism. A psychological explanation of left-handedness was also offered by Clark (1957). She stated that left-handedness is a revolt of

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of the individual which becomes a distinct disadvantage since society is based on right-handedness.

The best argument for a social theory of dominance development was presented by Hildreth (1949, III). She stated that handedness is learned. In other words, the acquisition of handedness follows the same laws of learning and habit formation as does all behavior resulting from practice or performance. When the proportion of right-handed individuals was plotted versus age in years, a very typical negatively accelerated learning curve resulted.

That early training and activity are important factors in the determination of dominance has been indicated by Palmer (1964) and Provins (1956). Hildreth (1949, II) stated that up to age three the child has little need in daily activities for specialized hand dexterity, and that consistent sidedness does not occur until the child learns motor coordination. However, Burke (1969) found motor training did not significantly enhance the development of lateral preference in first grade children, but it did assist in the development of lateral awareness.

The development of handedness was reported to be an outcome of ontogenetic patterning and organization by Gesell and Ames (1947). They believed ambidexterity, if it exists at all, would seem to be an abnormality.

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In summary, the bulk of evidence indicates that handedness is a product of both heredity and environment, rather than being due entirely to one or the other. Barsley (1966) concluded that the question of handedness has now become one of treatment for a familiar, accepted phenomenon.

Characteristics of Dominance

The qualities peculiar to hand dominance differ in many ways from the characteristics of eye dominance. This apparent difference may have been confounded by the various methods used to evaluate handedness and by the emphasis placed on right-handedness in all societies. In contrast, the establishment of eye dominance has not been influenced by social conditioning.

Eye Dominance

Although not equally distributed in the population, the distribution of eye dominance is not as extreme as handedness. Left-eye dominance is more common than left-hand dominance (Miles, 1929; Hildreth, 1949, III). Eye dominance in left-handed people is equally divided between left and right eyes, while in right-handed people one-third are left-eyed and two-thirds are right-eyed (Hildreth, 1949, III). Crider (1944), who classified eye dominance as right, left, or impartial-eyed, also found approximately 30 percent of right-handed individuals were left-eyed.

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Other characteristics of ocular dominance have been identified by Hildreth (1949, III) as:

1. At birth, infants are ambi-eyed and remain so until control of hand function is needed.
2. Eye movements develop in infancy ahead of hand movements. Throughout life, the eyes control and direct the hands.
3. The eye dominance established early in infancy persists unless the dominant eye becomes incapacitated.
4. The choice of the sighting eye is purely involuntary because there is no social convention to influence the pattern of development.
5. Establishment of ocular dominance does not appear to be as essential for performance of skilled tasks as is manual dominance.
6. There is a connection between dominant eyedness and early handedness habits.

A definite relationship has been found between eye dominance and head tilt (Greenburg, 1960). Right-eyed subjects tend to carry their heads to the left and left-eyed subjects tend to carry their heads to the right. The ambi-eyed do not manifest a consistent head tilt. Greenburg suggested a functional interpretation of this phenomenon; namely, that the dominant eye is unconsciously carried

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There is ample evidence to show that eye dominance is firmly established prior to school age (Clark, 1957; Hildreth, 1949, III). Once established, it does not appear to be possible to train the non-dominant eye to become dominant. Even though the preferred eye may have better visual acuity than the non-preferred eye, visual acuity is not the basis of eye dominance (Clark, 1957).

No significant difference has been found between the sexes in distribution of eye dominance (Crider, 1944), but there is an apparent sex difference in the distribution of handedness. Males exhibit left-handedness twice as frequently as males (Hildreth, 1949, II). Present evidence indicates this difference is probably due to environmental rather than hereditary factors (Clark, 1957).

It is generally agreed that the correlation between eyedness and handedness is low (Gesell and Ames, 1947; Cuff, 1931; Hildreth, 1949, III). That is, eye and hand dominance are not related in a substantial proportion of the population.

<u>Hand Dominance</u>

It has been suggested that hand dominance becomes manifest as early as the sixth month of infancy and is fairly well established at the age of one year (Wile, 1934).

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Hand preference then becomes fixed, partly from inherited urges and partly as a result of parental direction and later social education. Gesell and Ames (1947) found a relatively clear-cut right dominance in the majority of children at two years of age, but that certain periods thereafter were characterized by bilaterality.

There have been attempts to predict handedness at an early age. In 1924, Parson thought handedness was directly caused by a fixed type of eyedness and could thus be predicted. It is now agreed that handedness does not arise as an effect of eyedness (Cuff, 1931). The tonic-neck reflex in infants was found to be predictive of handedness in 14 out of 19 cases by Gesell and Ames (1947). They reported that left-handedness was related to a strong infantile left-tonic-neck reflex.

There appears to be a close relationship between the age at which dominance appears and the degree of dominance (Clark, 1957). Right-handedness is apparent at an earlier age than left-handedness and left-handed individuals are not as strongly left dominant as right-handed individuals are right dominant (Hildreth, 1949, II).

Most people show inconsistencies in hand usage and every physically normal person is left-handed to some degree. The choice of hand used depends on the specific situation. New skills can be learned as easily with the left or the right hand (Hildreth, 1949, III). Hildreth was a strong proponent for the training of handedness, *and*

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and stated that young children can be easily trained away from left-hand usage. The occasional advantages of being left-handed are far out-weighed by the disadvantages (Hildreth, 1950, V). Left-hand persistence is due to an emotional resistance, according to Hildreth, and unless the child who persists in left-hand usage is encouraged and helped to become proficient, he may always be inferior.

Experts differ on the question of whether handedness, once established, should be changed. Some believe there are no deleterious effects if it is done in a psychologically sound manner (Blau, 1946). Blau's study points out that training to a degree sufficient for reversing most children may be conducted without emotional problems. In the past, efforts to switch handedness of children resulted in many problems (real and imaginary) and a fear of changing handedness developed (Oxendine, 1968).

Implications

Several attempts to link abnormalities to specific hand or eye dominances have been made. Barsley (1966) reported that 16-30 percent of the inmates in mental institutions were left-handed, and that 15 percent of epileptics were left-handed. This is a significantly greater proportion than found in the normal population (5-10%). A good point has been made by Hildreth (1949, III) to explain this phenomenon. She stated that the increased number of defectives who are left-handed is due to their being less trainable and unable to benefit from instruction than are other individuals. This would agree with her theory that handedness is trainable and follows a normal learning curve. In another instance, Trembly (1968) found polio victims who had contralateral dominance of hand and eye were more frequently paralyzed than unilateral-dominant individuals. He suggested increased nervous tension in these individuals made the neural system more susceptible to the polio virus.

Stuttering and left-handedness are correlated. Stuttering is most noticeable in children who lack consistent handedness or who are delayed in establishing dominance (Hildreth, 1950, IV). The stuttering subsides when a higher degree of consistency in handedness is established.

Various opinions regarding the role of lateral dominance in motor performance have been recorded. In the domain of sports, games, and recreation, Jackson (1905) advocated ambidexterity to be an advantage. He lamented the one-handed man as deficient and inferior. Parson (1924) and Clark (1957) both proposed that coordination is hampered unless the dominant hand and eye are on the same side of the body. Hildreth (1949, I) stated that individuals who have not achieved manual dominance are less effective or may even be handicapped in motor perform

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performance, and that delay in establishing dominance leads to uncertainty, confusion, and awkwardness in performing motor skills.

Incidence of Dominance in the Population

It is general knowledge that laterality is not evenly distributed in the population. Individuals who primarily use the left hand in unimanual activities are a minority. Left-eyed individuals are also a minority, although the percentage is not as extreme as that of handedness. On the other hand, footedness appears to be the most evenly distributed due to a high percentage of foot ambidexterity (Irwin, 1938).

The incidence of right-handedness in the population is estimated to be between 70 and 98 percent, depending on the population investigated, the author reporting, and the tests of handedness employed. Cuff (1931) reported that 93 percent of college students and children (grades one to eight) were right-handed. Uhrbrock (1970) found 83 percent of male college students to be right-handed, while 76 percent of champion athletes were right-handed. No difference was found between the two populations in left-handedness (13%), but the athletes were considerably more ambilateral.

The prevalence of left-handedness has increased in the United States during the past three decades. Cuff (1931) reported the existing condition to be from 2-6

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percent left-handed. A Detroit study in 1941, showed 6.4 percent of 13,438 elementary school children were left-handed with the proportion of boys being nearly twice as large as that of girls (Barsley, 1966). In another Michigan study of 225,000 students conducted in 1947, 10.1 percent of students in first grade were found to be left-handed, while only 6.6 percent were left-handed in twelth grade (Barsley, 1966). Karpinos and Grossman (1953) disclosed that 8.67 percent of selective service registrants (males) were left-handed. Hildreth (1949, II) reported left-handedness to vary from 7 percent in children to 4 or 5 percent in the adult population and to be the lowest among college students. She believed it may have been as high as 33 percent in prehistoric man. Cuff (1931) indicated native left-handedness would be between 20-30 percent today if it were not for pressures of society affecting the ratio. Clark (1957) disagreed with Cuff. She stated that an enforced change of handedness by a society cannot account for the proportionate difference in right-left dominance, because the incidence of left-handedness among the congenitally blind is as high as it is in the normal population. Clark also reported left-handedness to be more common among twins, with 18-20 percent of pairs of twins having one left-handed member.

The incidence of eyedness is more clear-cut than that reported for handedness. Left-eyedness appears to occur i

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occur in approximately 30 percent of the population (Crider, 1944; Cuff, 1931), while the same authors report 62 percent and 70 percent of right-eyedness. Lower percentages of right-eyedness were published by Uhrbrock (1970) who found 56 percent of athletes to be right-eyed, while 47 percent of college males were right-eyed.

The occurrence of unilateral, contralateral, and mixed dominance of hand and eye in the population was of interest to the present study. After reviewing the percentages of unilaterality reported in the literature (Way, 1958; Adams, 1965; Clark, 1957; Sinclair and Smith, 1957; Tyler, 1971; Horine, 1968), it appears that approximately 57 percent of the population have unilateral hand and eye dominance. Similarly, a generalization may be made that about one-third (33%) of all individuals are contralateral in hand and eye dominance (Hildreth, 1949, III; Tyler, 1971; Sinclair and Smith, 1957; Cuff, 1931; Adams, 1965; Clark, 1957; Way, 1958). Mixed dominance varies from 10-13 percent as reported by Horine (1968) and Tyler (1971).

Measurement of Dominance

The literature reveals that dominance has been determined by various methods depending on the individual researcher. There is no established, standardized procedure that is universally adopted and accepted. Available tests appear to have originated in the first half o

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half of the twentieth century. Recent tests, such as the group test for eye dominance developed by Friedheim and Zener at Duke University and reported by Greenburg (1960), are merely a modification or reapplication of the older ones. Handedness, with its variability between tasks, is more difficult to access than eyedness.

Tests of Eyedness

The early studies in the measurement of dominance centered around the comparative visual acuity of the two eyes. It has since been determined by Downey (1933), Crider (1944), and others that visual acuity is unrelated to eye dominance.

Sighting preference during binocular vision appears to be the most satisfactory method of determining eye dominance. When an object is sighted with both eyes open, fixation is actually due to the functioning of one eye (the dominant eye), although subjects are not conscious of this fact and have the impression that they are using both eyes. Binocular vision tests that have been used include sighting through a cone, a hole in a card, a ring, or aligning a pencil with some object.

The origin of the Hole-in-Card Test is traced back to Durand and Gould (1910). They used a card with a hole in the center, a piece of tubing pushed through the hole, and an attached handle. The disadvantage of this method was holding the handle with only one hand. This fault was corr

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was corrected by Dolman (1919). He used a 13 by 20 centimeter card with a 3 centimeter round hole in the center, and had the subject grasp one end of the card with each hand. The subject raised the card slowly at arm's length while looking intently at a spot of light six meters distant.

The necessity for unconscious sighting during eye dominance tests was first stressed by Miles (1929). His test is called the A-B-C Test of Ocular Dominance with the A-B-C meaning Area-Blackness-Comparison. The method utilized a tapered cone through which test cards were sighted. Each test card contained two round spots, each different in size and shade of color. The attention of the subject was controlled by giving a short exposure of the card and having the subject indicate which spot was larger and which was darker. The subject viewed the card with both eyes open, looked through the large end of the cone toward the small end and unconsciously lined the cone up with the dominant eye. The dominant eye was readily observable by the examiner. A series of ten such trials were suggested. There was extremely high consistency between trials using this method, with a reliability of 0.95 for the test. Cuff (1931) used a similar eye dominance test and reported a reliability coefficient of 0.97 for measurement consistency.

The use of a battery of eye dominance tests does not appear to have an advantage over a simple test that

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is repeated a sufficient number of times. Four tests of eyedness were studied by Buxton and Crosland in 1937. They reported reliability coefficients for the manuscope (a small darkened box developed by Parson, 1924); for the hole-in-card; for ring sighting; and for a monocular sighting test. The tests were pooled into a battery which had an overall reliability of 0.85. Of the individual tests, the hole-in-card was found to have the highest reliability (r=0.97) using ten trials. The authors concluded that typical simple tests of eye preference, when repeated, prove to be statistically reliable. Using a battery of seven tests, Crider (1944) supported the findings of Buxton and Crosland. His battery had a reported reliability of 0.98. Crider also reported that sex, handedness, intelligence, or visual acuity did not influence test results.

Further investigation into tests of eyedness failed to discover other methods with higher reliability or greater ease of administration. The Phi Test of dominance described by Jasper and Raney (1937) was very elaborate and its correlation with other tests was low. Retinal-rivalry tests also have low correlation with other tests of eye dominance (Washburn, Faison, and Scott, 1934). The group test reported by Crovitz and Zener (1965) involving the pencil alignment procedure, is suggested only as a screening device to use with large groups.

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Tests of Handedness

Numerous techniques have been employed in an effort to assess handedness. Most of these can be classified by their utilization of preference, strength, speed, motor tests, or simultaneous bimanual drawing as determiners of the dominant hand. None of the tests give a true picture of handedness with its extreme variability.

Preference tests to determine handedness have used either the questionnaire method or the performance of important unimanual activities. Although widely employed, questionnaires have not proven to be reliable indicators of the hand actually used in the performance of the activity (Barnsley and Rabinovitch, 1970; Blau, 1946). Questionnaire items that have proven reliable are those easily tested by performance, namely, hammering, cutting with scissors, card dealing, spinning a top, winding a watch, holding a toothbrush, sharpening a pencil, writing, cutting when eating, drawing, throwing, and holding a tennis racquet (Hull, 1936). An Index-of-Dominance is usually employed in either the questionnaire or performance methods using the formula of $\frac{R-L}{R+L}$ to score responses (Hildreth, 1949, I). (R is the number of right-hand responses, and L is the number of left-hand responses.) Fox (1957) used a battery of 29 items and concluded that strength and dexterity tests were probably more indicative of hand dominance than a test of reaching for some object. Cuff (1931) found the throwing test indicates the d

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the dominant hand in nine out of ten cases, and reaching tests in eight out of ten cases. The accuracy test of target throwing was found to be superior to strength and speed for diagnosis of hand dominance by Burge (1952).

Relative strength tests of the right and left hands may be a doubtful measure of dominance, as there seems to be little connection between power and handedness ability in intricate movements. However, one hand usually does have greater strength than the other hand and Henry (1961) found strength to be 54 percent specific to the dominant hand.

Speed tests have involved speed of tapping and precedence of movement of the two forearms in response to a sequence of three light stimuli (Vogel, 1935). The main criticism of these tests is that the effect of practice gained by one hand in other activities probably transfers to the skills employed in the speed tests. Reaction time and movement time between the two limbs does not differentiate preferred from non-preferred hands (Barnsley and Rabinovitch, 1970).

Motor tests give a relative comparison of performance with the right and left hands. Barnsley and Rabinovitch (1970) state that although the same skills are to be found in either hand, the preferred hand is characterized by superior performance. Dimond (1971) suggests that the cerebral hemispheres are not isolated units, but work through each other to control the function of the limbs, and th

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and that control may be switched as the tasks demand the respective specialization of each hemisphere. The fact that each limb is directly connected with one hemisphere does not ensure that its function is controlled by that hemisphere alone.

The simultaneous bimanual drawing tests of Van Riper (1934) have been used in many clinics as a diagnostic instrument. It is considered to be too elaborate for field testing.

Most authorities agree that handedness is far too complex to be described as simply right or left. It can best be viewed as a continuum from left to right with most individuals located somewhere between the two extremes. Clark (1957) has said:

> It is impossible to measure native left-handedness since society's attitude distorts it at an early age, and the actual amount uncovered depends on the tests employed. Even the use of a battery of tests does not necessarily produce a completely reliable measure of handedness . . . as the pressure towards right-handedness varies markedly from community to community, district to district, and even family to family, even within any one generation, one cannot estimate strength of preference from the number of activities for which the left hand is used . . . (p. 12-13).

Current thinking indicates hand preference should be considered task specific (Collins, 1961; Lotter, 1960; Cuff, 1931; Norrie, 1967). Therefore, the preferred hand should be determined from actual performance of the task or tasks of concern. When determining the preferred hand for a task, it is important to take the precaution of not favoring either hand through the arrangement of objects for the test.

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Dominance and Motor Proficiency

Numerous investigators have attempted to discover the relationship of different dominance patterns to the performance of motor skills. The early studies in the realm of physical education appeared in the 1930's with the work of Vogel (1935), Tuttle and Travis (1935), and Irwin (1938). They were characterized by the measurement of dominance using tests involving a simple flexion movement of the forearm from a key in response to a stimulus. Tests of dominance using other large muscle activities and related to gross motor skills are found in the 1950's in the studies of Fox (1957), Sinclair and Smith (1957), and Way (1958). Beginning in the 1960's and continuing into the 1970's, research pertaining to dominance and its relationship to physical education and athletic activities has become more abundant.

The literature is replete with studies that show various conflicting conclusions about the degree of association between laterality and motor performance. A clear-cut relationship between dominance and skill has yet to be established. The studies reporting that laterality is not a factor in motor skill acquisition or performance will be reviewed first, followed by those claiming superiority of particular lateralities.

When comparing groups that displayed unilateral dominance, contralateral dominance, and a lack of dominance in one or more of the three body parts, Tyler (1971) found no si

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no significant differences between groups in the rate of learning two fine motor and one gross motor skill. He concluded that individuals with different dominance patterns are equally capable of learning new motor skills, or "that lateral dominance . . . is not a limiting factor in motor skill performance and skill acquisition." This view differs from that expressed by Clark (1957) and Hildreth (1949, I) who regarded unilateral dominance as advantageous. Tyler suggested that if dominance is a factor in acquiring motor skill, it is an empirical phenomenon which is modifiable through practice, and not a neurologically predetermined phenomenon subject to little change. Putman (1971) studied the learning ability of right-handed college women on the pursuit rotor. They were given 5, 10, or 20 trials of 20 seconds duration. Results indicated the degree of first hand practice did not affect the total amount learned with either the right or left hand.

The efficiency of teaching methods in relation to the dominant and non-dominant musculature has received some attention in the literature. Lambert (1951) studied whether it would be more effective to teach a two-handed skill to the non-dominant musculature first. He concluded it made no difference which hand was trained first in learning a two-handed skill, and the most effective method was to train both musculatures together. In a similar study, the basketball skills of dribbling, shooting, and

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passing were taught to fifth grade children (Thomas, 1969). One group was taught to use the dominant hand only and the other group taught to use both hands equally during 12 weeks of daily instruction. With the exception of a half-minute shooting test using the left hand, no significant differences were found between the two groups of children.

The relationship between dominant eye, hand, and foot with the take-off foot in selected skills of locomotion was investigated by Garrison (1969). No significant differences were found between eye, hand, and foot dominance, singularly or in combination, and the take-off foot. However, the findings revealed that relationships do exist between eye and hand laterality, hand and foot laterality, and eye and foot laterality.

The performance of ten year old boys on tests involving dynamic balance, motor educability, speed of arm movements, and shuttle run were compared to their exhibited lateral dominances (Horine, 1968). There were no differences in level of performance between the various laterality groups.

Handedness does not appear to be a factor in the timing of limb movement patterns. Norrie (1967) studied the effects of unequal distances and handedness on timing patterns of the limbs. She reported that the limb which was required to travel the greater distance started first and finished last. The distances involved seemed more important than handedness in determining the pattern of

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movement used. One hand was not favored over the other when the movement distance was equal.

An intriguing aspect of laterality is the role it may have on accuracy in motor performances. Several authors have reported negative results. Cratty and Williams (1968), using line drawing without vision, found hand dominance had no effect upon accuracy of performance. However, since the sample contained a much larger number of right-dominant individuals (46) than left (11), this may have tended to mask the true role of hand dominance. No significant difference was found in success of basketball free throw shooting between unilateral and contralateral groups in a study by Shick (1971). Staples (1971) compared unilaterally-dominant male basketball players on shooting accuracy under three visual conditions, each in combination with four shooting positions. Results indicated shooting accuracy was best under the conditions of binocular vision and better under monocular vision with the dominant eye than with the non-dominant eye. Shooting accuracy decreased as the distance from the basket increased and was more accurate when the shots were attempted directly in front of the basket than from equidistant positions at the side.

Several investigators have reported no relationship between lateral dominance and motor ability in specific sports. Baseball hitting and dominance were studied by Adams (1965) and Baughman (1968). Adams found the contral

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contralateral batters did not perform better than the unilateral batters, even though their dominant eyes faced the pitcher. Baughman found no difference between unilateral and contralateral batters in ability to place hit, although a significant difference was reported in favor of using both eyes as compared to using only the dominant or non-dominant eye. Lacrosse throwing ability did not differ between the unilateral and contralateral groups studied by Cooke (1969). In swimming, Sinclair and Smith (1957) determined that dominance of eye, hand, and foot was not related to side preference for breathing and swimming the sidestroke. They did discover, however, that swimmers who breathe to the right side in the front crawl tend to swim the sidestroke on the left side and vice versa. Fox (1957) and Frahm (1967) investigated the pertinence of dominance to bowling. Frahm concluded that eye-hand dominance did not appear to be a factor in learning the hook delivery by the spotting method. Fox suggested that many individuals using the right hand were in reality native left-handers. Twenty such beginning bowlers were identified and four subjects were taught to bowl left-handed while the other sixteen bowled right-handed. The left-handed bowlers were significantly poorer in performance. The conclusion was that bowling involves more than the use of the arms, and it is possible the long established coordinations of eye, hand, and foot are more important than hand dominance in learning a new skill.

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Therefore, the preferred hand should be used to bowl rather than the natively dominant hand.

Unilateral Dominance

Several investigators have obtained results which indicate unilaterally-dominant individuals are superior in motor ability. It is intriguing that all of these studies, except one, were published since 1965. This observation may or may not have importance, as several studies since 1965 have also reported the lack of a significant relationship between lateral dominance and motor proficiency.

One of the most common applications of monocular vision is in rifle shooting. Banister (1935) became interested in eye dominance as a factor in shooting ability when he discovered that infantrymen with the best vision did not always score highest on shooting tests. Following the collection of data on 1,000 infantrymen, he reported, "the results show that the dominant eye is an important factor affecting ability with the rifle, and that the man whose right eye is dominant has a considerable advantage, other things being equal, over other men when required to shoot from the right shoulder."

Unilateral groups have performed consistently better than corresponding contralateral groups on the pursuit rotor. Poindexter (1965) tested male and female unilateral and contralateral groups on 30 trials of the

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pursuit rotor. The unilateral group was composed of individuals who were right-eyed and right-handed, and the contralateral group of those who were left-eyed and right-handed. No left-handed individuals served as subjects in the study. Results indicated the unilateral groups were superior in performance. Males were, in general, superior to females; however, the unilateral females exceeded the contralateral males after the tenth trial and maintained a slight superiority throughout the remaining trials.

It has been proposed that unilaterally-dominant individuals have better coordination than contralaterally-dominant individuals (Robinson, 1965). Robinson compared 50 unilateral junior high boys and 50 contralateral junior high boys on 25 tests of reaction time, 15 large muscle hand-eye movement tests, and 8 small muscle hand-eye movement tests. The unilateral group out-performed the contralateral group on all tests except those requiring accuracy in large muscle movements. The groups performed equally well in large muscle accuracy tests.

Unilaterally-dominant individuals have been found to perform highest on the Scott Motor Ability test, while contralateral individuals performed lowest (Kisler, 1971). The mixed group (dominance not clearly decided in a member) also out-performed the contralateral group. Results showed eye-foot laterality combinations have some influence on performance of the basketball throw for distance.

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Contralateral Dominance

Two studies obtained results indicating contralateral individuals out-performed other dominance types. The role of eye and hand dominance on motor ability of college males was investigated by Roth (1942). Results of the various laterality groups in order of performance were: (a) RE,LH; (b) RE,RH; (c) LE,RH; (d) ambiocular, ambidextrous; (e) ambiocular, RH; and (f) LE,LH. The right-eyed, left-handed men out-performed all groups, and subjects who were ambilateral in hand and eye preference showed no definite extremes of motor ability. In 1968, Baughman recorded baseball batting averages for an entire season and found contralaterals achieved a significantly higher number of bases on balls than did the unilateral group.

Mixed-Lateral Dominance

Only one study claimed the superiority of mixed-dominant individuals in motor ability. In 1958, Way used the Scott Motor Ability tests and skills of archery, bowling, badminton, and tennis to study the effect of lateral dominance on motor ability of college women. There was no indication that unilateral individuals have higher skill than contralateral persons. Among Way's conclusions were: (a) that women with mixed-dominance are superior in motor ability to those with unilateral or contralateral preference; and (b) that motor ability seemed to be related to foo

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to foot ambidexterity since combinations of preference that included foot ambidexterity resulted in higher motor ability scores. This provides support for Clark's (1957) contention that the ability to use either foot is possibly of more value in sports than in other motor activities.

Dominance and Accuracy of Direction

The earliest reference to dominance as a factor in accuracy was found in the Bible Old Testament book of Judges, Chapter XX, verses 15-16. The tribe of Benjamin had a group of left-handed individuals who could sling stones with unusual accuracy. Since special note was made of this feat, it was evidently considered to be a superior performance.

Investigators in several studies identified a significant relationship between laterality and activities where accuracy of direction was important. Whiting (1969) measured the accuracy of throwing at a target by six, nine, and thirteen year old males and females using their preferred and non-preferred hands. Results showed that at six years, the right-handed child appears to have a distinct advantage in throwing for accuracy, but that those who were left-handed tended to be more accurate than those who were right-handed at the ages of nine and thirteen years. One of Way's conclusions in 1958, was that laterality seemed to be of greater importance in activities that stress accuracy of direction toward a fixed target (as in archery and bowling

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bowling) than in activities that do not. In studying the direction of missed shots by college women in basketball free throw shooting, Shick (1971) found no significant difference between the unilateral and contralateral groups in errors toward the dominant hand. However, the contralateral group did make significantly more errors toward the non-dominant hand (toward the dominant eye's side of the body).

The relationship of lateral dominance to visual and non-visual directionality has received some attention. The visual directionality of autokinetic movement was studied in right and left-handed subjects by Wishner and Shipley (1954). They found that right-handed persons reported movement more often to the right than to the left, whereas left-handed persons reported movement equally to the right and left. In the study of Cratty and Williams (1968), which involved the task of line drawing without vision, the results indicated that lines drawn with the right hand tended to veer slightly to the left and lines drawn with the left hand veered to the right. However, hand dominance was judged not to be a factor in this "crossing-over" phenomenon.

In summary, the literature on lateral dominance and motor proficiency reveals that conflicting conclusions have been reached by different investigators using different skills. A significant portion of the older evidence would seem to indicate that dominance has an insignificant role in motor skills. However, many studies

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conducted within the past twenty years have found significant differences between laterality groups. Whether these recent significant findings may be due in part to improved research designs, improved statistical techniques, changing cultural patterns, or other variables requires further investigation.

CHAPTER III

RESEARCH METHODS

The purpose of the study was to investigate the effects of individual differences in hand and eye dominance on the performance of a selected motor task. More specifically, the study attempted to determine if hand and/or eye dominance influenced: (a) accuracy of throwing at a target; (b) directional errors made in the right or left halves of the target; and (c) directional errors made in the top and bottom halves of the target.

Subjects

A population of 230 Sophomore high school girls, currently enrolled in the required physical education program at Eastern High School, Lansing, Michigan, was tested for hand and eye dominance and classified into strata based on exhibited lateralities. The four possible strata were RH-RE, RH-LE, LH-RE, and LH-LE.

The results (Table 3.1) showed that the population of Sophomore girls was approximately 94 percent right-handed, 6 percent left-handed, 60 percent right-eyed, and

40 percent left-eyed. Fifty-seven percent were unilateral in hand-eye dominance and 42 percent were contralateral. These figures correspond with the incidence reported in populations by Crider (1944), Cuff (1931), Barsley (1966), Uhrbrock (1970), and Way (1958).

TABLE 3.1.--Laterality of Sophomore Population.

Strata	No.	Percent	Mean age of selected sample (n=11)
RH-RE	127	55.2	15.9
RH-LE	89	38.7	16.0
LH-RE	8	3.5	16.3*
LH-LE	6	2.6	16.5**
Totals	230	100.0	16.2

*Includes three upper class girls.
**Includes five upper class girls.

Based on the results of a preliminary pilot study (Appendix A), n=11 was estimated to be a necessary and sufficient sample size from each strata. Due to the paucity of left-handed Sophomore girls, both left-handed groups were filled by selecting left-handed Juniors and Seniors from elective physical education classes. A disproportionate, random sampling technique was used in order to produce estimates for the left-handed groups with greater precision than a proportionate sample would yield, and to provide equal allocation of stratified subjects. A table of random numbers was employed to select the experimental subjects. The mean age of the sample selected was 16.2 years.

Determination of Eye Dominance

Each subject was tested to determine their dominant eye using the Hole-in-Card method (Appendix B). It is a simple test to administer, is frequently used, and when repeated ten times has an established reliability of r=.97 (Buxton and Crosland, 1937; Crider, 1944). Ten trials of the test were given with the subject sighting through the hole in the card (held in both hands) at different figures or letters displayed on cards held by the examiner 10 feet (3.0 meters) away. Each card was displayed for approximately one second. The examiner looked past the card and noted which eye the subject used unconsciously to sight the object. The eye that was lined up with the hole in the card was recorded for each trial. The dominant eye was determined as the one used for the majority of sightings. Of the 238 subjects tested, 233 used the same eye for all 10 trials, three used the same eye for 9 out of 10 trials, and two used the same eye for 8 out of the 10 trials. To obtain unconscious sighting by the subject, as suggested by Miles (1929), subjects were not told the true purpose of the test. They were told their quickness and sharpness of vision was being tested.

Several points regarding the administration of eye dominance tests, as cited by Clark (1957), were followed. Care was taken to eliminate the effects of the dominant hand by having the subject hold the card with both hands. When such precautions was taken, the correlation between eyedness and handedness is low. Similarly, care was taken to insure that the subject kept both eyes open and looked directly through the hole in the card. The advantage of using the Hole-in-Card method was that the investigator could determine the dominant eye and did not have to rely on the subject's report.

Determination of Hand Dominance

Hand preference for the study was determined by asking the subject, when commanded, to pick up a dart (which had been placed at the subject's midline on a table directly in front of her) and to throw it as quickly as possible at a dartboard 10 feet (3.0 meters) away. The subject was cautioned not to take time to aim, to ensure the choice of hand would be their natural hand for throwing. Five darts were thrown in this manner and the hand used was recorded. All subjects used the same hand for all five trials. To mask the true purpose of the test, each subject was told it was a test of their ability to react quickly.

Research Design

The study was essentially an Ex Post Facto design because the independent variables, hand and eye dominance, had already been established in the subjects and thus pre-assigned them to comparison groups. The four comparison groups obtained from the hand and eye dominance testing were: Group I--right-handed, right-eyed subjects; Group II--right-handed, left-eyed subjects; Group III--left-handed, right-eyed subjects; and Group IV--left-handed, left-eyed subjects.

Weighted dart throwing was used to obtain measures for the three dependent variables; overall accuracy, directional errors in the right and left halves of the target, and directional errors in the top and bottom halves of the target. It was reasoned that weighted darts would reduce the chance for bias due to previous participation in dart throwing with regular darts.

Apparatus

A 36 x 36 inch (91.5 x 91.5 centimeter) target (Figure 3.1) made of a compressed material was mounted in a vertical position between two uprights. The uprights were constructed so the target face could be adjusted to the height of each subject. The target face consisted of six concentric circles of equal width (4.5 centimeters) drawn on an off-white board in black ink, with each

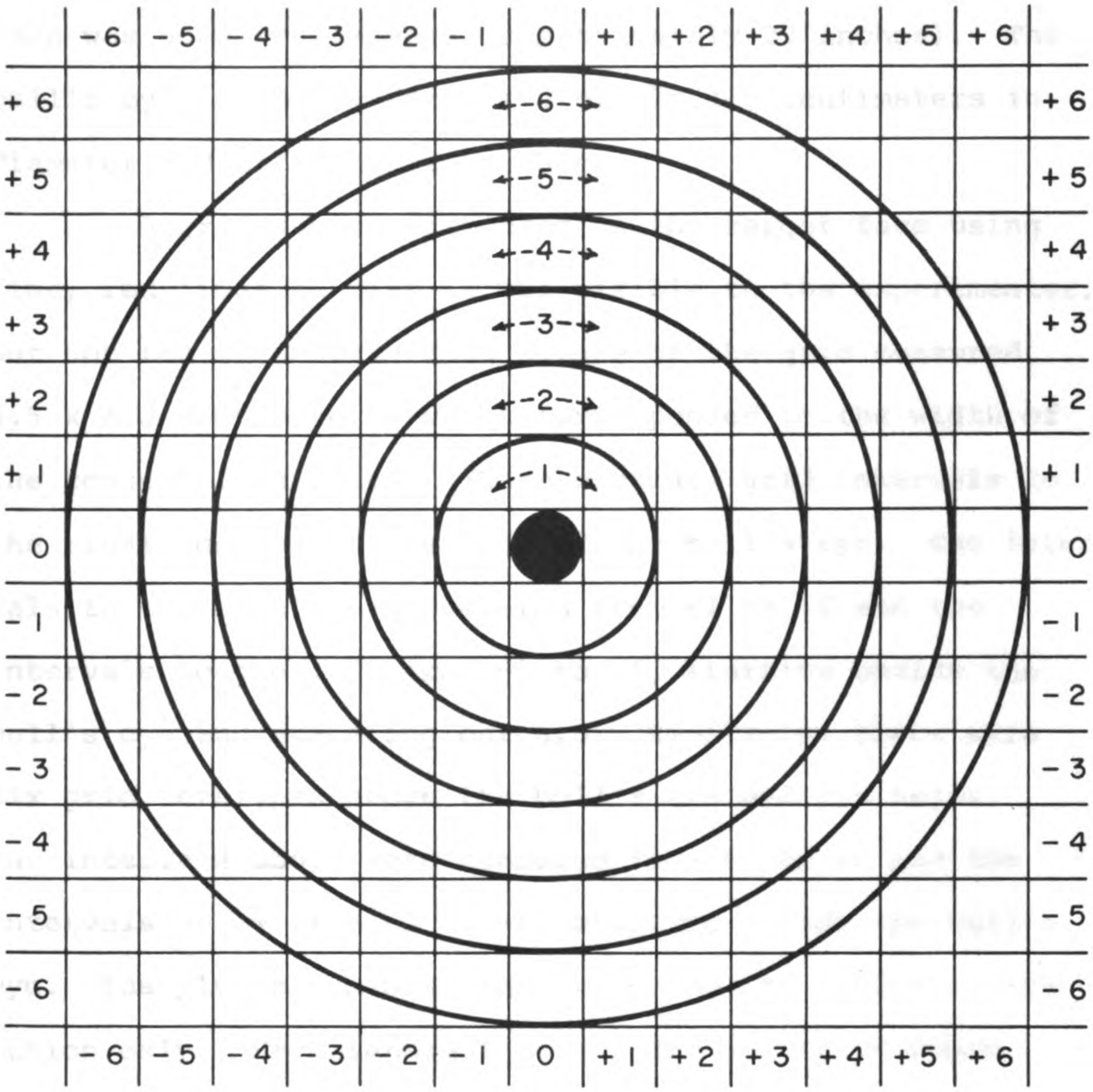

Figure 3.1 The Target Face

Scale: 1 cm. = 4.5 cm.

demarcation line being 2/16 of an inch (3 millimeters) wide. The mid-point radii of the intervals thus formed were 4.5, 9.0, 13.5, 18.0, 22.5, and 27.0 centimeters, respectively. The total scoreable diameter of the target face was 58.5 centimeters (approximately 23 inches). The bull's eye in the center was a circle 4.5 centimeters in diameter and solid black in color.

A grid was superimposed on the target face using fine, red lines so that it was visible to the experimenter, but not the subjects. Each square of the grid measured 4.5 x 4.5 centimeters, which corresponded to the width of the concentric circles. There were six grid intervals to the right and six to the left of the bull's eye. The intervals to the right were numbered from +1 to +6 and the intervals to the left from -1 to -6, starting beside the bull's eye and numbering outward. Similarly, there were six grid intervals above the bull's eye and six below. The intervals above were numbered from +1 to +6 and the intervals below from -1 to -6, starting beside the bull's eye. The plus and minus signs were used to indicate direction only. Each interval or directional error score (one to six) could be converted to distance from the bull's eye by multiplying by 4.5 centimeters.

The darts used were manufactured by the Unicorn Dart Company in England (code 03285), had an overall length of 6.5 inches (16.5 centimeters) and a metal point of .87 inch (2.3 centimeters). The weighted metallic grip was

2.62 inches (6.7 centimeters) long, and the upper end of the shaft was wood and had a length of 1.75 inches (4.5 centimeters) on the end feathered. The average weight of the six darts used during the study was 29.36 grams with a range of 29.24-29.44 grams. (One of the original five darts was broken during the study and replaced by one of comparable weight.)

Measures

Darts were thrown at the target from a distance of 10 feet (3.0 meters). The 10 foot subject-target distance was adopted because it was found to be the best distance from the board for adults (Johnson, 1919), and is close to the nine feet used in the English "20-Point" Dart Game. Each dart thrown received three scores. One for accuracy, one for right-left directional error, and one for directional error above or below the bull's eye.

Accuracy (X_1) was measured using the six concentric circles. A zero was recorded for a bull's eye, one point for a hit in the innermost circle, two points for a hit in the second circle, and so forth out to a score of six in the sixth concentric circle. An accuracy score of seven was given for any hits beyond the sixth circle. Thus, the lower the score, the more accurate the throw.

Right-left directional error scores (X_2) indicated the magnitude of the error in the horizontal plane and its direction from the bull's eye. A plus was used to show the throw was to the right and a minus to the left of the bull's eye. Scores ranged from zero in the interval containing the bull's eye to +6 at the far right and -6 at the far left. A score of seven was given for any hits beyond these boundaries. Lower scores indicated less deviation from the target center (greater accuracy) in the horizontal plane.

Above-below directional error scores (X_3) indicated the magnitude of the error in the vertical plane and its direction from the bull's eye. A plus was used to show the throw was above and a minus below the bull's eye. Scores ranged from zero in the interval containing the bull's eye to +6 at the top edge of the target and -6 at the bottom edge. A score of seven was given for any hits beyond these boundaries. Lower scores indicated less deviation from the target center (greater accuracy) in the vertical plane.

Procedures

Data was secured for the study during April, 1974. Each subject attended two measurement sessions of dart throwing within a period of seven days. Two sessions were used to avoid boredom of the subject and to obtain the desired number of trials. During each of the two measurement sessions, each subject was given five successive practice throws (determined from the Pilot Study, Appendix A) followed by a brief interval while the darts were retrieved by the investigator. Five additional sets of five trials each were given and the 25 trials were scored for accuracy, R-L (right-left) directional error, and A-B (above-below) directional error. The interval between sets was only long enough to score and retrieve the darts.

To remove the possibility of external invalidity due to subjects' knowledge of research, efforts were made to keep the subjects uninformed as to the true purpose of the study. In order to accomplish this objective and also to increase motivation, the subject was given 100 points for each "bull's eye" and 50 points for a hit in the circle adjacent to the bull's eye. No points were awarded outside these two areas. This scoring system also provided immediate feedback for the subject.

All tests and measurements were performed by the investigator during the regularly scheduled physical education class of the subject in the same unoccupied room at the school. Only the investigator and subject were present for each session.

Data Collection

The top edge of the target face was adjusted to match each subject's head height. This placed the bull's eye of the target at approximately shoulder height, which was about the level of dart release. Using a carpenter's right-angle square and tape measure, a restraining line was marked 10 feet (3.0 meters) from the target with a two foot piece of tape. The exact center of the target was located on the restraining line and indicated by placing a piece of tape perpendicular to the restraining line. A "T" was thus formed. The subject was instructed to stand with one foot on the line indicating the center of the target. (The foot to be used was not specified to avoid biasing the data in favor of ipsilateral or contra-lateral-dominant individuals.) Other than this, no special position of the feet was required except that one foot had to touch the 10 foot restraining line and could not go over it. A subject could stand with feet side by side or in stride position.

The method of throwing the darts was not controlled except that a posterior-anterior overhand throw was required. The dart was held between the thumb and first two fingers with the hand above the subject's throwing shoulder. The throw was made by extension of the flexed forearm and wrist.

Scoring and Recording

During the first measurement session, trials 1-5 were allowed for practice and were not scored. Each trial 6-30 received three scores; one for each of the dependent variables X_1, X_2, and X_3. The X_1 (accuracy) score was recorded as an integer from zero to seven, representing hits in the concentric circles of the target. The X_2 (R-L directional error) score was recorded as an integer from zero to seven, representing the distance from the bull's eye, and was preceded by a plus or minus to indicate the direction of the error. The X_3 (A-B directional error) score was recorded as an integer from zero to seven, representing the distance from the bull's eye, and was preceded by a plus or minus to indicate the direction of the error.

The second measurement session was recorded in a similar manner with trials 31-35 used for practice and trials 36-60 scored for X_1, X_2, and X_3. All scores can be converted to their equivalent distances from the center of the target; i.e., an accuracy score (X_1) of four would indicate the throw was 18.0 centimeters (4 x 4.5 cm.) from the center of the target, and a R-L directional error score of minus three would indicate the throw was 13.5 centimeters to the left of the bull's eye.

Treatment of the Data

The data was treated as a fixed-effects, 2 x 2 design having right and left categories of hand dominance, and right and left categories of eye dominance. Main effects were obtained for hand dominance and for eye dominance on each of the three dependent variables. Interaction effects of hand-eye dominance (RH-RE, RH-LE, LH-RE, LH-LE) were obtained for the three dependent variables. The influence of ipsilateral dominance and contralateral dominance on each dependent variable was obtained by grouping the RH-RE and LH-LE groups together (ipsilateral), and the RH-LE and LH-RE groups together (contralateral).

Sets of five trials each were used to organize the data into more representative scores than were yielded by individual trials. (Darts were thrown in sets of five.) That is, accuracy was represented by summing the scores for five trials, and R-L and A-B directional errors were represented by algebraic summation of the scores for five trials. Data was submitted to the CDC 6500 computer at Michigan State University for analysis.

Statistical Procedures

Two-way analysis of variance (ANOVA) was used to evaluate the influence of hand and eye dominance on overall accuracy, R-L directional errors, and A-B directional errors. *A priori* comparison tests were used to evaluate the influence of ipsilateral and contralateral dominance on overall accuracy, R-L directional errors, and A-B directional errors.

The use of multivariate analysis of variance (MANOVA) was investigated based on the correlation shown between dependent variables on the pilot study. R-L directional error had little relationship to accuracy ($r=.03$) or to A-B directional error ($r=-.12$). Accuracy and A-B directional error also were not highly related ($r=-.41$). MANOVA, therefore, was not deemed necessary for analyzing the study.

Significance Level

Alpha was set at the .05 level for the study. However, the ANOVA's for accuracy and A-B directional error were tested at the .025 level due to the additive effect caused by the dependency existing between the two variables (revealed by the pilot study, Appendix A).

The .05 level of significance was selected for the study because it agrees with that conventionally used in education and the behavioral sciences. The investigator believed the risk of committing a Type I error could be tolerated in view of the possible importance that significant findings might have for future research.

CHAPTER IV

RESULTS AND DISCUSSION

The study was undertaken to determine the influence of lateral dominance on throwing accuracy, on the direction of errors made in the right and left halves of the target, and on the direction of errors made in the top and bottom halves of the target. The chapter will begin with a brief description of the relationships found between the three dependent variables. Results will then be presented and analyzed separately for each variable in this order: accuracy (X_1), R-L directional error (X_2), and A-B directional error (X_3). Finally, a discussion offering some rationale for the observed data will be presented.

Relationships Among Dependent Variables

The BASTAT program was utilized to compute simple correlations between pairs of the dependent variables (Table 4.1). The results indicated that R-L directional error was not significantly related to either of the other two variables. R-L directional error had a correlation of $r=-.03$ with accuracy. The same correlation coefficient

TABLE 4.1.--Correlations Between Dependent Variables.

	X_1	X_2	X_3
X_1 (Accuracy)	1.000	- .033	- .385
X_2 (R-L error)		1.000	- .240
X_3 (A-B error)			1.000

had been obtained between these two variables on the pilot study, except the relationship was positive (r=+.03). The correlation of R-L directional error with A-B directional error was r=-.24, which was slightly higher than that obtained on the pilot study (r=-.12). Accuracy and A-B directional error exhibited the highest correlation, r=-.39. This was slightly lower than the pilot study correlation between the two variables (r=-.41). The relationship between accuracy and A-B directional error was not high enough to permit prediction (R^2=.16).

Statistical Results

The AOV program for the CDC 6500 computer at Michigan State University was used for the analyses. Line graphs have been used to present pictures of the performances of the four laterality groups and of the ipsilateral-contralateral groupings.

Accuracy

The LH-RE group was least accurate during both sessions of dart throwing as indicated by the upper curve in Figure 4.1. Although not as noticeable in Trials 6-30 as in Trials 36-60, the LH-LE and RH-RE groups occupied a middle position, and the RH-LE group was the most accurate. This phenomena was reflected in the mean accuracy scores for the groups. Means for the LH-RE, LH-LE, RH-RE, and RH-LE groups were, respectively: 3.03, 3.20, 3.20, and 3.59. Each mean, when multiplied by 4.5 centimeters, gives the average distance from the bull's eye for the group.

An analysis of variance (ANOVA) was not significant for the main effects of hand dominance and eye dominance or for their interaction (Table 4.2). The power of the tests were found to be less than .20, which was too low to detect significant differences between groups.

The *a priori* comparisons test between the ipsilateral (RH-RE and LH-LE) and contralateral (RH-LE and LH-RE) groups failed to show a significant difference (F=.35). In the graph of Trials 6-30 (Figure 4.2), the ipsilateral group appeared to be more accurate than the contralateral group. This pattern was not repeated during Trials 36-60, however.

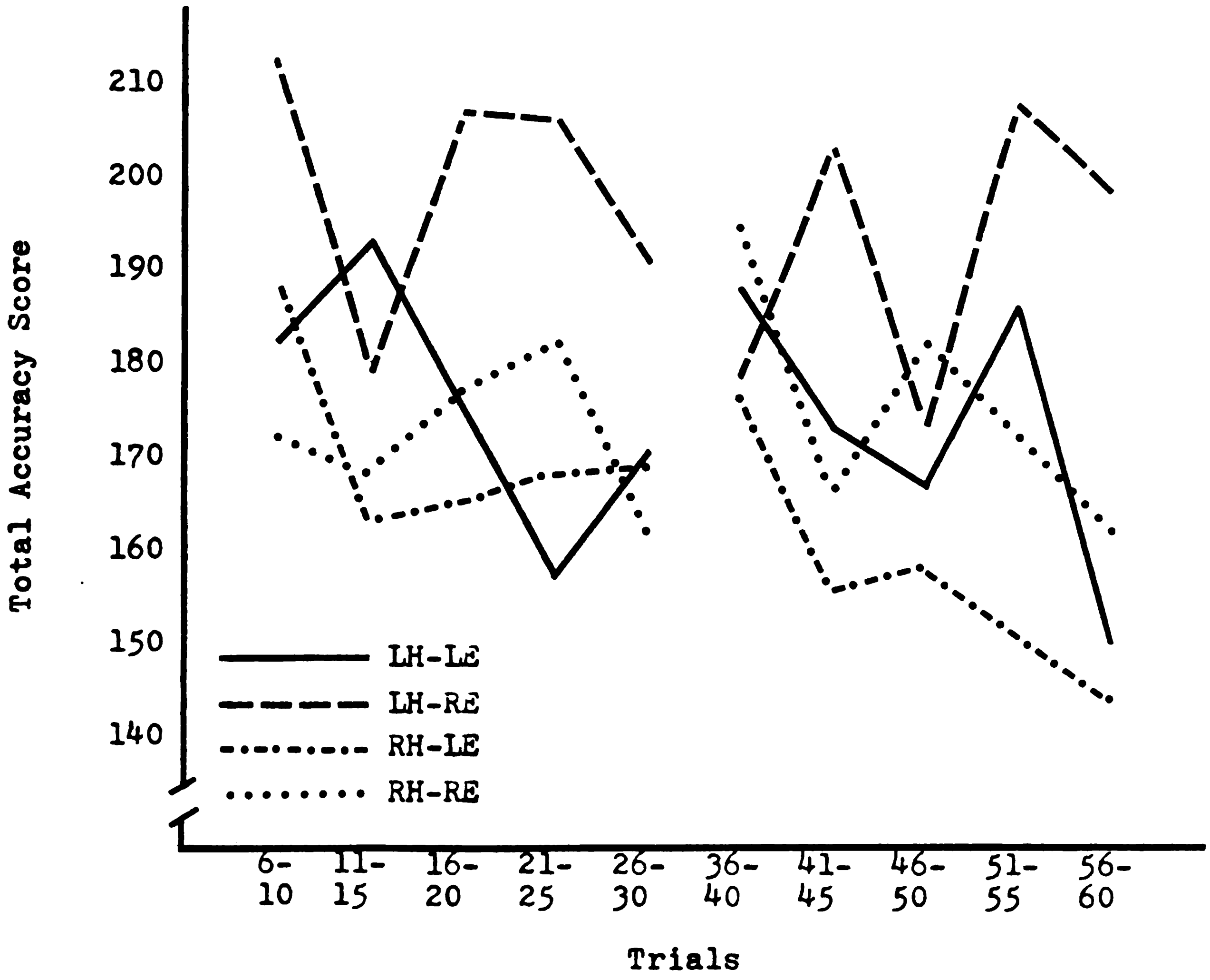

Figure 4.1.--Overall Accuracy by Laterality Groups.

TABLE 4.2.--ANOVA of Accuracy Scores.

Source	SS	df	MS	F	P
A (Hand)	.885	1	.885	2.39	.130
B (Eye)	.862	1	.862	2.33	.135
AB	.130	1	.130	.35	.556
Error	14.828	40	.371		
Total	16.706	43			

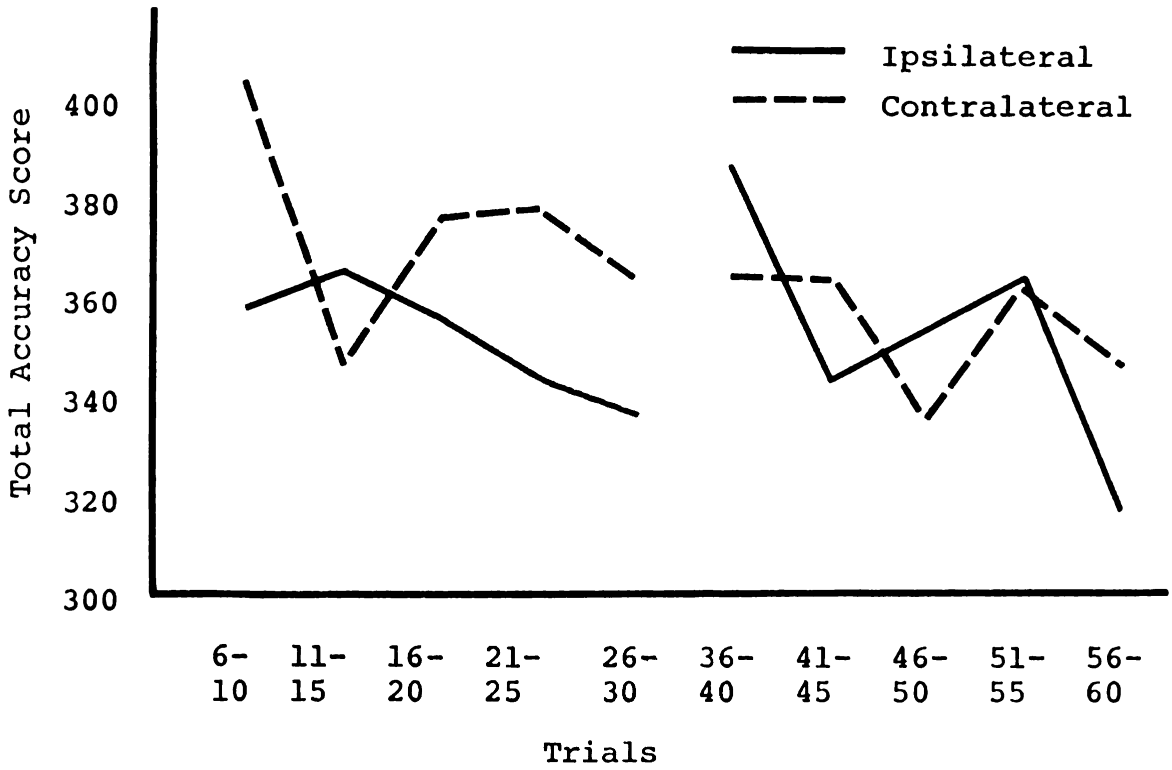

Figure 4.2.--Ipsilateral-Contralateral Accuracy.

R-L Directional Error

The graph of the results of Trials 6-30 (Figure 4.3) indicates that all left-handed subjects threw to the right of target center for the majority of their trials, as shown by their curves in the positive half of the graph. The RH-RE group varied from side to side, but tended to be more positive than negative. The RH-LE group consistently threw to the left of target center, and became more deviant with increasing trials.

The pattern changed somewhat during Trials 36-60 (Figure 4.3). The contralateral groups (RH-LE and LH-RE) continued to throw to the side of the target opposite their throwing hand. That is, the LH-RE group threw to the right half of the target and the RH-LE group threw to the left half of the target. The ipsilateral groups (RH-RE and LH-LE) varied from side to side with an average very close to center. The two ipsilateral groups had curves that were very similar during Trials 46-60.

The ANOVA for R-L directional error (Table 4.3) did not demonstrate the main effects of hand dominance and of eye dominance to be significant factors in the direction in which errors were made. The interaction effect of hand and eye was also not significant. Power for the test was less than .30, which was not sufficient to detect significant differences between laterality groups.

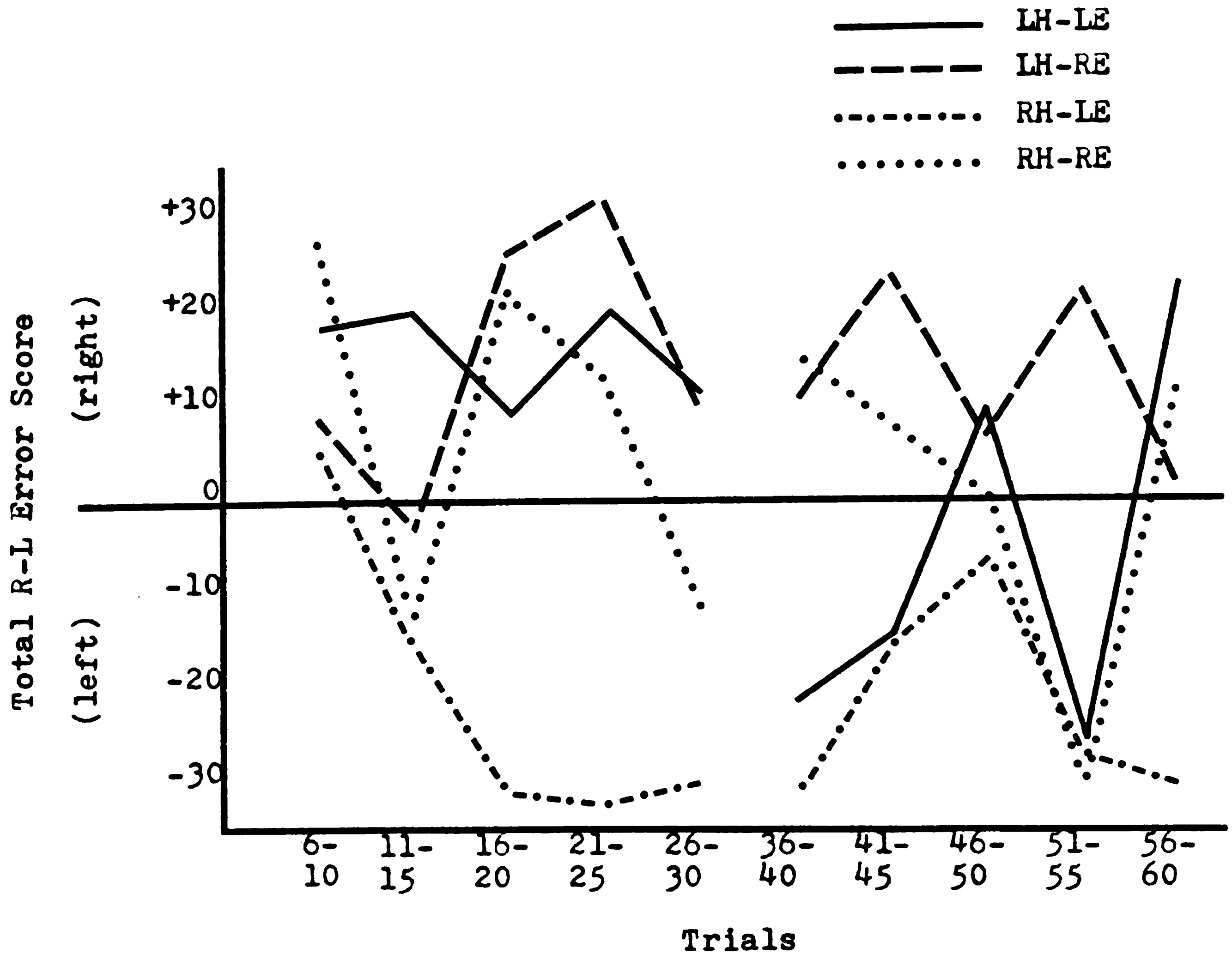

Figure 4.3.--R-L Directional Error by Laterality Groups.

TABLE 4.3.--ANOVA of R-L Directional Error.

Source	SS	df	MS	F	P
A (Hand)	1.146	1	1.146	2.16	.149
B (Eye)	1.107	1	1.107	2.09	.156
AB	.260	1	.260	.49	.488
Error	21.216	40	.530		
Total	23.728	43			

A plot of ipsilateral versus contralateral groups (Figure 4.4) showed the ipsilateral group threw to the right of center and the contralateral group threw predominantly to the left of center in Trials 6-30. The pattern was similar for both groups. This effect, so evident during Trials 6-30, did not recur during Trials 36-60. The tendency of both groups to reverse sides acted to negate the effects of Trials 6-30 in the overall effects for 50 trials.

The means obtained for the four groups confirmed the observed "crossing-over" phenomena of contralateral individuals (LH-RE = -.25; RH-LE = -.39), and the tendency of ipsilateral individuals to deviate equally to the right and left of center (RH-RE = +.08; LH-LE = +.09).

The negative mean for the RH-LE group created a problem for the *a priori* comparisons test due to the algebraic cancellation of contralateral means which acted to obliterate the true situation. Reversion to the use of

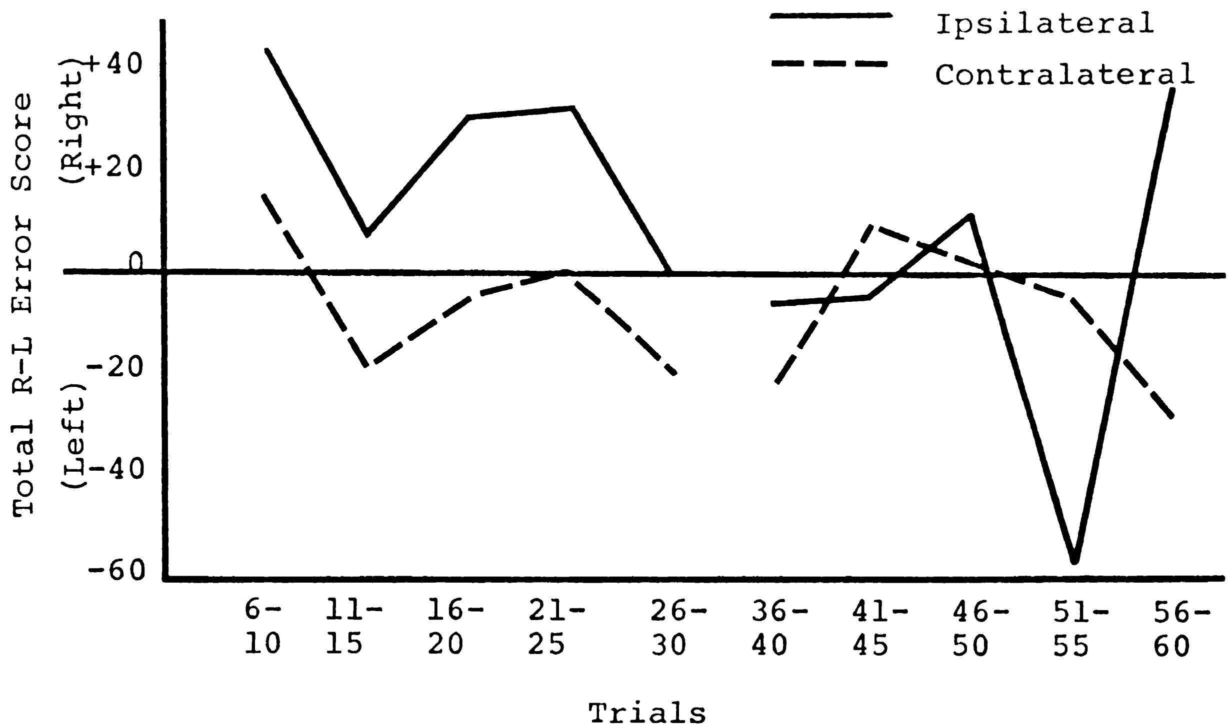

Figure 4.4.--Ipsilateral-Contralateral R-L Error.

absolute scores would result in simply another measure of accuracy and not of directional error. The problem was solved by changing the reference point for deviations from that of the bull's eye to that of the means for handedness (Scale A, Figure 4.5). That is, the new points of reference were the means obtained for all left-handed subjects (+.17) and for all right-handed subjects (-.15). Deviations from these points reflected the influence of eye dominance on the direction of the throw. If the eye tended to correct the error by moving the mean toward zero, the deviation was considered positive. If the influence of eye dominance moved the mean in the other direction (away from zero), the deviation was considered negative. The correction scores thus obtained for each group were: RH-LE = -.24; LH-RE = -.08; RH-RE = +.23; LH-LE = +.08 (Scale B, Figure 4.5).

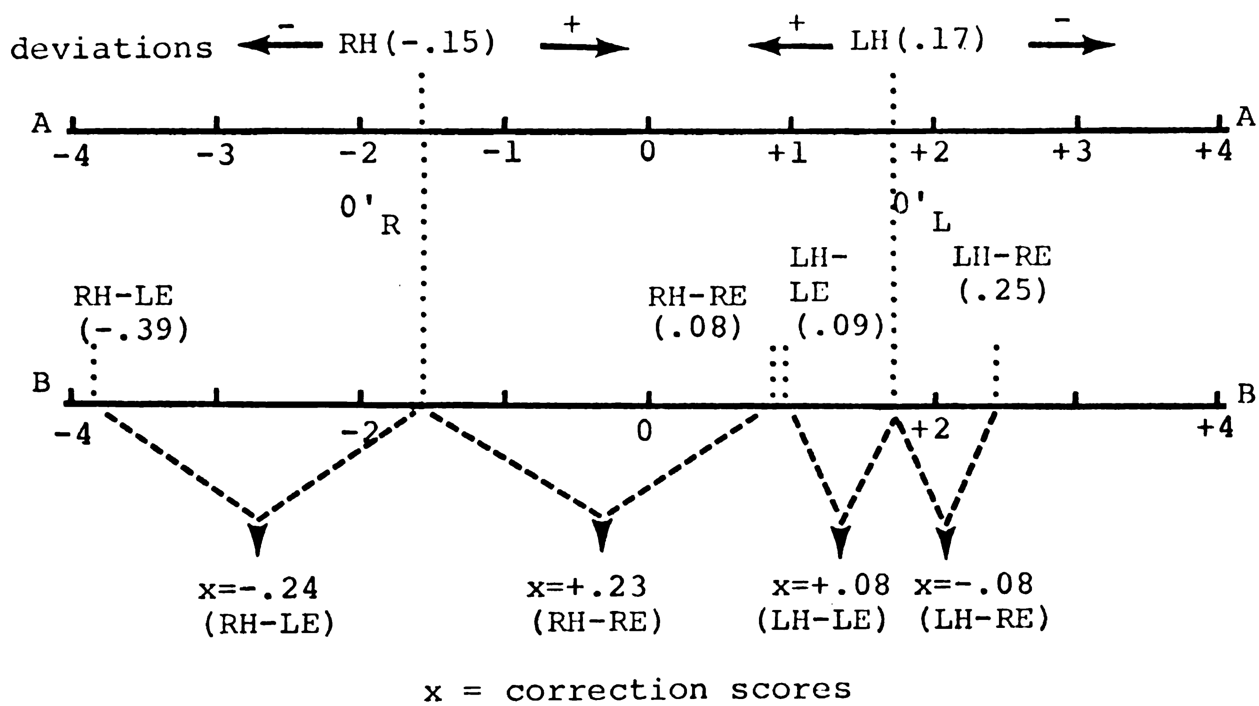

Figure 4.5.--Correction Scores from Means of Handedness.

The *a priori* comparisons test utilized the correction scores to compare ipsilateral and contralateral dominance of hand and eye on the right-left direction of errors. The obtained F = 2.06 was not significant at the .05 level.

A-B Directional Error

All groups threw consistently to the bottom half of the target, as shown by the curves in Figures 4.6 and 4.7. The right-handed groups were least deviant. The obtained means were: RH-LE = -.247; RH-RE = -.315;

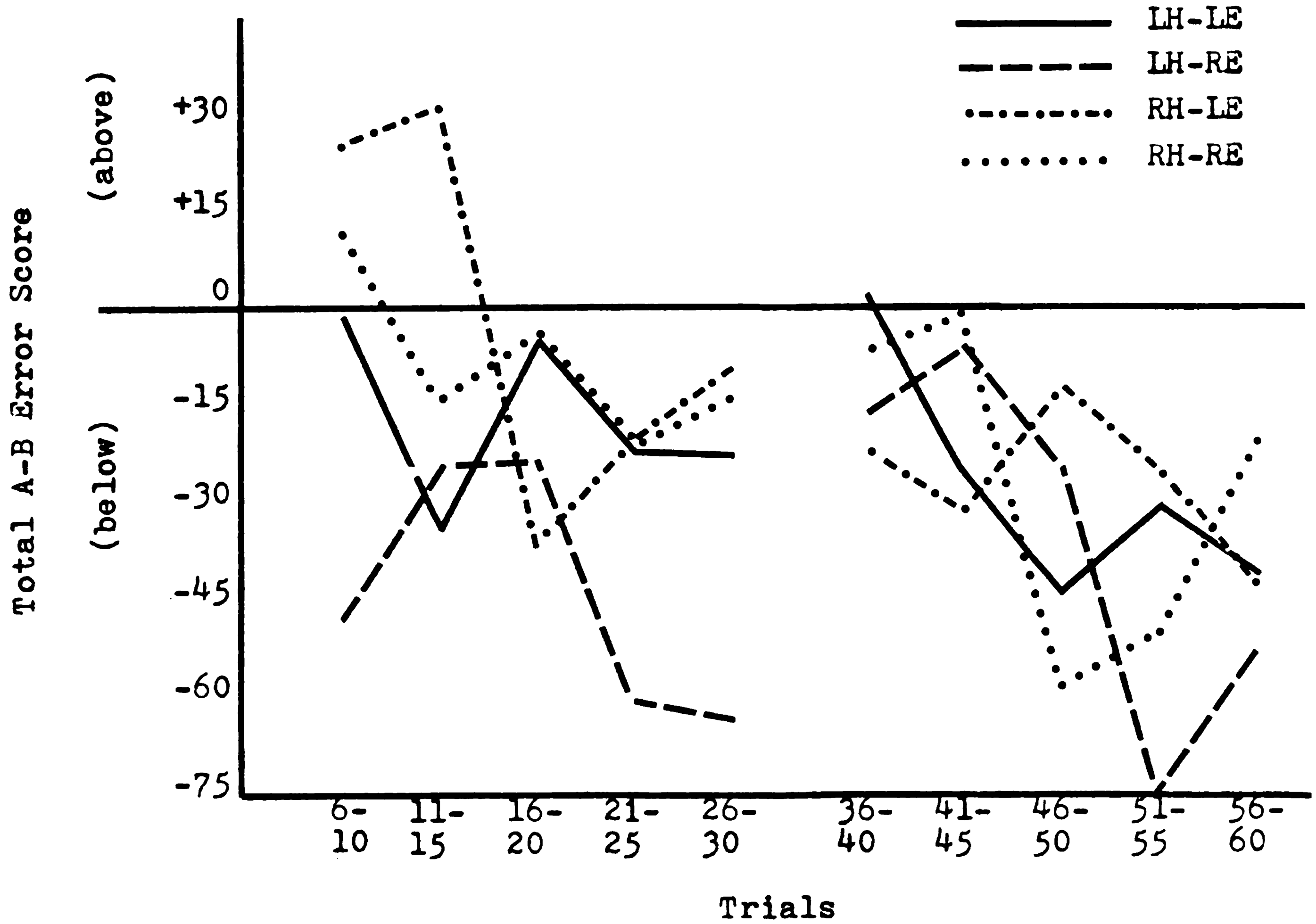

Figure 4.6.--A-B Directional Error by Laterality Groups.

Lh-LE = -.396; LH-RE = -.709. The LH-LE and RH-RE groups tended to have similar patterns during Trials 6-30 (Figure 4.6), but not during Trials 36-60.

The ANOVA (Table 4.4) indicated hand dominance, eye dominance, and the interaction of hand and eye dominance were not significant factors in the direction of errors made in the top and bottom halves of the target. Power of the tests was low, being less than .20 in each case. The a priori comparisons test between ipsilateral and contralateral groups failed to show a significant difference, with F = .36.

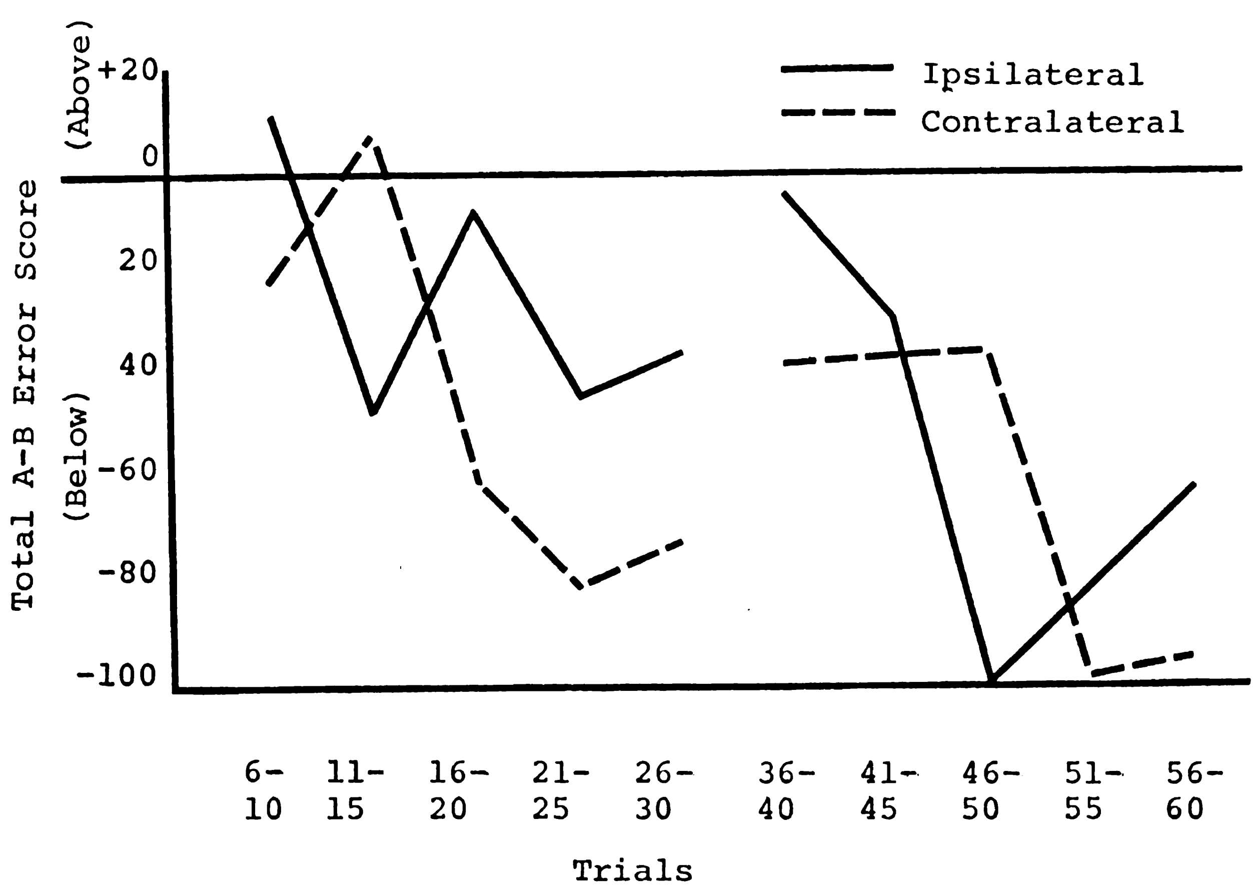

Figure 4.7.--Ipsilateral-Contralateral A-B Error.

TABLE 4.4.--ANOVA of A-B Directional Error.

Source	SS	df	MS	F	P
A (Hand)	.813	1	.813	1.78	.189
B (Eye)	.397	1	.397	.87	.356
AB	.165	1	.165	.36	.550
Error	18.237	40	.456		
Total	19.613	43			

Discussion

The moderate correlation found between accuracy of throwing (as measured using concentric circles) and errors above or below a horizontal line drawn through the target center can be logically explained. Accuracy is essentially a function of the power of the throw, the angle of release, or some combination of these factors. These same factors are involved in errors made above or below target center. A weak throw will drop to the bottom half of the target, especially when weighted darts are used. Likewise, the angle of release is crucial to the A-B direction of the error. Releasing the dart too soon results in a hit above the center of the target, and holding the dart too long results in a downward trajectory and a hit in the bottom half of the target. The negative correlation between accuracy and A-B directional error should be readily apparent, as all groups consistently threw below the bull's eye. As accuracy increased, indicated by a throw close to the bull's eye, the A-B directional error decreased, and vice versa.

The distance of the throw is related to both the A-B direction of errors and the R-L direction of errors. It is related to the A-B direction due to the power factor discussed previously. Distance is, however, deemed more important in the direction of R-L errors than in A-B errors (Moffett, 1942). Any error in the R-L direction of the throw is magnified as the distance traversed by the object increases. Thus, the "crossing-over" phenomena exhibited by the contralateral subjects should become more evident with an increase in throwing distance.

Some rationale for the observed effects of hand and eye dominance on the R-L direction of errors is offered. As noted in scale A of Figure 4.5, left-handed subjects tended to throw to the right of center and right-handed subjects to the left of center. The pectoralis muscles contract to bring the arm and shoulder toward the mid-line of the body. The movement continues until the throwing arm is in line with the dominant eye. If the dominant eye is on the same side of the body as the throwing arm, the mid-line movement (R-L direction) is halted short of the mid-line. This effectively acts to correct the natural cross-body movement for ipsilateral individuals. If the dominant eye is not on the same side of the body as the throwing arm, the mid-line movement (R-L direction) continues across the mid-line to line up with the contralaterally dominant eye. This action accentuates the natural R-L movement of the throwing arm. These results were depicted in scale B of Figure 4.5. The distances involved between the mid-line and the dominant eye are indeed small, but these small R-L directional errors are magnified as distance from the body increases.

The mean R-L directional error for the total sample used in this study was found to be +.01 using the BASTAT program. This was less deviant than the horizontal-directional scores reported by Malina (1968). The tendency in the present study for a mean score to the right of center on the first session and a mean score to the left of center on the second session can also be observed in the data presented by Malina. No explanation for this reversal is attempted at this time.

The investigator was curious concerning the frequency of errors made to the right or left of the bull's eye by groups differing in hand and eye dominance. A 2 x 4 Chi-Square contingency test yielded no significant difference between the four laterality groups in the frequency of errors right and left of target center. However, a comparison of ipsilateral and contralateral groups on frequency of errors to the dominant and non-dominant eye sides of the target was statistically significant at the .05 level. The 2 x 2 Chi-Square contingency test revealed the contralateral group made significantly more errors toward the dominant eye side of the target than toward the non-dominant eye side. The ipsilateral group did not differentiate significantly between dominant and non-dominant eye sides of the target in frequency of errors made. This discovery would tend to support the findings of Shick (1971) who found contralateral subjects made a higher percentage of errors toward the dominant eye side of their body.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of the present investigation was to determine the influence of hand dominance, eye dominance, and combinations of hand and eye dominance on the accuracy of throwing at a target , and on the direction of errors made when throwing at a target. The directions considered were the right and left halves of the target and the upper and lower halves of the target.

Eleven subjects were randomly selected from each of four laterality strata (right-handed and right-eyed; right-handed and left-eyed; left-handed and right-eyed; left-handed and left-eyed) which had been obtained from a population of 238 high school girls at Eastern High School, Lansing, Michigan. They ranged in age from 15 years to 19 years. The mean age was 16.2 years. Approximately 82 percent of the sample were Sophomore girls enrolled in a required physical education program. The remaining 18 percent were Junior or Senior girls enrolled in an elective physical education program.

Each subject was given 30 trials of dart throwing during each of two class periods. The first five throws of each session were allowed for practice and the last 25 throws were scored for accuracy, R-L directional error, and A-B directional error. Darts were thrown in sets of five trials each and scores by sets were used to analyze the data.

Graphs of scores by sets of trials were constructed for each laterality group on accuracy, R-L directional error, and A-B directional error. Patterns were not consistent between the two sessions of dart throwing.

Analysis of variance using scores by sets of trials failed to detect significant differences between laterality groups on accuracy of throwing, R-L direction of errors, or A-B direction of errors. *A priori* comparison tests of ipsilateral and contralateral-dominant groups on the three dependent variables failed to show significant differences between the groups.

Conclusions

The following conclusions were drawn from the data within the limitations of this study:

1. Hand dominance, eye dominance, and combinations of hand and eye dominance failed to be significant influences on the accuracy of throwing at a target.

2. Hand dominance, eye dominance, and combinations of hand and eye dominance failed to significantly influence the direction of throwing errors when errors were measured by magnitude and direction of deviation.
3. Ipsilateral and contralateral dominance of hand and eye failed to be significant factors on the direction in which errors were made or on the accuracy attained when throwing at a target.

Recommendations

Some suggestions for future research on the problem investigated in this study are:

1. Since the power of the test used to analyze the data was low, the study should be repeated using larger sample sizes.
2. A study of errors made following attainment of a higher degree of skill in dart throwing, and of the results obtained when an uninterrupted session of dart throwing is used, would be of interest.
3. The frequency of errors made toward the dominant and non-dominant eye sides of the body by ipsilateral and contralateral

individuals should be investigated. A parallel study might be used to determine the magnitude of the deviations.

APPENDICES

APPENDIX A

PILOT STUDY

PILOT STUDY

The pilot study was conducted in February, 1974, to determine the learning curve of dart throwing and to investigate the correlation between the three dependent variables. A knowledge of the dependency between variables was necessary to make decisions related to the statistical analyses of the main study. Specifically, a determination of which trials should be used to avoid a learning factor was sought; an estimate of the variability of each dependent variable was required to calculate a necessary and suficient sample size for each comparison group to be used in the main study; and an estimate of the dependency existing between the three variables was necessary to evaluate the feasibility of using MANOVA to analyze the main study and to adjust significance levels to accomodate dependence if separate ANOVA's were employed instead of MANOVA.

Twenty available college women were used as subjects (mean age 20.5 years) with five subjects in each of the four laterality groups (RH-RE, RH-LE, LH-RE, LH-LE). Subjects were asked to throw 30 darts in sets of five each during each of two sessions separated by a one week period of time. All 60 throws were scored for X_1

(accuracy), X_2 (R-L directional error), and X_3 (A-B directional error) in the same manner to be used in the main study. Data was analyzed by the BASTAT program of the CDC 6500 computer at the Michigan State University Computer Laboratory.

Results

The obtained means by trials (Table A-1) and the graphing of learning curves (Figure A-1) for each dependent variable both indicated a large improvement in performance occurred between the first and second sets of five trials in each session, with a relative leveling off thereafter. It was decided to allow the first five throws of each session for practice and to score the final 25 throws for the dependent variables.

The standard deviation of each variable for 50 trials (Table A-1) indicated a variability of approximately one-half interval (about 2.25 cm.). Using this information, an estimate of a necessary and sufficient sample size for each group was determined to be n=11.

MANOVA was deemed unfeasible based on the correlation between X_1, X_2, and X_3 for 50 trials (Table A-1). In fact, the correlations of X_2 with X_1 and X_3 were so trivial that R-L directional error could be considered independent of accuracy and A-B directional error.

TABLE A-1.--Pilot Study Statistics.

	Trials	Mean	Standard Deviation	Sign. of the Mean
X_1 Accuracy	1-5	19.20	5.53	.005
	6-30	2.80	.57	.005
	1-30	2.97	.59	.005
	31-35	15.90	4.97	.005
	36-60	2.67	.64	.005
	31-60	2.75	.66	.005
	1-5 + 31-35	3.51	.89	.005
	6-30 + 36-60	2.73	.56	.005
	1-30 + 31-60	2.86	.58	.005
X_2 R-L error	1-5	4.15	8.92	.051
	6-30	.27	.74	.121
	1-30	.36	.79	.054
	31-35	.20	7.27	.903
	36-60	- .13	.53	.281
	31-60	- .10	.60	.448
	1-5 + 31-35	.44	1.43	.190
	6-30 + 36-60	.07	.54	.574
	1-30 + 31-60	.13	.60	.343
X_3 A-B error	1-5	3.15	12.15	.260
	6-30	- .25	.88	.205
	1-30	- .11	1.05	.644
	31-35	- .30	8.19	.872
	36-60	- .44	.66	.008
	31-60	- .38	.66	.020
	1-5 + 31-35	.29	1.66	.452
	6-30 + 36-60	- .35	.68	.034
	1-30 + 31-60	- .24	.78	.180

	Correlations X_1	X_2	X_3	Significance of Regression	
X_1	1.000	.033	- .412	X_1---X_2	P=.892
X_2		1.000	- .115	X_1---X_3	P=.071
X_3			1.000	X_2---X_3	P=.628

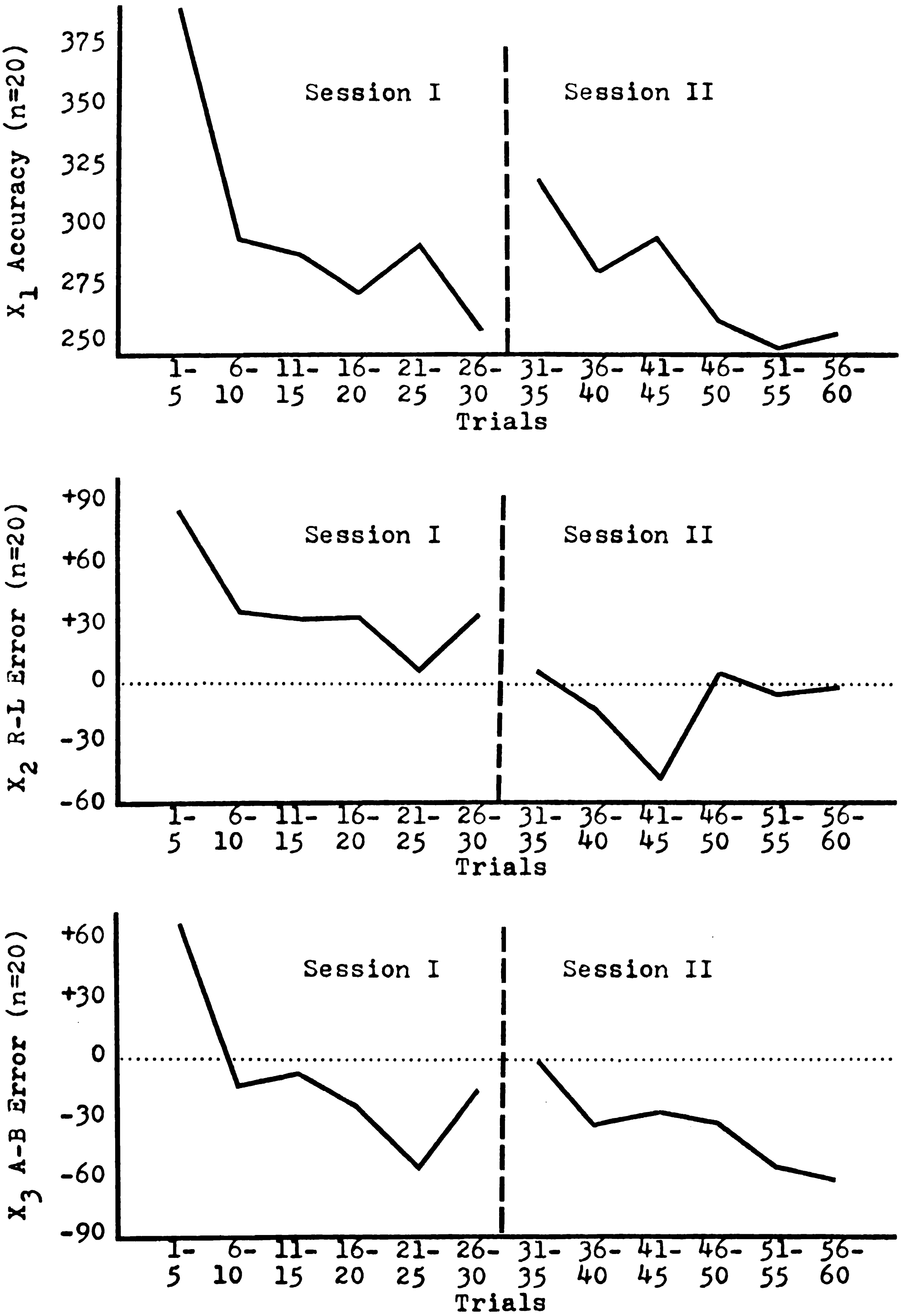

Figure A-1.--Learning Curves for Dart Throwing.

Conclusions

1. Trials 6-30 of the first measurement session and trials 36-60 of the second session would be scored in the main study.
2. An estimated necessary and sufficient sample size for each comparison group would be n=11.
3. Two-way ANOVA would be used to analyze the main study. The significance level for the ANOVA of R-L directional error would be held at the .05 level originally set for the study. The significance level for the ANOVA's on accuracy and A-B directional error would be set at .025 due to the additive effect of the dependency between the two variables, and the desire to hold the overall significance level to .05.

TABLE A-2.--Pilot Study Raw Data.

Trials:	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60
					X_1 (Accuracy) for Group I (RH-RE)							
Subject												
001	14	9	9	15	4	8	9	7	10	10	10	7
002	12	10	10	7	9	13	14	16	19	11	13	8
003	11	11	13	11	13	16	18	10	6	17	9	11
004	16	21	16	13	11	11	16	12	10	10	9	10
005	27	12	12	11	13	14	18	21	12	11	7	11
					X_1 (Accuracy) for Group II (RH-LE)							
Subject												
006	19	10	21	16	18	16	17	15	22	19	14	16
007	20	18	21	12	23	17	19	17	24	15	11	21
008	19	15	14	18	14	13	8	12	14	9	9	13
009	27	17	22	15	14	11	21	18	10	14	18	14
010	15	14	9	9	16	12	18	14	12	10	8	7

TABLE A-2.--Continued.

Trials:	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60
X_1 (Accuracy) for Group III (LH-RE)												
Subject 011	15	16	11	17	16	6	16	9	20	14	16	12
012	21	17	14	14	14	10	13	10	13	11	13	9
013	26	10	14	9	14	13	17	15	15	15	14	11
014	24	15	11	13	11	8	17	12	17	16	13	9
015	24	20	18	21	23	19	21	15	23	23	12	19
X_1 (Accuracy) for Group IV (LH-LE)												
Subject 016	8	15	10	10	11	11	6	7	10	8	7	10
017	22	19	14	14	8	15	7	10	11	10	11	8
018	25	14	19	15	23	21	19	21	13	15	23	17
019	21	17	11	18	19	12	24	15	17	13	16	22
020	18	13	18	13	17	11	20	24	15	9	15	18

TABLE A-2.--Continued.

Trials:	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60
X_2 (R-L directional error) for Group I (RH-RE)												
Subject												
001	-01	00	-04	00	+02	-01	-01	-02	-04	-01	00	+04
002	+01	-01	-03	-03	-04	-03	-07	-05	-04	-04	-01	-05
003	+08	-01	+10	+05	-04	+03	+14	+04	00	+16	+07	+05
004	+12	+08	00	-04	+02	-01	+06	-02	-01	+02	-01	-02
005	+23	+04	+02	+04	-01	+10	+11	+01	00	-05	+02	+01
X_2 (R-L directional error) for Group II (RH-LE)												
Subject												
006	+06	+01	-07	-02	-08	00	-09	-07	-09	+02	-02	-11
007	+04	-01	-09	-03	-08	-07	00	-06	-11	+07	+01	-03
008	+06	-03	-01	00	-07	+04	-01	+08	-08	+01	-03	-04
009	+09	+01	+06	-03	-05	+02	+03	-04	-02	-09	+06	-02
010	+06	+04	-03	+02	+01	00	-07	+07	-06	-02	-01	+03

TABLE A-2.--Continued.

Trials:	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60
X_2 (R-L directional error) for Group III (LH-RE)												
Subject 011	-04	+06	+04	+03	+03	-01	-07	-02	+08	+02	+05	+03
012	-07	-04	+10	+08	+07	+01	-02	-01	+10	-02	+04	+03
013	-14	-04	-01	+01	-04	+05	-03	+02	00	-06	-07	-02
014	-07	-02	+02	-02	-01	+02	-06	00	-03	-03	-01	+02
015	+18	+11	+06	+14	+13	+10	+05	00	-03	-06	-04	+02
X_2 (R-L directional error) for Group IV (LH-LE)												
Subject 016	-03	+01	+01	+03	00	-02	-05	-02	-01	-02	-02	-04
017	+04	+03	+08	+01	+06	-01	+01	+05	00	-01	+02	00
018	+15	+05	+13	+02	-01	+16	+03	-16	-09	+12	00	+09
019	+05	+03	+01	+04	+14	-01	+16	+05	-03	+05	-01	-01
020	+02	+02	-03	+02	00	-03	-07	00	-03	00	-07	-03

TABLE A-2.--Continued.

Trials:	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60
X_3(A-B directional error) for Group I (RH-RE)												
Subject 001	+05	+02	+02	-04	+03	-06	-02	-01	-04	-01	-02	-03
002	-02	+03	-01	-02	-01	+03	-02	-10	+08	-02	-05	-05
003	+05	-07	-01	-05	-05	+04	+06	-06	-05	-01	-03	-01
004	+04	-17	+05	-07	+02	00	-08	+12	+03	+06	+01	+05
005	+23	+09	-02	+03	-01	00	-13	-18	+09	-05	-01	+05
X_3(A-B directional error) for Group II (RH-LE)												
Subject 006	-11	-01	-05	-10	-05	-03	00	-02	-03	+03	-06	-01
007	-05	-12	-09	-06	-10	-05	-12	-04	-15	-03	-03	-12
008	+17	-05	-01	+05	+02	-01	-03	+04	-03	-03	-01	-04
009	+18	+12	+18	+09	+03	+11	+15	+04	00	+11	+10	-04
010	+11	+01	-07	+04	-09	-04	-02	+07	-07	-01	-01	+01

TABLE A-2.--Continued.

Trials:	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60
X_3(A-B directional error) for Group III (LH-RE)												
Subject 011	-02	-09	-05	+01	-03	-05	+01	-02	+02	-07	-11	-04
012	-03	+05	+01	-04	-01	-07	+02	+06	+01	-06	+04	+01
013	+21	+04	+03	-03	+01	+11	+12	-03	+03	+01	+03	+01
014	-11	+08	+06	-04	-03	+01	-02	-07	-14	+08	-09	00
015	-10	-07	-03	-08	-06	+01	-03	00	-02	-13	-05	-12
X_3(A-B directional error) for Group IV (LH-LE)												
Subject 016	+02	-04	-04	-02	-01	-04	00	-03	-03	-05	-03	-02
017	+15	+08	+05	-01	-03	+02	+02	+05	-01	-08	+01	-08
018	-20	-11	-09	-08	-12	-09	+01	-09	+01	-06	-15	-01
019	-07	+06	+03	+07	-06	-10	-14	-02	+04	-08	00	-09
020	+13	-01	-06	+08	-03	+03	+16	-04	-05	+06	-11	-11

APPENDIX B

EYE DOMINANCE TEST

THE HOLE-IN-CARD EYE DOMINANCE TEST

A card 10.1 cm. by 23.0 cm. with a hole in the center of 6 mm. diameter was used to sight objects presented by the investigator at a distance of 10 feet (3.0 meters). Each card presented had a different figure or letter displayed which was large and clear. The object cards measured 12.8 cm. by 20.3 cm.

Instructions to the subject were:

> I am going to test your quickness and sharpness of vision by showing you cards on which there is a letter or figure. I will sit at that desk, and you will sit at this desk. Leave the card with the hole in it on the desk until I tell you to raise it. When I say "ready, up," pick up the card using both hands and hold it about 6 inches (15 cm.) from your face.

The investigator demonstrated, but turned sideways so the subject could not see her face directly, but could see the distance involved.

> Be sure to keep both eyes open. Look through the hole in the center of your card at the card which I will hold up just beneath my chin. I will hold it for one second. When I put my card down, put yours down, and then tell me what you saw on my card, and what color it was. Do you have any questions about what I want you to do?

The investigator recorded the eye seen through the hole for each of the ten trials. To score eyedness, a +1

was given for each right-eye response and a -1 for each left-eye response. A final positive score indicated a right eye dominance or tendency, and a final negative score indicated a left eye dominance or tendency.

APPENDIX C

RAW DATA

TABLE C-1.--Raw Data.

Trials:	6-10	11-15	16-20	21-25	26-30	36-40	41-45	46-50	51-55	56-60
					X_1 (Accuracy) for Group I (RH-RE)					
Subject										
001	8	15	17	13	10	10	18	10	11	16
002	23	13	16	18	16	18	15	16	21	13
003	9	16	12	16	8	9	15	10	11	18
004	12	13	13	10	14	16	12	19	13	14
005	17	17	21	18	18	27	19	15	20	16
006	21	17	13	11	14	17	16	20	15	13
007	17	18	15	14	19	13	14	19	14	9
008	19	22	24	22	20	15	14	13	18	9
009	13	9	18	18	11	25	14	21	10	21
010	16	20	13	21	19	17	16	27	17	22
011	19	10	17	23	15	29	15	14	25	13
					X_1 (Accuracy) for Group II (RH-LE)					
Subject										
012	16	13	20	14	17	13	14	14	17	11
013	21	17	12	13	17	20	13	8	15	15
014	13	15	17	16	15	22	7	17	13	12
015	18	9	10	14	15	12	13	14	13	13
016	22	16	19	24	19	19	21	20	16	19
017	17	11	22	22	17	23	14	16	16	12
018	21	10	15	12	11	12	18	13	8	9
019	21	18	12	16	17	18	15	17	22	14
020	11	13	10	14	10	14	15	18	11	18
021	17	20	16	13	16	15	14	8	12	15
022	14	23	14	12	17	16	14	15	9	8

TABLE C-1.--Continued.

Trials:	6-10	11-15	16-20	21-25	26-30	36-40	41-45	46-50	51-55	56-60
X_1 (Accuracy) for Group III (LH-RE)										
Subject										
023	20	19	15	13	13	15	19	14	18	17
024	11	18	20	11	20	9	20	17	15	18
025	24	13	14	17	19	7	21	21	18	25
026	23	16	20	21	25	18	17	12	14	17
027	13	12	19	26	18	22	20	14	19	17
028	5	10	13	9	10	12	10	10	9	9
029	27	13	18	16	13	19	14	14	14	24
030	25	15	26	27	18	19	24	16	24	20
031	19	18	18	18	18	15	16	15	27	21
032	24	26	29	29	19	29	27	21	33	14
033	23	21	17	21	19	15	17	21	19	18
X_1 (Accuracy) for Group IV (LH-LE)										
Subject										
034	20	14	13	16	16	14	12	7	10	7
035	10	14	21	18	14	11	8	8	8	8
036	20	15	10	22	11	22	12	12	14	12
037	13	20	19	10	16	15	21	16	24	22
038	13	16	13	9	22	11	17	13	18	8
039	28	31	31	18	24	30	27	17	25	21
040	16	18	18	15	20	15	13	21	12	13
041	20	21	10	17	15	19	24	29	26	14
042	16	13	12	7	9	15	10	17	19	19
043	15	18	14	13	9	24	12	16	18	17
044	13	15	16	14	16	14	19	13	14	10

TABLE C-1.--Continued.

Trials:	6-10	11-15	16-20	21-25	26-30	36-40	41-45	46-50	51-55	56-60
X_2 (R-L directional error) for Group I (RH-RE)										
Subject										
001	+03	-01	+08	+03	+04	+02	+10	-01	-02	+03
002	+10	+04	+01	+08	+04	00	-06	+04	+02	00
003	-02	-05	+02	+01	-04	00	+02	-04	-06	+07
004	-02	-02	-02	-07	00	+06	+05	00	+03	+03
005	-01	-03	+02	+03	+08	+09	+01	+03	-05	-04
006	00	+04	+05	+03	-01	00	+01	+02	-05	00
007	-11	-05	-09	+05	-09	-01	-03	-09	-03	-01
008	+16	+11	+15	+09	-05	+08	+05	00	-01	+01
009	+04	-02	+04	+01	-01	-08	-04	+07	00	+01
010	00	-05	+04	-11	-06	-02	-04	+03	-02	+02
011	+09	-08	-08	-02	-01	+01	+02	-03	-11	00
X_2 (R-L directional error) for Group II (RH-LE)										
Subject										
012	+08	-03	+01	-07	-02	+05	-05	+04	-04	-06
013	+07	+12	-01	+08	-04	-05	-08	-02	-05	-01
014	+09	00	-07	-06	-06	-06	+02	-06	00	+01
015	-03	+01	+02	-07	+04	+04	+02	+03	+02	00
016	-11	-04	-08	-05	-04	-04	+04	-04	-01	-06
017	+05	-04	-05	-06	-06	-04	-09	-12	-07	-07
018	+05	00	00	00	+04	00	+01	+06	-01	-02
019	+06	+05	-03	+02	+04	-02	+06	+01	-07	+01
020	+02	+06	+05	+04	00	+03	-06	+13	-02	-05
021	-13	-16	-10	-05	-11	-13	-08	-04	-02	-07
022	-09	-13	-05	-10	-09	-10	+06	-05	00	+02

TABLE C-1.--Continued.

Trials:	6-10	11-15	16-20	21-25	26-30	36-40	41-45	46-50	51-55	56-60
				X_2(R-L directional error) for Group III (LH-RE)						
Subject										
023	+04	-07	-03	+07	+01	+03	00	-01	+02	+01
024	+05	+11	+06	+08	+11	00	+10	+05	+02	+04
025	-10	-01	-02	+03	-03	+02	+01	-02	+07	-06
026	-10	-06	-08	-03	-08	-05	-06	-05	-07	-04
027	-09	-03	-10	+10	-10	-10	+02	-08	+01	00
028	-01	+02	+01	+03	00	+03	+02	-04	+03	+04
029	+02	-05	+08	+04	+08	+03	+07	+06	+03	+03
030	+03	-01	+14	-07	+11	+01	+02	+04	-10	-05
031	+10	+01	+01	+02	+01	-01	-10	-03	+05	00
032	+14	+05	+13	+09	-01	+11	+07	+11	+04	-02
033	+01	+01	+06	-04	00	+03	+09	+04	+12	+07
				X_2(R-L directional error) for Group IV (LH-LE)						
Subject										
034	00	-01	-07	+01	-07	00	-06	00	+01	+02
035	+03	+11	+20	+08	+07	-01	-02	+06	-03	-03
036	-01	-07	-04	+07	+01	-05	-02	+05	-07	-01
037	-03	+09	-03	-01	+01	00	+06	-01	+04	+01
038	-02	-07	-03	+01	-02	-01	-02	-03	-04	+03
039	+05	+04	-09	-06	+07	-02	-14	-09	-10	+04
040	+09	+09	+14	00	+03	-03	+06	+04	+01	+04
041	-10	-15	-04	-03	-04	-07	-08	-06	-16	-03
042	+04	+04	-07	+02	-02	00	+01	+04	+02	00
043	+07	+09	+07	+05	+04	-04	+03	+08	+03	+10
044	+06	+04	+05	+06	+03	+02	+04	+02	+02	+06

TABLE C-1.--Continued.

Trials:	6-10	11-15	16-20	21-25	26-30	36-40	41-45	46-50	51-55	56-60
				X_3(A-B directional error) for Group I (RH-RE)						
Subject										
001	-01	-06	+08	+03	-01	-04	+02	+03	+05	-09
002	+02	-08	00	+01	+02	-01	+07	-07	-04	+03
003	+01	+03	-02	+07	00	-04	-02	-05	00	+10
004	00	+04	-05	+02	+04	-06	-04	-04	+01	-11
005	+07	-03	+05	-07	+04	+07	+04	-01	-13	+02
006	+02	-03	-02	-05	-05	+04	00	-09	-09	-02
007	+02	+09	+01	-02	+05	-03	+01	-12	+02	00
008	+06	+08	+01	-04	-01	-01	-02	00	-12	-01
009	-01	-03	+01	-15	-07	-02	-10	-04	-10	-16
010	-02	-14	-04	-13	-06	-07	-04	-18	-13	-02
011	-04	-01	-06	+12	-08	+11	+07	-01	+04	+06
				X_3(A-B directional error) for Group II (RH-LE)						
Subject										
012	+10	+07	+01	+01	-10	+05	+05	-06	00	-03
013	-01	+01	-03	-08	-09	-03	+02	-01	-06	-08
014	+09	+03	-06	+09	+09	-09	+01	-09	+03	-08
015	-04	+06	00	+05	-05	+07	-04	+12	+02	-04
016	-03	-07	-09	-19	+01	+01	-12	-04	-03	-12
017	+09	+01	-01	-04	-03	+05	-07	-01	-02	+02
018	-04	+01	-02	-07	-03	-04	-10	-02	-07	-04
019	+11	+08	00	+14	+11	-06	+04	+12	-03	+04
020	+05	+05	-08	-02	00	-02	-08	-05	-09	-07
021	-04	+02	-02	-06	-02	-06	-03	-02	+03	00
022	-02	+05	-06	-03	+02	-09	+01	-05	-02	-02

TABLE C-1.--Continued.

Trials:	6-10	11-15	16-20	21-25	26-30	36-40	41-45	46-50	51-55	56-60
X_3(A-B directional error) for Group III (LH-RE)										
Subject										
023	-02	-04	-03	-01	-08	-01	-10	-06	-08	-08
024	00	-09	-14	00	-04	+04	-01	-09	-05	-13
025	-09	+04	+02	-07	-10	+02	+05	-07	00	-10
026	+14	00	+05	-07	-15	-05	+06	00	+04	+02
027	-01	-02	+03	-13	+04	-02	-15	+07	-11	-06
028	-01	+01	-02	-02	-03	00	-02	00	00	00
029	-09	+02	+02	-02	+06	+04	+02	+07	+03	+16
030	-22	-04	-07	-04	-04	-08	+01	-09	-07	-08
031	-05	+10	-01	+02	-03	-03	+09	+02	-13	-10
032	00	-14	-07	-21	-10	-05	-02	-12	-25	-07
033	-12	-08	-01	-05	-16	-02	+02	+03	-13	-09
X_3(A-B directional error) for Group IV (LH-LE)										
Subject										
034	+06	00	+09	-06	+04	-10	+02	-04	+03	-04
035	+07	-07	-03	-03	-08	-04	-01	-03	-06	-06
036	00	-01	+07	-02	00	+13	-05	-04	-02	-07
037	+10	-12	+01	-05	+04	+04	-15	-10	+08	-02
038	+04	+09	+09	+04	+02	+01	+03	+07	+06	00
039	-12	+01	-19	+11	-20	-06	+02	+01	-15	00
040	-12	-07	-06	-07	+08	00	-06	-18	00	-10
041	+04	+02	+02	-04	00	+08	+04	+02	-05	-04
042	-08	-10	+02	-07	-05	+10	-03	-10	-13	-03
043	-01	-06	00	-02	00	-09	-01	-02	-01	+01
044	+01	-02	-07	00	-07	-04	-05	-02	-05	-06

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