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The analysis of these data revealed that there was no statistically significant relationship between the two measures of visual depth perception, nor between visual depth perception as measured by the Howard-Dolman Apparatus and scores on the Dyer Wallboard Test. A small, positive correlation was found between visual depth perception as measured by the Keystone Telebinocular and scores on the Dyer Wallboard Test. These findings seem to indicate that there is

little relationship between factors of visual depth perception and general tennis ability. The lack of correlation between the two measures of visual depth perception appears to indicate that the two instruments used in this study to measure depth perception are measuring either different phenomena, or different factors of the same phenomena, visual depth perception.

The Fisher's "t" test for the significance of difference among small, uncorrelated groups was used to ascertain the difference between high and low groups of visual depth perception as measured by each of the instruments of depth perception and high and low groups of general tennis ability.

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A STUDY OF
THE RELATIONSHIP BETWEEN VISUAL DEPTH PERCEPTION AND GENERAL TENNIS ABILITY

by

Elsa M. Heimerer

A Thesis Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
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Master of Science in Physical Education

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Approved by

Thesis Advisor

APPROVAL SHEET

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Marie Riley

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CHAPTER I

INTRODUCTION

As human beings, we use our eyes to see, our ears to hear, and our hands to touch in order to become acquainted with the external world. By these means we adjust ourselves to the objects and events around us. With our eyes, ears, and hands we play games--we see a chance to run an open field, as in hockey; we hear the signals for the ball snap, as in hall ball; we handle a ball, as in softball. These are just a few of the objects and events that a person must become acquainted with while participating in physical education activities. (10:18).

In order to better understand one's movement behavior, the writer has first turned her attention to the term PERCEPTION. Perception is a broad, general term referring to one's awareness of the presence of objects, qualities, or events in the environment; perception is "the immediate response of the organism to the energy impinging on sense organs." (4:23) Cratty claims

> Perception is a dynamic process, involving more than a response to sensory stimulation. It is a holistic term referring to meanings attached to an

> object, event, or situation occurring within spatial and temporal proximity of the individual. Perception is continuing . . . immediate . . . [as well as] dependent . . . upon the context in which the event occurs and upon past experience. . . . [perception] involves organizing, feeling change, and selecting from among the complexity of events to which humans are continually exposed, so that order may be attached to experience. (8:75)

If perception is a process whereby a person can attach significant meanings to his environmental situation, then there is a relationship between perceptual awareness and environmental situation. It is the function of perception to bring man into contact with the world outside himself through the medium of his senses. (11:34, 9)

Perception and Vision

A basic, scientific problem in studying perception is to identify and understand the principles that govern the awareness of self and of objects, qualities and events in the environment. It is not enough to merely perceive and accept the realness of the world, the objects in it and the events of it; the question of how man perceives or becomes aware of the world and the objects in it must be considered. Perception, per se, is a broad, meaningful term, but too inclusive for consideration here. The writer is more specifically interested in one factor of perception--that of vision for it appears that vision is of utmost importance in sports participation. In human beings the retinal surface of the eye contains over one hundred million separate sensory end-organs; that is more than is contained by any other human sensory organ. Therefore, the visual messages received by the brain are most complex and most important in man's perception of space. Events happening at a distance are represented in the brain via the sight patterns. Since there is a great concentration of nerve endings packed into a very small space, the brain has become dependent on vision and the visual sensations seem to have much easier access to the mind than any other of the sensory patterns. (1:18, 48, 52, 54, 59) It appears that one of the most important functions of perception in man is the reception of symbolic messages, particularly symbolic visual messages. However, Bannister and Blackburn cast some doubt on this idea of the importance of vision in one's ability to participate and succeed in sports.

> A 'GOOD EYE' is usually considered to be all important for proficiency at such games as . . . tennis . . . in which a fast-moving ball has to be hit with speed and precision either by the hand itself or by an instrument held in the hand. But, provided the individual can see, the 'good eye' appears to be quite independent of visual acuity. Many of the best players have an acuity far below normal. In all probability the 'good eye' is not a true eye factor at all. It seems rather to be a very high innate visuo-muscular coordination, which enables the one who possesses it to hit the ball with his racket or bat held so that the planes of the face make a particular angle being determined

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> by the way in which the ball is moving, and it enables him to hit the ball in exactly the right position in space and at the correct speed, with the time judged to an extraordinary degree of nicety. As is well known, all this may be accomplished by a man with very poor (uncorrected) visual acuity. (22:382)

This visuo-muscular factor of movement behavior that Bannister and Blackburn mention is generally referred to as visual perception. Morgan (14) claims that visual perception of objects is learned; but much is probably unlearned due to the fact that our sense organs and nervous system tend to organize or modify perceptions into single patterns of objects.

> . . . all awareness of ourselves and of the world depends upon physical energy in various forms striking sense organs. What our brain receives is various patterns of neural impulses, not copies of various objects. 'We do not perceive the world, we only perceive our senses.' The objects we see . . . are the result of radiant energy in the form of waves reaching the retina of the eye. (14:161, 170)

It is not just the principles of perception that govern the awareness of self, and of objects, qualities, and relationships in the total environment. It is not just the movement of the image as a stimuli impression on the retina of the eye that accounts for the perception of movement. It is also the brain, the eye as well as the other sense organs, and the muscles, which together give man information that aids in visually perceiving the external world.

Visuo-Motor Perception

"Movement is the key to growth and development; to sensory inputs and motor outputs; to sensing, knowing and learning." (45:1) The human body is built for action, for movement. There is a relationship between the eye, the hand, and the brain, hence the term visuo-motor. The development of special combinations of movements, such as the eyes and the hands lay the foundation for eye directed hand movements. As Arnold Gesell stated, "Vision is the dominant factor in human development." (45:2) Through use of the visual mechanism, man can gain information about his world, within and beyond his reach. It is for these reasons that the writer has become interested in visual perception in terms of the child, his growth and developmental patterns, and in relation to motor performance. A child's world of space is developed through his vision, from himself outward and beyond his reach. However, the child must combine the tactual, proprioceptive, auditory, and verbal experiences with the visual experiences in order to assure ultimate visual development. (45:1-4)

Although there is some question of supporting clinical research, the Dolman-Delacato concept of neurological organization as the basis for all learning contends that ". . . if a child's visual mechanism can be made to function effectively, improvements of other functions follow." (21:122) During the first year of life, such basic human behaviors as visually following an object, grasping and manipulating an object with the hands develop in a highly patterned and predictable way. Movement behavior develops in as patterned a way as does the development and growth of the physical structure. The child learns to develop specific eye movement patterns which are necessary for quick, accurate visual inspection of the world. These eye movements then aid in learning to use vision to obtain information about the world without the extraneous motor actions. (45:3) (21:121-122)

Sports and Vision

Most sports require a high degree of visual skill if athletic competency is to be achieved in athletic performance.

> We must not overlook the perceptual aspect of motor learning because the recognition of cues to respond becomes a more and more important part of the learning as we advance into higher levels. If we are to catch or hit a ball, we must perceive it. . . . In throwing, we must perceive when to throw and where. Cue perception, reduction in number of cues necessary to release adapted action, and the speeding up of cue recognition are basic to our progress into higher hierarchies of motor learning in most of our competitive sports. (32:68)

Outside of athletic situations, most visual functions depend on relatively static cues. Differentiation and discrimination primarily depend on foveal acuity. (46:1) In contrast, sports situations require utilization of many cues, such as the many factors involved in distance judgment and peripheral vision.

> Generally, investigations are carried out which compare perceptual-motor activities having highly dissimilar input qualities. For example, a test of static depth perception, involving the slow and deliberate alignment of rods within a tube, [Howard-Dolman Apparatus] is often compared to fencing, basketball, or baseball skill, activities which require the rapid response to objects in space. (8:136)

According to Cratty, these are descriptions comparing qualities which cannot and should not be compared. One's perception of space determines the direction of his behavior as he lives and moves about in space. One learns to relate one object to another geometrically and he learns to relate between objects and himself. Vision is of primary importance in this perceptual process; it is by means of sight that one gains cues with which to compare various objects with each other and with himself in space. (8:135)

Visual-perceptual, hand-eye skills are the basis for many sports activities. "Keeping your eye on the ball" (3:121) is rather a notorious cliche of the physical education profession. Because of the initial problem of selection and use of reliable and valid tests of visual perception, and the difficulty in measuring a relationship of the variables of motor performance and visual performance, there has been limited research done relating visual performance to motor performance or motor performance to visual performance. And there is little evidence to support the idea that visual perception is an important factor in athletic success. The question of a relationship as well as the degree of the visual perceptual factor present in physical activities remains.

Research in visual perception might be of help in understanding the concept of athletic skill as well as providing a basis for deeper investigation into the realm of motor ability.

The writer agrees with the thesis set forth by Griffith:

> . . . that all men do not have to be born with special ability to make use of the whole field of vision. . . . such ability can be acquired and that, as a matter of fact, it is acquired by the few who are know to profit by it. The point is that too much of athletic training is given over to the mechanics and tactics of a game and not enough to the human being who undertakes to play the game. We pay more attention to physical condition and to the development of strength than we do to the development of certain simple mental capacities. There are psychological as well as tactical fundamentals in athletics. (10:32)

The physical mechanics of motor skills are stressed long before importance is placed on the mental aspects of motor performance. Quoting William James that "practice makes perfect" (26:401), it is easily understood why a high degree of visual skill and visual perception is usually found in champion athletes. Griffith continues:

> It ought now to be clear that successful athletic competition depends upon a skillful use of our perceptual apparatus as well as upon strategy, tactics and physical strength. It ought also to be clear that skillful use of the perceptual apparatus is gained in the same way as we gain skill elsewhere, i.e., by long and constant practice. (10:38-39)

There have been a limited number of studies concerning the relationship between visual perception and athletic skills. Because a player must make estimates of distance involving moving objects in many activities in physical education, the writer was particularly interested in studying one facet of man's total perceptual organization--that of visual depth perception.

CHAPTER II

STATEMENT OF THE PROBLEM

It was the purpose of this study to:

1. Determine if there is a relationship between visual depth perception and general tennis ability.

2. Determine if there is a difference in visual depth perception between tennis players of differing levels of ability.

3. Determine if there is a difference in general tennis playing ability of subjects with good and poor visual depth perception.

4. Determine the relationship of two measures of visual depth perception: one test of real depth perception (rod-type test), the Howard-Dolman Apparatus; one test of apparent depth perception (stereograms), the Keystone Ophthalmic Telebinocular.

DEFINITIONS

Ability to Visualize Spatial Relationships: The ability of a performer to see where objects are located as well as to realize their geometrical inter-relationships. This factor may be related to the factor of insight into the nature of the skill as well as the factor of depth perception. (13:7)

<u>Acuity</u>: Monocular vision; the capacity of either eye to recognize small space intervals in the discrimination of form. (49:25)

<u>Accommodation</u>: A kinesthetic cue from the muscles of the eye which contributes to the perception of depth. . . . the adjustment of the lens in each eye to the distance of an object . . . the ciliary muscles . . . enable the lens to focus the visual image on the retina by relaxing and contracting in varying degrees. . . . It is possible that kinesthetic impulses from the ciliary muscle provide a monocular cue to depth . . . [which] can work only for distances up to about twenty feet, for beyond that distance, further accommodation of the eye is negligible. (14:174-175) (12:100)

<u>Binocular</u>: . . . the simultaneous use of the two eyes. (14:666)

<u>Closure</u>: The tendency to fill in gaps in stimulation in order to perceive the whole object, not disjointed parts. (14:169)

<u>Convergence</u>: The combined movement of the two eyes such that light from a single source falls on the two fovea causing the eyes to adjust so that a single, distinct view of the object is seen. At a distance greater than seventy feet, the line of eye sight is parallel. At a near distance, the eyes turn inward, toward each other, so that they may fixate on the object. Thus the eyes converge and since there is kinesthetic information concerning the amount of convergence present, this factor may serve as a cue to the depth response of an object in space. (12:51, 101) (14:174) (11:44)

<u>Coordination</u>: The ability of the performer to perform types of movements quickly and accurately into specific movement patterns. This factor is associated with insight into the nature of the movement, with kinesthetic sense and with a person's perception of relationships. Coordination can be improved through training and practice. (3:546, 120)

<u>Depth Awareness</u>: The perception of depth in visual space due to either a monocular or binocular cue; e.g., stereopsis, peripheral vision, size of objects, interference of one object in view of another, motion in space, shadows, size change for distance. (49:25)

Depth Perception: A factor associated with one's ability to judge the relative distance of objects and of persons from himself. Such judgment is dependent upon several different elements which may be combined into one mental process. (13:6)

Figure-Ground Perception: The ability to distinguish objects or events from their general background; to perceive such objects or events as clearly standing out from a background. (14:167)

Image: The image of an object received on the back of the eyeball varies inversely in size according to the actual distance of the viewed object. That is to say, the farther away an object is, the smaller the size of the image of the viewed object on the retinal wall. (12:101)

Inter-Pupillary Distance: The distance between the eyes. The greater the inter-pupillary distance, the greater the differences in the retinal disparation of the two eyes, with a consequent increase in one's ability to judge the relative distance of objects. (22:382-383)

Judgment Concerning Time, Height, Distance, and Direction: This involves the ability of a performer to judge various relationships of objects and of persons with himself as illustrated in judging a fly ball or judging a pitched ball in batting. This factor is usually associated with depth perception, with the ability to visualize spatial relationships, and with an insight into the nature of the skill. (13:8)

Linear Perspective: The tendency of parallel lines to converge as they extend farther away from the observer. (8:123)

Monocular: Pertaining to the use of only one eye.

Movement: In moving the head, one observes that objects in the visual field appear to move. The objects that are nearest to the person appear to move in the opposite direction while distant objects appear to move in the same direction as movement of the head. (14:173)

Movement Parallax: The apparent speed and extent of movement of objects in the field of vision varies with the distance of the objects from the observer as the observer moves his head or the position of his eyes. Near objects appear to move far and fast; distant objects seem to move little and slowly. This cue seems to be a factor in judging absolute and relative distance. (12:104) (11:84)

Perception: Process whereby the organism relates itself to its surroundings, experiencing objects, activities of objects and relationships between objects. The observer interprets, discriminates, and identifies objects and conditions that are existing in the environment. Perception is concerned with bodily mechanics and is controlled by the stimuli received, by the motivation and the memory of the observer. (4:4-5) (47:53)

Perceptual-Motor: Process which includes both input (sensory or perceptual activities) and output (motor or muscular activities) and these two types of activities cannot be separated because what happens to one area automatically affects the other area. An activity, in totality, includes input, integration, output, and feedback. (47:53)

Perceptual-Speed: A factor involving a person's ability to perceive quickly the nature of a situation and to act appropriately to the situation. The initiation of an act is also dependent upon the performer's insight into the nature of the skill and upon depth perception. (13:7)

Peripheral Vision: Visual sensations which arise from the visual sense cells that lie outside the central foveal area of the retina. (47:53)

Pursuit (Visual): The act of tracking, following, pursuing a target with the eyes. (47:53)

Retinal Disparity: A slightly different view of a solid object is seen when the object is viewed by the two eyes because the two images of the object do not fall on exactly the same part of the fovea of the retina since the two eyes are separated from each other by about two and one-half inches. The object's images are less alike in the two eyes when the object is very close than when it is far away. Because of these differences, the observer gains cues to depth perception. (14:173)

Sensory-Motor Coordination: Involves the motor coordination of the eyes with the head, the hands, and the feet, as in the . . . hitting, the catching, the striking . . . of balls. Probably this factor is combined with other factors of depth perception. (13:7)

Size: The discrimination of distances depends on the size of the retinal image provided by the object. (11:44)

Stereopsis: Depth perception due only to the correlated vision of both eyes. (49:25)

Stereoscopic Vision: Concerns the principles of seeing the third dimension in binocular parallax. Because of the fact that the images of the two eyes are located at different positions, even though their fields of view overlap, and the dissimilarity between the images in the two eyes, the facts of stereoscopy play an important role in the perception of the third dimension. (4:229) And even though each eye receives a slightly different view of the environment, the observer sees the environment not as two different views, but as one single scene with depth. (15:27)

Telebinocular: The trade name for the Keystone Stereoscopic vision-testing and vision-training device. (49:26)

Usable Vision: The visual acuity of either eye with the other eye seeing. (49:26)

Visual: Pertaining to the use of the eyes.

CHAPTER III

REVIEW OF LITERATURE

This study was primarily concerned with the relationship of visual depth perception and general tennis ability.

In tennis there is a demand that one constantly make certain judgments concerning distance and movement.

> Before every stroke at the ball the player must make a judgment as to how fast or how slow to return the ball, a judgment as to where to place it on the court or a judgment as to how much territory his opponent can cover. After skill has been acquired in placing a ball the rest of a tennis game depends upon the skill which a man acquires in outjudging another man's movements, his speed, the distance he can cover while the ball is flying over the net. . . . (10:45)

Perceptual-Motor Activities

Tennis is a sport that demands visual judgment concerning the many situations that arise while playing the game. In tennis, as in many physical education activities, one must make estimates of distance involving moving objects. However, there is the question of how important this eye factor is in the actual execution of certain tennis skills and how important the eye factor is in skillful tennis performance.

The ability of the average person to estimate a distance of an object with his eye is notoriously low. (10:42) It is obvious that depth perception improves as children grow older. But there is still some uncertainty concerning the respective roles of maturation and learning in the development of perception. (14:171) And yet, before a child can pursue certain academic subjects, he must be able to perceive, visually perceive, at a given skill level. (43:1) The basis for much that the child does academically and in physical activity lies in his ability to perceive objects, events, and situations occurring within his environment. It is not unusual for a distinction to be made between input (sensory or perceptual activities) and output (motor or muscular activities). According to the Kephart thesis, such a division of input and output activities is impossible. These two functions occur in a "closed cycle" and so anything that happens in one area affects the other area. According to Kephart, one must think of these two functions as a hyphenated term "input-output" and in like manner of the hyphenated term "perceptual-motor" activities. (12:62)

Factors of Perception

One receives information concerning environmental spatial relationships in various ways. The most direct information is received from kinesthesis or the muscle sense. From the degree of relaxation of tension in his muscles, one can estimate the amount of muscular movement required to make contact with an object. Through this estimation of the amount of movement required, a person can estimate the distance of the object from himself. Through this translation of movement into space, one can obtain knowledge of the distance to an object. (12:91) The muscular, kinesthetic sense contributes to one's perceived depth of the environment not only as a direct cue through eye movements but also because one gains an understanding of distance by walking and moving about in the world. (14:178)

The most direct cue to spatial orientation is movement, for one can estimate how far he had to move and thus determine how far away the object was from him. However, a person can locate an object in space by use of his vision alone, an indirect cue to spatial orientation. Since one cannot always judge distances through direct, overt movement, vision becomes a very important indicator of spatial relationships.

> Vision, however, can give us rapid estimation of space and, if we have learned to use it, accurate estimates which we may substitute for those acquired more slowly through movement. Furthermore, vision can give us numerous estimates at once. We can look at a number of objects and can locate them all in space simultaneously. . . . Vision . . . gives

> us a number of clues which can be used to interpret distance and location in space. (12:98-99)

Vision is a means whereby one can relate to externality at various distances from the body. (4:208)

A concept of space and spatial relationships depends upon one's ability to locate many objects in space simultaneously so as to maintain the relationships between objects themselves and the objects and the observer. (12:110)

It is upon the sense organs and the stimuli that excite these organs that a person's awareness of himself and of the environment around him basically depends. As Johannes Müller, an early nineteenth-century physiologist, said, "'We do not perceive the world, we only perceive our senses.'" (14:161) Objects are seen as a result of radiant energy in the form of waves reaching the retina of the eye. (14:161) ". . . all awareness of ourselves and of the world depends upon physical energy in various forms striking sense organs. What our brain receives is various patterns of neural impulses, not tiny copies of various objects." (14:170)

In understanding visual perception, one must recognize the importance of stereoscopic vision. "Stereoscopic vision underlies all precision of movement and manual skill, as well as giving us the foundation of the accurate comprehension of the external world. . . ." (20:155) For a human being, vision is the dominant mode of perception and stereoscopic vision is the predominant way of seeing all external objects. (20:155)

> . . . depth perception has its basis primarily in the existence of two eyes. The fact of binocular parallax, or stereoscopic vision, is commonly referred to as the main explanation of depth perception. It is usually stated that the binocular cue is supplemented by 'monocular' cues for the perception of distance. . . . It is supposed that these latter signs or indicators of depth are not innate but are learned in the course of experience. . . . (9:417)

Perceptual Development and Performance

Perceptions are a combination of what a person knows the object to be plus his sensory image of the object on the retina. Perceptions of objects correspond more closely to the true object than to the sizes of images on the retina or to the general sensory stimulus. (14:177) This raises the question as to the extent to which perceptions are learned and to which they are inborn. According to Morgan, facts suggest that a person must do a great deal of perceptual learning during the first few years of life. At this time, vision is most developed in the center of the field and little developed in the periphery. There is little or no shape, form, or depth perception and a great deal of distortion. (14:181)

"Some of this perception of objects is a matter of learning . . . but much of it is probably an unlearned property of our sense organs and nervous system. These structures tend to organize or modify our perceptions into simple patterns or objects." (14:165) In partial disagreement, Kephart talks of "games of experience" in which one perfects the sensory-motor process and learns to match sensory data to motor data by the manipulation of things and of his own body in relation to things. One must learn to make a sensory impression the basis for an appropriate motor response. (12:13) Bartley also considers the influence of experience on perceptions:

> . . . all observers do not see alike. . . . the observer brings something to the occasion. Sometimes this is labeled past experience, . . . set, . . . attitude . . .knowledge of the situation. . . . they all indicate that the observer is not a fully neural or passive system that is acted upon from without. Certain predispositions of the observer have to be taken into account here as in every case in dealing with perception. (4:179)

According to Vernon:

> . . . there seems to be little doubt that in all familiar spatial settings the observer's previous knowledge as to the nature of the spatial surroundings exerts a considerable influence upon the spatial relationships which he actually perceives. (18:85)

Another important factor of athletic performance concerns the coordination of the eyes with the feet, hands, or head. Many sports skills involve a ball; the performer must keep his eye on the ball in order that he might judge such variable factors as speed, distance, direction, and size. The "keeping your eye on the ball" factor is closely related to depth perception, kinesthetic sense, insight into learning, agility, and relaxation. Skills involving coordination of the eyes with the hands include activities involving hitting, batting, catching, fielding, and throwing. In such activities the performer must accurately judge the speed and direction of an object and be able to adjust his body and body parts in relation to the object. (3:121) In considering eye-hand coordination,

> Johannes Lange pointed out that the hand plays the part of a tool which connects our 'personal space' with the 'space around us.' . . . the acquisition of skill implies the establishment of new levels of relations between personal and extra-personal space. . . . (31:14)

According to Kephart's closed-cycle theory, an organism's input-output functions work together in perceptual-motor activities as one process. The motor part of an activity cannot truly be separated from the perceptual part of an activity. (28:130)

According to McCloy in his studies of motor educability, two of the ten factors considered important in motor learning were "good vision" and "peripheral vision." In addition three of the less important factors of motor educability pertained to vision:

1. sensory motor coordination of eyes with head, hand, and foot.
2. judgment of relationship of subject to external objects.
3. ability to visualize spatial relationships. (33:28-39)

It is very probable that many sport skills involve the factor of depth perception. The ability to field a fly ball, to catch a pass, to hit a thrown ball are just a few of the many situations in athletic participation which seem to be related to depth perception. (13:236) However, distance judgments of objects projected against the sky are much more difficult and less reliable than if the objects were located at a distance on the ground. (6:271)

Through space and spatial relationships a person observes the relationship between objects in the environment. One can only observe relationships between objects insofar as he can locate them in space and observe them in a spatial relationship within the environment. In order to compare two objects, a person must have an adequate space in which to put them while he makes comparisons. (12:93)

Literature Related to Depth Perception

The factor of visual perception considered in this study was depth perception. Armstrong defines depth perception as ". . . the ability to appreciate or discriminate the third dimension, to judge distance, and to orient oneself in relation to other objects within the visual field." (2:71) The common characteristic of depth phenomena is reported by Braunstein:

> A visual pattern, which when stationary is reported to appear two-dimensional by most observers, is transformed in some manner, and upon viewing this transformation at least some observers report seeing a form moving in other than the frontal plane, seeing a three-dimensional object in motion, or seeing a three-dimensional scene. (23:422)

In athletic activities, one is concerned with the depth perception of moving objects. In measuring the relationship between motor performance and visual function, neither visual factors nor variables of motor performance are easily broken down into specific measurable functions. It is difficult to find adequate instruments to measure visual perceptual abilities. In sports activities one is concerned with depth perception of moving objects. Wyburn suggests, "Different mechanisms may underlie static and dynamic visual acuity, and an individual's static acuity is no guide to his dynamic acuity." (20:233) Also, in testing depth perception, it is important that only those factors be considered which are inherent in the individual and which operate at a distance greater than twenty feet. (2:77)

Measurements of Visual Depth Perception

The Howard-Dolman Apparatus is frequently used as the measuring device in a study of depth perception. This apparatus was first adapted from a piece of equipment used by Brooksbank James of England in 1908. An adaptation of this original apparatus, developed by Captain Henry J. Howard in 1919, replaced the stereoscopic tests used in the classification of aviation applicants. Howard developed the test as one of binocular parallax because he believed this to be a pure visual factor uninfluenced by experience. According to Howard's findings, a depth perception of 20-30 mm. was the distinguishing point between normal and abnormal perception. (29:659, 668) In the depth perception apparatus developed by Howard, the rods were manipulated by an operator. In a more recent adaptation of the Howard-Dolman Apparatus, the subject himself aligns the two rods by manipulating two strings. According to Armstrong, a depth perception of 30 mm. on this adapted apparatus should be the distinguishing line between normal and abnormal depth perception. (2:78)

The Howard-Dolman Apparatus is a traditional test of depth perception. Since the objects compared are two vertical rods, this apparatus is often referred to as a "rod" test. (36:379)

Stereoscopic vision serves as a basis for many spatial discriminations. (11:44) In using a stereoscope, a person perceives depth with the stereoscopic object. This depth is termed "relative" distance and is partly accounted for by the binocular effect. A person also sees "absolute" distance; i.e., he sees the object located at a certain distance in front of the head. This "absolute" distance is accounted for by the factors of accommodation and convergence. (6:220)

Tests have been devised, on the same basis as the stereoscope, to determine the accuracy of a person's ability to judge the distance of an object. This type of test is often referred to as a "depth test" in visual examinations using the Keystone Telebinocular. In looking at a picture through a stereoscope, the addition of the stereoscopic clues makes surfaces and elements of figures stand out sharply in depth. Also the consciousness of three dimensions in space is greatly increased. (12:103-104)

The Keystone Telebinocular tests the usable vision of each eye, placing importance on the factor of binocularity, with the two eyes working together. The Keystone Visual Survey Tests consist of many different stereographic card tests of which depth perception (stereopsis) is one test. (7:69)

Studies Relating Factors of Vision to Depth Perception

Attempts to relate visual depth perception to sport skills have produced varying statistical evidence. A study concerning the relationship between depth perception and inter-pupillary distance was conducted by Bannister and Blackburn. (22) They measured the inter-pupillary distance of 258 undergraduate students at Cambridge and compared the measurements with the students' athletic proficiency at ball games. The results showed that those with greater inter-pupillary distances on the whole were better players in sports activities involving batting and throwing balls. "This is probably due to the better stereoscopic vision which the greater width makes possible." (22:384) On the basis of this study, Clark and Warren (24) studied the effect of inter-pupillary distance on depth perception. They used the Howard-Dolman Apparatus for measuring depth perception and an interpupillary distance gauge for measuring inter-pupillary distance. They compared the scores for athletes with the scores for an unselected group of men. Clark and Warren found that there was no significant relationship between inter-pupillary distance and depth perception. They found that the depth perception of the group of athletes was not significantly superior to that of the unselected group of men. They further concluded:

> Either depth perception as measured by the [Howard-Dolman Apparatus] test is relatively unimportant in ball games of the nature of those included, or the test does not give an accurate measure of depth perception. In either event, the application of the results of this test to practical situations may be seriously questioned. (24:487)

Studies Relating Visual Perception to Athletic Performance

Olsen (34) studied the relationship of psychological capacities and success in college athletics to determine if there were significant differences in reaction time, depth perception, and visual span of apprehension between groups of varsity athletes, intermediate athletes, and non-athletes at the college level. The Howard-Dolman Apparatus was used to measure the depth perception of the three groups of college men. Reliability of the depth perception tests was +0.893. The results of this study showed that the athletes, varsity and intermediate, had better depth perception than the non-athletes. Significant differences were not found, however, between varsity athletes and intermediate athletes in depth perception.

Olsen also determined the relationship between the athletes' depth perception scores and their sports skill score in soccer, baseball, and hockey. There were twenty-one varsity soccer players who were tested on four skills: distance kicks, obstacle dribble, placement accuracy kick, and goal kick for accuracy. The correlation between their skills score and their depth perception score was -0.184.

Thirteen varsity baseball players were tested on four items: accuracy throw, distance throw, base running speed, and seasonal batting average. The correlation between their skills score and depth perception score was -0.075.

When scores of the twenty-six varsity hockey players whose athletic skill was determined by the average number of goals and assists made per game were correlated with depth perception, the resulting correlation coefficient was -0.172.

Russian studies, reported by Graybiel, Jokl, and Trapp (27), measuring the effect of visual functions of heterophoria, accommodation, and depth perception on selected motor skills show a more positive correlation between depth perception scores and sports skills than those found by Olsen. In studying depth perception, a device similar to the Howard-Dolman Apparatus was used in which strings moved a mobile rod along side a stationary rod; only the center portions of both rods were visible to the subjects. Thirty tennis players were found to have considerably better depth perception than one-hundred twenty-two football players. A correlation was found between athletic efficiency of the tennis and soccer players and their depth perception scores. Sportsmen did much better in depth perception scores than untrained subjects. The conclusion of this study was that as a group the more skillful players perceived depth more accurately.

Winograd (37) studied the relationship of timing and vision to be successful hitting in baseball. Vision was tested on the Keystone Ophthalmic Telebinocular and DB Series of Slides. He used four groups of subjects: high school players, varsity athletes, rejected baseball candidates, and non-athletes. He found that differences in stereopsis were distinguished between varsity baseball players and non-athletes. He noted that the superiority of the athlete to the non-athlete showed up not only in degree, but also in variety of eye functions. Since some varsity baseball players had poor vision, his evidence supports the idea that clarity of vision within the normal range does not necessarily differentiate athletes from non-athletes. He further suggested that

> . . . other forms of compensation [in batting performance]; i.e., muscular strength,

> correct stance, form, and proper mental attitude are probably developed to a greater degree in compensation for visual inferiority. (37:493)

Studies Related to Perceptual-Motor Learning

In a study by Fleishman (25) concerning the role of kinesthetic and spatial-visual abilities in perceptual-motor learning, results showed that depth perception makes learning a sport skill easier in the early stages of learning.

> It would seem that initially, exteroceptive cues (spatial-visual) provide information which guides Ss' movements. . . . Once a given level of proficiency is reached and errors tend to be smaller, spatial cues are not as effective. . . . The Ss high in spatial ability have an advantage only in the earlier stages of learning. . . . (25:11)

Perhaps such an "advantage" is the factor that determines who will become a successful, skilled performer.

Mail (38) was concerned with the influence which depth perception might have in the beginning stages of skill learning. She questioned the possibility of a relationship existing between a person's choice of preferred activity and his ability to perceive depth or visual space. She tested forty-one subjects, who had had one term of tennis instruction, on the Dyer Tennis Test and four tests of binocular depth perception. The depth perception scores were correlated with the tennis skill test score. The four tests of depth perception were two apparent visual depth perception tests: the

Keystone View Ophthalmic Telebinocular and the Titmus Stereo Circles Test; and two real visual depth perception tests: the Modified Howard-Dolman Apparatus and the American Automobile Association Distance Judgment Test. Mail found that these depth perception tests were not highly related, that the tests of simulated depth perception measured more of the same aspects of perception than did the tests of real depth perception.

> When tested, many students in these classes scored below the average or expected level on more than one test of vision. Three subjects . . . who were unable to fuse disparate images on the Telebinocular and Stereo Circles Test remarked that they rarely saw a tennis ball until it was very close to them. This suggests that a student who evidences trouble in learning a new ball-handling skill may have a vision problem which has not manifested itself in reading diagnosis, but which handicaps her on the court or field. (38:49)

Ross (41) studied the relationship of eye-hand coordination and visual perception in elementary school children. She used the Keystone Telebinocular visual tests and developed four eye-hand coordination tests: ball bounce test, wall pass test, target toss test, and ring toss test. From her results it was evident that visual skills and motor skills of children in the elementary grades tested were still in a developmental process. However, she did find positive correlations between eye-hand coordination and visual perception, which indicate that what a child did in the motor skill test was partly dependent on the child's visual skill.

Studies Relating Effect of Sport Skills to Visual Function

Hubbard (30) studied the movement of the eyes in a batting situation in order to determine the visual basis for tracking a pitched ball in terms of head-eye movements. Electromyography, cinematography, analysis of published photographs, and observation of players under game situations were used to study the visual-perceptual basis for batters tracking pitched balls. He found that when a batter tracked a pitched ball with a head movement, he did not swing at the ball; if the batter did swing, movements of the eyes provided the primary basis for tracking. He also concluded that the ball was not tracked to the time of contact but that perceptual integration of sensory stimulation made it feel so.

Tussing (35) studied the effects of football and basketball practice on visual function. He used the Keystone Telebinocular to test visual functions. Evidence from his testing suggests that practice in basketball and football does not cause impairment of a player's vision. He found that in basketball, visual acuity is improved, especially in the non-dominant eye, perhaps because the eyes are used more in basketball than in football. He also concluded that vision of the "100 percent" type was not necessary for either basketball or football performance.

Griffith has said, "it ought to be clear that skillful use of the perceptual apparatus is gained in the same way as we gain skill elsewhere, i.e., by long and constant practice." (10:38) In addition he states:

> In tennis there is a constant play and interplay of judgements [sic.] as to distance and movement. After skill has been acquired . . . the rest of a tennis game depends upon the skill which a man acquires in out-judging another man's movements, his speed, the distance he can cover. . . . (10:45)

Miller (39) explored the relationship between sports skill and the ability to perceive, analyze, interpret, and react to visual cues as measured by selected tests which involved visual perception. Part of this study was concerned with the factor of depth perception, which was measured by the Keystone Telebinocular Multi-Stereo Professional Performance Tests. The results of this study demonstrated that skillful players were better able to perceive depth than low-skilled athletes. She agreed with Olsen (34) that the ability to perceive depth is of no significant difference between champion performers and near-champion performers.

Miller further hypothesized that developing visual-perceptual abilities might be specific to the nature of the activity and the demands of the activity on the performer.

> Those concerned with the teaching of sport skills should seek methods of improving such visual-perceptual skills as the ability to judge distance, to make perceptual closures. . ., [and] to make quick and adaptive choices from the visual cues in space. In other words, train vision to take place from the general to the specific. . . . Certainly sports involve a concept of larger movements and larger spaces than do those vocations for which the traditional tests of spatial visualization have been designed. (39:175-176)

In conclusion, from the studies reviewed, the writer notes that the results of testing to determine the relationship between visual perception and sports skills vary greatly. In general, it can be said that some definite relationship does appear to exist between athletic success and visual depth perception, with athletes having better depth perception than non-athletes, but no differentiation between skilled athletes and near-skilled athletes in the factor of depth perception.

CHAPTER IV

PROCEDURE

It was the purpose of this study to determine the degree of relationship between visual depth perception and general tennis ability. The writer was also interested in determining if there were a difference in visual depth perception between tennis players of differing levels of ability as well as seeing if there were a difference in the tennis playing ability of subjects with good and poor depth perception. This study also involved determination of the relationship between two measures of visual depth perception: one test of real depth perception (rod-type test), the Howard-Dolman Apparatus; one test of apparent depth perception (stereograms), the Keystone Ophthalmic Telebinocular.

Selection of Subjects

Thirty-six women students who were enrolled in intermediate tennis classes or were members of the women's tennis club at the University of North Carolina at Greensboro during the second semester of the academic year 1967-1968 were purposively selected as subjects for this study. The writer met with the two intermediate tennis classes during the second week of classes in the spring semester and explained the purpose of this research study and outlined the procedure for the administration of the tennis skill test and the depth perception tests. The writer also met with members of the women's tennis club of the University of North Carolina to explain the purpose of this study and outline the testing procedures. Each student who volunteered to participate in the study was asked to complete information on a 4 x 6 index card, which was then used as a score card for the Dyer Wallboard Tennis Test. A sample of this score card may be found in the Appendix. From stated information from members of the classes and the tennis club, it was determined that all of the students who were selected as subjects for this study had had experience in beginning tennis classes or had had some recreation or class tennis experience. The writer chose to term these subjects tennis players of intermediate tennis playing ability. At the time of the initial meeting of the writer with the two intermediate tennis classes and the women's tennis club, each subject was given the Scott-French Revision of the Dyer Wallboard Test (3:322-324) and her scores were recorded on the score card. Each subject was then scheduled for an individual appointment to be tested on the two instruments used in this study as measures of visual depth perception.

Selection of Testing Equipment

For the purpose of this study, two measures of visual depth perception were selected: one test of real depth perception (rod-type test), the Howard-Dolman Apparatus; one test of apparent depth perception (stereograms), the Keystone Ophthalmic Telebinocular Tests.

The Howard-Dolman Apparatus, which is a traditional measure of depth perception, is called a "rod" test because the objects compared are two vertical rods. The Howard-Dolman Apparatus tests the ability of a person to use the binocular parallactic angle in judging depth. (36:379) This apparatus is a black box with only three sides: front, back, and bottom. It is 24 1/2 inches long and 11 1/2 inches wide. On the inside of the back panel of this box-type apparatus is a white piece of paper which aids in the reflection of light. On the front panel there is a rectangular opening, 7 1/2 inches by 3 inches, through which an individual can view the two black vertical rods; the two rods are 1/4 inch apart laterally. One of the black vertical rods is mounted stationary at the center of the floor of the box; the other black vertical rod can be moved forward and back, by means of the manipulation of two strings held in the subject's hands, along a track that is parallel to the mounted stationary rod. A small millimeter scale is marked off on the floor of the box to measure the horizontal distance between the two rods. The movable rod is placed at various set distances off center and the subject attempts, by means of the strings, to place it as nearly as she can judge opposite the stationary rod or such that both rods are equidistant from her. The result of each attempt is read directly off the millimeter scale, the results of all the trials averaged, and the average depth perception score recorded. (2:77)

Tomlin (42) reported a reliability coefficient for the Howard-Dolman Apparatus at a distance of 10 feet as .82, with the theoretical application of the Spearman-Brown Prophesy Formula. Tomlin claimed that the Howard-Dolman Apparatus at a distance of 10 feet and the use of six trials proved to be sufficiently reliable.

The Keystone Ophthalmic Telebinocular, a test of apparent depth perception using stereograms, was also chosen as an instrument in this study for measuring depth perception. The Keystone Visual Survey Tests consist of stereographic card tests which provide information on an individual's visual efficiency covering a wide field of functional aspects of vision. In using these tests, the usable vision of each eye is tested while the other eye is open and seeing, placing importance on binocularity, with the two eyes working together. (7:69) The cards testing depth perception (stereopsis) in this survey were chosen by the writer to be used in this study.

Stereopsis is the clue to distance or depth that is manipulated in stereo photographs. (12:103) In using a stereoscope, an individual perceives depth within the stereoscopic object. This depth perception is termed relative distance; it is accounted for in part by the binocular factor. However, the individual also sees the object located at a certain distance in front of the head. This distance is termed absolute distance and is based not upon binocular disparity but upon the factors of accommodation and convergence. (6:220) When an individual sees an object, the retinal image in the left eye is different from the retinal image in the right eye. This difference in retinal images serves as the basis for many visual discriminations, such as distance discrimination. (11:44) Stereopsis is an important clue to depth perception and to relative location in space. Looking through a stereoscope, the difference which the addition of this clue makes in viewing a stereo-picture is quite distinct. The surfaces and elements of objects sharply stand out in depth and the consciousness of three dimensions in space is greatly enhanced. The Keystone Visual Survey Tests have been designed on the same basis as the stereoscope or depth photographs to determine the accuracy of an individual's ability to interpret stereopsis, the displacement of images between the two eyes, as a clue to the distance of an object. (12: 103-104)

The Keystone Visual Survey Tests are given with both eyes open and are therefore termed tests of "usable binocular vision". This is an important factor for this is the manner in which the eyes are used in an environmental situation. (49:1) Most people with two eyes rely on stereopsis for judging distance. And it is the factor of stereopsis, which is accomplished by a triangular process of the two eyes, that is particularly valuable in judging the placement of two objects in a new situation. It is a known fact, however, that some individuals have the ability to judge distance in other ways, such as by size clues, placement clues, and by reference to other objects whose distance is known. (48)

For the purpose of this study, the writer selected eighteen test cards for use with the Keystone Telebinocular instrument. (See Appendix for series and identification numbers of cards.) Three cards testing usable vision of both eyes, the right eye, and the left eye were selected for the purpose of having the subject become familiar with the Keystone Telebinocular Apparatus. The remaining cards were chosen to measure the ability of the subject to judge distance solely by the use of binocular stereopsis vision. (48) All tests were given at the Far Point setting on the Keystone Telebinocular. "Far Point" is the equivalent of an actual distance of twenty feet. When the cardholder is moved all the way out to the stop, the card exposed is at "Far Point". (49:6)

For the purpose of this study, the writer chose the Scott-French Revision of the Dyer Wallboard Test, a backboard volleying test, as a measure of general tennis ability. The purpose of this test is to measure the subject's ability to rally a tennis ball as rapidly as possible against a backboard using forehand and backhand strokes. (7:328) A validity coefficient of .61 with subjective ratings as the criterion has been reported by Scott and French; a reliability coefficient of .80 computed on the performance of college women has also been reported. (3:323)

Test Administration

With the assistance of four physical education graduate students trained in the method of scoring the Scott-French Revision of the Dyer Wallboard Test, each of the two intermediate tennis classes was tested on the Dyer Wallboard Test during one class period. The subjects who were members of the women's tennis club were tested during a regularly scheduled practice period. Before the testing began, the writer explained and demonstrated the testing procedure to the class. The class was then grouped into four squads and each squad reported to a testing station. One subject in each of the four squads was tested at one time with the writer acting as the central timer, and one graduate student acting as scorer at each of the stations. Each subject was given three thirty-second trials. The number of legal hits for each trial was recorded by the graduate student scorer. The subject's score for the Dyer Wallboard Test was the total number of legal hits for all three trials. (3:324)

Each subject was scheduled for an individual appointment to be tested on the depth perception apparatus in room 56 of Coleman Gymnasium at the University of North Carolina at Greensboro. Each subject who normally wore glasses for distance vision wore her glasses for this testing session as well as for the Dyer Wallboard Test. During this testing period each subject was first tested on the Keystone Telebinocular and then on the Howard-Dolman Apparatus. The administration of these tests of visual depth perception took approximately twenty minutes. The tests were administered in a quiet room. During the administration of the tests on the Keystone Telebinocular, the lighting in the room was dimmed and brilliant sunlight excluded, as was suggested in the manual of instructions. Only the writer, who was the examiner, and the subject were in the room during the testing session.

To begin testing on the Keystone Telebinocular instrument, the subject was seated in a desk chair in front of the table where the instrument was placed. Adjustments were made on the instrument by the writer so that the subject's back and head were erect, shoulders level but relaxed, and feet comfortably on the floor or rung of the chair. After a comfortable and correct posture had been attained, the subject was asked to maintain this posture during the testing period. The subject was reminded to keep her head against the head rest on the instrument and to hold her head still and level.

The instructions for administering the card tests for the Keystone Telebinocular instrument were then given orally to the subject and her score was recorded on the score sheet. Instructions for these tests and a sample score sheet may be found in the Appendix. The writer began the testing on the Keystone Telebinocular instrument with the cards testing usable vision in order that the subject would become familiar with the instrument and the testing procedure. The Multi-Stereo Test Cards and the Multi-Stereo Repeat Tests were administered as the stereopsis tests. These stereograms form a series in which the differences in linear separation decrease, making more and more difficult the identification of that rod which is supposed to stand out. Card A of this Multi-Stereo Test Series measured stereopsis from 3 to 25 percentage. The remaining cards were of the Multi-Stereo Repeat Test Series, measuring stereopsis from 45 to 100 percentage. The writer chose this latter card series because each individual card was a test for stereopsis at a specific level of percentage and required ten judgments by the subject at that particular level. As stated on the Multi-Stereo Test Key Card, "To establish reliability at any given disparity level, 8 out of 10 judgments should be correct." When the subject made less than 8 of the 10 judgments correctly, her score for that disparity level was recorded. The writer then immediately retested the subject with the cards for the previous disparity level, the same disparity level, and the following disparity level. This was done until the level of disparity was determined where 8 out of 10 judgments consistently were made correctly by the subject. In this manner reliability was established. The last level where 8 out of 10 judgments consistently were made correctly was recorded as the percentage score of stereopsis for the subject being tested. Upon completion of the test of visual depth perception on the Keystone Telebinocular, the subject was tested on the Howard-Dolman Apparatus.

To begin the testing on the Howard-Dolman Apparatus, the subject was seated in a desk chair facing the apparatus at a distance of 10 feet. The instructions for administering the test on this apparatus were given to the subject. After giving the instructions, the writer demonstrated the use of the strings in moving the adjustable rod. The subject was then handed the strings, one for each hand, by which to manipulate the movable rod. The subject attempted to place the movable rod, by means of the strings, as nearly as she could judge opposite the stationary rod or such that both rods appeared equidistant from her. The movable rod was placed at a different setting by the writer before each of the six trials. The result of each of the six trials was read directly off the millimeter scale on the floor of the apparatus and recorded on the subject's score sheet. This reading indicated the difference in millimeters between the movable rod and the stationary rod placed at the zero mark on the scale. The results of the six trials were averaged. The subject's score for visual depth perception as measured on the Howard-Dolman Apparatus was recorded on the score sheet as the average depth perception score for the six trials.

Treatment of Data

The statistical procedures used in this study were as follows:

1. Pearson-Product Moment correlation coefficients were computed for the total group of subjects using raw scores. The scores from the two instruments used to measure depth perception were correlated to determine if they were measuring the same thing. The scores for each of the depth perception measures were also correlated with the scores from the tennis backboard test.

2. To determine the level of performance in general tennis ability, the ten subjects who had the highest scores on the Dyer Wallboard Test were designated as Group A_t.

Group B_t was composed of the ten subjects who had the lowest performance scores on the tennis backboard test. The Fisher's "t" test for the significance of difference among small, uncorrelated groups was used to ascertain the difference between the high and low groups in general tennis ability and visual depth perception.

3. To determine the degree of visual depth perception on the Keystone Telebinocular, the twelve subjects with the best stereopsis percentage scores constituted Group A_k. The thirteen subjects who had the lowest scores on the Keystone Telebinocular comprised the low group, Group B_k.

4. The Howard-Dolman Apparatus was also used as a measure of visual depth perception in this study. Group A_h, indicating a high degree of depth perception, was comprised of nine subjects. Group B_h was comprised of the nine subjects whose scores indicated a poor level of visual depth perception as measured by the Howard-Dolman Apparatus.

5. The Fisher's "t" test for the significance of difference among small, uncorrelated groups was used to ascertain the difference between high and low groups of visual depth perception as measured by each of the instruments of visual depth perception and general tennis ability.

The five percent level of confidence was established as an accepted indication of a significant statistical difference for the scores between Groups A and Groups B.

CHAPTER V

ANALYSIS AND INTERPRETATION OF DATA

This study was conducted to determine the relationship between visual depth perception and general tennis ability as measured by the Dyer Wallboard Test. As defined by Armstrong, visual depth perception is ". . . the ability to appreciate or discriminate the third dimension, to judge distance, and to orient oneself in relation to other objects within the visual field." (2:71)

Two tests of visual depth perception were used in this study: one test of real depth perception (rod-type test), the Howard-Dolman Apparatus; one test of apparent perception (stereograms), the Keystone Ophthalmic Telebinocular. The Scott-French Revision of the Dyer Wallboard Test was used as a measure of general tennis ability.

The subjects were thirty-six women students who were enrolled in intermediate tennis classes or were members of the women's tennis club at the University of North Carolina at Greensboro.

The range of scores, means, and standard deviations for each of the measures of visual depth perception and the test of general tennis ability are recorded in Table I, page 51. For the Howard-Dolman Apparatus, a mean score of 15.75 was computed. According to the literature, Howard reported a depth perception of 20-30 mm. as the distinguishing point between normal and abnormal depth perception. (29: 659, 668) Armstrong reported that a depth perception of 30 mm. should be the distinguishing line between normal and abnormal depth perception. (2:78) According to the manual for the Howard-Dolman Apparatus, an average depth perception of persons, regardless of vision, at 20 feet was reported to be 18.6 mm. with both eyes. (42:33) As measured in this study, the mean score of visual depth perception computed for the Howard-Dolman Apparatus was better than that reported in the literature as a "normal" depth perception score.

For the Keystone Telebinocular, a mean score of 59.167 percent was computed. According to the manual and guide for this instrument, a percentage score of stereopsis of 25-70 percent is termed "fair". (48) It is interesting to note that there were no subjects who had scores less than the 25 percentage level of stereopsis. As measured in this study on the Keystone Telebinocular, all scores were above the poor level of stereopsis.

TABLE I

RANGE OF SCORES, MEANS AND STANDARD DEVIATIONS FOR EACH OF THE MEASURES OF VISUAL DEPTH PERCEPTION AND THE TEST OF GENERAL TENNIS ABILITY

(N=36)

Test	Range of Scores	Mean	Standard Deviation
Howard-Dolman Apparatus	2 - 57 mm.	15.75 mm.	12.67
Keystone Telebinocular	25 - 95 %	59.167 %	15.75
Dyer Wallboard Test	16 - 47	29.56	8.08

Null hypotheses were stated with regard to the relationship of visual depth perception and general tennis ability. The first null hypothesis established was

> (1) There is no significant relationship between the two measures of visual depth perception, i.e., the Keystone Telebinocular and the Howard-Dolman Apparatus.

The raw scores for the two measures of visual depth perception were correlated to determine if these instruments were measuring the same thing. As indicated in Table II, page 53, the correlation coefficient found for the two measures of visual depth perception, the Howard-Dolman Apparatus and the Keystone Telebinocular, was low and negative (-.26). The data from this study indicated that no significant relationship did exist between these two measures of visual depth perception; this null hypothesis was accepted. It is doubtful that these two instruments were measuring the same thing. In support of this doubt, Clark and Warren reported, "Either depth perception as measured by the [Howard-Dolman Apparatus] test is relatively unimportant in ball games of the nature of those included, or the test does not give an accurate measure of depth perception." (24:487)

The second null hypothesis established was

> (2) There is no significant relationship between visual depth perception as

TABLE II

CORRELATION COEFFICIENTS FOR MEASURES OF VISUAL DEPTH PERCEPTION AND TEST OF GENERAL TENNIS ABILITY

(N=36)

Test	Howard-Dolman Apparatus	Keystone Telebinocular	Dyer Wallboard Test
Howard-Dolman Apparatus	---	-.26	-.025
Keystone Telebinocular	-.26	---	.345*
Dyer Wallboard Test	-.025	.345*	---

*Significant at five percent level of confidence.

measured by either the Keystone Telebinocular or the Howard-Dolman Apparatus and general tennis ability as measured by the Dyer Wallboard Test.

The writer used the formula for the correlation of data from raw scores to determine the relationship of scores for each of the visual depth perception measures and scores for the Dyer Wallboard Tennis Test. These correlation coefficients are recorded in Table II, page 53.

The null hypothesis was not found tenable. From the data, it appears that a very low relationship, if any, exists between visual depth perception and general tennis ability. The correlation coefficient for the tennis test and visual depth perception as measured on the Howard-Dolman Apparatus was -.025, indicating no relationship between these two factors. This finding is similar to that of Olsen (34) who reported low and negative correlation coefficients for athletes' depth perception scores and their sport skill scores in soccer, baseball, and hockey. However, the writer found a significant positive correlation (.345) for depth perception and general tennis ability with the Keystone Telebinocular as the measure of visual depth perception. This finding is similar to that reported in Russian studies by Graybiel, Jokl, and Trapp. (27) In regard to this finding, Mail (38) did a study using four tests of visual depth perception, two of which were the Howard-Dolman Apparatus and the Keystone Telebinocular. Mail reported that the depth perception tests were not highly related but that the tests of apparent perception (the Keystone Telebinocular, for one) measured more of the same aspects of visual perception than did the tests of real depth perception (for one, the Howard-Dolman Apparatus).

In this study the writer was also interested in determining if there were a statistically significant difference between a high group (Group A) and a low group (Group B) on each of the measures of visual depth perception and on the tennis backboard test. The writer chose to classify those subjects who showed a high degree of visual depth perception as measured in this study by the Howard-Dolman Apparatus and the Keystone Telebinocular as Group A_h and Group A_k respectively. Those who demonstrated a high level of general tennis ability as measured by the Dyer Wallboard Test were termed Group A_t. The writer classified those subjects with poorer depth perception as measured on the Howard-Dolman Apparatus or the Keystone Telebinocular as Group B_h and Group B_k respectively. The subjects who demonstrated poor general tennis ability as measured by the Dyer Wallboard Test were designated Group B_t.

The third null hypothesis established was

> (3) There is no significant difference between Groups A_t and B_t, Groups A_k and B_k, and Groups A_h and B_h.

The Fisher's "t" test for small, uncorrelated groups was used to determine the significance of difference between the means for Groups A and Groups B for each of the measures of visual depth perception and the test of general tennis ability. The range of scores, means, standard deviations and "t" values may be found in Table III, page 57.

This hypothesis was found not tenable at the five percent level of statistical confidence. From these data, it can be assumed that within the intermediate range of tennis ability, there is a high intermediate and a low intermediate level of general tennis ability. It would also appear that within a range of visual depth perception, there is a statistical difference between those subjects demonstrating a high degree of visual depth perception and those demonstrating a low degree of visual depth perception as determined by either of the measures of visual depth perception.

The fourth null hypothesis established was

> (4) There is no significant difference between the visual depth perception mean scores on the Howard-Dolman Apparatus and the Keystone Telebinocular of the High and Low Groups in general tennis ability.

TABLE III

RANGE OF SCORES, MEANS, STANDARD DEVIATIONS AND THE SIGNIFICANCE OF DIFFERENCE FOR HIGH AND LOW GROUPS ON EACH OF THE MEASURES OF VISUAL DEPTH PERCEPTION AND THE TEST OF GENERAL TENNIS ABILITY

	High Groups Group A				Low Groups Group B				
Test	N	Range	Mean	S.D.	N	Range	Mean	S.D.	"t"
Dyer Wallboard Test	10	35-47	40.4	3.64	10	16-24	20.3	2.6	13.49*
Keystone Telebinocular	12	70-95	77.5	8.78	13	25-45	43.46	5.33	11.35*
Howard-Dolman Apparatus	9	2-7	5.33	1.49	9	23-57	33.56	12.52	6.36*

*Significant at the five percent level of confidence

$"t"_{.05} = 2.10$ for N=18

$"t"_{.05} = 2.07$ for N=23

$"t"_{.05} = 2.12$ for N=16

The Fisher's "t" test for small, uncorrelated means was used to ascertain the significance of difference between the mean depth perception scores of the high (Group A_t) and low (Group B_t) groups in general tennis ability. These data are recorded in Table IV, page 59.

The hypothesis was found tenable; no significant difference was found between the mean depth perception scores of the high and low groups of general tennis ability. These results indicate that players of high intermediate tennis ability and low intermediate tennis ability do not differ significantly in their ability to perceive depth as measured in this study. It is interesting to the writer to note that Miller (39) similarly reported that the ability to perceive depth did not differ significantly between champion performers and near-champion performers.

The fifth null hypothesis established was

(5) There is no significant difference between general tennis ability as measured by the Dyer Wallboard Test of high and low groups in visual depth perception as measured by the Keystone Telebinocular.

The Fisher's "t" test for small, uncorrelated means was used to ascertain the significance of difference between mean tennis ability scores of Group A_k and Group B_k. These data are recorded in Table V, page 60.

TABLE IV

THE SIGNIFICANCE OF DIFFERENCE BETWEEN THE MEAN DEPTH PERCEPTION SCORES OF THE HIGH AND LOW GROUPS IN GENERAL TENNIS ABILITY

Test	Mean Difference	"t"
Keystone Telebinocular	13.00	1.83
Howard-Dolman Apparatus	2.50	.68

TABLE V

THE SIGNIFICANCE OF DIFFERENCE BETWEEN THE MEAN SCORES OF GENERAL TENNIS ABILITY FOR THE HIGH AND LOW GROUPS IN VISUAL DEPTH PERCEPTION AS MEASURED ON THE KEYSTONE TELEBINOCULAR

Test	Mean Difference	"t"
Dyer Wallboard Test	7.77	2.34*

*Significant at the five percent level of confidence.

$"t"_{.05} = 2.07$ for N=23

The null hypothesis was rejected at the five percent level of confidence; a significant difference was computed for general tennis ability of Group A_k and Group B_k. These results show that the group which was able to perceive depth better also was significantly better in general tennis playing ability. This statistical evidence is similar to that reported in the research literature that athletes are better able to perceive depth than low skilled athletes (39) and non-skilled athletes. (27; 34)

The sixth null hypothesis established was

> (6) There is no significant difference between general tennis ability as measured by the Dyer Wallboard Test of high and low groups in visual depth perception as measured on the Howard-Dolman Apparatus.

The Fisher's "t" test for small, uncorrelated means was used to ascertain the significance of difference between tennis ability scores of Group A_h and Group B_h. These data are recorded in Table VI, page 62.

This null hypothesis was found tenable. On the basis of these measurements, the results do not support the previous hypothesis established with the Keystone Telebinocular as the measure of visual depth perception.

The lack of correlation between the two measures of visual depth perception used in this study seems to indicate

TABLE VI

THE SIGNIFICANCE OF DIFFERENCE BETWEEN THE MEAN SCORES OF GENERAL TENNIS ABILITY FOR THE HIGH AND LOW GROUPS IN VISUAL DEPTH PERCEPTION AS MEASURED ON THE HOWARD-DOLMAN APPARATUS

Test	Mean Difference	"t"
Dyer Wallboard Test	.45	.10

that these measures are measuring either different phenomena, or different factors of the same phenomena, visual depth perception. This lack of correlation may be a factor supporting the conflict of results reported in hypotheses five and six of this study concerning the significant difference between general tennis ability of high and low groups in visual depth perception. The evidence from this study would seem to support the statement by Cratty that the Howard-Dolman Apparatus is a test of static depth perception and cannot and should not be compared with activities which require visual judgment of objects in space. (8:135-136)

From an analysis of the data, the Keystone Telebinocular appears to be a better measuring device than the Howard-Dolman Apparatus; however, this conclusion is the writer's, based mainly on observation of subjects within the testing situation.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This study was conducted to determine the degree of relationship between visual depth perception and general tennis ability. It was the purpose of this study to determine if there were a difference: (1) in visual depth perception between tennis players of differing levels of ability; (2) in the tennis playing ability of subjects with good and poor visual depth perception. A comparison also was made of the relationship of two measures of visual depth perception: one test of real depth perception (rod-type test), the Howard-Dolman Apparatus; one test of apparent depth perception (stereograms), the Keystone Ophthalmic Telebinocular. The Scott-French Revision of the Dyer Wallboard Test was used as the measure of general tennis playing ability.

The subjects chosen for this study were women students who were enrolled in intermediate tennis classes or were members of the women's tennis club at the University of North Carolina at Greensboro.

Pearson-Product Moment correlation coefficients were computed for the total group of subjects to determine the relationship between the two measures of visual depth perception. The relationships between visual depth perception scores and scores from the tennis test were also determined. The following results were obtained:

1. There was no relationship between the two measures of visual depth perception, the Howard-Dolman Apparatus and the Keystone Telebinocular.

2. There was no relationship between depth perception as measured by the Howard-Dolman Apparatus, a test of real depth perception, and scores on the Dyer Wallboard Tennis Test.

3. There was a small positive correlation between depth perception as measured by the Keystone Telebinocular, a test of apparent depth perception, and scores on the Dyer Wallboard Tennis Test.

On the basis of these results, the writer concludes that there is little, if any, relationship between the factors of visual depth perception and general tennis playing ability. The lack of correlation between the two measures of visual depth perception appears to indicate that the two instruments used to measure visual depth perception in this study are measuring either different phenomena, or different factors of the same phenomena, visual depth perception.

A Fisher's "t" test for small, uncorrelated groups was used to determine the significance of difference between: (1) the mean depth perception scores of a high and a low group in general tennis ability; (2) the mean scores of general tennis ability for the high and low groups in visual depth perception as measured on the Keystone Telebinocular; (3) the mean scores of general tennis ability for the high and low groups in visual depth perception as measured on the Howard-Dolman Apparatus. The five percent level of confidence was taken to be indicative of a significant statistical difference between scores. The analysis of these data revealed that:

1. Within the intermediate level of general tennis ability, there was a high intermediate and low intermediate level of performance. Within the range of visual depth perception as measured in this study, there was a group of subjects who demonstrated a high degree of visual depth perception and a group who demonstrated a poor degree of visual depth perception for each of the measures of visual depth perception.

2. There was no significant difference between mean depth perception scores of high and low skill level groups of intermediate general tennis ability.

These results indicate that players of high intermediate tennis ability and players of low intermediate tennis ability do not necessarily differ in their ability to perceive depth as measured in this study.

3. As a group tested on the Keystone Telebinocular and studied according to high and low levels of visual depth perception, a significant difference was found between general tennis ability and visual depth perception.

The group which was able to perceive depth better as measured on the Keystone Telebinocular was significantly better in intermediate general tennis playing ability.

4. As a group tested on the Howard-Dolman Apparatus and studied according to high and low degree of visual depth perception, statistical analysis did not show a significant difference between general tennis ability and visual depth perception.

The results of this study indicate that a player with a high degree of intermediate tennis skill does not significantly perceive depth better than a player with a low degree of intermediate tennis ability. On the other hand, there was an indication that a high degree of visual depth perception as measured on the Keystone Telebinocular corresponded with a high level of intermediate tennis ability. However, there is some doubt cast upon this hypothesis according to the results of the Howard-Dolman Apparatus, a measurement of visual depth perception also used in this study; no significant difference was found to exist between the mean scores of general tennis ability for the high and low groups of visual depth perception on the Howard-Dolman Apparatus.

The findings of this study do not necessarily prove that the Keystone Telebinocular was a better instrument in measuring visual depth perception than the Howard-Dolman Apparatus; nor do the results prove that visual depth perception is important in better skills of general tennis ability; but such conjectures are possible.

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APPENDICES

APPENDIX A

RAW SCORES FOR EACH OF THE MEASURES OF VISUAL DEPTH PERCEPTION AND THE TEST OF GENERAL TENNIS ABILITY

Subject	Howard-Dolman Apparatus	Keystone Telebinocular	Dyer Wallboard Test
1	23 (B)	65	41 (A)
2	6 (A)	70 (A)	40 (A)
3	17	80 (A)	45 (A)
4	18	45 (B)	41 (A)
5	2 (A)	85 (A)	47 (A)
6	7 (A)	55	42 (A)
7	6 (A)	45 (B)	33
8	5 (A)	25 (B)	19 (B)
9	57 (B)	45 (B)	27
10	9	45 (B)	30
11	12	60	22 (B)
12	32 (B)	75 (A)	40 (A)
13	16	50	35 (A)
14	28 (B)	50	28
15	5 (A)	90 (A)	29
16	10	45 (B)	28
17	8	50	22 (B)
18	26 (B)	45 (B)	16 (B)
19	9	60	25
20	4 (A)	65	21 (B)
21	29 (B)	55	26
22	8	70 (A)	31
23	8	87 (A)	34
24	13	45 (B)	25
25	8	70 (A)	35 (A)
26	18	45 (B)	24 (B)
27	6 (A)	95 (A)	16 (B)
28	12	70 (A)	26
29	7 (A)	60	21 (B)
30	8	70 (A)	38 (A)
31	24 (B)	70 (A)	28
32	27 (B)	65	30
33	56 (B)	45 (B)	28
34	17	45 (B)	23 (B)
35	17	45 (B)	29
36	9	45 (B)	19 (B)

(A): high level of intermediate general tennis ability or high degree of visual depth perception.

(B): low level of intermediate general tennis ability or low degree of visual depth perception.

APPENDIX B

TEST DESCRIPTIONS

SCOTT-FRENCH REVISION OF THE DYER WALLBOARD TEST (3:322-324)

Instructions:

The player stands behind the restraining line holding a tennis racket and two tennis balls. On the signal, "Ready, Begin" the ball is put into play by bouncing it and stroking it against the wall. The rally continues for 30 seconds, using any stroke desired. If the ball gets out of control, another ball is started in the same manner in which the test was started. Balls hit short of the restraining line or which land below the 3-foot mark do not score but sometimes help to keep the rally going. After the initial bounce to start the rally, the ball may be hit on the volley or after any number of bounces. The player should get 2 more tennis balls from the racket face on the floor whenever needed to keep the rally going. Three 30-second trials are given. The score is the total number of hits for all three trials. A legal hit to score must land above the 3-foot line on the wall and must be contacted from behind the 27 1/2-foot restraining line.

Scoring:

Three 30-second trials are given. The score is the total number of legal hits for all three trials.

HOWARD-DOLMAN APPARATUS (42;44)

Instructions:

You will sit in this chair facing the apparatus. There are two rods--one is stationary and the other is movable by manipulation of these two strings which you are holding. Hold one string in each hand. When you are asked, by means of manipulating the two strings, place the movable rod as nearly as you can judge opposite the stationary rod so that both rods appear to be equidistant from you according to the way you see them. You will have six trials. When you have completed each trial, place the strings in your lap and remove your hands. Remember not to move your head or body during the trials. Do not squint. This is not a timed test; do try to do your best.

Trials:

Before each of the six trials, the movable rod is set at the following positions, in relation to the stationary rod:

Trial 1: 200 millimeters behind the stationary rod;
Trial 2: 200 millimeters in front of the stationary rod;
Trial 3: 150 millimeters behind the stationary rod;
Trial 4: 150 millimeters in front of the stationary rod;
Trial 5: 100 millimeters in front of the stationary rod;
Trial 6: 100 millimeters behind the stationary rod.

Scoring:

The movable rod is reset after each trial. When the subject has placed the strings in her lap and removed her hands, the trial is completed. The difference in distance between the movable rod and the stationary rod is read directly from the scale on the floor of the apparatus and recorded in millimeters. The score for the six trials is totaled and an average of the six trials is determined. The score is recorded as the average depth perception score for the six trials.

KEYSTONE TELEBINOCULAR TEST (48;49)

Instructions:

You will now be looking at several cards through this instrument. After the instrument has been adjusted to your sitting posture, maintain an erect, comfortable posture, keeping your head still against the head rest. Throughout this testing period keep both eyes open. As you look at each card, try to answer the questions that I ask as best you can. You are not being timed.

Cards: KEYSTONE VISUAL SURVEY TESTS

Card 4 1/2 (DB-1D) Usable Vision, Both Eyes

Looking at sign no. 1, do you see five diamonds? Do you see a black dot in the diamond to the left? Now where is the dot in sign no. 2, top? bottom? left? or right? Go on to signs 3-10.

Card 5 (DB-3D) Usable Vision, Right Eye

Same instructions as for card 4 1/2.

Card 6 (DB-2D) Usable Vision, Left Eye

Same instructions as for card 4 1/2.

Card 7 (DB-6D) Stereopsis

Looking at line no. 1 you will see a star, square, cross, heart, and ball. One of these figures stands out, is closer to you. Which figure is closer to you in line 1? Go on to lines 2-12.

Cards: Multi-Stereo Card Test and Multi-Stereo Repeat Card Test

You are now looking into a room at a box. In this box there are several rods at different distances from you. Look at rods numbered 1 and 2. Is one of these rods closer to you or are they both the same distance from you? If you reach out to touch one of these two rods, which one would be closer to you? Now look at rods numbered . . . Which rod is closer to you in this pair?

Card A: Multi-Stereo Test A

Card 1 thru Card 13: Multi-Stereo Repeat Tests

Scoring:

The last level where 8 out of 10 judgments consistently are made correctly is recorded as the percentage score of stereopsis for the subject being tested.

General scoring:

poor stereopsis:	25% or less
fair stereopsis:	25% - 70%
good stereopsis:	75% - 80%
excellent stereopsis:	85% - 100%

APPENDIX C

SCHEDULE CARD FOR VISUAL DEPTH PERCEPTION TESTING

My appointment to be tested on the depth perception apparatus in Coleman Gymnasium in Room 56 is on (day)___________________________________ at (time) ________. Please be prompt. If you wear glasses for distance vision, please wear them to this testing session. Thank you for cooperating in my study.

APPENDIX D

SAMPLE SCORE CARDS

SAMPLE SCORE CARD
DYER WALLBOARD TEST

Name ______________________________ Class: Fresh
Soph
Dorm ______________________________ Jr
Sr

Do you normally wear glasses? Yes No

Dyer Wallboard Test: Trials: (1) _______
(2) _______
(3) _______

SAMPLE SCORE SHEET

KEYSTONE TELEBINOCULAR

Name: ________________________________ No. ________

Wears Glasses: ____Yes ____No Class: ________

Usable Vision	1	2	3	4	5	6	7	8	9	10
4 1/2 (B)	L	B	T	L	R	T	L	B	B	R
5 (R)	T	R	L	T	B	B	L	R	T	R
6 (L)	B	L	R	R	T	L	B	L	R	T

Stereopsis	1	2	3	4	5	6	7	8	9	10	11	12
7	+	○	✳	○	□	□	♡	+	✳	+	♡	○

Card A	Answer	Stereopsis
1 - 2	1	3%
4 - 5	4	5%
7 - 8	8	10%
10 - 11	10	25%

% SCORE ______

Card #	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	Stere-opsis
1	1	3	3	4	6	7	7	8	10	10	45%
2	1	2	4	5	5	6	8	8	10	11	50%
3	2	3	3	4	6	6	8	8	10	11	55%
4	1	3	3	4	6	7	7	9	9	10	60%
5	2	2	4	5	5	7	7	9	9	10	65%
6	1	2	4	5	5	6	8	8	10	11	70%
7	1	3	3	5	5	6	8	8	10	11	75%
8	2	3	3	5	5	6	8	9	9	10	78%
9	2	3	3	4	6	6	8	9	9	10	80%
10	1	2	4	5	5	7	7	8	10	10	85%
11	2	2	4	5	5	6	8	8	10	11	90%
12	1	3	3	4	6	7	7	9	9	10	95%
13	1	2	4	4	6	6	8	9	9	10	100%

SAMPLE SCORE SHEET

HOWARD-DOLMAN APPARATUS

DYER WALLBOARD TEST

HOWARD-DOLMAN APPARATUS

	+ in front / o in back	of stationary rod (millimeters)
Trials: 1.	________	________
2.	________	________
3.	________	________
4.	________	________
5.	________	________
6.	________	________

TOTAL SCORE ________

AVERAGE SCORE ________

DYER WALLBOARD TEST (HITS)

Trials: 1. ________

2. ________

3. ________

TOTAL SCORE ________