PERCEPTUAL-PREDICTION ABILITY OF FEMALE SOFTBALL BATTERS

by

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This thesis is dedicated to my mother and father who never faltered throughout it all.

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ABSTRACT

The purpose of this study was to determine the relationship between skill level and perceptual-prediction ability of college aged female softball batters and also to determine if the length of viewing time affected their perceptual-prediction ability. Of the 140 subjects administered a batting pre-test to determine skill level assignments, 14 highly-skilled and 14 low-skilled subjects were randomly selected for further testing on the Motion-Perception Analyzer.

The perceptual-prediction task required subjects to predict when a moving ball would collide with a stationary target. Each subject was given five trials at 2 seconds' viewing and five trials at 4-seconds' viewing time on which to base her predictions. The subject was scored according to the Mean Constant Error, Variable Error, and Absolute Error of her five trials at each viewing period.

Significant differences were found between the two viewing periods for subjects' VE and AE scores. No significant differences were revealed between the two skill levels for scores of $\overline{CE}$, VE, or AE, nor for the viewing periods' $\overline{CE}$.

It was concluded that performance of the perceptual-prediction task on the Motion-Perception Analyzer seemed to be insensitive to differences in skill levels of female college softball batters, and that longer viewing periods of the moving ball afforded subjects a better opportunity on which to base their predictions.

CHAPTER 1

NATURE AND SCOPE OF THE PROBLEM

"Keep your eye on the ball!" is a teaching cue commonly used in many sports. Teachers and coaches have been telling batters for years to look at the pitched ball up until the moment of its contact with the bat. However, Whiting (1969) pointed out that from the point of view of "acting upon information received" from the eyes, it is not always possible to watch the ball all the time when a fast ball skill is involved. As a result of a cinematographic analysis of university batters, Hubbard and Seng (1954) were among the first to discover that the primary basis for tracking a pitched ball was with eye movements; however, tracking with eye movements could not be continued up to the actual contact of the bat with the ball. In every case, the ball was found to be tracked no closer than 8 to 15 feet from the plate, leading the authors to conclude that once the momentum of the swing of the bat was determined, on the basis of previous estimates of the instant and position at which the ball would arrive over the plate, further tracking served no purpose. Weiskopf (1975) seemed to agree with these previous findings when he advised batters that visualization is the basis for anticipation in athletic competition. He proposed that if a batter were properly trained, he could develop the ability to follow the ball until contact is <u>almost</u> made since high speed sequence pictures had revealed that the hitter follows the ball only to an area approximately six feet in front of the plate.

Cognizant of this information, the teacher or coach is faced with a dilemma of giving the batter difficult instructions to follow--should he actually have him try to keep his eye on the ball until contact or face the unhappy consequence of having the batter not track the ball for as long as possible. Hubbard and Seng (1954) warned of this second possibility should the performer be told that tracking of the ball's entire path of flight is an impossible task. As an alternative approach, correct timing with the right amount of power at the critical point has been suggested for learning emphasis by Poulton (as cited by Whiting 1969).

Thus, it can be said that involved in the execution of striking a projectile are the factors of predicting when the ball will be in the correct place for hitting, when to initiate the stroke in order to reach the ball at that time, and the effort that is needed to be applied to the stroke. All of this information must be computed in a fraction of a second to allow the adaptive responses to be executed in order to successfully complete the skill.

Statement of the Problem

The present study was undertaken in order to examine the relationship between the batting ability of female softball batters and their perceptual-prediction ability. Specifically, the study sought to determine the relationship between skill level in batting and the ability to predict when a moving ball would strike a stationary target. A secondary purpose was to ascertain whether the length of viewing time affected ability to predict the instant of contact in the perceptual-prediction task.

Hypotheses

For the purpose of the present study, the following hypotheses were formulated.

Research Hypotheses 1

High-skilled college aged women batters will perform better than low-skilled college women softball batters when performing a prediction task on the Motion-Perception Analyzer.

$\underline{Ho1}_A$. Only chance differences will be found between highly-skilled batters on the prediction task as measured by the batters' mean constant error scores.

$\underline{Ho1}_B$. Only chance differences will be found between highly-skilled and low-skilled batters on the prediction task as measured by the batters' variable error scores.

$\underline{Ho1}_C$. Only chance differences will be found between between highly-skilled and low-skilled batters on the prediction task as measured by the batters' absolute error scores.

Research Hypothesis 2

Both highly-skilled and low-skilled batters will perform the prediction task more successfully following a viewing period of a moving object for a 4-second interval than when viewing the object for a 2-second interval.

$\underline{Ho2_A}$. Only chance differences will be found between the two viewing periods of the moving object as measured by the batters' mean constant error scores.

$\underline{Ho2_B}$. Only chance differences will be found between the two viewing periods of the moving object as measured by the batters' variable error scores.

$\underline{Ho2_C}$. Only chance differences will be found between the two viewing periods of the moving object as measured by the batters' absolute error scores.

Scope of the Study

The study was designed to include only those University of Arizona female students enrolled in beginning and intermediate level softball classes during the spring semester 1975, and, for comparison purposes, varsity and junior varsity intercollegiate women softball team members for the 1975 competitive season. Therefore, the results of the present study must be interpreted and generalized to only women softball batters of limited ability and limited years of playing experience. Since the subjects in the study were college-aged and many were second semester freshmen, their exposure to the skill of batting has been limited. Even team members would not have the exposure and practice that a professional batter would have, for example, since the activity for her was one of being more "sport" oriented rather than being that of a profession. The ability of the batters in this study was also viewed within the confines of the teacher or coach's philosophy as well as the learning cues used by her in the directions given to the batter, which did not come under the control of the present study.

Further, the Motion-Perception Analyzer is not an extensively tested device. Test-retest reliability for the prediction task performed had not been established prior to this study. Perceptual-prediction ability was also operationally defined for the purpose of this study and did not necessarily coincide with widely used definitions. However, the investigator and her research assistant were trained in the use of the machine and held many extraneous variables constant, leading them to be confident in results obtained on the machine as being relatively accurate estimates of the subjects' prediction ability as defined for the purposes of this study.

Terminology

Terms used throughout this study were operationally defined as follows.

1. Error Scores. As suggested by Schmidt (1975), three methods of assessing the amount and nature of the subject's error in performance of the perceptual-prediction task were utilized in this study. They are (a) Absolute Error (AE)--a measure of the average amount by which the subject was in error irrespective of the "earliness" or "lateness" of her responses. Absolute values,

rather than negative or positive values were used in the computation of this error score. (b) Mean Constant Error ($\overline{CE}$)--This error score carried a sign value which related to the investigator how the subject tended to respond on the average in relation to the Mean Prediction Time (the time that was required for the moving ball to collide with the stationary target). A negative $\overline{CE}$ designated an "early" prediction of target collision, while a positive $\overline{CE}$ represented a "late" prediction. (c) Variable Error (VE)--a score of the subject's repeatability of consistency in her responses about her own mean performance (her $\overline{CE}$).

2. Highly-skilled Batters. Batters scoring 46 points or better on the batting pre-test (a score of 60 points was a perfect score).
3. Low-skilled Batters. Batters scoring 28 points or less on the batting pre-test.
4. Perceptual-Prediction Ability. As measured by the Motion-Perception Analyzer, this ability was the subject's prediction of the precise moment when the moving ball would collide with the stationary target, based on 2-seconds' and 4-seconds' viewing time before vision was blocked and prediction of the instant of collision made.
5. Prediction Task. The Motion-Perception Analyzer (designed by Morris 1972) was adapted so that the subject was allowed to view a ball moving forward on a diagonal track at the subject's eye level towards a stationary target. The subject's task was to predict the precise moment when the moving ball would collide with the stationary target.

Significance of the Study

In the teaching of ball skills to performers at all skill levels, a major responsibility of the coach or teacher is to direct the student's attention toward the appropriate informational cues available in the student's environment. A performer may be poorly skilled for various reasons. Poor skill may result from a lack of practice, or it may be that the student has not been directed toward the appropriate informational cues, or even possibly, that she has been directed towards *in*appropriate information (Whiting 1969). There are many questions unanswered concerning "appropriate" information in sports skills, particularly in batting skills. For example, what is "appropriate" information for batting skills? Is the "appropriate" information the same for all skill levels? Such questions must be answered before the teacher or coach can aid the performer in achieving his full potential. The present study was undertaken in an attempt to find some answers to the "Keep your eye on the ball!" dilemma.

This study was also significant in that it carried out further experimentation on a testing device, the Motion-Perception Analyzer, designed by Morris (1972), on which only one study had been performed previously. The present study adapted the machine to handle a different task than that developed and used by Morris, and thereby further explored the potential of the Motion-Perception Analyzer as a testing device for measuring the perceptual abilities and tasks involved in movement skills.

CHAPTER 2

REVIEW OF LITERATURE

A review of the literature pertaining to this study is presented in this chapter. General information concerning visual perception as well as laboratory expe iments investigating relevant aspects of visual perception were reviewed. Due to the lack of information available on softball batters, studies involving male baseball batters were included since it was felt that the basic mechanics of batting were comparable for the two sports. Thus, the following review is divided into two main sections entitled, "Perception," and "The Perceptual Skill of Batting."

Perception

Cratty (1968, p. 106) defined perception as "the process of organizing and giving meaning to experience." It is "extracting information from stimulation" which emanates fromobjects, surfaces, and events in the world around us; although the information may be different from the object or event, it specifies them (Gibson 1970, p. 98).

Gentile (1972) suggested a two-stage perceptual theory of learning. Stage one is a cognitive or exploratory stage, during which the student attempts to "get the idea of the movement." The student identifies and attends to environmental conditions in order to formulate a motor plan that is effective. Short-term memory of the goal and of the plan will still be available to the performer following the execution of the movement. During stage two the orientation of the learner is to reach a particular level of skill. In order to do this, he must develop a response repertoire in which there is an exact number of motor patterns to match the number of possible regulatory stimulus subsets. He must not wait for the event to occur before organizing his motor play or he will be ineffectual due to inherent time lags in his system. Rather, he must receive and process information concerning the nature of extent of change in order to predict what conditions are going to be like in the immediate future. The prediction is based on input of the immediate or more distantly removed past. In order to facilitate the selection process, he "primes" some patterns as more likely to be used than others.

Perception and learning are interdependent. Perception is influenced by individual factors such as personality traits, attitudes, emotional conditions, experiences, and expectations, as well as environmental variables. According to Singer (1968, pp. 82-83), in order to "learn," the individual must . . .

> 1. . . . be able to attend--to disregard extraneous and irrelevant information.
>
> 2. . . . be selective in perception, thereby reducing the number of stimuli surrounding the object and allowing it to be perceived more easily and quickly. Selective attention is a process associated with highly skilled performers.
>
> 3. . . . be set; to know what to look for; to have the ability to single out objects necessary in all motor activity. Set is demonstrated by the learner when there is a minimal involvement of the senses.
>
> 4. . . . be motivated--must have the will to perceive if he is to attend to the necessary cues influencing discrimination.

5. . . . call upon previous experiences from similar situations with the same objects to help in facilitating the perceptual process.

6. . . . have knowledge of results available to him in perceptual-learning. The person always perceives something through his own efforts, and knowledge of resilts helps to reinforce the perceptual act, even though it may not be accurate.

For the purpose of further exploring the topic of visual perception, this section has been divided into subtopics of selective attention, psychological refractory periods, anticipation-prediction, pursuit tracking, as well as the perception of space, depth, and motion. Each subtopic will be examined individually. Studies relating to each subtopic and having possible implications to the present study will also be reviewed.

Selective Attention

Skilled performance is built upon the complex interaction between man and his environment. As stated by Broadbent (1958, pp. 295-296), the skilled man must

> . . . select correct cues from the environment, make decisions upon them which may possibly involve a prediction of the future, and initiate sequences of responses whose progress is controlled by feedback, either through the original decision-making mechanism, or through lower order loops.

Selective attention to the display (that part of the external environment likely to be of use--or in some cases necessary--in performance of a skill) is required because of limitations of the sense organs (Whiting 1969). The individual filters and selects one channel of information at a time in order to obtain efficient use of a limited neural mechanism, which places restrictions on the speed with which items of information can arrive (Broadbent 1958). Consciously, or unconsciously, attention is focused upon particular areas in the athlete's environment. The particular focus is likely to be determined by past experiences as well as the present skill being performed. Processing the information received gives rise to decision making which will affect the performance of the skill (Whiting 1969).

Psychological Refractory Period

The first and most marked feature of the cerebral processing of sensory information is its time-lag or "central delay" (Craik 1948). When two stimuli are presented for reaction, the time taken to respond to the second stimulus is sometimes unduly long when the stimuli occur close together in time (Broadbent 1958). If a second stimulus succeeds the first very rapidly, within about 0.05 seconds, the second and the first may be apprehended together and responded to as a single stimulus, as if the two stimuli had registered before the computing system had started to operate. Craik (1948, p. 145) referred to this computing system as a "modification of the relation between input, or optic-nerve message, . . . and the output, or limb movement." Stimuli arriving between these two intervals are either disregarded, responded to after the first, or cause general disturbance and conflict in the individual (Craik 1948). In addition to being ineffective near the decision point, advanced event information may even be detrimental if presented too soon to the decision point (Schmidt 1968).

According to Craik (1948), this limitation to response frequency is not determined by the sense organ, or by muscle and limb, but by a cerebral limit. The central organizing time for highly probable stimuli is supposed shorter than that for improbable ones, and thus, the limitation is essentially one of the rate of handling information. This theory, proposed by Broadbent (1958), of a perceptual system of limited capacity, required a short-term store for information arriving while the perceptual system is fully occupied (Broadbent 1958).

Even the most simple skills involve sequential, coordinated patterns of movements of the various body segments (Schmidt 1968). Ball skills, and in particular ballistic strokes to a stationary or moving ball, involve short time durations. The psychological refractory period can be a decidedly limiting factor when added to a normal reaction time, which must occur before a modification to a committed course of action can be initiated (Whiting 1969). Therefore, time lags inherent in the system require that the athlete plan ahead, both in terms of the likelihood of certain events occurring and in terms of determining which motor patterns may be required (Gentile 1972).

One of the advantages of confusing the display for opposition players is that they read the cues incorrectly and make an inappropriate response, resulting in longer than normal reaction time to initiate a corrected response (Whiting 1969). Thus, the successful pitcher develops a repertoire of various types of pitches. He throws a curve ball, a "sinker," or a "riser," each pitch designed to change its flight pattern just prior to crossing the plate. Consequently, the batter, expecting the ball to arrive in a certain area, has to adjust his swing at the last minute to accommodate these unsuspected changes, a very difficult task to perform.

Anticipation-Prediction

In human skilled performance, various means have been adopted which make it possible for information necessary for subsequent actions to arrive while other actions are being carried out; thus, allowing sensory and motor conduction times to overlap (Broadbent 1958). Evidence generally indicates that anticipation and timing are independent of classical reaction time and consequently can be learned. However, there is substantial forgetting over retention intervals of up to five months (Schmidt 1968).

Determiners of anticipation can be said to be spatial and temporal factors. Spatial anticipation is a prediction of where a stimulus will occur (direction, extent, etc.), while temporal anticipation involves the prediction of the time of arrival of the stimuli (Schmidt 1968).

Changes in the nature of the stimulus predictability produce different responses. The first category, known as "receptor-effector anticipation" or more briefly the "eye-hand span," is limited by the fact that input to and output from the organisms are somewhat incompatible. At high rates of transmission, there cannot be too large an amount of information within the nervous system at one time. However, at low rates of transmission, the span can be increased by usage of a short-term storage of recirculating information through the system during intervals in the arrival and departure of information (Broadbent 1958).

In "perceptual anticipation," the second category, long-term storage is used (Broadbent 1958). Skills involving the interception of a moving object in three-dimensional space rely upon this type of strategy (Broadbent 1958, Schmidt 1968, Stadilus 1972, Whiting 1969). According to Broadbent (1958, pp. 284-285),

> The eye records the position of the ball well in advance of the movement, but the position is not that at which the blow is struck, because the ball moves during the reaction time. The movement, however, obeys rules which the player has frequently observed to be followed previously. The response to the last member of this sequence is initiated before the whole series has occurred objectively; so that the response and event occur simultaneously and the bat strikes the ball.

After considerable practice, the anticipated responses become automatic, freeing the subject to perform other tasks simultaneously (Schmidt 1968). The individual must be able to make his prediction based on the anticipated speed and direction of the object flight. He preprograms a motor response that matches the characteristics of the expected flight. The preprogramming is a crucial step because of the rapid rates at which the object may be propelled (Stadilus 1972). The predictability of an occurrence can be described in terms of its coherency and its complexity. Coherency refers to the degree to which there is a consistent pattern in the stimulus. The series of stimuli emanating from a rolling ball are coherent in that one can predict the future stimuli from those of the present through learning the pattern. Complexity, on the other hand, refers to the number of possible stimuli which could occur in the series. The greater the number of possible outcomes, the greater the complexity and the poorer the amount of predictability in the series (Schmidt 1968).

When the object is propelled into flight, the performer's task changes from expectancy to actual object flight informationand the participant must quickly determine if his expectancy was correct (Stadilus 1972). By monitoring the object's flight over a certain distance, the individual is able to obtain information about the velocity and acceleration of the ball on which to make his prediction. It seems that this information is not processed continuously, but rather it is taken in during brief periods, and actions of the eye muscles or other effectors are initiated as a result of the processing of "chunks" of information (Whiting 1969).

Time available to monitor the object's flight is dependent upon the speed at which it was propelled (Stadilus 1972). The amount of time required to detect changes in the ball's flight is important to consider. It is also necessary to consider at what stage in the ball's flight it is necessary for such perceptual moments to occur in order to make reliable predictions (Whiting 1969).

During and after the programmed interception response, the performer receives information feedback concerning his performance which will affect his next response decisions (Whiting 1969). Through understanding these various components, Stadilus (1972) feels the teacher may be able to detect particular problems in the performer's techniques and correct them, instead of simply labelling the performance as poor and recommending practice of a general nature.

Pursuit Tracking and Anticipation-Prediction

Pursuit tracking has two aspects which are common to a number of skills. First,it involves the interception of a moving target and secondly, it involves matching a function relating position and time

(Poulton 1957). In the chain of responses, the sense organ is the first of two steps. In tracking tasks, the eye fixates the aiming-point on the target as steadily as possible, whether the target be stationary or moving. Sensory messages are then sent continuously up the optic nerve, where the second step, the computing system, takes over. This reception consists of a modification of the relation between the input, or optic-nerve message, and the output, the limb movement made in response to the stimuli (Craik 1948).

Tracking performance on a target moving with a simple harmonic motion, allowing no opportunity for receptor-effector anticipation, will show a lag between input and output. After repeated experience with the target motion, however, this lag will be abolished. Perceptual-anticipation allows for the elimination of lags in response and makes the task independent of the objective occurrence of external events, thus making it possible to combine the task with other tasks (Broadbent 1958).

When the subject is given the task of rapid acquisition of a moving target, the target will have moved before he has completed his response movement. For the acquisition to be correct, he has to know in advance the position which the target will occupy at the time his response movement has been finished. In addition, he has to make a prediction about the nature and size of his muscular contractions required to reach this point (Poulton 1957). Two possible sources of information available for use in determining the future position of the target are as follows.

1. Receptor anticipation, where the receptor mechanism has to function ahead of the response mechanism. In such a case, the future track of the target would have been displayed ahead of time for the subject.
2. Perceptual anticipation, in which the future track of the target is not displayed ahead, but the track contains constants or statistical properties which are known to the subject from past experience. The target is moving in a predictable direction at a predictable speed. In addition, the subject must also predict the position which the target will occupy as his response movement is completed (Poulton 1957).

Pursuit tracking tasks reviewed in the literature were found to be primarily of the radar-tracking-type, which utilized a two-dimensional viewing screen. In some cases college-aged students were used as subjects, but on the whole, excerpts from the general population served as the samples. Not one study was found that used athletes specifically as the sample group tested.

According to Gottsdanker (1952), one noteworthy characteristic of the human tracker was found to be his ability to produce a smooth, continuous path of motion. It was felt that this ability might be accomplished through anticipation of the motion of the target. The tracker was found to make intermittent corrections at half-second intervals and that the more the predictive motion rather than position correction was utilized, the smoother the path of the motion. Each subject had his individual acceleration tendencies; therefore, acceleration was felt to be a characteristic of the person rather than of the pattern he was continuing.

A further study performed by Gottsdanker (1955) concluded that no measure of prediction-motion provided a satisfactory forecast of skill in tracking. Additional support was given to the hypothesis that foregoing rates are smoothed or integrated in continuation.

In a task where two targets moved down perpendicular "streets" toward a point of intersection, the subject was asked to indicate where the variable target would be at the instant the standard target reached the intersection. Gottsdanker and Edwards (1957) discovered that for both accelerated and constant-velocity targets, the prediction was based on relative positions at the time of target disappearance rather than differential velocities of the two targets.

When subjects were required to distinguish between accelerated and constant velocity motion of targets across a viewing screen, they were found to be insensitive to gradual changes in velocity (Gottsdanker, Frick and Lockhard 1961). It was shown to be more difficult for subjects to identify instantaneous change or to distinguish between two ongoing motions of different constant velocities. Acceleration of the target motion was not detected as such, but rather it was inferred from successive impressions of different rates. Negative acceleration was found to be more accurately detected than positive. This was felt to be attributable to the subject's inability to judge a motion near the time of its onset.

Angel, Garland and Fischler (1971) concluded that a short latency central process was used in correcting motor errors. Subjects performed a pursuit tracking task in which the center of the visual display was screened so that they were not allowed to see the response marker during the initial part of each response. Visual feedback provided was reversed on alternate blocks of target steps. Previous suggestions that errors can be amended by a central mechanism which does not require sensory feedback, was felt to be confirmed as false moves were corrected at times when the response marker was invisible. In executing a subsequent response, the subject might compare the motor program in actual use against the "right" program, and should there be a discrepancy between the two, the subject could amend the error on the basis of this central information, even though the cursor was still concealed from view.

Davis and Behan (1960) allowed subjects varying lengths of viewing periods from which to make extrapolations or predictions from the disappearance of a simulated airplane blip to its reappearance. After the target was removed, they were required to dead-reckon it for ten minutes. In the case of prediction motion, there was found to be a tendency for subjects to tend toward the mean, adopting a more conservative approach to their estimate of the probable position of the target. When subjects had a very limited amount of information about the speed and direction of the target, further opportunity to view the blip did not result in improved performance. A decrease in error was found from trial one to trial two, but there was no improvement after trial two.

In a similar study performed by Weiner (1962), in which subjects were required to predict the future position of a target after it had disappeared, it was concluded that a human operator may be able to make motion predictions equally as well with minimal exposure to target input (i.e., from a 2-second sample of target motion as from a 16-second sample) and that target speeds exert a greater influence on prediction accuracy than did the factors of the duration of the target exposure or the mode of response to it (i.e., tracking vs. monitoring). Again, as in the study performed by Davis and Behan (1960), there was found to be significant learning from one session to the next. These results were felt to indicate that perhaps only a minimal amount of exposure of the target under control is necessary in order to make accurate motion-prediction of constant rate targets in its future positioning after disappearance from the field of view.

There is a hierarchy in the use of perceptual cues in the prediction of the reappearance of a moving object, according to Bonnet and Kolehmainen (1969). Spatial cues are easier to use than velocity cues, which in turn are easier than time cues. No general rule can be applied to all situations, however, because different strategies are used at different times, depending upon the relative ease of the utilization of those cues when all are available in the situation. A given cue is more accessible in a situation where it is constant than in one where it varies.

A prediction situation was devised by Gerhard (1959) in which the subject was required to press a button when he judged a moving light, which had disappeared, would have reached a specific point. Results of the study showed a systematic relationship between the variability of the subject's performance and the time the light was invisible. Significant changes in the subject's behavior were found as a result of variations in the temporal relationships of events occurring as a result of movement of an object, rather than the velocity of the object as such.

Prediction of the future course of a moving target may involve more path estimation rather than speed estimation, as concluded by Foot (1969). The study investigated the accuracy of prediction in a task requiring estimation of the point of coincidence of two pointers rotating at different rates, the tracking one closing on the leading one with a speed ratio of 3:2. Error in estimation was found to increase linearly with increasing the prediction-span; increasing the viewing span had only a slight effect upon mean error. Increasing the opportunity for continuous viewing did not provide the subject with anything like the same increment in usable information. It was also felt that the slight differences in the accuracy of prediction could be a feedback problem. Foot further concluded that prediction ability is far from being a unitary attribute and the ability to predict in one situation is not necessarily correlated with the ability to predict in another.

Perception of Depth and Space

All observable movements may be described in spatial terms. In order to perform sports skills effectively, therefore, one must be able to make judgments about the movement of objects in space. Cratty (1968,

p. 107) lists four primary attributes which human beings must evidence when observing and reacting to various spatial problems.

1. The ability to structure the situation, to synthesize complex information.

2. The ability to select an object or objects out of space with which to deal in some way.

3. The ability to make judgments rapidly, "perceptual speed."

4. The ability to make varied judgments, "perceptual flexibility."

Space is referred to in the literature, as being either "near" or "extended" (Cratty 1964, Vernon 1962). As stated by Cratty 1964, p. 119):

> Near space may be structured through visual-motor integrations of various types, while farther removed events and objects may only be accurately structured by hypothesizing what probably would be the characteristics of distant objects if they could be actually handled. The perception of objects in space far removed is based upon standards and wualitative relationships gained through the structuring of near space.

Perception of extended space, therefore, is primarily dependent upon visual and auditory information integrated with temporal judgments.

Most muscle activities utilize three dimensions in space. Dimensions of the retinal image normally correspond fairly accurately to the dimensions of the visual field. However, no aspect of the retinal image directly reproduces perception of the third dimension of space, depth, or distance. Therefore, we are obliged to infer it from certain characteristics of the retinal images (Vernon 1962).

Monocularly, several cues have been suggested by Cratty (1964, p. 121) serve to organize perceptions containing depth, as well as height and breadth.

1. A near object overlaps and partly blocks out portions of objects farther away (the interposition effect).

2. Objects or surfaces contain texture. This cue is related to the invariance principle which holds that smaller objects will be perceived as being located farther away, while larger ones will be perceived as being closer.

3. Known standards serve the individual in perceiving objects' distances and/or size based on knowledge gained in the past concerning the objects being observed presently.

4. Linear perspective provides the observer the knowledge of the tendency of parallel lines to converge as they extend away from the observer.

The third dimension in space, however, is more advantageously perceived through the use of man's two eyes; the different spatial positioning of the two eyes enables the perceived object's images on the retinae to be somewhat unlike. This phenomenon of unlikeness is referred to as retinal disparity (Vernon 1962). Binocular depth cues are obtained partially from the "additional roundness" afforded the observer as the two eyes see slightly different portions of the same object (Cratty 1964). This phenomenon is labeled as "stereoscopic vision" and is based on the fact that distance is perceived in the brain on the basis of the interception of the convergence of these two cues (Whiting 1969). This procedure is useful only in determining the location of a single object (such as a ball in flight). It does not function for more than one object at a time and at different distances from the eyes. For computations of this nature, "disparity" occurring between the images of the objects on the retinae on both eyes is utilized.

Therefore, accuracy in determining distance in binocular vision is enhanced by means of convergent and divergent movements of the eyes in focusing on objects of various distances. The eyes converge (look inwards) to focus on a near object, and as the object recedes, the eyes gradually diverge until they look in parallel directions at distant objects (Vernon 1962).

Convergence and disparity are effective only for distances of about 100 meters according to Vernon (1962), but for only 20 feet according to Whiting (1969). With objects at a greater distance, disparity of the two images becomes so small (both eyes are essentially looking straightforward, in parallel directions) that in essence people become one-eyed. Monocular vision of depth can be perceived with readjustment on the part of the individual and utilization of other information from the display (Whiting 1969, Vernon 1962).

Vernon believes that perception of stereoscopic vision seems to develop spontaneously, but that accurate estimation of distance from binocular cues does depend on learning from past experiences.

Kunnapas (1968), in an experiment investigating distance perception as a function of four reduced perceptual cues and one full cue condition, concluded that binocular disparity is an important cue for depth since convergence is usually a weak determiner of perceived distance, even at distances of one or two meters. Retinal image size was also found to be one of the most important cues for the judgment of distances; alone it provided approximately the same estimation as binocular disparity together with convergence but was found to have much less power than a full-cue condition (which included accommodation, binocular disparity, convergence, and retinal image size) in determining distance.

Under certain conditions, perception of size and distance may seem to be a single process but may, in fact, be responses to different aspects of the same stimulus situation (McDermott 1968). McDermott conducted an experiment involving size judgments of a standard object made under two comparison field conditions--one with only relative distance cues present and the other with only absolute distance cues present. Absolute cues were those described as supplying information between the observer and the object (accommodation and convergence) while relative cues were those not providing this distance information but rather distance information about difference in distance between one object and another (linear perspective, retinal disparity, interposition, and movement parallax). Size, except in the case of disparity, was perceived in the presence of individual cues to distance in terms of retinal image size. Relative distance cues seemed to have little effect upon size. The difference in distance information available in the two comparison fields appeared to make little difference in perceiving the size of objects.

In a depth discrimination study, which utilized an optically simulated large target located in a textureless environment at simulated distances along the sagittal plane out to 12,800 feet, Vincent et al. (1969) favored a change in retinal image size as the most significant cue to depth localization. It was felt to be doubtful that binocular disparity, which involves differences between the images in the two eyes, played a significant role in the results because the targets were viewed sequentially rather than simultaneously. Comparisons would have to be made from images in the process of being recorded, to a trace of the image which had been made three seconds earlier. While comparisons would not be impossible with regards to disparity, the authors felt it to be highly unlikely, based upon knowledge of the visual system available to them at that time. Therefore, they concluded that comparisons based solely on size changes requiring a comparison of present stimulation with the trace of past stimulation were responsible for the distance perception of the two stimuli.

If an operator is presented with unfamiliar objects in a situation where secondary cues to distance are lacking, e.g., in an otherwise completely dark room, his judgments of size and distance are not reliably related to the actual sizes and distances of the objects. Foley (1968) tested the hypothesis that in stereoscopic vision a perceived size to perceived distance ratio corresponds to a constant visual angle. He found that in the absence of secondary cues, unanalyzed non-stimulus variables, such as an operator's preconception of the range of stimuli that are likely to be presented, appear to exert a major influence on judgments of size and distance, and that the depth/distance ratio increases more rapidly as a function of disparity than does size/distance ratio as a function of visual angle.

Gogel and Mertens (1968) allowed subjects to view monocularly, two luminous rectangles of the same size but with different retinal sizes in an otherwise dark room. The retinally smaller rectangle was perceived as being the more distant rectangle, not as a result of the difference in their perceived size per unit of retinal sizes, but rather as a result of the change in perceived size per unit of retinal size between the objects. The authors further stated that this size cue to relative distance occurs between irregularly as well as regularly shaped familiar objects and probably would occur also between any objects having perceived sizes regardless of their shape or complexity. The use of a comparison field or comparison objects can invalidate the resulting measurement of the perceived distance to objects or the perceived distance between them.

Perception of Motion

The perception of movement in space is a function of the size of the objects and their luminescence as well as their speed and other cues available to the observer (Cratty 1964). It is partly dependent upon the individual's ability to judge time intervals accurately (Cratty 1968).

Position memory is involved in the perception of motion. The observer compares the position of an object at one point in time with his "memory" of its position earlier in time (Kinchlas and Allan 1969). The accuracy of this comparison appears to be limited by "noise" in the observer's eye positioning system, the major components of which are involuntary eye movements and are believed to be cumulative with time. The extent to which noise in the positioning mechanism of the eye would degrade movement discrimination is dependent upon the observer's sense of eye position. If this sense were poor, there might be the possibility of mistaking displacement of a retinal image produced by eye movement with one produced by real movement of the object. Drift adds a constant to the retinal displacement produced by the actual movement stimulus pattern. "Flicks," or "corrective" saccadic movements correcting a displacement of the target from the fovea, in no way reduce the observer's uncertainty as to the cause of a target's displacement, whether this displacement be caused by eye drift or actual movement of the target.

Perception of movement in two-dimensional space is more accurate in the peripheral portions of the eye than within the central visual field. Cratty (1964) attributed this phenomenon to the inherent defense mechanism which is built into the human organism alerting him to danger more quickly as objects usually approach from the sides. Vernon (1962) further explained that as soon as man becomes aware of such movement, he immediately turns his head and eyes until the object's image falls on the center of the retina where it can be interpreted more acutely.

Head movements have been found to be kept to a minimum when tracking fast-moving objects toward the observer (Cratty 1964). At times, balls in sports may approach or retreat too rapidly to be accurately tracked (when functional limitations of the visual system are taken into account (Cratty 1968). As the ball approaches, the angle subtended by the ball at the eye will change at a rate dependent upon the speed of the ball. Estimations of such characteristics may also be affected by the relationship of the moving object to its background (Whiting 1969). The ratio of the distance of the object from the observer and its velocity gives the observer the time taken by the object to reach the observer. Weinberger (1971) also felt that there was sufficient information available on the monocular retina of the observer to make his estimation of the time of juncture with the moving object.

Judgments of velocity depend upon the position and movement of the observer, the perceived distance of the object from the observer as well as the perceived size of the object in motion (Cratty 1964). The more rapidly the objects are moving, up to a point, Cratty (1968) believes the perception of distance of moving objects will improve.

Movement perception denotes perception of a change in position (Kinchlas and Allan 1969). It is not produced primarily by the movement of the images of objects across the retina, as the eyes are always moving to and fro in the head, and thus images of stationary objects are constantly moving across the retina (Vernon 1962). Rather, it is determined mainly by a change in position of objects in relation to their background which appears to be stationary. Vernon (1962, p. 150) also stated that "as with the perception of space, we acquire various concepts of movement associated with particular objects, and ideas about the speed and relative speeds of movements." Thus, we acquire the ability to judge the speed of moving objects with considerable accuracy in relation to their own movements and we learn how to intercept the flight of a ball. If the object moves across a homogenous background, a situation referred to by Kinchlas and Allan (1969) as producing absolute movement perception, its velocity appears to be less than if it were moving across a variegated background. Kinchlas and Allan (1969) would refer to this latter situation as one producing relative movement perception. Due to the lack of stationary figures against which to contrast, the motion would cause the object to be more noticeable and therefore would appear to be moving faster (Vernon 1962).

Gibson (1968) rejected the assumption that displacement of the retinal image over the retina is the basis for all perception of motion. Instead, he proposed a theory in terms of the ambient array of light in which the registering of subjective bodily movements by vision is contrasted with the detection of objective environmental motions. Physical motion is not the same as optical motion. The image is perfectly-stationary, being anchored to the world, and the retina moves relative to the image. The retina is continually moving behind its image. There are two main types of events which have corresponding optical events that could induce an experience of motion or movement if the light entered the eye-motion of the object in the environment and movement of the observer. Any surface or object in the environment reflecting, or emitting, light can move in a variety of ways relative to the permanent environment, thus altering the perspective of its texture and its edges in the ambient light. The important kinds of information the retina seems to record, therefore, are continuous transformations of form and texture and descriptions of texture (the occlusion of transformation), allowing perception of motion to result from something that happens in ambient light, not the motion of light itself over the retina.

Another theory of motion was proposed by Held and Freedman (1963, p. 457): "Initial position and subsequent displacement of the eye geometrically determines certain properties of the ensuing stimulation of the retina of that eye." When the eye rotates about an axis through its center, all imaged points move across the retina at a velocity of rotation of the eye. As the eye rotates toward an external point that casts its image on the retina, all other images' points move radially outward from the central image point originating on the line of translation. There is a one-to-one relation between the directions of translation, movement, and corresponding centers of flow patterns on the retina; hence, for every different direction of translation, the center of radial flow is different.

Dynamic Visual Acuity (DVA) is a term used by Burg and Hulbert (1961) to designate the ability of an observer to discriminate an object when there is relative movement between the observer and the object. They discovered that the relationship between dynamic acuity and static acuity (both tested monocularly) for a target was low; training did not alter this correlation in any way. Acuity for a target was found to deteriorate markedly and progressively as angular velocity of the target increased while DVA performance could be improved both through practice and target illumination, whether it be moving with the subject stationary or vice versa. The importance of static acuity as a determiner of DVA became progressively less as target velocity increased.

One of the earliest studies performed in this area explored the relationships of three variables, brightness, visual angle, and speed of movement. Crook (1937) found that movement discrimination was closely allied to the perception of flicker, but not strictly identical, in their underlying mechanisms. Discrimination of movement was found to be best at relatively slow speeds.

Slater-Hammel (1955) explored the estimation of movement as a function of the distance of movement perception and target distance. Absolute error was found to increase significantly with increases in target distance.

The rate at which an image moves across the retina is a function of the rate at which the object moves across the operator's field and the distance of the object from the operator (Rock, Hill and Fineman 1968). The authors felt that the critical test of size constancy is one in which speed perception is studied under conditions where no frame of reference exists, such as in a totally dark room. It was concluded that wherever size constancy prevails and to whatever degree, speed constancy should also prevail to the same degree. If the speed of the moving object was constant, then the farther away it was, the slower was the rate of displacement of its image.

Van Waters (1934) found that when two lights were presented in a dark room and one light was made to move while the other was stationary, the observer was subject to considerable error in judgment of horizontal motion. Factors found to increase accuracy of this judgment of motion were an increase in speed and fixation of a moving light while factors tending to decrease accuracy were a decrease in speed, fixation of a stationary light, and fixation of a smaller light. One light was perceived to be more mobile (meaning the susceptibility of the light to have an illusory effect--to appear to move, when in effect it was stationary) than the other when it was smaller and it was fixated. Conditions resulting in one light being perceived as increasingly more mobile were: when it was smaller and the speed was decreased, when it was smaller and difference in size was increased, when it was fixated and the speed was decreased, and also when it was both fixated and a small light. No evidence was found to show that practice tended to decrease the illusion. Rather, there was a slight tendency for individuals to make stereotyped judgments and persist in certain errors throughout practice.

Rotary motion can be detected by an operator even when it is superimposed on translational motion (Alexander and Cooperband 1966). Results of their study indicated that the primary cue used in the task was the rate of change of the relative bearing between two moving objects in order to predict their future positions in space. The operator seemed to estimate either the extrapolation distances or extrapolation times of each target from some critical point (such as their point of disappearance) to the intersection point. Any factor making the comparison of these time or distance estimates more difficult (such as increasing the discrepancy of the speeds of the two objects or increasing the intersection angle) increased the error of judgment. Error was also found to be higher for slower speeds than for faster ones.

Muller-Lyer figures were used in a study performed by Cohen (1967) in which he found phenomenal velocity to be closely related to phenomenal space. Both phenomenal motion path length and phenomenal velocity were found to be less in the periphery than on the fovea; vertical motion was experienced as being faster than horizontal motion. A background effected the perceived displacement directly, rather than indirectly, by its affect on perceived velocity. It was concluded that while phenomenal velocity and phenomenal space vary in a similar manner in many situations, the one variable is not directly dependent on the other.

Schmidt (1969) had subjects try to move a slide so that an attached pointer "hit" a moving target. The movement time was varied by having subjects move at maximal or moderate speeds, by changing the starting points, and by adding or not adding an additional load to the task. Knowledge of results was provided. Factors affecting movement time partially determined timing accuracy. Responses were found to be preprogrammed and subjects tended to hold movement time constant and correct the error on the previous trial by adjusting the starting time. Schmidt concluded that task characteristics affecting the size of the movement time may be significant determiners of timing accuracy.

Visual Perception and Athletes

Cratty (1968) observed that it is difficult to determine whether perceptually superior people enter athletics or whether participation in certain sports enhances certain perceptual attributes. He made this statement based on the knowledge that measureable perceptual differences have been identified between athletes and non-athletes. He further hypothesized that it would seem possible to improve the perceptual capacities of athletes in various ways.

Studies relating visual perception to motor performance are not numerous, however. Sage (1971) attributed this to the fact that measures used to ascertain visual perception in a laboratory setting are highly artificial in comparison to the dynamic situations found during motor performance when visual perceptions must normally be made. Contrived situations are virtually not found in sports. Laboratory tests of depth perception, for example, often show little relationship with dynamic situations, due to the variety of depth cues available in real life which cannot be replicated in isolated testing.

Banister and Blackburn (1931) were concerned with the "good eye" phenomenon that is usually associated with some proficiency in games involving fast-moving balls, realizing that the ball must be hit with speed and precision either by the hand itself or by an instrument held in the hand. The authors concluded that this "phenomenon" is not really a true eye factor at all. It seemed to be independent of visual acuity since many of the best ball players observed by the authors were found to have an acuity far below normal. Rather, the "good eye" was felt to be dependent on a very high innate visuo-muscular coordination. Only one of the elementary "true eye" factors tested gave positive results, the inter-pupillary distance (IPD). The authors described its possible importance with the assertion that the wider apart the eyes, the greater will be the disparation of the two retinae, with a consequent increase in the ability to judge the relative distance of objects. Subjects' IFD's were measured to the nearest mm and compared to their subjectively rated ability at games. Those with the greater distance between the pupils, on the whole, were the better players.

Accommodation (the ability of the eye to adjust its focus to various distances) was measured by Graybriel,Jokl and Trapp (1955) in well-trained athletes. No deviations from the normal standards were found. When ocular muscle balance studies by the same researchers were conducted on individuals, "champion" athletes were found to have a more perfect eye-moving apparatus than non-athletes. The presence of orthophoria (the ability to fuse into a single visual picture two images of the same object as viewed by both eyes) in champion athletes at rest as well as after strain was felt to reflect an innate ability and to indicate an aptitude for the sports under reference. Changes in ocular muscle balance were less marked following canoeing, swimming, and track races than after playing basketball and volleyball. The data led the authors to conclude that the effect of exercise on the motor control mechanisms of the eye differs between sports that require repetitive action and play activities which are characterized by a continuous sequence of unpredictable situations, necessitating a more frequent oculo-motor adjustment. As a group, more skillful players were also found to perceive depth more accurately than the non-skilled group.

Olsen (1956), on the other hand, concluded that psychological capacities of reaction time, depth perception, and span of apprehension when compared to certain sports of varsity athletes had very low correlations. Baseball skills correlated by means of a Pearson r statistical test with the psychological capacities were accuracy throw, distance throw, base running speed, and batting average for the season. Correlations ranged from a -0.075 for depth perception and the baseball skills to a +0.496 for choice reaction time and the baseball skills. However, when the same psychological capacities were tested on three groups of college males who were designated as either athletes, intermediates, or non-athletes, and not correlated to actual motor performance in a specific sport, significant differences were found among the three groups. Athletes were found to be superior to non-athletes in all three tests and were also found to be superior to intermediates with reference to reaction time.

The Perceptual Skill of Batting

The player in a ball skill situation must initiate his response one reaction time plus one movement time before the ball is in a position for hitting or catching. Whiting (1969), in further reference to the phenomenon which is called transit reaction time, stated that this reaction time will be more critical in fast ball skills than in ball skills of a slower pace. Apparently there is a reasonable range over which the reaction time may vary without generally upsetting the skill, allowing the player to be successful without requiring his timing to be 100 percent accurate since there is usually a "degree of error" possible.

According to Whiting, players with faster reaction times can, if they wish, let the ball travel farther before initiating an action. Theoretically, then, the batter can use the additional time to monitor other aspects of the display, waiting for later deviations in the ball's flight and thus react more adaptively.

Miller and Shay (1964) tested nine male softball pitchers for speed and found an average ball velocity of 59.95 mph (88 feet per second). Because of the shorter pitching distance in the game of softball as compared to baseball, it was conjectured that the softball batter must react and bring the bat over home plate in less time. Of the 258 male freshmen tested as to when they would initiate their swing while watching the aforementioned pitchers, a mean reaction time of .215 seconds was found. These averages would find the ball 29.33 feet from home plate before 116 of the students began their swing and in 41 cases the ball would be less than 20 feet from the plate. It was concluded that those subjects would have sufficient time to bring the bat over the plate with this caliber of pitcher but would be unsuccessful because of their reaction time if facing a softball pitcher with greater velocity.

Breen (1967) concluded from his cinematographic analysis that one characteristic outstanding hitters seemed to have in common was their ability to adjust their head from pitch to pitch in order to get the best and longest possible look at the flight of the ball. These head adjustments were small and could not be detected with the naked eye when viewing the hitter. However, as viewed from the film records, good hitters were making constant adjustments to accomplish proper fixation upon the point of delivery and to get both eyes focused on the ball longer. By reducing the angle at which he saw the ball, the batter was able to observe it from an eye position similar to that of the catcher. Based on his findings, Breen (1967) concluded that the smaller the angle between the hitter's line of vision and the flight of the ball, the better the hitter perceived the ball.

Pursuit movements of the eyes with the head essentially fixated were found by Hubbard and Seng (1954) to be used in tracking a pitched ball. In no instance was the ball able to be tracked clear up to contact with the bat. The tracking movements of the eyes stopped while the ball was still 8 to 15 feet from the plate. The authors offered two possible explanations for this finding: since the lack of additional useful information could not be provided by further tracking the ball once the bat was underway, the tracking stopped; or possibly tracking ceased because pursuit movements of the eye actually break down at such relative velocities. Hubbard and Seng (1954) did caution the reader that this finding should not mean that in the teaching and coaching of batting, tracking the ball for as long as possible should be minimized. The performer might run the risk of not tracking the ball long enough in order to make the necessary predictions.

By giving learners the cue, "Watch the ball," Whiting (1969) felt that it would appear that the eyes are being used to obtain information enabling the batter to anticipate both spatially and temporally future behavior of the ball prior to its accurate interception by a limb or an extension thereof. This appears to agree with the findings of Hubbard and Seng. Yet, McCord (1969) indicated that perfect eye focus on the ball must be maintained during the entire swing, keeping the eyes in focus as much as possible on the ball hitting the bat. He did admit, however, that this is practically impossible to do. However, if the "blur" can be seen, correct eye focus for the batter can be assured. Hubbard and Seng (1954) admitted that although they did not find any evidence in their study that the eyes were focused on the ball at contact, and although it seemed unlikely, there might be very special circumstances under which it would be possible to track the ball to contact on certain pitches. Another possible explanation would be that either accurate prediction of the ball's path and sensory cues from bat contact might be merged to form the illusion of "seeing" the ball hit and "knowing" where it would go.

"Athletes are coached in everything but their most important asset, vision" (Weiskopf 1975, p. 18). He also claimed that in order to hit a baseball sharply and consistently, the ability to focus, converge, and control the eyes individually and together are equally important. Hubbard and Seng (1954) found that there was no direct evidence of convergence in the batters used in their study, but rather there was evidence that the eyes appeared to change from near to distant focus as the ball approached. These eye control factors, when combined with visual perception of depth, motion, form, direction, and the perception of time, will function together efficiently. Then and only then, can a hitter bring his natural physical abilities to their maximum effectiveness. Winograd (1942), in comparing high school players, college varsity players, rejected college candidates, and non-athletes, found superiority evidenced in varsity players over non-athletes, found superiority evidenced in varsity players over non-athletes in choice and directed timing tests. He found no significant correlations between vision and timing tests and batting criteria of batting average, slugging average, and runs batted in. He concluded that other factors, such as muscular strength, correct stance form, and proper mental attitude are probably developed to a greater degree in compensation for visual inferiority.

Slater-Hammel (1960) concluded that it takes time for a stimulus to activate a sense organ. The athlete, therefore, needs to anticipate in order to keep up with the present. In order to do this, he uses experience from the past and he extrapolates from the immediate present so that he can meet the present-to-be. The batter will be able to hit the ball because he is able to anticipate both when it will reach the plate and where it will be when it reaches home base. His degree of success depends on his ability to estimate internal and external conditions. Weiskopf (1975) added that in order for a ball player to play his best he must be physically relaxed. Increased tension will cause the player to over-swing or body tightness may disrupt his timing. This increased energy output shifts automatically to body awareness, rather than concentrating on the ball flight. A hitter will see the ball best when he is relaxed.

Summary

Research in the area of visual perception and its possible implications to the visuo-motor skill of batting was reviewed. The general topic of visual perception was divided into subtopics for purposes of discussion.

Selective attention to certain cues in the environment was found to be necessary in the performance of complex motor skills. Due to limitations of the neural mechanism which place restrictions on the speed with which items of information can arrive, the individual filters and selects one channel of information at a time.

A psychological refractory period, or central time-lag, has been found to occur when two stimuli are presented too close together. The necessity for an athlete to plan ahead both in terms of the likelihood of certain events occurring and in terms of determining which motor patterns may be required was stressed.

Anticipation-Prediction was suggested as one means by which humans make it possible for information necessary for subsequent actions to arrive while other actions are being carried out.

The perception of space and depth are interdependent. Since space is three dimensional and no aspect of the retinal image directly reproduces perception of this third dimension, monocular and binocular cues to its inference were suggested.

Several theories on the perception of motion were presented. Position memory, retinal displacement produced by a movement stimulus pattern, change in the retinal image size caused by the angle at which objects approach the observer, and a theory in terms of the ambient array of light in the environment were suggested as possible explanations as to the means by which man perceives motion.

There is some controversy present today as to whether perceptually superior people enter athletics or whether participation in certain sports enhances certain perceptual attributes. Research in this area is difficult to interpret as the athlete must be taken out of his environment and tested in isolated situations which may lack certain perceptual cues upon which he normally bases his decisions. An athletic display is constantly changing; such as "uncontrolled" display is not feasible when scientific research. These "deficiencies" should be considered when drawing conclusions from statis testing situations to dynamic performance.

Studies attempting to provide insight into perceptual characteristics of outstanding hitters were reviewed. The head was found to adjust from pitch to pitch, but was fixated during actual tracking movements of the pitched ball. Batters were also found to be unable to follow the ball clear up to its actual contact with the bat. Some controversy was found to exist as to whether the eyes converged on the moving ball throughout its entire flight path. The batter must be physically relaxed in order to control his concentration in order to observe the ball rather than having his concentration shift to body awareness.

CHAPTER 3

DESIGN OF THE STUDY AND PROCEDURES USED

The purpose of the present study was to examine the relationship between batting ability and perceptual capabily. The interaction between two skill levels of female batters' predictions on the Motion-Perception Analyzer, as well as the length of the viewing period of the moving object on which to predict its collision with the stationary target, were the objects of statistical analysis.

Test administration procedures for both the batting pre-test and the perceptual-prediction task, plus statistical treatment of the data obtained from both tests are presented in this chapter.

Subjects Participating in the Study

The subjects selected for the present study were college women enrolled in beginning and intermediate level softball classes and members of the varsity and junior varsity women's softball team at The University of Arizona during the second semester of the 1974-75 school year. A batting pre-test was administered to all those who were enrolled in softball classes or who qualified for one of the two softball teams. In all, 140 beginning, intermediate, and team members were tested. From the 26 high scores on the test (ranging in test values from 46-55, 0.95 to 1.81 standard deviations above the mean of 35.99, 15 "highly-skilled" subjects were randomly selected. Fifteen "low-skilled" subjects were also randomly chosen from the 24 low scores on the test, with values that ranged from 2-28, 0.76 to 3.24 standard deviations below the mean of 35.99 (see Appendix C). The subjects chosen ranged in age from 18-21, with an average age of 19.04 and a standard deviation of 1.11 years. Most of the subjects selected were second semester freshmen who were enrolled in physical education classes in order to fulfill the two unit requirement of the university, with the exception of softball team members and physical education majors and minors. Appendix F contains information concerning class or team assignment (i.e., beginning, intermediate, varsity, or junior varsity), ages and scores on the batting pre-test of the subjects who were further tested on the Motion-Perception Analyzer.

Securing Permission and Cooperation of Participants

The investigator obtained the permission of these physical education instructors who were teaching either a beginning or intermediate level softball class during the second semester of the 1974-75 school year, to individually test each student's batting ability. For comparison purposes, varsity and junior varsity women softball team members for the 1975 competitive season were also administered the batting pre-test. The instructors, coach, and students were all very cooperative, both during and after the administration of the test. As the investigator tested the students at a time in the semester when the teacher was administering other skills tests, the batting test was easily incorporated into the day's lesson plan.

Once chosen to be a subject, the student was contacted individually during her next class period and a testing time and date for the perceptual-prediction task was arranged that was convenient for the student, the investigator, and the researcher's assistant.

Description of the Pitching Machine

The model of the pitching machine used in the administration of the batting pre-test was entitled "Jugs Junior" and manufactured by JoPaul Industries (Figure 1). The machine was approximately four and one-half feet tall. A rubber wheel was located atop the tripod base, and revolved when the machine's electrical circuit was activated. The softball was placed through the chute where it was seized between a curved pad and the clockwise-revolving wheel; the machine was only capable of throwing straight balls at a speed that was selected by the operator, the calibration being in feet per second.

To aim the pitch, the feeding chute was rotated either up or down in order to correct for high or low pitches, and then locked into position with the T-handle bolt. In making side-to-side adjustments (inside-outside pitches), the upper portion of the machine was rotated and locked in place with the T-handle bolt at the hub. Thus, the machine could be adjusted easily for batters of different heights to insure pitching strikes. The strike zone in fast pitch women's softball is between the batter's shoulders and knees and covers every corner of home plate.

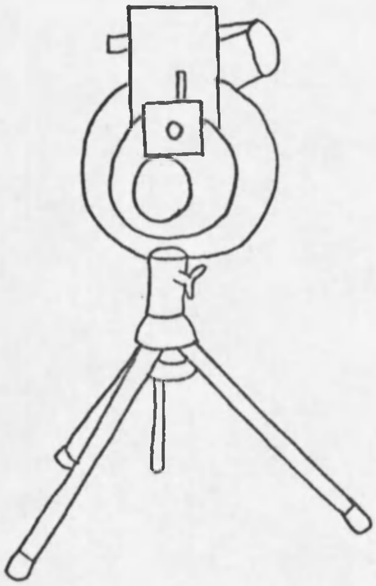

Figure 1. Jugs Junior Pitching Machine.

The Batting Pre-Test

Administration of the Batting Pre-Test

The investigator contacted each softball instructor individually and selected dates for test administration that would be convenient with the instructor and that would not disrupt normal class procedures. One scoresheet per class was filled out prior to attending class with each student's name listed alphabetically on the sheet.

The speed of the machine was set at 55 on the Jugs Junior machine scale and checked frequently throughout the class period to insure that each student's pitches were the same speed. The speed was chosen as 55 as it was a comparable speed to that which had been clocked previously as to the velocity of the pitch being thrown by the fastest varsity pitcher. Prior to testing, the investigator clocked, with a calibrated three-second sweep stop watch, ten pitches by the machine at a distance of 50 feet from a wall. The time clocked was from the moment the ball was fed into the machine, until it hit the wall. The values obtained are presented in Appendix B. The highest and lowest values were discarded and the remaining eight averaged to give the approximate pitching speed of 50.42 feet per second at machine setting 55. It was decided that this was a desirable velocity since this would be challenging for varsity players yet reasonable for the beginners.

The investigator introduced herself to the class and explained to the students that she was performing a study on the perceptual-prediction ability of female college softball batters and was administering a batting pre-test to all members of softball classes and team members in a search for 15 highly-skilled and 15 low-skilled softball batters. It was further explained that the subjects would be randomly selected from the highest scores and lowest scores on the test and would be asked to participate in further testing that would take place in the Motor Performance Laboratory. If they did not feel that they had the time to devote to possible further testing, they were asked not to participate in the pre-test. Every student in the classes participated.

The batting pre-test instructions were then read to the students as a group (see Appendix A). The softball diamond was divided into different point value divisions. The areas were shown to the students and scoring procedures for the test were explained (see Figure 2 for diamond markings). Of the 20 pitched balls for each batter, 0 points were awarded for a swing and a miss, or for no swing at all (batters were instructed to swing at every pitch); 1 point was awarded for a ball whose first bounce was within the ten-foot radius circle around home base; 2 points were awarded for the ball's first bounce being within the half-moon between first and third base and the plate, whether the ball was fair or foul; and 3 points were awarded for the ball's first bounce in the area beyond the first base-third base half-moon, fair or foul.

One of the students was selected as the recorder. She stood by the investigator at the pitching machine (this position was rotated around to other class members as well). The batter received three pitches to begin with, and was told not to swing at them. These pitches were delivered for the purpose of checking to see whether or not the ball was passing over the plate and within each batter's strike zone. The batter

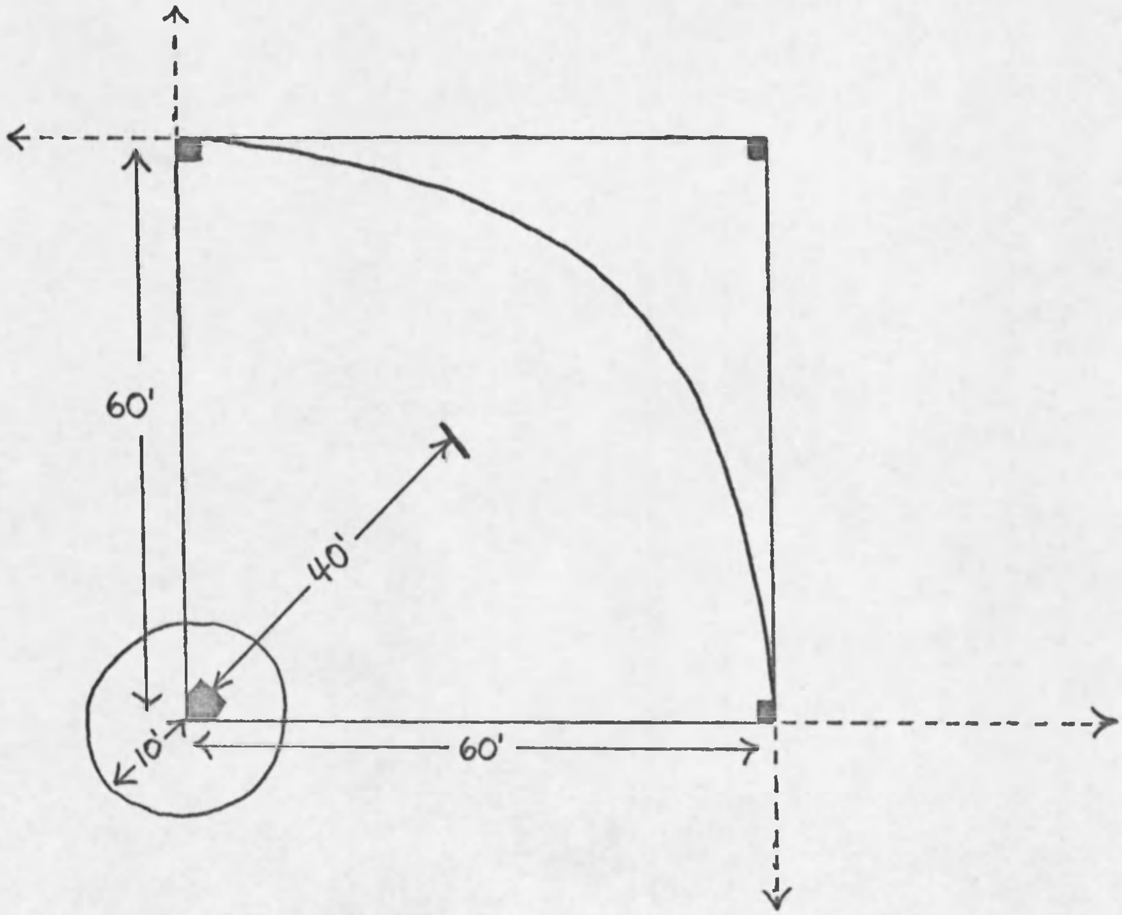

Figure 2. Field Marking for Batting Pre-Test.

also was able to observe the way in which the investigator "presented" the ball to her before feeding it to the machine, and the speed with which the machine "pitched" the ball.

After "taking" the first three pitches, the batter stepped into the box and was pitched 20 balls in succession. Each ball was "presented" by the investigator before it was fed into the machine. If a pitched ball was out of the batter's strike zone, the pitch was disregarded and another ball was delivered to the batter to take its place.

Scoring the Batting Pre-Test

Each batted ball of the 20 pitches was allowed to hit the ground first before being fielded and returned to the feeder/investigator. The ball's score was called aloud and the recorder marked the score in its appropriate box on the scoresheet. The batter was told when she had approximately three or four of her allotted 20 pitches remaining. Two days were required in order to test all members of the class.

Once everyone had completed the test, the point total for the 20 pitches was added and tallied on a master sheet. The scores ranged from 55 (of a possible 60) to 2, with the over-all group mean being 35.99 and a standard deviation of 10.49. From the 26 highest scores over-all, ranging in point value from 46-55, 15 highly-skilled subjects were randomly selected. From the 24 lowest scores, which ranged in point value from 2-28, 15 low-skilled subjects were randomly selected. These 30 subjects were to be further tested on the Motion-Perception Analyzer for their perceptual-prediction ability.

Description of the Motion-Perception Analyzer

The Motion-Perception Analyzer was designed by Morris (1972) as a testing instrument that would present the subject with a visual display of moving objects in three dimensional space. For the purpose of the present study, the investigator adapted the device's original testing task (performed by Morris (1972) to one that would require the subject to make a prediction based upon her perception of a moving object and its eventual collision with a stationary object. A picture of the testing device is presented in Figure 3.

The machine was divided into two chambers: the front chamber facilitated the subject's viewing of the three-dimensional display. The rear chamber contained nine moving objects, the size of table tennis balls (1-1/2 inches in diameter) which traveled on designated pathways. Nine object shields were also designed to prevent the subject from viewing the objects and also to provide a storage place for the objects when they were not involved in the subject's visual display.

The present study involved only one of the moving objects. The moving ball utilized originated from the right back corner of the rear chamber and moved from this starting position toward a stationary target that was placed at the end of its pathway (Figures 4 and 5). The target was 1-7/8 inches in diameter and had a hole in its center through which the string, which facilitated the ball's movement, passed. The target was placed at an angle so that the subject could perceive it as being at the end of the diagonal pathway on which the ball was moving. The center hole assured that the ball's movement would not be impaired through

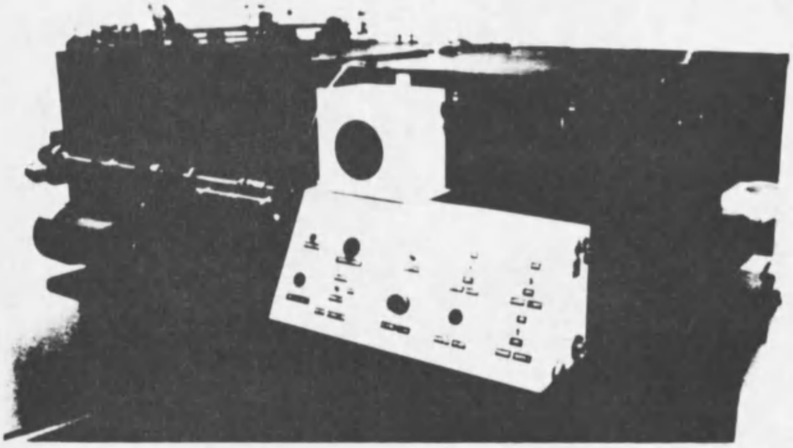

Figure 3. The Motion-Perception Analyzer. -- Taken from Morris (1972), with courtesy and by permission.

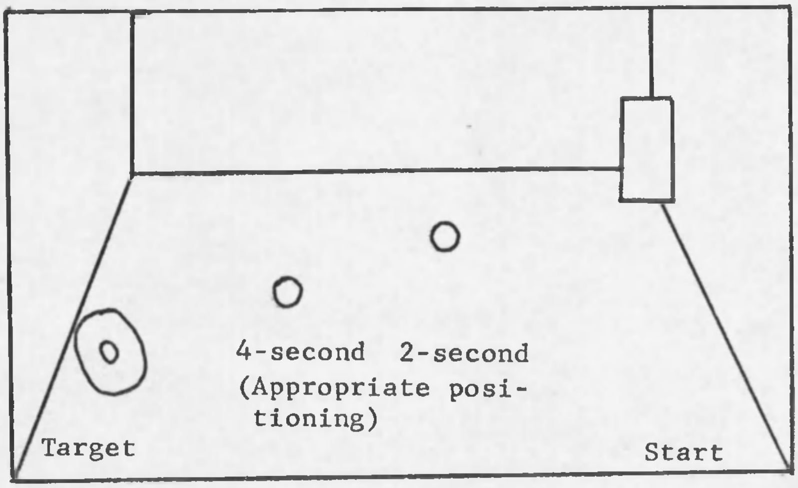

Figure 4. Schematic Drawing of the Viewing Display of the Prediction Task on the Motion-Perception Analyzer.

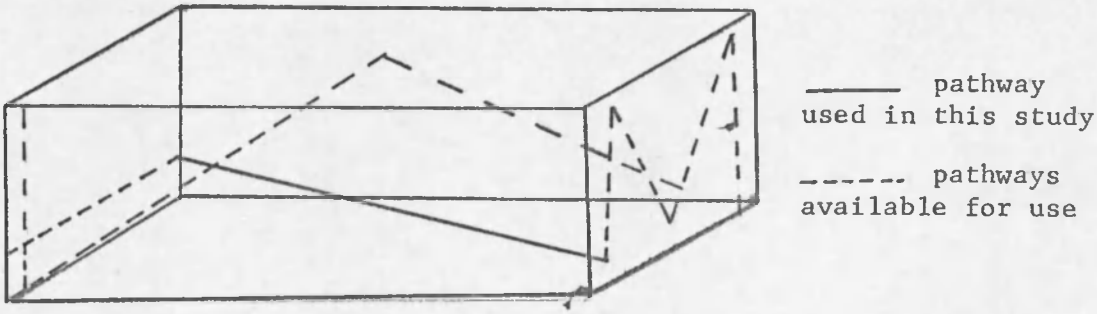

Figure 5. Side View of the Motion-Perception Analyzer.

contact of the cardboard target with the string. The moving ball's pathway was 3-3/4 inches above the floor of the rear chamber and parallel to it.

Black lights lit up the interior of the rear chamber. The chamber walls and object shields were painted with flat black paint. The target and moving objects were fluorescent so that only they were visible in the display window.

A dividing screen could be dropped directly in front of the subject's view. During the testing procedures, this screen was used as a means by which the subject's view of the moving object was blocked after the allotted time of its viewing.

Driving mechanisms, by which the machine was controlled, were attached to the outside of the machine (Figure 6). A variable speed motor, drive shafts and drive wheels, and thumb screws activated the moving objects. These were attached to the side and top of the Motion-Perception Analyzer. The moving objects were attached to black nylon thread. Their initial movement was accommodated by manual manipulation of the location of the objects in the proper starting positions. Painted marks on the thread and exterior of the instrument assured consistent origins for the moving object once aligned. Tension was then exerted on the thumb screw. When the motor was activated, the thread moved over the drive wheels, causing the moving object in the rear chamber to begin on its pathway towards the stationary target.

A control panel was located on the front half of the side of the Motion-Perception Analyzer (Figure 6). Electrical operation of the

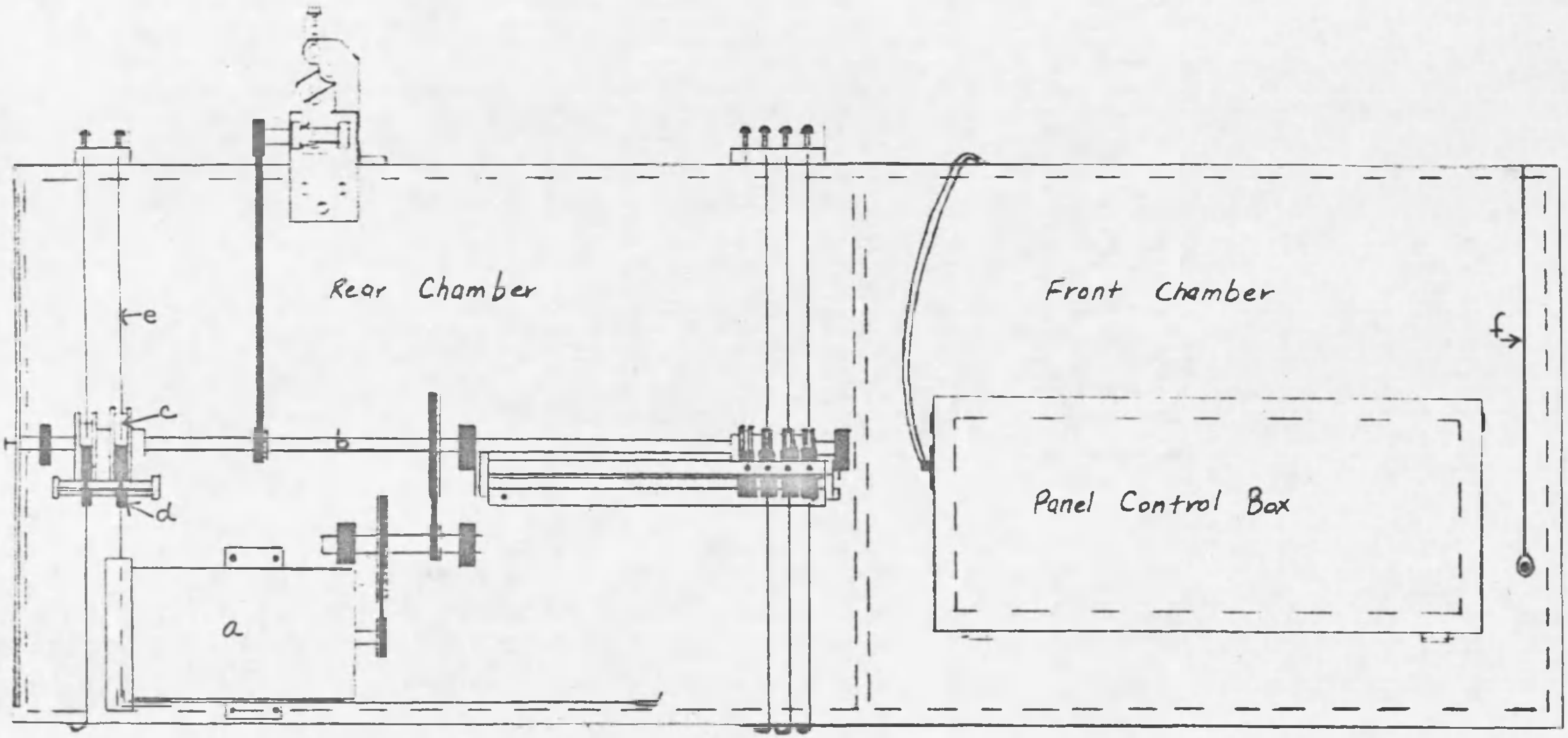

Figure 6. Side View of the Motion-Perception Analyzer. -- (a) Speed motor, (b) drive shafts, (c) drive wheels, (d) thumb screws, (e) thread (black nylon), (f) cord for the dividing screen. Taken from Morris (1972), with courtesy and by permission.

machine was controlled here. The moving object could be started and stopped and its velocity regulated. The cord for the dropping of the dividing screen was located to the right of the control panel.

A viewing window was located at the front of the machine. The subject's response to the task was monitored by her pressing of a response button located at her lower right, near the base of the machine.

Operational Responsibilities of the Research Assistant

The presence of one research assistant was necessitated in order to operate the perceptual-prediction task on the Motion-Perception Analyzer. He was stationed at the instrument's rear chamber throughout the testing. His responsibility was to manually position the moving object for the perceptual-prediction task. After the subject had performed the task, he would relocate the object to its starting position behind the storage location. He would then apply the necessary tension to the thumb screw which would cause the thread to move along the drive wheel resulting in the object's motion. Consistency in the tension applied to the thumb screw was crucial for the task's test reliability. Therefore, a mark was placed on the screw by which it was aligned for each task, in an attempt to hold the ball's velocity constant throughout each subject's testing.

Operational Responsibilities of the Investigator

An individual scoresheet for each subject was prepared on which the random order of viewing times of the moving object had been listed.

The investigator initiated the movement of the object by engaging the button located on the control panel of the testing instrument. A stop watch with a three-second sweep, which had been calibrated one month before the testing began, was placed atop the machine within the investigator's sight. One second before the task was to begin, the subject was alerted. As the starting button was pushed, the shutters of the viewing window were opened and the object began to move toward the stationary target. The subject was allowed to see the ball for either 2-, 3-, or 4-seconds of viewing times, depending on which trial was involved. At the end of the allotted viewing period, the dividing screen was dropped, blocking the subject's view of the moving object (Figure 4). As soon as the viewing screen had been dropped, the research assistant loosened the tension on the drive wheel, causing the object to stop its motion. This action prevented possible damage to the instrument should the subject mak make a late prediction, which would cause the ball to collide with the wall of the instrument. Such an action had no repercussion on the subject's prediction as the object was no longer within her visual display. The subject was instructed to push the response button at the precise moment that she predicted the moving ball would collide with the stationary target. As soon as she pushed the response button, the time clock was stopped, the viewing windows were closed, and the investigator flipped the switch, deactivating the testing device. At this moment, the investigator read the prediction time from the Dekon Timing device and recorded it on her data sheet. This prediction time was recorded as the subject's prediction of the moving ball's collision with the stationary target. The timer was reset and the next trial of the perceptual-prediction task was ready to be performed.

Calibration of the Motion-Perception Analyzer

The time required for the moving ball to travel the distance from its origin to the stationary target, was of utmost concern for it provided the basis for scoring of the prediction task. Therefore, it was imperative that every precaution be taken to hold the velocity of the moving object as constant as possible.

Prior to each testing session, the motor was "warmed up," as it was discovered that the moving object had a tendency to travel the distance faster after the Motion-Perception Analyzer had been in operation for awhile. The investigator and research assistant calibrated the testing instrument. This procedure involved the investigator seating herself at the viewing window as if she were a subject. She could operate the device from this position. When the object was in its starting position and proper tension had been applied to the drive wheel, the system was activated. The moving object was allowed to travel the distance towards the target. When it had reached the target, the response button was pushed and the time recorded from the Dekon timer. This procedure was followed for seven trials or until seven trials of similar times were recorded. The longest and shortest traveling times were discarded and the remaining five averaged to give the Actual Prediction Time. The same procedure of calibration was executed following the subject's completion of the testing session. The Actual Prediction

Time before the testing session were averaged to provide the Mean Prediction Time (MPT) on which the scoring of the prediction task was based.

Every attempt was made to keep the time required for the object to travel the distance similar for all 28 subjects. The mean distance time for the 28 testing trials was 5:407 seconds with a standard deviation of 0.149 seconds. The range of travel time was from 5:227 to 5:769.

Administration of the Perceptual-Prediction Task

The perceptual-prediction task on the Motion-Perception Analyzer was administered individually to each subject by the investigator and one research assistant. The conditions surrounding the testing situation were kept near constant for all subjects. No one was allowed into the Motor Performance Laboratory during the testing session in order to maintain as quiet an atmosphere as possible, one that would be conducive to concentration on the prediction task.

Before each subject arrived for her scheduled testing, the testing instrument was calibrated so that the time for the ball to cover the distance was relatively constant for each subject. Each subject was given five trials at 2-seconds of viewing and five trials at 4-seconds' viewing of the moving object before her vision was blocked. To control any learning that might be involved from the order of viewing time, the order of the ten total viewing times was randomly assigned for each subject, before her arrival.

Once the Motion-Perception Analyzer was calibrated, the subject was summoned to enter the testing room. She was seated at the instrument's viewing window. Her age was recorded on the scoresheet. She was then asked whether or not she wore corrective lenses and if so, was she wearing them at the time she would be participating in the present study. It was the investigator's desire to have the subject perform the prediction task under identical visual acuity conditions as she had performed the batting pre-test.

The subject was trained on the testing instrument's procedures immediately before performing the perceptual-prediction task. Instructions were read to each subject in order to insure identical training sessions for all subjects (see Appendix D for complete instructions). During the training sessions, five trials at 3-seconds of viewing time on which the subject based her prediction of collision were provided. The subject's prediction times were read from the Dekon Timing device and recorded on the scoresheet by the investigator between each training trial. Feedback as to how close to the actual time the subject had predicted was not provided for the subject neither during the training nor the testing session. (A sample scoresheet may be found in Appendix E.)

Once the training trials were completed and any questions answered, the actual testing began. Procedures were identical to those of the training session, except the subject was allowed five trials of 2-seconds' and five trials of 4-seconds' viewing time on which to base her prediction. The order of viewing times was randomly assigned to each subject. She was not told before the trial began how long she would be allowed to see the ball; she was only told which trial number it was. Each trial was preceded by the investigator's command, which was given approximately one second before the trial was to begin.

Testing Trial #_____, to begin now . . . .

After each trial was completed and before the next one began, the investigator recorded the time from the Dekon Timing Device onto the subject's scoresheet.

The total training and testing session lasted about ten minutes. After the completion of the entire session, the subject was allowed to see her prediction times and to compare them with the actual predicted time that had been determined before the session began. Once the subject left the testing area, the instrument was again calibrated by the investigator and the research assistant to note any change in actual prediction time for the moving ball to reach the stationary target.

Scoring the Perceptual-Prediction Task

The pre-testing session Actual Prediction Time was averaged with the post-testing session Actual Prediction Time to supply an average estimate (MPT) of the amount of time required for the moving ball to traverse the distance to the stationary target. The MPT (Mean Prediction Time) was used as the comparison time for scoring purposes, as it accounted for any inconsistencies in the Motion-Perception Analyzer that might have occurred during the testing session.

In the measurement of motor performance where the individual must produce a given response at the proper time, accuracy may either be measured on a pass/fail basis or by assessing the nature and amount of the error. Schmidt (1975) suggested a more sophisticated level of scoring than merely awarding a pass/fail, one that estimated the subject's error according to its (1) average magnitude via the constant error, (2) the average inconsistency in producing the movements via variable error, and (3) absolute error.

Constant Error (CE). The subject's prediction time was recorded by the investigator from the Dekon Timing device during the testing session. This time was later compared to the MPT. If the correct response (the MPT) were allowed to represent zero, an early prediction made by the subject would result in a negative constant error and a late prediction would be scored as a positive constant error. The five constant error scores were then averaged for each viewing period and provided the investigator an estimate of the subject's Mean Constant Error ($\overline{CE}$).

For example, to score low subject 4's prediction scores for the 2-second viewing periods, the following calculations would be carried out:

Subject's Prediction Scores		MPT		CE
4:79	-	5:25	=	-0.460
5:43	-	5:25	=	0.180
4:98	-	5:25	=	-0.270
5:44	-	5:25	=	0.190
4:29	-	5:25	=	-0.960

$$\overline{CE} = \frac{(4{:}79-5{:}25) + (5{:}43-5{:}25) + (4{:}98-5{:}25) + (5{:}44-5{:}25) + (4{:}29-5{:}25)}{5}$$

$$\overline{CE} = -0.264$$

The signs of all five responses were taken into account when the scores were averaged and the $\overline{CE}$ carried the sign as well. This score told the investigator how the subject tended to respond, whether her predictions were early or late on the average.

<u>Variable Error</u> (<u>VE</u>). This score provided the investigator with a score that was more sensitive to the subject's inconsistency with respect to her own mean performance. It reflected the extent to which she tended to repeat her responses, or conversely, the extent to which she was inconsistent in her responses. Schmidt (1975, p. 29) defined it as the "variability of the subject's sensitive to the amount the subject varied within herself. The variability is expressed as a standard deviation of the subject's score computed over the five trials for each viewing period.

$$VE = \sqrt{\frac{\sum_{t=1}^{n} (X_t - \overline{CE})^2}{n}}$$

t = trial number

n = number of trials (5)

X_t = signed score for trial t

$\overline{CE}$ = subject's mean constant error for the group of trials in question.

For example, using the same values as in the constant error example:

$$VE = \frac{(-0.460 - (-0.264))^2 + (0.180 - (-0.264))^2 + (-0.270 - (-0.264))^2 + 0.190 - (-0.264))^2 + (-0.960 - (-0.264))^2}{5}$$

VE = 0.1852

<u>Absolute Error</u> (<u>AE</u>). Absolute Error, as with Variable Error, provided a score that was more sensitive, than was the Constant Error score, to the inconsistency of the subject in trying to achieve consistent responses. This measure of inconsistency has been widely used as a measure of error. It is literally "the average amount by which the subject was in error" (Schmidt 1975, p. 29). It is computed as the average difference (ignoring the direction of error) between the subject's prediction and the MPT. For illustrative purposes, once again using the same subject's prediction times:

$$AE = \frac{|4:79-5:25| + |5:43-5:25| + |4:98-5:25| + |5:44-5:25| + |4:29-5:25|}{5}$$

AE = 0.412

The Absolute Error indicated to the investigator that on the average, the prediction was 0.412 seconds off the MPT, but it did not indicate whether the responses were early or late predictions of collision with the target (see Appendix F for each subject's $\overline{CE}$, VE, and AE scores).

Subject Mortality in Testing

Thirty subjects were originally selected through the use of random selection procedures. However, during the course of the actual testing, one low-skilled subject failed to report for her testing session. She was called by the investigator and a new testing session was scheduled, for which she again failed to keep her appointment. When the investigator telephoned her to possibly schedule a third testing session, she was told that the subject had already gone home for summer vacation.

Since the statistical program used in the analysis of the data would not facilitate cells of unequal sizes, one highly-skilled subject's data had to be discarded. High Subject #1's data was questionable as the investigator and her assistant had had trouble calibrating the testing instrument for that particular session. Therefore, it was decided to disregard her data in order to keep the cells of equal size and not to invalidate the highly-skilled group's scores.

Experimental Design

The design of this study contained two factors: skill level and viewing time. Skill level of the subjects was not randomly assigned, but rather was pre-determined by achievement on a batting test given to a population of softball players in activity classes and team participants at The University of Arizona during second semester, 1975. Viewing time was a repeated measure as each subject was given test trials for both 2-seconds' and 4-seconds' viewing time. Each viewing time was expressed in three different ways, by the computation of three different error scores--Average Constant Error, Variable Error, Absolute Error. The experimental design is schematically represented in Figure 7.

				Viewing Time	
				2-Seconds	4-Seconds
Skill Level	Low	Low	1 14	Error Scores*	Error Scores*
	High	High	1 14	Error Scores*	Error Scores*

* This design was used to perform three separate analyses: one for each of three types of error scores--Mean Constant Error, Variable Error, and Absolute Error.

Figure 7. Model of Experimental Design.

Statistical Procedures

Once the test had been scored, the resulting data were analyzed. A statistical test for two-way analysis of variance was used to test the main effects and interactions of the two factors, skill level and viewing times for the three variables of scoring, $\overline{CE}$, VE, and AE. Statistical program ANOVA 45, which was available through The University of Arizona Computer Center, was used to compute the comparisons of interest between the variables.

Summary

This chapter was concerned with the subjects and procedures involved in the undertaking of the present study. All subjects were obtained through beginning and intermediate softball classes and varsity and junior varsity women's intercollegiate softball teams. They were classified as highly-skilled or low-skilled according to performance on a batting pre-test.

Subjects randomly selected were further tested on the Motion-Perception Analyzer. The test was administered individually to each subject by the investigator and one research assistant. The testing conditions were held nearly constant for all subjects.

A two-way analysis of variance statistical test was computed for subjects' scores of Average Constant Error, Variable Error, and Absolute Error.

CHAPTER 4

ANALYSIS OF THE DATA AND PRESENTATION OF THE FINDINGS

The research hypotheses for this study stated that highly-skilled softball batters would perform a prediction task on the Motion-Perception Analyzer significantly better than low-skilled batters and that both highly-skilled and low-skilled batters would perform the task significantly better after a 4-second viewing period than after a 2-second viewing period. The present chapter includes the results of the statistical analysis of the data and a discussion of the results as they apply to the stated hypotheses.

Results of the Batting Pre-Test

The distribution of scores for the batting pre-test may be found in Appendix C. Based on the results of the pre-test, the 140 subjects tested were divided into three groups--highly-skilled, low-skilled, and moderately-skilled. However, this latter group was of no interest to the present study. Means and standard deviations and size of the total population sampled as well as that of the two skill levels of concern are presented in Table 1.

A student's t-test was run to determine whether or not there was a statistically significant difference between the means of the highly-skilled and low-skilled subjects. The test yielded a t-statistic of

Table 1. Means and Standard Deviations and Range of Scores for Batting Pre-Test Scores.

Group	N	Mean	Standard Deviation	Range
All subjects	140	35.99	10.49	2-55
Highly-skilled subjects	26	49.46	2.34	46-55
Low-skilled subjects	24	20.38	7.77	2-28

18.22 with 48 degrees of freedom. The alpha level of significance was set at .05, and the tabled value required for significance was 1.67. Therefore, a significant difference in skill level was found to exist between the two groups of subjects used in the present study.

Analysis of Variance Results of Scores Obtained on the Motion-Perception Analyzer

Twenty-eight female subjects were tested for their perceptual-prediction ability on the Motion-Perception Analyzer. Their performance of the prediction task was assessed as to the amount and nature of the error produced; this was accomplished through estimates of each subject's Mean Constant Error, Variable Error, and Absolute Error (Schmidt 1975). The means of each skill level and the two viewing times for the three error scores of concern are presented in Table 2. Raw data scores from which these means were computed may be found in Appendix F.

Table 2. Means of Error Scores.

	$\overline{CE}$	VE	AE
Low-skilled, 2-seconds' viewing	-.447	.093	.661
Low-skilled, 4-seconds' viewing	-.338	.052	.427
High-skilled, 2-seconds' viewing	-.460	.072	.713
High-skilled, 4-seconds' viewing	-.321	.040	.461

A two-way analysis of variance statistical test was calculated for each of the three error scores in order to test for significance of the main two variables of interest (skill level and viewing time), which were central to the present study.

Analysis of Variance for Mean Constant Error Scores

The Mean Constant Error was an assessment of how the subject tended to respond (on the average) in relation to the target. In addition to telling how close her predictions were to the Mean Prediction Time (on the average), it indicated whether the subject tended to make early or late predictions (designated as being either negative or positive, respectively). Results of the analysis may be found in Table 3.

The F ratio for "Skill Level" (A) was obtained by dividing the Mean Square value (MS) for A by the MS value of "Subjects Within Groups."

Table 3. Analysis of Variance Summary Table for Mean Constant Error Scores.

Source of Variation	Degrees Freedom	Sum Squares	Mean Squares	F Ratio
A (Skill Level)	1	.000021	.000021	.000041
Subjects Within Group	26	13.229181	.508815	
B (Viewing Time)	1	.214768	.214768	2.541874
A x B	1	.003090	.003090	.036572
B x Subjects Within Groups	26	2.196801	.084492	

* Note: Significant at the .05 level F .05 (df 1,26) = 4.23.

Likewise, F ratios for "Viewing Time" (B) and A x B interaction were obtained by dividing respective MS's by the MS value of "B x Subjects Within Groups." This same procedure was followed for the other two error scores as well in order to obtain their respective F ratio's.

Neither of the two main effects, performance by skill level nor by viewing time, was significantly different between the two groups involved according to their $\overline{CE}$ scores; that is, with respect to highly-skilled vs. low-skilled grouping or to 2-second vs. 4-second periods of viewing.

Analysis of Variance for
Variable Error Scores

Variable Error scores expressed the extent to which the subject tended to repeat her responses. In other words, it was the "variability" of her performance about her own mean (her $\overline{CE}$). Table 4 shows the results of the analysis of variance for this particular error score.

Table 4. Analysis of Variance Summary Table for Variable Error Scores.

Source of Variation	Degrees Freedom	Sum Squares	Mean Squares	F Ratio
A (Skill Level)	1	.003790	.003790	1.465017
Subjects Within Group	26	.067259	.002587	
B (Viewing Time)	1	.019296	.019296	8.349632*
A x B	1	.000275	.000275	.118996
B x Subjects Within Groups	26	.060096	.002311	

* Note: Significant at the .05 level F (df 1,26) = 4.23.

No significant difference in performance according to skill level was found. However, a significant difference at the .05 level was found for both skill level groups with respect to the amount of time they were allowed to see the ball moving towards the stationary target. Thus, all subjects tended to be significantly less inconsistent with the 4-second viewing period than with the 2-second viewing period. When interaction between the two variables was assessed (A x B), no significant difference was again found, implying that "inconsistency" in the subjects' responses did not result from their particular skill level group assignment, but rather from the amount of viewing time afforded.

Analysis of Variance for Absolute Error Scores

This method of scoring was also sensitive to the subject's inconsistency. However, it revealed the average amount by which the subject tended to be in error, without regard to her "earliness" or "lateness" in predictions. The "absolute" score of each subject's ten trial prediction scores, as opposed to negative or positive scores, was used in assessing this particular scoring of the subject's performance. Presented in Table 5 are the results of the analysis of variance for each subject's Absolute Error scores.

In agreement with results obtained through $\overline{CE}$ and VE, no significant difference in performance was found between subjects of the two skill levels for their respective Absolute Error scores. A significant difference at the .05 alpha level was again found for the amount of viewing time allotted the subjects. However, when viewing time was "corrected" for skill level, once again there was found to be no significant difference in performance for viewing time according to skill level grouping.

Table 5. Analysis of Variance Summary Table for Absolute Error Scores.

Source of Variation	Degrees Freedom	Sum Squares	Mean Squares	F Ratio
A (Skill Level)	1	.025834	.025834	.139428
Subjects Within Group	26	4.817410	.185285	
B (Viewing Time)	1	.824743	.824743	15.760424*
A x B	1	.001207	.001207	.023065
B x Subjects Within Groups	26	1.360579	.052330	

* Note: Significant at the .05 level F (df 1,26) = 4.23.

Evaluation of Null Hypotheses

Of the six null hypotheses established at the conception of the present study, two were rejected on the basis of the findings of the research performed. Those rejected were:

$Ho2_B$: Only chance differences will be found between the two viewing periods of the moving object as measured by the batters' variable error scores.

$Ho2_C$: Only chance differences will be found between the two viewing periods of the moving object as measured by the batters' absolute error scores.

The remaining four null hypotheses failed to be rejected. Those null hypotheses left standing at the conclusion of the present study were:

$Ho1_A$: Only chance differences will be found between highly-skilled and low-skilled batters on the prediction task as measured by the batters' mean constant error scores.

$Ho1_B$: Only chance differences will be found between highly-skilled and low-skilled batters on the prediction task as measured by the batters' variable error scores.

$Ho1_C$: Only chance differences will be found between highly-skilled and low-skilled batters on the prediction task as measured by the batters' absolute error scores.

$Ho2_A$: Only chance differences will be found between the two viewing periods of the moving object as measured by the batters' mean constant error scores.

Discussion of the Findings

Predictions of the moving ball's collision with the stationary target, on the whole, tended to be "early." Negative Mean Constant Error scores as reported in Table 1 and also in raw data form in Appendix F, exhibit this tendency. A factor which could have led to the early predictions was a characteristic of the Motion-Perception Analyzer's motor. Once the viewing screen had been dropped following the designated viewing time allotment and resulting in the subject's view of the display being blocked, the research assistant's task was to loosen the tension on the drive wheel in order to stop the motion of the ball. This action was a precautionary attempt to prevent collision of the ball with the side of the instrument, should the subject make a late prediction. If this were to happen, operational failure would result. Loosening the tension on the screw stopped the moving ball, but ti did not turn off the motor; this was accomplished by the subject's prediction of the ball's collision with the target. Once she pushed the response button to make her prediction, the system was closed and the motor was turned off. However, this did not occur until one to three seconds after her vision was blocked, depending upon the viewing period involved. Consequently, the motor had a tendency to speed up, which might have given the subject the illusion that the ball had accelerated on its pathway towards the target, and possibly resulting in her making an early prediction of its collision with the target.

The actual training and testing session of the subject was not lengthy. It lasted approximately 10-15 minutes. However, as a result of efforts to schedule testing times to accommodate three schedules (the investigator's, the research assistant's, and the subject's), most of the testing sessions had to be scheduled during Finals Week of the spring semester, 1975. Therefore, subjects may have had lapses in attention and/or concentration for the performance of the prediction task. However, the investigator found every subject to be very cooperative and several showed an intense interest in the study and their respective performance on the prediction task.

No significant difference in performance as measured through the subjects' Mean Constant Error, Variable Error, and Absolute Error scores was found to exist between the two skill levels of softball batters. Although a student's t-test revealed a significant difference in performance of the two skill levels on the batting pre-test, perhaps the two groups were too homogenous with respect to perceptual skill level. Assignment of subjects to a particular skill level group was based on their performance on the batting pre-test. From those qualifying as highly-skilled and low-skilled batters based on criterion performance scores, subjects later performing the prediction task were randomly chosen from these two skill level groups. This pre-test was a sample of the student's actual batting ability, a highly complex motor skill. Factors other than perceptual-prediction ability are involved in batting performance. Reaction time, movement time, batting mechanics of stride length, body positioning, and trunk rotation are additional components of batting performance. The perceptual-prediction task on the Motion-Perception Analyzer was designed to only test one of these complex interacting factors. Since no significant difference was found between skill levels on the prediction task, perhaps another of these suggested factors may account for differences in performance.

Test reliability of the batting pre-test was not established prior to the actual batting testing session. Therefore, the pre-test may have failed to yield a true assessment of the subjects' true batting performance who were selected for further testing. Reliability of the investigator and her research assistant in administering the prediction task on the Motion-Perception Analyzer were also not established. These two factors may have contributed to the finding of nonsignificant differences between skill levels in performance of the prediction task on the Motion-Perception Analyzer.

Exactness of prediction may not necessarily be crucial in many ball skills since there is a reasonable range of "error" within which the performer can work. Thus, the accuracy with which a prediction of trajectory of a ball from early cues can be carried out is questionable (Whiting 1969). The basis of the scoring of the prediction task performed in the present study was the preciseness with which the subject could predict the moving ball's collision with the stationary target. Thus, the implications of Whiting's statement must be considered when interpreting the data obtained from the present study and making generalizations to performance of the perceptual skill of batting in a dynamic game situation.

A significant difference was found between the two viewing periods. This would tend to be in agreement with what was suggested in the literature. Additional viewing time was used to monitor the ball's pathway in making more accurate predictions of its collision with the stationary target (Whiting 1969, Williams and Underwood 1968, Weiskopf 1969). However, no significant difference according to skill level and viewing time was found to exist. Cratty (1968) stated that in the learning of complex perceptual-motor skills, perceptual factors have been found to be more prominent during the initial stages of learning, while motor factors (such as movement speed, reaction time, etc.) are more important during later stages.

Perhaps the low-skilled subjects used in the present study were ready to enter into this second stage of learning, implying that the teacher should be using different cues than simply "Keep your eye on the ball!" Wrist action or body positioning might be stressed instead as additional learning cues to batting performance. Breen (1967) concluded from his cinematographic analysis of batters that outstanding hitters seemed to adjust their head from pitch to pitch to allow the longest possible look at the ball's flight. Hubbard and Seng (1954) discovered that pursuit tracking movements of the eyes with the head fixed in position (as in the perceptual-prediction task performed on the Motion-Perception Analyzer), were a common occurrence when a swing resulted and contact of the bat with the ball was made. However, if the ball was missed, or no swing taken, batters had a tendency to turn their head and watch the ball into the catcher's glove <u>or</u> turn their head laterally with the swing that had missed the ball. These findings have implications for the teacher or coach as learning cues that could possibly be supplied to the batter.

Another possible explanation for the lack of significant difference between skill levels may be found in the conditions surrounding the testing on the Motion-Perception Analyzer. In a real game or class situation, the batter is under various kinds of pressure to perform. Thus, he may have a tendency to be tense and over-anxious. This would cause him to swing too early or not track the ball for as long as possible and thus, not take advantage of additional viewing time on which to base his predictions. Any generalizations made from laboratory testing situations where extraneous variables are held to a minimum, to a dynamic situation, must, therefore, be carefully made.

The inherent "predictability" of the task on the Motion-Perception Analyzer may also provide an explanation for the absence of significant difference found between the two skill levels. Each trial on the Motion-Perception Analyzer was identical to the one immediately prior to it, with the exception of the viewing time allowed. The ball always started from the same place and the velocity of its pathway towards the stationary target was nearly constant. However, in a game situation, the pitched ball is usually on a relatively unpredictable path. In such a situation, the expert will not need to watch the ball's flight for as long as the unexperienced player. In addition, according to Whiting 1969, p. 35, he will:

> . . . require less time to discriminate, program, and make decisions on the information he receives about the position of the ball, the direction and force of the wind, the state of the ground, the position of the other players (runners on base), and the many other cues in the display . . . .
> . . . for these reasons, it is questionable whether in many game situations the ball is ever on a completely predictable path except to the player who has experienced so many different situations in that sport that he is able to select the appropriate cues for response even in such difficult circumstances (p. 19).

Winograd (1942), after finding no significant correlations between vision and timing tests and his established batting criteria, concluded that other factors (such as muscular strength, correct stance form, and proper mental attitude) are probably developed to a greater degree in compensation for visual inferiority. Assessment of such physical characteristics was beyond the scope of the present study.

Vernon (1962) has listed as one of the functions of education, teaching the observer how to search carefully and attentively, studying carefully in certain situations, and selecting particular details for examination irrespective of the field of view of which they are a part. Thus, the teacher or coach should be aware of all factors involved in the particular situation. He should also realize that people do vary in their capacity to perceive or at least to cognize their surroundings just as they vary in other psychological capacities. Variations in quickness and accuracy with which perceptions are made, as well as the ability to control one's direction and concentration of attention are to a considerable extent functions of training and experience, but may also have an innate basis, like intellectual efficiency (Vernon 1962).

Summary

This chapter presented the results of the statistical analyses of the data pertaining to the two skill levels of subjects and the two viewing periods of the moving object which were involved in the present study. Analysis of variance computations were required to determine significant differences, if any, that existed between skill level and length of viewing time.

No statistically significant differences in performance were found to exist between the two skill levels of subjects involved. It was suggested that subjects may have been too homogenous in perceptual skill level despite the statistical significant difference between the means of batting performance of the two groups of subjects randomly chosen.

A significant difference in performance on the basis of the length of viewing time, as scored by Variable Error and Absolute Error, was evidenced. Comparisons and contrasts were made between the actual perceptual-prediction skill of batting and the prediction task performed on the Motion-Perception Analyzer. Additional cues and points of diagnostic interest to the coach or teacher were presented for possible use in learning situations in order to supplement the over-used learning cue of "Keep your eye on the ball!"

CHAPTER 5

SUMMARY, MAJOR FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

This chapter briefly outlines the organization of the study, reports the major findings and conclusions, and presents recommendations for further study.

Summary

The present study was designed to determine the relationship which existed between highly-skilled and low-skilled softball batters and their perceptual-prediction ability; it also dealt with the length of viewing time that the subject was allowed to see the moving ball on which to base her prediction.

The literature revealed that in the perceptual-motor skill of batting, the performer was unable to track the pitched ball up to the moment of its actual contact with the bat. Pursuit tracking with eye movements stopped when the ball was 6 to 15 feet in front of the plate. Based on this information, it was hypothesized that highly-skilled batters would perform a perceptual-prediction task on the Motion-Perception Analyzer significantly better than low-skilled batters; it was further hypothesized that both skill levels would make predictions significantly more accurately following a 4-second viewing period than following a 2-second viewing period.

Subjects were randomly selected from those qualifying as highly-skilled and low-skilled batters based on their performance on a batting pre-test administered to members of softball classes and softball team members. Twenty-eight subjects (14 in each group) were further tested on the Motion-Perception Analyzer. .

The perceptual-prediction task required that the subject predict the precise moment when a moving ball would collide with a stationary target placed at the end of its pathway. During the training session, each subject was given five prediction trials allowing her to see the moving ball for three seconds before her vision was blocked. During the testing session, five trials of 4-seconds' viewing time and five trials of 2-seconds' viewing time were randomly presented to the subject. Prior to each trial, she was not told how long she would be allowed to see the ball before her vision was blocked; she was only told which trial number it was. The trial was scored according to the subject's prediction of the length of time required for the ball to cover the distance as compared to the Mean Prediction Time that had been predetermined as the actual time required for the ball to collide with the target. A negative score signified an "early" prediction while a positive score designated a "late" prediction. The five trials' scores for each viewing period were averaged to yield a score of Mean Constant Error. From the $\overline{CE}$, Variable Error and Absolute Error were further calculated to afford an assessment of the amount and nature of the error produced by each subject for the two viewing periods of interest to the present study.

Major Findings

A two-way analysis of variance statistical test was utilized as a test for significant difference between the two skill levels and two viewing periods for the three error scores of each subject's predictions.

Nonsignificant F ratios (0.05 level) were found to exist between the two groups of subjects' Mean Constant Error, Variable Error, and Absolute Error scores according to their skill level group assignment. A nonsignificant F ratio (0.05 level) was also found for all subjects' $\overline{CE}$ scores for 2-seconds' and 4-seconds' viewing time. However, significant F ratios (0.05 level) were found to exist between viewing periods for all subjects' VE and AE scores.

Therefore, of the six null hypotheses established at the onset of the present study concerning chance differences between subjects and viewing periods according to scores of $\overline{CE}$, VE, and AE, only two were rejected. Significant differences were found between 2- and 4-seconds' viewing periods according to subjects' VE and AE scores, resulting in the rejection of these two null hypotheses.

Conclusions

The perceptual-prediction task, as performed on the Motion-Perception Analyzer, seems to be insensitive to differences in skill level of female college-aged softball batters.

It was also concluded that longer viewing times of a moving object appeared to afford the observer a better opportunity on which to base predictions of its arrival at a certain point in space. These predictions would also have a tendency to be less inconsistent following viewing periods. Thus, batters should be encouraged to watch the pitched ball for as long as possible and react to it physically based on predictions made from the longer monitoring of the ball's flight pathway.

It also appears that additional learning cues to "Keep your eye on the ball!" should be supplied the batter in an attempt to improve performance.

Recommendations for Further Study

Future study on the Motion-Perception Analyzer that involves perceptual-prediction tasks is recommended. The following additions or changes to the procedures followed in the present study are suggested.

1. Skill level group assignment should be made based on different procedures than the ones used in this study. Performance on a batting test performed on more than one day would provide a more accurate assessment of a performer's skill level. Better distribution of point values to batted balls would provide the investigator more discriminating evidence of performance (i.e., a five-point scale of scoring rather than a three-point scale, or not allowing foul balls as high a point value as fair balls). Possibly skill level assignments could be made using batting criteria of combined Batting Average, Slugging Average, and Runs Batted In, as suggested by Winograd (1942).
2. Perceptual-prediction ability could be tested between athletes of many years' experience (in one sport in particular, or a cross section of varsity athletes) as compared to the perceptual-prediction ability of the "average" college student (perhaps

randomly chosen from a population of students not enrolled in a physical education class and/or someone who has never competed on an athletic team). Since the literature revealed that more experienced players make decisions and predictions based on early monitoring of the ball's flight (Whiting 1969), would those having more athletic experience make more accurate predictions following a 2-second viewing period than following a 4-second viewing period?

3. As a follow-up study to the present study, identical testing procedures could be followed on a second day using the same group of subjects in order to test for improved performance on the prediction task as a result of additional exposure to the Motion-Perception Analyzer. This would reveal an estimate of the amount of learning involved in this particular prediction task over several trials.

4. The prediction task could also possibly be used as a training session for low-skilled batters. Once designated as a low-skilled performer and provided several testing sessions on the Motion-Perception Analyzer, performance could again be assessed to see if it had been improved in any way.

5. Knowledge of results could be supplied to subjects concerning the accuracy of their predictions on the Motion-Perception Analyzer to see if performance would be enhanced.

6. Testing the subject's perceptual-prediction ability using different ball velocities would reveal his sensitivity to

acceleration or deacceleration of the ball's movement. Position memory would also be tested as velocities would be compared from one trial to the next. However, in order to perform this task, if similar scoring techniques to the ones used in this study were to be used, some type of device that would be available during the testing session would have to be utilized that would provide the Actual Prediction Time required for the ball to cover the distance toward the target, against which his prediction would later be compared for scoring purposes.

7. Testing involving more than one ball track in the Motion-Perception Analyzer is recommended. Prediction time could be assessed for a ball moving towards a person and away from the person, for example. Or possibly, vertical motion vs. horizontal motion prediction could be assessed for the same group of subjects.

APPENDIX A

INSTRUCTIONS FOR BATTING PRE-TEST

I. Purpose of the Test

To distinguish between highly-skilled and low-skilled college women softball players.

II. Procedures

1. Each student will receive 20 pitches from the batting machine.
2. Three will be given before the batter steps into the batting box. (These are given to determine if the ball is coming in the batter's strike zone and to allow the batter to observe the speed of the pitch.)
3. Once the testing begins, you must swing at every pitch, unless it is badly cut out of your strike zone; the determination of such a pitch will be left up to the discretion of the investigator--if a bad pitch should occur, another pitch will be substituted in its place.
4. Scoring will be according to where the batted ball takes its first bounce. (Check the diagram for point areas.)
5. Are there any questions?

III. Review and Testing Organization of the Class

1. You will receive only 20 pitches and then rotate. Please keep moving.

2. Those shagging balls in the field should roll them back to the machine and the ball feeder (who always "presents" the ball to the batter before feeding the ball to make the batter aware of the ensuing pitch).
3. One person should always be warmed up and ready to go, in order to keep things moving swiftly.
4. I will feed the balls and I will have a recorder to be at the machine with me. Your score will be called out loud after every pitch.
5. Are there any questions?

APPENDIX B

PITCHING VELOCITY OF JUGS JUNIOR PITCHING MACHINE

Machine Setting = 55

Distance = 50 feet from the wall

Ball #	Time	Velocity (feet per second)
1	1.06	50.16
2	1.09	49.13
3	1.02	51.69
4	1.14	47.54*
5	1.00	52.52
6	.90	57.41*
7	1.09	49.13
8	1.11	48.46
9	1.01	52.11
10	1.06	50.16

Sum = 403.36

Mean = 50.42 feet per second

* Those times discarded and not figured into the average velocity.

APPENDIX C

BATTING PRE-TEST RAW DATA

Raw Score	Tally
60	
59	
58	
57	
56	
55	1
54	1
53	
52	2
51	4
50	5
49	4
48	3
47	3
HI 46	3
45	4
44	4
43	6
42	3
41	2
40	8
39	6
38	7
37	7
36	11
35	9
34	3
33	3
32	3
31	2
30	7
29	5

Highly-skilled data:
$\bar{x}$ = 49.46
sd = 2.34
n = 26

Total group data:
$\bar{x}$ - 35.99
sd = 10.49
n = 140

Raw Score		Tally
LO	28	1
	27	2
	26	7
	25	
	24	1
	23	1
	22	1
	21	3
	20	1
	19	
	18	1
	17	2
	16	
	15	
	14	
	13	
	12	
	11	1
	10	
	9	
	8	
	7	
	6	1
	5	
	4	
	3	
	2	2

Lo-skilled data:
$\bar{x}$ = 20.38
sd = 7.77
n = 24

APPENDIX D

TRAINING AND TESTING INSTRUCTIONS FOR MOTION-PERCEPTION ANALYZER

I. Show the Object

This ball is exactly like the ball you will see when you look into the box.

This target is exactly like the target you will see when you look into the box.

II. Explain the Instrument

Let me explain to you how this instrument works.

When I push this button (System Start) the window opens and when you push this button (Response Button) the window closes.

Please be seated.

Move towards the machine so that you can look through the window.

Can you see all four white spots on the screen? (This is to insure that S can see the perimeters.)

Please remove your face from the viewing window, place your hand on the response button, and push.

Now with your face in the viewing position and your finger on the Response Button, face all the way in, we will open and shut the shutter in order to acquaint you with the noise of the machine and the flaps open and closing in your face.

III. Explain the Task

When you look into the box this time, you will see a ball moving toward a stationary target.

Did you see it?

This time when you look into the box, you will only be allowed to see the ball moving for three seconds of time, and then your vision will be blocked.

Now let me show you what I mean.

During the testing, after the screen has been closed and your vision has been blocked, your task will be to predict the precise moment when the moving ball will collide with the stationary target.

To do this, you are to push the button at the exact moment you predict the ball will hit the target.

This time will then be recorded on this device here (indicate the Deacon Timer) and will then be compared later to the already determined time it takes the ball to reach the target.

Now let us try it . . . Your face is all the way in, finger is on the button . . . .

IV. Questions

Do you have any questions?

V. Review

We will now repeat the task to make you feel more comfortable with the procedures.

These things are very important to remember for each trial:

1. that your face is all the way in so that you can see the perimeters as before when you looked for the four white spots.
2. that your finger is ready on the Response Button before each trial begins.
3. and that after the shutter has been closed, you will push the button at the exact moment when you predict the moving ball will collide with the stationary target.

Do you have any questions?

VI. Test the Subject's Understanding of the Procedures to be Followed

To insure adequate training of the subject, the preceding will be repeated five times, allowing the subject a viewing time of three seconds, diagonal track, timer reset after each trial, and the time recorded for each of the five trials.

Each of the training trials should be preceded by the E saying: Training trial #_____ to begin now . . . .

VII. Testing Procedures

Now that you have an adequate understanding of the procedures to be used, the testing will begin.

You will be given five trials at four seconds' viewing time and five trials at two seconds' viewing time to predict the ball's collision with the target. The order of the viewing times has been randomly assigned to each subject and you will not be told before each trial how long you will be allowed to see the ball, you will only be told which trial number it is (e.g., Trial #1, #2, #3, etc.).

Do you have any questions?

We will now begin . . .

Testing trial #_____ to begin now . . . .

APPENDIX E

SAMPLE SCORE SHEET FOR TESTING ON MOTION-PERCEPTION ANALYZER

Subject________________ Testing Day and Time________________

Level and Section__________ Vision______________

Batting Score_________ Level_________ Testing Sequence: __ 1 __ 2 __ 3 __ 4 __ 5

Age______ Actual Prediction Time______________ __ 6 __ 7 __ 8 __ 9 __ 10
(A.P.T.)

Training			Testing					
3-second trials	Time	Constant Error (Time-APT)	2-second trials	Time	Constant Error	4-second trials	Time	Constant Error

Average Constant Error________ C.E.________ C.E.________
Variable Error________ V.E.________ V.E.________
Absolute Error________ A.E.________ A.E.________

APPENDIX F

MEAN CONSTANT ERROR, VARIABLE ERROR, AND ABSOLUTE ERROR FOR HI- AND LO-SKILLED SUBJECTS

Lo-Skilled

Subject No.	Age	Class Level	Batting Score	Vision	2-Second C.E.	2-Second V.E.	2-Second A.E.	4-Second C.E.	4-Second V.E.	4-Second A.E.
1	-	Beg.	27	-	-0.428	0.0156	0.428	-0.278	0.0215	0.278
2	-	Beg.	17	-	-0.416	0.1384	0.416	-0.520	0.1315	0.520
3	19	Int.	21	20/15*	-0.585	0.0383	0.585	-0.375	0.0223	0.375
4	18	Beg.	26	20/20**	-0.264	0.1852	0.412	-0.372	0.0137	0.372
5	18	Beg.	26	***	0.291	0.1452	0.4354	0.211	0.0872	0.3434
6	18	Beg.	21	*	-1.444	0.0521	1.444	-0.750	0.0713	0.750
7	21	Beg.	20	20/20****	-0.598	0.0484	0.598	-0.360	0.0567	0.3632
8	19	Int.	26	20/20	0.563	0.1011	0.563	0.223	0.0678	0.239
9	18	Int.	11	***	-0.197	0.1387	0.2686	-0.641	0.0679	0.641
10	18	Int.	24	20/20-C.	0.045	0.0629	0.1878	-0.031	0.0296	0.1322
11	20	Beg.	2	20/20**	-1.409	0.1201	1.409	-0.739	0.0739	0.739
12	18	Beg.	26	***	-0.676	0.0041	0.676	-0.472	0.0499	0.472
13	19	Beg.	26	glasses	-1.431	0.0550	1.431	-0.637	0.0095	0.637
14	19	Beg.	17	No glasses: unclear in 1 eye.	0.297	0.1991	0.399	0.015	0.0196	0.123
-----No Show-----										

* No glasses.
** Glasses
*** Glasses--not worn.
**** Corrected 20/20

C = Contact lenses.

Hi-Skilled

Subject No.	Age	Class Level	Batting Score	Vision	2-Second C.E.	2-Second V.E.	2-Second A.E.	4-Second C.E.	4-Second V.E.	4-Second A.E.
-----Miscalibrated Machine-----										
1	18	Int.	47	***	-0.765	0.0445	0.765	-0.349	0.0110	0.349
2	21	Int.	50	20/20*	-1.001	0.0253	1.001	-0.551	0.0408	0.551
3	18	JV	47	20/20*	0.122	0.0833	0.2796	-0.150	0.0402	0.1724
4	18	JV	55	Muscle	-1.267	0.0532	1.267	-0.683	0.0362	0.683
5	19	Beg.	48	problem: rt eye*						
5	19	Beg.	48	20/20*	-0.631	0.0499	0.631	-0.137	0.0683	0.2494
6	19	Int.	51	20/20-C.	-1.424	0.0259	1.424	-0.554	0.0230	0.554
7	19	JV	50	20/20-C.	-1.483	0.2684	1.483	-0.963	0.0115	0.963
8	18	Int.	50	20/20-C.	-0.292	0.0311	0.292	-0.224	0.0237	0.2288
9	18	Int.	46	Close 20/20*	-0.529	0.0252	0.529	-0.263	0.0361	0.263
10	20	JV	46	***	-0.166	0.1059	0.2828	-0.740	0.0207	0.740
11	21	V	49	20/20*	-0.498	0.0665	0.498	-0.662	0.0445	0.662
12	21	V	48	***	0.245	0.0655	0.2534	-0.061	0.0229	0.1402
13	20	Beg.	50	20/20-C.	0.767	0.0493	0.767	0.511	0.0668	0.511
14	20	V	54	20/20*	0.479	0.1177	0.5114	0.325	0.1084	0.3894

* No glasses
** Glasses
*** Glasses--not worn.

C = Contact lenses.

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