THE RELATIONSHIP BETWEEN PITCH COUNT AND HITTING SUCCESS IN MAJOR LEAGUE BASEBALL

By

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CHAPTER I

INTRODUCTION

Ted Williams, who in 1941, had a batting average of .406, and is arguably the best hitter in the history of baseball, has described hitting a baseball as the most difficult single skill in all sports (Williams & Underwood, 1982). Since the 1940's, increases in players' size, muscular strength, coordination, flexibility, bat speed, and other attributes have played an integral part in the development seen among players today. However, the question remains regarding these attributes and their relationship with hitting success. Many experts in the field today believe baseball players are faced with four dimensions involved in hitting a baseball. We do know that successful hitting in major league baseball today requires the ability to be able to: 1) visually track release point from a pitchers hand; 2) recognize rotation on the baseball as to whether the pitch is a fastball, curveball, slider, change-up, split-finger fastball, etc.; 3) recognize location as to whether the pitch will cross somewhere in the strike zone; and, 4) decide whether to swing at the ball or not swing at the ball. Knowing or predicting the swing response allows the hitter to determine when to initiate the swing so that the bat arrives over the plate at the same time the ball does (Schmidt & Sherwood, 1982).

With a pitched ball traveling at a speed of 89 miles per hour from a distance of 60 feet 6 inches away from the plate, a hitter has only about 460 milliseconds to decide and execute a swing response (Schmidt, 1991). The bat itself is only in motion for 160 milliseconds (Hubbard & Seng, 1954) and the neurological impulses which trigger the swing must occur about 170 milliseconds before the bat motion starts (Slater-Hammel, 1960). The remaining 130 milliseconds are dedicated to decisions about other important factors such as making the swing arrive on time, on plane, and in rhythm (Ward, 1995 presentation at Mid-America Baseball Camp). Therefore, the neurological signal to trigger the action must be given 330 milliseconds before the ball arrives at the plate (Schmidt, 1991). All decisions about whether or not to swing at the ball must be made in the first 130 milliseconds, that is, well before the ball has traveled halfway to the plate (Schmidt,1991). Considering these facts, it is no surprise that baseball players are faced with an enormously difficult task in trying to hit a round ball with the curved surface of a bat. Although in recent years in major league baseball, with the increase in batting averages, number of runs batted in, and number of home runs, one might guess that hitters are rising to the challenge presented by this formidable hitting task.

Statement of the Problem

The problem will be to investigate the relationship between hitting success and the various pitch counts (0-0, 0-1, 0-2, 1-0, 1-1, 1-2, 2-0, 2-1, 2-2, 3-0, 3-1, 3-2). A subproblem will be to examine this same relationship when considering hitting capability. The premise is that good hitters produce hits by relying more on the pitch count and location of the pitch rather than tracking the flight of the baseball in its entirety to the point of initial contact with the bat. The results of this investigation may indicate that the probability of producing a hit is greater when the hitter is ahead (2-0, 2-1, 3-0, 3-1, 3-2) of rather than behind (0-0, 0-2, 1-2, 2-2) in the pitch count. Even if good hitters do possess special mechanical, information processing, and decision-making skills, the pitch count may be the largest determinant of hitting success.

Purpose of the Study

The purpose of the study will be to determine the predictability and probability of hitters producing a hit in specific pitch counts. In this study, batting statistics from every player of the 1996 Major League baseball season will be analyzed to determine the probability of all hitters producing a hit in specific pitch counts. The subjects used in this study will be all of the hitters in both the American and National League of Major League baseball. The batting statistics will be used to determine the proportion of hits produced during a hitters count (3-0, 3-1, 2-0, 2-1, 3-2) versus the proportion of hits produced during a pitcher's count (0-0, 0-2, 1-2, 2-2). The data will be obtained from Statistics Incorporation, located in Skokie, Illinois.

Justification for the Study

Traditionally, beginning at an early age and continuing on through a hitter's development, the mechanical and physiological aspects of hitting are emphasized over the cognitive skills associated with successful hitting. Perhaps if coaches would spend more time teaching these cognitive skills, such as awareness of the various pitch counts, then younger players might develop new skills which could enhance hit production. It may be possible to establish ways for hitters to get into a hitter's pitch count rather than a pitcher's count. Such a strategy will not likely guarantee a hit, but may increase the likelihood of a hit, especially as the level of competition increases and the velocity of the baseball surpasses the ability of the human brain to record and control accurate motor responses.

These findings may help hitters utilize their decision-making skills to produce movement times and more accurate judgments before initiating a swing response. It has been shown that a hitter cannot recognize the small deviations in bat positions which produce the mechanical errors of hitting, such as dropping the bat an inch lower than normal (Breen, 1967). Cinematography reveals that there are no apparent differences in swing mechanics when a batter is hitting well by comparison to hitting poorly (Breen, 1967). The mechanical deviations are so small that one cannot discover any discrepancies by viewing a motion picture. Therefore, hitters may be incorrectly attempting to improve hitting mechanics rather than learning to concentrate on seeing the ball, anticipating the right location for a pitch, and/or considering the pitch count. Available literature, including explanations regarding the science of hitting, information processing, and visual eye movements, may be useful for sport psychologists, coaches, and players who attempt to teach or coach hitting.

Delimitations

The study will be delimited to:

1. All hitters in both the American and National leagues of Major League baseball (N=831) during the 1996 baseball season.

2. The player statistics available were selected from a large database company located in Skokie, Illinois.

3. The variables associated with the twelve pitch counts (0-0, 0-1, 0-2, 1-0, 1-1, 1-2, 2-0, 2-1, 2-2, 3-0, 3-1, 3-2) and the number of hits in those pitch counts.

Limitations

The limitations for this study will include:

1. The available data for major league baseball players during the 1996 year.

2. The data as encoded and delivered from Statistics Incorporation.

3. The inability to determine if hitters actually look for location during a pitch or guess as to what pitch would be thrown.

Assumptions

The following assumptions were made for this study:

1. In major league baseball, hitters rely more on pitch count and location of the pitch rather than visually tracking the entire flight of the baseball.

2. The other factors which might influence the decision to swing or not are randomly distributed across the various pitch counts.

Hypotheses

Major league baseball hitters are faced with an overwhelming amount of information when they step up to the plate. With the velocity of the baseball reaching speeds up to 100 miles per hour; information processing, decision-making skills, and reaction time have to coincide with the pitch arriving at the plate. The human brain cannot process the capacity of information in the amount of time provided (460 milliseconds from the time the pitcher releases the baseball until the baseball arrives at home plate) (Schmidt, 1991). Therefore, allowing for the hitter to use the present pitch count along with location of the pitch to predict when he will initiate a swing response. The only way to compensate for this much information to help the hitter decide when to swing, is to look at the present pitch count. The information provided in this research will help prove that a hitters probability of producing a hit is greater when he is ahead in the count, due to early predictions of when to initiate a swing response. The measurements used in this statistical analysis will be a higher percentage of hits a hitter produces when he is ahead in the pitch count.

Hypotheses

The following hypotheses for this study will be tested at the .05 level of significance:

1. There will be no difference in the average number of hits among the 11 pitch counts.

2. There will be no significant differences in batting averages when comparing the hitter's counts with the pitcher's counts.

3. There will be no differences in the batting averages when comparing below average hitters, average hitters, and above average hitters.

4. There will be no combination of pitch counts which can discriminate significantly among the three hitting groups.

Definition of Terms

For consistency of interpretation the following terms are defined:

1. Anticipation of Coincidence The ability to make a motor response coincident with the arrival of an object at a designated point.

2. Anticipatory Saccade Eye Movements Predict the trajectory of an object and as to where it would cross an area.

3. Attentional Benefit The increase in response speed at a cued location.

4. Attentional Cost The decrease in response speed at an uncued location.

5. Atypical An untypical style of hitting.

6. Batspeed The amount of force a hitter uses to get the bat through the strikezone.

7. Hitter A player who bats or whose turn it is to bat, as in baseball.

8. Below Average Hitter Batting average < 250.

9. Breaking-Pitch Any pitched baseball that has a change in trajectory or movement upon arrival to home plate.

10. Capacity Limited The brain's inability to process information concurrently.

11. Cinematography Filming a hitter during an at-bat, for the purpose of seeing mechanical errors in the swing.

12. Clear the Hitting Zone The distance a hitter's hips should travel before striking the baseball.

13. Closed Stance Where the left foot of the hitter is slightly positioned forward or closer to home plate.

14. Cognitive Transformation The ability to transfer psychological information throughout the body.

15. Coordination The ability to utilize both sides of the body effectively.

16. Correct-Slow Response Responding more slowly to a task while making fewer errors.

17. Decisional Processes Reflects the subjects strategy or response.

18. Eye Movements/Fixations The eyes ability to focus and maintain visual contact of an object.

19. Feedback Informative reaction or response provided from internal or external cues.

20. Final Combination of Force Resultant force.

21. Flexibility The ability to maintain the normal range of motion in the major joints of the body.

22. Fovea The region of the retina that produces the sharpest vision.

23. Functional Processes Automatic processing devices used to detect signals with few distractions.

24. Good Hitting Average Batting average 265 - 328.

25. Grip The way a hitter positions his hands on the baseball bat.

26. Ground Reaction Forces Creating energy from the ground up through the body.

27. Hand-eye Coordination The ability to make precise and accurate judgments utilizing the hands and eyes.

28. Hitting Position Position of the body where the athlete is balanced with his feet shoulder width apart and on the balls of his feet.

29. Information Overload Subjecting the brain to more information than it is accustomed.

30. Information Processing The brain's ability to examine and evaluate external and internal cues.

31. Kinematics of Hitting The mechanics and motions of hitting.

32. Leverage The amount of force generated from the midline of the body.

33. Location The place where someone or something is located.

34. Mechanical Transformation The ability to transfer programmed information throughout the body.

35. Millisecond One thousandth of a second.

36. Movement Distance from the body to contact.

37. Movement Time The interval of time from the initial movement in response to a stimulus until the completion of a specified movement.

38. Muscular Strength The ability to exert force against a significant resistance.

39. Noise Cues Refers to irrelevant information provided by the environment (i.e. opponent).

40. Open Stance Where the left foot of the hitter is positioned slightly back or away from home plate.

41. Optional Processes Voluntary and strategic information gathered from experience.

42. Pitch Count To consider or regard. To list or name numerals in order. To have merit or value.

43. Predictability To tell in advance, usually on the basis of facts.

44. Quick Zone The distance between the knees after the stride.

45. Reaction Time The interval of time between the onset of a stimulus and the initiation of response.

46. Rotation To turn around an axis or center point. To alter in a fixed routine of succession.

47. Saccadic Eye Movements Used in reading text or scanning a roomful of people.

48. Sensitivity Processes Reflects the physical properties of the receptor (i.e. eye).

49. Serially Organized The ability to organize patterns of events.

50. Signal Cues Relevant information appearing in the environmental field which requires a motor or non motor attentional response.

51. Signal Detection Theory (SDT) The ability to discriminate signal trials from noise trials by answering yes to signals and no to noises.

52. Smooth-Pursuit Eye Movements Used when tracking a moving object.

53. Spatial Component Requirement of accuracy in terms of where, in space, to swing to meet the baseball.

54. Straight Stance Hitter's feet are parallel to home plate.

55. Stride The distance between a hitter's feet after a pitched baseball.

56. Strong on the Backside Where the back shoulder of the hitter stays parallel to the ground and does not collapse or dip.

57. Temporal Component The accuracy in terms of knowing when to swing the baseball bat.

58. Temporal Information The ability to time the duration of the swing or event provides the human body with more precision, accuracy, and timing.

59. Velocity Rapidity of motion or operation. The rate of motion of a body in a certain direction.

60. Vergence Eye Movements Used when looking between near and far objects.

61. Vestibulocular Eye Movements Used to maintain fixation during head movements.

62. Wrong-Fast Response Responding faster to a task while making more errors in the process.

63. 2 X 2 Window of Opportunity Release point for pitch recognition and decision-making

CHAPTER II

RELATED LITERATURE

To address the specific issues of this study, the review of literature will include the following three categories: 1) science of hitting; 2) information processing in hitters; and, 3) visual eye movements in hitters. This may bring us to the question, "how do baseball players hit a moving baseball at speeds reaching 100 miles per hour with overwhelming power and consistency?" With this question being asked, we may need to learn more about: 1) how baseball players make decisions; 2) how the human brain controls movement; and, 3) the predictability of producing a hit in a certain situations. This condition is fulfilled by a professional baseball player hitting a baseball.

Motor Responses and Characteristics of Hitting

Ted Williams (Williams & Underwood, 1971) reported actually seeing the bat make contact with the baseball while hitting. While this may seem to be the case, the current understanding of the dynamics of hitting makes this notion implausible. Still today baseball players will even recount that they see a pitched baseball in its entire flight, from release point to the point of contact. Due to the extensive research of Bahill and LaRitz, this may in fact, not be true. Research indicates that when the velocity of the pitched baseball approaches 100 miles per hour linear, velocity produces angular (rotational) velocities greater than 500 degrees per second as the baseball passes the batter (Bahill & LaRitz, 1984). Further it is known that humans cannot track targets moving faster than 70 degrees per second (Schalen, 1980). Therefore, visually tracking a pitched ball with the intent of looking for a location in the zone cannot be a successful hitting strategy.

Professional baseball players no doubt have many qualities and characteristics that enable them to compete at a level of superiority over that of more ordinary players. However, the characteristics of baseball players of different hitting abilities and with different types of swings have received little scientific study (Mcintyre & Pfautsch, 1982). Some qualities that are known to be important with regard to hitting include: strength, speed, reaction time, depth perception, hand-eye coordination, balance, anticipatory coincidence, accuracy, and sound fundamental skills. The physical elements that do not have a significant impact in the game of baseball is height and weight. The general feeling among players is "no matter what your height or weight may be, if you can hit; you can play at any level." The nature of hitting a baseball is a unique skill for all baseball players and the velocity and change of trajectory during the flight of a pitched baseball makes the ball extremely difficult to hit. The more the baseball moves in trajectory, the longer it may take a hitter to react to a particular pitch. So in fact, hitters may be able to make some use of visual information in order to react and make decisions, and this information may have both spatial and temporal dimensions. Some hitters may be unusually gifted with superior information processing and decision-making skills, but it will still be impossible for them to use those skills during the 1500th of a second that it takes a baseball to travel the last 30 feet before reaching home plate (Schmidt, 1991). It seems more likely that good hitters rely on the present pitch count to help them make a decision to initiate a swing response. This notion becomes more pertinent as the pitching continues and the pitch count changes. If the hitter gets ahead in the pitch count (3-0, 3-1, 2-0, 2-1, 3-2), the advantage would seem to shift toward the hitter. The information about the location of the pitches may be more important than the type of pitch that might be thrown. Therefore, during a hitter's count the decision to initiate a swing response may be made more fluid. This circumstance would likely increase the probability of producing a hit.

In contrast, as the pitcher becomes ahead in the count (0-0, 0-2, 1-2, 2-2), the advantage shifts away from the hitter because the pitcher can choose from a larger variety of pitches which may be useful in a given situation. This circumstance, the possibility of more pitch options, causes an increase in the information processing and decision-making time for the hitter. This in turn would result in a longer reaction time, that is, longer for the hitter to initiate a hitting response. Therefore, the probability of producing a hit when the pitcher is ahead in the pitch count, becomes even more diminished for the hitter.

Situational Hitting

Few scientific studies have been reported which attempt to identify or compare the mechanical factors involved in purposely hitting a baseball (Mcintyre & Pfautsch, 1982). Beyond the physical, mental and mechanical factors associated with good hitting, there are certain situational factors which may present themselves such as: 1) early in the game as opposed to late in the game; 2) the position which the hitter hits in the line-up (lead-off hitter as opposed to a nine-hole hitter); 3) hitting with runners on base (situational hitting); 4) a hit-and-run play; and, 5) the ability to hit the ball to the opposite field. It will be necessary to hold constant these situational factors when considering how baseball players initiate a swing response. Information processing and perceiving environmental information become the major components in preparing, performing, and modifying certain motor responses such as hitting (Dunham, 1989).

Pitch Count and Location versus Velocity

Hitting presents a major challenge in information processing because of the number of variables and their possible interactions (Dunham, 1989). The pitch count may be the most important variable in whether a hitter will initiate a swing response or not. It is likely that the location of the pitch will be an important bit of stimulus information that the hitter must utilize during the flight of the baseball. Because the velocity of the pitched ball is far too great for hitters to actually determine spin and rotation, these variables are not important bits of stimulus information.

Differences in Pitches

The velocity of the fastball may be the reason why hitters are told to look for a fastball on any delivered pitch and to adjust to a breaking-pitch. The amount of time that elapses on a fastball is far greater than most breaking-pitches. Also, the trajectory of the baseball during a breaking-pitch, not the spin or rotation, helps determine location of the pitch. This may help hitters see rotation on the baseball. The pitch count again will help hitters make more of a immediate and prepared response to swing the bat.

The Science of Hitting

Although all sports are mentally and physically demanding, many experts agree that hitting is the most difficult hand-eye coordination sports skill, this is likely due to the precision, accuracy, and timing that it takes to successfully hit a baseball traveling at speeds between 80 and 100 miles per hour. Ted Williams once said, (Williams &

Underwood, 1971) about the difficulty of hitting, "Have you ever tried to walk through a dark and unfamiliar room full of furniture and not bump into something? Well, hitting is harder than that." Therefore, teaching this skill has proven to be very difficult. There are probably as many hitting strategies as there are hitting coaches. Gary Ward, former head baseball coach at Oklahoma State University, is a well recognized hitting coach and his technique encompasses all of the commonly accepted aspects of hitting. According to Ward, hitting is the sequential unlocking of body parts in order to maximize batspeed at the point of contact, while arriving on time, on plane, and in rhythm with the pitch. As prescribed, hitting also involves cognitive skills that direct motor responses to react to external stimuli, because the hitter reacts to the pitch by striding while simultaneously judging the pitch (Race, 1961). It is important to explain the basic hitting characteristics that most hitters possess.

Hitting

Hitting is a contest between the pitcher, who operates to strike out the hitter or cause him to hit the ball so that a put-out results, and the hitter, who is trying to hit the ball in order to reach base safely (Bunn, 1972). In studies by Seng, it was found that hitters have between 1/4th to 1/6th of a second from the beginning of the swing until contact is made. The average time it takes the baseball to travel from the pitcher to the plate is approximately 0.5 of a second. The average reaction time of a hitter (the time it takes for him to act after deciding whether to swing at the baseball) is approximately 0.1 of a second (Bunn, 1972). The actual step in preparation for the swing usually starts with the release of the baseball and is finished in approximately 1/24th of a second before the swing starts (Bunn, 1972). According to these times, no less important are the perfection of split-second timing of his sequence of movements and the development of a hitting technique that will produce the most efficient swing possible.

Many experts believe primary importance is developing the swing so that the bat meets the ball squarely with the greatest amount of force that can be controlled. The selection of a bat is a significant item in developing an optimum speed of the swing. A safe rule to follow (because of the current practice) is to select a bat that is lighter than the one that feels just right (Bunn, 1972).

Upon the selection of the bat, it is desired to transfer a significant amount of force to the ball. Experts believe the bat should be held so that there is little recoil when both the ball and the bat meet. The bat should be held so that the part of the hands between the knuckles and the wrist is directly behind the bat. The proper grip is to hold the bat so that the middle joint of the fingers of both hands are in alignment (Carroll, 1959). Holding the bat in this manner will allow the hitter to have forearm extension and wrist joint extension.

The position of the hitter at the plate determines his ability to watch the ball throughout its flight, to relax before taking a position of readiness for the pitch, and to swing in the plane of the ball (Bunn, 1972). The back foot should have a firm contact with the ground and should remain in contact with the ground until after the ball is hit (Bunn, 1972). Hitters have many idiosyncrasies with respect to their position at the plate and many of these have no value so far as the basic principles of batting are concerned, but they may serve as a psychological crutch to the hitter.

To assist the requirements for tracking the baseball, relaxation, and swing, the hitter should stand close enough to the plate to be able to hit a baseball on the outside edge. Although, Seng (1952), found that hitters did not track the ball to the plate with visible pursuit movements of the head. He contends the eyes do not see when they are moving within the sockets by quick jerks.

In order for the hitter to be completely relaxed while waiting for the pitcher, the hitter should rest the bat on his shoulder. This position may conserve energy and decrease tension. The bat should be drawn back of the shoulder with the line of the bat slightly above the horizontal plane (Bunn, 1972). The hands should be held in close to the shoulder and the top hand shoulder-high. The left forearm (for a left-handed hitter) should point in a vertical position. The right forearm will be almost horizontal. Experts believe this position permits a more controlled swing. The hitter can shorten the radius of rotation of the bat appreciably by keeping the hands and arms close to the body (Bunn, 1972). This will enable the hitter to have a more rapid and forceful swing.

When the pitcher is ready to deliver a pitch, the hitter lifts the bat from the relaxed position on his shoulder in readiness for the pitch. As the pitch is released, the hitter takes a short stride. The short stride will take the hitter down into a loading or preparatory position. The step should be slightly to the right (for a left-handed hitter) in order to permit the hips to rotate freely. The step should not, however cause the hitter to fall away from the plate. As the step is completed, the body starts to rotate from the shoulders and hips (Bunn, 1972). The forearms begin to extend and finally the wrists are extended as the ball is hit. All this happens much faster than it takes to explain. Slater-Hammel (1959), found that a fastball can be no closer than 20 to 30 feet from the plate and a curveball no closer than 17 to 27 feet from the plate if the hitter is to be able to get his bat around in time. Breen (1967), studied hundreds of hitters and analyzed thousands of feet of film to determine the qualities present in a good hitter. His research confirms the points that have been presented here. The foregoing discussion of the technique of batting does not take into consideration strategy in hitting or place hitting

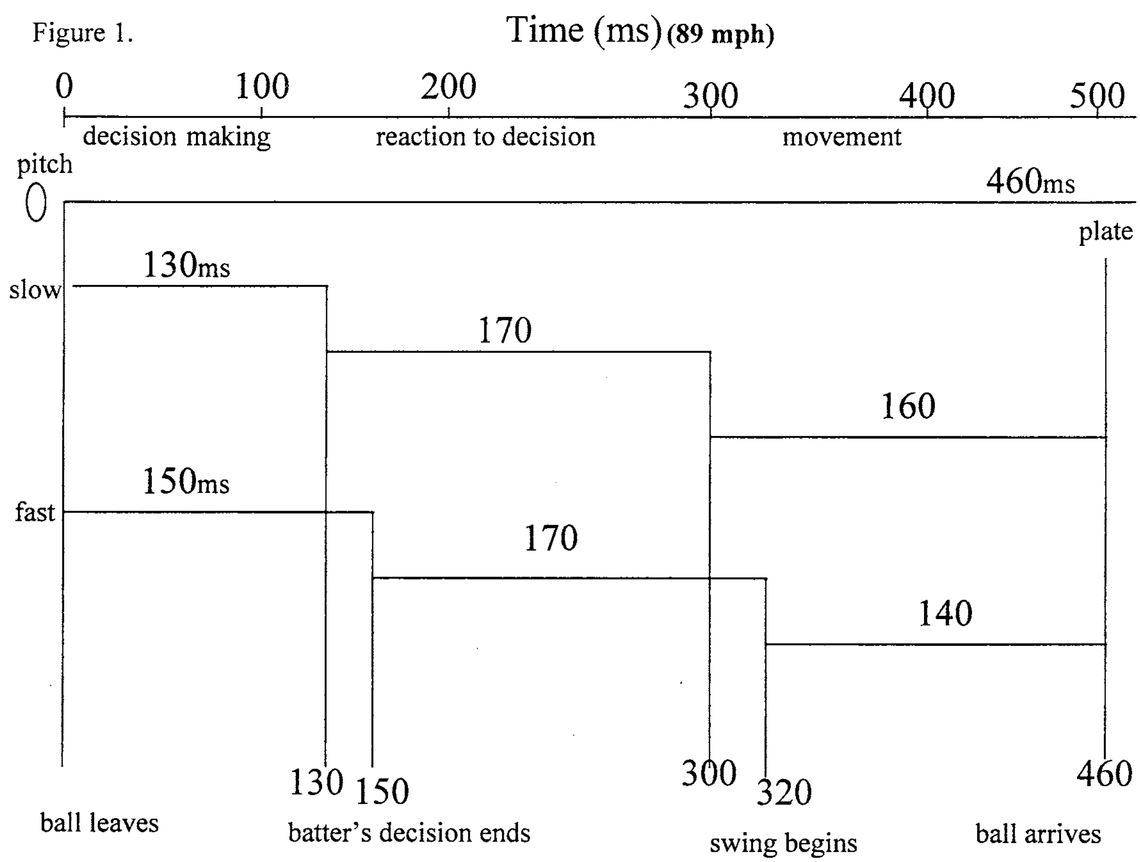
Ground Reaction Forces

Even though the kinematics and mechanics of hitting will vary from hitter to hitter, the same processes occur during every swing. These processes include: anticipation and timing, prediction of the baseball's spatial trajectory and arrival at the coincidence point, and production of quick movements that must be forceful and accurate (Schmidt, 1991). The energy generated for these characteristics is transferred from the ground upward through the body in a mechanism referred to as ground reaction forces. Movement of all body segments results from the translation and rotation of the body and the bat during the batting sequence due to ground reaction forces (Messier & Owen, 1985).

Mental Preparation and Kinematics

As the hitter stands inside the on-deck circle, he tries to achieve a proper attentional focus. Before approaching the plate, the hitter might mentally practice by imagining different types of pitches, pitch-counts, and hitting situations. As the hitter steps-up to the plate, attentional focus means that the effects of crowd noise, loud-speaker, organ music, and other external stimuli are totally blocked-out. The hitter sees only the movements and hears only the sounds that the pitcher makes. As the pitcher makes his delivery to the plate, the hitter engages in a series of cognitive and mechanical events which last for about one-half of a second, the time it takes a pitched ball to travel to the plate (see Figure 1.).

Figure 1.



Many experts believe hitting is similar to boxing, suggesting in order to deliver a significant punch, a boxer must shift all his weight toward the front leg. As in the case of hitting, where the hitter must shift his weight toward the front leg in order to drive the baseball with authority. Also, most hitting coaches contend they have never seen a boxer knock-out an opponent delivering a punch with his weight on the back foot. Of course, these differences will vary according to each hitter.

Pitch Location and Ball Contact

On an inside pitch, the hitter leads with the barrel of the bat through the zone making contact out in front of the left side of the body. By keeping the hands above and on the inside of the baseball, the hitter is able to make contact with the ball farther out in front of the plate. On a pitch down the middle, the hitter follows the same hitting pattern for the inside pitch, but makes contact well in front of the plate. Generally speaking an outside pitch is the most difficult pitch to hit because it presents the largest angle at which the hitter sees the ball. Therefore, it is more difficult for the hitter to locate the exact position of the ball (Breen, 1967). This may be the reason why pitchers get out more hitters by pitching over the outside corner of the plate.

Opposite Field Hitting

The ability to hit the ball to the opposite field is an important skill in baseball (Williams, 1971). There are several situations that may require the ball to be hit to the opposite field, most notably the hit-and-run play (Mcintyre & Pfautsch, 1982). On an outside pitch, the hitter lets the baseball travel longer or deeper into the strikezone before making contact. For an opposite field hit, the swing of the bat is initiated relatively late and contact is made with the ball as it passes over home plate (Mcintyre & Pfautsch, 1982). Conversely, Williams (1971) stated that, for an opposite field hit, the hands should precede the hitting area of the bat as contact is made with the ball and that the lead elbow should not fully extend during the swing. Although some player-to-player variability no doubt exist, these two versions of the swing have received little scientific study (Mcintyre & Pfautsch, 1982).

Teaching Interpretations

This interpretation of the science of hitting will differ substantially from hitter to hitter. In teaching beginners or in coaching hitters one should minimize the importance of tracking the ball as long as possible. While teaching young hitters, it is probably better to emphasize tracking the ball up to contact, knowingly that is impossible to track the entire flight of the baseball rather than to teach them that it is impossible and unnecessary to track the baseball and run the risk of having them not track the ball as long as possible (Hubbard & Seng, 1954).

Information Processing

A hitter's information processing ability influences decision-making, reactivity, movement time, and the actual movement of the swing. The amount of information that a hitter can process can either enhance hit production or it can alter the mechanics of the swing so that hit production is reduced. As mentioned earlier, there are four dimensions of information processing regarding a pitched baseball. The hitter must: 1) visually track release point from a pitchers hand; 2) recognize rotation on the baseball as to whether the pitch is a fastball, curveball, slider, change-up, split-finger fastball, etc; 3) recognize location as to whether the pitch will cross somewhere in the strikezone; and 4) decide whether to swing at the ball. The sources of errors in quick movements does not include feedback mechanisms or error correction mechanisms. The act of hitting in its entirety occurs too quickly to invoke the slower feedback and error correction mechanisms.

A motor program is a set of neurological instructions which are responsible for determining the ordering of muscle contractions and the amounts of force that must be generated in the participating muscles (Schimdt,1991). To complete an action such as hitting, motor programs direct the various muscles to contract with just the right amount of force in coordination with each other, so that the final resultant is in line with the intended movement (Schmidt, 1991). If any of this activity is in error, such as too great a muscle contraction of any muscle, then the movement's direction will be in error as well and this will likely result in not hitting the pitched baseball (Schmidt, 1991),(as seen in Figure 2.).

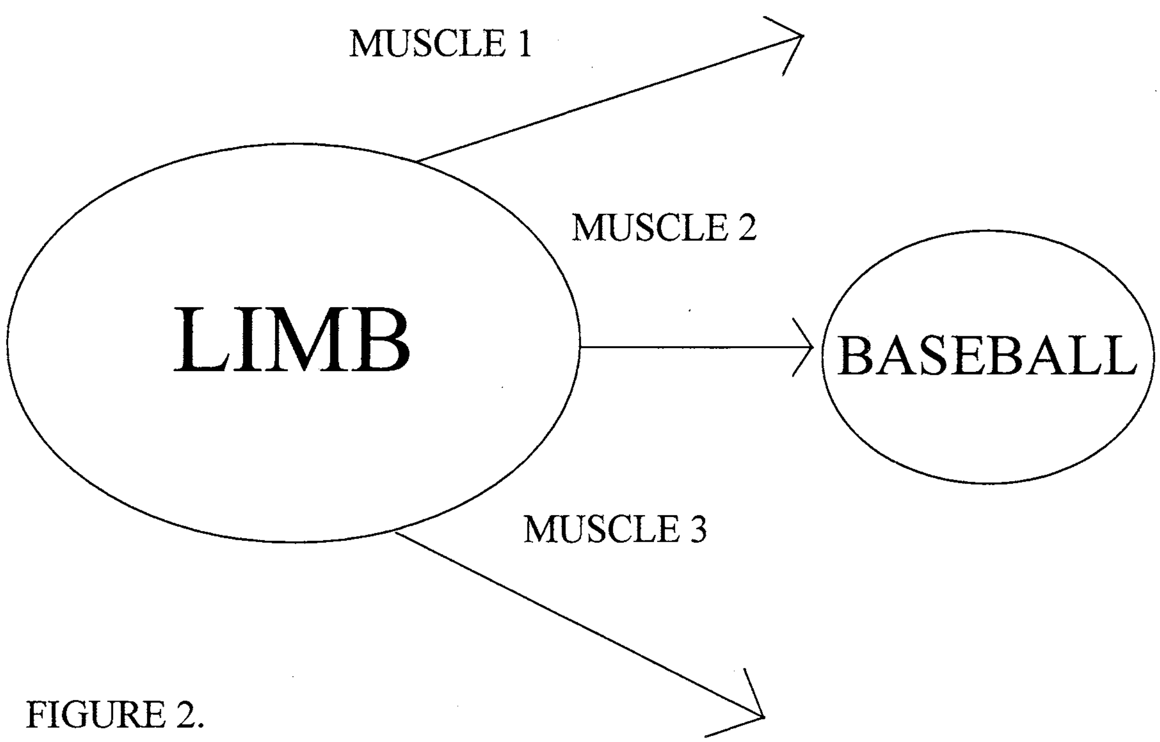


FIGURE 2.

The errors and inconsistencies likely result from within the processes that translate the motor program's output in the central nervous system into movements of the body part (Schmidt, 1991). This is the main reason why hitters are not very successful while attempting to hit a pitched baseball. It is difficult for the human behaving system to execute information processing in a rapid and accurate manner with just the right amount of force exerted by the appropriate musculature.

Spatial and Temporal Components

There are two types of accuracies associated with information processing while hitting. These are: 1) spatial (the requirement for accuracy in terms of *where* to swing to meet the baseball); and 2) temporal (the requirement for accuracy in terms of knowing *when* to swing the baseball bat). These two accuracy components represent standards of achievement which must be met by the swing response. For practical applications, when spatial accuracy is the only goal, the hitter should make the movement slower to reduce the errors (Schmidt, 1991). For example the hit-and-run play is effective because the hitter is just trying to make contact with the ball in a large strike zone in order to either put the ball in play or to protect the runner. According to Schmidt (1991), his research discusses a major contribution to this problem. Schmidt cited Paul Fitts, a psychologist, as developing a principle known as Fitts' Law. In his book regarding spatial and temporal decisions, Fitts' (1954) important point described when the accuracy requirements of the movement were relaxed (e.g., with wide targets), movement times were faster than when there were stringent accuracy requirements (narrow targets). For example if the hitter waits longer to start his swing, he will be more accurate spatially. This may also result in less movement in his body. This is what good hitting instructors teach, that is, having the hitter wait until the last possible moment to swing. This technique invariably helps hitters produce better results in terms of judgment and accuracy. A variation on this basic idea is to make the first part of the swing quick, then the second half of the movement to allow feedback-based corrections near the baseball

(Schmidt,1991). Using this technique, the hitter's initial movement is as rapid as possible but the second half of the swing slows down toward the location of the pitch. For hitters, bat velocity reaches a maximum value within 20 to 32 milliseconds prior to contact and decreases at contact (Messier & Owen, 1984). According to Messier and Owen, the evidence shows that there is a deceleration of the bat prior to contact, which results in the hitters not finishing with a strong follow-through. This may not allow the baseball to travel with distance and with less velocity due to deceleration of the swing upon contact with the baseball (Messier & Owen, 1984). As hitters make contact with the baseball, they should continue with the same amount of force and velocity throughout the entire swing. The findings of Mcintyre and Pfautsch (1982) also support these conclusions. They found that maximum bat speeds occurred within 13 to 16 milliseconds prior to contact and then decelerated at contact (Messier & Owen, 1984). Apparently in slower movements, making delayed actions enhances the hitter's capability to use feedback (Schmidt, 1991). This means that when hitters identify a fastball, it is possible to make adjustments to the swing response due to the reduced velocity of the baseball.

Many sport-related human movements like hitting a baseball require extremely forceful contractions of muscles. This results in nearly maximal movement speeds which are so important in hitting a baseball (Schmidt, 1991). Temporal accuracy is best reflected in the word timing. Information processing for temporal accuracy plays an integral part in the timing necessary to produce a hit. Temporal accuracy results when the hitter is able to time the duration of the swing. Knowing or predicting the action duration allows the hitter to determine when to initiate the swing so that the bat arrives over the plate at exactly the same time as the ball (Schmidt, 1991). Proper timing on a consistent basis is a critical factor in hitting and is probably what separates the average hitters from the great hitters. Fortunately the temporal component of hitting can be isolated. Timing skills seem to be learned according to different principles than those associated with spatial accuracy (Schmidt et al., 1979). The correct use with temporal information allows more precision, accuracy, and timing in hitting. The temporal information helps the hitter make decisions about the movement time for the swing and decisions about the initiation of the swing response both of which can be utilized to decrease timing errors and make the movement more temporally accurate (Schmidt, 1991). Although the temporal information will contribute more than the spatial information regarding the efficacy of the swing response, both types of information are needed to produce accuracy in hitting.

Signal/Noise Detection

Coaches and athletes frequently indicate that achieving a peak performance in sports depends primarily on the ability of athletes to process information in a short period of time. Athletes are frequently confronted with critical information via visual and auditory signals. They have to extract the significant clues from this information and the extraction process is a function of the uncertainty of the task and of the signal/noise ratio which derives from it (Coombs, Daves, & Tversky, 1970). Signals are the relevant bits of information which appear in the environmental field and some signals need to be followed by appropriate motor and/or attentional response. Noise refers to the irrelevant bits of information provided through the environment (e.g. opponent's jersey color) and typically it is to be ignored (Nougier, Stein, & Bonnel, 1991). Another approach to the understanding of signals and noise have been proposed by Green and Swets (1966), as signal detection theory (SDT). In this instance, the hitter's task is to discriminate signal trials from noise trials by answering *yes* to signals and *no* to noises. The possible outcomes of a signal trial from a hitter's standpoint are: 1) a correct decision, such as a hit or contact with the baseball, based on accurate signal detection or 2) an incorrect decision, such as swinging and missing the baseball, based on the failure to detect the signal. The possible outcomes of a noise trial are: 1) correct rejection, such as holding back a swing response on a breaking pitch or 2) false detection, such as not being able to initiate the swing response on a pitch down the middle (Nougier, Stein, & Bonnel, 1991). The main features of the SDT include sensitivity and decisional criterion. Sensitivity refers to the physical properties of the receptor (e.g. eye) and decision criterion refers to the person's strategy or response (e.g. the decision to initiate a swing response or not)(Nougier, Stein, & Bonnel, 1991). The hitter must see the baseball, process that visual information, and then decide to swing or not. Hitters are inundated with information which must be processed in a short amount of time. Information processing capacity in humans is organized serially and is limited in size. Therefore, hitters are able to organize the pattern of a pitched baseball but they are unable to process all of the available information at once (Nougier, Stein, & Bonnel, 1991). It follows then that hitters must selectively attend to specific information such as pitch count and location in order to increase the likelihood of producing a hit.

Functional and Optional Processes

Two kinds of processes can be utilized to determine how hitters respond to a pitched baseball. The first process is functional (Nougier, Stein, & Bonnel, 1991). The hitter is endowed with automatic processes which are used to detect the signals. This automaticity allows the hitter to process information quickly with few distractions.

Automaticity is acquired, that is, it is inherited. Rather, it is developed with extensive training and experience in a specific sport skill. This type of information processing will enhance the hitter's ability to react nearly automatically to a 90 mile an hour fastball.

The second process is optional (Nougier, Stein, & Bonnel, 1991). This process is voluntary and strategic information for the athlete. As with functional processes, this process is also not inherited but rather developed with time and experience for each hitter. The more plate appearances a hitter has, the more likely he will learn about opposing pitchers and the types of pitches he will encounter. He can use this valuable information for personal judgment about the decisions he makes during plate appearances.

Anticipation

During hitting, most hitters react more quickly when they know what pitch is coming or if the pitch count is to their advantage. They predetermine to swing if the pitch is deemed to be in the correct (anticipated) location. According, to Posner and Snyder (1975), a hitter can be cued to expect a stimulus (a pitch) to occur with high probability at one specific location in space and with much lower probability at any other location. Their research has shown that subjects are faster to respond to the most probable location and slower to respond to the uncued location (Nougier, Stein, & Bonnel, 1991). These results lend good support to the idea of using pitch count and location to improve the likelihood of producing a hit in baseball. The hitter can use the current pitch count along with an anticipated location to predetermine his swing response, increasing the batspeed, and thereby increase the probability of producing a hit. Posner and his colleagues (Posner, 1980 et al), describe the increase in response speed at the cued location as an *attentional benefit*; and they describe the decrease in response speed at the uncued location as an *attentional cost.* Therefore, a hitter who is ahead in the pitch count would have an attentional benefit, whereas the hitter who is behind in the pitch count would be subject to an attentional cost. Increasing the cost/benefit ratio may occur when hitters respond to more relevant and more frequent signals. Recall that preparation for the swing response has both functional and optional process dimensions. These two dimensions may converge with one another at any given time during information processing. Thus information processing during the pitch can be accelerated by decisions which are made prior to the pitch being released to the hitter. This may help explain the difference between a good hitter (batting average > .300) and being a below average hitter (batting average < .250). This late information processing time may enhance reaction time and movement time which in turn increase the hitter's ability to perform functioning optimally during a crucial game situation.

Quickness vs Accuracy in the Swing

It might be reasonable to postulate that a faster swing might produce better hitting. According to Fitts (1966), responding faster to a task usually means making more errors in the process (wrong-fast). In contrast to increased speed, responding more slowly to the task means making fewer errors (correct-slow) (Fitts, 1966). Considering information processing then, the hitter should plan on making a quick and accurate swing, instead of a fast and out-of-control swing. In order to be productive over time, a hitter should make minimal number of cognitive and mechanical errors during each plate appearance.

Segments of Fixations

From an information processing point of view, the trajectory of a pitched baseball can be divided into two segments viewed as a series successive fixations. These two segments are the first thirty feet and the last thirty feet of the travel distance. The hitter, through his own experience of watching how baseballs travel through space, acquire knowledge regarding velocity, trajectory, and location of the baseball. Thus, based on past experiences a hitter might be able to predict the future trajectory of certain pitches. With pitch-count, location, and accurate predicting on the fewest possible movements of the baseball, hitters can learn to narrow the possible path that the pitch will travel. Other available information becomes largely irrelevant towards increasing the likelihood of hitting a pitched baseball. So much for the popular dictum about "keeping your eye on the ball" (Kay,1957). Perhaps that adage should be replaced with, "plan ahead." Further, we can now more fully understand the fallacy of some axioms which seem to prevail regarding hitting. This includes such sayings as the skilled hitter has "all the time in the world" or "I can see the entire flight of the baseball until contact." As we have seen, the skilled hitter can appreciate some events more quickly than the unskilled because they are less uncertain for him, that is, they carry less irrelevant information (Kay, 1957). This results in an attentional benefit for the hitter. This information is even more beneficial when the baseball reaches speeds between 82 and 100 miles per hour. The amount of visual and information processing time is minimal and information overload occurs. It is likely that with experience, hitters have a general vicinity of where the baseball is projected to travel or cross the plate.

Visual Eye Movements

Information-processing theory predicts that sport performers gain information from their environment through the use of a systematic pattern of eye movements/ fixations (Shank & Haywood, 1987). Most baseball players are coached to "read " the rotation of the baseball early in the flight of the pitch so they can better predict the future location of the ball when it arrives in the hitting zone (Hyllegard, 1991). This may in fact be true for the first few milliseconds of flight, but it may not be true for the baseball's flight through the entire distance. The stimulus object (ball) is continuously visible during its flight, and it is not suddenly presented (Hubbard & Seng, 1954). Consequently, swing initiation is a problem of tracking a moving object, predicting its course and, at some point in its flight, deciding to swing or not (Hubbard & Seng, 1954). Not surprisingly, good hitters utilize a brief "window-of-opportunity" or release point for pitch recognition and subsequent decision-making. It is further thought that hitters may also have certain perceptual cues associated with the release point. This could include cues for ball rotation, pitch trajectory, velocity, and the pitcher's motion. The constraints imposed by the time required to execute a bat swing limit the amount of time available for information processing and decision-making (Hyllegard, 1991). It is therefore presumed that at some point during the flight of a ball any further cues that can be detected will serve no functional purpose in modifying decisions or responses (McLeod, 1978).

Types of Visual Eye Movements

A hitter gathers visual information from the pitcher's first movement to the end of the ball's trajectory (Shank & Haywood, 1987). There are certain types of visual eye movements commonly used in such activities as hitting a pitched baseball. The types of visual eye movements that humans use are: 1) saccadic eye movements, which are used in such activities as reading text or scanning a roomful of people; 2) vestibulo-ocular eye movements, used to maintain fixation during head movements; 3) vergence eye movements, used when looking between near and far objects; and 4) smooth-pursuit eye movements, used when tracking a moving object. These four types of eye movements have four independent control systems involving different areas of the brain (Bahill & LaRitz, 1984). Their neurological properties are different among one another and each is affected differently by fatigue, drugs, and disease (Bahill & LaRitz, 1984). Of these four types of eye movements, hitters use saccadic, vestibulo-ocular, and smooth-pursuit movements to help track the flight of a pitched baseball. Vergence eye movements are not used in this process because of the short distance (60 feet 6 inches) from the pitcher's mound to home plate.

Normally for a striking type of motion, a hitter would use eye movements, head movements or both to visually track the flight of a ball. Although this normal type of tracking might be seen in most hitting situations, it may not be the specific type of tracking in the case of hitting a pitched baseball. According to Bahill and LaRitz, if hitters track the ball with head movements only, they will fall behind in the last five feet of flight. If they track with eyes only, they will also fall behind in the last five feet of flight. If they track with only head movements and smooth-pursuit eye movements, the result is the same. Research suggests that hitters can track the ball during the last half of the flight (30 feet), but they eventually lose track of the baseball during the last five to ten feet before the ball arrives at home plate. From this we conclude that for hitters to be successful, they must make saccadic eye movements to a predicted point ahead of the ball. They must continue to follow the ball with peripheral vision, and finally, at the end of the ball's flight, resume smooth-pursuit tracking with the ball's image on the fovea (Hubbard & Seng, 1954; Bahill et al. 1981; et al. 1983; Bahill & LaRitz, 1983).

Research by Bahill and LaRitz (1984), compared the ability of graduate students and one professional baseball player to visually track the flight of a baseball. Graduate students were able to track the flight of the ball well, until the ball reached nine feet in front of the plate, at which point they started to fall behind and lose sight of the ball. The results produced by the professional baseball player indicated that he tracked the ball until it was five feet in front of the plate, then he completely lost track of the baseball. He did keep his eye on the ball longer than any of the other subjects. However, none of the subjects were able to track the pitched baseball up to contact with the bat (Hubbard & Seng, 1954). In general, tracking movements of the eyes stopped while the ball was still eight to fifteen feet from the plate. This was likely due to the fact that pursuit movements of the eyes break down at such relative velocities (Hubbard & Seng, 1954). The professional baseball player was able to repeat his stance consistently and make better judgments regarding the pitch location and trajectory. He also had better head-eye coordination, that is, tracking the ball with equalized head and eye movements. Obviously, the professional athlete had faster smooth-pursuit eye movements than the graduate student subjects. In fact, the professional baseball player had faster smooth-pursuit eye movements than any reported in the literature (Bahill & LaRitz, 1954). There are some useful generalizations to be made from this study. First, the subjects never actually had to swing the bat at any of the pitches; making it possible that head-eye coordination would be different if the subjects did swing the bat. And second, they simulated the easiest pitch for a hitter to track (high and outside fastball), which could have also made a difference in head-eye movements while tracking the ball.

Nonetheless, it is clear from these simulations of Bahill and LaRitz (1984), that even professional hitters cannot keep their eyes on the baseball during the entire flight of the pitch. This also did not include a swing response. This makes it difficult to believe that Ted Williams could see the ball make contact with his bat. The only possible way Williams could do this was if he made a anticipatory saccade that put his eye ahead of the ball and then let the ball catch up to his eye (Bahill & LaRitz, 1954). In other words, employ a strategy that predicted the trajectory of the ball and where it would cross the plate. Visual search strategies can be used to sample relevant locations in the visual display so that a response can be made at the proper time (Shank & Haywood, 1987). But even by employing this strategy, the hitter could not track the entire flight of the ball because of his slow reaction time. The implications is that hitters do not keep their eyes on the ball during the initial part of its flight. Information about the ball is obtained from movement (and expansion) of the ball's image across the eyes' retina (Shank & Haywood, 1987). An advanced hitter has learned from experience to focus his attention on the ball, and to block-out other or less important information. These players fixate on the anticipated release point during a pitched baseball. Again, this may help young hitters learn how to predict the actual trajectory and location of the ball when it crosses the plate. This may be easier said than done, but having a hitter's pitch-count could help the hitter predetermine his swing response, thus increasing his chances of producing a hit.

Differential visual-search strategies could also be used and they are in agreement with the information-processing viewpoint (Shank & Haywood, 1987).

CHAPTER III

METHODS AND PROCEDURES

Introduction

The purpose of the study was to determine the predictability and probability of hitters producing a hit in specific pitch counts. In this study, batting statistics from every player of the 1996 Major League baseball season were analyzed to determine the probability of all hitters producing a hit in specific pitch counts.

Subjects

The study was conducted during the Spring, 1997. The subjects consisted of the 831 major league baseball hitters from both the American and National leagues who had a minimum of one plate appearance during the 1996 baseball season. The hitting statistics from the entire 1996 Major League season (historical data), were utilized in the statistical analyses. All names, records, statistics, and data were public information and consent to conduct the study was obtained from the Institutional Review Board at Oklahoma State University (Appendix A). The data for the study were provided from Statistics Incorporation, Skokie, Illinois. This agency specializes in compiling sport statistics from numerous professional sports. Statistics Incorporation partially funded this investigation by offering the data at a substantially reduced cost.

The following information for each player was provided on a diskette obtained from Statistics Incorporation:

1) A list, in alphabetical order, of each major league baseball player (N=831) who had a minimum of one plate appearance during the 1996 major league baseball season.

2) The total number of hits each player produced in all 12 pitch-counts during the entire season.

3) The total number of plate appearances each player had in all 12 pitch-counts during the entire season.

Research Design and Statistical Analyses

The data were uploaded to the IBM 3090-200S Vector mainframe computer for analysis using the SPSS 4.1 statistical programs (SPSS Reference Guide, 1990). In order to test the hypotheses the following statistical tests were performed: 1) a one-way ANOVA on the batting averages at the various pitch counts, 2) a two-way ANOVA on the batting averages considering the main effects of pitch count and batting group, and a discriminant analysis using the pitch counts as dependent variables.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of the study was to determine the predictability and probability of hitters producing a hit in specific pitch counts. In this study, batting statistics from every player of the 1996 Major League baseball season were analyzed to determine the probability of all hitters producing a hit at the various pitch counts. The subjects were all of the hitters (N=831) in both the American and National League of Major League baseball.

The results are presented by hypotheses in the subsequent pages. For each of the various statistical tests, the .05 level of significance was used as the alpha level.

RESULTS

The means and standard deviations for the average number of hits at each pitch count were calculated for the total sample. As can be seen in Table 1, the summary data are listed two ways. They are ordered once by logical pitch count and then again according to the size of the mean. It should be noted that the 3-0 pitch count was excluded from all analyses. The data reveal that hitters simply do not attempt to hit a pitched ball when the count is 3-0.

Table 1
[a]Average number of hits at the various pitch counts.

Ordered Pitch Count	Mean ± SD	Mean Ordered Pitch Count	Mean ± SD
0 - 0	9.1 ± 11.62	0 - 0	9.1 ± 11.62
0 - 1	5.3 ± 6.79	1 - 1	5.9 ± 7.38
0 - 2	2.2 ± 2.98	1 - 0	5.7 ± 7.19
1 - 0	5.7 ± 7.19	0 - 1	5.3 ± 6.79
1 - 1	5.9 ± 7.38	2 - 2	5.2 ± 6.69
1 - 2	4.8 ± 5.98	1 - 2	4.8 ± 5.98
2 - 0	2.2 ± 3.22	3 - 2	4.3 ± 5.63
2 - 1	4.2 ± 5.56	2 - 1	4.2 ± 5.56
2 - 2	5.2 ± 6.69	0 - 2	2.2 ± 2.98
3 - 1	1.9 ± 2.80	2 - 0	2.2 ± 3.22
3 - 2	4.3 ± 5.63	3 - 1	1.9 ± 2.80

[a]$N = 831$.

Hypothesis One

Hypothesis one stated that there would be no difference in the average number of hits among the 11 pitch counts. A one-way analysis of variance (ANOVA) was used to compare the means displayed in Table 1. The Newman-Keuls multiple range test was used for mean comparisons. The Analysis of Variance (ANOVA) yielded statistically significant results $F_{(10,8300)} = 275.00$ ($p < .001$). The results of the Newman-Keuls post-hoc test are shown in Table 2. Underlined means are not significantly different from one another.

Table 2

Comparison of means among the eleven pitch counts.

Counts	3-1	2-0	0-2	2-1	3-2	1-2	2-2	0-1	1-0	1-1	0-0
Means	1.86	2.17	2.17	4.17	4.27	4.75	5.25	5.32	5.74	5.89	9.12

Therefore Hypothesis One was rejected. There were significant differences among nearly all of the pitch counts. The 0-0, 0-1, 1-0, and 1-1 pitch counts were the most favorable counts from a hitter's point of view. The 3-1, 2-0, and 0-2 pitch counts were the least favorable counts from a hitters point of view.

These results provide a quantitative answer to an age old question in baseball, that is, which counts are the pitcher's counts and which counts are the hitter's counts. There is no universal agreement among experts in baseball regarding the exact nature of these two counts, but anecdotally many expert coaches and players perceive the 3-1 pitch count to be the most favorable time to produce a hit. These data suggest something else. The hitter's most productive plate appearance is the 0-0 count with an average of 9.1 hits per plate appearance. This mean is nearly twice as large as the next closest mean and, therefore, provides very persuasive evidence for its inclusion as part of the hitter's count. In contrast, the hitter's least favorable plate appearance occurs in the 3-1 count with an average of 1.9 hits per plate appearance. Ironically, many "experts" in baseball believe that this 3-1 count is the most favorable condition for a hitter to produce a hit.

Based on the means displayed in Table 2, it was decided to operationally define the hitter's counts as 0-0, 0-1, 1-0, and 1-1. In so doing, it is possible to advise hitters and coaches to be keenly aware of the first two balls which are pitched. The hitter's likelihood of producing a hit is maximized during the early stages of the pitch count. The likelihood of producing a hit then decreases throughout the remaining pitches. Conversely, the pitcher's counts were operationally defined to be 3-1, 2-0, and 0-2 since means at these counts seem to separate themselves from the other counts.

The researcher recognizes the limitations imposed by these results. The decision to swing or not swing at a pitched ball is not made entirely on the basis of the pitch count. A variety of personal, social, and environmental factors may influence the occurrence of hits in the various pitch counts (Taylor & Cuave, 1994). It is assumed that these factors distribute themselves relatively evenly among all of the pitch counts, but further research is warranted to investigate this assumption.

Hypothesis Two and Hypothesis Three

Having previously defined hitter's and pitcher's counts, it was necessary to determine levels of achievement in hitting which could be used to operationally define above average, average, and below average hitters. Examination of the distributions of total hits across the various pitch counts yielded an interesting result. Some hitters made so few appearances at the plate that they could hardly be considered to be hitters. Therefore, the distribution tended to be skewed by the presence of extreme scores on the low end of the distribution. It was decided to use the 50th percentile of the distribution as the cutoff point for being a hitter or not. This eliminated 150 players who made very infrequent trips to the plate during the entire 1996 season. From the remaining 681 hitters, the three hitting groups were formed based on season batting average. The groups were formed in such a way as to include approximately 80 players in each group and still have groups be distinctive both logically and statistically. The hitters were then grouped accordingly: 1) below average hitters (.186-.217 *n*=85), 2) average hitters (.232-.248 *n*=79), and 3) above average hitters (.265-.328 *n*=76).

In order to test Hypothesis Two and Three, a two-way ANOVA was conducted with Group at three levels (above average, average, and below average hitters) and Count at two levels (pitcher's counts and hitter's counts). Hypothesis Two states that there would be no significant differences in batting averages when comparing the hitter's counts with the pitcher's counts. As can be seen in Table 3 by examining the marginal means for the two pitch counts, the hitter's count average is significantly greater than the pitcher's count average.

Table 3
Means and standard deviations for the three hitting groups by pitch count.

	Pitcher's Count	Hitter's Count	Marginal Means
Above Average Hitters	.238 ± .0585	.358 ± .0386	.298 ± .0330
Average Hitters	.201 ± .0550	.315 ± .0351	.258 ± .0270
Below Average Hitters	.162 ± .0679	.277 ± .0456	.219 ± .0330
Marginal Means	.199 ± .0680	.315 ± .0520	

As can be seen in Table 4 when examining the main effect of count, this difference is statistically significant. Therefore Hypothesis Two was rejected. Hitters have greater batting averages in the hitters counts (0-0, 0-1, 1-0, and 1-1) than in pitchers counts (3-1, 2-0, and 0-2).

Hypothesis three states there will be no differences in the batting averages when comparing below average hitters, average hitters, and above average hitters. Table 3 displays the three marginal means for the three hitting groups. As can be seen in Table 4 when examining the main effect of Group, there are significant differences among the three hitting groups. The Neuman-Keuls post-hoc test revealed that all three hitting groups were found to be significantly different from one another.

Table 4

Analysis of variance results for batting average.

Source	SS	df	MS	F
Group	.50	2	.25	128.34*
Error	.46	237	.00	
Count	1.63	1	1.63	481.74*
Group X Count	.00	2	.00	0.14
Error	.80	237	.00	
Total	3.39	479		

*Significant at the .001 level.

Therefore Hypothesis Three was rejected. Since the three hitting groups were selected in a manner designed to make them distinct, this result was expected. Perhaps more importantly are the sizes of the means themselves. These means may represent the first published attempt to quantify the hitting dimension of a player's capability. This provides a reasonable operational definition for above average, average, and below average hitting success in major league baseball.

It should be noted that the interaction effect shown in Table 4 is not statistically significant. Failure of the Group x Count effect to reach significance adds another dimension to these findings. There is no uniqueness to having a certain level of hitting success at a given group of counts. Above average hitters are not necessarily more successful in either the pitcher's counts or the hitter's counts. The same applies to the other two hitting groups. Using a univariate approach, hitting success is deemed important and so is the pitch count but they are independent of one another.

Hypothesis Four

Hypothesis four states that there will be no combination of pitch counts which can discriminate significantly among the three hitting groups. A stepwise discriminant analysis was performed to determine if any linear combination of pitch counts might discriminate among the three hitting groups. A classification analysis at each step revealed the percentage of cases that could be classified correctly using the significant discriminant functions. Table 5 shows at each step in the analysis: the pitch count, the Wilks' Lambda test statistic, and the percentage of correct classifications by group and for the overall sample. The Wilks' lambda test statistic was significant at each and every step in the

Table 5

Discriminant analysis and classification analysis results.

	Pitch Count	*Wilks' Lambda	Hitting Groups: Above Ave. 1	Ave. 2	Below Ave. 3	Overall
Step 1	0-0	.775	62%	25%	57%	48%
Step 2	2-2	.594	76%	43%	67%	62%
Step 3	0-1	.527	75%	49%	72%	65%
Step 4	1-2	.438	75%	60%	66%	67%
Step 5	3-2	.374	80%	65%	74%	73%
Step 6	2-1	.328	85%	75%	81%	80%
Step 7	1-1	.293	90%	72%	81%	81%
Step 8	3-1	.265	86%	72%	89%	83%
Step 9	1-0	.238	87%	76%	89%	84%
Step 10	0-2	.215	86%	81%	88%	85%
Step 11	2-0	.210	89%	82%	88%	87%

*Significant at the .001 level.

analysis. Therefore Hypothesis Four was rejected. Eleven different combinations of pitch counts can be used to discriminate among the three hitting groups, but there are different levels of success when using the data to classify the hitters. Even so, by Step 5 hitting ability and pitch count are so well linked that three-quarters of the cases can be correctly classified according to the pitch count. Further, by using the previous operational definitions for a pitchers count and a hitters count, it is noted that the hitters counts tend to appear earlier than the pitchers counts in the discriminant analysis (see Table 6). Multivariately then, a hitter's position in the pitch count can be an important

Table 6

Prevalence of hitter's versus pitcher's count in the discriminant analysis.

	Simple Count	Hitter's or Pitcher's Count
Step 1	0-0	H
Step 2	2-2	
Step 3	0-1	H
Step 4	1-2	
Step 5	3-2	
Step 6	2-1	
Step 7	1-1	H
Step 8	3-1	P
Step 9	1-0	H
Step 10	0-2	P
Step 11	2-0	P

determinant of the likelihood for hitting success. In particular, the first pitch or two appears to be the most critical from a hitter's perspective. Following those pitches, the count tends to change in favor of the pitcher.

DISCUSSION

The problem of the study was to: 1) determine the probability of hitters producing a hit in specific pitch counts and, 2) investigate the relationship between hitting success and the various pitch counts. A subproblem was to examine that relationship when considering pitcher's count versus hitter's counts. The premise was that good hitter's produce hits by relying more on the pitch count and location rather than tracking the flight of the baseball in its entirety to the point of initial contact with the bat. The data were the hitting statistics from all of Major League Baseball in 1996.

Even though hitting is of great interest in baseball it has not been studied in detail over the last few decades. There are not many studies in the literature regarding the relationship between pitch count and hitting success in baseball. The findings from this investigation then represent one of the few attempts to quantify and publish selected aspects of hitting. These findings may provide baseball players and coaches with useful information regarding predictability and probability of hitters producing a hit in specific pitch counts. This information may help baseball hitters and coaches determine the best possible pitch counts to produce a hit.

The data revealed that there is a profound difference in hitting success when comparing pitcher's counts and hitter's counts. Operational definitions for hitter's counts versus pitcher's counts were necessary in order to investigate this phenomena. This information alone is important for subsequent research given the lack of such in the literature. Previously it was thought that hitters produce more hits in these ill-defined hitter's counts versus the equally nebulous pitcher's counts. Many experts previously perceived the hitter's counts to be 3-0, 3-1, 2-0, 2-1, 3-2, but the data from this did not show that to be the case. The hitter's most favorable counts were 0-0, 1-1, 1-0, 0-1. Also, what experts had previously perceived to be pitcher's counts 0-0, 0-2, 1-2, 2-2, proved to be different as well. The data showed that the hitter's least favorable pitch counts were the 3-1, 0-2, 2-0 counts, thus these were identified as pitcher's counts.

The benefit of this new information indicates that expert coaches and players may need to revise what they perceived to be pitcher's counts and hitter's counts. Also, the age-old "Williams" theory of not swinging at the first pitch may need to be reconsidered by most, if not all hitters. Especially, if the hitter is looking for a specific pitch in a specific zone. Managers in the major leagues may benefit from this data in trying to incorporate offensive strategies during the course of the game. They may try the hit-and-run earlier in the pitch count, or they may try straight stealing in various pitch counts instead of waiting until certain patterns of pitch counts arise in the game. Managers and hitters may or may not have the green light automatically during the 3-1 count according to the minimal amount of hits produced at that count.

Pitchers should use this information and continue to go right at the hitters with a first pitch strike. Until hitting coaches and hitters make the adjustment of swinging earlier in the pitch count they need not worry as much about getting hit hard with the first few pitches. Pitchers will continue to have the upper hand as far as getting ahead early in the pitch count if they start the hitter off with a strike. By retiring the first hitter of every inning, pitchers will develop a high level of confidence in their pitching performance. Also, they may not have a high pitch count during the game which in turn may allow them to stay in the game a lot longer.

Interesting results emerged when examining the number of hits at each specific pitch count. Recall that experts previously tended to a perceive hitter's counts as 3-0, 3-1, 2-0, 2-1, 3-2. In this study the most productive plate appearances were very early in the count. The data suggests that the first two pitches are critical for hitters. After those two pitches, probabilities for hitting success decrease. Since we know that it is impossible to visually track a pitched baseball all of the way to the bat, it seems reasonable to conclude that better hitters utilize pitch count and location more efficiently than poorer hitters. This difference alone may help hitters work their way into a hitter's count during a plate appearance. This concept may help coaches teach young hitters to look for certain pitches during a plate appearance rather than swinging at any random pitch. This information should help both hitters and coaches develop offensive strategies during the game itself. As mentioned earlier, offensive strategies may include swinging earlier in the pitch count and giving the hit-and-run signal a lot sooner than in the past. Other suggestions may be getting the runners moving (stealing) earlier in the count instead of waiting for two strikes to be placed on a hitter. Pitchers could use this information to see where most of the hits occur according to pitch count. But since they know that hitters rarely like to swing at the first pitch, they can continue to start the hitter off with a first pitch strike and get ahead of the hitter.

This study revealed important differences among below average, average, and above average hitters and the various pitch counts that produce hits. When considered multivariately, hitting success at the various pitch counts helps characterize below average, average, and above average hitters. Varying degrees of success emerge when classifying the three hitting groups using the per-pitch count hitting average, but these findings profoundly link hitting success with pitch count. These findings do not agree with many experts in the field who suggest waiting until the hitter is hitting deeper in the count before starting the runners moving. This finding may help coaches in generating better offensive strategies during the course of the game. There are no pitch count variables that will predict perfectly when a basehit will occur. But taken as a whole, pitch count information is very revealing when considering hitting success.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The purpose of the study was to determine the predictability and probability of hitters producing a hit in specific pitch counts. In this study, batting statistics from every player of the 1996 Major League baseball season were analyzed to determine the probability of all hitters producing a hit at the various pitch counts. The subjects were all of the hitters (N=831) in both the American and National League of Major League baseball. The results are presented by hypotheses in the subsequent pages. For each of the various statistical tests, the .05 level of significance was used as the alpha level.

The means and standard deviations for the average number of hits at each pitch count were calculated for the total sample. As can be seen in Table 1, the summary data are listed two ways. They are ordered once by logical pitch count and then again according to the size of the mean. It should be noted that the 3-0 pitch count was excluded from all analyses. The data reveals that hitters simply do not attempt to hit a pitched ball when the count is 3-0.

FINDINGS

The principle investigator can be assured that major league baseball players utilize present pitch count and location of pitches rather than the restricted visual tracking of the baseball, especially as the velocity of the baseball reaches speeds of between 82 and 100 miles per hour. It seems more likely that above average hitters rely more on the present pitch count to help them make a decision to initiate a swing response. An analysis of the marginal means among the three hitting groups and the pitcher's versus hitter's counts revealed the following significant results: 1) above average hitters produced a better batting average in the pitcher's count than the average and below average hitters, 2) concurrently, above average hitters produced a better batting average in the hitter's count than the average and below average hitters, 3) although, there was not a significant difference between the 11 pitch counts and the three hitting groups. As mentioned earlier, the most interesting finding in the study that the greatest number of the hits were produced according to the 11 pitch counts. Experts in the field may utilize these findings during strategic opportunities in a game and also note that what they perceive as a hitter's count may need to be reconsidered.

Hypothesis One stated that there would be no difference in the average number of hits among the 11 pitch counts. This was the most interesting finding in the study. The data showed that when considering the various pitch counts alone, there were significant differences among the 11 pitch counts. Therefore, Hypothesis One was rejected.

Hypothesis Two states that there would be no significant differences in batting averages when comparing the hitter's counts with the pitcher's counts. There was a significant difference between the pitcher's and hitter's counts in favor of the latter when considering batting averages. Therefore, Hypothesis Two was rejected.

Hypothesis Three stated there will be no differences in the batting averages when comparing below average hitters, average hitters, and above average hitters. The researchers formulated three hitting groups due to hitting success at the various plate appearances during the season. The data showed that all three hitting groups were significantly different among each other. Therefore, Hypothesis Three was rejected.

Hypothesis Four states that there will be no combination of pitch counts which can discriminate significantly among the three hitting groups. The Wilks' Lambda test statistic revealed that numerous combinations of per-pitch count averages could be used to discriminate among and classify correctly the hitters. Therefore, Hypothesis Four was also rejected.

CONCLUSIONS

Within the limits of this study, it was concluded that:

1. The data showed that when considering the various pitch counts alone, there were significant differences among the 11 pitch counts. According to what many experts in the field consider the most favorable pitch counts for hitters, this was the most interesting finding in the study.
2. There was a significant difference between the pitcher's and hitter's counts in favor of the latter when considering batting averages.
3. The researchers formulated three hitting groups due to hitting success at the various plate appearances during the season. The data showed that all three hitting groups were significantly different among each other.
4. The Wilks' Lambda test statistic revealed that numerous combinations of per-pitch count averages could be used to discriminate among and classify correctly the hitters.

Therefore, it may be concluded that:

1. Expert coaches and players may need to reconsider their definitions of pitcher's and hitter's counts.

2. Hitters may want to look for pitches to hit earlier in the count.

3. Good hitters utilize present pitch count and location of pitches more efficiently than poorer hitters.

RECOMMENDATIONS

This study addressed the relationship between pitch count and hitting success in major league baseball. While the results do not convincingly guarantee the production of hits, there is evidence where most hits occur and the pitch counts that are most favorable for hitters as seen in Table 2. Even the greatest hitters fall prey to the modern desire to see as many pitches as possible.

Within the limits of the study, it is recommended that:

1. The better the pitcher, the more you should attack the first pitch.

2. If the pitcher is great, you probably should always swing at the first offering. No pitcher in baseball is effective on the first pitch. Conversely, every pitcher in baseball is effective when he gets ahead in the count.

Ted Williams, recognized as the best hitter in baseball, rarely swung at the first pitch. He formulated a theory to not swing at the first pitch that worked only for him, and incredibly, everybody believed it. For decades nobody could argue with Williams because nobody had enough data-who would keep a record of every pitch in every game? This year the facts arrived, and it's official: Williams theory has been disproved. According to these results, everybody should be swinging at a lot more first pitches.

This data reveal the first pitch is often the best one you are going to get. Most pitching coaches say, "Get ahead of the hitter." Unknowingly, most hitters let the pitchers get ahead of them. After all, the first pitch is the only pitch of every at-bat when you are guaranteed not to be behind in the count. It is the only pitch by which the pitcher has not had a chance to set you up, or expose one of your weaknesses. It is obvious that you can't strike out on a 0-0 count. The reason why hitters would spot pitchers a strike is still unknown in the game of baseball.

For a quarter of a century, hitting theories have been completed dominated by Williams' approach. Hitters have believed that great hitters take the first pitch and make the pitchers work. The more you see a pitcher, the more you study him. The few who did not follow Williams rule actually apologized for their faults. They would admit they would be better hitters if they followed Ted's way.

In the last decade, baseball statistics have evolved to the era of the computer chip. Gradually it is become commonplace to hear expert players and coaches verbalize ideas, whether they know it or not, from people with calculators or computers. For example, many experts can now tell you that baseball is a game of firsts. The most important hitter of an inning is the first batter. Also, the most important pitch to any hitter is the first pitch.

All this came from statisticians. But baseball may not yet have learned the most important of all its important firsts. Someday in the near future, one of baseballs least questioned clichés will be, "Do not get behind in the count." How could we have overlooked something some obvious for so long?

The more you look at the new numbers baseball has at its disposal, the more conclusive evidence is that, for a large majority of hitters, the quickest road to improvement is to be less "patient" and more aggressive. Why, for instance, would a team try to "tire out" the opposing starting pitcher by taking pitches? This is the age of five-deep bullpens. No one gets to face tired pitchers anymore. There is certainly no pattern of decreased production with increased aggressiveness. Swing! It is your only hope.

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APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL

OKLAHOMA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD
HUMAN SUBJECTS REVIEW

Date: 04-16-97 **IRB#:** ED-97-098

Proposal Title: THE RELATIONSHIP BETWEEN PITCH COUNT AND HITTING SUCCESS IN MAJOR LEAGUE BASEBALL

Principal Investigator(s): Steven W. Edwards, Larry Guerrero

Reviewed and Processed as: Exempt

Approval Status Recommended by Reviewer(s): Approved

ALL APPROVALS MAY BE SUBJECT TO REVIEW BY FULL INSTITUTIONAL REVIEW BOARD AT NEXT MEETING, AS WELL AS ARE SUBJECT TO MONITORING AT ANY TIME DURING THE APPROVAL PERIOD.
APPROVAL STATUS PERIOD VALID FOR DATA COLLECTION FOR A ONE CALENDAR YEAR PERIOD AFTER WHICH A CONTINUATION OR RENEWAL REQUEST IS REQUIRED TO BE SUBMITTED FOR BOARD APPROVAL.
ANY MODIFICATIONS TO APPROVED PROJECT MUST ALSO BE SUBMITTED FOR APPROVAL.

Comments, Modifications/Conditions for Approval or Disapproval are as follows:

Signature:
Chair of Institutional Review Board
cc: Larry Guerrero

Date: April 17, 1997

VITA

Larry Michael Guerrero

Candidate for the Degree of

Doctor of Education

Thesis: THE RELATIONSHIP BETWEEN PITCH COUNT AND HITTING SUCCESS IN MAJOR LEAGUE BASEBALL

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