SENIOR RESEARCH PROJECT

FSU College of Optometry

Anthony B. Leach
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EYE MOVEMENT STRATEGIES OF BASEBALL BATTERS

Robert L. Carter, O.D.
Rick Billings, O.D.
Anthony B. Leach

ABSTRACT

The eye movement patterns utilized by five college varsity baseball players during actual batting practice were monitored using a modified electrooculography technique. The results indicate that the more successful batters utilized a "pursuit-saccade" as opposed to a "pursuit-only" eye movement pattern, and the most successful batter was able to achieve fixation (presumably of the impact area) prior to impact.

KEY WORDS

Baseball vision, eye movements, sports vision.

INTRODUCTION

Many optometrists have wholeheartedly embraced the "sports vision" principles of vision enhancement, but little research has been published concerning which visual skills are important in certain athletic activities, or what visual strategies lead to better athletic performance.

Recent non-optometric literature has elucidated the visual difficulties encountered by baseball players while attempting to hit a pitched baseball, and very sophisticated techniques have been utilized to measure eye and head movement patterns in batting simulations.

The basic difficulty is that the often-heard coaching instructions such as "keep your eye on the ball" and "watch the ball until it hits the bat" are physiologically impossible for even "hall-of-famers" to accomplish if these instructions are meant to tell batters that they should foveally track the pitched baseball throughout the entire duration of the pitch. The human pursuit movement mechanism simply cannot achieve the angular velocity that is required to do so.

The angular velocity of the pursuit movements necessary to foveally track a straight pitch has been calculated using the formula shown in Figure 1.[a] This formula for instantaneous pursuit velocity

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Insert Figure 1 about here

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demand has been computerized along with similar instantaneous demand formulas for pursuit acceleration, accommodation velocity, accommodation acceleration, vergence velocity and vergence acceleration.[b] The relative angular velocities of an "inside corner," "heart of the plate," and "outside corner" 77 mile per hour pitch were generated and are displayed graphically in Figure 2.

Insert Figure 2 about here

This figure shows that the relative angular velocities of these pitches exceed 100°/sec, when the ball is still 10, 14 and 17 feet in front of the plate, respectively. Previous research indicates that the human pursuit mechanism cannot smoothly track objects with a velocity greater than 100° /sec. Bahill[1] measured maximum gaze velocity (head plus pursuit eye movement) of a major league player at 150°/sec, but even this value allows foveal tracking of a 77 m.p.h. pitch only to within 8, 12 and 14 feet respectively.

These previous studies have only been visual simulations in the laboratory without swing attempts. The task was not to hit a pitched ball, but rather to visually track it as long as possible. Our experiment was different in that the eye movement patterns of college players were measured during actual batting practice. The task of the subjects in this study was to hit the ball rather than visually track it as long as possible.

METHODS

Five right-handed batters were recruited from the Ferris State College varsity baseball team to serve as subjects in this pilot study. A pitching machine was placed upon a regulation pitching mound inside a batting cage and calibrated (using a radar gun) to deliver 77 m.p.h. straight pitches to the home plate area at a distance of 60.5 feet from the pitching rubber. The pitching machine released the ball 3.5 feet in front of the rubber to compensate for the stride that a pitcher would take in a wind-up prior to the release of the ball. The initiation of the event (pitch) was monitored by placing a laser and photocell on an optical bench in front of the pitching machine. As the ball broke the laser beam, the amplified output of the photocell produced a deviation on a physiograph trace. In addition, the subjects used a bat equipped with strain gauge which monitored the strain induced by the swing of the bat and the specific strain caused by the bat-ball impact. Output from the photocell and the strain gauge were recorded together on one physiograph channel and served as a time reference in order to analyze the timing of the eye movements relative to the position of the ball during the pitch.

The batters wore a forehead reference electrode and measuring electrodes at the outer canthus of each eye, which determined electrooculograph (EOG) potentials. This electrode positioning allowed measurement of and differentiation between lateral pursuit and/or saccadic eye movements based upon velocity changes. These EOG potentials were plotted on a second physiograph channel and, prior to taking batting practice, 30° amplitude, saccadic and pursuit calibrations were measured for each individual batter. A diagram of the apparatus is shown in Figure 3.

Insert Figure 3 about here

The trace of the strain gauge also enabled determination of the outcome of the event in that a "take" (no swing), a swing and a miss, and a swing with ball-bat impact each resulted in distinguishable recordings. These characteristics allowed correlation between eye movements employed and success in the task of hitting the ball, as opposed to simply measuring the ability of an observer to track the incoming pitch as long as possible. Each subject was "thrown" approximately 10 warm-up pitches and then measurements were determined on the next 25 to 55 pitches.

RESULTS

The eye movement patterns exhibited by the subjects during swing attempts showed little intrasubject variability and fell into two distinct categories described as "pursuit-saccade" and "pursuit-only." These patterns are illustrated by the upper traces in Figures 4a and 4b respectively. Dextroversions (rightward eye movements from the release point toward the impact area) are represented by upward deflections and

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Insert Figure 4 about here

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the calibrations bars represent 20° deviations. The oscillating peaks and valleys in these traces are "noise" in the recording system caused by body movements of the batters and resulting movement of the recording wires. The bottom traces in Figures 4a and 4b are the laser switch/ strain gauge timing and outcome recordings. Figure 4a illustrates a "swing-with-bat-ball-contact" and Figure 4b illustrates a "swing-and-a-miss." The sudden increase in slope shown in the eye movement trace in Figure 4a represents the abrupt increase in velocity at the initiation of a saccade approximately 340 msecs after release, while the relatively flat recording preceding this point represents the initial pursuit. The gradual increase in slope shown in Figure 4b illustrates an ever increasing pursuit velocity without a saccade prior to the initiation of the swing.

Four of the five subjects consistently utilized the "pursuit-saccade" strategy when they chose to swing at the pitch, while only one batter utilized the "pursuit-only" strategy when he chose to swing. Table 1 correlates eye movement strategy with success as measured by contact percent (swings with contact x 100 divided by total swings). The subject who used the "pursuit-only" strategy had the lowest contact percentage in this study.

Insert Table 1 about here

The strain gauge (lower) trace in Figure 4c shows only gentle oscillations that occurred as the batter made the preparatory movements prior to initiating the swing, but not the obvious strain induced by either a full swing or impact. The eye movement patterns exhibited by the subjects showed considerable intrasubject variability in these "take" situations, in that each subject demonstrated both types of strategies in different "take" situations.

DISCUSSION

Vergence movements were not monitored because the velocity demands necessary are beyond the human range, and that vergence movements are unimportant in this task since the amplitude needed is only about 3°.

However, analysis of the usable data illustrates that most batters consistently employ a "pursuit-saccade" strategy of eye movements rather than a "pursuit-only" strategy, and these batters were more successful in the task of hitting the ball. In addition, the subject who made contact the greatest majority of the time was also the only subject who consistently timed the saccade to stop prior to or at impact. This further suggests that a strategy of "pursuit-saccade-fixation of impact" is the best eye movement strategy that a batter can employ when making a swing attempt. Given the latencies of visual and proprioceptive sensory signals, as well as the latencies of the motor acts involved in a swing, one has to ask: "Of what value is the fixation of impact to the batter?" The above-mentioned latencies plus the phenomenon of saccadic suppression[5] force one to conclude that any visual information received in the last 120 msec of the pitch is useless in allowing the batter to alter the swing.

We postulate the existence of a "trigger mechanism" that is initiated when the batter makes the decision to swing. Information received prior to pulling the trigger (initiation the swing) is used to "aim" the bat at a certain area in space and time. Once the trigger is pulled, the act cannot be altered by the batter, so foveal tracking is not necessary and perhaps not even desirable.

Studies with golfers have indicated the existence of a "trigger-mechanism" in that once the downswing is initiated, swing alterations cannot be made and visual input does not aid in performance.[6] Similarly, once a baseball batter "reads" the pitch and decides where and when to try to put the bat on the ball, he "pulls the trigger" and becomes a golfer in the sense that the predicted impact area is chosen and is stationary. He must then time the arrival of the bat and the ball at this chosen stationary spatial point of predicted impact. Fixation of impact using a pre-impact saccade may aid in guiding the motor act of swinging the bat to the chosen point, or may simply be a sign of excellent timing on the part of the batter.

CONCLUSIONS

It is obvious that batters cannot "keep their eyes on the ball" by foveally tracking it throughout the duration of the pitch. Batters must use either 1) a "pursuit-only" strategy which results in their eye movements lagging behind the ball, or 2) a "pursuit-saccade" strategy which results in their eye movements "jumping" ahead of the ball. In spite of the limited number of subjects in this study, the "pursuit-saccade" eye movement strategy appears to be used by the more skilled baseball batters and fixation of impact appears to be associated with successful performance. This study utilized only relatively slow (77 m.p.h.), straight, consistently placed pitches, which made the task much simpler than it would be during game conditions, where the pitcher could alter the trajectory, placement, release point and/or speed of the pitches, but it appears that sports vision experts and batting coaches should encourage batters to "read the pitch" with a pursuit, saccade to the impact area, and fixate impact with the eyes stationary to improve their performance in this difficult task.

We believe that vision enhancement training programs for baseball batters should be designed to improve pursuit and saccadic skills and/or the ability to predict the arrival of incoming objects in time and space. We further believe that the best visual enhancement training program for improving batting performance should center around having the athlete take more supervised batting practice instead of performing in-office visual training procedures. However, more research obviously is necessary to fully understand this and the other complex visual tasks involved in athletic events before one can fully understand, predict or measure the benefits of any visual enhancement program.

FOOTNOTES:

a. Carter, J.M. personal communication, 1982.

b. LASA Research Group. "Accomodative Velocity, Convergence Velocity, Version Velocity Calculation Programs." 1514 Burke NE, Suite C; Grand Rapids, MI 49505.

REFERENCES

1. Bahill A.T., Laritz, T. "Why Can't Batters Keep Their Eyes on the Ball?" American Scientist 1984; 72: 249-53.

2. Allman, W.F. "The Swing's the Thing." Science 1985 (April).

3. Burke, R.M. "Control of Eye Movements," Moses, R.A., ed. Adler's Physiology of the Eye, 6th ed. St. Louis: C.V. Mosby, 1975: 123-65.

4. Berson, E.L. "Electrical Phenomenon in the Retina," Moses, R.A., ed. Adler's Physiology of the Eye, 6th ed. St. Louis: C.V. Mosby, 1975: 482.

5. Shickman, G.M. "Time-dependent Functions in Vision," Moses, R.A., ed. Adler's Physiology of the Eye, 6th ed. St. Louis: C.V. Mosby, 1975: 629-83.

6. Cochran, A., Stabbs, J. "Programming the Swing: Some Mental Aspects of Golf," The Search for the Perfect Swing. Philadelphia: J.B. Lippincott, 1968: 100-04.

TABLE 1. Eye Movement Strategy versus Batting Success

Subject Number	Total Pitches	Hit	Missed	Take	Check	Contact Percent	Eye Movement Strategy
1. (WH)	25	17	2	6	0	89.5	pursuit-saccade
2. (BH)	53	38	5	7	3	88.4	pursuit-saccade
3. (JD)	55	37	12	4	2	75.5	pursuit-saccade
4. (EH)	55	36	10	5	4	78.3	pursuit-saccade
5. (SK)	30	11	7	9	2	61.1	pursuit-only

FIGURE LEGENDS

Figure 1. Relative Angular Velocity Formula:

V_{ϕ} = instantaneous angular velocity (radians/second);

d = perpendicular distance between batter and line of flight (meters);

h = distance between ball and batter (meters);

V_p = velocity of pitch (meters/second).

Figure 2. Relative Angular Velocity versus Distance of Ball from Plate (77 m.p.h. pitch).

Figure 3. Diagram of Apparatus.

Figure 4. Physiograph Recordings: upper traces = eye movements; lower traces = laser switch/strain gauge recordings

a) Pursuit-Saccade-Fixate Strategy;

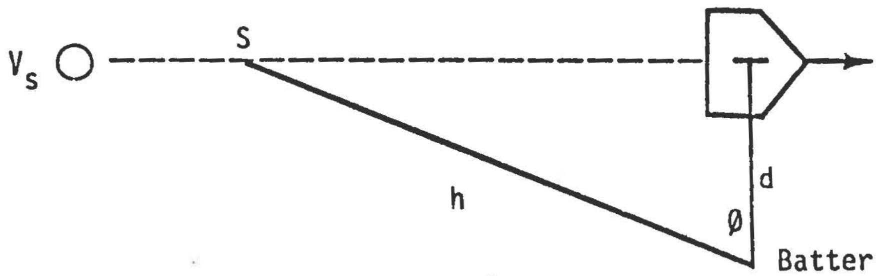
b) Pursuit-Saccade Strategy;

c) Pursuit-Only Strategy.

Table 1. Eye Movement Strategy and Batting Success.

Figure 1. Relative Angular Velocity of Pitch

Derivation of Formula



V_s = velocity of pitch (m/sec)

d = perpendicular distance between batter and line of flight (m)

h = distance between ball and batter (m)

v_ϕ = relative angular velocity (radians/sec)

= dV_s/h^2

Figure 2. Relative Angular Velocity versus Distance from Plate

(77 mph fastball)

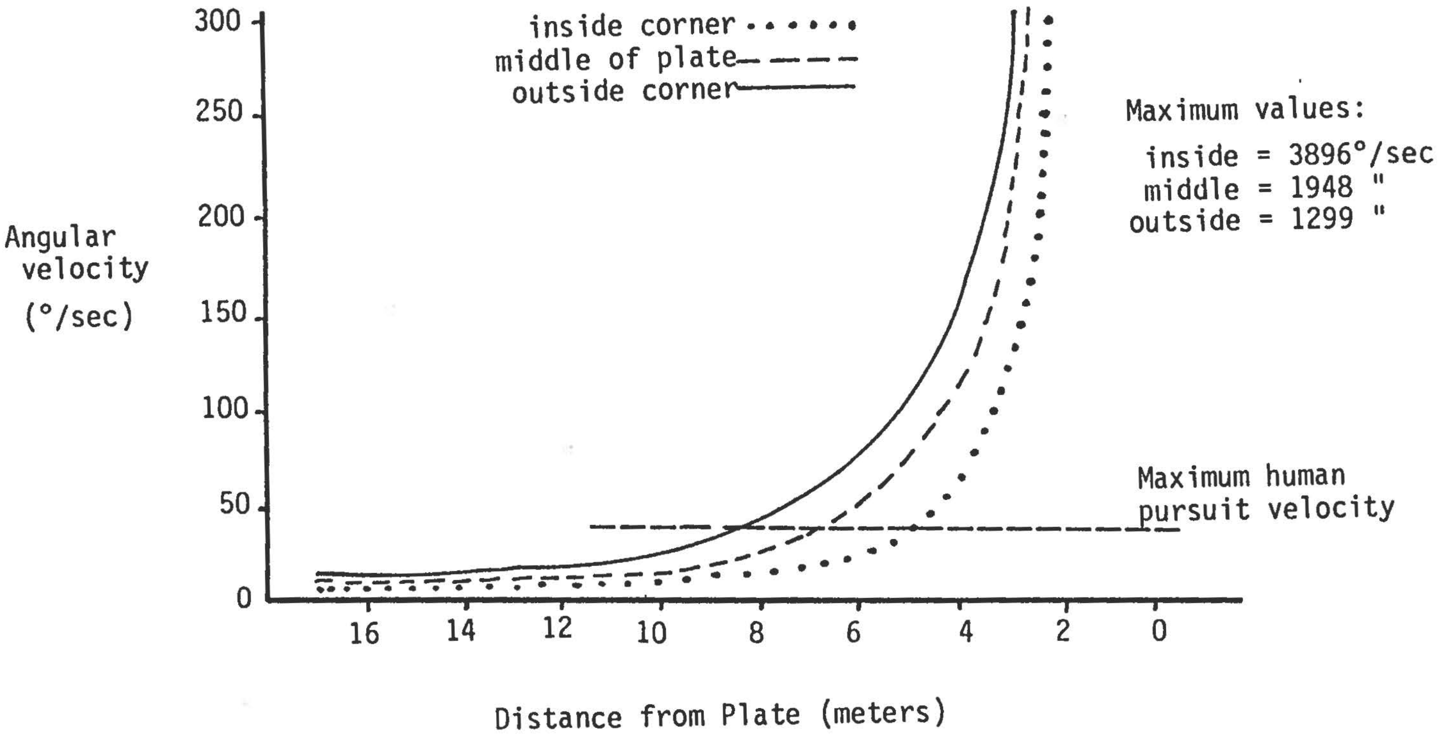


Figure 3. Diagram of Apparatus

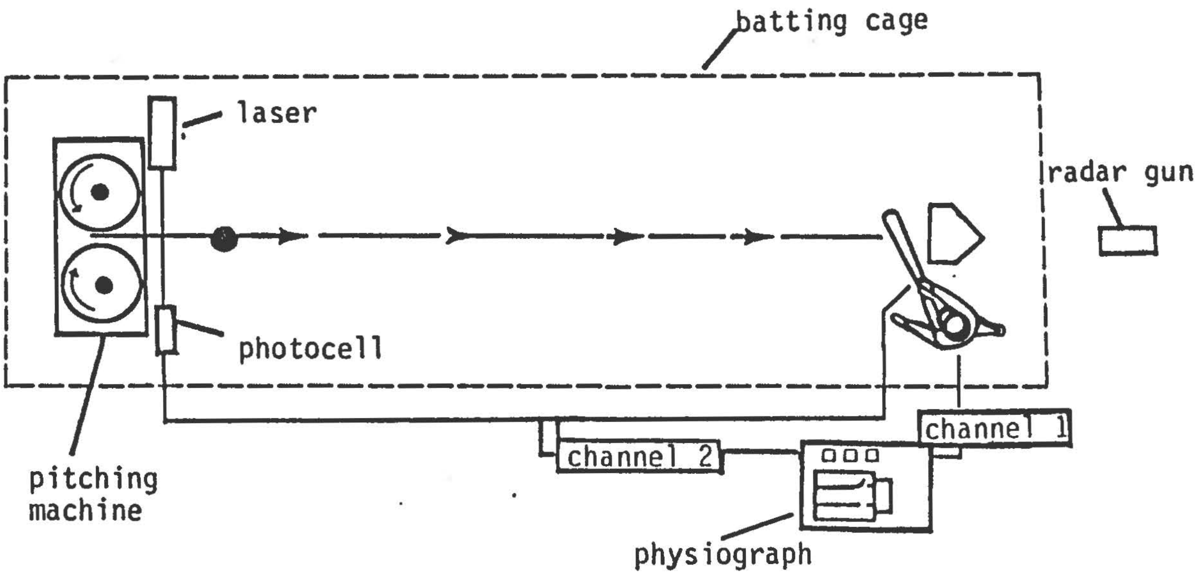
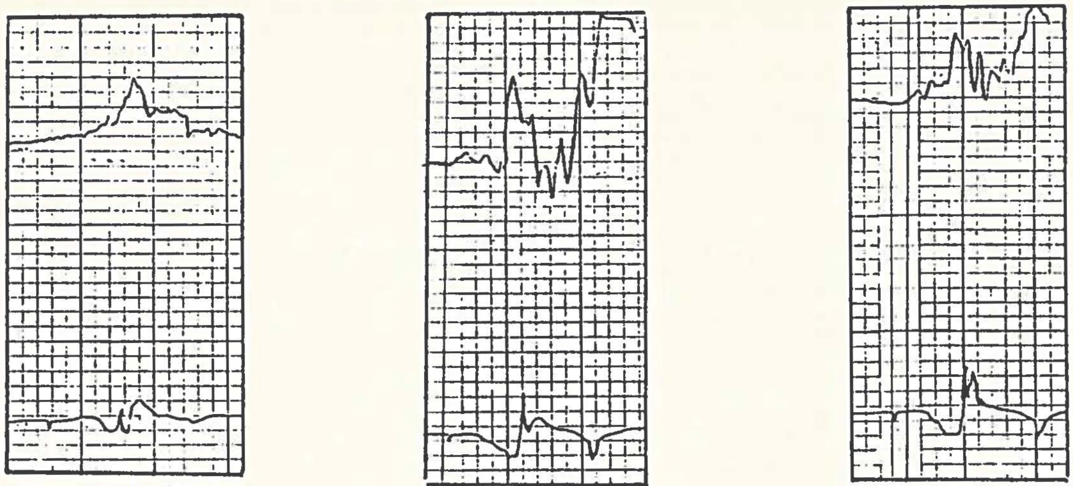
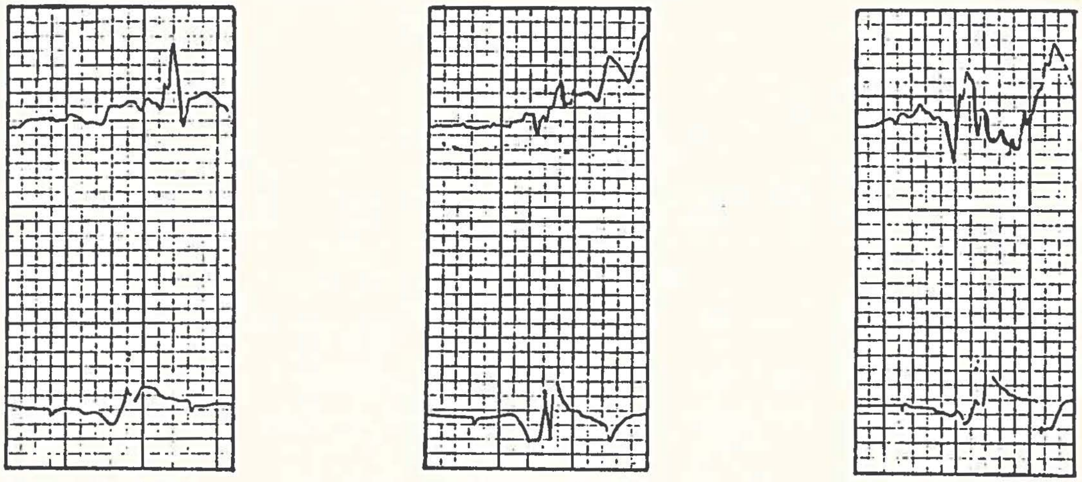


Figure 4a.



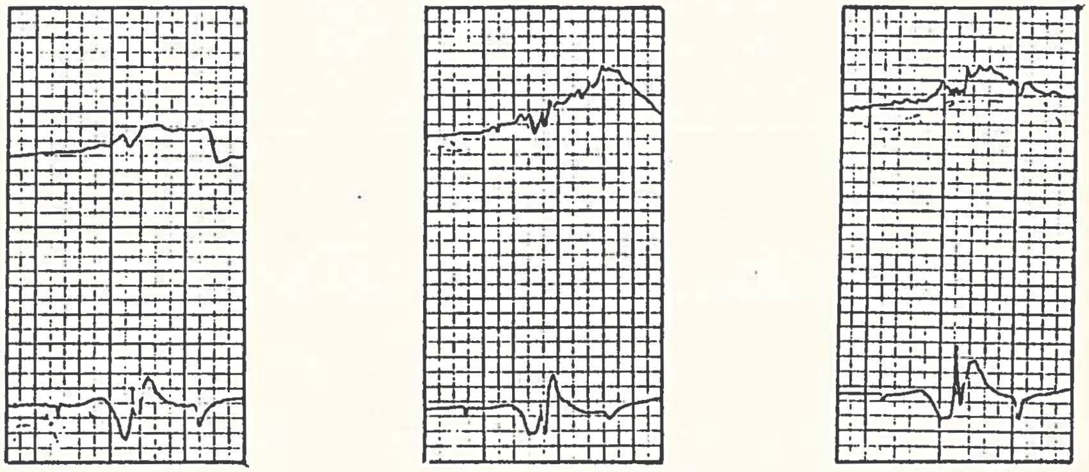
Pitch 18 (WH) Pitch 20 (WH) Pitch 25 (WH)

Figure 4b.



Pitch 3 (JD) Pitch 14 (JD) Pitch 17 (JD)

Figure 4c.



Pitch 1 (SK) Pitch 13 (SK) Pitch 22 (SK)

Figure 5. Correspondence between Eye Position and Ball Position "Pursuit-saccade-fixate" Strategy