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### Spin rate and seam orientation as visual cues in baseball

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## Spin rate and seam orientation as visual cues in baseball

### Abstract

This study investigated the viability of baseball spin direction and seam orientation as visual cues in predicting the flight path of pitched baseballs and thus increasing hitting accuracy. Ten male Optometry students served as subjects. Using an instrument designed to minimize all visual cues associated with a simulated pitched baseball aside from spin direction and seam orientation, the subjects viewed a striped ball with three possible seam orientations at varying spin rates. Viewing distance, time, and stripe size were chosen to closely simulate the parameters of professional pitches. Results indicated that subjects were able to accurately resolve the stripe orientation and spin direction at an average maximum spin rate of 490 RPM, with a range of resolvable spin rates between 355-800 RPM. As professional fastball spin rates vary between approximately 1500-1800 RPM, we have concluded that the visual systems of average young healthy males are not capable of resolving seam orientation and spin direction of professional fastball pitches. Further studies testing professional or high level amateur baseball players are required to determine the viability of using these visual cues as a training technique to improve hitting percentage.

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**SPIN RATE AND SEAM ORIENTATION AS VISUAL CUES IN BASEBALL**

BY

KURT KUSKIE

&

LYLE REGIMBALD

A THESIS SUBMITTED TO THE FACULTY OF  
THE COLLEGE OF OPTOMETRY  
PACIFIC UNIVERSITY  
FOREST GROVE, OREGON  
FOR THE DEGREE OF  
DOCTOR OF OPTOMETRY  
MAY, 2002



ADVISOR:

BRADLEY COFFEY, O.D.



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Grade Page

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## BIOGRAPHY

**Kurt Kuskie** is a 2002 graduate of Pacific University College of Optometry. He earned a Bachelors of Science degree in Industrial Distribution from the University of Nebraska at Kearney in 1995. Upon graduation, he is interested in starting a private practice or participating in a co-management setting.

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## ABSTRACT

### Spin Rate and Seam Orientation as Visual Cues in Baseball

Kurt Kuskie, Lyle Regimbald

This study investigated the viability of baseball spin direction and seam orientation as visual cues in predicting the flight path of pitched baseballs and thus increasing hitting accuracy. Ten male Optometry students served as subjects. Using an instrument designed to minimize all visual cues associated with a simulated pitched baseball aside from spin direction and seam orientation, the subjects viewed a striped ball with three possible seam orientations at varying spin rates. Viewing distance, time, and stripe size were chosen to closely simulate the parameters of professional pitches. Results indicated that subjects were able to accurately resolve the stripe orientation and spin direction at an average maximum spin rate of 490 RPM, with a range of resolvable spin rates between 355-800 RPM. As professional fastball spin rates vary between approximately 1500-1800 RPM, we have concluded that the visual systems of average young healthy males are not capable of resolving seam orientation and spin direction of professional fastball pitches. Further studies testing professional or high level amateur baseball players are required to determine the viability of using these visual cues as a training technique to improve hitting percentage.



## **ACKNOWLEDGEMENTS**

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## INTRODUCTION

It is accepted that in order to succeed in sports one must not only display superior physical skills but must also possess an excellent visual system (1,2). With the dawning of sports vision testing and training as an optometric discipline it has been documented that athletes have better visual abilities than non-athletes and these visual abilities are trainable and transferable to the performance of the athlete. In general, the athletes possess larger usable visual fields, enhanced peripheral acuity, larger motion perception fields, more accurate depth perception, better dynamic visual acuities, higher contrast sensitivity, better ocular motilities, and faster visual cortical processing speeds (1,2).

A sport with incredible visual demands is America's favorite pastime, baseball. Ted Williams, arguably the best hitter since baseball's beginnings, has described hitting a baseball as "the most difficult single act in all of sports" (3,4). In fact, his lifetime batting average is only .344, which means that he was able to successfully hit the ball and reach the bases on only three out of ten attempts. Williams' slugging percentage was .634. This translates into the number of times he was able to make contact with the ball putting it in fair play. Although this seems like a relatively poor performance level, it is surprising that batters are capable of achieving this task at all, given the environmental and neuro-physiological limitations of humans.

Baseball is a physically difficult sport because it relies on split-second reaction time and is restricted by the physiological limits of nerve impulses. A batter's judgment, decision-making and body movements require hundreds of

thousands of nerve cells working simultaneously. The cells responsible for whether or not a batter swings the bat are perhaps the slowest cells in the visual motor pathway (5). These cells receive their input from the eye via the visual cortex. The process of information transfer regarding the velocity, trajectory, and spin of the baseball from the retina to the higher visual cortex takes at least  $43/1000$  sec (5). Due to human physiological limitations in speed at which the bat can be swung, the decision to swing at a 90-95 mph pitch must be made during the first 25-30 feet of the ball's flight (6). As the total flight time is slightly less than 0.5 seconds, this leaves slightly less than 0.25 sec for these decision cells to decide if, when, and where to swing the bat.

Experienced batters utilize several visual cues in determining the type of pitch delivered and where it will cross the plate. One such cue is the differences in the pitcher's grip of the ball for various pitches. For example, in delivering a fastball the pitcher's index and middle finger are straight over the top of the ball as it is released. Throwing a curveball, the pitcher wedges the ball between his thumb and forefinger slightly off center as the ball is thrown with the pitcher's wrist turned at a 90 degree angle. Other visual cues used by experienced batters are arm and wrist motions which vary for different pitches. Spin pattern and seam orientation play crucial roles in the ball's trajectory. In general a ball will curve in the same direction as it is spinning. This is known as the Magnus Effect (7). A major league curve ball can veer from a straight line as much as 16.7 inches by the time it crosses home plate depending on the seam orientation (8). A four-seam pattern in the direction of the ball's spin (four lines of stitching pass across

the face of the spinning ball with each revolution) will curve more than a similarly pitched two-seam pattern (7). These conclusions have been determined using wind tunnel testing, high-speed photography, and mathematical modeling and computer simulation (9).

The quicker a batter can recognize a pitch being released, the more successful he will be in making contact with the ball. The focus of this study was to determine if batters can feasibly use the spin and seam orientation of a pitched baseball as visual cues to discriminate between pitches.

## LITERATURE REVIEW

In reviewing the literature related to sports vision and baseball one may find several studies that investigated and compared visual abilities of competitive baseball players. In a study by Solomon et al. (10) the dynamic stereo acuity of major league hitters was compared to that of major league pitchers. Using an instrument employing 9X10 cm variable polarized targets similar to Wirt circles mounted on a movable light box, subjects wearing polarized filters viewed the targets as they moved towards them on a four-meter track. Accuracy, as well as speed of stereopsis was measured. The results indicated significantly higher accuracy among hitters than that of pitchers.

In a study by Hoffman et al. (11) contrast sensitivity was measured and found to be significantly better among college varsity baseball players than optometry students. The subjects were tested using the Arden method (12) whereby subjects viewed six plates containing gratings of varying frequencies at

57 cm. Each grating has varying levels of contrast from the top to the bottom of the plate. Results of this study indicated that varsity baseball players are significantly more sensitive to lower levels of contrast at all spatial frequencies than the control group of optometry students. Other studies indicate better visual acuity, distance stereo acuity, and contrast sensitivity for major league baseball players versus minor league players (13).

In addition to these studies of sensitivity to contrast, researchers have conducted studies of binocularity and its role in baseball through the use of the Pulfrich phenomenon in which an object, oscillating in a frontal two dimensional plane, appears to orbit in three dimensions when light from the object is attenuated before entering one eye. Experimentation by Hofeldt et al. (14,15) consisted of a stereophotometer with an oscillating pendulum traveling at three cm per cycle and 70 cycles per minute. Light intensity from the instrument was attenuated with a linear gradient neutral density filter wheel that was placed in front of the subject's eye(s). Hofeldt hypothesized that a superior visual system would have higher thresholds for eliciting the illusion and lower thresholds to stop the illusionary state. The hypothesis held true for the professional baseball players who had superior visual systems and consistently performed better than minor league players. Specifically, for major league players greater light attenuation was required to achieve the illusion, and it was lost with less change in light levels to the filtered eye. The researchers claim, "a minimum of 47% of the variation of the batting averages of the major league players tested can be accounted for by variations in the stereophotometric results" (14, 15).

Using similar methods the authors tested the ability of subjects to hit baseballs in a batting cage while wearing neutral density filters over both eyes or over each eye individually (15). Their observations show that filtering both eyes equally had no significant effect on performance (87% vs. 94% with no filters). Interestingly, binocular viewing with a filter before the preferred eye caused significantly greater reduction in hitting than with the filter placed over the opposite eye (36% hitting percentage vs. 80%). This suggests an ocular dominance effect within the motion stereopsis system.

A study by Wold et al. (16) demonstrated significant and long lasting improvement in visual abilities following vision therapy including pursuits and saccadic movements, accommodative facility, convergence, acuity, binocular alignment, focus alignment relationships, fusion, and stereopsis. An important question to consider is whether enhanced visual abilities are transferable to the performance of the athlete.

Several studies have been performed and support the theory that the visual skills necessary for specific sports can be successfully enhanced through sports vision therapy (17-22). According to Nishizawa (23) a vision therapy program emphasizing accommodative facility, visual tracking and locating skills, stereopsis, the interaction of accommodation and convergence, and certain vision oriented baseball training methods developed by Harrison (24) correlated to significantly improved solid contact hitting.

A similar study by Revien (25) showed the effects of vision training on athletic performance. After participating in vision therapy, members of the New



York Sandlot Baseball Club improved their collective batting average by 72 percentage points over the previous year's average while the control group of players with the same amount of batting practice but no vision training improved by only 29 percentage points. In addition the non-trained players strike-out percentage remained about the same (22.1%) while the visually trained players struck out only 9.2% of the time as compared to 17.2% in the previous year.

Several testimonials from athletes who have undergone vision therapy claim their performance in sports has improved specifically due to the vision training. Lou Piniella improved his batting average from .279 to .312 following vision training using a vectogram to enhance binocularity (26). George Brett underwent similar vision training to enhance depth perception. After the training, he no longer experienced periodic double vision while going after pop-ups at third base (26). There are several other examples of players who claim to have greatly improved their performance following vision training, including Barry Bonds, Bobby Bonilla, Don Mattingly, Tony Gwynn, and Will Clark (26).

An excellent review of specific techniques used in sports vision enhancement training by Coffey and Reichow (27) is available. The authors describe traditional methods of accommodation and vergence facility training. In addition, techniques aimed at enhancing visual reaction and response speed, eye-hand coordination, peripheral vision, and dynamic visual acuity are discussed.

Specific studies and training techniques designed to enhance a batter's ability to determine rotation and seam orientation of a pitched ball are relatively

few. A study by Osborne et al. (28) investigates the effectiveness of using visual cues to highlight the seams of baseballs to improve the hitting of curve balls. Using 1/4 and 1/8 inch orange stripes marking the seams of baseballs compared to unmarked balls the researchers demonstrated that subjects hit a significantly greater percentage of marked than unmarked balls.

The focus of the current study is to investigate the ability of humans to accurately identify the spin direction and seam orientation of a simulated pitched baseball.

## METHODS

Subjects chosen for this study consisted of ten male optometry students between 23 and 32 years-old. Preliminary screening of subjects revealed that each participant demonstrated at least 20/20 BVA, using a standard projected Snellen chart. The subjects exhibited normal binocular motor and sensory fusion, as determined by cover testing and BVAT distance stereo acuity measurements. Each subject demonstrated 30 sec arc stereo acuity or better. In addition, the subjects demonstrated contrast sensitivity at or above the normal range as measured and graphed by the Vector Vision contrast sensitivity test (29).

Dynamic visual acuity was measured using a variable speed rotating Landolt C projection system subtending ten minutes of arc at a three meter test distance as described by Coffey and Reichow (2). The recorded findings from the current study were compared to the results published by Coffey and Reichow

and found to be significantly similar. The threshold of resolution of moving targets for all participants in this study was found to be between speeds of 63-79 rpm. This correlates to a normative average of  $44.2 \pm 13.3$  rpm for Olympic athletes as determined in the Coffey and Reichow study (2).

In addition, each subject displayed eye-hand reaction and response times between 180-250 msec and 310-430 msec, respectively, using the Reaction Plus instrument (2). These results compare to the eye-hand reaction and response values of  $207 \pm 70$  msec and  $350 \pm 130$  msec as published in *Optometric Evaluation of the Elite Athlete* (2).

The instrument used in this study was designed to minimize all visual cues associated with a pitched baseball aside from spin direction and seam orientation. This was accomplished by using a ball mounted on a rotating shaft driven by an electric motor. The speed of rotation was varied between 200-1000 RPM and was controlled by a voltage rheostat. The ball used in this test was a hollow plastic ball the size of a regulation baseball painted white with four black equally spaced stripes (100% contrast) measuring one cm wide to approximate the width of a baseball seam (Figure 1).

An aperture of 2.0 inches in diameter was used to prevent the subject from seeing the sides of the ball and the mounting shaft. Three different stripe orientations (135, 180, 45 degrees) were presented by rotating the motor and shaft assembly in 45-degree steps around the z-axis. All movable parts were concealed in a 3.5 ft x 4 ft x 1.5 ft wooden box painted flat gray (Figure 2). The apparatus was placed flat on the ground, and subjects viewed the rotating

ball stimulus through an angled front surface mirror mounted above the rotating ball.

Figure 1. Illustration of Ball Markings at each Orientation

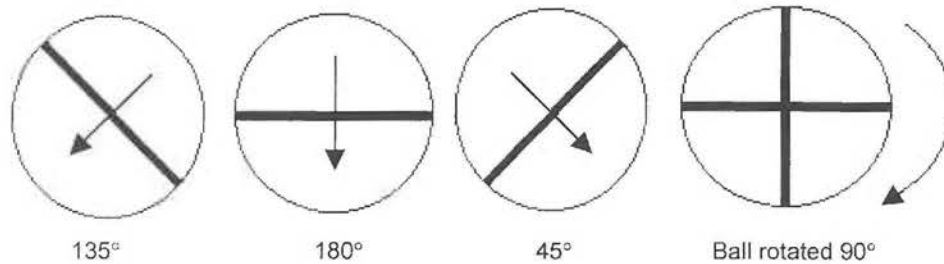
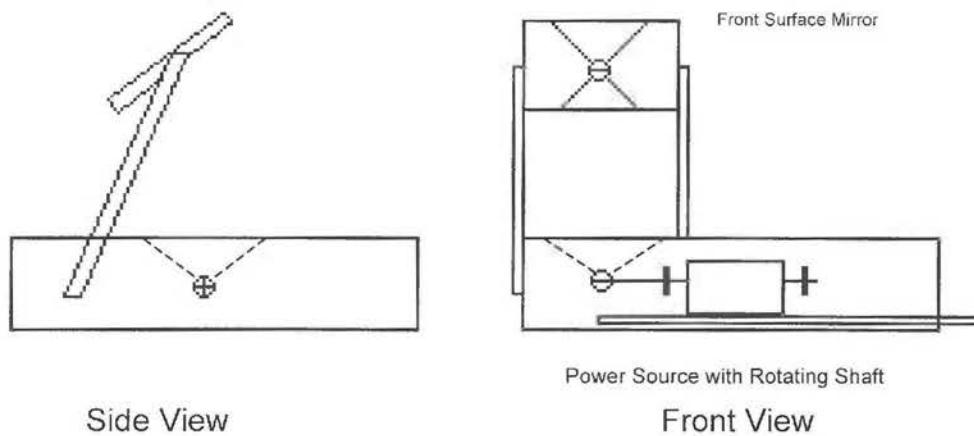


Figure 2. Testing Apparatus Side and Front View



Subjects viewed the ball from a distance of 23 feet. This distance approximates the closest ball position at which a batter must decide whether or not to swing at an 80 mph pitch. Viewing time was controlled by a shutter system that illuminated the rotating ball for 0.5 seconds, slightly longer than the amount of time required for a major league pitch to travel from the pitcher's hand to home plate.

The main objective of these trials was to evaluate the subject's ability to identify and discriminate between three different spin orientations (135, 180, 45 degrees) at five varying spin rates. The spin rates were 200, 400, 600, 800, and 1000 RPM.

Prior to testing, subjects were able to view balls at all three spin orientations in order to be familiar with testing protocol. During actual testing, each spin orientation was presented to each subject five times in random order at each of the five different spin rates (a total of 15 trials per spin rate). The first 15 presentations were performed at 200 RPM allowing subjects to comfortably distinguish between the three response choices. Each successive set of 15 presentations was increased in spin rate by 200 RPM until the final speed of 1000 RPM was achieved. Subjects were instructed to call out verbally an answer of "one," "two," or "three" which corresponded to the seam orientation of the ball presented at 135, 180 or 45 degrees respectively. The subjects were instructed to respond immediately after each presentation (three alternative forced choice).

## RESULTS

At each spin rate tested greater than seven correct responses out of fifteen trials was considered significant. Less than seven correct answers were considered to be correct due to chance alone. At a ball rotation speed of 200 RPM all subjects tested were able to correctly identify at least 14 of the 15 presentations. When the ball rotation speed was increased to 400 RPM and

faster, the performance of each subject varied considerably. Each individual's performance at each rotational speed is illustrated by Figures 3-12.

An intercept value of 7 correct responses was extrapolated for each subject from the performance graphs (Figures 3-12). The spin rates corresponding to this intercept value were considered to be the threshold rotation rates above which the subjects could no longer accurately determine spin orientation and direction. These spin rates are shown in parentheses where the intercept line crosses the actual performance plot in Figures 3-12. Figure 13 represents the average for all of the subjects and illustrates the average threshold for this sample.

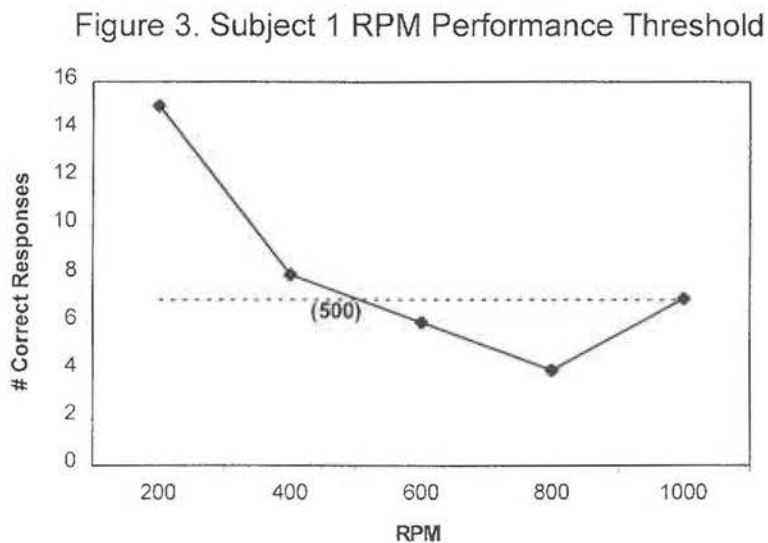


Figure 4. Subject 2 RPM Performance Threshold

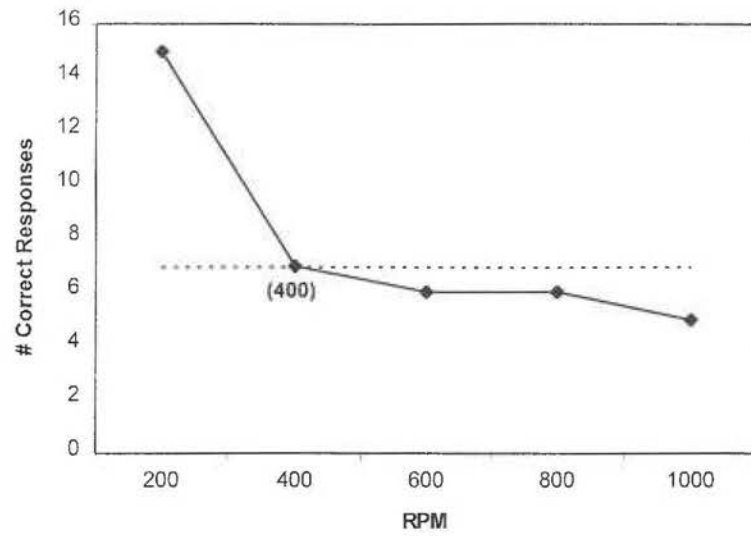


Figure 5. Subject 3 RPM Performance Threshold

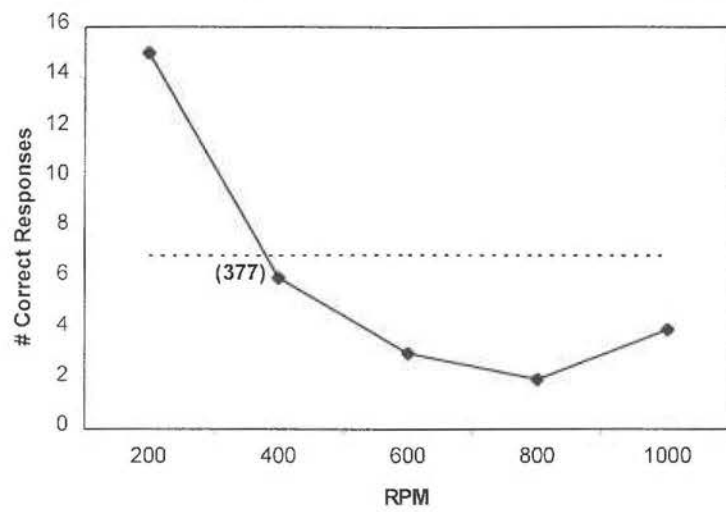


Figure 6. Subject 4 RPM Performance Threshold

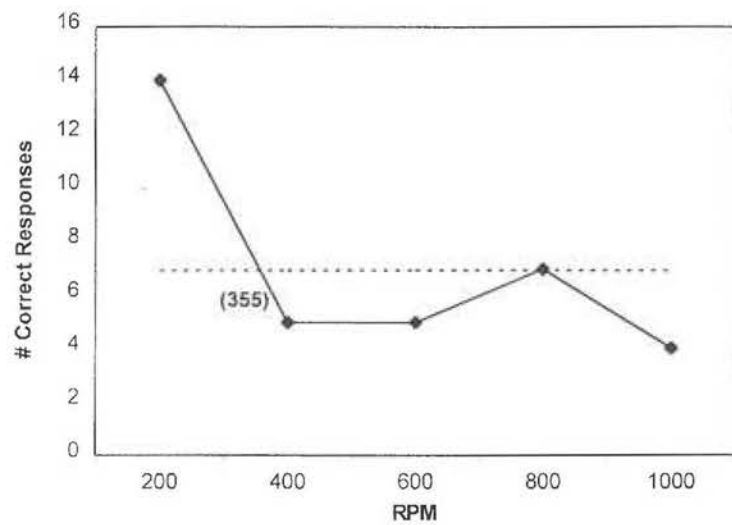


Figure 7. Subject 5 RPM Performance Threshold

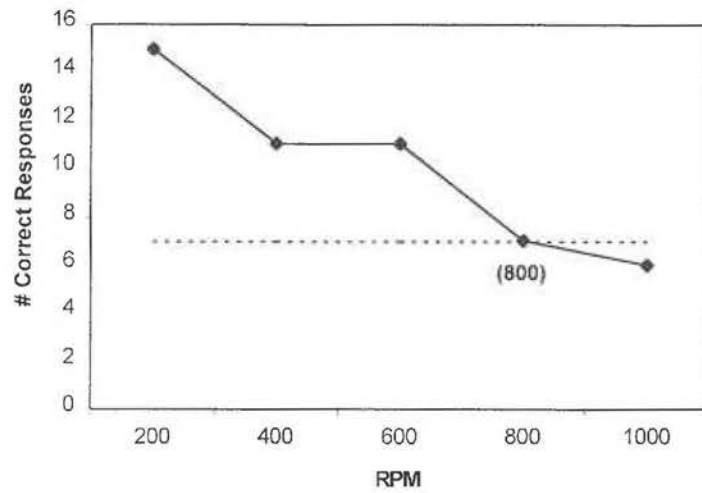


Figure 8. Subject 6 RPM Performance Threshold

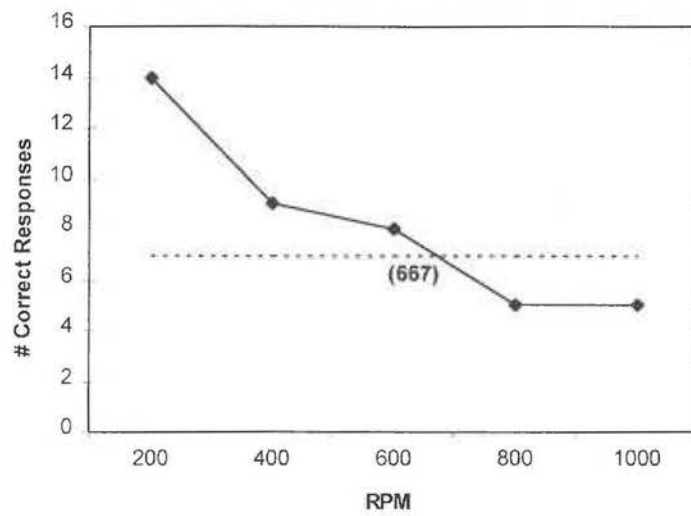


Figure 9. Subject 7 RPM Performance Threshold

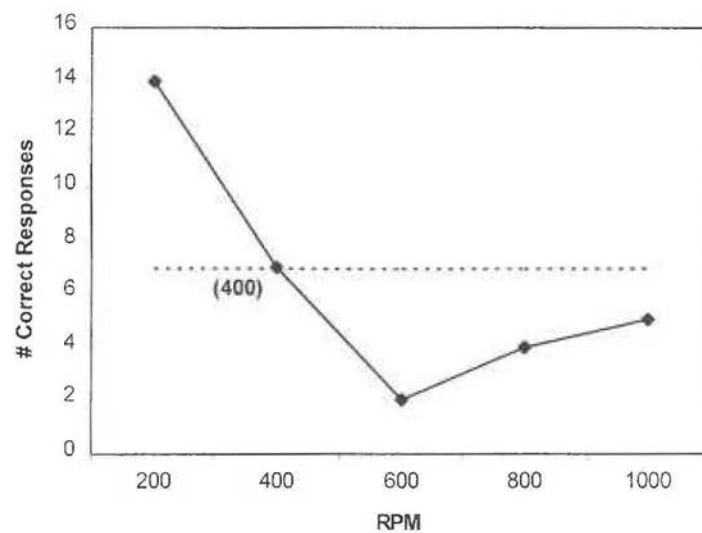




Figure 10. Subject 8 RPM Performance Threshold

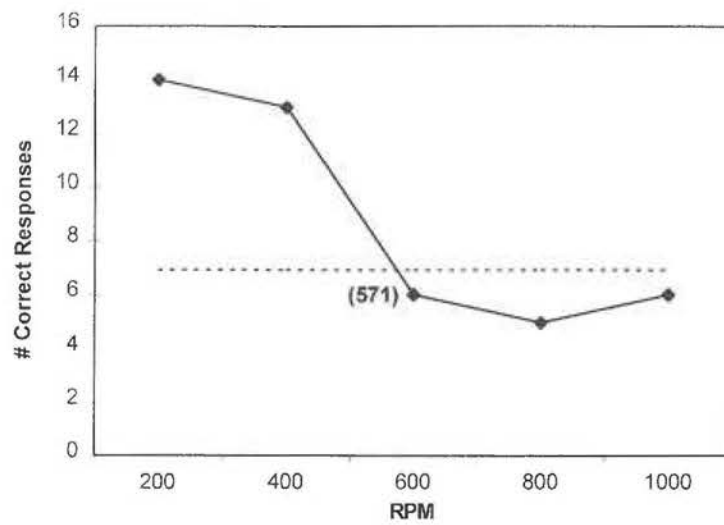


Figure 11. Subject 9 RPM Performance Threshold

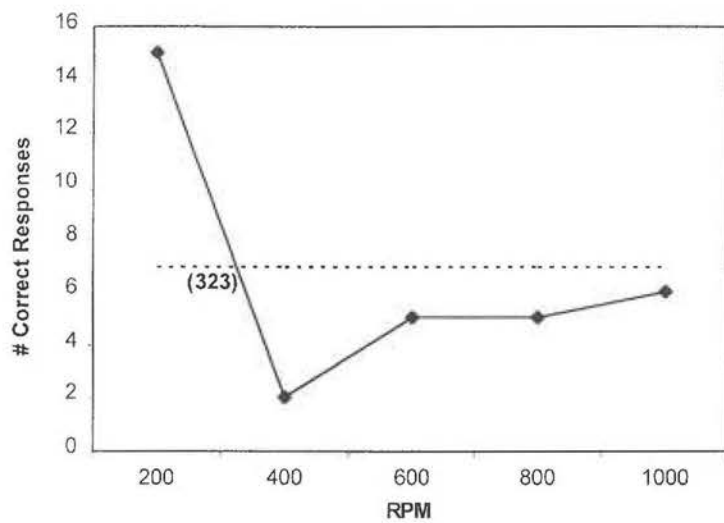


Figure 12. Subject 10 RPM Performance Threshold

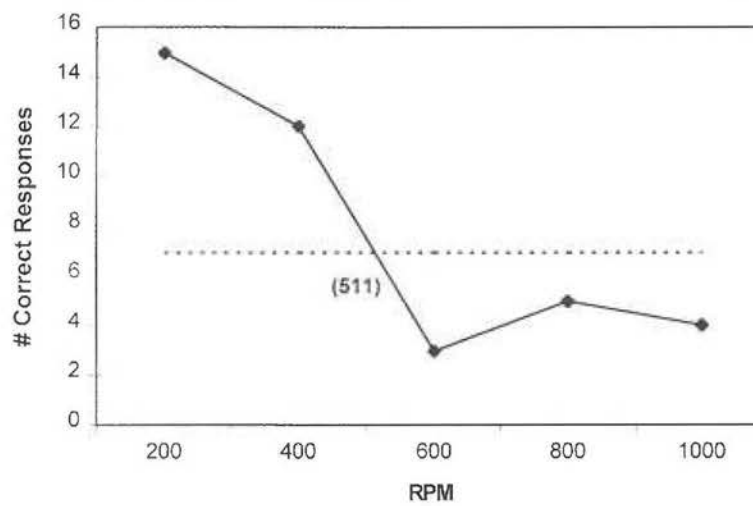
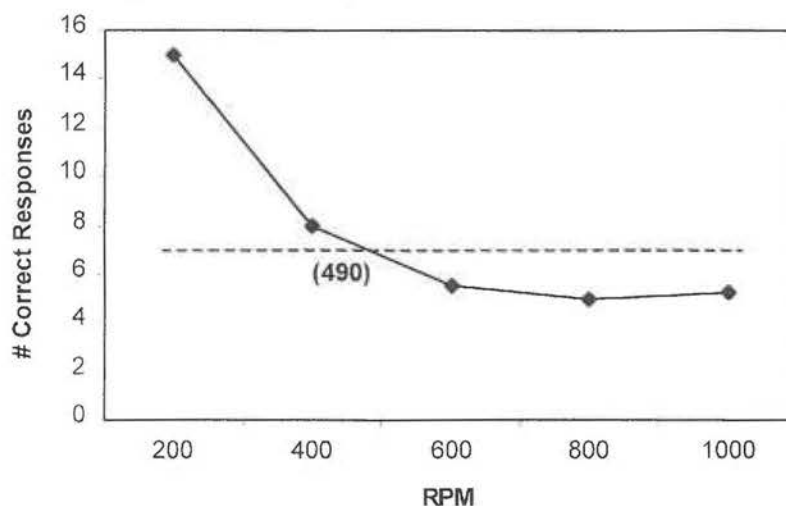
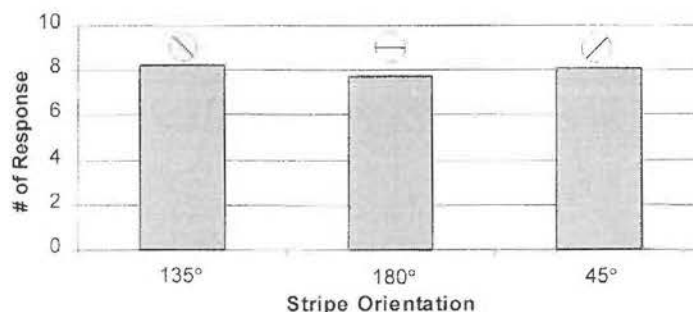


Figure 13. Average RPM Performance Threshold



Data was tabulated and graphed in an attempt to determine whether the subjects were more (or less) sensitive to one particular stripe orientation. A trial of less than seven correct responses was defined as random chance or guessing and was therefore not included in the orientation comparisons. Figure 14 demonstrates the average number of correct responses for each of the three orientations for the sample. Orientation #1 is a 135-degree oblique stripe pattern with stripes diagonally up and to the left. Orientation #2 is a 180 horizontal stripe pattern, and orientation #3 is a 45-degree oblique pattern with stripes diagonally up to the right.

Figure 14. Ave. Number of Correct Responses per Orientation



## DISCUSSION

The ability to successfully hit a baseball is dependent on several visual factors including cues from observing a pitcher's hand, wrist, and arm motion, ball velocity and trajectory, as well as ball spin rate, spin direction, and seam orientation. The intent of this study was to determine normal observers' ability to discriminate seam orientation and spin direction in a simulated pitched baseball task.

The average spin rate of a major league fastball varies from 1500-1800 RPM (25-30 RPS) with a maximum of four stripes per revolution of the baseball creating a flicker frequency of between 100-120 Hz (30, 31). Flicker frequency in this context is defined by the number of light-dark intervals/sec that are presented in the rotation visual stimulus (simulated baseball). As the frequency of flicker is increased a certain frequency is reached at which flicker is no longer resolved by the human visual system. This is defined as the "Critical Flicker Frequency" (CFF) (32). This limitation is a result of the speed of neural processing from the retina to visual cortex.

The point at which a subject first sees flicker is defined as the CFF threshold. Flicker rates above this threshold are viewed as a constant solid hue. In the context of this study, balls rotated at a rate above this threshold were perceived as a fused gray ball. The balls rotated at a rate below the CFF threshold were seen as a white ball with distinguishable black markings. The reciprocal of this value represents the relative sensitivity for flicker resolution (32).

This study utilized 100% contrast between black and white striped balls. The CFF function suggests a maximum flicker rate of approximately 70 Hz at 100% contrast. It is interesting to note that the flicker frequency of a spinning major league fastball is approximately 100 Hz or higher placing the detection of a baseball spin at the upper limits of human physiology relative to CFF. To complicate matters, the contrast level of a spinning baseball is less than 100% due to the red stitching.

Using the current methodology the subjects displayed a range of CFF from 21.5 Hz to 53.3 Hz and an average CFF of 32.7 Hz. The data suggest that our subjects could not resolve the stripe orientation and spin direction of a pitched baseball with spin faster than approximately 490 RPM. It would be beneficial to run this experiment using professional baseball players as subjects. It is possible that subjects with extensive baseball experience might be able to differentiate the seam orientation and spin direction of a baseball spinning at rates approaching 1500 RPM or 100 Hz. Appropriate sports vision training and a modification of the current testing protocol might be beneficial for training athletes to discriminate seam orientation and spin direction at high RPS.

After analyzing the performance data a question arose as to a subject's sensitivity differentiation between horizontal and oblique ball stripe orientations. Hubel and Wiesel determined in the early 1960's that the cells of the visual striate cortex are most sensitive to bars and stripes of light in specific orientations and that different cells are sensitive to different orientations (33). As these cortical neurons are orientation selective, it has been suggested that the

development of this orientation sensitivity may be influenced by visual experience. Support for these theories was gained in the 1970's through experiments with animals raised in environments consisting of only one spatial orientation (34-36). Results showed these animals to have a disproportionately large number of cortical neurons sensitive to one particular orientation and relatively few neurons sensitive to other orientations. It is believed these sensitivities may be largely influenced by visual experience. This would explain why the human visual system may be more sensitive to horizontal and vertical bars or stripes of light than to oblique bars of light because most of our visual world consists predominantly of horizontal and vertical lines.

We analyzed the proportion of correct responses to obliquely presented stripes compared to that of horizontally presented stripes. The results revealed no appreciable difference in the proportion of correct responses of obliquely vs. horizontally presented stripes. These findings were consistent for all subjects tested. This suggests that batters are not more sensitive to horizontal or vertical stripe orientations compared to oblique presentations (fastball vs. curveball).

This current study utilized a random sample of young male subjects which makes it difficult to extrapolate the findings to the potential performance of high-level baseball players. In order to accurately assess the feasibility of using seam orientation and spin direction as visual cues to aid in the successful hitting of a baseball, further studies analyzing professional or high level amateur baseball players using this methodology are necessary.

## CONCLUSION

Findings of this study reveal that the visual systems of average healthy young males are not capable of reliably detecting the spin direction and seam orientation of a simulated major league pitch. A professional baseball pitcher delivers a fastball that spins at approximately 1500 RPM which equates to a CFF of 100 Hz. It was found that the average RPM performance threshold for the subjects in this study was only 490 RPM which correlates to an average CFF of 32.69 Hz which is significantly less sensitive than is needed to successfully differentiate a major league pitch. Additional findings suggest that visual sensitivity of our subjects was not different for any particular seam orientation (oblique vs. horizontal). There was not a significant difference in the number of correct responses between oblique versus horizontal seam patterns (Figure 14).

Future applications of this methodology may include adaptation of the protocols to be utilized as a screening tool for professional baseball organizations to assess the readiness of prospective players to face major league pitchers. The concepts discussed may also be used to develop a sequential training regimen in which subjects are exposed to successively higher rates of ball spin depending on rate of performance improvement as monitored by calculating CFF at equally spaced time frames throughout the training regimen. The intended benefit of this training would be that as the athlete improved, he might enjoy increased ability to identify different pitches resulting in improved batting average and slugging percentage, therefore, making the player much more valuable to a professional team.

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## APPENDICES

## Baseball Spin Detection Consent Form

Thank you for participating in this Pacific University College of Optometry Thesis Project. The researcher's purpose is to determine a baseball player's ability to recognize spin patterns of a pitched baseball.

<b>Principle Investigator:</b>	Bradley Coffey O.D.	
<b>Researchers:</b>	Kurt Kuskie	(503) 521-8079
	Lyle Regimbald	(503) 439-0182

This study involves visual presentations of the spin pattern characteristic of specific baseball pitches. Subjects will be asked to view 45 spin presentations of a striped ball with varying orientations at different revolutions per minute. Subjects will be given the choice of three responses corresponding to stripe orientation and will be asked for a verbal answer following each presentation.

The purpose of this study is to define the visual limits that correspond to detection of baseball spin. We then intend to use this information and Optometric training techniques to further enhance the ability of a batter to visually determine the spin and trajectory of a pitch.

Although there are no foreseeable risks involved in this experiment, any injury associated with this experiment is not the fault of Pacific University, the experimenters, or any organization associated with the experiment. You should not expect to receive compensation or medical care from Pacific University, the experimenters, or any organization associated with this experiment.

During your participation in this project you are not a Pacific University Clinic patient or client. All questions should be directed to the researchers and/or the faculty advisor who will be solely responsible for any treatment (except in an emergency). You will not be receiving complete eye, vision, or health care as a result of participation in this project; therefore, you will need to maintain your regular program of eye, vision, and health care. If you have any further questions please contact the above named researchers.

**Participation in this project is voluntary. Refusal to participate will involve no penalty to you and you may discontinue participation at any time.**

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**I have read and understand the above. (I am 18 years of age or older or this form is signed by me and my parent or guardian.)**

*Subject Name (Please Print):* \_\_\_\_\_

*Subject's Signature:* \_\_\_\_\_

*Printed name and signature of parent or guardian if subject is under 18 years of age:*

*Address:* \_\_\_\_\_

*Phone number:* \_\_\_\_\_

*Date:* \_\_\_\_\_

*Name and address of person not currently living with you who could locate you.*

### Baseball Spin Detection Project

Age: \_\_\_\_\_ Yrs of Competitive Experience: \_\_\_\_\_ Slugging %: \_\_\_\_\_

VA OD: \_\_\_\_\_ Cover test Far: \_\_\_\_\_ Habitual Rx OD: \_\_\_\_\_  
 OS: \_\_\_\_\_ Near: \_\_\_\_\_ OS: \_\_\_\_\_  
 OU: \_\_\_\_\_

Distance Stereo: 240 \_\_\_ 180 \_\_\_ 120 \_\_\_ 60 \_\_\_ 30 \_\_\_ 15 \_\_\_  
                           Y/N    Y/N    Y/N    Y/N    Y/N    Y/N

**Contrast Sensitivity :**

3 \_\_\_\_\_  
 6 \_\_\_\_\_  
 12 \_\_\_\_\_  
 18 \_\_\_\_\_

Visual Motor Response: Practice Test  
 RH: \_\_\_\_\_  
 LH: \_\_\_\_\_  
 Dynamic VA: \_\_\_\_\_

Attempt	Answer 200 rpm	Answer 400 rpm	Answer 600 rpm	Answer 800 rpm	Answer 1000 rpm
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					