

Article ▶ Baseball Seam Recognition Under Temporal Constraints

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ABSTRACT

Background: Different pitch types produce different patterns on a baseball as balls spin toward the batter. Batters have only about 250ms to examine and make use of these patterns in determining pitch trajectory. The purpose of the current study was to measure subjects' ability to determine seam orientation on spinning baseballs with and without temporal constraints.

Methods: Two separate studies were performed, with ten subjects in each study. In both studies, subjects were asked to determine one of three possible seam orientations of a spinning baseball. In the first study, subjects viewed baseballs monocularly under two conditions. In one condition, subjects were given unlimited time to determine the seam orientation. In the other condition, subjects were given 286ms to determine the seam orientation. In the second study, subjects viewed baseballs monocularly in one condition and binocularly in the second condition, with unlimited time to determine the seam orientation. Each subject gave 63 responses in all conditions.

Results: In Study 1, seam recognition performance was significantly better ($p=0.015$) with unlimited viewing time (52.06% correct) compared to limited viewing time (37.62% correct). In Study 2, no significant difference ($p=0.52$) between binocular and monocular viewing (76.03% and 74.29% correct, respectively) was observed.

Conclusions: The difference in seam recognition performance for the limited versus unlimited viewing times (28% reduction with limited viewing) was significantly greater than the difference in performance in comparing binocular and monocular viewing.

Keywords: baseball, batting, seam recognition, temporal constraints

Background

Baseball batting is extremely difficult due to the temporal and spatial constraints of the task. A pitch thrown at 90mph will reach a batter in less than half a second, so the batter may only have about 250ms (or less) to decide when and where the ball will arrive and whether to swing the bat. Batters then attempt to strike the ball at or near the center of percussion or "sweet spot" on the bat, an area only about 4-6 inches in length and 1/3-1/2 inch in the vertical dimension.¹

To determine when and where a pitched ball will arrive at the plate, the batter could make use of information before and after a pitch is released.²⁻⁵ Pre-pitch predictive information might be gained from contextual cues such as the pitch count or the presence of baserunners, knowledge of a pitcher's capabilities and tendencies, or assessment of the pitcher's arm angle upon pitch release.

Once the pitcher releases the ball, time-to-contact with the ball can be estimated from the change in both the retinal image size and retinal disparity as the ball approaches the plate.^{6,7} Regarding retinal image size, the ratio (termed tau) of the current retinal image size of the pitched ball to the rate of image size expansion may be used to estimate time-to-contact. Regarding retinal disparity, the ratio of the current (horizontal) convergence angle of the ball to the rate of change of relative (horizontal) disparity of the pitched ball may also be used for time-to-contact estimations. On the other hand, to make judgments of where a pitched ball will arrive, batters could use

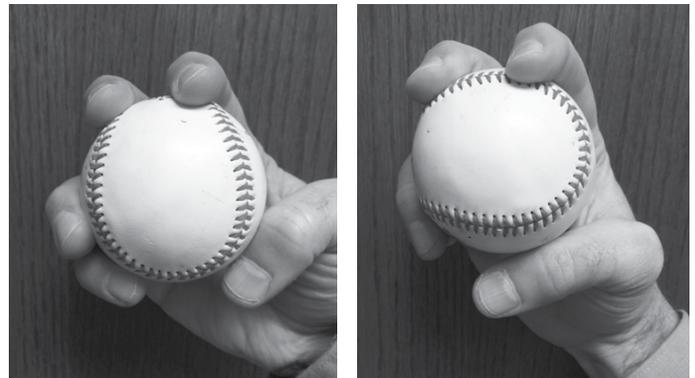


Figure 1. Two-seam (1a) and four-seam (1b) grips.

contextual and visual cues to estimate the speed of the ball, which is proportional to the height of the ball when it reaches the batter.²

Another visual cue that batters might potentially use in determining the ball's trajectory is the appearance of the seams on the ball as it spins toward the plate.⁸⁻¹⁰ For example, the seam appearance of a curveball can differ from that of a fastball, and a curveball is slower and demonstrates more downward deflection than a fastball. Further, fastballs delivered using different grips (described below) may drop at different rates.

Bahill and colleagues^{8,9} have detailed the appearance of pitched baseballs thrown using different grips and releases. Here we focus only on fastballs and curveballs. A fastball can be thrown using a two-seam or four-seam grip (Figure 1). The

two-seam fastball is said to drop more rapidly than a four-seam fastball. In the case of the two-seam pitch, the ball is gripped so that the index and middle fingers are oriented with the seams (see bit.ly/2qIMfZR). The four-seam pitch is gripped so that the index and middle fingers are perpendicular to the seams. Upon release, backspin is applied to the ball. Therefore, the two-seam fastball results in the appearance of two red vertical (overhand delivery) or diagonal seams (non-overhand delivery).^{8,9} The four-seam release, on the other hand, results in thinner and more numerous red vertical (or diagonal) lines compared to the 2-seam release. These thin lines are superimposed on a blurry gray background.^{8,9} In the case of a curveball, topspin is applied to the ball. This can result in a similar appearance to that of a four-seam fastball, with the possible inclusion of a red dot or a red annular circle on the ball.

While it is known that these lines or dots on the ball will appear, the question that arises is whether baseball batters can and do make use of these cues in batting.

There have been few studies investigating the ability of a batter to recognize seam orientation or to perform the related task of determining the rotational direction of a spinning baseball.

Hyllegard¹⁰ examined the role of the seam pattern in pitch recognition. He asked college-level baseball players and college (non-baseball playing) students to identify the direction of spin (topspin or backspin) of pitches seen on video. In some cases, the ball had no visible seams, while in other cases, normal or enhanced seams were used. While pitch recognition performance was lower for the non-baseball players, for both the baseball players and the non-baseball players, the presence of seams had a statistically significant effect on subjects' ability to determine the spin type. The duration of pitch exposure (initial 200ms or the entire pitch) did not have a statistically significant effect on pitch recognition. This latter result is similar to the findings of Burroughs, who showed that college baseball players could accurately differentiate breaking pitches from straight pitches exposed for only 170ms.¹¹

Gray² investigated the ability of six experienced college baseball players to "hit" simulated pitches displayed on a computer monitor. Batters were exposed to pitches with and without rotational cues. Rotational cues (topspin and backspin) resulted in a reduction in spatial error in 4 of the 6 batters and a reduction in temporal error for 3 of the 6 batters. In another study, Gray and Regan¹² demonstrated that rotational cues influenced subjects' perception of the vertical motion of a (simulated) pitched baseball.

While these studies demonstrate that the presence of seams improves pitch recognition and can positively affect batting in experienced batters, a question that remains unanswered is how various contextual and visual cues to pitch trajectory are weighted to determine when and where the pitch will arrive. In order to improve batting, it may be useful

to focus one's training on those cues that are weighted most strongly. Perhaps rotational cues related to seam direction are relatively weak or unreliable in isolation, but the reliability of these cues is improved when presented in conjunction with other cues, such as the increase in retinal image size of the approaching ball or the pitcher's arm angle when the pitch is released.¹³

There are only two studies in which the ability to detect the seams on a spinning baseball have been assessed independent of other cues to trajectory. Bahill et al.⁸ tested the detection of seams on a four-seam fastball and a two-seam fastball and concluded that a non-athlete with normal vision could see the seams created by a two-seam fastball at 16 feet (4.88m) and the thin lines on a four seam fastball at 10 feet (3.05m). Such distances are most likely too short to provide information that could influence the trajectory of the batter's swing. On the other hand, a pilot study from our laboratory¹⁴ suggested that seam recognition performance was substantially better than that found by Bahill et al. Finally, at least in the case of this latter study, subjects were given unlimited time to assess the seams on the spinning baseballs. The effect of temporal constraints on seam recognition performance is not known.

The purpose of the studies described here was to measure subjects' ability to determine the orientation of the seams on a rotating baseball with and without temporal constraints similar to those encountered by baseball batters.

Methods

These studies and the associated consent forms were approved by The Ohio State University Biomedical Institutional Review Board. Data were collected on 20 adult subjects (male and female) across two studies. All subjects signed the informed consent document prior to data collection. To be eligible for the study, subjects had to be between 18 and 40 years of age, as this is the typical age range of baseball and softball players. Additionally, subjects were required to have best-corrected visual acuity of 20/20 in each eye. Data on refractive error were not collected.

Subjects who wore refractive correction were not required to wear the same type of correction (contact lenses or spectacles) at the two study visits. Contrast sensitivity under conditions where subjects are presumably given unlimited time to respond has been compared many times between spectacles and contact lenses.¹⁵⁻³² In those studies in which statistical comparisons of contrast thresholds between spectacles and contact lenses were performed, some have found a reduction in contrast sensitivity with contact lenses compared to spectacles at one or more spatial frequencies,^{17,19,20,30} while others have reported a relative reduction with spectacles.^{21,31} Still others have reported no difference in contrast sensitivity between contact lenses and spectacles.^{18,22,24,25,28-30,32} Most of these studies have been performed using spherical contact lenses, although one study involved toric contact lenses.²⁸ In any event, the preponderance of differences reported in

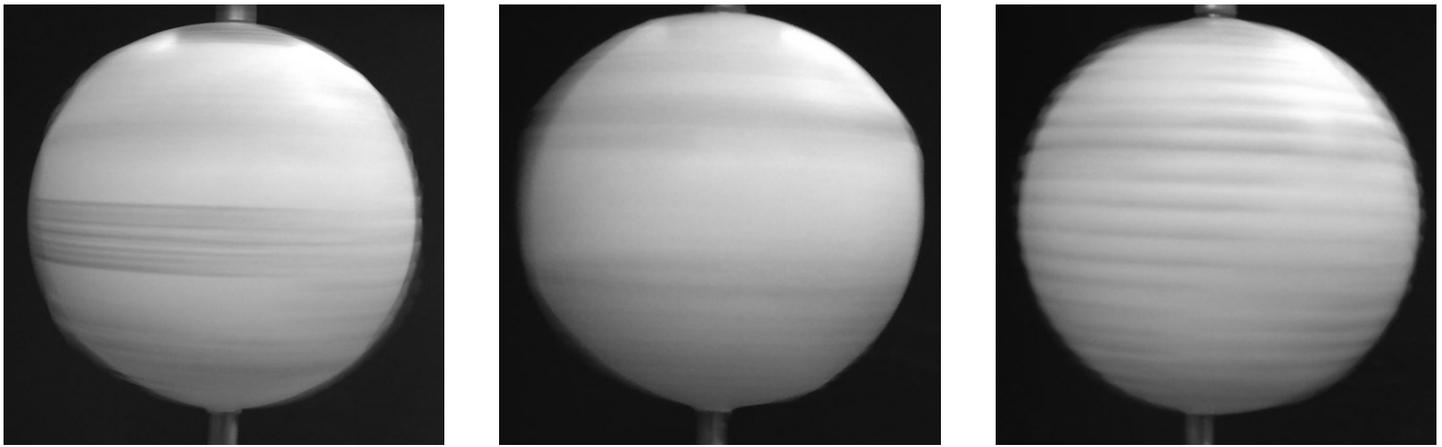


Figure 2. Two Far (2a, left), Two Close (2b, middle), and Zero (2c, right) seam orientations.

these studies would not be expected to change the contrast threshold to such an extent that vision of the seams on a baseball would be precluded with either refractive modality.

In addition to static comparisons of contrast sensitivity with spectacles and contact lenses, short-term changes in contrast sensitivity with contact lenses after blinks have been examined.³³⁻³⁶ Contrast thresholds largely stabilized in less than 200ms after the blink for both spherical soft contact lenses and rigid gas permeable lenses. Contrast thresholds for soft toric contact lenses stabilized about 200ms after the blink. Since the stimulus exposure duration in these previous studies was very short (16ms), these results suggest that blink-induced changes in contrast threshold would not influence the results of the current experiments (even under conditions where the stimulus duration was limited) regardless of refractive correction.

Two separate studies were performed. Ten different subjects participated in each study.

General Experimental Set-up

All studies were performed indoors under ballasted fluorescent lights. A photodiode placed near the location of the ball was used to measure the flicker from these lights. Flicker at a frequency of 120Hz could be found, but the percent flicker was very low (<2%).

A drill press (Sears Craftsman, model #E148193) was used in both experiments.^{8,9} The drill press was mounted on an adjustable table, which could be moved vertically and horizontally for alignment. A black background was placed behind the baseball to reduce distractions and to provide a uniform background.

Subjects were asked to view a baseball (glued to a drill bit) after the drill bit was inserted into the drill press. The baseballs were Rawlings (Town and Country, MO, Model OLB3) balls. A label on these balls states that they are 5 ounces in weight and 9 inches in diameter. In comparison, according to the 2017 Official Rules of Baseball (atmlb.com/2qAPjr2), the acceptable range of baseball weights is 5 to 5.25 ounces,

and the acceptable range of baseball diameters is 9 to 9.25 inches.

There were black labels near the top, in the center, and near the bottom of the ball. For each presentation, the ball was spun in the drill press at a rate of 1358rpm. This spin rate is similar to that used by Bahill et al.⁸ and results in an apparent smearing of the individual seams of the ball, but this spin rate is lower than that of a typical fastball thrown by a Major League Baseball pitcher.³⁷ The rotational velocity used in this experiment could result in a “flickering” effect in the case of one or both of the two-seam orientations described below. For a typical two-seam fastball, for most of a revolution two red seams are apparent, but once during this revolution the seams approach one another, and it is possible that only one seam is briefly seen.⁸ This flicker would probably not be evident with the four-seam orientation.

The horizontal illumination was measured at a location close to that of the ball using a LiteMate (Model 504) photometer (Photo Research, Burbank, CA). This illumination was found to be about 400 lux.

Study 1: The Effect of Temporal Constraints on Seam Recognition

Two shutters (Melles Griillot, Rochester, NY, model #04 IES 003) were used in the first study. One shutter was placed 7.6cm from the subject’s eye. This shutter (diameter 1.9cm) remained open for all trials and so effectively served as an aperture to assist in aligning the subject’s eye on the baseball. A second shutter was placed 4m from the subject’s eye. The diameter of the aperture produced when this latter shutter was opened was 3.5cm. This equated to a visual angle of about 0.50deg. The purpose of this shutter was to limit the time over which the subject could observe the spinning baseballs.

Each subject was tested on two different days. These testing sessions were separated by a minimum of two days. Subjects performed one of two randomly selected trials on each day.

On both testing days, the subject first sat about 11ft (3.35m) from the spinning baseballs mounted in the drill press. The subject was then asked to observe (binocularly) a

Table 1. Monocular Results for Study 2

Actual orientation	Incorrect guess	Percentage of total incorrect guesses
2 Close	2 Far	44.90%
	Zero	55.10%
2 Far	2 Close	25.86%
	Zero	74.14%
Zero	2 Close	25.45%
	2 Far	74.55%

Table 2. Binocular Results for Study 2

Actual orientation	Incorrect guess	Percentage of total incorrect guesses
2 Close	2 Far	61.90%
	Zero	38.10%
2 Far	2 Close	8.33%
	Zero	91.67%
Zero	2 Close	14.58%
	2 Far	85.42%

spinning ball at three possible orientations (Figure 2). For each orientation, the subject was told in which orientation the baseball was spinning.

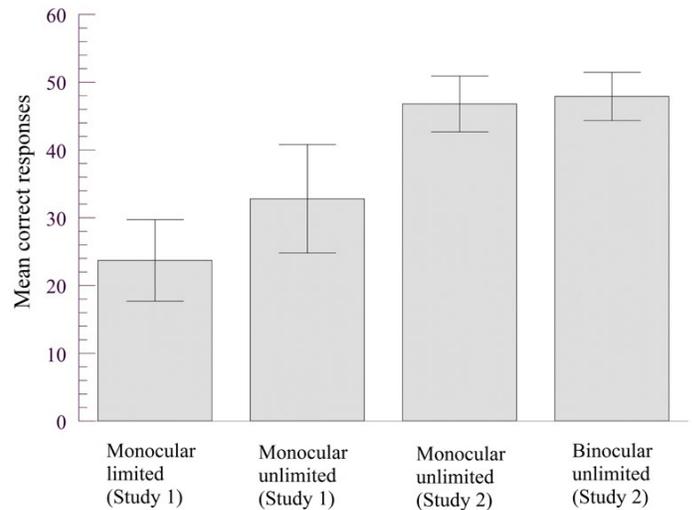
The three orientations of the baseball used in this experiment were as follows:

1. “Two Far” (Figure 2a). This orientation to some extent simulated a two-seam fastball (although the rotational axis was 90 degrees away), such that the spinning ball produced two relatively wide horizontal red stripes that were relatively far from one another. The dark label in the center of the ball produced a somewhat dark horizontal stripe in the center of the ball when the ball was spun.

2. “Two Close” (Figure 2b). This orientation was produced by inserting the drill bits into the spinning ball at an angle of approximately 30 deg relative to the angle of drill bit insertion used for the “Two Far” orientation. The spinning baseball produced two relatively wide (red) horizontal stripes separated by a lesser vertical extent than those in the “Two Far” orientation. The labels produced a somewhat dark horizontal stripe that was near or just below the upper horizontal stripe.

3. “Zero” (Figure 2c). This orientation simulated that of a four-seam fastball to some extent. Thus, when the ball was spun in the drill press, the pattern was of many very thin red horizontal lines on a blurred grey background. The black labels on the ball produced a somewhat wide and somewhat dark horizontal stripe near the top of the ball.

Next, subjects were seated at a distance of 36ft and 1in (11m) from the ball. The subject’s left eye was patched. Subjects placed their chin in the chin rest and looked through the two shutters at a ball mounted in the drill press. The cart holding the drill press was then moved to center the mounted baseball in the opening of the shutter at 13.1ft (4m). While the entire baseball was visible through this shutter, the background

**Figure 3.** Mean (and standard deviation) of correct responses in the four conditions.

of the ball was obscured by the shutter aperture. After the subject was properly aligned, he or she was again shown one spinning baseball at each of the three seam orientations described previously and informed as to the orientation of these balls. On those days when exposure duration was limited by the shutter at 13.1ft (4m), this shutter was opened and closed three times to demonstrate the exposure duration. The subjects were not provided with any practice trials beyond these just-described demonstrations. By providing similar demonstrations in the two studies (described below), differences in the results of these two studies were not likely to be the result of subjects misunderstanding the requirements of the task.

A total of 63 balls were presented to each subject on each day. Three balls were available for each of the three seam orientations. Each of these nine balls were presented randomly 7 times. This yielded 21 presentations of each of the three orientations for each trial. For every presentation, a black curtain was used to obscure the ball from the subject prior to exposing the ball. After the ball was mounted in the drill press and the drill press was turned on, the curtain was moved to the side to allow the subject to view the ball.

Limited Exposure Duration Trial

During the trials in which the shutter at 4m was used to control the exposure duration, the subject was notified that the shutter was about to open, and then the shutter was promptly opened via a push-button on the shutter control box. After viewing the baseball, subjects were given unlimited time to report the number and location (Far or Near for the two seam orientations) of any seams detected on the ball. Fixation was not monitored in this experiment or in Study 2 (described below). The largest fixation error for these subjects was likely to be <1deg, and this would have occurred only if subjects fixated the outside edge of the shutter. While it has been shown that contrast sensitivity decreases linearly with eccentricity from the

fovea, fixation errors of <1deg would result in very minimal effect on contrast sensitivity.³⁸

Exposure duration was determined based on a 90 mile per hour (40.2m/s) fastball. For a 90 mile per hour pitch, and assuming the ball is released about 55 feet (16.76m) from the batter, the batter has approximately 420 milliseconds (assuming a constant linear velocity) until the baseball arrives. However, a swing requires 160-200 milliseconds to complete, so the batter has only about 220-260 milliseconds to determine when and where the ball will arrive. Therefore, in order to simulate the time a batter has to make these temporal and spatial decisions, we wanted the duration of ball exposure to be close to this time window.

A shutter controller (Melles-Grillot, Rochester, New York, #04ISC001) was used to open the shutter. The duration that the shutter remained open was assessed using a laser and photocell. For 13 measurements, the mean exposure duration was found to be 286.6ms (the standard deviation of this mean was far less than 1ms).

Over a period of 286ms, a pitch traveling at a constant linear velocity of 90 miles per hour (40.2m/s) would traverse a distance of 37.8 feet (11.51m). Subtracting this value from 55 feet (16.76m) (the distance from the release point of the pitch to the batter) yields 17.2 feet (5.26m). This means that in 286 milliseconds, a 90 mile per hour pitch travels from the pitcher's hand at 55ft (16.76m) to a location 17.2ft from the batter. Subjects were therefore situated 36.08ft (11m) from the spinning baseballs, as this is midway between the distance at which the pitcher releases the ball and the distance of the ball from the batter 286ms after the pitch is released.

Unlimited Exposure Duration Trial

For the trials where exposure duration was not limited, the shutter near the eye and the shutter at 4m remained in place and open. The procedures in this trial were otherwise identical to those in the limited exposure duration trial.

Study 2: Monocular vs. Binocular Seam Recognition

Because the seam recognition performance in Study 1 was lower than expected,¹⁴ a second study was completed. In this study, the effect on seam recognition of binocular viewing versus monocular viewing was examined. In these experiments, no apertures were present between the subject and the mounted baseball.

Testing in this study was very similar to that in Study 1. Ten subjects were tested. Each subject returned for testing on two different days, separated by a minimum of two days. Subjects performed one of two (monocular or binocular) randomly selected trials on each day of the study; by the end of the second day, every subject had completed both trials.

Subjects were given unlimited time to view the baseball in both the monocular and binocular conditions. After viewing the baseball and determining the seam orientation,

subjects were given unlimited time to give their response to the examiner.

Results

Study 1 (Unlimited Viewing time vs. Limited Viewing Time)

In the trials with limited viewing time, subjects responded correctly on a total of 237 of the 630 presentations (37.62%). The mean number of correct responses per subject was 23.7 ± 6.02 (range 13 to 34). In the trials with unlimited viewing time, subjects responded correctly on a total of 328 of the 630 presentations (52.06%). The mean number of correct responses was 32.8 ± 8.01 (range 19 to 48). The mean (absolute) difference between the number of correct responses in the limited and unlimited viewing time conditions was 9.30 ± 9.36 , with 9 of the 10 subjects demonstrating a larger number of correct responses in the unlimited viewing time condition. Thus, reducing the exposure duration resulted overall in a 28% [$1 - (237 \text{ correct (limited time)} / 328 \text{ correct (unlimited time)})$] reduction in correct responses. Comparing the total number of correct responses in each scenario (paired t-test), performance was significantly better ($p=0.015$) with the unlimited viewing time.

Study 2 (Monocular Viewing vs. Binocular Viewing)

In the monocular trials for Study 2, subjects responded correctly on 468 out of 630 baseballs presented (74.29%). The mean number of correct responses per subject was 46.8 ± 4.13 (range 37 to 50). In the binocular trials of Study 2, subjects responded correctly on 479 out of 630 baseballs presented (76.03%). The mean number of correct responses was 47.9 ± 3.57 (range 42 to 54). The mean (absolute) difference between the number of correct responses in the binocular and monocular viewing time conditions was 3.3 ± 4.06 (4 subjects had more correct responses under monocular conditions, 4 had more correct under binocular conditions, and 2 had an equal number of correct responses in the two conditions). Comparing the total number of correct responses in each scenario, there was no significant difference in performance (paired t-test: $p = 0.522$) between the binocular and monocular conditions.

As mentioned in the introduction, it is possible that subjects could distinguish between the two-seam (i.e., Two Far) orientation and the Zero seam orientation by looking for flicker associated with the two-seam orientation.⁸ The Two Close orientation also produced some flicker, in that in each rotational cycle, the top seam would reach a point near the top of the ball and nearly disappear from view. Further, in each rotational cycle, the bottom seam would reach a point near the bottom of the ball, mostly disappearing from view. The extent to which the flicker was apparent for the Two Close orientation compared to the flicker for the Two Far orientation is not clear. If subjects utilized flicker to differentiate the seam orientations, then one of two things would be expected. If

the flicker was apparent for both the Two Far and Two Close orientations, one would expect that subjects would be less likely to confuse the Zero seam orientation with either the Two Far or Two Close orientations, while the Two Far and Two Close orientations would more likely be confused for one another. On the other hand, if flicker was apparent for the Two Far orientation but not for the Two Close or Zero seam orientations, then one would expect that subjects would be equally likely to confuse the Two Far orientation with the other orientations. To address this, incorrect responses in Study 2 were examined.

In both the monocular and binocular conditions, the percentage of correct responses was similar between the different seam orientations. For the monocular condition, the percentage correct was 76.67% (Two Close), 72.38% (Two Far), and 73.81% (Zero). For the binocular condition, the percentage correct was 80.00% (Two Close), 71.43% (Two Far), and 77.14% (Zero). As shown in Tables 1 and 2, if subjects reported the wrong orientation when the Two Far orientation was presented, then they were far more likely to report the Zero seam orientation than the Two Close orientation. Similarly, if subjects reported the wrong orientation when the Zero seam orientation was presented, then they were far more likely to report the Two Far orientation than the Two Close orientation. These results do not support the supposition that subjects made use of the presence of flicker in judging seam orientation. These data instead suggest that the darker line produced by the labels at the top of the Zero seam orientation (Figure 2c) likely resulted in some difficulty in distinguishing the Two Far orientation from the Zero seam orientation.

Comparisons between Study 1 and Study 2

A t-test was used to compare the mean difference in correct responses for the limited versus unlimited viewing times (Study 1) to the mean difference in correct responses for the binocular and monocular viewing conditions (Study 2). The mean differences for the two studies were significantly different (t-test: $p=0.037$).

The mean number of correct responses in all four conditions (Study 1 and Study 2) is shown in Figure 3. When comparing the total number of correct responses under monocular conditions and unlimited viewing time in Study 1 (apertures present) and the total number of correct responses under monocular conditions in Study 2 (no apertures), it can be seen that the number correct is lower for Study 1. A t-test between these results demonstrated that the two were significantly different ($p<0.001$).

Discussion

Baseball pitches are usually thrown such that they spin, potentially producing red stripes, red dots, or red circles from the seams that are characteristic of different pitch types. Furthermore, the labels on a baseball can also create patterns on the spinning ball. Once the pitch is released, in addition

to properties such as the change in retinal image size and the change in binocular disparity of the approaching ball, these stripes, dots, or circles might be used to determine the pitch trajectory and ultimately to improve batting.^{2,6,8-10} A Pritchard Photometer (Model 1980A, Photo Research, Burbank, CA) was used to measure the luminance from the top stripe created by the seam on a baseball and the adjacent white area (closer to the ball's center) as the ball spun in the drill press in the Two Far orientation. The Michelson contrast for these two adjacent areas was found to be about 4%, which is expected to be visible to the subjects. (If one calculates the spatial frequency using the average separation of the two red seams, the spatial frequency for this target is about 4 cycles/degree.)³⁹ However, batters have only about 250ms to assess these post-release visual cues and to decide when and where a pitch will arrive and whether to swing the bat.

The results of this study demonstrate that in determining the presence and location of the stripes on a spinning ball, limiting the viewing time of subjects (Study 1) has a much more substantial effect on performance than does monocular compared to binocular vision (Study 2). Combining all of the subjects in each condition together, the percentage of correct responses with no temporal constraints was 28% greater than that with temporal constraints.

While it is expected that the negative influence of temporal constraints on seam recognition will hold up under different conditions of illumination, the percentage of correct responses under different experimental conditions could vary.

In comparing monocular performance between Study 1 and Study 2, performance levels with unlimited viewing time in Study 1 were much lower than those of Study 2 (Figure 3). This suggests that some feature of Study 1 (other than the monocular testing conditions) influenced the result. It might be the case that the shutter at 13.1ft (4m) in Study 1 influenced seam recognition. For example, subjects may have accommodated on the shutter (instead of the baseball). However, the accommodative demand of this shutter was only 0.16 diopters more than that of the ball. Another possibility that must be considered is that the shutter at 13.1ft (4m) eliminates the background, and although unintended, possibly also eliminates small portions of the edge of the ball. Perhaps there are subtle cues obtained from viewing the edge of the ball (against the background) that improve the subject's ability to discern the stripes on the ball.

In addition to the potential influence of the shutter aperture on the results, different illuminants such as stadium lighting or sunlight may differentially affect the results when compared to the indoor lighting used in the current experiment. For example, scattering by the atmosphere could create glare in bright sunlight that might reduce the contrast of the seams on the ball.⁴⁰

The reduction in seam recognition performance under temporal constraints in the current experiment stands in contrast to the results of previous investigations. Hyllegard¹⁰

and Burroughs¹¹ reported that when seams were apparent on the ball, experienced baseball players could discern the type of pitch (topspin or underspin) under temporal constraints.

There are some potential explanations for the discrepancies in the results of the current studies and these previous studies. First, in the previous studies, the pitcher was presumably in view when the pitch was released. Batters may consider seam direction cues to be more reliable in the presence of other visual cues to pitch trajectory such as the pitcher's arm angle or the pitcher's release point. Second, precession, the wobbling of a spinning object about a second axis, might provide some clues as to the pitch type that would not be evident in the current experiment.⁹ Finally, although the baseball experience of the subjects in the current studies was not recorded, it is likely that these individuals were not as experienced or accomplished as were the participants in previous studies.

Perhaps accomplished players are more efficient at seam orientation tasks under temporal constraints than are less accomplished players. It is difficult to draw definitive conclusions from the results of studies comparing novice and expert performance under temporal constraints in baseball-related tasks. In Hyllegard's pitch recognition task,¹⁰ for both novices and experts, performance was similar whether the pitch was exposed for the first 200ms or for the entire pitch.

Paull and Glencross⁴ compared the length of time required for expert and novice baseball players to decide the likely location of baseball pitches (seen on video) at the time these pitches arrive at home plate. The experts demonstrated faster decision times than the novices. The experts' faster decision times were associated with better estimates (compared to the novices) of the location of the ball at the time the pitch reached the batter. However, in a second study, these investigators found that experts were only modestly better than novices at determining pitch trajectory over the first 240ms of the pitch. Reichow and colleagues found a positive correlation between the batting average of college players and the ability of these players to identify the type of pitch being thrown by a pitcher seen in a picture when these pictures were exposed for 200ms.⁴¹ This latter study suggests that temporal processing is correlated with proficiency in baseball batting. If experts are indeed more efficient at pitch recognition tasks under temporal constraints, one of the cues of which experts might make more efficient use is the flicker cue mentioned in the methods. This cue may allow a batter to differentiate pitches thrown using a two-seam grip from those thrown using a four-seam grip. The subjects in the current study did not make use of the flicker cue, but it could be that more accomplished players do make use of this cue.

A recent paper by Fadde⁴² describes studies on occlusion-based training for baseball pitch recognition. This training is at least partially based on previous results demonstrating that experts recognize pitch trajectories more quickly than do novices and that hitting can be improved if pitch recognition time is shortened. The methodology is such that subjects are

exposed to pitches over short time periods, and then subjects are asked, for example, to indicate the type of pitch. Subjects are then given feedback as to their performance. In future studies, subjects could be provided with more practice trials in the limited exposure duration trial (and perhaps given feedback as to their performance), as this may reduce the discrepancy in seam recognition performance between the limited and unlimited duration trials found in Study 1.

Conclusion

In summary, subjects in this study performed well on a seam recognition task under both monocular and binocular conditions in the absence of temporal constraints, while the addition of temporal constraints resulted in a much more significant reduction in performance.

Acknowledgments

The work described in this manuscript formed the basis for Dr. Daniel Hagee's Master of Science thesis in Vision Science from the Ohio State University.

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