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Original Article

SURVEY OF VISUAL AND PREDICTIVE ASPECTS OF BATTING AND EYE CARE UTILIZATION IN BASEBALL PLAYERS

Jacob Terry, Nick Fogt*
The Ohio State University College of Optometry, Columbus, Ohio

Author for correspondence: Nick Fogt: fogt.4@osu.edu

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ABSTRACT

Recent laboratory studies suggest that baseball batters use pre-pitch and post-pitch cues in batting and that high-level batters have excellent visual acuity. This study aimed to survey baseball batters on eye and head tracking and fixation behaviors, whether players received eye examinations during their playing careers, and on players' recollections of coaching advice. An online survey was sent to potential respondents. Fifty-nine current or former baseball players who participated at the college level (54) or above (5) completed all (58) or most of the survey. Most were Division 3 college players. Survey responses suggested that pre-pitch and post-pitch cues were used by batters and that eye and head-tracking behaviors were similar to those in laboratory studies. Survey answers on batters' behaviors largely matched answers on coaching advice. Most respondents had received an eye examination while playing, but most had not discussed vision therapy.

Keywords: *survey; sports; eye-head movement; batting coaching; eye examination*

INTRODUCTION

Baseball batting is a very difficult task as evidenced by the fact that the best batters at the highest levels only achieve success about 30% of the time.[1] To hit a baseball into the field of play, the temporal error of the bat swing must be less than 9 ms and the spatial error must be less than 0.50 inches.[2]

Recent studies of predictive and visual cues in baseball suggest that batters use pre-pitch or contextual cues, kinematic cues associated with the pitcher's motion, and visual cues after the pitch is released to guide the bat swing.[3–6] Further, expert batters tend to fixate on the pitcher's hand or arm when the pitcher releases the ball, while novice or non-expert batters tend to look closer to the midline of the pitcher's body upon pitch release.[7–9] There is also accumulating evidence that the head is rotated more than the eye in tracking baseball pitches and that gaze is maintained on the ball at least until an anticipatory saccade in the direction of the batter occurs.[10–18] Finally, studies have demonstrated that good visual function is common in highly

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accomplished batters.[19–21] In the study described here, adult baseball players were asked to complete a survey on baseball batting. To the authors' knowledge, this is the first survey to examine whether the conclusions of laboratory studies on vision in batting match batters' perceptions of their in-game behaviors. Differences between the results of laboratory studies and in-game behaviors could result from any of the following. First, batters' perceptions of what visual cues they use and how they move their head and eyes in batting could be inaccurate. Second, in-game behaviors may vary from laboratory behaviors because there is likely to be increased variability in the pitch speed and pitch velocity in games compared to laboratory studies.[2] For example, in studies of head and eye movements in batting, players have been asked to view pitchers on a screen[3,7–8] or to bat pitches in a virtual reality simulation,[13] or to bat pitches from a pitching machine that produced relatively predictable pitch trajectories or pitch speeds,[10,12,14–15] or to bat pitches thrown by a pitcher in a setting other than in a game.[16,17] Finally, studies demonstrate that assessments of athlete behavior vary depending on how representative or "coupled" the experimental task is to the task required in competition.[22-23] This latter finding suggests that laboratory and in-game behaviors may vary because the laboratory task differs from the task needed for the actual competition.

In addition to comparing laboratory and in-game perceptions of behavior, since good vision has been found in expert baseball players[19–21] and since there is evidence that vision training may positively influence batting,[24–30] another goal of this study was to determine whether the survey respondents had received an eye examination while playing and whether they had discussed vision therapy with anyone. A final goal of the study was to determine whether players typically make use of coaching advice in batting.

The purposes of this investigation were, therefore to examine the sources of information that batters believe they make use of in games, to assess the head and eye movement and gaze behaviors that batters believe they execute in games, to assess the utilization of eye care services in baseball players, and to compare batters' recollections of coaching advice to batters' in-game behaviors as indicated by the survey answers.

MATERIALS AND METHODS

An online survey was created in Qualtrics (Provo, UT). The authors created the questions, and the survey was intended to take only a brief time to complete. The lead author (J.T.) is a former college baseball player, and the other author (N.F.) has published manuscripts on head and eye movements in baseball batting.[18] The questions on the survey were designed to address each phase of batting, including the pre-release period, the release period, and the post-release period as shown in Figure 1.

In addition, questions regarding batters' recollections of coaching advice and the batters' eye care history were included. The survey questions and results are shown in Figures 1 and 2 and Tables 1, 2, 3, and 5.

The survey and study procedures were submitted to The Ohio State University Biomedical Sciences Institutional Review Board, and the study was deemed exempt. No identifying information was collected from survey takers. A consent form was included at the beginning of the survey, and survey takers indicated they were providing informed consent. Specifically, subjects responded to the statement, "I have read the consent form, and I am providing informed consent to participate in the study." Subjects clicked a button next to the response "Yes, I am providing informed consent and will participate" to indicate that they were providing informed consent. The other option which could have been selected was "No, I do not wish to participate." A question in the survey was also included, which asked whether the survey takers were 18 years of age or older. By including individuals 18

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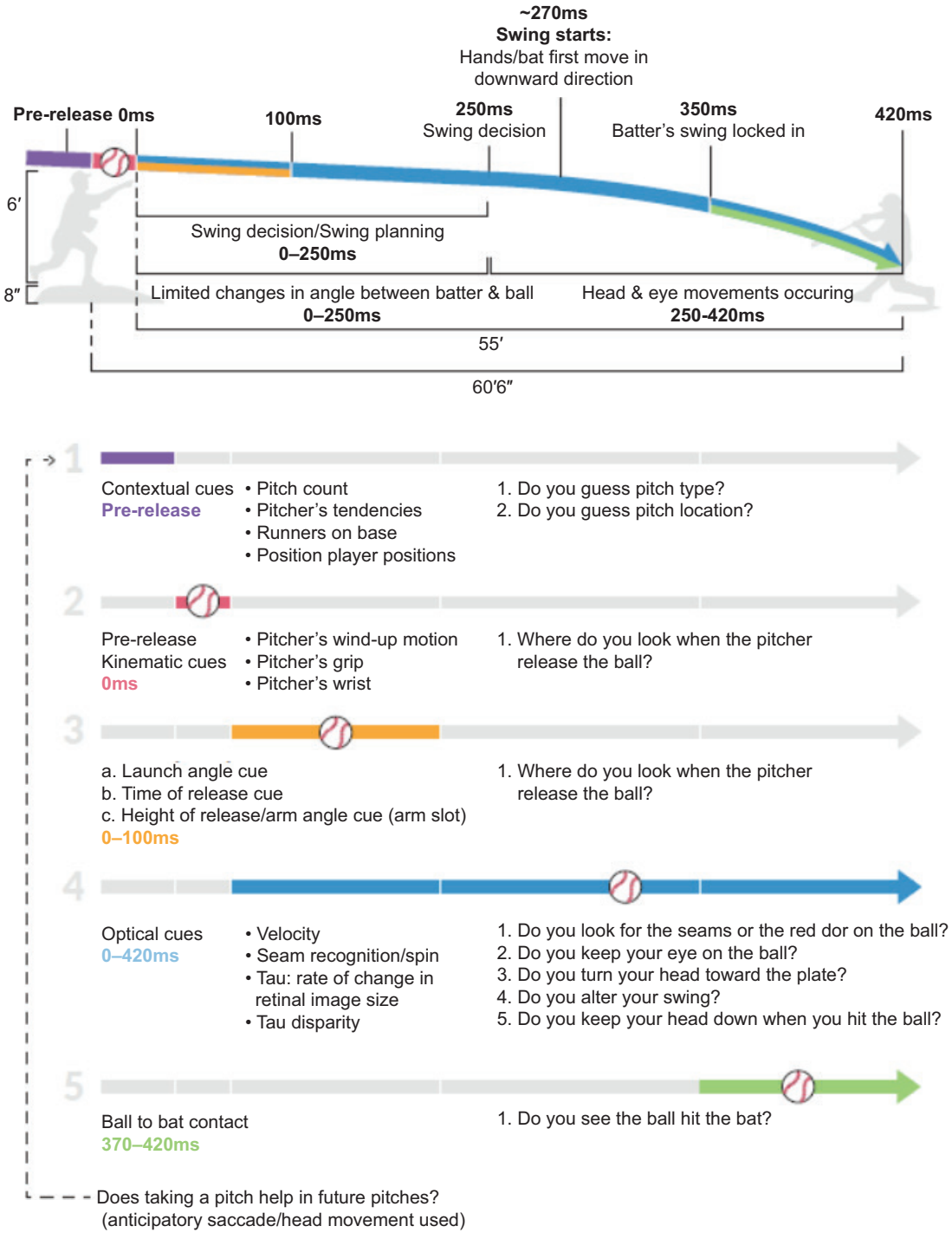
FIG. 1 The relationship of survey questions to the phases of a 90-mile-per-hour pitch.[31,32]



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or older, only consent of the survey respondent was required. All survey respondents whose data is included in the following analyses answered "yes" to these questions.

A recruitment script approved by The Ohio State University Biomedical Sciences Institutional Review Board was e-mailed or texted to individuals in the United States. The script contained a brief description of the study and a link to the survey, and a statement that the survey could be forwarded to others that may be interested in completing or forwarding the survey. The link to the survey was sent by the authors to about 51 individuals who were known to have played baseball at the college level or above and who knew one of the investigators personally, 9 coaches who knew one of the investigators personally, 2 individuals known by one of the investigators who had not played baseball at the college level or above but who were thought to be acquainted with individuals eligible to complete the survey, and 71 coaches at the college level in the state of Ohio who were identified through internet searches.

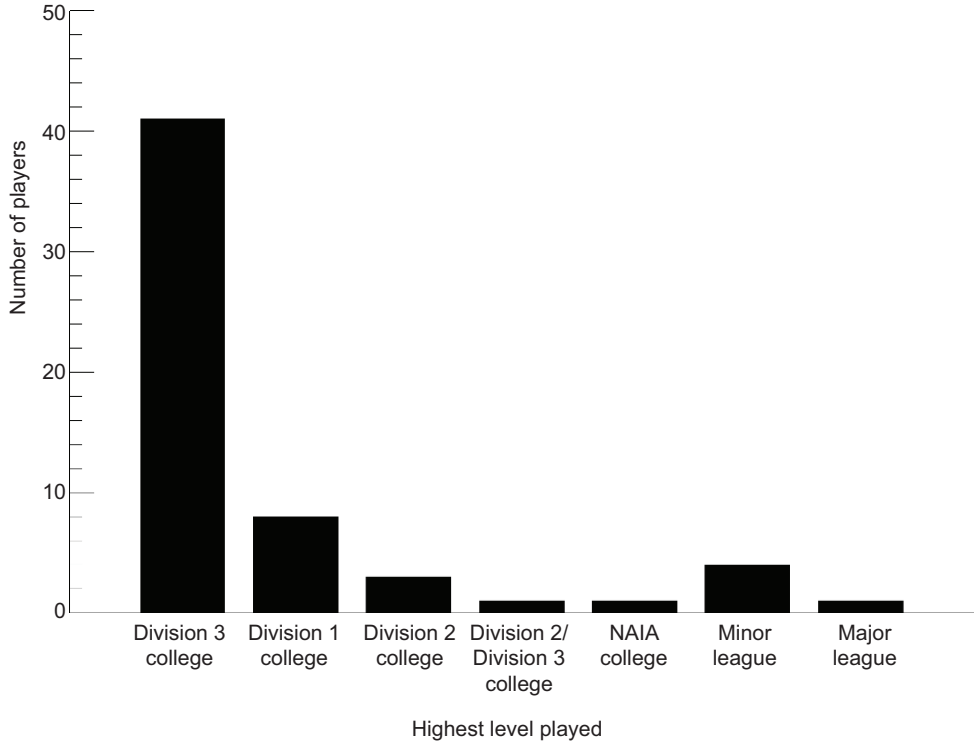
RESULTS

A total of 59 individuals who indicated that they had played baseball at the college level or above provided informed consent and answered all of the survey questions (58 respondents) or all but four of the questions (1 respondent).

Characteristics of survey respondents

Two questions were asked to determine at what level survey takers were competing in or most recently competed in and to determine the highest level that players had competed in. The distribution of answers for these two questions matched except for two individuals described below, so only the results of the question regarding the highest level competed in will be described here. These results are shown in Figure 2.

FIG. 2 The number of respondents for whom the highest level played was as indicated on the x-axis.



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Fifty-four survey takers indicated that college was the highest level they had competed in: specifically, 41 respondents answered Division 3 college, 8 answered Division 1 college, 3 answered Division 2 college, 1 answered Division 2/Division 3 college, and 1 answered National Association of Intercollegiate Athletics (NAIA). Those individuals who specified Divisions 1, 2, or 3 were presumed to have competed in the National Collegiate Athletic Association (NCAA). Division 1 NCAA athletes compete at the highest level of intercollegiate athletic programs. NCAA Division 1 institutions generally have the highest athletic budgets and offer the highest number of athletic scholarships. NAIA institutions generally have smaller athletic budgets than NCAA institutions. One of the 41 individuals included in these analyses as a Division 3 college player answered that the highest level they competed at was high school, but the level they were currently competing in or most recently competed was Division 3. The other 5 players indicated they had competed professionally at the minor league level (4) or the major league level (1). One of these latter individuals said their highest competitive level was minor league, but they were currently competing at the Division 1 college level. This individual is included as a minor-league player here.

Questions were asked to assess the player's current playing status, the player's typical role (position player or pitcher), the player's number of years competing in organized baseball, and the player's typical batting average. These questions and responses to these questions are shown in Table 1.

One of these questions was whether the survey takers were currently competing in organized baseball. Forty-eight of 59 individuals (81%) answered "yes" to this question. Therefore, while the reliability of survey answers may have been reduced for some respondents because memories fade over time, poor recall was unlikely to have influenced the majority of survey takers. Forty-three of 59 players responded that they were best described as position players (presumably a position other than pitcher), 11 responded that they were best described as pitchers, and 5 individuals answered that they could best be described as a position player and a pitcher. Regarding the number of years that survey takers had played organized baseball, 23 answered more than 15 years, 32 answered 11-15 years, and 4 answered 6–10 years. Most survey takers, therefore, had at least 11 years of experience in organized baseball. Survey takers were also given ranges to indicate where their typical batting average fell. Batting average is calculated by dividing the number of hits by the number of at-bats, discounting walks in which the batter reaches base because the pitcher throws four pitches outside the strike zone, and discounting cases where the batter was hit by a pitch, and discounting sacrifice fly balls or sacrifice bunts in which the batter hits the ball in such a way as to advance a runner or runners along the base paths. Five individuals indicated that their typical batting average was over .400, 30 chose the range .300-.399, 23 chose the range .200-.299, and 1 chose the range .100-.199.

TABLE 1 Characteristics of Survey Respondents

Are you currently competing in organized baseball?	Yes 48 (81.4%)	No 11 (18.6%)		
Which of the following best describes you?	Position player 43 (72.9%)	Pitcher 11 (18.6%)	Both position player and pitcher 5 (8.5%)	
How many years have you played organized baseball?	6-10 4 (6.8%)	11-15 32 (54.2%)	More than 15 years 23 (39.0%)	
In which of these ranges is your typical batting average?	.100-.199 1 (1.7%)	.200-.299 23 (39.0%)	.300-.399 30 (50.9%)	Over .400 5 (8.5%)

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Prediction, gaze location, and eye and head tracking behaviors

Survey questions throughout this section and the distribution of answers to these questions are summarized in Table 2. The bound on the error estimation was determined to compare the responses for a particular question.[33] Since the highest level in which most of the respondents competed was the Division 3 (NCAA) college level, the bound on the estimation error was calculated after determining that there are approximately 12000 current Division 3 college players.[34] The equations used to calculate the bound (B) were as follows[33]:

$$Npq/((N\text{-}1)D + pq) \text{ and } D = \frac{B^2}{4}$$

where n = the number of survey respondents, N = the number of potential respondents in the population, p is the estimator of the population proportion = 0.5, and q = 1 – p. The bound on the error estimation was determined to be 13%. If one assumes that each potential answer for a question has a bound of 13%, then answers must differ by more than 26% to be considered different. Therefore, asterisks are applied to answers in Table 2 for questions in which the answer with the greatest percentage of response exceeded the answer with the next most common response by more than 26%.

If the question is not how often batters behave in a particular way but rather whether batters ever perform in that way, then a binary approach can be applied to all of the questions in Table 2 except

TABLE 2 Prediction, Eye and Head Movements, Viewing the Seams on the Ball, and Taking a Pitch. The Asterisks Indicate Questions for Which the Greatest Percentage Response Exceeded the Next Most Common Response By 26%

Do you try to guess the type of pitch (for example a fastball or curveball) before it is pitched?	Always 12 (20.3%)	Sometimes 41 (69.5%)*	Never 6 (10.2%)	Don't know 0(0%)
Do you try to guess the pitch location (for example, "outside") before it is pitched?	Always 9 (15.3%)	Sometimes 31 (52.5%)	Never 19 (32.2%)	Don't know 0(0%)
Where do you look when the pitcher's hand/glove separate just before the pitch is delivered?	Pitcher's hand/ball 36 (61%)*	Pitcher's head 16 (27.1%)	Pitcher's elbow 2 (3.4%)	Don't know 5 (8.5%)
Do you keep your eye on the ball?	Always 41 (69.5%)*	Sometimes 18 (30.5%)	Never 0 (0%)	Don't know 0(0%)
Do you turn your head toward the plate as the ball comes toward you?	Always 30 (50.9%)	Sometimes 19 (32.2%)	Never 6 (10.2%)	Don't know 4(6.8%)
Do you keep your head down when you hit the ball?	Always 34 (57.6%)	Sometimes 24 (40.7%)	Never 1 (1.7%)	Don't know 0(0%)
Do you look for the seams or a red dot on the baseball as the pitched ball travels through the air toward you?	Always 22 (37.3%)	Sometimes 27 (45.8%)	Never 9 (15.3%)	Don't know 1(1.7%)
Do you see the ball hit the bat?	Always 12 (20.3%)	Sometimes 33 (55.9%)*	Never 13(22.0%)	Don't know 1(1.7%)
Do you change your swing after it has started if the pitch is not what you expected?	Always 6(10.2%)	Sometimes 38(64.4%)*	Never 14(23.7%)	Don't know 1(1.7%)
When you take a pitch, does that help you to time yourself up to make better contact in future swings?	Always 27(45.8%)	Sometimes 31(52.5%)	Never 1(1.7%)	Don't know 0(0%)

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the question regarding where batters look when the pitch is delivered. For all but this latter question, the percentage of "always" and "sometimes" responses were combined and compared to the percentage of "never" and "don't know" responses. For all of the questions examined in this way, the percentage of responses for the combination of "always" and "sometimes" answers exceeded the combination of "never" and "don't know" responses by more than 26%.

Questions related to coaching

The next survey questions to be discussed here concerned batters' recollections of coaching advice. These questions aimed to determine whether coaches prioritized vision-related instruction and compare batters' perceived behaviors to the coaching advice they had received. These questions and the percentage of respondents who responded for each answer are shown in Table 3.

A rough determination as to whether batters' perceived behaviors were as expected based on the coaching advice they received was made by comparing the results of the questions shown in Table 4. Related questions are shown in the same row in the table.

A paired t-test was used to compare the answers to these related questions. When the "yes" responses from the coaching questions were compared to the "always" responses from the behavioral questions, the mean difference was not significantly different although the difference trended toward significance ($p = 0.074$, $T = 2.26$). The paired t-test when the "yes" responses from the coaching questions were compared to the sum of the "always" and "sometimes" behavioral responses showed that the mean difference was not significant ($p = 0.324$, $T = 1.09$).

Questions related to eye examinations and vision training

The purpose of the last two questions on the survey was to examine the utilization of eye care services in baseball players (Table 5). In response to the question of whether respondents had an eye examination in the time they played, 75.9% answered "yes," 22.4% answered "no," and 1.7% (1 respondent) answered "not sure." In response to the question of whether the players had ever discussed vision therapy/eye training with anyone, 70.7% answered "no," 25.9% answered "yes," and about 3.5% answered "not sure."

Comparison of batting average categories to survey results

Individuals with higher batting averages may behave differently or prioritize different visual cues than those with lower averages.[3,8,9,10,16,18] Therefore, survey answers for several questions were compared

TABLE 3 Coaching

Have you been coached to look at the pitcher's hand when the pitch is delivered?	Yes 41(70.7%)	No 9 (15.5%)	Not sure 8(13.8%)
Have you been coached to keep your eye on the ball when you bat?	Yes 58(98.3%)	No 1 (1.7%)	Not sure 0
Have you been coached to look for the seams on the ball when the ball is pitched?	Yes 49(84.5%)	No 7 (12.1%)	Not sure 2(3.5%)
Have you been coached to turn your head with the ball?	Yes 18(30.5%)	No 25 (42.4%)	Not sure 16(27.1%)
Have you been coached to keep your head down when you bat?	Yes 51(86.4%)	No 2 (3.4%)	Not sure 6(10.2%)
Have you been coached to look where the bat hits the ball when you swing at the ball?	Yes 42(71.2%)	No 12 (20.3%)	Not sure 5(8.5%)

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TABLE 4 Questions Used In Comparing Coaching Advice To Behavioral Response

Coaching advice	Behavioral responses
Have you been coached to look at the pitcher's hand when the pitch is delivered?	Where do you look when the pitcher's hand/glove separate just before the pitch is delivered?
Have you been coached to keep your eye on the ball when you bat?	Do you keep your eye on the ball?
Have you been coached to look for the seams on the ball when the ball is pitched?	Do you look for the seams or a red dot on the baseball as the pitched ball travels through the air toward you?
Have you been coached to turn your head with the ball?	Do you turn your head toward the plate as the ball comes toward you?
Have you been coached to keep your head down when you bat?	Do you keep your head down when you hit the ball?
Have you been coached to look where the bat hits the ball when you swing at the ball?	Do you see the ball hit the bat?

TABLE 5 Eye Examinations and Vision Training

In the time you played, have you or did you have an eye examination?	Yes 44 (75.9%)	No 13 (22.4%)	Not sure 1 (1.7%)
Have you ever discussed vision therapy/eye training with anyone?	Yes 15 (25.9%)	No 41 (70.7%)	Not sure 2 (3.5%)

between the survey takers who reported batting averages less than .300 (n=24) and those who reported averages equal to or greater than .300 (n=35).

Overall, the responses from both groups for these questions were very similar. A chi-square test was performed in Minitab version 14.2 (Minitab Incorporated, State College, PA) to compare the results between batting average groups for each question in Table 2. In cases when neither group selected a response, that response was not included in the chi-square analysis. After the initial chi-square analysis that included all of the available data, if the expected cell count from the chi-square analysis for a particular response was less than 1 then the results for that response were eliminated for both batting average groups and then the analysis was performed again. For only one question, was the expected count less than 1 for a particular response for only one batting average group.For all but one question, the chi-square analysis yielded a non-significant p-value ($p>.05$) in comparing the batting average groups. However, for the question "Do you change your swing after it has started if the pitch is not what you expected?" the p-value associated with the chi-square analysis was $p=.028$ (Pearson chi-square statistic = 7.166, df=2).

DISCUSSION

One purpose of this project was to survey baseball batters to understand which cues batters use or believe they use to determine whether laboratory measures of eye movement, head movement, and gaze locations are similar to those reported by baseball batters. A second purpose was to gather batters' recollections of coaching advice, and a third purpose was to assess whether baseball batters had received an eye examination and whether they had discussed vision therapy/eye training with anyone during the time they played.

Cues for batting

Broadly, these results suggest that pre-pitch cues are used by the respondents. Two survey

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questions addressed prediction before pitch release (Table 2). One question asked whether batters guessed the pitch type before pitch release and the other asked whether batters guessed the pitch location before the pitch release. While most players responded that they made these predictions, the most common answer was sometimes (69.5% for pitch type and 52.5% for pitch location). The fact that "sometimes" was the most common answer suggests that there are situations in which kinematic cues from the pitcher's motion or post-release cues, such as the launch angle of the pitch, the seams of the ball, or optical cues associated with ball flight are used in predicting the pitch type and pitch location.[3,5] Although the percentage of respondents who answered either "sometimes" or "always" was similar for pitch type (about 90%) and pitch location (about 68%), the higher value for pitch type may suggest that pitch type is easier to predict than is pitch location, and a good prediction of pitch location is more likely to require cues in addition to contextual cues. The results of the question regarding whether taking a pitch helps in making contact in future swings (about 53% answered "sometimes" and about 46% answered "always") also suggests that batters make use of cues before pitch release, as information from previous pitches may reinforce predictions regarding future pitches.[2,10,35]

Questions were also asked to ascertain where batters believe their gaze is located around pitch release and whether the gaze is maintained on the ball throughout some or all of the pitch (Table 2). The interpretation of these results is based on the notion that the gaze is directed at locations where information is available for the observer to successfully perform the task.[36,37]

The first of these questions asked where batters look when the pitcher's hand/glove separate just before the pitch is delivered. There is substantial literature on the quiet eye, defined as the gaze fixation or gaze tracking movement before an action.[38–40] The quiet eye has been demonstrated in many sports and is thought to represent a period of perceptual processing beneficial in executing the action. It might be expected then, that batters would maintain their gaze near the location of pitch release around the time the pitcher throws the ball as this would ensure that the launch position, launch angle, baseball seam direction, and early optical cues for time to contact could be most efficiently assessed.[35,41–46] Indeed this behavior has been demonstrated experimentally.[7–9] About 61% of respondents answered that they viewed the pitcher's hand/ball when the pitcher's hand/glove separate just before the pitch is delivered, while about 27% answered that they viewed the pitcher's head. Viewing the pitcher's head or body is a gaze strategy novice baseball batters employ.[8,9] Given that the survey takers in the current study were primarily college players, it is somewhat unlikely that the level of expertise of these players accounts for these "head fixation" responses. Instead, it may be that some survey takers answered that they fixated the head because it may be difficult for the batter to locate the ball behind the pitcher's body when the pitcher pulls the pitching arm back (that is, away from the batter) before pitch release. Therefore, the disparate answers to this question may have occurred because some survey takers focused on the portion of the question that mentions the earlier time the glove and ball separated, and other participants interpreted the question as directed at the later time just before the pitch was delivered. The many respondents who answered that they looked at the pitcher's hand/ball just before the pitch was released suggests that these batters prioritize early visual cues for batting. Further work will be required to determine whether some proficient batters do, in fact, look at the trunk just before the pitch is delivered and whether there is useful kinematic information gained from such a gaze strategy.

There were other questions suggesting that baseball batters also prioritized cues following the pitch's release (Table 2). One of these questions was whether batters kept their eye on the ball. The most common answer was always (about 69%), and any respondent who did not answer "always" answered "sometimes." Maintaining gaze on the ball allows

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batters additional time to assess time to contact information (as perhaps provided by a monocular ratio of the instantaneous retinal image size of the ball to the rate of change in the ball's retinal image size and a binocular ratio of the instantaneous relative binocular disparity of the ball to the rate of change in the relative binocular disparity of the ball), or the orientation of the seams.[47-50] In support of the idea that batters are tracking the ball to gather information to predict the ball's future trajectory, 46% of survey respondents reported that they "sometimes" looked for the seams or a red dot on the baseball and 37% responded that they "always" looked for these features. If batters do indeed look for the seams on the ball, this suggests that batters are tracking the ball for at least a portion of the pitch trajectory because previous studies have demonstrated that the seams likely cannot be resolved immediately upon release of the ball from the pitcher's hand[35,43] or over short exposure durations (<300ms).[45]

Survey takers were also asked to indicate whether they believed they altered their swing after it started in response to an unexpected pitch. While about a quarter of the participants answered "never," the rest answered either sometimes (64%) or "always" (10%). Such adjustments of an ongoing swing must be based on post-pitch information.

Finally, one question could indicate that contextual cues, post-release cues, or both are utilized. When survey takers were asked whether they saw the ball hit the bat, about 56% of the respondents answered "sometimes" and about 20% answered "always." It may be that attempting to see the ball hit the bat helps batters to predict the location of future pitches and therefore reinforces contextual cues for future pitches.[10] On the other hand, attempting to see the ball hit the bat could suggest that post-release cues are assessed throughout the pitch trajectory and that adjustments to the swing are ongoing throughout much of the pitch trajectory.

In summary, the survey results suggest that contextual and post-pitch cues are at least sometimes utilized by many of the baseball batters who responded to the questions in the survey.

Comparison of survey answers and laboratory measures of gaze, eye and head movements

The survey responses related to gaze, eye, and head movements were largely as predicted from laboratory-based studies of these movements.[10–18] These questions included whether batters kept their eye on the ball, turned their head toward the plate, kept their head down when batting the ball, and saw the ball hit the bat. However, many batters chose "sometimes" in response to some of these questions. This suggests that while laboratory studies have correctly identified behaviors that are at times used by baseball batters, these laboratory studies may not capture the variability in gaze, eye, and head movements induced by less predictable game conditions. For example, batters may not always maintain their gaze on the ball because they make an anticipatory saccade[16,17] or because their prediction of the pitch trajectory is wrong and the sight of the ball is lost. Similarly, head movements in the direction of the ball may not occur if an anticipatory saccade is made earlier in the trajectory, or if the batter's prediction of the pitch trajectory is in error and the normal coordination of the eyes and head is disrupted.

Coaching advice

Another purpose of this project was to examine the coaching advice provided to players regarding gaze fixation early and late in the pitch, gaze tracking once the ball is released, head movements, and seam identification (Table 3). As suggested earlier, seam recognition is a likely indicator that gaze is on the ball for a substantial amount of the pitch trajectory, and therefore coaching players on seam recognition is to some extent, equivalent to encouraging batters to keep their eyes on the ball.

The answers to these questions were generally yes, which were generally consistent with the survey respondents' answers regarding their behaviors in batting. That is, respondents appeared to follow coaching advice. For example, batters recalled being coached to keep their eye on the ball, and the answer to whether batters did, in fact keep their eye on the ball was also highly positive. The mean difference

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between the percentage of "yes" answers to the percentage of "always" responses ("always" was a potential response in all but one of the questions included in this analysis) trended toward significance. Perhaps unsurprisingly, when the percentage of "yes" responses from the coaching questions was compared to the sum of the "always" and "sometimes" responses in the behavioral questions, the mean difference was not statistically significant.

Internal focus training has been defined as training directed at specific actions to help an individual achieve a particular goal.[45] Coaching advice addressed in the survey such as "keep your eye on the ball" or "keep your head down" can be considered internal focus instructions. On the other hand, a growing body of evidence suggests that there is no "one size fits all" solution to achieving a goal-directed action.[51] In this latter view, training should allow individuals to figure out what works for them by providing external focus instructions or by using a constraints-led approach in which athletes focus their attention external to the body (e.g., the bat in baseball batting) or on the outcome of their movements. For example, Gray demonstrated that in a virtual batting simulation, internal focused training was less effective in increasing the batted ball's launch angle for experienced hitters than external focus training and training based on the constraints-led approach.[51] For the internal focused training, participants were given these instructions: "get your hands under the ball," "move your arms at an upward angle," and "drive up, off your back foot." For the external focused training, participants were given these non-body related instructions: "get the bat on the same plane as the incoming pitch," "drive the ball over the infield," and "contact the bottom half of the ball." Finally, the constraints-led training required participants to hit a ball over a simulated barrier in the outfield. While the survey results in the current study suggest that internal focused instruction is common, future surveys could assess whether internal focused training is augmented by external focus and constraints-led training approaches.

Questions related to eye care

Data are demonstrating that professional baseball players have excellent visual acuity[19] and that visual function correlates with performance.[21] On the other hand, there are indications that Snellen visual acuity of 20/20 or better may not be required in batting a ball, at least when the pitch trajectory and pitch speed are relatively predictable.[52-56] Given these disparate findings on the effect of refractive blur on batting, it seems reasonable to accurately correct any refractive error in baseball batters. About 1/4 of the respondents answered that they had not had or were unsure whether they had received an eye examination while playing. The results may suggest that there is a need for eye care for baseball players,[57] or alternatively that vision is very good in baseball players.[19] Further work in this area will be required. It is unclear whether survey respondents assumed that a vision screening (for example, a visual acuity measurement) constituted an eye examination or whether the term "eye examination" was taken to mean a comprehensive eye examination.

The survey question regarding whether survey respondents had ever discussed vision therapy/eye training with anyone yielded very different results from the question regarding eye examinations. Despite studies demonstrating that vision therapy may result in improvements in baseball batting.[24–30] 71% of respondents answered "no," 26% answered "yes," and about 3% answered "not sure" in response to whether they had discussed vision therapy. While further clinical trials will be needed to establish the efficacy of vision therapy for baseball batting, the results of this survey suggest that there is an opportunity for eye care practitioners to engage in discussions on recent studies of vision therapy and baseball batting with patients, coaches, athletic trainers, and teams.[30]

Comparison of results between batting average categories

A common approach in sports science is comparing attributes in expert athletes to those in less

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accomplished or novice athletes. If these attributes are not the same, then these differences may result in better performance for the experts. Therefore, the decision was made to compare the answers to the survey questions in Table 2 between the individuals who indicated that their batting average was typically less than .300, and those who answered that their batting average was typically .300 or above. There was little difference in the responses between these groups, as shown by the chi-square analyses. The implication of this result is unclear at this time. Individual batting averages were not assessed, and it is possible that the overall batting average in the lower batting average group was similar to that in the higher batting average group.

STUDY LIMITATIONS

Limitations of the approach in this study include those common to all survey research. First, sampling bias may have occurred because data were only collected from those willing to complete a survey. For example, likely, some coaches did not forward the survey, and some college teams may have had more representation than others. It is possible that participants could have been familiar with previous research published by the investigators, leading them to give answers related to previous laboratory studies. However, this is unlikely as the respondents were asked about perceived behaviors during all pitch periods (pre-pitch, ball-in-flight, post-pitch) and about coaching advice. Finally, the diversity of topics in the questions made it difficult for an individual to know the investigators' specific hypotheses for all of these aspects of batting.

CONCLUSIONS

The major findings from this study are as follows. The results suggest that the batters surveyed in this study use contextual cues as evidenced by their responses to questions regarding prediction, and post-pitch cues as evidenced by their responses to questions regarding gaze tracking. In addition, responses to questions related to gaze, eye, and head tracking movements were mostly consistent with laboratory measures of these movements. For some questions related to tracking movements, the most common response was "sometimes" which may suggest a larger degree of within-subject variability in game behaviors compared to those in the laboratory.[10-18] The most parsimonious explanation for this discrepancy is that pitch trajectory is less predictable in games, and this may disrupt the normal coordination of the eyes and head. In addition to the reduced predictability resulting from the wider array of pitches thrown by pitchers in games compared to the laboratory, unpredictable conditions may be brought about because the environmental conditions (e.g., lighting, wind) vary from game to game and because the level of distraction in games can change (e.g., crowd noise). An alternative hypothesis regarding the influence of pitch predictability on head and eye movements and gaze tracking is that if the pitch is *more* predictable, then gaze tracking behaviors such as keeping one's eye on the ball might be less necessary.[58] This could also lead to "sometimes" responses to the survey questions. However, laboratory conditions with predictable pitch trajectories have not demonstrated significant variability in gaze, eye, and head-tracking responses.[18]

The survey questions related to coaching advice were consistent with those on batting behaviors. That is, respondents indicated that they followed coaching advice. The questions around coaching were directed toward internal focus training. Future studies can assess whether baseball coaches have adopted external focus training and constraints-led approaches.

Finally, in response to the questions about eye care, most respondents indicated that they had received an eye examination while playing, but only about 26% of respondents stated that they had discussed vision therapy/eye training with someone. These results suggest that sports vision practitioners can discuss vision therapy with individuals, coaches, and teams.

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