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Original Article

A COMPARISON OF CARDINAL GAZE SPEED BETWEEN MAJOR LEAGUE BASEBALL PLAYERS, AMATEUR PROSPECTS, AND NON-ATHLETES

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ABSTRACT

Purpose

Sensorimotor variables have been shown to predict performance in professional baseball players. However, cardinal gaze speed in baseball players has received only limited attention. This study tested the hypothesis that the cardinal gaze speed in Major League Baseball (MLB) players would be faster than in amateur prospects and non-athletes.

Method

Seventeen MLB athletes, 160 amateur prospects, and 128 non-athletes were tested using an eye-tracking test (i.e., the RightEye CGP test) designed to measure cardinal gaze speed.

Results

MLB players had significantly faster cardinal gaze speed than either amateur prospects or non-athletes. Moreover, there were significant differences in cardinal gaze speed across different directions.

Conclusions

This was the first study to examine the speed of gaze in the cardinal positions in an athletic context. The results highlight the significant difference in cardinal gaze speed between MLB players, amateur prospects, and non-athletes.

> People always told me that my natural ability and good eyesight were the reasons for my success as a hitter. They never talk about the practice, practice, practice.
>
> —Ted Williams[1]

As Ted Williams noted, visual characteristics work together with practice as important determinants of performance in baseball. Two groups of studies have examined the relationship between visual characteristics and performance in baseball. The first group of studies showed that visual characteristics differ between professional baseball players and non-athletes.[2–5] The second group of studies showed that visual characteristics predict performance in baseball.[6,7] Among the studies that have examined the relationship between visual characteristics and performance in baseball, some operationalized performance as level of play (e.g., professional versus recreational) and others operationalized performance as game statistics (e.g., batting average, etc.).

Four studies showed that visual characteristics differ between professional baseball players and non-athletes. First, Hoffman et al compared 25 college baseball players and 30 optometry students and reported that the baseball players had higher levels of contrast sensitivity than the students.[3] Second, Boden et al compared 51 youth ballplayers and 52 non-ball players and found that young baseball players had better static stereo acuity than non-ball players.[2] Third, Uchida et al compared eight college baseball players and eight non-athletes and reported that the baseball players had better dynamic visual acuity than the non-athletes.[5] Fourth, Hunfalvay et al compared 52 professional golfers, 265 professional baseball players, and 107 non-athletes and found that the professional athletes had better static stereo acuity than non-athletes.[4]

Two studies showed that visual characteristics predict performance in baseball. First, Hoshina et al assessed 102 professional baseball players and reported a significant difference in kinetic visual acuity between pitchers and fielders.[7] Second, Burris et al. assessed 252 professional baseball players and identified several visual characteristics that predicted on-base percentages, walk rates, and strikeout rates.[6] Visual characteristics that were strong predictors of performance included visual clarity, contrast sensitivity, depth perception, near-far quickness, target capture, eye-hand coordination, and perception span.

Thus, research has shown that visual characteristics are related to performance in baseball. More skilled/ professional baseball players have better visual characteristics than less skilled/ non-professional baseball players; and better visual characteristics (e.g., better contrast sensitivity and depth perception) predicted better performance. There is a visual characteristic, the speed of the eye movements in the CGPs, which has received only limited attention.

The CGPs are "positions of gaze which reflect the primary action of the six extraocular muscles."[8] The extraocular muscles, the lateral rectus, the medial rectus, the inferior rectus, the superior rectus, the inferior oblique, and the superior oblique, work in synergy with one another to move the eye up and down, side to side, and to rotate the eye.[9] These muscles work either individually or in combination to produce the full suite of different movements of the eyes.[10] The six extraocular muscles of the eye are striated muscles and they adapt to the stresses and demands placed on them, such as exercise and training.[11]

The ability to move to the CGPs is routinely assessed in clinical settings as an indicator of the functioning of the extraocular muscles and of cranial nerves III, IV, and VI.[12] The most commonly used clinical test of the ability to move to the CGP involves a vision specialist drawing an "H" in the air with their finger (or another object) in front of an individual's face and asking them to follow the tip of the finger or object with their eyes without moving their head. When conducting the H test, vision specialists examine the client's eye movements to determine whether they are smooth and coordinated. A similar test for the ability to move to the CGP is conducted from a center target, moving the clinician's finger out to the eight peripheral CGPs in a "star-like" fashion. The H and star-like tests require the vision specialists to detect the salient characteristics of oculomotor abnormalities based on clinical experience, that is by using the naked eye to observe movement.[12] Unfortunately, reliability is low for the H and star-like tests irrespective of the experience level of the vision specialist conducting the exam.[13,14]

Over the past several decades, the use of eye-tracking devices linked to algorithmic analysis has become increasingly common. Eye-tracking devices have been used to examine eye movements for visual health, wellness, and peak performance.[15–17] Eye trackers provide highly specific, objective eye movement recordings by examining the eye many times per second (i.e., from 120–1000 hz [18]) and they have been shown to produce high levels of measurement accuracy.[19]

PURPOSE

Given the importance of superior visual skills in baseball, and the lack of awareness of how the speed of gaze in each of the cardinal positions contributes to expert sports performance, the purpose of this study was to compare the cardinal gaze speed of Major League Baseball (MLB) players with those of amateur prospects and non-athletes. This study tested two hypotheses. The first hypothesis was that cardinal gaze speed would differ across the eight cardinal gaze directions. It was hypothesized that cardinal gaze speed would differ across the Speed Up, Speed Upper Right, Speed Right, Speed Down Right, Speed Down, Speed Down Left, Speed Left, and Speed Upper Left directions. Because visual characteristics have been shown to differ between professional baseball players and non-athletes, the second hypothesis was that cardinal gaze speed would differ between (MLB) players, amateur prospects, and non-athletes.

METHODS

Participants

Participants were a convenience sample of individuals tested using the RightEye CGP test.[4,20–22] The sample included 17 MLB players, 160 amateur prospects, and 128 non-athletes. MLB players were between the ages of 19 and 34 years ($M = 25.8$, $SD = 3.7$) and had a minimum of 732 (732 to 5416) at-bats in the major league. Amateur prospects were between the ages of 15 and 19 years ($M = 16.7$, $SD = 2.1$) and non-athletes were between the ages of 18 and 32 years (M = 24.8, SD = 3.9). All participants were male. The majority ($n = 197$) of the participants were white (10 MLB players, 109 amateur prospects, 78 non-athletes). Fifty-six participants (4 MLB players, 29 amateur prospects, 23 non-athletes) were black. The remaining 52 participants were either Asian, Hispanic, Native-Hawaiian, or Other. The majority ($n = 262$) of the participants were right-handed (20 MLB players, 143 amateur prospects, 99 non-athletes). The remain-ing 43 participants were either left-handed (n=37) or ambidextrous (n= 6).

MLB players and amateur prospect participants were RightEye clients and testing was conducted by the sport vision doctors for their teams. Non-athletes were also RightEye clients and testing was conducted by experienced vision specialists. All testers were experienced sport vision specialists (e.g., optometrists, ophthalmologists) and had received and completed RightEye education and training prior to testing. All subjects provided written informed consent to participate in this study in accordance with IRB procedure (IRB: UMCIRB 13-002660). This study has been conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Cardinal Gaze Position Test

The study measured cardinal gaze speed using the RightEye Cardinal Gaze Position (CGP) test. In the RightEye CGP test, the participant looks at a central target and then, in random order, the eight peripheral CGPs. The test provides measures of saccadic latency and cardinal gaze speed (i.e., the time it takes for the eye to move an 8.68° visual angle from the center to the peripheral target). RightEye tests have been shown to have acceptable reliability and validity.[4,20–22]

PROCEDURE

Following written informed consent, participants were asked to complete a pre-screening questionnaire that included basic demographic, health, and vision questions as well as a visual acuity test where they were required to identify four shapes (a circle, square, diamond, and triangle) at 4mm in diameter. If any of the pre-screening questions were answered positively or any of the vision screening shapes were not correctly identified, the participant was excluded from the study. Based on the pre-screening questionnaire, participants were excluded for the presence of neurological disorders (such as concussion, traumatic brain injury); vision-related issues (such as extreme tropias, phorias, static visual acuity of worse than 20/400, nystagmus, cataracts, or eyelash impediments); and consumption of drugs or alcohol within 24 hours of testing.

Participants were seated in a stationary (non-wheeled, non-height adjustable) chair at a desk in a quiet, private testing room or commercial office. They were asked to look at a NVIDIA 24-inch 3-D Vision monitor that could be adjusted in height and was fitted with an SMI 12-inch 120 Hz remote eye tracker. The eye tracker was connected to an Alienware gaming system and a Logitech (model Y-R0017) wireless keyboard and mouse. The accuracy of the eye tracker was 0.4 degrees within the desired headbox of 32 cm × 21 cm at 60 cm from the screen. Participants' heads were unconstrained.

For standardization of testing, participants were asked to sit in front of the eye-tracking system at an exact measured distance of 60 cm (ideal positioning within the head box range of the eye tracker) from the eye tracker. A nine-point calibration test was conducted using the eye tracker to ensure the participant's eye movements were detected at each of the 9 locations involved in cardinal gaze, on the computer screen. Upon successful calibration, the RightEye CGP test was completed.

Participants were asked to look at the center of the screen where an icon of the solar system would appear. They were then instructed that an arrow would appear from the solar system with an icon of an alien at the end of it. Figure 1 shows the instructions for the CGPs test. The participants were asked to look at the alien as quickly and accurately as possible as soon as it appears on the screen. Figure 2 shows the picture of the alien and the icon in the CGP test. Once the eye tracker located the participant's eye on the alien, the alien icon "exploded". An animation of the correct performance on this test was shown to participants before the testing commenced. Each of the eight cardinal positions of the eyes was tested in random order.

FIG. 1 Figure shows the instructions for the Cardinal Gaze Positions test.

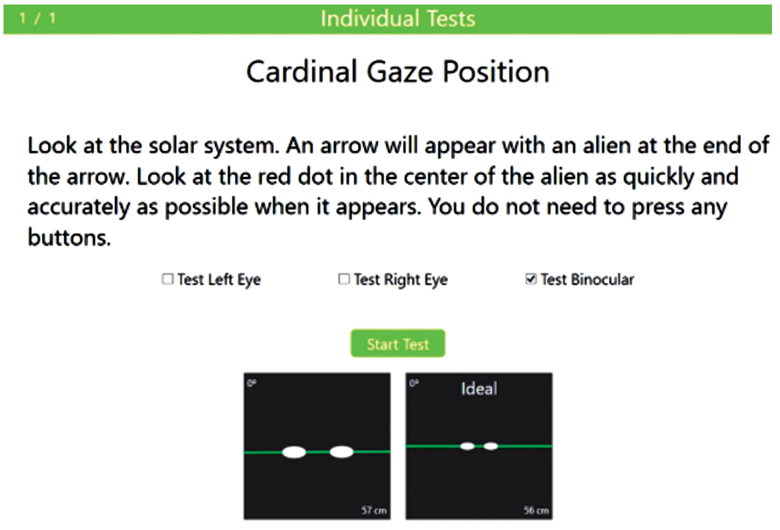
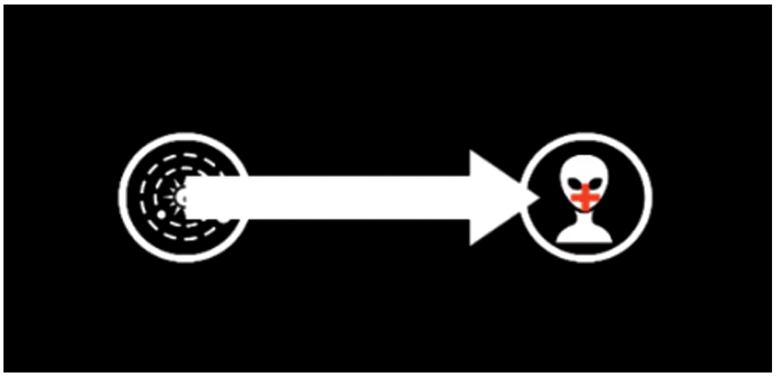


FIG. 2 Picture of the Cardinal Gaze Position Test.



Data Analysis

To test the hypothesis that there would be differences in the cardinal gaze speed of professional baseball players, amateur prospects, and non-athletes, the data were analyzed using a mixed model ANOVA. The ANOVA included one between-subjects factor. Participants were either professional baseball players, amateur prospects, or non-athletes. The ANOVA included one within-subjects factor. That is, cardinal gaze speed was assessed in the eight cardinal gaze directions, including (1) the Speed Up Direction; (2) the Speed Upper Right Direction; (3) the Speed Right Direction; (4) the Speed Down Right Direction; (5) the Speed Down Direction; (6) the Speed Down Left Direction; (7) the Speed Left Direction; and (8) the Speed Upper Left Direction. Significant main effects were decomposed using a series of Bonferonni-corrected planned comparisons across direction and group.

RESULTS

Preliminary Analysis

The preliminary analysis included an examination of cardinal gaze speed data for outliers, for normality, for homogeneity of variances, and for sphericity. Examination of studentized residuals for values greater than ±3 revealed a single outlier. The outlying data point was removed from further analysis. Normality of the cardinal gaze speed data was assessed using the Shapiro-Wilk's normality test. Cardinal gaze speed was not, initially, normally distributed, as assessed by the Shapiro-Wilk's test ($p < .05$). Subsequently, the cardinal gaze speed data was transformed via the Two-Step procedure.[23] The Two-Step procedure was utilized because it maintains the original series mean and standard deviation and makes the transformed data easier to interpret.

The transformed cardinal gaze speed data were normally distributed as assessed by Shapiro-Wilk's test ($p > .05$). For Speed Down, Speed Down Left, and Speed Left, there was homogeneity of variances, as assessed by Levene's test for equality of variances, $p > .05$. For Speed Down Right, Speed Right, Speed Up, Speed Upper Left, and Speed Upper Right, the assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances, $p > .05$. As a follow-up, homogeneity of variances was also assessed by plotting studentized residuals against predicted values and visually examining the resulting scatterplots.[24] Consistent with homogeneous variances, the vertical spread of the studentized residuals was similar across the predicted mean values. Mauchly's test indicated that the assumption of sphericity had been violated ($\chi 2[27] = 50.12$, $p = .004$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.85$).

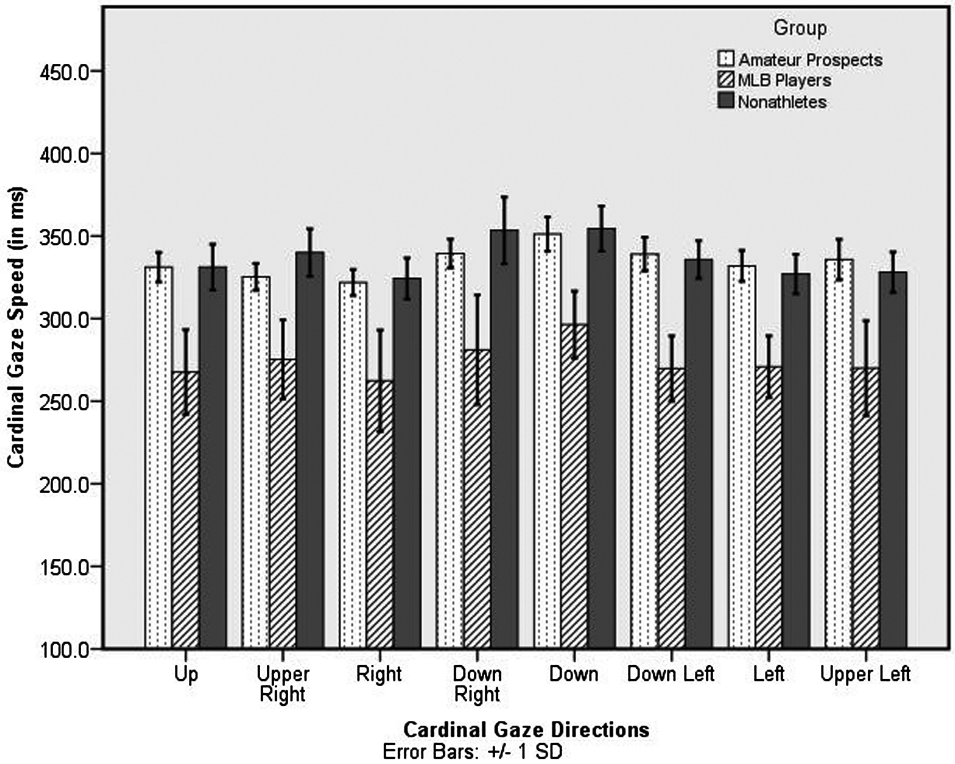
MAIN ANALYSIS

The main analysis included a mixed model ANOVA, with direction as a within-subjects factor and group as a between-subjects factor. There was no statistically significant interaction between group and direction of eye movement on cardinal gaze speed, F (13.4, 2002) = .89, $p = .56$, partial $\eta 2 = .006$. Figure 3 shows the means and standardized errors for cardinal gaze speed in the eight directions across the MLB players, amateur prospects, and non-athletes. Therefore, the main effects of direction and group were examined separately.

For direction, the results showed a statistically significant difference in mean cardinal gaze speed across the cardinal gaze directions, F (6.67, 2002) = 8.63, $p < .001$; partial $\eta 2 = .028$. All pairwise comparisons were run and the 95% confidence intervals and p-values reported are Bonferroni-adjusted. As can be seen in Table 1, there were significant differences in cardinal gaze speed across the cardinal gaze directions.

Speed down was the slowest of the cardinal gaze directions. The estimated marginal means for cardinal gaze speed scores were 337 (SE = 6.89) ms for speed down and 306 (SE = 7.44) ms for Speed Down Left, a statistically significant mean difference of 31.0, 95% CI [9.18, 52.9] ms, $p < .001$. The estimated marginal means for speed down were also slower than the means for: (2) speed left, 300 (SE = 7.42) ms, a statistically significant mean difference of 37.2, 95% CI [13.3, 61.2] ms, $p < .001$; (3) speed right, 285 (SE = 7.41) ms, a statistically significant mean difference of 52.4, 95% CI [30.8, 74.0] ms, $p < .001$; (4) speed up, 298 (SE = 7.36) ms, a statistically significant mean difference of 39.3, 95% CI [16.9, 61.7] ms, $p < .001$; (4) speed upper left, 299 (SE = 7.56) ms, a statistically significant mean difference of 38.1, 95% CI [13.7,

FIG. 3 Means and standardized errors for Cardinal Gaze Speed in MLB players, amateur prospects, and non-athletes.



62.5] ms, p < .001; and (5) speed upper right, 303 (SE = 7.23) ms, a statistically significant mean difference of 33.5, 95% CI [11.5, 55.5] ms, p < .001. Speed down was significantly slower than all other cardinal gaze directions (except for speed down right).

Speed right was the fastest of the cardinal gaze directions. The estimated marginal means for cardinal gaze speed scores were 285 (SE = 7.41) ms for speed right and 337 (SE = 6.89) ms for speed down, a statistically significant mean difference of -52.4, 95% CI [-74.0, -30.8] ms, p < .001. The estimated marginal means for speed right were also faster than the means for speed down right, 316 (SE = 7.51), a statistically significant mean difference of -31.2, 95% CI [-53.7, -8.7] ms, p = .01. Speed right was significantly faster than speed down and speed down right.

For group, the results showed a statistically significant difference in mean cardinal gaze speed between professional baseball players, amateur prospects, and non-athletes, F (2, 300) = 22.2, p < .001; partial $\eta 2$ = .129. All pairwise comparisons were run and the 95% confidence intervals and p-values reported are Bonferroni-adjusted. As can be seen in Table 2, there were significant differences in cardinal gaze speed between MLB players, amateur prospects, and non-athletes.

MLB players had the fastest cardinal gaze speeds. The estimated marginal means for cardinal gaze speed scores were 238 (SE = 14.7) ms for MLB players and 341 (SE = 4.81) for amateur prospects, a statistically significant mean difference of -102, 95% CI [-140, -65.1] ms, p < .001. The estimated marginal means for cardinal gaze speed scores were 238 (SE = 14.7) ms for MLB players and 337 (SE = 5.38) for non-athletes, a statistically significant mean difference of -98.1, 95% CI [-136, -60.4] ms, p < .001. The estimated marginal means for cardinal gaze speed scores were 341 (SE = 4.81) ms for amateur prospects and 337 (SE = 5.38) for non-athletes, a nonsignificant mean difference, p = 1.0.

TABLE 1 Pairwise Comparisons for Normalized Cardinal Gaze Speed (in ms) Across the Cardinal Gaze Directions

(I) Direction	(J) Direction	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Differenceb	
					Lower Bound	Upper Bound
Up	Down	-39.3*	7.11	.000	-61.7	-16.9
	Down Left	-8.23	7.87	1.000	-33.0	16.6
	Down Right	-18.1	7.49	.455	-41.7	5.5
	Left	-2.04	7.62	1.000	-26.1	22.0
	Right	13.1	7.31	1.000	-9.9	36.2
	Upper Left	-1.20	6.77	1.000	-22.6	20.1
	Upper Right	-5.76	7.21	1.000	-28.5	17.0
Upper Right	Down	-33.5*	6.97	.000	-55.5	-11.5
	Down Left	-2.47	8.23	1.000	-28.4	23.5
	Down Right	-12.3	7.55	1.000	-36.1	11.4
	Left	3.72	8.07	1.000	-21.7	29.2
	Right	18.9	7.50	.35	-4.8	42.5
	Up	5.76	7.21	1.000	-17.0	28.5
	Upper Left	4.56	7.59	1.000	-19.4	28.5
Right	Down	-52.4*	6.86	.000	-74.0	-30.8
	Down Left	-21.3	7.22	.095	-44.1	1.4
	Down Right	-31.2*	7.14	.000	-53.7	-8.7
	Left	-15.1	7.73	1.00	-39.5	9.2
	Up	-13.1	7.31	1.00	-36.2	9.9
	Upper Left	-14.3	7.32	1.00	-37.4	8.8
	Upper Right	-18.9	7.50	.35	-42.5	4.8
Down Right	Down	-21.2	6.97	.072	-43.1	.8
	Down Left	9.9	7.31	1.00	-13.2	32.9
	Left	16.1	7.46	.90	-7.44	39.6
	Right	31.2*	7.14	.000	8.72	53.7
	Up	18.1	7.49	.46	-5.51	41.7
	Upper Left	16.9	7.44	.67	-6.56	40.4
	Upper Right	12.3	7.55	1.00	-11.4	36.1

(*continued*)

TABLE 1 Pairwise Comparisons for Normalized Cardinal Gaze Speed (in ms) Across the Cardinal Gaze Directions

(I) Direction	(J) Direction	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Differenceb	
					Lower Bound	Upper Bound
Down	Down Left	31.0*	6.94	.000	9.18	52.9
	Down Right	21.2	6.97	.072	-.79	43.1
	Left	37.2*	7.59	.000	13.3	61.2
	Right	52.4*	6.86	.000	30.8	74.0
	Up	39.3*	7.11	.000	16.9	61.7
	Upper Left	38.1*	7.75	.000	13.7	62.5
	Upper Right	33.5*	6.97	.000	11.5	55.5
Down Left	Down	-31.0*	6.94	.000	-52.9	-9.18
	Down Right	-9.88	7.31	1.00	-32.9	13.2
	Left	6.19	7.47	1.00	-17.4	29.7
	Right	21.3	7.22	.095	-1.43	44.1
	Up	8.23	7.87	1.00	-16.6	33.0
	Upper Left	7.03	7.87	1.00	-17.8	31.8
	Upper Right	2.47	8.23	1.00	-23.5	28.4
Left	Down	-37.2*	7.59	.000	-61.2	-13.3
	Down Left	-6.19	7.47	1.00	-29.7	17.4
	Down Right	-16.1	7.46	.90	-39.6	7.44
	Right	15.1	7.73	1.00	-9.20	39.5
	Up	2.04	7.62	1.00	-22.0	26.1
	Upper Left	.84	7.95	1.00	-24.2	25.9
	Upper Right	-3.7	8.07	1.00	-29.2	21.7
Upper Left	Down	-38.1*	7.75	.000	-62.5	-13.7
	Down Left	-7.03	7.87	1.00	-31.8	17.8
	Down Right	-16.9	7.44	.67	-40.4	6.56
	Left	-.84	7.95	1.00	-25.9	24.2
	Right	14.3	7.32	1.00	-8.77	37.4
	Up	1.20	6.77	1.00	-20.1	22.6
	Upper Right	-4.56	7.59	1.00	-28.5	19.4
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
[b]. Adjustment for multiple comparisons: Bonferroni.						

TABLE 2 Pairwise comparisons for normalized cardinal gaze speed (in ms) in MLB players, amateur prospects, and non-athletes

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Differenceb	
					Lower Bound	Upper Bound
MLB Players	Amateur Prospects	-102*	15.5	.000	-140	-65.1
	Non-athletes	-98.1*	15.7	.000	-136	-60.4
Amateur Prospects	MLB Players	102*	15.5	.000	65.1	140
	Non-athletes	4.26	7.22	1.00	-13.1	21.6
Non-athletes	MLB Players	98.1*	15.7	.000	60.4	136
	Amateur Prospects	-4.26	7.22	1.00	-21.6	13.1
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
[b]. Adjustment for multiple comparisons: Bonferroni.						

CONCLUSIONS

As hypothesized, MLB players moved their eyes in the cardinal gaze directions more quickly than either amateur prospects or non-athletes. That is, there were significant differences in cardinal gaze speed between MLB players and amateur prospects, and between MLB players and non-athletes. Moreover, there were nonsignificant differences in cardinal gaze speed between amateur players and non-athletes.

These findings are consistent with previous research in that a visual characteristic (i.e., cardinal gaze speed) was influenced by the level of performance (MLB player, amateur prospect, and nonathlete) in baseball. More skilled/ professional baseball players were shown to have better visual characteristics (i.e., faster visual cardinal gaze speed) than less skilled/ non-professional baseball players or non-athletes. Previous studies [2–5,7] have identified differences in contrast sensitivity, static acuity, and dynamic acuity between professional athletes and non-athletes.

As hypothesized, there were differences in the speed of eye movements in the CGPs. Speed down was significantly slower than all other cardinal gaze directions, except speed down right. In addition, speed right was significantly faster than the speed down and speed down right directions.

Very little research has been conducted on the speed of gaze positions. However, the previous discussion has suggested that due to human evolutionary history, horizontal eye movements were perhaps most important and therefore more practiced and refined than other directions of gaze.[25] For example, scanning a forest for prey or food would often be carried out in the horizontal plane. Scanning bases in baseball may benefit from this possible evolutionary adaptation. Additionally, playing baseball often and for a long period during a person's life (average MLB player is 25.8 years old and AP player is 16.7 years of age) may hone this skill further.

Research on vision training has found that eye movement speed is related to the number of muscles activated during the task.[11] When testing eye movements in the horizontal plane, back and forth, left, and right for sixty seconds and repeating the exercise in the superior (upward) gaze, several changes occur. According to Wilson and Falkel, most people report fewer eye movements per minute in the superior gaze.[11] Most people report a significant increase in fatigue when doing this exercise in the superior gaze compared to the horizontal gaze. Wilson and Falkel note, that with practice the speed, endurance, and accuracy of all positions of gaze can be improved.[11] That both MLB and AP players show collectively fast eye movements most likely reveal a sport-specific practice effect. In baseball, an efficient upward gaze is needed to track balls for catching. The sport-specific nature of this visual requirement leads to specific practice techniques that improve baseball athletes' superior CGPs.

If a gaze weakness is found, it can conceivably be trained.[26–30] Some low-tech practical examples of training drills include the use of different colors balls, or balls with numbers and letters on them that need to be identified quickly and accurately when thrown by a partner toward the athlete into different CGPs.[27] Such drills can be fun, competitive, and work not only on good eye-hand coordination but also the coordination of eye muscles for faster and more accurate cardinal gaze speed.[29] Conversely, high-tech training may include eye tracked games such as those that change the difficulty level of a video game based on the eye movements detected,[31] and the Dynavision board (https://www.dynavisioninternational.com/) where athletes must respond by tapping on lights that appear in random gaze locations. Vision training drills can also be repeated to induce eye fatigue and ultimately train more consistent performance over time.[32]

In summary, this study showed significant differences in the speed of eye movements in the CGPs between MLB players, amateur prospects, and non-athletes. The study also showed significant differences in the speed of eye movements in the different cardinal gaze directions.

The study had both strengths and weaknesses. Using the RightEye CGP eye-tracking test was a strength of this study. As mentioned previously, algorithm-based eye-tracking tests have been shown to produce high levels of measurement accuracy.[19] The relatively small sample size of MLB players was a weakness of this study. Unfortunately, relative to amateur prospects or non-athletes, there are simply fewer professional baseball players available to take part in the research. To counteract this limitation, future studies should recruit a greater number of MLB players and players at various minor league levels. Such an examination could provide a roadmap for understanding skill acquisition and may provide ongoing benchmarks for assessing and training baseball players. Coaches and athletes may use such quantitative benchmarks to measure their performance as they move up the competitive baseball organizational levels, from A to AA for example.

It is possible to identify several future directions for research based on the findings of the current study. Firstly, an extension of this research could be conducted by examining positions of play within sports, such as baseball to determine if further specific performance patterns of CGPs exist. For instance, differences in cardinal gaze speed between pitchers and hitters can be examined to determine position-specific sources of visual expertise. In addition, examining the cardinal gaze speed of athletes from other sports will help to establish sport-specific cardinal gaze speed "ideals" for athlete training and development purposes. Future research should also examine the CGP performance of individuals from across a wide range of ages to determine if age impacts the speed of gaze in the cardinal positions. Additional research could also consider adding accuracy, saccadic latency (the time it takes to move the eye once a stimulus is presented in the CGPs) as well as viewing each eye independently to determine disparity and more specifically pinpoint nerve and muscle pathways that could be trained using vision therapy.

FUNDING STATEMENT

This study was not supported by internal or external funding.

INFORMED CONSENT

All subjects provided written informed consent to participate in this study in accordance with IRB procedure (IRB: UMCIRB 13-002660).

DATA SHARING POLICY

The data that support the findings of this study are available from the corresponding author, [KK], upon reasonable request.

DISCLOSURE STATEMENT

Co-author, Melissa Hunfalvay is Co-Founder and Chief Science Officer of RightEye, a health technology company headquartered in Bethesda, MD, USA.

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