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The Relationship between Visual Skills and Batting Performance of Elite Major League Baseball Batters

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Abstract

Purpose: The purpose of this study was to investigate the relationship between the visual skills and batting performance of elite professional baseball players.

Methods: The correlation of archival Vizual Edge Performance Trainer® (VEPT) data and regular season batting statistics of 20 elite Major League Baseball (MLB) hitters were evaluated using Pearson's correlations (r). Subjects were then separated into VEPT quartiles and batting quartiles, and descriptive statistics were used to evaluate the contribution of vision to elite batting performance.

Results: Significant large and moderate positive correlations were found between several visual skills and batting performance for the elite batters. Additionally, evidence of significant differences in batting statistics among players of dissimilar visual abilities supports the existence and implications of these relationships. Conclusion

Based on the results of this study, it appears that, even amongst elite batters, those with greater visual capacities may exhibit significantly superior batting performance as measured by on-base percentage (OBP), slugging percentage (SLG), on-base plus slugging (OPS), and bases-on-balls percentage (BB%). Batting averages (AVG) may also be affected by differences in visual skills, though to a lesser extent.

Applications in Sport As such, these results may be used by scouts, managers, trainers, and coaches to improve player evaluation and training protocols.

INTRODUCTION

Many regard the act of hitting a baseball to be one of the most difficult tasks in all of sports [1-3]. Consider a major-league batter attempting to hit a fastball traveling at 145 km/h (90 mph) and pitched from just 18.4 m (60.5 ft) away [4]. Under these conditions, the athlete has approximately 0.4 seconds in which to locate the ball, evaluate its spin and trajectory, choose to swing, and execute the appropriate movement before the ball crosses the plate. To further complicate matters, the batter is also attempting to contact the ball at the bat's center of percussion: the approximately 7.6 cm (3 in) area of the bat that generates greatest exit velocity [5]. Even if the batter manages to hit the ball squarely within this "sweet spot", a temporal error of just 7 milliseconds is enough to foul the ball out of play [6].

The scenario above holds true even under the best of circumstances, in which a batter is told the exact characteristics of the forthcoming pitch. Obviously, this is not how the sport of baseball is played. In fact, if a batter's goal is to hit the ball, it is the pitcher's job to prevent that from happening. To do so, he must try to confuse the batter by altering the pitch speed and placement. There are many different types of pitches, and a starting pitcher usually has three or more options to choose from at any given time [7]. As such, the characteristics of pitches delivered within a single at-bat can vary greatly: from a 93 km/h (58 mph) eephus pitch to a 161 km/h (100 mph) fastball [8]. Some closing pitchers can deliver the ball even faster, such as Aroldis Chapman who posted the fastest pitch of 2016 at a blistering 169.1 km/h (105.1 mph) [9]. Add to this the fact that the pitch can be delivered anywhere within or just outside of the strike zone, and the task seems all but impossible.

Looking at this feat from a purely quantitative perspective, it is a wonder that well-pitched balls are ever hit. However, despite these seemingly insurmountable circumstances, hits do occur, albeit infrequently. Hits are so unlikely that a 30% success rate is considered exceptional. In fact, Ted Williams, one of the greatest hitters of all time, referred to baseball as, "the only field of endeavor where a man can succeed three times out of ten and be considered a good performer" [10] (p. 5).

In order to increase the likelihood of a successful hit, batters are often coached to keep their "eyes on the ball." This mantra speaks to the perceived importance of visual skills within the sport of baseball, yet, it is somewhat misleading. The mere act of swinging the bat takes around 0.2 seconds [11], which means the hitter must begin the swing when the ball is approximately half way to him. It has been stated, therefore, that a batter could close his eyes at the midpoint of the ball's flight and be able to hit it with the same precision as if he tracked it all the way in [6]. While some may interpret this to mean that visual skills are of little importance for hitters, this could not be further from the truth. In fact, Adair's comments highlight the necessity for superior visual skills.

In the context of hitting a baseball, better vision equates to more time for decision making and swing refinement [12,13]. Those with better visual skills are able to identify pitch characteristics earlier in the delivery, giving them more time for analysis prior to deciding whether to swing. Superior vision also allows for greater discernment of the ball's trajectory, allowing the batter to more accurately anticipate the location of the pitch as it crosses home plate and adjust his swing accordingly. Based on these inferences, evaluation and training of an athlete's visual skills have become areas of great interest [14].

Sports vision training techniques and equipment have been around for quite some time; however, relatively recent technological advancements have sparked enormous growth within this field [15]. One example is the development of the Vizual Edge Performance Trainer® (VEPT) by Vizual Edge, LLC [16]. This patented technology consists of a battery of online, two- and three-dimensional visual skills tests that provide an overall evaluation of an athlete's visual capacities. Furthermore, VEPT also serves as a visual training aid, giving the athlete access to the evaluation exercises in order to enhance areas of weakness. Tools such as these are may be of great value, as studies have shown that enhancements in vision can translate into sport performance improvements. For example, Spaniol et al. found that collegiate baseball players who engaged in visual skills training generated significantly greater batted-ball velocities than those who did not receive the treatment [17]. In a 2015 study involving the University of Cincinnati baseball team, Clark et al. demonstrated that a pre- and in-season vision training program led to significant improvements in all team batting statistics [18]. Similarly, a 2014 study of 19 collegiate baseball players showed that a visual skills training program improved both strikeout rates and number of runs created [19].

While evidence for the usefulness of sport vision training continues to grow, which skill (or skills) provides the greatest benefit is still unknown. This is primarily due to the fact that different sports place different demands on the visual system [20]. For instance, archers may benefit from greater static visual acuity, allowing them to focus on a stationary target; whereas, tennis players may require greater dynamic visual acuity to return a served ball [21]. Independent meta-analyses have shown that, in general, expert athletes tend to be better at identifying meaningful perceptual signals, have greater aptitudes for focus of attention, and quicker visual processing than their non-expert or non-athlete counterparts [22,23]. However, identification of the visual capacities that differentiate performance levels within individual sports remains elusive.

Although, some studies have specifically investigated the effect of visual skills on the level of performance in striking sports, such as cricket and baseball. For example, it has been shown that cricket batsmen rely heavily upon visual information, with eye movement strategies and abilities contributing to variations in skill level [24,25]. In 2014, a study involving 352 Minor League Baseball (MiLB) players found that athletes with better visual skill scores had significantly higher batting performance indicators, such as batting average, on-base percentage, on-base plus slugging, and strikeout rates [26].

Despite undertakings such as these, the relationship between vision and player expertise within a given sport remains poorly understood [27]. Therefore, the purpose of this study is to investigate the relationship between the visual skills and batting performance of elite professional baseball players. It is hypothesized that small to moderate relationships exist between visual skills and batting performance indicators of elite batters. Additionally, differences in batting performance based on visual skills and visual skill contributions to batting success will be examined. Results of this research may identify those visual skills which are necessary for elite batting performance. If so, visual training programs utilized by baseball coaching staff may be created or modified in order to address areas of weakness and further improve batting performance.

MATERIALS AND METHODS

Subjects

Potential subjects were identified as those elite Major League Baseball (MLB) batters for whom visual skills data was available from Vizual Edge, LLC. For this study, "elite batters" are defined as those MLB athletes who finished the 2016 regular season with a batting average (AVG) among the top 50 qualifying hitters. According to mlb.com, "A batter must have 3.1 plate appearances per team game played to qualify for league leadership in AVG." [28]. Of the 30 batters for whom VEPT data was provided, 20 of these athletes met the criteria of an "elite batter" as defined above. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Office of Research Compliance Institutional Review Board of Texas A&M University – Corpus Christi (HSRP #60-17).

Procedures

All data used in this study were previously and independently collected by outside entities. Visual skills testing were conducted by professional baseball scouts using the VEPT software as part of pre-draft player assessments between the years 2005 and 2012. Subtest scores for eye alignment, depth perception, convergence, divergence, visual recognition, and visual tracking were captured and used to generate a single quantitative representation of overall visual ability, referred to as the Edge score (ES). All visual skills data for the current study was provided to the authors by Vizual Edge, LLC and is proprietary.

Batting performance indicators for the 2016 MLB regular season include AVG, on-base percentage (OBP), slugging percentage (SLG), on-base plus slugging (OPS), bases on balls percentage (BB%), and strikeout percentage (K%). Pre- and post-season batting statistics were not included in the current study. Statistics for AVG, OBP, SLG, and OPS are in the public domain and were collected by the main researcher from the online repository located at www.mlb.com (28). BB% was calculated by dividing an athlete's number of bases on balls (BB) by his total number of plate appearances (PA). Similarly, K% was calculated by dividing number of strikeouts (K) by PA. All data used in the calculation of these statistics were also obtained by the primary researcher from www.mlb.com [28].

Statistical Analyses

VEPT subtest scores, composite Edge scores, and batting statistics for each of the 20 subjects were compiled by the main researcher into a single Microsoft Excel spreadsheet for data analysis. All statistical analyses were performed using Microsoft Excel with the optional Analysis ToolPak Excel add-in activated. An alpha level of $p \leq 0.05$ was required to indicate statistical significance for all tests.

Initially, Vizual Edge, LLC provided the authors with VEPT data for 30 MLB batters. Upon receiving the data, it was determined that only those who ranked among the top 50 qualifying batters for the 2016 MLB regular season should be included in the study. This eliminated 10 of these batters from consideration. However, in order to be certain that the remaining athletes were truly elite, a statistical analysis of batting performance indicators was performed. First, the 30 MLB players for whom VEPT data was available were divided into two categories: elite (AVG rank ≤ 50, n = 20) and non-elite (AVG rank > 50, n = 10). Descriptive statistics (mean ± standard deviation (SD)) were calculated for the batting performance indicators of both groups, and an independent samples t-test was conducted to evaluate the difference in means. Additionally, batting statistics of the elite group (n = 20) were compared to those of all other batters who qualified for league leadership in 2016 (n = 126). Again, this was accomplished by an independent samples t-test to evaluate the difference in means between the two groups.

Afterward, a Pearson product-moment correlation value (r) was generated for each of the visual skill scores and batting statistics of the elite group (n = 20). This was accomplished by creating a correlation matrix using the "Correlation" feature of the Analysis ToolPak Excel add-in. The strength of the relationship was assigned according to the absolute value of r and based on the following scale: $r \leq 0.3$ indicated a small relationship; $0.31 \leq r \leq 0.49$ moderate; $0.5 \leq r \leq 0.69$ large; $0.7 \leq r \leq 0.89$, very large; and $r \geq 0.9$ represented a near perfect relationship [29].

Next, using the data sorting feature within Excel, each of the 20 elite athletes was ranked based on his performance of the different visual tests. A cursory look at visual alignment and depth perception data sets revealed them to be too similar and the data points too rigid to allow for the creation of meaningful quartiles and, thus, was excluded from this portion of the study. Therefore, upper quartile (UQ) and lower quartile (LQ) groups were created for each of the nine remaining visual skills subtests: ES, convergence accuracy (C%), convergence station score (CS), divergence accuracy (D%), divergence station score (DS), recognition response time (RT), recognition accuracy (R%), tracking time (TT), and tracking accuracy (T%). Batting statistics (AVG, OBP, SLG, OPS, BB%, and K%) were then collected for each UQ and LQ subject. Descriptive statistics (mean ± SD) were calculated for all visual and batting parameters for the nine individual UQ and LQ cohorts. Independent samples t-tests were conducted within the Excel spreadsheet to examine the difference between the means of all UQ and LQ visual skill groupings.

Finally, using methods similar to those outlined above, the 20 elite subjects were then ranked according to their individual batting statistics. This allowed for the creation of UQ and LQ cohorts for the six batting performance indicators: AVG, OBP, SLG, OPS, BB%, and K%. Visual skill scores (ES, C%, CS, D%, DS, RT, R%, TT, and T%) were then compiled for each UQ and LQ subject. Descriptive statistics (mean ± SD) were calculated for all batting indicators and visual skill subtests for the six unique UQ and LQ groups. Independent samples t-tests were conducted within the Excel spreadsheet to examine the difference between the means of all UQ and LQ batting performance groups.

RESULTS

Elite vs. Non-Elite Hitters

Table 1 highlights the descriptive statistics (mean ± SD) of batting performance indicators for the elite (n = 20) and non-elite (n = 10) athletes for whom VEPT data was available. The elite group had significantly better scores for AVG, OBP, and OPS ($p < 0.001$) as well as SLG ($p < 0.01$) when compared to the non-elite group. No significant differences were noted for BB% or K% (Table 1).

Table 2 shows the descriptive statistics (mean ± SD) of batting performance indicators for the elite group (n = 20) as compared to all other qualifying batters (n = 126). The elite group had significantly better scores for AVG, OBP, SLG, and OPS ($p < 0.001$). No significant differences were noted for BB% or K% between groups (Table 2).

Correlations of Batting Performance and Visual Skills

Table 3 reveals the correlations (r values) between the batting performance indicators and visual skills of the elite batters (n = 20) identified in this study. A large, positive correlation between BB% and CS (r = 0.67) was found to be significant at the p < 0.01 level. Significant ($p < 0.05$) large and positive correlations were also noted between OBP and CS (r = 0.57), SLG and R% (r = 0.51), OPS and R% (r = 0.51), as well as K% and ES (r = 0.51), C% (r = 0.51), and CS (r = 0.56). Additionally, moderate positive relationships were found to exist between OPS and CS (r = 0.49; $p < 0.05$) as well as BB% and C% (r = 0.47; $p < 0.05$). No other significant relationships between batting and vision were identified (Table 3).

VEPT Quartiles vs. Batting Performance

A significant difference ($p < 0.01$) was noted between the UQ and LQ mean scores for each visual skill component (ES, C%, CS, D%, DS, RT, R%, TT, T%). This indicated that a comparison of each group's corresponding batting statistics was appropriate.

Within the ES grouping (Table 4), the upper quartile was found to have a significantly higher mean K% than the lower quartile (0.181 vs 0.116; p <0.05). A significantly higher mean K% was also noted for the upper quartile in the CS grouping

Table 1. Descriptive statistics (mean ± SD) of batting performance indicators for elite and non-elite MLB batters (for whom VEPT data was available) and determination of statistical differences (*p* values).

Batting Performance Indicators	Elite (*n* = 20)	Non-Elite (*n* = 10)	*p*
AVG	0.309 ± 0.017	0.267 ± 0.020	<0.001
OBP	0.379 ± 0.026	0.335 ± 0.035	<0.001
SLG	0.514 ± 0.042	0.449 ± 0.067	<0.01
OPS	0.893 ± 0.058	0.783 ± 0.096	<0.001
BB%	0.097 ± 0.029	0.086 ± 0.038	0.437
K%	0.172 ± 0.050	0.184 ± 0.023	0.487

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 2. Descriptive statistics (mean ± SD) of batting performance indicators for elite and non-elite (all other qualifying) 2016 MLB batters and determination of statistical differences (*p* values).

Batting Performance Indicators	Elite (*n* = 20)	Non-Elite (*n* = 126)	*p*
AVG	0.309 ± 0.017	0.267 ± 0.024	<0.001
OBP	0.379 ± 0.026	0.334 ± 0.029	<0.001
SLG	0.514 ± 0.042	0.448 ± 0.056	<0.001
OPS	0.893 ± 0.058	0.782 ± 0.074	<0.001
BB%	0.097 ± 0.029	0.085 ± 0.030	0.106
K%	0.172 ± 0.050	0.191 ± 0.052	0.123

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 3. Correlation values (*r*) of batting performance indicators and visual skill subtest scores of elite MLB batters (*n* = 20)

Batting Performance Indicators	Visual Skill Scores										
	ES	A	DP	C%	CS	D%	DS	RT	R%	TT	T%
AVG	0.05	0.01	-0.21	-0.09	0.10	0.34	0.34	-0.12	0.22	-0.11	-0.32
OBP	0.36	0.05	-0.08	0.27	0.57 †	0.26	0.27	-0.11	0.28	-0.33	-0.11
SLG	0.26	-0.20	0.01	0.12	0.32	-0.34	-0.06	-0.15	0.51 †	-0.15	0.11
OPS	0.36	-0.12	-0.03	0.21	0.49 †	-0.13	0.08	-0.16	0.51 †	-0.27	0.02
BB%	0.41	0.03	0.09	0.47 †	0.67 ‡	-0.01	-0.01	0.05	0.14	-0.37	0.08
K%	0.51 †	0.06	0.27	0.51 †	0.56 †	-0.19	-0.16	-0.28	0.40	-0.13	0.43

† Significant correlation ($p < 0.05$); ‡ Significant correlation ($p < 0.01$). ES = Edge score; A = alignment; DP = depth perception; C% = convergence accuracy; CS = convergence station score; D% = divergence accuracy; DS = divergence station score; RT = recognition response time; R% = recognition accuracy; TT = tracking time; T% = tracking accuracy; AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 4. Descriptive statistics (mean ± SD) of batting performance indicators for upper quartile (UQ) and lower quartile (LQ) Edge scores (ES) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
ES	**86.70 ± 1.71**	**74.93 ± 4.33**	**<0.001**
AVG	0.322 ± 0.018	0.313 ± 0.017	0.439
OBP	0.399 ± 0.027	0.371 ± 0.016	0.080
SLG	0.536 ± 0.031	0.489 ± 0.058	0.156
OPS	0.935 ± 0.043	0.861 ± 0.064	0.066
BB%	0.108 ± 0.038	0.085 ± 0.010	0.223
K%	0.181 ± 0.045	0.116 ± 0.022	0.020

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

(Table 6) as compared to the LQ cohort (0.213 vs 0.139; p <0.05). Upper quartile groups for RT (Table 9) and R% (Table 10) both demonstrated significantly higher mean OPS scores than their LQ counterparts (0.926 vs 0.850 and 0.923 vs 0.825, respectively; $p < 0.05$). The UQ group for R% also had a significantly higher mean SLG than the LQ group (0.529 vs 0.461; $p < 0.05$). No significant differences were noted between any of the batting performance indicators for the C% (Table 5), D% (Table 7), DS (Table 8), TT (Table 11), and T% (Table 12) groupings (Table 4-12).

Batting Performance Quartiles vs. VEPT

A significant difference ($p < 0.01$) was found between the UQ and LQ mean scores for each of the batting performance indicators (AVG, OBP, SLG, OPS, BB%, and K%). This indicated

Table 5. Descriptive statistics (mean ± SD) of batting performance indicators for upper quartile (UQ) and lower quartile (LQ) convergence accuracies (C%) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
C%	**99.0 ± 1.0**	**92.2 ± 1.8**	**<0.001**
AVG	0.318 ± 0.019	0.317 ± 0.017	0.919
OBP	0.389 ± 0.034	0.380 ± 0.012	0.590
SLG	0.505 ± 0.045	0.510 ± 0.050	0.893
OPS	0.895 ± 0.069	0.890 ± 0.059	0.905
BB%	0.104 ± 0.033	0.083 ± 0.016	0.237
K%	0.175 ± 0.050	0.136 ± 0.053	0.278

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 6. Descriptive statistics (mean ± SD) of batting performance indicators for upper quartile (UQ) and lower quartile (LQ) convergence station scores (CS) of elite batters and determination of statistical differences (p values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
CS	**63.6 ± 9.0**	**20.6 ± 4.8**	**<0.001**
AVG	0.312 ± 0.009	0.313 ± 0.017	0.876
OBP	0.403 ± 0.034	0.377 ± 0.014	0.162
SLG	0.543 ± 0.021	0.507 ± 0.048	0.158
OPS	0.946 ± 0.051	0.884 ± 0.055	0.103
BB%	0.126 ± 0.040	0.086 ± 0.013	0.065
K%	0.213 ± 0.032	0.139 ± 0.055	0.032

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 7. Descriptive statistics (mean ± SD) of batting performance indicators for upper quartile (UQ) and lower quartile (LQ) divergence accuracies (D%) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
D%	**96.6 ± 0.9**	**89.8 ± 1.8**	**<0.001**
AVG	0.314 ± 0.023	0.300 ± 0.006	0.250
OBP	0.380 ± 0.024	0.369 ± 0.021	0.462
SLG	0.506 ± 0.044	0.549 ± 0.019	0.083
OPS	0.886 ± 0.059	0.917 ± 0.035	0.326
BB%	0.083 ± 0.020	0.094 ± 0.022	0.444
K%	0.157 ± 0.047	0.198 ± 0.046	0.205

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 8. Descriptive statistics (mean ± SD) of batting performance indicators for upper quartile (UQ) and lower quartile (LQ) divergence station scores (DS) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
DS	**32.4 ± 3.8**	**13.6 ± 3.3**	**<0.001**
AVG	0.315 ± 0.023	0.300 ± 0.007	0.212
OBP	0.380 ± 0.024	0.364 ± 0.013	0.234
SLG	0.521 ± 0.038	0.527 ± 0.032	0.793
OPS	0.900 ± 0.048	0.890 ± 0.029	0.712
BB%	0.083 ± 0.021	0.090 ± 0.016	0.557
K%	0.159 ± 0.044	0.194 ± 0.038	0.211

= batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 9. Descriptive statistics (mean ± SD) of batting performance indicators for upper quartile (UQ) and lower quartile (LQ) recognition times (RT) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
RT	**0.95 ± 0.15**	**1.88 ± 0.21**	**<0.001**
AVG	0.314 ± 0.014	0.304 ± 0.011	0.250
OBP	0.386 ± 0.029	0.360 ± 0.012	0.107
SLG	0.540 ± 0.018	0.490 ± 0.059	0.102
OPS	0.926 ± 0.042	0.850 ± 0.054	0.038
BB%	0.096 ± 0.039	0.082 ± 0.012	0.460
K%	0.172 ± 0.042	0.131 ± 0.030	0.111

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 10. Descriptive statistics (mean ± SD) of batting performance indicators for upper quartile (UQ) and lower quartile (LQ) recognition accuracies (R%) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
R%	**100.0 ± 0.0**	**89.8 ± 2.9**	**<0.001**
AVG	0.323 ± 0.017	0.302 ± 0.014	0.061
OBP	0.394 ± 0.030	0.364 ± 0.008	0.065
SLG	0.529 ± 0.025	0.461 ± 0.024	0.002
OPS	0.923 ± 0.040	0.825 ± 0.022	0.001
BB%	0.101 ± 0.036	0.089 ± 0.017	0.521
K%	0.181 ± 0.045	0.155 ± 0.066	0.487

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 11. Descriptive statistics (mean ± SD) of batting performance indicators for upper quartile (UQ) and lower quartile (LQ) tracking times (TT) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
TT	**0.45 ± 0.01**	**0.66 ± 0.04**	**<0.001**
AVG	0.312 ± 0.021	0.308 ± 0.021	0.783
OBP	0.381 ± 0.026	0.369 ± 0.016	0.395
SLG	0.512 ± 0.041	0.500 ± 0.036	0.641
OPS	0.893 ± 0.055	0.870 ± 0.046	0.482
BB%	0.097 ± 0.021	0.083 ± 0.020	0.308
K%	0.181 ± 0.068	0.167 ± 0.065	0.756

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 12. Descriptive statistics (mean ± SD) of batting performance indicators for upper quartile (UQ) and lower quartile (LQ) tracking accuracies (T%) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
T%	**95.6 ± 1.3**	**73.4 ± 12.7**	**<0.01**
AVG	0.313 ± 0.011	0.314 ± 0.013	0.987
OBP	0.370 ± 0.014	0.369 ± 0.034	0.936
SLG	0.508 ± 0.035	0.483 ± 0.053	0.352
OPS	0.878 ± 0.040	0.853 ± 0.079	0.411
BB%	0.074 ± 0.006	0.098 ± 0.041	0.216
K%	0.153 ± 0.036	0.124 ± 0.042	0.237

AVG = batting average; OBP = on-base percentage; SLG = slugging percentage; OPS = on-base plus slugging; BB% = bases on balls percentage; K% = strikeout percentage

Table 13. Descriptive statistics (mean ± SD) of visual skill subtest scores for upper quartile (UQ) and lower quartile (LQ) batting averages (AVG) of elite batters and determination of statistical differences (p values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
AVG	**0.331 ± 0.012**	**0.291 ± 0.004**	**<0.001**
ES	82.20 ± 8.78	80.92 ± 2.06	0.760
C%	96.0 ± 4.2	95.8 ± 1.3	0.922
CS	42.6 ± 23.3	36.0 ± 9.4	0.572
D%	94.8 ± 2.3	93.4 ± 3.4	0.463
DS	28.6 ± 8.2	22.8 ± 8.3	0.300
RT	1.10 ± 0.30	1.25 ± 0.26	0.403
R%	97.8 ± 3.0	94.6 ± 3.6	0.166
TT	0.54 ± 0.09	0.55 ± 0.12	0.886
T%	81.6 ± 18.7	89.0 ± 5.1	0.419

ES = Edge score; C% = convergence accuracy; CS = convergence station score; D% = divergence accuracy; DS = divergence station score; RT = recognition response time; R% = recognition accuracy; TT = tracking time; T% = tracking accuracy

that a comparison of each group's corresponding visual test scores was appropriate.

The upper quartile of the SLG grouping (Table 15) demonstrated a significantly higher mean R% than the lower quartile (96.2 vs 90.8; $p < 0.05$). For the OPS grouping (Table 16), the upper quartile was found to be superior to the lower quartile in terms of both mean ES (85.02 vs 78.82; $p < 0.05$) and mean R% (97.8 vs 90.8; $p < 0.05$). Within the BB% grouping (Table 17), the UQ cohort outperformed the LQ in terms of C% (98.0 vs 94.4; $p < 0.05$) and CS (55.0 vs 31.6; $p < 0.05$). No significant differences were found between any visual skill scores for the AVG, OBP, and K% groupings (Table 13, Table 14, and Table 18, respectively).

Table 14. Descriptive statistics (mean ± SD) of visual skill subtest scores for upper quartile (UQ) and lower quartile (LQ) on-base percentages (OBP) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
OBP	**0.417 ± 0.020**	**0.354 ± 0.007**	**<0.001**
ES	82.88 ± 8.90	79.52 ± 3.34	0.451
C%	97.0 ± 4.1	96.6 ± 1.1	0.840
CS	54.2 ± 23.8	37.2 ± 7.6	0.166
D%	93.6 ± 2.1	91.4 ± 3.2	0.234
DS	24.8 ± 5.0	18.2 ± 8.1	0.159
RT	1.40 ± 0.23	1.63 ± 0.43	0.328
R%	97.2 ± 3.1	93.4 ± 3.1	0.091
TT	0.49 ± 0.08	0.54 ± 0.11	0.481
T%	82.8 ± 18.5	87.6 ± 6.3	0.598

ES = Edge score; C% = convergence accuracy; CS = convergence station score; D% = divergence accuracy; DS = divergence station score; RT = recognition response time; R% = recognition accuracy; TT = tracking time; T% = tracking accuracy

Table 15. Descriptive statistics (mean ± SD) of visual skill subtest scores for upper quartile (UQ) and lower quartile (LQ) slugging percentages (SLG) of elite batters and determination of statistical differences (p values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
SLG	**0.559 ± 0.010**	**0.454 ± 0.013**	**<0.001**
ES	82.54 ± 4.06	78.82 ± 3.11	0.142
C%	96.0 ± 1.9	94.8 ± 3.1	0.481
CS	44.0 ± 18.3	30.4 ± 11.5	0.198
D%	93.6 ± 3.8	94.8 ± 1.5	0.527
DS	26.6 ± 9.4	25.6 ± 5.4	0.842
RT	1.43 ± 0.59	1.54 ± 0.39	0.729
R%	96.2 ± 3.5	90.8 ± 3.7	0.045
TT	0.50 ± 0.04	0.56 ± 0.11	0.250
T%	89.4 ± 5.3	85.4 ± 7.6	0.362

ES = Edge score; C% = convergence accuracy; CS = convergence station score; D% = divergence accuracy; DS = divergence station score; RT = recognition response time; R% = recognition accuracy; TT = tracking time; T% = tracking accuracy

Table 16. Descriptive statistics (mean ± SD) of visual skill subtest scores for upper quartile (UQ) and lower quartile (LQ) on-base plus slugging (OPS) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
OPS	**0.963 ± 0.026**	**0.818 ± 0.014**	<0.001
ES	85.02 ± 3.81	78.82 ± 3.11	0.022
C%	96.6 ± 2.6	94.8 ± 3.1	0.351
CS	52.6 ± 22.2	30.4 ± 11.5	0.082
D%	94.6 ± 2.3	94.8 ± 1.5	0.874
DS	28.6 ± 6.3	25.6 ± 5.4	0.445
RT	1.19 ± 0.39	1.54 ± 0.39	0.194
R%	97.8 ± 2.9	90.8 ± 3.7	0.010
TT	0.48 ± 0.03	0.56 ± 0.11	0.150
T%	89.8 ± 5.5	85.4 ± 7.6	0.325

ES = Edge score; C% = convergence accuracy; CS = convergence station score; D% = divergence accuracy; DS = divergence station score; RT = recognition response time; R% = recognition accuracy; TT = tracking time; T% = tracking accuracy

DISCUSSION

Elite vs. Non-Elite

A regular season batting average of 0.300 is often used to identify an elite hitter [30]. However, based on the results of the preliminary statistical analysis, it was determined that the 20 batters selected for this study were, indeed, statistically superior to the others in terms of AVG, OBP, SLG, and OPS. In fact, the mean batting statistics of the 10 hitters excluded from the study were nearly identical to those of the other 126 batters who qualified for league leadership in 2016. However, no significant differences were noted between any groups for BB% or K%.

Correlations of Visual Skills and Batting Performance

In general, the hypothesis asserted by the authors was supported by the results of this study. Significant correlations were found between visual skills and batting performance for the elite batters. Additionally, evidence of significant differences

Table 17. Descriptive statistics (mean ± SD) of visual skill subtest scores for upper quartile (UQ) and lower quartile (LQ) bases-on-balls percentages (BB%) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
BB%	**0.137 ± 0.027**	**0.068 ± 0.002**	**<0.01**
ES	84.56 ± 3.59	81.38 ± 3.22	0.179
C%	98.0 ± 1.2	94.4 ± 2.1	0.016
CS	55.0 ± 18.8	31.6 ± 10.0	0.040
D%	93.2 ± 0.8	94.4 ± 3.7	0.520
DS	23.2 ± 4.0	28.0 ± 10.8	0.395
RT	1.33 ± 0.26	1.27 ± 0.49	0.792
R%	96.2 ± 3.5	95.4 ± 3.8	0.740
TT	0.50 ± 0.08	0.57 ± 0.11	0.328
T%	90.2 ± 4.8	88.4 ± 8.8	0.703

ES = Edge score; C% = convergence accuracy; CS = convergence station score; D% = divergence accuracy; DS = divergence station score; RT = recognition response time; R% = recognition accuracy; TT = tracking time; T% = tracking accuracy

Table 18. Descriptive statistics (mean ± SD) of visual skill subtest scores for upper quartile (UQ) and lower quartile (LQ) strikeout percentages (K%) of elite batters and determination of statistical differences (*p* values).

Performance Variables	UQ (*n* = 5)	LQ (*n* = 5)	*p*
K%	**0.108 ± 0.011**	**0.236 ± 0.020**	**<0.001**
ES	78.04 ± 7.18	82.50 ± 2.93	0.235
C%	93.8 ± 4.1	97.0 ± 1.9	0.154
CS	27.8 ± 15.6	43.4 ± 16.2	0.160
D%	95.2 ± 2.0	93.2 ± 2.6	0.213
DS	27.4 ± 5.5	21.8 ± 7.7	0.222
RT	1.49 ± 0.37	1.27 ± 0.19	0.269
R%	92.8 ± 5.6	97.2 ± 3.0	0.163
TT	0.54 ± 0.10	0.50 ± 0.08	0.579
T%	78.8 ± 17.9	90.8 ± 3.0	0.177

ES = Edge score; C% = convergence accuracy; CS = convergence station score; D% = divergence accuracy; DS = divergence station score; RT = recognition response time; R% = recognition accuracy; TT = tracking time; T% = tracking accuracy

in batting statistics among players of dissimilar visual abilities supports the existence and implications of these relationships.

Though recognition accuracy had large positive relationships with the power indicators (SLG and OPS), convergence subtest scores appeared to have the greatest correlation with batting statistics in general. Convergence station scores demonstrated large positive relationships with BB% and OBP, as well as a moderate positive correlation with OPS. Convergence accuracy showed a large positive correlation with K% and a moderate positive correlation with BB%.

Convergence describes the eye movements employed while an object moves toward an observer [31]. As a batter must be able discern information about a pitched ball as it travels to him, it is understandable why this skill would be highly correlated with batting success. Yet, the nature of this relationship is still ambiguous. For instance, it may be that superior convergence skills are necessary for successful batting. However, convergence is listed among those visual skills that can be enhanced via training [31]. Therefore, better batters may simply have superior convergence skills as a result of frequent exposure to the visual stimulus of a pitched ball. As such, further research is required to determine the extent to which this specific visual skill contributes to batting success.

Interestingly, ES and CS both had large positive relationships with K%. This was not anticipated. High scores for ES and CS equate to better visual abilities, which should, in theory, translate into fewer strikeouts. As a lower K% is indicative of superior performance, positive correlations were only expected for visual skills in which a lower score also corresponded to better performance, such as RT and TT. Therefore, any other significant correlations associated with K% were expected to be negative.

VEPT Quartiles vs. Batting Performance of Elite Batters

When subjects were divided into quartiles based on visual skill subtest scores (Tables 4–12), significant differences were noted for several batting statistics. For example, players with greater accuracy scores on the recognition response test were found to have superior SLG and OPS. Upper quartile performers for RT were also found to have significantly better OPS scores than their counterparts.

Surprisingly, those with better ES and CS scores also had significantly higher strikeout percentages. This would have been predicted by the results of the correlation analysis, but it was not expected prior to beginning the study. In fact, this is in direct opposition to the findings of Spaniol et al. [26], who noted a significantly lower strikeout rate in the top quartile of ES scores as compared to the lower quartile (0.216 vs 0.248).

However, this discrepancy may be explained by population differences. For example, the mean batting average for the upper quartile of the Spaniol et al. [26], study was reported to be 0.268 (no SD given). In the current study, UQ mean batting average was substantially higher (0.331 ± 0.012). Therefore, this anomaly may be a function of the psychology of elite batters. For instance, power hitters may view reaching base on balls as a failure. Despite having the visual skills required to identify a bad pitch, their K% may be abnormally high as a result of swinging and missing as they attempt to increase their number of home runs or runs batted in (RBI). Further research is warranted to examine this hypothesis and explain the discrepancies between the two studies.

Batting Performance Quartiles vs. Visual Skills of Elite Batters

After dividing subjects into groups based on batting performance, significant differences were also noted for several visual skills (Tables 13 –18). The upper quartile for the BB% group, for instance, was found to have significantly higher C% and CS subtest scores. Batters with higher OPS and SLG scores were found to have significantly higher recognition response times. Furthermore, the better OPS performers also exhibited Edge scores significantly higher than their counterparts. Unsurprisingly, the results seen here are very similar to those outlined above and seem to be predicted based on the correlations discovered.

While this level of analysis may seem superfluous considering the VEPT quartile outcomes (Section 4.3), it is not without purpose. In fact, the results obtained here work in conjunction with those previously mentioned to facilitate a better understanding of the identified relationships. For example, a high correlation was noted between CS and BB%. Therefore, one might expect that those with greater convergence skills would have significantly better BB%, but that was not the case (Table 6). However, when grouping subjects according to BB% performance (Table 17), those with greater numbers of bases on balls do, in fact, tend to score significantly higher on tests of convergence. Therefore, the combined results indicate that, although a strong correlation exists between these two attributes, having superior convergence alone may not be enough to generate superior bases-on-balls percentages. There must be other unidentified factors that contribute to success in this area. Future research should be designed to identify these unknown variables.

Practical Significance and Applications

Practical significance was also identified for several batting statistics. Perhaps the most glaring examples are among the R% grouping (see Table 10). Here, the upper quartile outperformed the lower in terms of both AVG (0.323 vs 0.302, p = 0.061) and OBP (0.394 vs 0.364, p = 0.065). Though the differences are not enough to reach statistical significance, they are nevertheless meaningful.

In fact, in a 2005 study, Houser found on-base percentage to be the primary batting statistic that contributes to team success [32]. Only walks plus hits per inning pitched (WHIP), a pitching statistic, was found to be more valuable. In light of this discovery, Houser states that OBP should be heavily emphasized when making staffing and payroll decisions. As such, the practical importance of these statistics cannot be overlooked. Other areas of potential significance for OBP include: ES (0.399 vs 0.371, p = 0.080); RT (0.386 vs 0.360, p = 0.107); and CS (0.403 vs 0.377, p = 0.162).

Beyond player evaluation, the results of the current study also provide meaningful contributions to the areas of visual skill training. While studies have already shown that specific visual skills of baseball players can be enhanced through training [18,33], the current study provides further evidence of the importance of convergence, recognition time, and recognition accuracy for batting expertise. Furthermore, training programs which address areas such as these have been shown to enhance batting performance [17-19]. As such, it is recommended that visual skills training be incorporated into the routine training of baseball players. Specifically, training programs should be designed to enhance those skills outlined above while addressing areas of individual weakness.

Contrary Findings

Surprisingly, no significant relationships were found between recognition response times and any batting statistic in the current study. This runs contrary to what would be expected based on previous research [34,35]. In a 2005 study involving 22 collegiate and 17 professional baseball players, Kida et al. found the go/no-go reaction time to decrease significantly as expertise increased [34]. In a similar study, the go/no-go reaction times of 24 college baseball players were also found to differ significantly when grouped according to level of baseball performance [35].

One possible explanation for this disparity between the current and previous studies may be the way in which the response times were captured. The recognition time recorded by the VEPT software is a simple reaction time, in which a visual stimulus generates some pre-determined motor response. In the above scenarios [34,35], the authors were specifically testing a “go” reaction time, in which the subject must select an appropriate response, which requires greater cognitive ability. However, a positive relationship has been noted between simple and “go” reaction times [34].

During the recognition response evaluation, VEPT tracks not only the response time but also the response accuracy (R%). First, three arrows are shown on the computer screen. Immediately after the arrows have faded, the athlete must respond by pressing the keyboard arrows in the same order in which they appeared on the monitor. The goal is to react as quickly and accurately as possible. However, incorrect button presses only affect the accuracy score, not the response time. By mathematically manipulating RT and R%, the VEPT software is, in a roundabout way, able to assess a type of go/no-go response that is reflected in the overall Edge score.

This is important to consider, as the current study did find a significant, large positive correlations between R% and SLG (r = 0.51, p <0.05) as well as R% and OPS (r = 0.51, p <0.05). In order to better evaluate the results of this study against those previously mentioned, however, the manner in which VEPT manipulates these RT and R% scores must be elucidated. Unfortunately, due to the proprietary nature of the formula for the Edge score calculation, further analysis of this go/no-go condition is not possible.

Another unexpected result was the lack of significant correlations between tracking subtest scores (TT and T%) and batting statistics. In a review of the literature pertaining to cricket batting [25], elite players were found to have greater pursuit tracking capabilities than lesser skilled players. Due to similarities between the sports, this relationship should hold true for expert baseball players as well, so it was surprising that it was not seen here. However, it is important to recognize that Portus and Farrow [25] specifically identified differences between elite and non-elite players; whereas, the current study was only conducted with elite batters. Therefore, the lack of significant findings in these areas may be due to population differences. As such, the fact that significant correlations were not detected does not necessarily mean that tracking capacities are not important for batting success. In fact, according to Uchida et al. [36], the enhanced tracking abilities of baseball players' eyes seems to indicate that superior tracking is a necessity for superior batting performance.

Limitations

Perhaps the greatest limitation to the current study was the age of the visual skills data. On average, VEPT subtest scores were collected 6.83 (± 1.83) years ago. Playing ball sports, such as baseball, has been shown to improve visual skills [37]. Though all the athletes in this study had been active in the sport for many years prior to this initial test, the visual stimuli associated with a ball pitched at the professional level are undoubtedly different from those of lower leagues (high school, college, MiLB, etc.). Therefore, it is quite possible that their vision during the 2016 season was significantly better than these older VEPT scores would indicate.

Additionally, according to the Vizual Edge website [38], multiple MLB teams use the VEPT software as a tool to improve visual skills. Players from several of the teams mentioned in these online testimonials are included in the current study. Consequently, it is possible that, for some subjects, using the VEPT trainer has led to significant improvements in visual capacities beyond what would be expected from traditional baseball conditioning and practice alone.

Ideally, athletes would be re-tested at the start of each season to provide up-to-date information on current visual skills and thus creating enhanced research opportunities. However, access to the visual skills data presented here was only possible because it was collected before the players were associated with a professional team. Unfortunately, once a player is drafted, any subsequent visual performance data captured becomes property of the parent team, making it much more difficult to obtain.

A further limitation was the homogeneity of visual alignment and depth perception scores. Fifteen of the 20 subjects had perfect visual alignment scores, and 17 had perfect scores in tests of depth perception. While this thwarted the creation of meaningful quartiles for statistical analysis, the fact that nearly all of the subjects demonstrate these flawless scores may point to their necessity for elite batting performance. In fact, Vizual Edge asserts that, although up to one step of alignment deviation is considered normal, perfect visual alignment is desired for elite athletes [31]. However, further studies are warranted to substantiate these claims.

CONCLUSIONS

The results of this study provide a unique insight into the contributions of visual abilities to elite baseball batting performance. In summary, it appears that the visual skill with the greatest correlation to batting success, even among elite hitters, is convergence. As such, it is recommended that drills which address convergence be utilized in the visual training programs for batters of all abilities. This can be accomplished using a variety of tools and techniques [39]. However, teams using the Vizual Edge Performance Trainer should note that this skill is addressed in conjunction with divergence, in a test of "Vizual Flexibility" [31].

Furthermore, when utilizing the VEPT software for evaluation of player potential, care should be taken to look beyond the composite Edge score. While ES does provide an overall indication of visual abilities, its correlation to elite batting performance appears limited, at best. Instead, it is recommended that subtest scores for C%, CS, R%, and RT also be scrutinized, at a minimum. The current study has identified these visual skills as being either statistically or practically significant contributors to OBP. As this individual batting statistic has been found to be associated with team success more than any other [32], these visual skills should be emphasized during player training and evaluation.

However, it is important to remember that the baseball swing is a highly complex movement that requires the coordination of many different biomechanical factors [40]. Ted Williams once said, "you can't make a hitter, but I think you can improve a hitter" [41] (p. 196), and visual skills training is just one avenue for enhancing batting performance. There are a host of physiological, psychological, and cognitive attributes that can contribute to a hitter's level of expertise. Therefore, evaluation of visual skills and prescription for improvements should always be within the context of the individual player's strengths and weakness.

Applications in Sport

These results of this study may be used by scouts, managers, trainers, and coaches to improve player evaluation and training protocols. In terms of potential training protocols, visual training programs utilized by baseball coaching staff may be created or modified to address the areas of convergence, recognition time, and recognition accuracy for batting expertise as well as a player's areas of weakness to further improve batting performance.

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Author Contributions

J.H. and F.J.S. conceived and designed the experiments; J.H. performed the experiments; J.H. and F.J.S. analyzed the data; J.H. wrote the paper.

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