The Hand-Eye Coordination Of Professional Baseball Players: The Effect On Batting

Daniel M. Laby, MD [1]
David G. Kirschen, OD, PhD [2,3]
Usha Govindarajulu, PhD [4]
Paul DeLand, PhD [5]

1- Sports and Performance Vision Center, State University of New York College of Optometry, New York, NY
2- Southern California College of Optometry, Marshall Ketchum University, Fullerton, CA.
3- Jules Stein Eye Institute, University of California at Los Angeles, Los Angeles, CA
4 - Department of Epi & Biostatistics, State University of New York, Downstate Medical Center, Brooklyn, NY
5 – Emeritus Professor of Mathematics, Department of Mathematics, California State University, Fullerton, CA

Correspondence: Daniel M. Laby MD, Director, Sports and Performance Vision Center, SUNY College of Optometry, Suite 519, 33 West 42nd Street, New York, NY 10036, tel: 508-507-0158, email: dlaby@sunyopt.edu

Abstract

Purpose: To describe the hand-eye coordination/reaction time (HEC/RT) ability and evaluate its relationship to the baseball batting performance of professional baseball players.

Methods: A commercially available HEC/RT system was used on 450 professional baseball players from six MLB teams. Results were retrospectively compared to standard, career, plate-discipline metrics.

Results: Statistically significant correlations were found between the HEC/RT metrics, tested at high speed, and several plate discipline batting metrics. When comparing the players with the top 20% of HEC/RT results to those with the bottom 20% of HEC/RT results, the better HEC/RT group had 3 fewer at bats before gaining a walk (10 vs 13, 22% decrease), as well as swinging 6-7% less often at balls, and fastballs, in the strike zone as compared to the poorer HEC/RT group. Based upon an individual's HEC/RT results we are able to predict, with a specificity of 93%, if they are in the bottom 20% of plate discipline ability for this population.

Conclusions:

These results not only describe the HEC/RT ability of professional baseball players but also show a significant relationship between a baseball player's HEC/RT ability and their batting performance. These are the first results, on a large group at the professional level, to demonstrate statistically this relationship. These results can be used in player selection, indicating that batters with better HEC/RT are more likely to reach the major-league level and be more productive for their team. Further studies will be needed to demonstrate whether training better HEC/RT results in improved batting performance.

Key words: hitting, vision, reaction, walks

Introduction

The synchrony between the visual system and the motor system is a critical component to human action. Our ability to see a target and make a coordinated, perfectly timed, motor response to achieve a specific task is vital to our day to day activities. The skill of coordinating eye and body movements, sometimes called eye-hand coordination, is particularly important in high-speed sport movements such as hitting a pitch in baseball.

It takes less than half a second for a 95-mph fastball to reach home plate. The ability to see the early trajectory of a pitched baseball, and make a well-timed motor action to swing the bat so it strikes the ball dead center at precisely the right point in the swing, and at the optimal moment as the ball crosses the plate represents ideal hand-eye coordination and reaction time (HEC/RT).

Many authors (1,2) have described HEC/RT, or motor skill, as a series of decisions and resulting motor movements to accomplish a specific task. In fact, HEC/RT represents the integration of visual information, perceptually based decisions, and motor movements to accomplish a specific task. The speed at which this occurs depends on many factors, some visual, some perceptual and some motor related.

The literature describes the average static visual acuity of professional baseball players as 20/12, while some even approach the limit of human vision at the 20/8 level (3). Description of the average refractive error and optical aberration of the eyes of professional baseball players has shown that the visual system is driven by low order optical aberrations, with no significant high order aberrations different from a general population (4). Similarly, the stereo acuity as well as the contrast sensitivity of this population has been shown to be superior to that found in the general population (3).

Several authors (5) have described the perceptual tools used by athletes to optimize HEC/RT ability, including the construction of a series of programmed responses to specific visual information. These models, based on previous experience, enable the elite athlete to select a pre-programmed motor action allowing them to appear able to “predict” future events as opposed to simply reacting.

For a well-coordinated, and rapid, motor response, the system must function at peak performance, with both optimal input from the visual system along with ideal processing of this information followed by an efficient propagation to a motor response, should there be a decision to swing.

Review of the literature reveals that HEC/RT has been tested using several devices in many different sports over the past several decades. In a 1983 report (6), Sherman described the use of an early test of HEC/RT, the “Saccadic Fixator” board to evaluate HEC/RT in athletes. In this study, Sherman described that of the 16 sports he tested, the baseball players had among the best scores on this test of HEC/RT in this collegiate cohort.

More recently, Ellison and colleagues (7) described their use of another HEC/RT testing system, the Sports Vision Trainer (SVT). In this report, the authors found that the system had a high retest reliability given proper familiarization with the system (r=0.82 to 0.89). Wells et al (8) described their experience using the Dynavision D2 HEC/RT testing system, specifically addressing the reliability of this test of HEC/RT. The authors found the Dynavision D2 system to be a reliable device given that “adequate practice is provided” prior to testing. As described above, many systems are available to assess a subject’s HEC/RT with no single system currently considered to be the gold-standard measure.

Lastly, several authors, including for example Zupan , Arata, Wile, and Parker (9) found that users of HEC systems could be trained to improve HEC/RT results. In their study, trained athletes showed a 25% improvement in the HEC/RT score following training. The potential for improved HEC/RT with training suggests there may be a possibility that training HEC/RT could result in potential on-field improvement in performance, if HEC/RT is in fact related to baseball performance.

In this project, we describe the normal levels of HEC/RT for professional baseball players, using a commercially available test of HEC/RT (the SVT: Sports Vision Trainer). Additionally, this report will describe the relationship between HEC/RT ability and batting ability in this large cohort of professional baseball players (major and minor leaguers). Batting ability will be assessed through standard plate discipline metrics that are most dependent on the batter’s ability, and least dependent on the defense.

Materials and Methods

Participants

Four hundred and fifty professional MLB (major and minor league) baseball players were included in this analysis. Athletes were evaluated during the 2012, 2013 and 2015 spring training seasons. In the event that any single player was tested more than once during that period, only their most recent results were included in the analysis. Thus, each member of the cohort represented a single professional baseball player. One hundred five athletes were major league players while 345 were minor league players. The average length of service for the major league players was (M $\pm$ SD) 3.9 years $\pm$ 3.6 years, and was 0.14 years $\pm$ 0.17 years for the minor league players. The major league players had, on average, 3563 $\pm$ 1719 individual at bats per player, while the minor league players had an average of 1134 $\pm$ 920 at bats per player. All athletes were male and represented a total of six professional (MLB) baseball clubs and their affiliated minor league teams.

This retrospective review was approved by the State University of New York, College of Optometry, Internal Review Board (IRB).

Materials and Design

Each player underwent a standard battery of tests of visual function during the beginning of each spring training season. These tests were designed to measure the ability as well as any change in ability to properly perceive and process visual information.

This report details a portion of that assessment, the results of the Sports Vision Trainer (SVT) system (Sports Vision PTY Ltd., Australia). The SVT is a 32 sensor pad touch board which is portable and was carried from team to team each spring. The board was always used in the "landscape orientation".

<u>Testing Procedure</u>

The first of the two testing modes is termed "proactive". In this configuration, a single spot on the board illuminates and the player is asked to press/strike the lighted target as quickly as possible. Once the light it pressed, another light positioned randomly on the board immediately illuminates, and the player once again must press that light as quickly as possible. The SVT records, in milliseconds, how long it takes the player to hit the 20 randomly positioned targets. The aim in this mode is to, as quickly as possible, strike the 20 lights to obtain the shortest elapsed time.

The second mode is called "reactive". In this mode, the system is in control of when the targets are illuminated, and turns on and turns off the target lights at a given pre-set interval. Thus, the athlete's task is to strike the light before it turns off in order to receive credit for that particular target. This mode is run twice, initially leaving the lights on for 600 milliseconds, and then a second time with an illumination period of 400 milliseconds. In the reactive mode the percentage of properly hit targets as compared to all possible targets is recorded.

The reactive mode has an additional protocol that is termed "Go-NoGo" (GNG). In this configuration, green or red lights are illuminated for either 600 or 400 milliseconds. The athlete is instructed to only hit the green lights and to let the red lights turn off on their own without being struck. The system records the percentage of red and green lights struck, respectively.

Plate Discipline Metrics

Baseball batting metrics have been developed which are more exclusively dependent on a batter's own ability with minimal, if any, influence by the abilities of the defensive players. These measurements have been termed "plate discipline" as they reflect the batter's ability to swing at pitches he feels he can hit successfully, while not swinging at balls outside the strike zone or ones within the strike zone that he is not able to successfully put into play.

Although there are many measures of plate discipline, we chose thirteen, which appeared to be most related to visual ability. The decision to swing at a pitch that is in or out of the strike zone as well as deciding to swing at a pitch that is a fastball and not swing at other types of "trick" pitches are all related to a batter's visual ability, hand-eye coordination, and ability to react. In addition, we looked at three additional metrics (total at bats, highest level obtained and years of major league service) as a way to gauge the effect of experience (or age) on the visual metrics.

The thirteen plate discipline measures, as well as the three additional metrics used in this study are described below:

MissPct – overall swing and miss percentage on all pitches, lower value preferred

MisinZPct – overall miss percentage on pitches within the strike zone, lower value preferred

MisFbinZpct – overall miss percentage of only fastballs in the strike zone, lower value preferred

OvChasepct –percentage of swings on all pitches deemed outside strike zone, lower value preferred

fbChasepct –percentage of swings on only fastballs outside the strike zone, lower value preferred

inZSwPct – overall swing percentage of all pitches in the strike zone, lower value indicates a more discerning batter

inZfbSwPct – overall swing percentage of fastballs in the strike zone, lower value indicates a more discerning batter

abbb – at bats per base on ball (walk), lower value preferred

abso – at bats per strike out, higher value preferred

ab – total number of career at bats

MjService – total number of years in professional baseball (MLB minor and major leagues)

Highest Level – A measure of how a player has progressed thru the different levels of Major League Baseball (MLB). For example, Level 1 represents the Major League (expert) level, and Level 5 represents the A (novice) level

Contact Pct – A percentage measure of the number of times the batter hits the ball when he swings

ZContactPct – A percentage measure of the number of times the batter hits a ball when it is in the strike zone, when he swings

MisOutZPct – A percentage measure of the number of times a batter swings and misses at pitches that are outside the strike zone

OContactPct – A percentage measure of the number of times a batter hits a ball that it outside the strike zone when he swings

Statistical Method

The results of each test, for each player, were tabulated on a Microsoft Excel spreadsheet and basic statistical analyses were performed. Each player's results were only represented once in the working database. In cases where a player was tested in more than one season, only the most recent season's data was used. Career plate discipline statistics, for each athlete, were then combined with the SVT data. Career plate discipline statistics to date were used for analysis, as they provided the best overall measure of a batters' skill, minimizing the effect of any seasonal fluctuations. Pearson correlation statistics were calculated (AnalystSoft Inc., StatPlus:mac - statistical analysis program for Mac OS. Version v5. www.analystsoft.com/en and SAS version 9.4) for each vision metric and each plate discipline metric. Additionally, t-tests were conducted to compare the top 20% and bottom 20% for select HEC/RT metrics. Finally, Pearson correlation coefficients and two sided t-test results were calculated in order to corroborate and confirm the above results as well as to calculate several simple linear regression analyses on the data set.

Results

Part 1: Normative values for professional baseball players

Descriptive statistics for each of the HEC/RT variables are shown in Table 1. For both the GNG Red 0.6 as well as for the GNG Red 0.4 the average result was close to zero. This is due to the fact that the overwhelming majority of subjects did not strike any of the red lights when tested (as desired), resulting in low means and SD's for each. Two-sample t Test analysis shows no significant difference between the GNG Red 0.6 and GNG Red 0.4 tests. Additionally, there are statistically significant differences ($p<0.0001$) between each of the other HEC/RT tests.

Figure 1 demonstrates the distribution of results for each of the HEC/RT tests. The histograms for Proactive, Reactive 0.4 and GNG Green 0.4 demonstrates an approximate normal distribution of the results, while the Reactive 0.6 and the GNG Green 0.6 data shows a skew to the right indicating a non-normal data distribution. This grouping of results at the high-end suggests that the task was not sufficiently difficult for this cohort resulting in more than an expected number of the athletes to score well on the test. The GNG Red 0.6 and GNG Red 0.4 data are not included in additional analyses as almost all the results were identical and not helpful in differentiating subjects' ability.

The results of the Proactive scores, Reactive 0.4 and GNG Green 0.4 are presented in Table 2. Additionally, Pearson correlations were calculated for each of the HEC/RT tests performed. Statistically significant correlations ranged from 0.708 between Reactive 0.4 and GNG Green 0.4, to 0.205 between Reactive 0.6 and GNG Green 0.4. Of note is the relatively high correlation between Proactive score and Reactive 0.4 ($r = -0.668$) and GNG Green 0.4 ($r = -0.565$) respectively.

In light of the correlations noted above between the Proactive score and the Reactive 0.4 and GNG Green 0.4 scores, we considered whether all three metrics were important to include for further analysis. The Proactive score vs. both of the other reactive based scores had similar slopes (Reactive 0.4 and GNG Green 0.4 best fit trendlines). This similar slope suggests that they are similar in so much as athletes who performed well on one test also performed well on the other. A similar finding is noted between the Reactive and Proactive scores. The correlations were high, suggesting that only one of these tests was necessary to differentiate one athlete from another in terms of HEC/RT.

In addition to the HEC/RT results, we reviewed several plate discipline metrics for each athlete, as noted above. In addition, in order to determine if our cohort was in fact reflective of the general baseball population, we compared our cohort's plate discipline metrics to the same plate discipline statistics for Major League Baseball as a whole. Review of these values shows that our cohort is either identical to or very similar to the plate discipline metrics reported for all MLB players, suggesting that our analysis cohort is representative in ability, and on-field performance, to the larger population of major league baseball players.

Part 2: The relationship between HEC/RT and on-field performance

Pearson correlation coefficients between HEC/RT tests and plate discipline metrics are shown in Table 3. Correlations that were not statistically significant are not shown. A statistically significant correlation was noted between experience (career at bats (ab), Major League Service, and highest level: Major League, AAA, AA, A) and the HEC/RT results, where better HEC/RT ability correlated to more at bats, longer careers, and higher level of play.

Additionally, review of Table 3 readily demonstrates that only three of the HEC/RT tests were repeatedly correlated to on-field baseball performance, as evidenced in plate discipline ability. Specifically, the Proactive results, the Reactive 0.4 results and the GNG Green 0.4 results were repeatedly correlated to many of the different measures of an athlete's plate discipline ability. Additionally, the Proactive results were correlated to the largest number of plate discipline metrics (10 of 13 metrics). For the Proactive test, correlations ranged from 0.248 for "In-zone swing percentage" to a correlation of 0.0912 for "miss out of the strike-zone percentage", and its correlate, "out of zone contact percentage". Although the proactive results seem to only account for about 6% (r^2) of the variation in plate discipline at most, this is not surprising since there are certainly many factors that are necessary for successful batting in baseball.

Although statistical significance is commonly considered with p-values less than 0.05, when multiple correlations are performed the Bonferroni correction is often applied in order to reduce the occurrence of Type I error. In the above analysis, we performed 80 correlation calculations (5 HEC/RT tests x 16 Plate discipline metrics). Thus, only p-values less than 0.05/80 or 0.00625 should be considered statistically significant. At this stricter definition, InZSwPct as well as InZfbSwPct and abbb remain correlated with all three of the Proactive, Reactive 0.4 and GNG Green 0.4 tests. Additionally, several other plate discipline metrics show statistically significant correlations with other individual HEC/RT tests.

In an effort to understand further the effect of HEC/RT on plate discipline ability, we compared the top 20% of athletes and bottom 20% of athletes in each of the HEC/RT metrics evaluated. Proactive score (ProMean) for the top 20% was 7740 msec, while it was 11319 msec for the bottom 20% group. Reactive 0.4 and GNG Green 0.4 showed similar differences at 77% vs 34% and 60% vs 26% respectively. A two-tailed Student's t-test comparing the top to the bottom 20% groups on the various HEC/RT tests resulted in statistically significant differences between the top and bottom 20% groups. The levels of statistical significance (p-values) ranged from 1.19×10^{-54} to 2.78×10^{-9}.

In order to further evaluate the effect of HEC/RT ability on baseball performance, we compared the plate discipline ability of the baseball players with the best HEC/RT ability (top 20% of Proactive scores); to those with the worst HEC/RT ability (bottom 20% of Proactive scores). Table 4 details this comparison by displaying the mean and standard deviation for the top 20% and the bottom 20% of players as determined by their Proactive score. For each plate discipline metric, the averages of the two groups are compared (Student's t-test) and the level of significance of the difference is listed (Proactive p value column). For all but three of the plate discipline metrics, a statistically significant difference was found between the players with excellent HEC/RT and those with poor HEC/RT at the $p<0.05$ level. Differences ranged from 3 to 22%, with the difference in abbb (walk rate) being the largest with a 22% decrease in the number of at bats before a walk occurred in those players with excellent HEC/RT.

Once again, having performed 16 statistical evaluations (1 HEC/RT tests x 16 Plate discipline metrics) a Bonferroni correction can be applied. Thus, only p-values less than 0.05/16 or 0.003125 should be considered statistically significant. At this stricter definition, the difference between the top and bottom 20% Proactive groups in the InZSwPct as well as InZfbSwPct and abbb plate discipline metrics was statistically significant.

Figure 2 presents an interval plot of abbb vs. Proactive scores by proactive quintile groupings. The better four quintiles are relatively equal in their mean abbb, with only the fifth, and worst, quintile being different. This accounts for the statistical difference between the top 20% and bottom 20% of HEC/RT ability. Additionally, essentially, only the worst group (bottom 20%) has a poor mean walk rate (abbb) with the other four quintiles sharing almost the same mean walk rates.

Part 3: Testing the ability to use the Proactive scores to predict abbb (walk rate)

In order to test the reliability of using Proactive HEC/RT (ProMean) results to predict plate discipline, specifically in this example a player's walk rate, we split our database randomly into two groups. The first half of the database was used to calculate the Proactive cut-offs and mean abbb value for both the top 20% of athletes who scored well on the Proactive tests and the bottom 20% of the athletes who scored poorly on the Proactive test. When sorted by ProMean, the top 20% HEC/RT group of the split database had a mean walk rate (abbb) of 9.70 $\pm$ 3.07 vs a mean abbb of 13.51 $\pm$ 5.68 for the bottom 20% HEC/RT of the split database. Additionally, there is a significant difference in the abbb results of these two groups (p=0.00016). Similar to the results noted for the entire database as shown in Table 4.

Using these Proactive “cut-offs” for the best and worst HEC/RT groups, we looked at the second half of our cohort and predicted, based on Proactive cut-offs, which players would have excellent abbb rates vs. which players would have poor abbb rates. As noted above, the ability to predict is most useful in identifying those athletes (e.g. future prospects) in the bottom 20% of abbb. In this experiment, the proactive cut-offs predicted with a specificity of 93% (167/167+12, 167 athletes were predicted to not be in the bottom 20% and were actually not in the bottom 20%, while 12 athletes were predicted to be in the bottom 20% and actually *were not* in the bottom 20%), and a negative predictive value of 81% (167/167+40, in this case 40 athletes were predicted to not be in the bottom 20% and actually *were* in the bottom 20%) which players were not in the bottom 20% of abbb.

Discussion

The ability to successfully hit a pitched baseball depends on many factors. Clearly, visual ability is important, but is certainly only part of what is needed. Previous research (3) has noted that the visual ability, measured through visual acuity, of the average professional baseball player is approximately 20/12, several lines better than the accepted average of 20/20 in the general population. This report describes another, different, aspect of visually related ability, specifically hand eye coordination (HEC/RT), and its relationship to batting ability. By evaluating a batter's visual function as it relates to the decision to swing at a pitch (plate discipline), we gain insight regarding the many visual functions required for elite batting performance as well as create visual criteria that may be useful in predicting which batters will be more successful.

Review of the basic SVT results indicates that, for this cohort of Professional baseball players, the targets presented for 600 msec were too easy. On the other hand, the 400 msec tasks were sufficiently difficult to allow for a greater spread of player results.

Correlation (r) values for the SVT test showed significance in the Proactive, Reactive.4 and GNG Green.4 results with several of the plate discipline metrics. The low magnitude of the correlations themselves is not surprising when one considers the multiple visual, as well as physical, abilities that are critical to batting performance. It would not be expected that hand eye coordination alone would be highly correlated to batting performance, as many additional visual factors such as visual acuity, anticipation, visual concentration, to name only a few likely play a role in batting performance as well as the obvious physical factors of strength, timing, experience etc. Thus it is reasonable that hand eye coordination accounts for a maximum of 6% ($r = 0.2476$, $r^2 = 0.06$) of the variability in the plate discipline metrics.

The Proactive result was correlated with both the player's level of service (minor league level as well as major league) and the years of major league service – indicating players closer to the major leagues as well as players with more major league experience scored better on the hand-eye coordination test than others. Additionally, seven plate discipline metrics (MisOutZPct, OContactPct, OVChasePct, fbChasepct, inZSwPct, inZfbScPct, Abbb) were correlated with all three of the expected SVT measures (Proactive, Reactive.4, and GNG Green.4).

Another method of evaluating the role of HEC/RT in plate discipline is to compare the plate discipline ability of the players with the best (top 20%) hand-eye coordination with those of the worst (bottom 20%) hand-eye coordination. We noted that statistically significant differences are found in several of the plate discipline metrics considered. Specifically, the abbb, InZSwPct, and inZfbSwPct were very different between the two groups of HEC/RT ability. Other trends included the finding that players with more major league experience had better Proactive scores and players closer to the major leagues had better proactive scores as well. This may be intuitive as one would expect, if performance is indeed related to HEC/RT, that players with better HEC/RT ability are more likely to progress to higher levels of baseball.

These differences between the top and bottom 20% of HEC/RT abilities resulted in a 22% increase in ability to gain a walk (abbb of 10.208 vs 13.110), missing 15% less fast-balls in the strike zone, chasing 12% fewer fast-balls outside the strike zone and missing 8% fewer swings as compared to the poor hand-eye coordination group. Additionally, batters with better HEC/RT appear to be more discerning in deciding to swing at fastballs in the strike zone; swinging at fewer fast balls in the strike zone as compared to the poorer HEC/RT group. Thus, testing of HEC/RT is most useful in identifying those athletes who are in the bottom 20% of Proactive times as they will tend to have lower abbb scores as compared to the remaining 80% of athletes. Proactive score is less useful in directly identifying players who have the best abbb scores as the top four quintiles of players on Proactive testing have about equal abbb scores.

These results can translate into actual runs by taking the abbb as an example. The better HEC/RT group walked 3 at bats more often than the poorer group. Taken over a 610 at-bat average during a season, this results in an additional 13 walks per batter likely converting to an additional 4-5 scored runs produced by that batter alone. Considering the number of single run games per season as well as the possibility that these additional runs can be multiplied over the entire roster, building a roster of players with better HEC/RT ability could translate into a significant number of additional wins.

Review of Figure 2 indicates that only the bottom 20% group is statistically significantly different from the other quintiles. Thus, an attempt to improve a batter who is in the 3^{rd} quintile to the 1^{st} quintile would not be expected to result in improved abbb ability. But, improving a batter in the 5^{th} quintile, may in fact lead to improved batting performance. Additional data will be needed to evaluate any effect of correction/training on HEC/RT ability as well as any transfer to batting performance.

These data suggest a significant benefit in being able to identify batters who are in the top 80% of hand eye coordination ability and not in the bottom 20% of that ability, prior to their being signed by the team. By randomly splitting our database in half, we were able to determine the specificity (93%) as well as the negative predictive value (81%) of using the hand eye ability of a batter to “proactively” estimate their batting ability in the major and minor leagues. The use of this method to predict batting performance could be very beneficial in evaluating future team prospects and specifically their ability to perform in terms of batting ability, if given the opportunity to play professional baseball.

Much remains to be done in understanding the role of vision in sports, and specifically in baseball hitting ability. This report begins to explain the role of one skill, HEC/RT, in batting ability as measured through standard plate discipline metrics. Further, only a handful of plate discipline metrics were evaluated, and it is possible that others will be shown to be more significant in future research. Additionally, combining different and discrete vision metrics together may allow us to account for a greater portion of the variability noted in the batting performance between athletes.

Acknowledgments:

The authors did not receive any funding, equipment or technical support to perform this research.

Conflict of Interest:

None of the authors have any conflicts of interest with any portion of this report.

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Figure legends:

Figure 1: Histogram with best fit normal distribution superimposed for each of the five test protocols used. Left side from top to bottom, Proactive, Reactive 0.4, GNG 0.4 Green. On right side from top to bottom, Reactive 0.6 and GNG 0.6 Green. Note that on the Reactive 0.6 and GNG 0.6 Green tests results are bunched to the right indicating that a high percentage of the players scored very well on these tests resulting in poor ability to differentiate.

Figure 2: Interval plot of abbb vs Proactive results divided by quintile. Note that only in the fifth quantile (worst proactive scoring group do we see a significant difference in abbb, as compared to the other 80% of the cohort.