Utilizing the ImPACT Test to Predict Performance in College Baseball Hitters

By

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A Thesis Submitted to the Honors College

In Partial Fulfillment of the Bachelors degree
With Honors in
Psychology (B.S.)

THE UNIVERSITY OF ARIZONA
MAY 2013

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Date thesis submitted to Honors College:

May 1, 2013

Title of Honors thesis: Utilizing the ImPACT Test to Predict Performance in College Baseball Hitters

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ABSTRACT

The ImPACT test represents one of the main tools used by clinicians to assess the presence and severity of a student athlete's concussion (ImPACT Applications, Inc., 2011). Although past research has verified the utility of the ImPACT test for assessing cognitive status after concussion, no research has examined the ImPACT test's potential for predicting athletic performance in non-concussed athletes (ImPACT Applications, Inc., 2011). This study investigated whether particular composite scores on the ImPACT test can predict athletic performance. The composite scores on the ImPACT test include Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control. Previous literature showed that broad cognitive domains such as impulse control correlated with athletic performance (Kida & Matsumura, 2005). University of Arizona baseball players' freshman ImPACT test scores were correlated with their freshman year batting statistics, including batting average, slugging percentage, on-base percentage, strikeouts, and walks. The results showed no significant association between measures from the ImPACT test and the batting statistics. Therefore, the study suggests that the ImPACT test may possess no predictive ability for athletic performance in a non-concussed population.

Abstract

The ImPACT test represents one of the main tools used by clinicians to assess the presence and severity of a student-athlete's concussion (ImPACT Applications, Inc., 2011). The assessment consists of the Cognitive Efficiency Index (CEI), as well as composite scores in five domains of cognition including Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control. Although past research has verified the utility of the ImPACT test for assessing cognitive status after concussion, no research has examined the ImPACT test's potential for predicting athletic performance in non-concussed athletes (ImPACT Applications, Inc., 2011). Previous literature showed that broad cognitive domains such as reaction time or impulse control correlated with athletic performance (Kida & Matsumura, 2005). Thus, it is possible that ImPACT test scores may correlate with and therefore predict certain athletic performances. This study investigated whether particular composite scores on the ImPACT test can predict athletic performance. University of Arizona baseball players' freshman ImPACT test scores were correlated with their freshman year batting statistics, including batting average, slugging percentage, on-base percentage, strikeouts, and walks. It was hypothesized that Visual Memory and Visual Motor Speed composite scores would correlate negatively with strikeout percentage and correlate positively with the remaining baseball statistics. Additionally, it was hypothesized that the Impulse Control composite score (high = poor) and a subset of Impulse Control (total incorrect during distracter task) would correlate positively with strikeout percentage and correlate negatively with the remaining statistics. The final hypothesis stated CEI, Verbal Memory and Reaction Time composite scores would not be related to the baseball performance measures. The results supported the final hypothesis. Therefore, the study suggests that the ImPACT test may not possess predictive ability for athletic performance in a non-concussed population.

Utilizing the ImPACT Test to Predict Performance in College Baseball Hitters

Recently, identifying, preventing and treating a concussion have attracted much attention in medicine (McCrory, Meeuwisse, Johnston, Dvorak, Aubry, Molloy, and Cantu, 2009). One tool for assessing the presence of a concussion is the computerized concussion battery known as the Immediate Post-Concussion Assessment Testing (ImPACT) test. Although not the sole factor in determining presence and severity of concussion, the ImPACT test is used as part of a multifaceted concussion assessment program (Broglio, Ferrar, Macciocchi, Baumgartner, & Elliot, 2007). The ImPACT test assesses the neurocognitive and neurobehavioral components of a concussion, while providing post-injury cognitive and symptom data (Schatz, Pardini, Lovell, Collins, & Podell, 2006).

Currently, every college in the United States, and a majority of the high schools with athletic programs, require that incoming student-athletes take an initial ImPACT test to establish a baseline of cognitive functioning (ImPACT Applications, Inc., 2011). In the event that the athlete sustains a mild to severe head injury, he or she takes the ImPACT test again and the first test can be used as a comparison point from which to identify any potential cognitive changes. The difference between the two scores represents one part of the overall concussion assessment process.

The ImPACT test is comprised of a number of cognitive tests which, in various combinations, contribute to an overall Cognitive Efficiency Index (CEI) and five composite scores: Verbal Memory, Visual Memory, Visual Motor Speed, Reaction Time, and Impulse Control. The tests will be explained in more detail later in the method section. Although the ImPACT test was originally developed to assess cognitive status after a head injury, it may also have the potential to predict athletic performance in athletes without a neurological injury. Specifically, the ImPACT test may predict hitting performance in collegiate baseball players.

At this time, no investigations have examined the efficacy of the ImPACT test as a predictor of athletic performance in any sport, including baseball. While it is highly likely that many aspects of athleticism are underpinned by not only physical aptitude but also various cognitive abilities (e.g., attention), hitting may be a more complex physical skill that relies on multiple cognitive domains. The ability to connect ball and bat requires that several cognitive and physical skills work in unison including some of those cognitive abilities that are assessed by the ImPACT test (Kida & Matsumura, 2005; Nielsen & McGown, 1985). For example, quick reaction time, efficient visual motor speed, and impulse control might be required to swing at the correct pitch with the correct timing, while certain types of memory might be employed to recall past at-bats and use them to assist in future at-bats (Kida & Matsumura, 2005; McPherson & MacMahon, 2008; Nielsen & McGown, 1985; Reina, Moreno, & Sanz, 2007). Although the relation between the ImPACT test measurements and athletic performance has not been examined, past research has assessed the relation between certain cognitive domains similar to those found on the ImPACT test and athletic performance including domains of impulse control, visual motor speed, reaction time, and memory.

Impulse control. One area of relatively strong correlation is in the domain of impulse control or inhibition. Impulse control or inhibition incorporates one's ability to deliberately stop dominant or prepotent responses when necessary (Miyake et al. 2000). In baseball, the dominant response involves swinging at the baseball, and a key characteristic to a successful hitter involves the ability to inhibit one's intention of swinging when a bad pitch is thrown. Using a Go/No-Go task, Kida and Matsumura (2005) found that higher-skilled baseball players' decision-making reaction time was significantly quicker than that of low-skill baseball players. The Go/No-Go task measures one's ability to inhibit a dominant response in favor of a non-dominant response, which is a measure of impulse control. In the context of baseball, this ability may come into play when one must inhibit oneself from swinging at a ball due to a poor pitch. In compliment to one's ability to inhibit a dominant response, one must be able to perceive visual information contributing to the decision to swing or not relatively quickly. This has been referred to as visual motor speed (Reina, Moreno, & Sanz, 2007).

Visual motor speed. Visual motor speed has not yet been compared to baseball performance, but one study has investigated its association to handicap table tennis performance (Reina, Moreno, & Sanz, 2007). Experienced table tennis players, compared to novice players, performed faster motor responses and obtained useful information from racket-arm cues during the opponents serve (Reina, Moreno, & Sanz, 2007). This study supports the hypothesis that better players had better visual motor speed and were able to use visual cues more effectively to improve their athletic performance. Thus, it is possible that a similar association might be found between visual motor speed and hitting performance in baseball.

Reaction time. Although it would be intuitive to infer an association between simple reaction time and hitting performance, interestingly, the literature does not support such an association. According to past research, measures of simple reaction time are not typically associated with performance in baseball. For example, no association was found between reaction time and offensive ability (i.e., batting averages and slugging percentages) of individual players (Nielsen & McGown, 1985). Also, when comparing players with various skill level or baseball experience, no differences in simple reaction time were observed (Kida & Matsumura, 2005).

Visual and verbal memory. An additional consideration, given the last two composite measures on the ImPACT test, includes visual and verbal memory. Until now there have not been any investigations into the utility of predicting athletic performance from visual and verbal episodic memory. However, it does appear that experienced baseball players use baseball specific strategies to encode and retrieve important game events to prepare for their next at-bat (McPherson & MacMahon, 2008). These memories are arguably stored in various forms in long-term memory (LTM) including semantic and episodic systems. It may therefore be the case that a measure of episodic, visual memory might be associated with a players hitting performance.

The research highlighted above suggests cognitive performance in certain domains may be predictive of athletic performance. The ImPACT test provides a measure of cognitive functioning in all of these areas and, in addition, provides a global measure of response bias called the Cognitive Efficiency Index (CEI). The CEI was established for the ImPACT test to assess the balance or trade-off between an individual's speed and accuracy of response (ImPACT Applications, Inc., 2011). For example, an individual might sacrifice speed to increase their accuracy. Given that this measurement is specific to the ImPACT test, no research has examined its association to athletic performance.

Taken together, prior research suggests that the composite scores, including the CEI, on the ImPACT test might be able to predict certain athletic performances. Arguably, measures of athletic performance with a higher degree of complexity would be more likely to correlate with these composite measures of cognitive functioning, if we assume that more complexity requires a higher degree of cognitive processing. Ability to hit a baseball might be one such measure of athletic performance that requires a relatively complex set of cognitive processes in order to be successful (Gray, 2002). However, the relation between these composite scores and hitting performances, as well as the CEI and hitting performance remains unidentified. Thus, the question that this study aims to address is whether the ImPACT test can predict collegiate baseball players' hitting performance. Hitting performance can be measured in many different ways including batting average, slugging percentage, on-base percentage, walk percentage and strikeout percentage and all are considered in this study.

The first hypothesis is that the Visual Memory, Visual Motor Speed, and Impulse Control composite scores will predict hitting performance. Prior research has shown that experienced baseball players utilize memories from past games stored in LTM to aid performance in current games (Gray, 2002; McPherson & MacMahon, 2008). It is likely that the majority of these memories are visual in nature and so it is hypothesized that the Visual Memory composite of the ImPACT test will be positively correlated with batting average, slugging percentage, on-base percentage, walk percentage, and negatively correlated with strikeout percentage. Regarding visual motor speed, detecting the speed and location of a baseball thrown by a pitcher and then swinging the bat to connect with that baseball represents a visual motor task (Regan, 1997). Therefore, the individuals who possess better visual motor skills, including speed of visual motor processing, should obtain higher hitting statistics. Thus it is hypothesized that visual motor speed will be positively correlated with batting average, slugging percentage, on-base percentage, walk percentage, and negatively correlated with strikeout percentage. Finally, regarding impulse control, the ability to not swing when the ball is thrown poorly (and will thus be a "ball") represents the suppression of a dominant response (i.e. to swing). Since superior ability to inhibit action when a poor pitch is identified likely improves hitting performance, poorer impulse control should be associated with a lower batting average, slugging percentage, on-base percentage, walk percentage, and a higher strikeout percentage.

The second hypothesis of the study is that the Reaction Time composite, the Verbal Memory composite, and the CEI will not predict hitting performance. Given the past research on reaction time, no association is likely to exist. Regarding verbal memory, remembering words should not relate to athletic performances, which are more visual-motor, such as hitting a baseball. With the CEI's planned function of serving as a measure of response bias between memory and speed on a specific component of the ImPACT test (Symbol Match test), the relation to hitting performance does not seem likely. Although hitting a baseball may require aspects of memory and processing speed, the CEI does not represent an ideal measurement of these areas since the focus of the measure is response bias (Gray, 2002).

It is possible that these composite scores, having been comprised of a multitude of different tests, may not be sensitive enough to pick up an association between cognitive performance and athletic ability. Therefore, a third hypothesis is that in the event that no association between composite measures exists, perhaps more specific subtests will correlate with athletic performance. After assessing all the options, a subcomponent in the Impulse Control composite known as the total incorrect on the Interference Phase of X's and O's (test 3) was chosen. The interference task requires a fast decision similar to the one used during an at-bat situation. It is hypothesized that this subcomponent should positively correlate with strikeouts and negatively correlate with walks, batting average, slugging percentage, and on-base percentage.

Method

Participants

Twenty-seven University of Arizona freshman baseball position players (non-pitchers) comprised the participants. The majority of the participants were former players (n=23), while the rest were current players (n=4). The requirement for eligibility in the study included having at least 50 at-bats during their freshman year to ensure that hitting performances were sensitive and variable enough to allow for correlational analysis. An at-bat means an opportunity to hit. Each subject took the ImPACT test during the fall semester of the freshman year before beginning their first season. ImPACT test data were retrieved from archival data at the University of Arizona Athletic Department and de-identified by one of the department's employees.

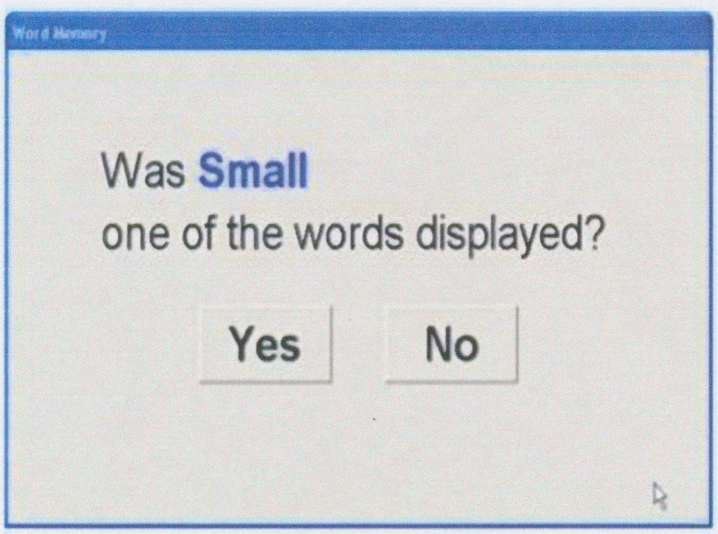
Study Design and Procedures

ImPACT test

The ImPACT test was completed in the athlete's first week of school during their freshman year. Three sections make up the test. Section one involves collecting demographic information and health history. In section two the participants complete a current concussion symptoms and conditions component comprised of rating 22 concussion symptoms on a 7-point Likert scale. Finally, in section three athletes complete a series of cognitive tests, which comprise six tests. For the purposes of this study the focus was on section three, the cognitive measures. The names of the tests are as follows: Word Memory, Design Memory, X's and O's, Symbol Matching, Color Match, and Three Letter Memory (ImPACT Applications, Inc., 2011). These tests consist of a number of different measures (e.g., reaction time, accuracy) that were combined to form the different composite scores. Below are the descriptions of each of these tests from the ImPACT Test Technical Manual Online 2007-2012, and what aspect of the test contributed to each of the composite measures.

Word Memory. This task evaluates attentional processes and verbal recognition memory using a word discrimination paradigm. Twelve target words are presented one at a time for 750 ms, and this occurs twice to facilitate the learning of the list. The subject's recognition is then tested via presentation of a 24-word list. The 24-word list consisted of 12 target words and 12 non-target words. The non-target words were chosen from the same semantic categories as the target words. Subjects responded by mouse-clicking the "yes" or "no" buttons (see Figure 1). Individual scores were provided both for correct "yes" and "no" responses as well as a total percent correct score. The verbal memory composite score utilized the total percent correct in recall for the Word Memory test.

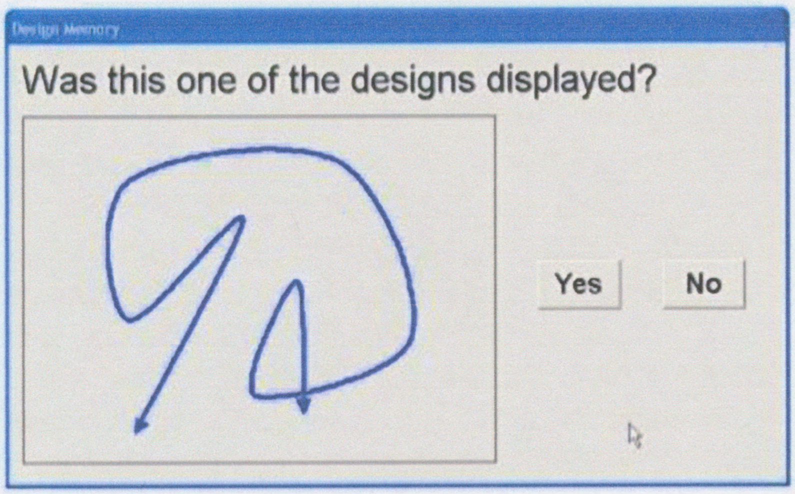
Figure 1. Word Memory Recognition Test



Design Memory. This task assesses attentional processes and visual recognition memory utilizing a design discrimination paradigm. Twelve target designs are presented one at a time for

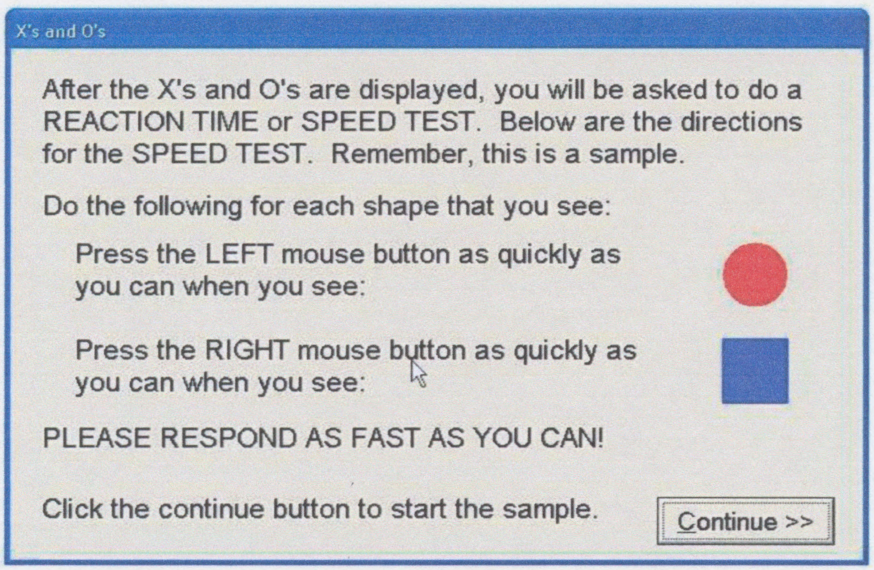
750 ms, and this occurs twice to facilitate learning. The subject is then tested for recognition of the 24 designs that was comprised of 12 target designs and 12 non-target designs. The subject responded by mouse-clicking the "yes" or "no" buttons (see Figure 2). Individual scores were provided both for correct "yes" and "no" responses as well as a total percent correct score. The Visual Memory composite utilized the total percent correct of design recall from the Design Memory test.

Figure 2. Design Memory Recognition Test.



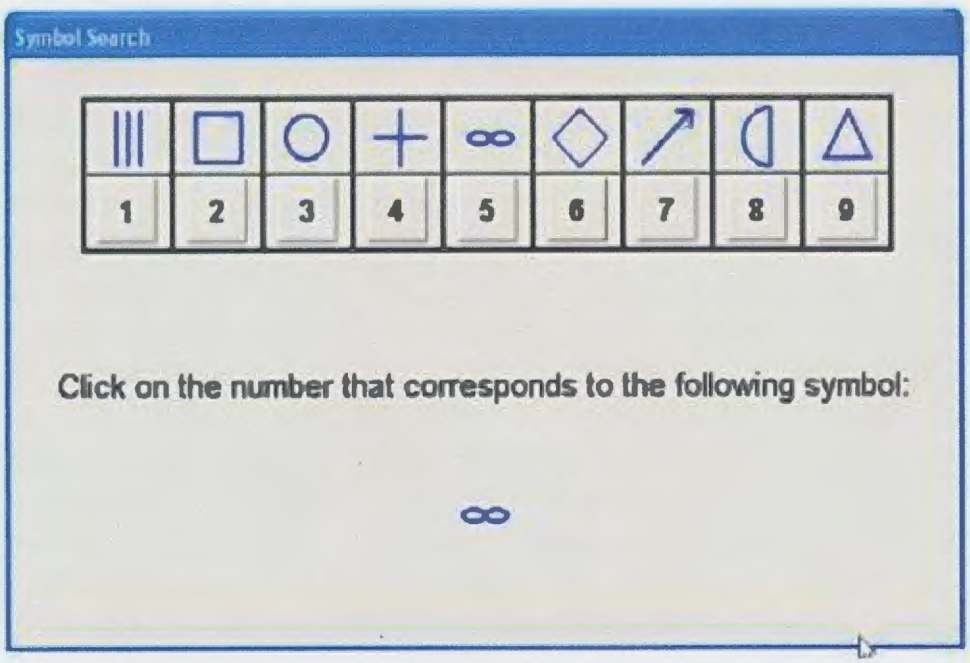
X's and O's. X's and O's is a measure of visual working memory as well as visual processing speed. It consists of a visual memory task and a reaction time distracter task to interfere with memory rehearsal. The subject practices the distracter task prior to presentation of the memory task. The distracter task is a choice reaction time test and several scores from this task are incorporated into the various composite measures. During this task, the subject is asked to take a specific action if a blue square is presented or if a red circle presented (see Figure 3). Once the subject completes the task, the memory task begins. First, a random assortment of X's and O's is displayed for 1.5 seconds. During each trial, three of the X's and O's are illuminated in yellow, and the subject has to remember their location. Immediately after the presentation of the three X's and O's, the distracter task re-appears on the screen. Following the distracter task, the memory screen (X's and O's) re-appears and the subject is asked to click on the previously illuminated X's and O's. Scores are provided for correct identification of the X's and O's (memory), reaction time for the distracter task, and the number of errors on the distracter task. Four trials occurred for each test. The Impulse Control composite utilizes the number of errors during the distracter task of X's and O's. This section of X's and O's was compared on its own with the hitting statistics. The Visual Motor Speed composite utilizes the number correct on the distracter task of X's and O's. Visual Memory composite utilizes the total correct from X's and O's recall. Reaction Time composite utilizes the average reaction time for the distracter task.

Figure 3. X's and O's Reaction Time Distracter Test.



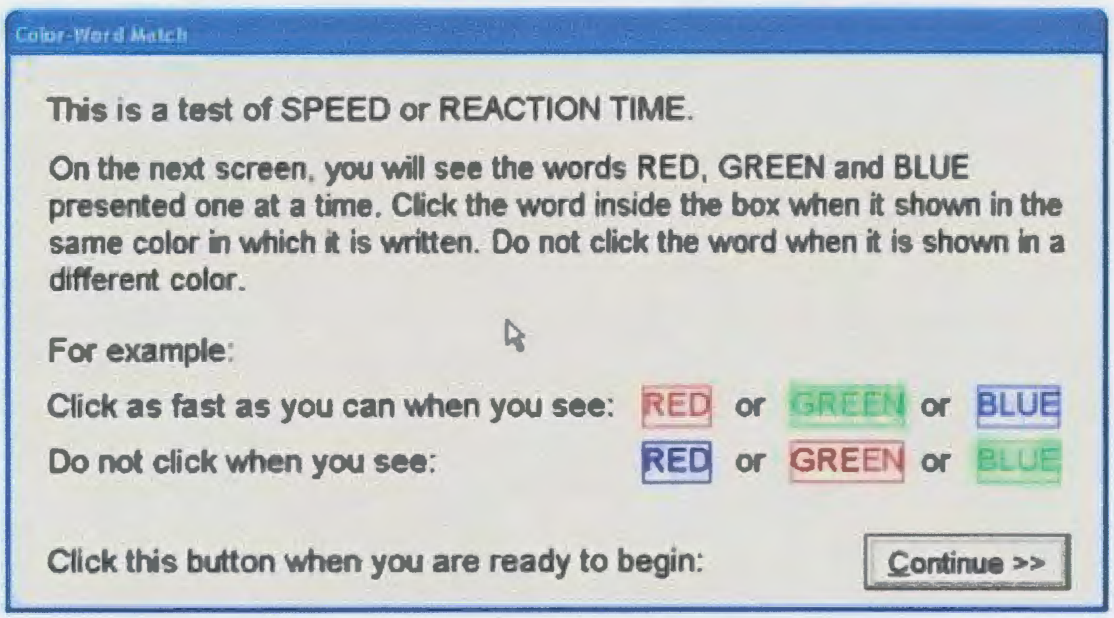
Symbol Matching. This task evaluates visual processing speed, learning, and memory. Initially, the subject is presented with a grid of symbols and numbers. The top row of the grid displays common symbols (triangle, square, arrow, etc) and directly below each symbol is a numbered button from 1 to 9. Each symbol goes with a number. Below this grid, a symbol is presented on the screen (see Figure 4). The subject's task is to two-fold; click the matching number as quickly as possible and remember the symbol/number pairings. Correct performance is reinforced through the illumination of a correctly clicked number in **GREEN.** Incorrect performance illuminates the number button in **RED.** Following the completion of 27 trials, the symbols disappear from the top grid. The symbols then appear below the grid, and the subject is asked to recall the correct number that is paired with it by clicking the appropriate number button. This test provides an average reaction time score for the initial symbol number matching (i.e., the 27 trials) and a score for the memory condition (i.e., how many correct symbol-number pairs they were later able to recall). Verbal Memory composite utilizes the total correct recall. Reaction Time composite incorporates the average correct reaction time.

Figure 4. Symbol Matching Test.



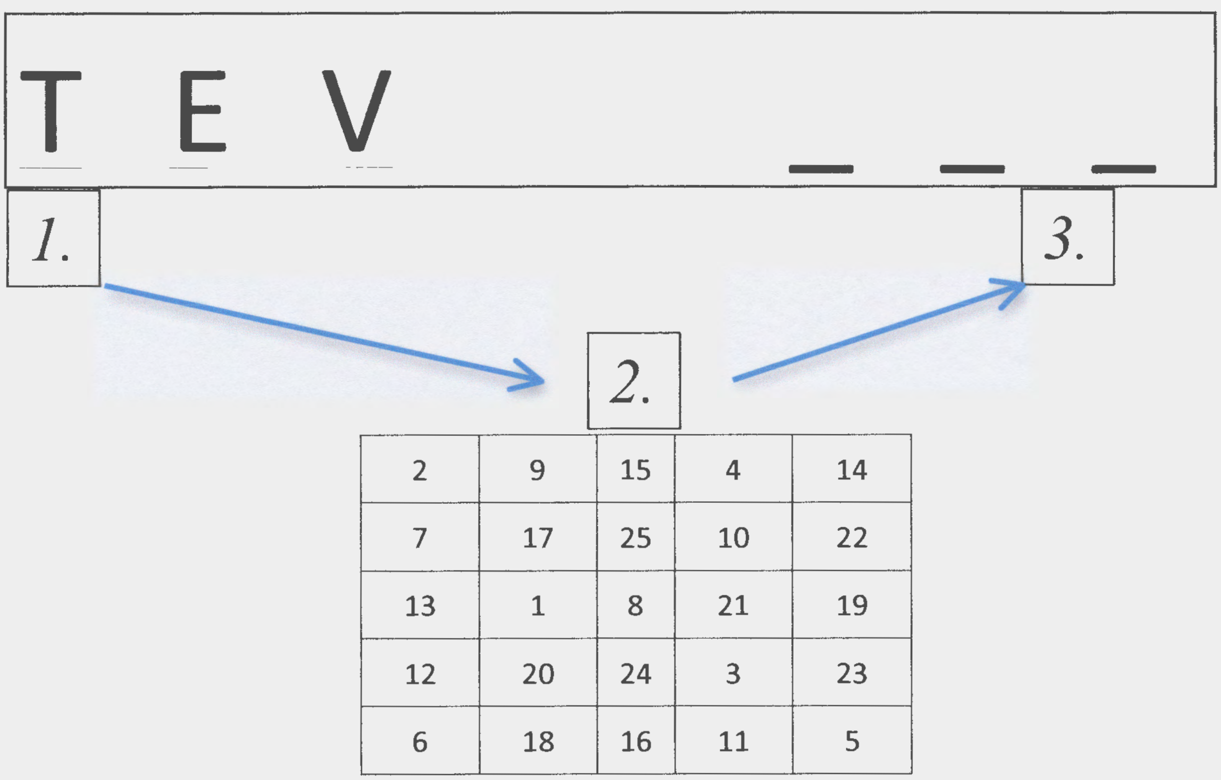
Color Match. This task is a choice reaction time task and also measures impulse control and response inhibition. First, the subject is required to respond by clicking a red, blue or green button as they are presented on the screen (see Figure 5). This procedure is completed to assure that subsequent trials will not be affected by color blindness. Next, a word is displayed on the screen in the same colored ink as the word or in a different colored ink. For example, the word "red" is presented in red ink, in the case of the former, or possibly blue or green ink, in the case of the latter. The subject is instructed to click in the box as quickly as possible only if the word is presented in the matching ink (i.e., the word and ink color are congruent). Impulse Control composite utilizes the number of correct associations between color and word. Additionally, Reaction Time composite incorporates the average correct reaction time.

Figure 5. Color Matching Decision-Making and Inhibition Task.



Three Letter Memory. This last task measures working memory and visual-motor response speed. First, the athlete is allowed to practice the distracter task, which consisted of 25 numbered buttons (5 x 5 grid). The athlete is instructed to click as quickly as possible on the numbered buttons in backward order starting with "25." Once the athlete completes this initial practice task, he or she is presented with three consonant letters on the screen. Immediately following the display of the three letters, the numbered grid re-appears and the athlete is instructed to click the numbered buttons in backward order as quickly as possible. After a period of 18 seconds, the numbered grid disappears and the athlete is asked to recall the three letters by typing them from the keyboard. Both the number placement on the grid and letters displayed are randomized for each trial. This test yields a score for memory (total number of correctly identified letters) and a score for the average number of correctly clicked numbers per trial from the distracter test. Five trials of this task were presented for each administration of the test. The Visual Motor Speed composite uses the average counted correctly on the distracter task. Additionally, Verbal Memory composite uses the percent of total letters correct.

Figure 6. Three Letter Memory Test



Note: Sequence of task: 1. Three letter consonants are first presented to the subject. 2. Then the countdown distracter task is presented for 18 seconds. 3. Three blank spots appear on the screen and the subject must recall the three letters from the first step.

Hitting statistics.

The hitting statistics were collected on the at-bats of the player's freshman year. The freshman at-bats were assessed, because they were the most temporally proximal to the completion of the ImPACT test. The following statistics were measured: batting average, walks, strikeouts, slugging percentage, and on-base percentage (see below for how these statistics are calculated). All of the data came from the Arizona Baseball website and the public has free access to the information.

Calculation of the ImPACT and Hitting Statistics

ImPACT scores. Each ImPACT composite score arose from unique combinations of the various tests (ImPACT Applications, Inc., 2011) (See TABLE 1). The Verbal Memory composite came from the average of the following scores: Word Memory (test 1) total percent correct, Symbol Match (test 4) total correct hidden symbols, and Three Letters (test 6) total percent of total letters correct. The Visual Memory composite came from adding Design Memory (test 2) total percent correct score and X's and O's (test 3) total percent correct memory score. The value was then divided by two. Visual Motor Speed composite came from X's and O's (test 3) total number correct during distracter task divided by four. This value was then added to the average counted correctly from the countdown phase of Three-Letters test (test 6) multiplied by three. This value was then divided by two. The Reaction Time composite was derived from the average reaction time from the correct responses in the distracter task in X's and O's (test 3) plus the Symbol Match (test 4) correct response average reaction time plus the Color Match (test 5) correct average reaction time. This summed value is then divided by three. Impulse Control composite was derived by adding the X's and O's (test 3) total incorrect on the distracter phase to the Color Match (test 5) total incorrect matches of color and word. The CEI is derived from the Symbol Match Score (Test 4) test. The formula for CEI is the (Total Correct responses when the symbols are hidden divided by 9) multiplied by (one minus reaction time when the symbols are visible divided by three), namely (Total Correct Hidden/9)*(1-(Rxn time visible/3)).

Table 1 Composition of Composite Measures

Impulse Control	a). Color Match: # of incorrect associations between color and word b). X's and O's: # errors on the distracter task
Visual Motor Speed	a). X's and O's: # correct on distracter task b). Three Letter Matching: Avg. counted correctly on distracter task
Visual Memory	a). Design Memory Total % Correct b). X's and O's total correct
Verbal Memory	a). Word memory: Total % correct b). Symbol Match: Total # of correct recall c). Three Letter Matching: % of total letters correct
Reaction Time	a). X's and O's: Avg. correct RT for distracter task b). Symbol Match: Avg. correct RT c). Color Match: Avg. correct RT
CEI	a). Symbol Match: Total correct recall and average reaction time for recall
Impulse Subtest	a). X's and O's: Total incorrect during interference phase

Hitting Statistics. The baseball statistics batting average, walks, strikeouts, slugging percentage, and on-base percentage all define a hitter differently. A batting average is defined as the number of hits divided by at-bats. A hit (H) occurs when a player reaches base by making contact with the ball and no fielding errors take place. If a player does this on 10 out of 20 at-bats their batting average is .500 (i.e., 10/20 =.500). An at-bat is an opportunity to get a hit. If a hitter endures a walk, hit by pitch (HBP), or sacrifice fly, they will not be counted as an at-bat.

A walk, also known as base-on-ball, (BB) occurs when a hitter does not swing at four pitches outside of the strike zone and they are awarded first base. HBP is when the player is hit by the ball during an at-bat. A sacrifice fly is when a ball is hit in the air, a player in the field catches it in their glove, and a base runner scores. A strike out happens when a third strike is across the plate and the player does not swing, or the player swings and misses. Slugging percentage represents the total bases achieved on hits divided by at-bats. For example, if a player hit a double (two bases) and a single (one base) in four at-bats, his slugging percentage would be .750. Finally, on-base percentage is the number of times the athlete reached a base (H + BB + HBP) divided by at-bats plus walks plus hit by pitch plus sacrifice flies. See TABLE 2 for a summary of the calculations used to generate the hitting statistics.

Table 2 Calculation of hitting statistics

Statistic	Description
Batting Average	Number of hits / by at-bats
Walk percentage	Number of walks / by at-bats
Strikeout Percentage	Number of strikeouts/ by at-bats
Slugging Percentage	Total bases achieved on hits / by at-bats
On-Base Percentage	Number of times reached base / by at-bats plus walks plus hit by pitch plus sacrifice flies.

Data Analysis

The data were analyzed with multiple Pearson's bivariate correlations in Statistical Package for the Social Sciences (SPSS). All correlations between cognitive scores on the ImPACT test and hitting statistics were run although only those hypothesized to be associated were examined. The alpha level was corrected to .01 to control for family wise error and reduce the probability of a Type 1 error.

Results

Assessing the Correlations of the Composite Scores and CEI with Hitting Statistics

The results of the Pearson's bivariate correlations indicated no significant relationship between the hitting statistics and the ImPACT composite Scores or the CEI (see TABLE 3). While this is in line with the second hypothesis (i.e., that the Verbal Memory and Reaction Time composite scores would not be correlated with hitting performance) the first hypothesis was not supported (i.e., that Visual Memory, Impulse Control, and Visual Motor Speed composites would be correlated with hitting performance).

Table 3 Correlations between Composite Scores and the CEI on the ImPACT test and Hitting Statistics

		VisMotor Spd	Mem (Verb)	Rxn Time	Imp Ctrl	Score	Mem (Vis)
BA	Pearson Correlation	0.21	0.00	-0.19	-0.12	0.04	0.00
	Sig. (2-tailed)	0.29	1.00	0.35	0.55	0.85	1.00
S%	Pearson Correlation	0.21	0.12	-0.17	-0.13	0.20	-0.25
	Sig. (2-tailed)	0.29	0.55	0.41	0.52	0.33	0.21
OBP%	Pearson Correlation	0.15	-0.07	-0.18	-0.14	-0.07	-0.15
	Sig. (2-tailed)	0.46	0.73	0.36	0.48	0.75	0.45
StrikeOut%	Pearson Correlation	-0.06	0.01	0.09	0.01	-0.11	0.19
	Sig. (2-tailed)	0.76	0.96	0.64	0.96	0.59	0.34
Walk%	Pearson Correlation	-0.02	-0.07	-0.07	-0.18	-0.07	-0.07
	Sig. (2-tailed)	0.91	0.73	0.72	0.37	0.73	0.74

Note: VisMotorSpd=Visual Motor Speed composite score, Mem(verb)=Verbal Memory composite score, RxnTime=Reaction Time composite score, ImpulseControl=Impulse Control composite score, Score= CEI, Mem(Vis)=Visual Memory composite, BA=Batting Average, S%= Slugging Percentage, OBP%=On-Base Percentage, StrikeOut%=Strike Out Percentage, Walk%=Walk Percentage

Assessing the Subcomponent Score of the Impulse Control Composite

Given that the first hypothesis was not supported, a Pearson's bivariate correlation was conducted on the X's and O's total incorrect on the distracter task (as per the third hypothesis). The results of this correlation were also not significant. (see TABLE 4).

TABLE 4 Correlation between X's and O's score and hitting performance

		BA	S%	OBP%	StrikeOut%	Walk%
xandointerfer	Pearson Correlation	-0.073	0.209	-0.079	0.249	0.029
	Sig. (2-tailed)	0.718	0.295	0.695	0.211	0.888

Note: xandointer=X's and O's total incorrect during distracter task, BA=Batting Average, S%= Slugging Percentage, OBP%=On-Base Percentage, StrikeOut%=Strike Out Percentage, Walk%=Walk Percentage

Discussion

While the results supported the second hypothesis, that verbal memory, reaction time, and CEI would not predict hitting performance, this finding is tempered by the fact that no correlations were found between any of the ImPACT test scores and hitting performance. Specifically, and in contrast to the first and third hypotheses, Visual Memory, Visual Motor Speed, and Impulse Control composite scores along with the X's and O's subtest did not predict any hitting performances (i.e., batting average, slugging percentage, on-base percentage, walk percentage, and strikeout percentage). The purpose of this study was to investigate the potential of the ImPACT test for predicting performance in baseball hitting in non-neurologically affected collegiate players. If such effects were found, one possible application might be to use ImPACT performance to assist the selection process during recruitment of student-athletes. Unfortunately, the results suggest that the ImPACT test does not posses the specificity or sensitivity to make such predictions. However, there were a number of limitations in the study that may have made it difficult to find such correlations.

The potential limitations in the study included small sample size, low power, limited range of athletic performance in the subjects, and possible suboptimal sensitivity and specificity of the ImPACT test. The combination of the low sample size and the fact that the population consisted of division 1 collegiate baseball players may have reduced the range of performance on the ImPACT test, making it difficult to find significant correlations. An extension of this study could incorporate high school and adolescent individuals to increase the range of performance as well as increase the power. Additionally, the ImPACT test may not be measuring the specific aspects of impulse control, visual motor speed, and visual memory that past research has shown to differentiate the hitting abilities of baseball players (Gray, 2002; Kida & Matsumura, 2005; McPherson & MacMahon, 2008; Regan, 1997).

Visual memory. After further consideration of the type of memory utilized and measured in the ImPACT test (declarative), it is perhaps not surprising that this task did not predict performance. Baseball players may have been more likely to utilize procedural or semantic memory mechanisms to encode/retrieve the relevant information and thus no relation was found between the Visual Memory composite and the hitting statistics (Gray, 2002). However, the contributions of visual memory should not be discounted altogether. Visual memory may contribute to the player's hitting ability as found in previous studies (Gray, 2002; McPherson & MacMahon, 2008). A potential significant difference may be that the ImPACT test assesses visual memory on stationary objects whereas the type of visual memory needed for baseball involves moving objects at very high speeds (Regan, 1997).

Visual Motor Speed. The ImPACT Technical Manual defines the Visual Motor Speed composite as a combination of visual processing, learning and memory, and visual-motor response speed. Each of these areas would appear to play an important role in a player hitting successfully (Gray, 2002; McPherson & MacMahon, 2008; Regan, 1997). It is possible , however, that the ImPACT test does not capture the differentiation in visual motor speed ability that results in various levels of hitting performance. In other words, the ImPACT test does not measure the type of visual motor speed ability that results in differences in performance across baseball players, but instead a different form of visual motor speed.

Impulse control. Impulse control also would appear to play a crucial role in one's ability to perform when hitting a baseball. The ability to not swing at a bad pitch and only hit favorable pitches differentiates the caliber of hitter (Kida & Matsumura, 2005). Again, the tests that make the Impulse Control composite do not utilize moving objects. The interference phase of X's and O's has stationary objects and also uses a multiple-task paradigm which increases cognitive load. The second contributor to the composite score, the Color Match Total Commissions, utilizes word stimuli, and identifying words does not occur when selecting the correct pitch during an at-bat. Therefore, different mechanisms in the brain could be used for various types of impulse control: utilizing solely motor functioning for moving objects and a different system for stationary objects (Aron, 2007; Gray; 2002; Sakagami 2006).

Conclusions

Perhaps a natural extension of this study is to examine whether the ImPACT test could be used to predict athletic performance in athletes who have sustained a concussion. In other words, would any correlation be found between the ImPACT scores after a concussion and the subsequent athletic performance? Currently, it is unclear whether a concussion actually affects player's performance. A potential study could involve utilizing the ImPACT test to identify the progress of the concussion and at the same time subjects could be assessed for non-contact athletic skills to better understand the association between concussions and their effects on athletic performance.

The goal of this study was to find a way to measure various cognitive abilities and use them to predict the abilities of collegiate baseball hitters. The derivation of such an algorithm might result in an additional dimension to recruiting and evaluating athletic potential and development. Unfortunately, the results from this study did not support the hypothesis and instead suggest that the ImPACT test does not predict hitting performance in non-concussed collegiate baseball players. However, given the limitations of the current study (i.e., small sample size, low power, and restricted range), additional investigations are needed to clarify the association between the ImPACT test and hitting performance.

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