9-15-2013

CORRELATING THE PURDUE SPATIAL VISUALIZATION TEST WITH THE WONDERLIC PERSONNEL TEST FOR AMERICAN FOOTBALL PLAYERS

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Graduate School ETD Form 9
(Revised 12/07)

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CORRELATING THE PURDUE SPATIAL VISUALIZATION TEST WITH THE WONDERLIC PERSONNEL TEST FOR AMERICAN FOOTBALL PLAYERS

For the degree of Master of Science

Is approved by the final examining committee:

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CORRELATING THE PURDUE SPATIAL VISUALIZATION TEST WITH THE WONDERLIC PERSONNEL TEST FOR AMERICAN FOOTBALL PLAYERS

A Thesis

Submitted to the Faculty

of

Purdue University

by

Karthik Sukumar

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

December 2012

Purdue University

West Lafayette, Indiana

For my grandfather whom I fondly called Appapa. I know he would have been extremely proud to see me do well. This is also dedicated to my grandmother who has protected me all my life. This thesis would have been incomplete without the love and affection of my parents. My second parents who have loved me and taken care of me like a son, my Periappa and Geethamma. I cannot thank you enough.

ACKNOWLEDGEMENTS

Firstly, I would like to thank Dr. Craig Miller for going out of his way to help me complete this research. His undying perseverance and ability to push me into doing my best cannot be reiterated enough.

Dr. Mohler, if it were not for your CGT 600 course in spatial ability, I would never have conducted research in this field. Thank you very much for your invaluable advice right from the start of my graduate program in Computer Graphics Technology (CGT).

I would like to thank Dr. Connolly for serving on my committee and helping me refine my thesis. Your guidance goes a long way into the completion of my thesis.

Thanks to Maria Nizovtseva, for being a great friend throughout the course of my Master's degree. We have been through everything and this journey has been amazing. Thank you.

For their assistance with the statistical analysis for my thesis, Faye Zheng and Xiaosu Tong, I am very grateful. Their selfless help with my thesis cannot go unmentioned.

I would also like to thank my sister-in-law, who is like a sister to me. Her support throughout the course of this thesis was very valuable. Thank you Ush!

I would also like to thank Chris Menezes for being a good friend during my time at Purdue. This thesis would be incomplete without thanking my amazing group of friends known as Chads. Thank you everyone for just being a great group. Thanks to Anuya, Raghav and Ramya for bearing with me while I struggled to complete my thesis.

Without the help of all the people mentioned above, this research would never have been possible. Finally, a big thanks to Angie Schutz and Regina Brown from the Department of Computer Graphics Technology for helping me with little problems I had during the course of my Master's degree.

TABLE OF CONTENTS

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Sukumar, Karthik. M.S., Purdue University, December 2012. Correlating The Purdue Spatial Visualization Test With The Wonderlic Personnel Test For American Football Players. Major Professors: Craig L. Miller and James L. Mohler.

This research study aims to find the relationship between the scores for the Purdue Spatial Visualization test (PSVT) and the Wonderlic Personnel test (WPT) for American collegiate football players. Fifty-five collegiate football players took part in the study by attempting the PSVT and the WPT. The scores on these tests were compared to find if there existed a correlation between the scores on both these tests. The results showed that the scores on both these tests had a significant correlation with respect to each other. But, the group that took the WPT before the PSVT showed a lower correlation between the scores. It was also observed that the age of the participants had a low/negative correlation to the scores on both the PSVT and the WPT, which can be a important topic of future research. The study proposes a more dynamic visualization measurement, which will be able to help scouts and coaches predict performance of athletes over a period of time.

CHAPTER 1. INTRODUCTION

This chapter introduces the essential aspects of the study being conducted. The research statement is specified in the beginning. The section then discusses the primary reason behind the study being conducted as explained by the statement of purpose, scope and significance. Important definitions focusing on the field of spatial ability and the study in general are specified. The imperative assumptions, limitations and delimitations integral to the research are also provided.

1.1 Research Question

This research investigates one primary research question.

- Is there a correlation between the Purdue Spatial Visualization Test (PSVT) and the Wonderlic Personnel Test (WPT) for American football players?

1.2 Statement of purpose

The purpose of this research is to understand and account for the differences between the Wonderlic Personnel Test (WPT) and the Purdue Spatial Visualization Test (PSVT). A correlation between these tests will raise the question as to whether a test specifically for American football is required in order to gauge a sportsman's ability to understand the space around him, because the Wonderlic test does not measure that ability in individuals.

Research conducted in the past has provided support that spatial ability is an important factor when it comes to sports (Lord & Garrison, 1998). Sportsmen and sportswomen have been known to have high visualization ability and usually score well on spatial ability tests (Glasmer & Turner, 1995). A spatial ability test measures the cognitive ability of an individual relate to rotation, visualization, and orientation.

The implications of this research could be far reaching, because the comparison between the WPT and PSVT might assist in understanding the need for a visualization test for football. Examining the performance of football players using spatial ability tests could provide information and answer to the above question.

1.3 Scope

Since 1970, the Wonderlic test has been extensively used to measure the intelligence of amateur college football players at the NFL Combine (Gill & Brajer, 2011). The NFL Combine is an event that is conducted every February in Indianapolis, Indiana. College football players participate in the event, but only through invitation. The players are tested on a variety of abilities, including mental and physical. Some examples

of the physical abilities tested are the 40-yard dash, 225-lb bench press and the 3-cone drill. The Wonderlic test is part of the mental testing procedure. All of the above-mentioned tests are an integral part of the draft procedure. Hence, teams give importance to the performance of football players on these abilities while drafting them.

On the other hand, spatial ability research has been active since the early 1900's (Eliot & Smith, 1983). Over the years, its importance in sports has been realized. Also, and most importantly, athletes have been known to perform exceedingly well on spatial ability tests, their scores being significantly higher than non-athletes (Lord & Garrison, 1998). Although, spatial tests have primarily not been used to understand the performance of athletes, its significance has been researched and well documented.

The dominant problem that has existed with the Wonderlic test is its inability to predict the performance of football players in the NFL (Dodrill, 1983). The test has failed in its endeavor, allowing for intense scrutiny and controversy (Dodrill, 1983). As it is known that spatial ability is high among athletes, it was deemed interesting to correlate the Wonderlic test and a spatial test to understand if there exists any commonality. The chief reason behind this correlation is to investigate the need for a spatial ability test that would be able to predict performance in the NFL in a better way than the Wonderlic test. A correlation between these tests would assist in answering this question while understanding the relationship among the variables involved in playing football.

The participants were American football players. These football players were chosen from a Big Ten institution. Hence, the validity of the football players was high, because they play in a competitive tournament. The football players were administered both the tests, one after the other. Both the tests were paper-based, rendering it easy to

monitor and calculate results. The scope was limited to intelligence and spatial ability testing.

1.4 Significance

A positive or negative correlation would answer some of the fundamental questions pertaining to the validity of the Wonderlic test. It would also assist in understanding the importance of visualization in football on a larger scale than it is currently understood. Also, the intrinsic factors that might have a role to play in visualization on the field will be recognized and evaluated.

The study might bring about a new aspect of football that has never been tested before. Until recently, the only test that has been administered to the football players in order to understand if intelligence can predict their performance is the Wonderlic Personnel test. But, the ability to visualize has not been used to understand the playing ability. A negative correlation can assist in understanding the importance of spatial ability in football. Mental imagery might also play a major role in the selection of players to the NFL. This research study could pave the way for a new football-specific test focused on visualization, rather than general intelligence.

The physical ability of a sportsperson has the possibility of decreasing because of age, but the visualization and mental ability decrease at a slower rate. Also, as far as it is known, a spatial test has never been used to predict performance of American football players.

1.5 Definitions

3-cone drill - It is a measurement of agility, change in direction and power. There are cones placed in an "L" formation and the athletes are supposed to run to each cone repetitively. The time to complete the entire task is calculated (McGee & Burkett, 2003).

40-yard dash - It tests anaerobic power, acceleration and speed. Time is recorded to complete 40-yards. Times are also recorded for 10-yards and 20-yards (McGee & Burkett, 2003).

225-lb bench press - The 225-lb bench press measures the upper body strength and athletes are instructed to complete as many repetitions as possible (McGee & Burkett, 2003).

Big Ten institutions - A collection of 12 universities that share a common goal of world-class research, technology and education. Athletics form an important part of their goal.

spatial ability - "Some scholars describe spatial ability broadly in terms of individual differences in the processing of non-linguistic information, while others describe it narrowly in terms of individual differences in performance on spatial tests" (Eliot & Smith, 1983, p. 1).

spatial orientation - Comprehending the arrangement of elements within a visual stimulus pattern and also the ability to remain unconfused by the changing orientation in which it is presented (McGee, 1979).

spatial relations - The speed in manipulating simple visual patterns by rotation, translation or transformation (Carroll, 1993).

visualization - "An ability to visualize a configuration in which there is movement or displacement among the internal parts of the configuration" (Thurstone, 1950, p. 518).

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1.6 Assumptions

The following assumptions are integral to the study being conducted:

1. The football players performed to the best of their ability on both the tests.
2. The Wonderlic Personnel test (WPT) and the Purdue Spatial Visualization test (PSVT) were accurate in their measurement of intelligence and spatial ability respectively.
3. The numbers of participants in the study were sufficient for correlational analysis.
4. The method chosen for this study was an appropriate representation of the research question.
5. The other factors in football do not affect the spatial ability of the football players.

1.7 Limitations

The following limitations are integral to the study being conducted:

1. This study was limited to the number of football players willing to participate in the study.
2. This study was limited to the accuracy of the WPT and the PSVT.
3. The study was limited to the co-operation of the football players participating in the study.
4. This study was limited to the amount of time provided by the football coach and team to test the players.
5. This study was limited to the information provided by the football team.
6. The study was limited to intelligence and spatial ability testing only.

1.8 Delimitations

The following delimitations are integral to the study being conducted:

1. The study was delimited to the American football team being tested.
2. The study was delimited to the facilities available at the Purdue University campus in West Lafayette, Indiana.
3. The visualization and intelligence of the football players.

1.9 Chapter Summary

This chapter outlined essential information about the study being conducted. It stated the research questions being investigated along with its scope and significance. The important assumptions, limitations and delimitations were delineated. The section also provided information on the reason for which the research is being conducted along with its importance for the future of sport. The following section will provide information on studies conducted pertaining to spatial ability and the Wonderlic Personnel Test.

CHAPTER 2. REVIEW OF LITERATURE

Spatial ability has been researched for over a hundred years. Although, the field is not widely known, its application is far reaching. Through the late 1800's and early 1900's spatial ability was not regarded as an essential component of intelligence. The understanding of spatial ability was included as a part of general intelligence 'g' as defined by Spearman (1927).

This review will define the importance of spatial ability by giving a brief overview of its history, the factors of spatial ability and its importance in sports. The focus will then shift towards the Wonderlic Personnel Test or the Wonderlic cognitive abilities test and how it relates to performance in the NFL. Its primary usage deals with testing intelligence of amateur football players at the NFL Combine every year before the NFL draft.

2.1 Approach to the literature review

The approach to this section was specific because of the vastness in spatial ability research. It was important to understand the essential characteristics of the research and state them. The papers discussed in the review have been collected from psychology journals as well as independent research conducted on spatial ability.

Essentially, spatial ability affects all walks of life including engineering, art, mathematics, mechanical design and music (Fennema & Sherman, 1977; Mohler, 2006). Research on spatial ability pertaining to sports has different aspects associated with it. The collection of articles related to this field primarily comes from sports psychology journals. A minimal amount of information on testing athletes has been presented in educational journals as well.

Research on the Wonderlic Personnel Test (WPT) focuses on its relationship with NFL performance and the position in the NFL draft (Berri & Simmons, 2011; Gill & Brajer, 2011). The research discussed pertaining to the WPT is primarily from sports journals, websites and independent studies. The variation in the collected research provides for interesting observations.

2.2 A brief history of spatial ability

Spatial ability research was nascent in 1883 when Galton projected his theory of imagery using spatial sense (Eliot & Smith, 1983). Later, Spearman in 1905 developed his two-factor theory of intelligence. He divided intelligence into general intelligence 'G' and several group specific factors 'S'. Simon and Binet developed the first spatial ability test around the same time Spearman proposed his theory. It was known as the "Scales of Intelligence" (Eliot & Smith, 1983).

Spatial ability research started gaining importance at the onset of World War I in 1918, when the United States Army conducted large scale testing procedures in order to enroll military personnel. These tests were called as Examination Alpha and Examination Beta (Eliot & Smith, 1983). Examination Alpha was administered to literate personnel

and consisted primarily of verbal material. Examination Beta was the battery of tests that included non-language tests, which were administered to the un-educated personnel. This was the first time that non-language and performance-based tests were administered on a large scale. Tests analogous to Examination Beta were later developed to test children for school enrollment and evaluate candidates for various occupations (Eliot & Smith, 1983). This was one of the first instances of a spatial ability test being used for selection of candidates. Later, Alexander (1935) and Kohs (1923) provided evidence for the existence of a spatial factor. The major breakthrough came when El Koussy (1935) proposed a group factor 'K' in the scores from spatial tests.

Over the years and predominantly between 1938 and 1961, researchers found spatial factors that differentiated from one another (Eliot & Smith, 1983). Lohman (1979) categorized spatial ability into three primary spatial factors. The factors were called visualization, spatial orientation and spatial relations. The definitions for these factors differed from researcher to researcher and caused considerable confusion during that period. Visualization is "An ability to visualize a configuration in which there is movement or displacement among the internal parts of the configuration" (Thurstone, 1950, p. 518). Comprehending the arrangement of elements within a visual stimulus pattern and also the ability to remain unconfused by the changing orientation in which it is presented was spatial orientation (McGee, 1979). Carroll (1993) defined spatial relations as the speed in manipulating simple visual patterns by rotation, translation or transformation.

2.3 Mental imagery and spatial ability in sport

Mental imagery can be defined as the ability to create pictographic representations in one's mind. The term 'mental imagery' is somewhat analogous to spatial ability because it assists in developing one's ability to visualize. Similarly, increased spatial visualization helps improve mental imagery (Ozel, Larue, & Molinaro, 2004). Mental imagery in sport has existed for a long time as sports psychologists have proposed this as an essential way to improve on-field performance (Hall, Rodgers, & Barr, 1990). Athletes use mental imagery to imagine themselves in a specific environment performing sporting activities. Creating mental representations of certain events assists in coordinating it with one's actual on-field performance (Martens, 1987; Rushall, 1992).

The earliest account of the use of mental imagery was studied when Mahoney and Avener (1977) distributed imagery questionnaires to 13 male gymnasts during the final trials for the U.S. Olympic team. The study concluded that the gymnasts who were selected into the Olympic team had superior levels of cognitive functioning and incorporated better mental imagery techniques. Kang, Mohler, Wright, Watts, Barry, and Mohler (2009) studied the effect of visualization on collegiate swimmers by finding a positive correlation between the time spent in visualizing and performance in competitions. Use of mental imagery was reported by elite soccer players in conjunction with competitions more than training and showed an increase in motivational aspects pertaining to the game (Salmon, Hall, & Haslam, 1994).

Another study by Lord and Garrison (1998) proposed that athletes have higher levels of spatial ability than non-athletes. The female athletes did as well as the males and

in some cases better than them on the spatial test. This was interesting because traditionally males have been known to have higher spatial ability than females (Harris, 1978). Hromatko and Butkovic (2009) studied 201 student athletes engaged in different sports by dividing them into three groups. The groups were created based on the levels of risk in playing that sport. The results established that sports involving a larger playing area [football, basketball, track and field] incorporated higher spatial functioning. Lejeune, Decker, and Sanchez (1994) researched the effects of mental imagery rehearsal on table tennis performance. An improvement in performance of the players was observed when mental rehearsal was combined with observational and physical techniques.

Ozel, Larue, and Molinaro (2004) tested the relationship between sport and spatial imagery. Athletes performed mental rotation tasks better than non-athletes and the vividness of their imagery was improved as well. It was also observed that the overall mental manipulation ability increases after engaging in sporting activities. Manning and Taylor (2001) demonstrate that ability in many sports requires visual-spatial judgment, speed, endurance and strength. Football is given as a prime example of one such sport.

Studies show that spatial and motor imagery entails high visual-spatial components (Annett, 1995). Also, sportsmen project high abilities of spatial imagery. High levels of testosterone have been associated with better sporting and spatial abilities (Pillay, 2006). The above results propose that spatial ability might be an important factor in order to perform better in sporting activities. These sporting activities are primarily inclusive of aggressive sports like football and wrestling. It was found to be analogous to males as well as females (Kimura, 1999).

Another study by Cumming and Hall (2002) examined an athlete's use of imagery in the off-season. It also examined whether imagery was part of their physical and technical preparation for competitive games. This subjective test showcased that national level athletes used imagery to assist themselves in better and more sophisticated ways compared to regional level athletes. This research does provide some encouraging results. A similar study exhibited the advantages of a mental imagery workshop to aid basketball players' on-court performance (Cumming, Hall, & Shambrook, 2004). Hult and Brous (1986) found out that men and women athletes use high amounts of visual-spatial skills in order to enhance their on-field performance and vice-versa.

This subsection is a brief overview and a document of justification for the existence of spatial ability in sports. It is difficult to discard the prominence and positive effect of spatial ability in enhancing athletes' on-field performance and imagery along with motor skills. Also, it is clear that spatial ability exists in higher quantities within sports requiring a larger playing area and is synonymous to aggressive sports.

2.4 The Wonderlic Personnel Test

A psychologist called Eldon F. Wonderlic in the 1930's created the Wonderlic Personnel Test [WPT] (Wonderlic Inc., 2011). It is a 12-minute test containing 50 questions. The test is used as an indicator to measure the problem-solving abilities of an individual in a variety of occupations. It came into prominence when Tom Landry of the Dallas Cowboys used it in 1970 to test the intelligence of his players in order to predict future performance (Gill & Brajer, 2011). The NFL has been using the WPT to measure

intelligence of amateur college athletes as a pre-draft assessment at the NFL Combine ever since (Merron, 2007).

The average football player scores 20 on the WPT. The scores vary according to playing positions. The quarterbacks score an average of 24, while the halfbacks score 16 (Gill & Brajer, 2011). In the 1975 draft, Pat McInally of Harvard received a perfect score of 50, which was also the highest score ever documented (McClellan, 2006).

2.5 The Wonderlic and the NFL

The Wonderlic Test has garnered praise as well as a lot of criticism. Studies conducted in relation to WPT and football performance have projected opposing results. Numerous studies have indicated a positive correlation of the WPT with performance, while others have showcased exactly the opposite (Dodrill, 1983; Gill & Brajer, 2011; Hendricks, DeBrock, & Koenker, 2003). Many variables influence performance of football players including 40-yard dash, height and weight. This subsection will detail and discuss some such pertinent studies.

The NFL draft procedure is a very detailed examination of an athlete's physical and mental ability. Berri and Simmons (2011) offer a comprehensive investigation of the draft procedure by emphasizing the complications involved in evaluating quarterbacks. They use statistical evaluations by measuring player performance. The primary statistic used was the NFL quarterback rating measure that was developed by Don Smith in 1971. Another metric explained the quarterback score, which was defined using variables like passing yards, passing attempts and interceptions. This measure provided performance information on the quarterback. There was no relationship between the draft position of

the quarterback and NFL performance. The variables like the 40-yard dash, height and the WPT score affected the NFL performance (Berri & Simmons, 2011).

Quarterbacks drafted earlier get more playing time and a much higher salary than quarterbacks drafted later (Quinn, Geier, & Berkovitz, 2007). However, this does not guarantee better performance from the higher drafted quarterbacks. This showcases the disparity in the quality of football played at a collegiate level and the NFL. Mirabile (2005) sought the relationship between intelligence and passing performance for 84 drafted quarterbacks in their first year of NFL. There was no significant relationship between the intelligence of quarterbacks and their passing performance. The same study also projected that players that obtained a higher score were not drafted earlier than others or paid more. Also, the other players on the team aid the quarterback's performance. A similar study by Kuzmits and Adams (2008) assessed no significant correlation between WPT and NFL success. NFL success was defined by on-field performance, games played and games started in the rookie year. However, wide receivers with better WPT scores received a higher salary in year two of their NFL career.

Substantial performance differences were noted between drafted and non-drafted players for the 2004 and 2005 seasons based on their measures in the NFL Combine (Sierer, Battaglini, Mihalik, Shields, & Tomasini, 2008). Drafted players typically perform better on 40-yard dash, bench press and the 3-cone drills. This information is useful, as it will aid in understanding the essential factors necessary to get selected into a NFL team. McGee and Burkett (2003) investigated the accuracy of the NFL Combine in predicting the draft status of a player. The NFL Combine tests the performance of the

athletes based on different physical aspects including 225-lb bench press, 40-yard dash [split into 10-yard and 20-yard times], 20-yard shuttle, 60-yard shuttle, 3-cone drill, vertical jump and standing broad jump. The draft status of wide receivers, running backs and defensive backs could be predicted well using information from the Combine. This proposes the positive correlation of the WPT because it is part of the testing procedures as well.

An essential factor of tests of intelligence and cognitive ability is long-term reliability and content validity. Dodrill (1983) tested the validity and reliability of the WPT. The WPT scores of 57 adults were correlated after an interval of five years. A high correlation of 0.90 was observed and its content validity was stable compared to another established test of intelligence called the Weschler Adult Intelligence Scale IQ test. This provides solidity to the test and labels it as an efficient measure of intelligence.

McDavid (1977) tested football players using a football skills and motor ability test. A general correlation was observed between the test scores and the criterion. A significant correlation was also established with the coaches' rankings of the players. A study by Hatch (2009) proposes a football-related intelligence test in place of the WPT. It entails the disparate impact of the WPT in its NFL use as well as in other employment fields. The study argues that African-Americans tend to score less on the WPT in all employment conditions and hence, the test cannot be held valid. Also, it has no bearing on the performance of the player.

Lyons, Hoffman, and Michel (2009) investigated the effect of general mental ability on NFL performances of 762 players. Its effect was also researched on the selection in the NFL draft and the number of games started in the NFL. General mental

ability does not seem to affect NFL performance, selection in the NFL draft or the number games started. Another intriguing research study conducted by Treme and Allen (2009) associates speed, media exposure and success on the field to selection. The amount of articles published about a player in local and national newspapers defined the salary during his rookie year.

In the above-discussed literature, it can be seen that NFL teams look at various factors while drafting players into the team. WPT is just one factor out of the plethora of factors that are measured. The other factors that are important in selecting players include the 40-yard dash, the bench press and the 3-cone drill. Also, the WPT does not seem to play an essential role in drafting players in the first few rounds. It comes into consideration in the latter rounds of the draft when the physical attributes of the players cannot be distinguished easily.

2.6 Review of statistical methods used in Wonderlic analysis

This section will review the different methods of statistical analysis used by researchers while testing an athlete's intelligence. The primary focus is to understand what methodology is best suited for this research and to build a case to explain the same. It will also highlight the effective sample sizes to bring about a reasonable conclusion to studies in this field. The analysis discussed in the following paragraphs highlights the importance of a robust and clear method to evaluate intelligence. Most of the research concentrates on correlation, which is the focus of this research.

The majority of studies conducted on the WPT and NFL performance entail use of t-tests for correlation (Kuzmits & Adams, 2008; Dodrill, 1983; Gill & Brajer, 2011;

Hendricks, DeBrock, & Koenker, 2003; McDavid, 1977; Treme & Allen, 2009). The papers discussed in the previous section, primarily use correlation in order to understand the relationship between the different variables affecting an athlete's performance in the NFL. The NFL Combine statistics that deal with the 40-yard dash, the 225-lb bench press, the WPT score and the 3-cone drill are correlated with pre-draft rankings and predict draft positions based on correlations.

Mirabile (2005) used an F-test to identify and explain relationships between the WPT, NFL Combine performances and draft rankings. Two models were created, one for passing efficiency and the second for total offense per game. After analyzing the mean and standard deviations for the variables in the study, an F-test was used to calculate the significance of both the models.

Another study by Gill and Brajer (2011) applied the Phelps model in order to test if WPT scores were viewed differently for Blacks than Whites. They developed a performance characteristic [see Equation 1] for draft position based on the WPT score, the race of the player and the coefficients that change depending on WPT scores.

Draft position =

$$\beta X_i + \alpha_1 Wonderlic_i + \alpha_2 Black_i + \delta_1 Black_i \times Wonderlic_i + \varepsilon_i \ldots\ldots\ldots(1)$$

The above parameters were described by ordinary least squares (OLS). Finally an F-test was used to calculate the p-value for the test of equality of WPT coefficients. The study observed that the Wonderlic scores were important in realizing the relative draft position for quarterbacks, offensive linemen and tight ends.

Lyons, Hoffman, and Michel (2009) correlated over 15 variables to investigate whether general mental ability played an essential role in NFL draft selection and the

number of games started in the NFL. After correlating all the variables, the z-scores were calculated. The z-scores were then transferred to t-scores because half the values in a z-table are negative.

It can be seen that the methods reviewed above are varied. It is difficult to group all the methods used into one specific analysis. Although, the methods are different, correlation is used predominantly for understanding the relationship between variables. Also, the majority of the studies use t-tests to test significance of the findings.

2.7 Chapter Summary

The WPT has been used for the last four decades to test amateur football players at the NFL Combine. Studies have shown problems existing with the WPT in understanding the relationship between intelligence and football performance. The contents of the WPT appear to focus on aspects that are not essential for enhancing on-field performance. Also, there might exist, a disparity in testing pertaining to different football players.

Hence, it is essential to understand the key components that allow a footballer to mentally perform better in the NFL. It is possible that spatial visualization is the answer. Correlation of the WPT and a spatial test would provide further information on this critical question.

The following chapter will provide information on the theoretical framework of the study. It will also chart a detailed methodology for testing by describing the testing environment, the sample set and the statistical tools to be used.

CHAPTER 3. FRAMEWORK AND METHODOLOGY

The primary motive behind this research was to investigate the existence of a correlation between the Wonderlic test and the Purdue Spatial Visualization test (PSVT). The most productive way to correlate the two tests was using a quantitative analysis. Also, the majority of the research pertaining to spatial and intelligence testing has been analyzed quantitatively.

This chapter will define the methodology used in the current study as well as outline the various aspects of analyzing the collected data. It will focus on the research question, the hypothesis, the variables, the varying levels of data and the sample set. Information on the size of the sample and how access was gained will be briefly mentioned. Finally, the statistical tools used for analysis and comparison of the data will be discussed.

3.1 Theoretical Framework

As mentioned earlier, this study is quantitative, using a correlational study design. The primary reason behind the correlation is the comparison of two different tests. A correlational study primarily focuses on understanding the relation between the different variables present in the study.

As this is a correlational study, there are no independent and dependent variables, because there is no cause-effect relationship being studied.

The following is a list of all the variables in the study:

1. The Wonderlic test scores of the football players. The number of correct questions answered on the test measures this.
2. The PSVT scores of the football players. This is again, measured by the number of correctly answered questions on the test.
3. The testing environment itself.
4. The correlational variable between the two tests.

The following two hypotheses were realized:

- H_o: There is no correlation between the WPT and PSVT scores.
- H_a: There is a correlation between the WPT and PSVT scores.

3.2 Sample Set

As the study being conducted was testing humans, it was necessary to identify the appropriate sample size. This would define the amount of football players needed to project a significant result for the correlation. The football players selected were from a Big Ten institution.

In order to recognize the appropriate sample size for finding a significantly low correlation, a Fischer's z-test for Pearson correlation was used. This test provides information on the sample size needed to understand that the correlation is significantly

low. It identifies the nominal power, by using the alpha value to recognize the sample size. The analysis showed that a correlation of 0.4 or less is needed to significantly specify that the two tests have low correlation. Hence, 0.4 becomes the threshold value for the study to be termed significantly successful. A nominal power of 0.85 was used and it was investigated that a sample size of 53 would suffice to confidently propose a low correlation. The alpha value considered was 0.05.

3.3 Testing Methodology

This subsection is divided into three further sections that provide information on the environment for testing, the permissions required to test human subjects, the ways in which access was gained to the football players and the different statistical tools used for analysis.

The testing was conducted on the July 25th, 2012 at 7 p.m. All the participants signed in before they sat down. Before the testing session began, the participants of the study were offered some pizza and refreshments. The football players participating in the study did not have a training session that particular day. Brief instructions on the purpose of the study were provided to the participants. The voluntary nature of participation for the study was also mentioned.

3.3.1 Environment

The environment created for testing was a very calm and peaceful setting that allowed the football players to perform to the best of their abilities. The participants were divided into two groups. It was conducted in two separate classrooms at the Big Ten

institution. The players were seated in their seats and instructions were provided based on the tests.

The shortened version of the PSVT was used, which contained three sections for visualization, spatial orientation and spatial relations. This amounted to a total of 36 questions, with each section containing 12 questions. Figure 3.1 provides an example of a question from Section 1. For this question, the appropriate three-dimensional object needs to be recognized from the given unfolded pattern (Guay, 1976).

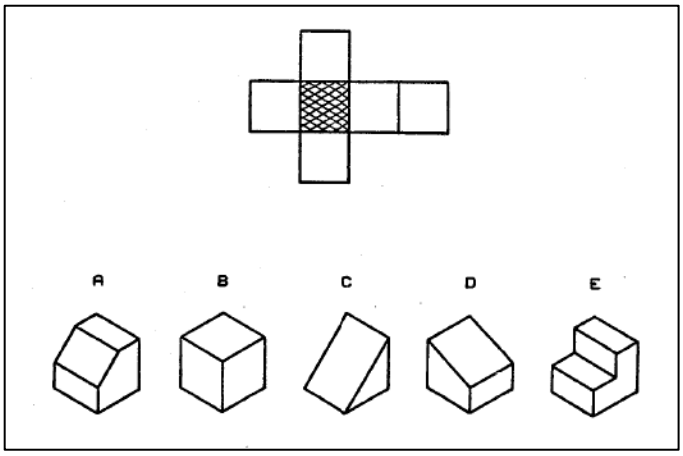

Figure 3.1. Example of Section 1 on PSVT

Figure 3.2 shows an example of a question from Section 2 of the PSVT. Out of the given choices, the correct rotated view of the object needs to be recognized (Guay, 1976). The rotation is similar to the example shown in the question. Figure 3.3 illustrates an example of Section 3 on the PSVT. In this question, the orientation of the object has to be recognized as given by the position of the dot (Guay, 1976).

The Wonderlic test consisted of 50 questions in all. The Wonderlic test had to be completed in 12 minutes, while the PSVT had to be completed in 30 minutes. A five-minute break was provided between the two tests for relaxation purposes. This also ensured that the participants began both the tests at the same time. The entire testing procedure, including the five-minute break equaled 47 minutes.

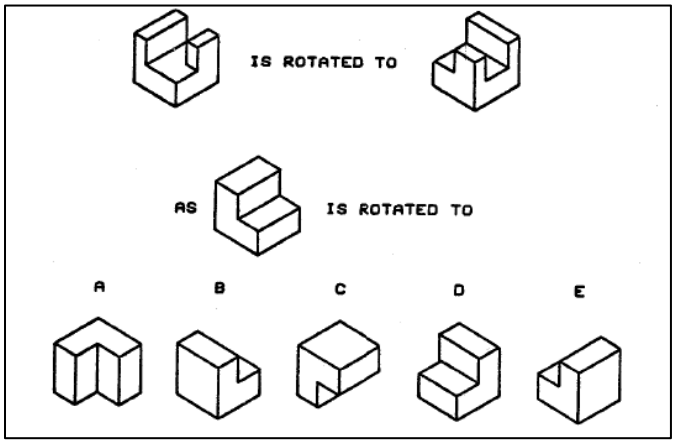

Figure 3.2. Example of Section 2 on PSVT

The participants were divided into two groups for a specific reason. One group was given the PSVT followed by the WPT, while the second group attempted the WPT followed by the PSVT. The two group scores were then correlated to investigate the effect of one test on the other. This was done to ensure that one test did not have an effect on the participant's performance in the ensuing test.

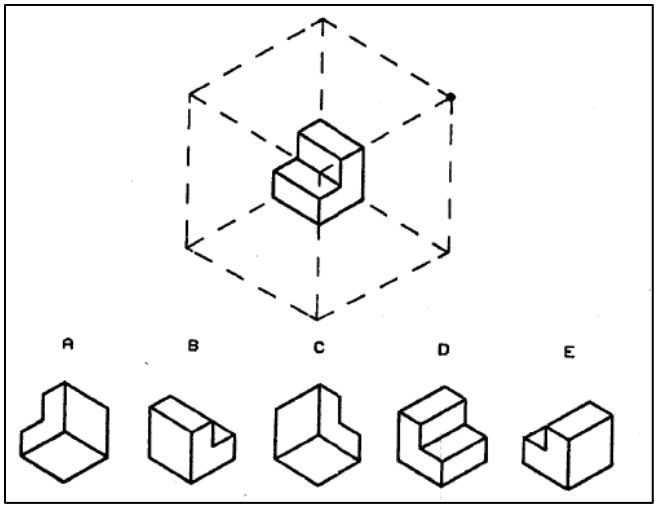

Figure 3.3. Example of Section 3 on PSVT

3.3.2 Permissions

It was essential to get permissions for testing the participants and to obtain the tests. Access was gained to the participants through Dr. Craig Miller, who spoke to the coach of the football team. The coach provided the permission to test the football players.

A company called Wonderlic Incorporated issues the Wonderlic test. It was bought from their website www.wonderlic.com. The Wonderlic test can be administered electronically as well as through paper. It was decided that the test would be administered through paper. Roland B. Guay created the Purdue Spatial Visualization test (PSVT) at Purdue University (Guay, 1976). This test is offered free of cost by the Purdue Research Foundation to all Purdue University students for research purposes.

An information sheet briefly explaining the study was also attached to the front of the testing booklet. This page also gave information about the voluntary participation of the study. The demographic information collected from the football players focused on

their age and playing position. No other information was collected from the participants. The demographics sheet asking the information was attached after the information sheet. Each participant was assigned a unique participant number in order to match it accordingly with his respective test scores. The numbers were assigned randomly at the beginning of the testing procedure. An application for Human Subjects Research was submitted to the Institutional Review Board (IRB), which monitors human subjects testing. It was decided in the beginning that no compensation would be provided, but later an amendment for compensation was submitted to the IRB. The participants were compensated with $40 for participating in the study. The permission to conduct the study as provided by the IRB is provided in Appendices C and D.

3.3.3 Analysis

This section will provide information on the various statistical tools used for analysis. It will outline the importance of the methodology used for analysis and define the reason as to why the analysis was done in a particular way. Also, variable specific analysis will be investigated. The threshold for the success of this study was defined by a correlation of 0.4 or less. This basically specifies that if the correlation between the Wonderlic test and the PSVT is 0.4 or less, it would be considered as significant.

As both the tests needed to be correlated, a simple correlation was the safest and easiest option. The scores of the football players on both the tests were compared using the SPSS statistical software. Pearson's correlation was used to understand this value. The software uses a simple equation that calculates the summation of the difference

between each score and the mean. The letter ‘r’ is the annotation for correlation. The correlation interval is [-1, +1].

3.4 Chapter Summary

This chapter provided information related to the methodology and framework of the study being conducted. It outlined information on the essential aspects of conducting a quantitative research study. The statistical tools that were used to analyze the information were tested along with the reason for employing the same. In summary, a simple correlation will definitively provide information pertaining to the comparison of the test scores.

CHAPTER 4. ANALYSIS OF DATA

The primary purpose of this study was to try and understand the correlation between the Purdue Spatial Visualization test and the Wonderlic Personnel test for American football players. The correlation was proposed as a way to understand if there is a need for a visualization test in order to measure the spatial ability of American football players. The participants were divided into two groups, with one group giving the PSVT followed by the WPT and the second group attempting the WPT followed by the PSVT. Although, the players were supposed to be randomly assigned their groups, juniors and seniors were placed in Group 1, while freshmen and sophomores were in Group 2. This was the result of the football personnel dividing the players in this way. A total of 55 players took part in the study, with 28 players forming one group (Group 1), and 27 players in the other group (Group 2). The group with 27 participants gave the PSVT first, followed by the WPT, while the group with 28 players attempted the WPT followed by the PSVT. The participants in the study were asked to provide their age and playing position as part of their demographic information.

This chapter focuses on the test results and the statistical analysis that were essential in providing answers to the hypothesis.

4.1 Test Results

This is section will provide data collected pertaining to the tests attempted by the participants. It will discuss both the tests used to measure the visualization and intelligence of the football players. Each test will be looked at in detail along with the scores of the participants. Patterns recognized in the data will be stated and pointed out in detail. The section will then focus on understanding why certain measures were taken to analyze the obtained data.

4.1.1 Testing Instruments

As mentioned earlier the Purdue Spatial Visualization test (PSVT) and the Wonderlic Personnel test (WPT) were the two ability tests administered to the participants. The PSVT is a spatial ability test that measures the visualization ability of an individual, while the WPT is an intelligence test.

4.1.1.1 Purdue Spatial Visualization Test

The Purdue Spatial Visualization test was given to all the players in July 2012. The PSVT that was administered contained 36 questions and consisted of three sections with developments being the first section, rotations as the next section and views as the last section. The developments section measured the visualization factor of spatial ability, the rotations section measured the factor called spatial relations and the views section tested the spatial orientation of the participants. Each section entailed 12 questions each. The time given for the PSVT was 30 minutes.

The scores obtained from the test were analyzed as a whole and on a group basis. The charts given below describe the results of the PSVT. One of the players failed to attempt a single question, hence that score had to be discarded as an outlier. The average score on the PSVT for all the players was 18.796. A very high standard deviation of 9.4257 was observed. A minimum score of 5 and a maximum score of 36 was recorded. Table 4.1 illustrates the scores.

Table 4.1. *Results of PSVT Scores*

N	Min Score	Max Score	Mean	Std. Deviation
54	5	36	18.796	9.4257

Tables 4.2 and 4.3 illustrate the PSVT scores according to each group. Along with the scores, information about player position and age are also provided. In Group 1 the mean score was 20.607, with the standard deviation being 9.024. For Group 2, the mean was 16.846 and the standard deviation was 9.632. The positions of the players were grouped together as offense and defense in order to maintain their anonymity. There was a third group that was created called as special team. This group included playing positions that are neither included in offense nor in defense.

Table 4.2. *Results of PSVT and WPT scores for Group 1*

No.	Age	Position	PSVT Score	WPT Score
1	23	Defense	11	7
2	20	Defense	18	17
3	22	Offense	9	9
4	22	Offense	23	31
5	21	Offense	29	24
6	22	Offense	13	28
7	21	Offense	24	33
8	21	Offense	10	19
9	20	Offense	16	31
10	21	Offense	28	29
11	21	Offense	9	23
12	20	Offense	35	28
13	22	Offense	32	27
14	22	Defense	33	24
15	23	Defense	33	23
16	21	Offense	23	30
17	21	Offense	21	18
18	21	Offense	17	32
19	20	Defense	36	21
20	19	Offense	16	20
21	21	Offense	12	22
22	21	Offense	9	5
23	19	Special Team	15	31
24	21	Offense	33	28
25	21	Offense	17	18
26	21	Offense	28	21
27	22	Offense	16	23
28	20	Defense	11	16

Table 4.3. *Results of PSVT and WPT scores for Group 2*

No.	Age	Position	PSVT Score	WPT Score
1	21	Offense	20	22
2	19	Offense	35	33
3	19	Offense	13	19
4	20	Offense	15	14
5	20	Defense	15	27
6	20	Defense	17	16
7	20	Defense	33	31
8	18	Offense	31	32
9	18	Offense	8	21
10	22	Defense	14	18
11	19	Offense	17	15
12	20	Offense	10	12
13	20	Defense	8	20
14	19	Defense	12	17
15	19	Offense	20	37
16	18	Offense	7	17
17	18	Special Team	35	32
18	20	Defense	11	16
19	19	Defense	7	25
20	18	Defense	15	17
21	18	Special Team	23	30
22	19	Offense	7	17
23	18	Special Team	13	22
24	20	Defense	36	31
25	19	Defense	11	10
26	20	Defense	5	17

Figure 4.1 displays the frequency of the test scores for all the participants on the PSVT. Four participants each got a score of 10, 15, 17 and 33 on the PSVT.

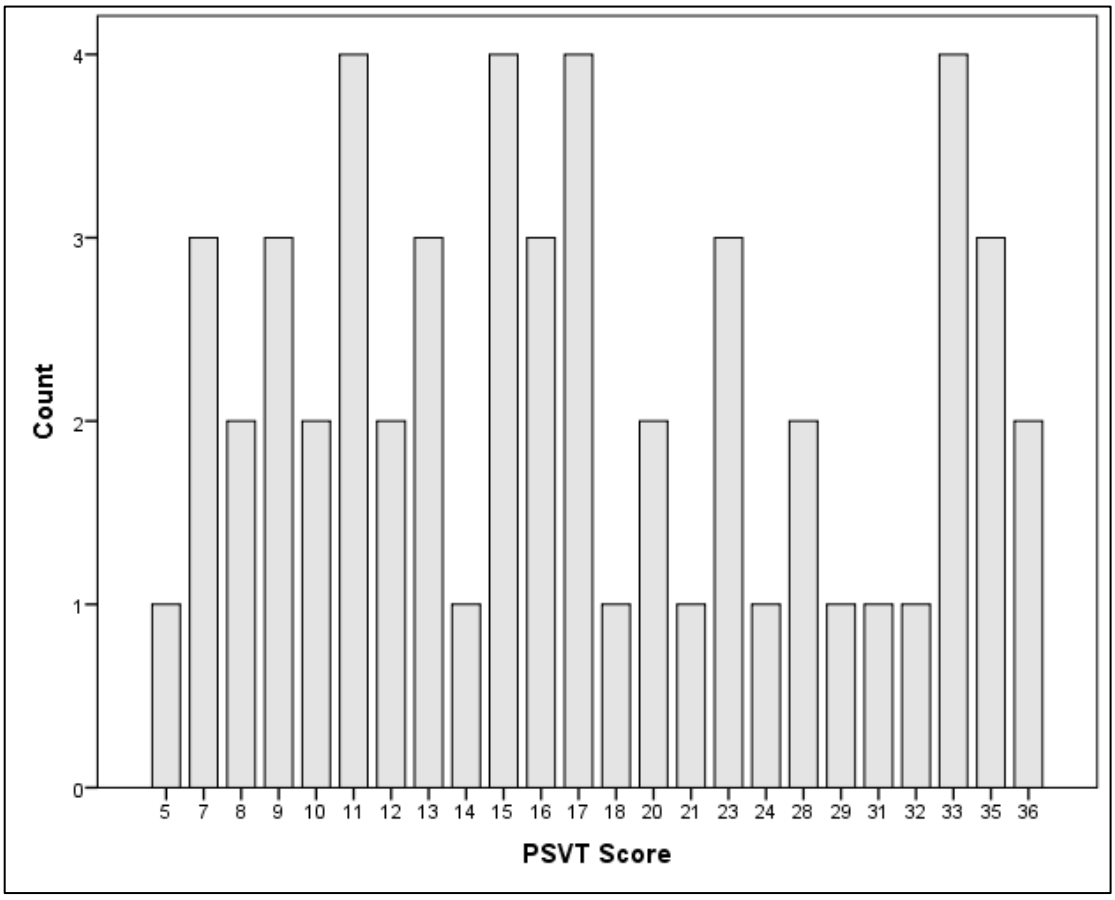

Figure 4.1. Frequency of the PSVT Scores

4.1.1.2 Wonderlic Personnel Test

Along with the PSVT, the Wonderlic Personnel test (WPT) was also given to the players at the same time. As discussed earlier, one group attempted the WPT before the PSVT, while the other group gave it after the PSVT. The WPT is a 12-minute test entailing 50 questions. Unlike the PSVT, the WPT is an intelligence test.

Similar to the PSVT, the WPT scores were analyzed as a whole and also group-wise. The average score on the WPT was observed to be 22.333. A standard deviation of 7.392 was calculated. The minimum score recorded was 5, while the maximum score was 37. Table 4.4 illustrates the WPT scores of all the participants.

Table 4.4. *Results of WPT Scores*

N	Min Score	Max Score	Mean	Std. Deviation
54	5	37	22.333	7.392

Table 4.2 and 4.3 illustrate the WPT scores for each player along with their position on the field and their age. The average score for Group 1 was 22.785, while the average for Group 2 was 21.846. The average scores for both the groups were close to each other.

Frequency of the WPT scores for all the participants is displayed in Figure 4.3. It can be seen that six participants got a score of 17 on the WPT, while five got a very good score of 31.

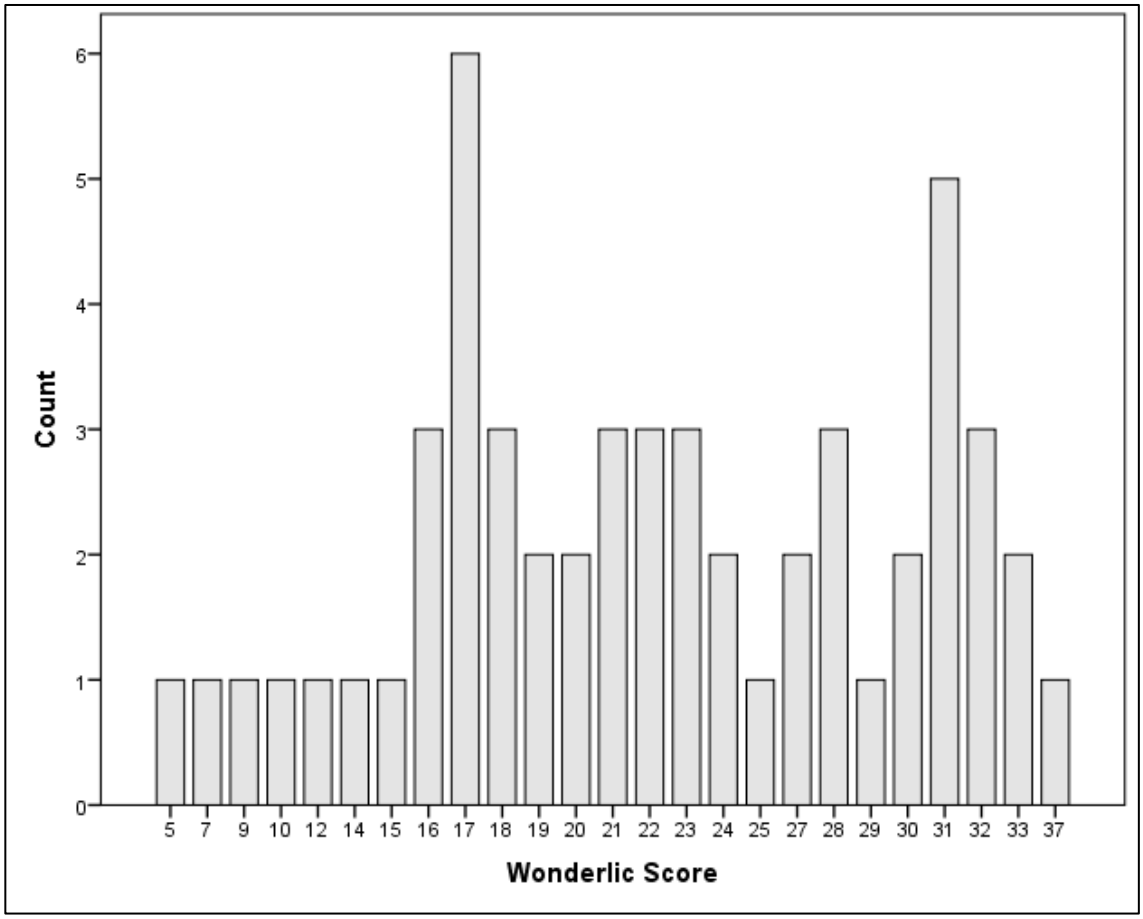

Figure 4.2. Frequency of WPT Scores

4.2 Statistical Analysis

This section provides an explanation for the correlational analysis that was the focus of the research question. The results of the correlation between the PSVT and WPT are projected along with certain trends in the scoring patterns of the football players. The scores on the PSVT and WPT will be evaluated along with a section-by-section breakdown of the scores.

4.2.1 Correlational Analysis

This section will focus on the primary research question that focuses on the correlation of player scores for both the tests. The player scores on each test were compared in order to correlate them. Pearson's correlation was used to understand if there existed any correlation between the tests. The correlation will be discussed for the player scores together and group-wise.

The correlation between the PSVT score and WPT score for all the participants (irrespective of the order) was found to be 0.590, which is significant. A low correlation was expected. A significant correlation could point to several scenarios. The participants performed similarly on both the tests. This could mean that both the tests have some commonality between them, although both the tests measure different individual abilities. Table 4.5 illustrates the correlation between the WPT and PSVT for all the participants

Table 4.5. *Correlation between WPT and PSVT scores*

		PSVT Score	Wonderlic Score
PSVT Score	Pearson Correlation	1	.590*
	Sig. (2-tailed)		.000
	N	54	54
Wonderlic Score	Pearson Correlation	.590*	1
	Sig. (2-tailed)	.000	
	N	54	54

* points to a significant correlation at the 0.05 level

Group 1 gave the WPT followed by the PSVT, while Group 2 gave the PSVT followed by the WPT. The correlation between the tests for Group 1 was 0.444, lower than the average correlation of 0.59. On the other hand, for Group 2, the correlation was observed to be 0.738, which is higher than the correlation recorded for Group 1. The above data suggests that there is a high possibility of one test having an effect on the performance for the other test. When the participants gave the WPT before the PSVT, the correlation was much lower. It is possible that giving the WPT before the PSVT has more effect on the test scores. WPT being a shorter test with more questions could have affected the participants' performance on the PSVT. Table 4.6 describes the correlation for participants from Group 1, while Table 4.7 shows the correlation for Group 2 participants.

Table 4.6. *Correlation between WPT and PSVT (Group 1)*

		PSVT Score	Wonderlic Score
PSVT Score	Pearson Correlation	1	.444*
	Sig. (2-tailed)		.000
	N	28	28
Wonderlic Score	Pearson Correlation	.444*	1
	Sig. (2-tailed)	.000	
	N	28	28

* points to a significant correlation at the 0.05 level

Table 4.7. *Correlation between WPT and PSVT (Group 2)*

		PSVT Score	Wonderlic Score
PSVT Score	Pearson Correlation	1	.738*
	Sig. (2-tailed)		.000
	N	26	26
Wonderlic Score	Pearson Correlation	.738*	1
	Sig. (2-tailed)	.000	
	N	26	26

* points to a significant correlation at the 0.05 level

4.2.2 Purdue Spatial Visualization Test

This section will look into each of the tests in detail by analyzing which section and questions were answered the most, and questions that were answered or omitted the most. The previous section has already provided information regarding the scores on the PSVT. The mean and standard deviation have been stated in relation to each group and for all the participants together.

For Group 1, the most answered section was section 3, with 197 correct responses, significantly higher than Group 1. For Group 2, the most answered section was section 2 (Rotations) with 152 correct responses. Section 1 (Developments) and section 3 (Orientation) had 144 and 142 correct responses respectively. The primary reason for high number of responses from Group 1 could be the fact that there were two more participants from that group. Also, the average score for Group 1 was significantly higher than Group 2. The largest number of correct responses was recorded for question 13 from Section 2 (Rotations) of the test. This value was 44. The lowest correct responses were for question 24 (Section 2) with only 12 participants answering it correctly. Figure 4.3 shows how all the sections relate to one another.

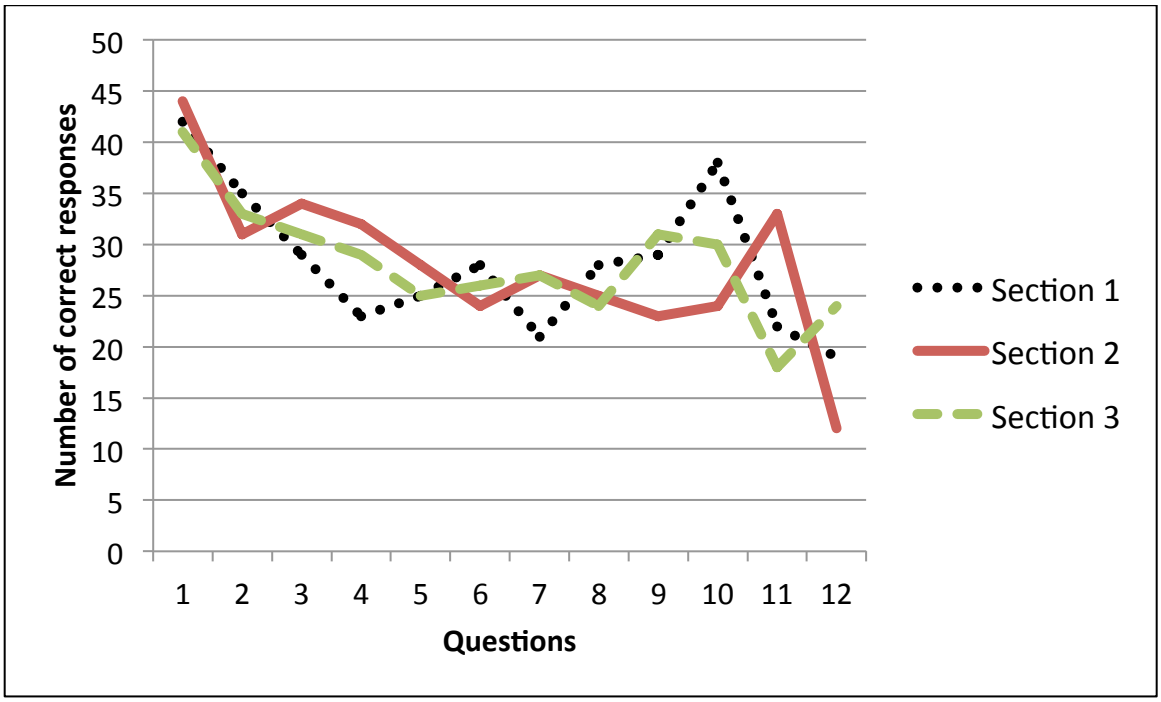

Figure 4.3. Comparing correct responses on each section

Figure 4.4 compares all the correct responses to each question in Section 1 (Developments) of the PSVT. As it can be seen, the first question of the section had the highest number of correct responses for this section. The number of correct responses for this question amounted to 42 for all the participants. The least correct responses on this section were for question 12, which is the last question for this section. This is understandable, as the difficulty of the questions gradually increases. In this section, one omission was noted. This omission corresponds to question 2, by one participant from Group 1.

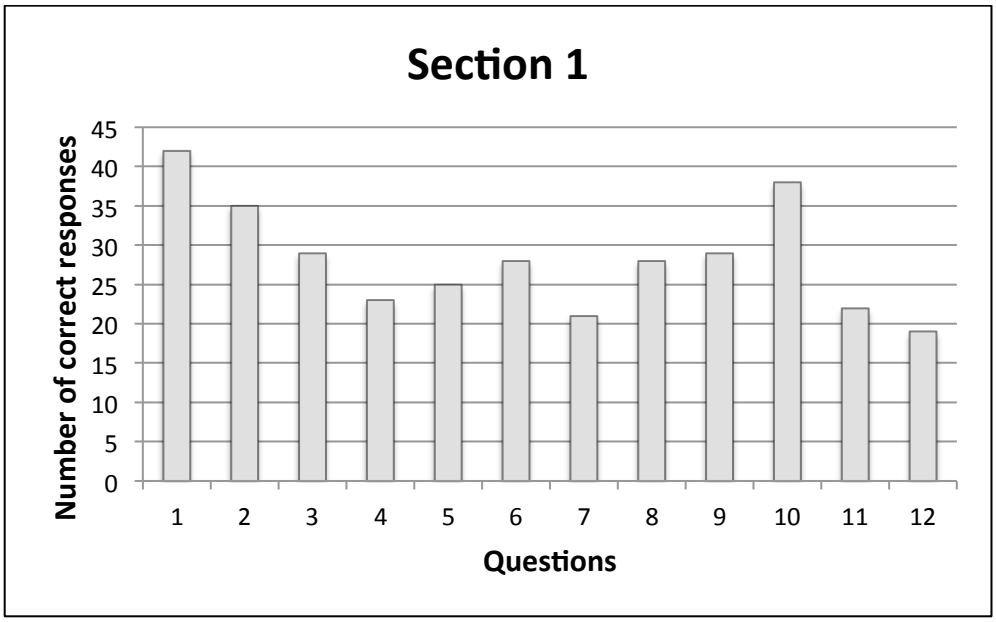

Figure 4.4. Number of correct responses on Section 1 according to each question

For Section 2 (Rotations), Figure 4.5 specifies the number of correct responses for each question on that section. The first question of the section projected the maximum correct responses, namely 44. Analogous to Section 1, the last question showed the least number of correct responses, the value being 12. Two omissions were observed in this section. Two participants omitted questions 13 and 18 from this section.

The number of correct responses on the last section of the PSVT (Views) is described in Figure 4.6. Again, the first question of the section had the maximum number of correct responses, amounting to 41. The participants recorded the least number of correct responses on question 35, which was the penultimate question of the section and the test itself. This number was 18. This section had the highest omissions compared to the other two sections on the test. One participant omitted five questions on this section, because of lack of time. These questions were the last 5 questions on the test. Three other

participants omitted one question each on this section, amounting to a total of eight omitted questions. The questions that were omitted on this section were 26, 28, 31, 32, 33, 34, 35 and 36.

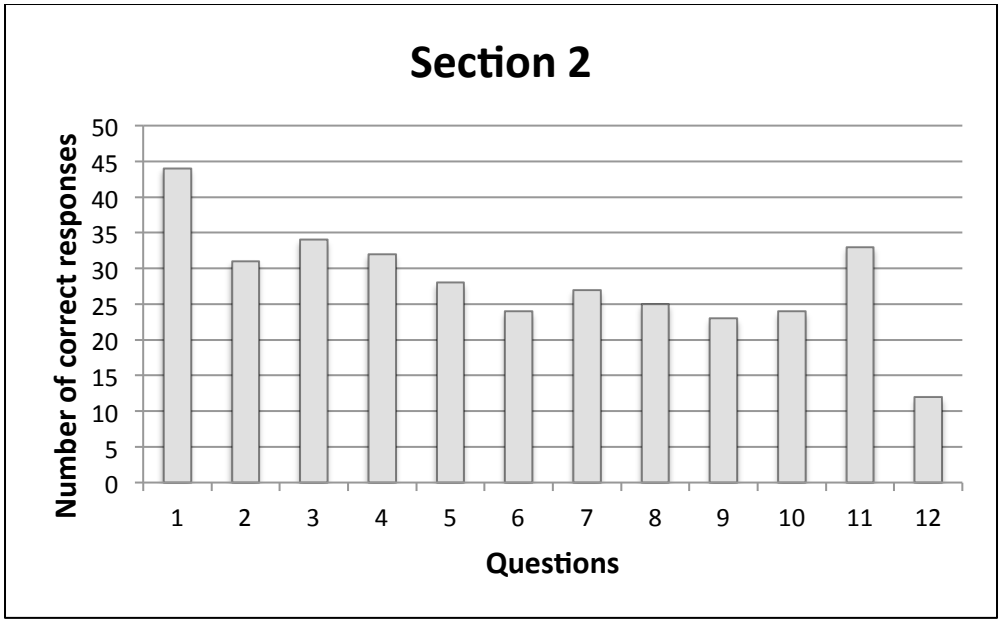

Figure 4.5. Number of correct responses on Section 2 according to each question

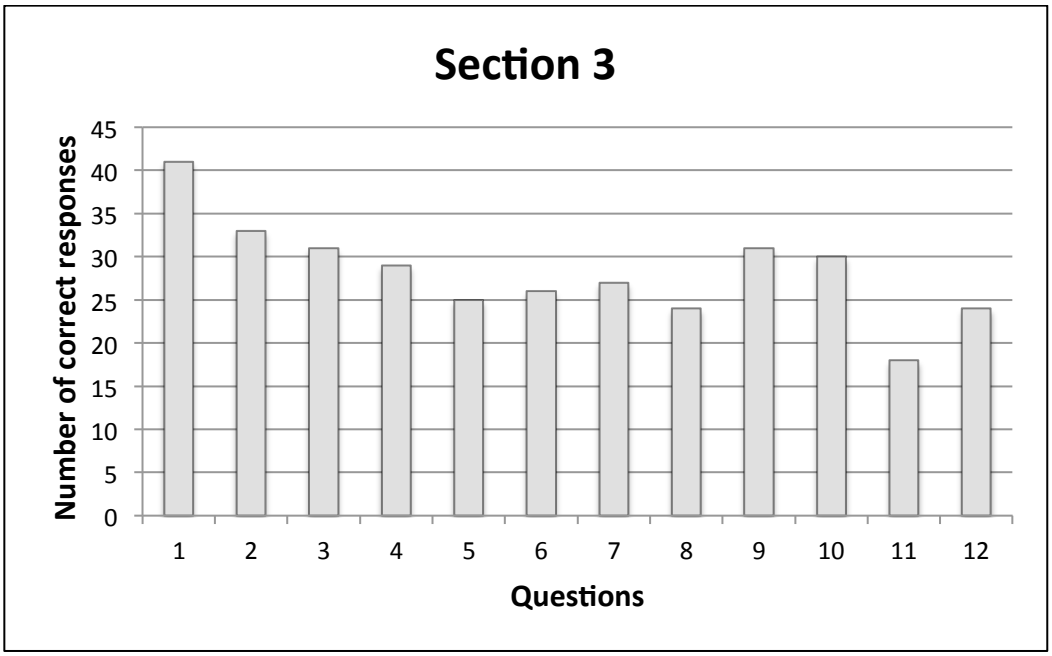

Figure 4.6. Number of correct responses on Section 3 according to each question

4.2.3 Wonderlic Personnel Test

Due to copyright restrictions, the questions on the Wonderlic Personnel test cannot be published.

4.3 Hypothesis Results

This section directly focuses on the primary hypothesis for this study. A correlational analysis between the Purdue Spatial Visualization test and the Wonderlic Personnel test provided results on how both the tests compared against each other. The value for this analysis ranges between -1 to 1, and is denoted by 'r'. For the null hypothesis to be rejected, the r-value had to be greater than 0.4. This meant that there lies

a significant correlation between the PSVT and the WPT. The null hypothesis of the study was as follows,

H_o: There is no significant correlation between the Purdue Spatial Visualization test and the Wonderlic Personnel test.

Pearson's correlation resulted in an r-value of 0.590, which was higher than the threshold value of 0.4. The null hypothesis, hence, was rejected. This meant that there exists a significant correlation between the PSVT and the WPT.

Figure 4.7 illustrates how the PSVT scores compare to the WPT scores for all the participants in the study. It can be seen that both lines that denote the PSVT scores and the WPT scores are in synchronization with each other. Most of the participants performed similarly on both the tests. This suggests that football players performing well on one test should typically also perform well on the other test, while football players performing poorly on one test, should perform poorly on the other test as well. It is important to mention that the scores of one of the participants had to be discarded because the PSVT score was recorded as zero.

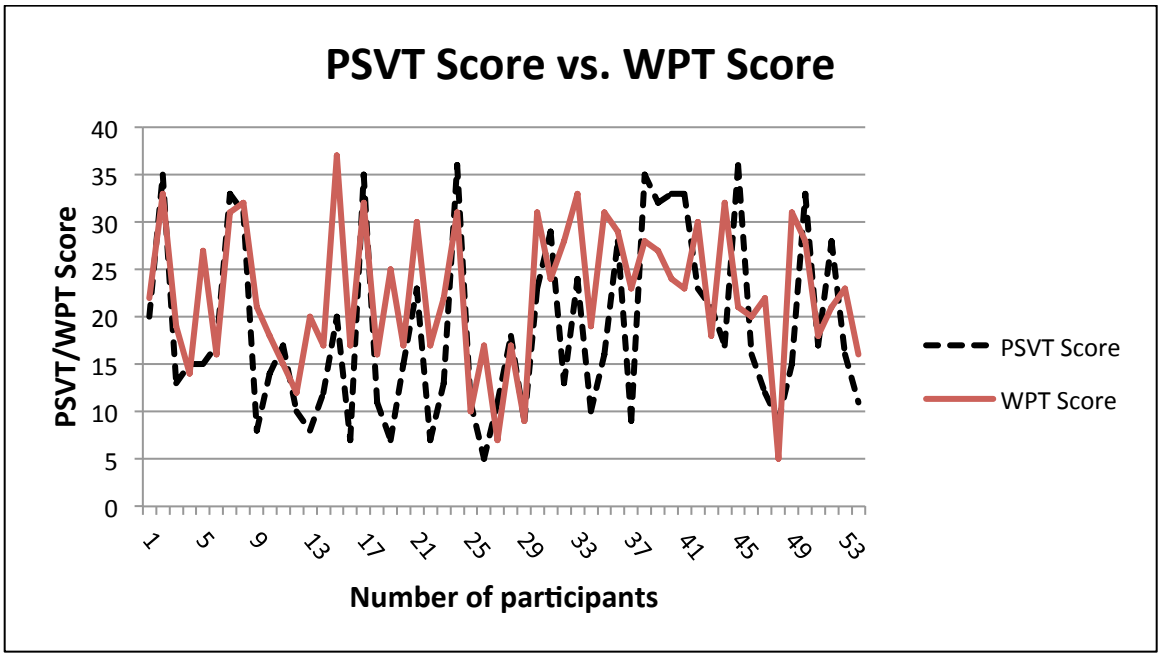

Figure 4.7. PSVT Scores versus WPT Scores

Although, there was no significant difference between both the tests when analyzing all the participants together, it was found that one test does have an effect on the other and the order does make a difference in the performance. The participants were divided into two groups. Group 1 gave the PSVT first, followed by the WPT, while Group 2 gave the WPT followed by the PSVT. It was observed that the correlation for Group 2 was 0.738, but surprisingly the correlation for Group 1 was 0.444. The value obtained for Group 1, although not significantly low, was very close to the value stated as being a low or no correlation.

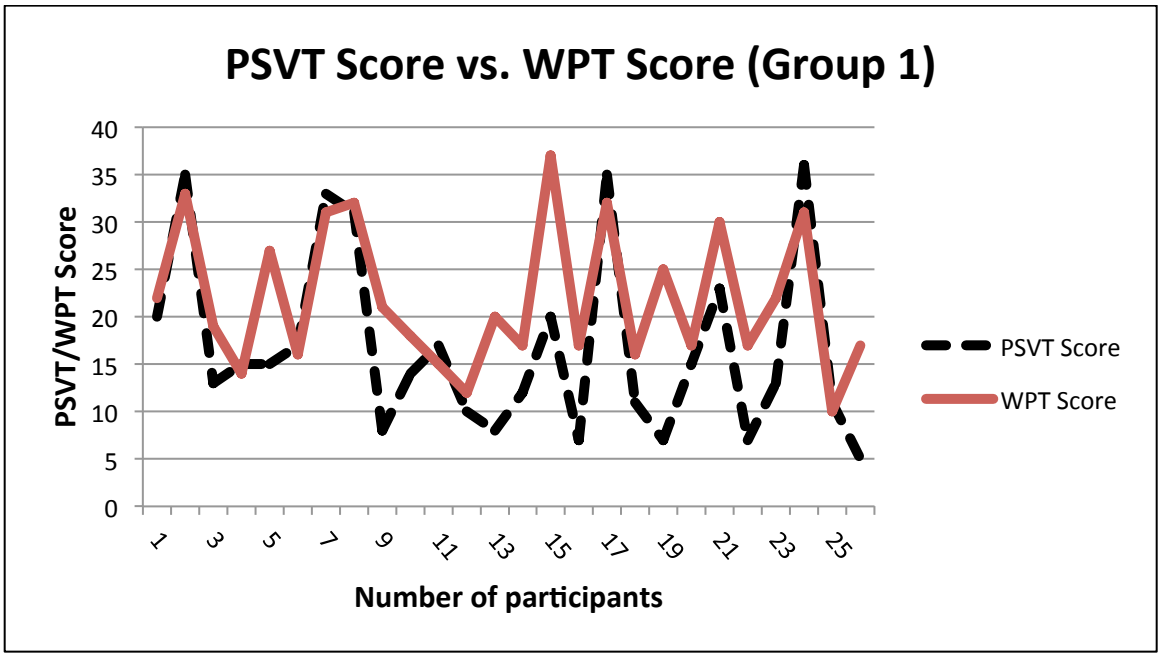

Figure 4.8. PSVT Scores versus WPT Scores for Group 1

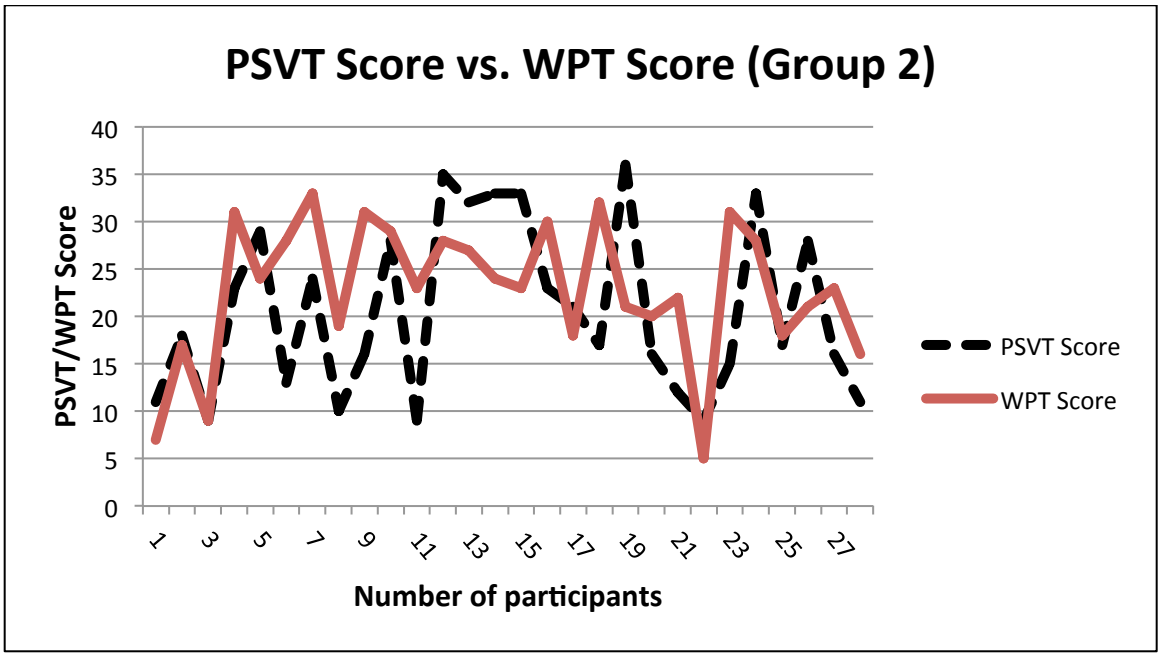

Figure 4.9. PSVT Scores versus WPT Scores for Group 2

Looking at the Figure 4.8, one can see a very close similarity between the scores on both the tests. But, Figure 4.9 displays a difference in the scoring patterns for both the tests. This was an extremely intriguing observation that was revealed in this study.

4.4 Summary

The results from all the testing pertaining to the study were discoursed in this chapter. The testing session was briefly described, along with the demographic questions that the participants were asked to answer. The demographics that were collected detailed the age and playing position of the participant. The testing session was undertaken in two separate rooms. All the participants gathered in one room, after signing the attendance sheet. After everyone was settled, they were provided brief instructions on the testing procedure and the purpose of the study. Each participant was provided a participant number, which was unique to that participant. Then, they were divided into two groups and asked to sit in different rooms. Each group, had a 5-minute break between the two tests, as consistency needed to be maintained.

After the brief explanation on the testing session, the chapter focused on the test results that were obtained from the testing session. For ease of understanding, this subsection was divided into two smaller sections detailing the two tests that were part of the study, namely, the Purdue Spatial Visualization test (PSVT) and the Wonderlic Personnel test (WPT). Scores obtained by the participants on both these tests were outlined and discussed. As there were two groups in the study, it was necessary to analyze the data separately pertaining to each group, as well as for all the participants together.

Correlation between the PSVT and the WPT was the primary motivation behind this study. The ensuing section threw light into the various statistical analyses that were conducted to find patterns in the data. This section started by concentrating on understanding how the PSVT scores compare with the WPT scores for football players. This analysis was also conducted pertaining to each group in the study.

As the PSVT is divided into three sections, it was important to understand how scores on each section relate to each other. The scores of all the participants were analyzed on each of the three sections in the PSVT. The maximum correctly answered section was identified along with the least correctly answered section. It was also seen, which question was correctly answered the most, along with the least answered question. The number of omitted questions in the test were identified and stated.

Finally, the results of the primary hypothesis were discussed. The comparison between the PSVT and the WPT was illustrated and certain patterns were identified. The results on the hypothesis showed that both the tests are related to each other in a significant manner, but the order of writing the tests makes a big difference in the comparison. It is possible that football players' performance on one test is synonymous with the other.

Although the correlation between the PSVT and the WPT was not low, certain aspects of the testing procedure and analyses have thrown light on encouraging future research. The next chapter will detail all such findings and conclusions of this study.

CHAPTER 5. SUMMARY, CONCLUSIONS AND FUTURE WORK

The final chapter of this thesis provides an explanation for the entire study. It provides a brief summary of the study. It also states the findings from the data analysis and discussion of the same. The ensuing section in this chapter details the conclusions of this research and explains the relevance of the findings. Finally, recommendations for future research are provided in the area of visualization for American football.

5.1 Findings

As mentioned earlier, the primary research question entailed whether there existed a correlation between the PSVT and the WPT. This section will describe the findings of this study as explained by the analysis conducted. Pearson's correlation was used to understand this measure. In Chapter 3, the threshold value for the correlation to be labeled as no or low correlation was 0.4. This was decided looking at the sample size of 53 with an alpha level of 0.05.

Although the primary hypothesis concentrated on correlation between the two tests, there were other factors in both the tests that had to be examined. Each test had to be looked at separately to identify patterns of answers. The frequency of the scores was also analyzed for both the tests individually. This provided a better understanding of how many people got a particular score range on the tests.

Correlational analysis of both the scores for each participant provided a value of 0.590. This value termed that the PSVT and the WPT had a significant correlation between them. These tests are similar in some way. The analysis also looked at the correlation for the participants within the groups, because there was vast difference in the values. For Group 2, the value was very high, which meant that the correlation was significant and the tests are very similar. However, for Group 1, this value was low, somewhere close to the threshold value, but still significant. This means that the order of taking the tests has a high impact on the scores of the participants. Especially when the WPT is administered before the PSVT, the correlation is much lower.

Although not part of the primary hypothesis, a similar correlational analysis was conducted between the ages of the participants and the scores on both the tests. It was seen that age and the scores on the PSVT had a very low correlation between them. Synonymous to the correlation between age and the PSVT scores, the WPT scores also provided the same conclusion. In fact, age and the WPT scores had a negative correlation between them. This points to the fact that younger football players perform better on the tests than older players.

The frequency of the PSVT scores showed that the scores were on the two extremes. There were participants who did very well on the test, close to no mistakes at all, while others who did poorly on the test. This can be explained by the very high standard deviation on the test scores.

Analysis of the PSVT test by looking into the performances according to each section brought out some interesting results. Group 1 recorded the highest number of correct responses compared to both the groups. The most answered section for the group

was Section 3, which measures Spatial Orientation. Question 13 had the highest number of correct responses on the test. This question is from Section 2 (Rotations) on the test. On the other hand, the least correct responses on the test were for question 24, again from Section 2 on the test.

The first question from each section recorded the maximum correct responses for that particular section. This is understandable, because the difficulty of the questions increases for each section. Although the maximum correct responses were from Section 3 on the test, it also recorded the highest number of omissions on the test. The primary reason for this section having a high omission rate could be synonymous to the fact that some of the participants could not complete the test.

The next section in the chapter will discuss the findings in detail and attempt to provide reasons for the same. It will try to evaluate the reason behind the findings.

5.2 Discussions of the Findings

This section will provide reasons for the findings in this study. It will look at the primary hypothesis along with each of the testing instruments. This section will be divided into three subsections entailing the above information.

5.2.1 Correlational analysis

The results for the primary hypothesis of this study pointed to the fact that the Purdue Spatial Visualization test and the Wonderlic Personnel test are significantly related to each other. This was contrary to the suggested threshold value in the study. Although, the PSVT is a visualization test and the WPT is an aptitude test, there seem to

be some factors in both the tests that allow for American football players to perform on similar lines in either of the tests. It can be argued that a sample size of 54 is quite low to conclusively propose that the performance on both these tests is related.

There are various factors that could have brought about this result. It is important to recognize the state of mind of the participants during testing day. The football personnel provided all the participants with pizza and refreshments before the testing session started. This could have definitely affected their performance in a positive or negative way. Too much food can cause laziness, but on the other hand eating food will definitely energize your mind and body. The motivation behind taking part in the study can be attributed to two factors. The Wonderlic Personnel test is an important test in a footballer's life. As this test is used in the NFL Combine as part of the testing procedure, it can be assumed that the participants took this test seriously and wanted to perform to the best of their abilities. On the other hand, the Purdue Spatial Visualization test has no effect whatsoever on their football career and the motivation behind doing well on the PSVT can be questioned. The second factor could be pertaining to the compensation that the football players received after the completion of the study. The compensation might have been the primary reason behind taking part in the study. This could have affected their performance on the tests.

The findings also presented us the correlation with respect to each group. Participants from Group 1 gave the WPT first and then the PSVT, while Group 2 participants gave the PSVT followed by the WPT. As mentioned earlier, the correlation between the scores for Group 2 was high, but the same correlation for Group 1 was comparatively low. This is extremely interesting because it clearly shows that the order in

which the tests are administered could be important to the performance on these tests. It should be noted that Group 2 had 26 participants compared to the 28 for Group 1.

There could be many reasons behind this huge difference between the groups. It was mentioned earlier that the WPT has more of an effect on the football players' career compared to what the PSVT has. This is important to keep in my mind because Group 1 attempted the WPT before they attempted the PSVT. Once they attempted the WPT, their motivation to perform well on the PSVT could have been high. This has a possibility of affecting the data.

On the other hand, Group 2 that had a much higher correlation between the test scores gave the WPT after the PSVT. The fact that PSVT was a completely unfamiliar test to them could have affected their overall confidence. Hence, their motivation to do well could have been affected for both the tests.

A second correlational analysis was also conducted to try and understand how age relates to test scores on both the tests. It was observed that for both the tests a very low correlation was seen. Especially for the Wonderlic test, the correlation was negative. This could possibly mean that the younger players perform better on both the tests as opposed to the elder players.

5.2.2 Purdue Spatial Visualization Test

The performance of all the participants on the Purdue Spatial Visualization test was defined by the mean score on this test. The standard deviation was very high, which shows that the scores were either low or high. After looking at the graph, it could be said

that there participants who did poorly on the test, while other who did very well on the test.

The PSVT is a test that measures the visualization ability of an individual in a static manner. But, when one looks at any sport and especially American football, all the plays are completely dynamic. It is possible that this played an essential role in the scoring pattern. The motivation to perform well on the WPT rather than the PSVT has already been mentioned earlier as being an important reason behind the scores on the PSVT.

Looking at the performance of the participants on PSVT according to each section, it can be seen that their performance was better on the last section of the test. This section was the views section that measures the spatial orientation ability of an individual. Spatial orientation is the ability through which an individual can understand and recognize the visual stimulus across different orientation through which it is presented (McGee, 1979). Out of the three primary spatial ability factors, spatial orientation is one factor that a football player might use the most on the field. When the quarterback calls a play, he must understand the position of the opposition defense and visualize where they might end up, before changing his calls. This process entails great understanding of the entire field and viewing the field from different orientations. Spatial orientation is defined by the above process, hence it can be argued that one of the reasons the players did better on that section is due to high spatial orientation ability.

The participants performed well on Question 13, which was part of Section 2 (Rotations) on the test. Figure 5.1 shows Question 13 of the test. One of the reasons why the participants did well on this test could be the fact that this was a single rotation

problem. The question shows that the object has been rotated once in the counterclockwise direction on one axis, namely the y-axis. Looking at the object that needs to be rotated, one can see that it has an inclined plane. It is easy to identify the answer because of the orientation of the inclined plane.

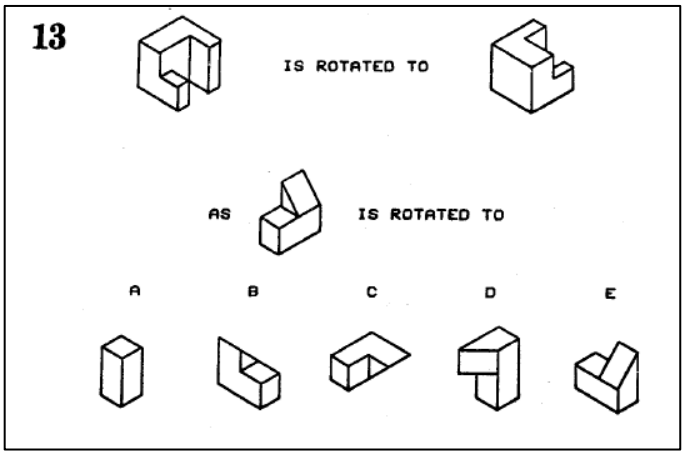

Figure 5.1. Question 13 on the PSVT

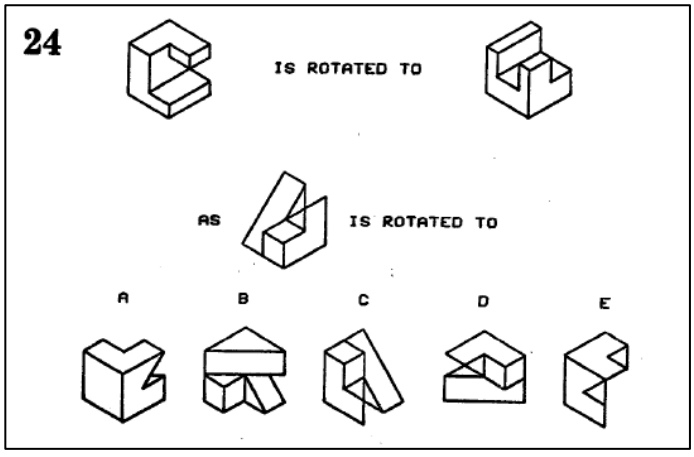

Figure 5.2. Question 24 on the PSVT

The question on which the least answers were recorded was Question 24. This question was from section 2 on the test as well. Looking at the question as shown in Figure 5.2, it can be seen that the question is much more complicated. The rotation on the question is completed on multiple axes making it more difficult. Also, the object that needs to be rotated has multiple inclined planes with different orientations. The multiple rotations along with the inclined planes make it complicated for the participant to visualize the rotations.

5.2.3 Wonderlic Personnel Test

The performance of the participants on the Wonderlic Personnel test was average, in concurrence with the research pertaining to Wonderlic testing (Gill & Brajer, 2011). The average score of the participants was around the score stated in the research mentioned in Chapter 2 of this study. The standard deviation was high, but not as high as compared to the PSVT.

The scoring patterns on the WPT are concentrated more towards the right as compared to the PSVT. Very few participants scored below 15. It needs to be kept in mind that the WPT was out of 50. The motivation to do well on this test is also an important factor that needs to be taken into account.

5.3 Conclusions

This section reviews the conclusions of this study grounded on the primary hypothesis of the study. The resulting are the conclusions that are imperative and based on the findings from this study.

The conclusions of the study are as follows:

1. For American football players, the scores on the Purdue Spatial Visualization test and the Wonderlic Personnel test have a significant correlation to one another.
2. Although both these tests are significantly correlated, the order in which these tests are administered has a bearing on the scores of the participants.
3. It was intriguing to observe that age had a low correlation with the PSVT and WPT scores for the participants, although this was outside the scope of the study.

5.4 Recommendations for future work

This section outlines a list of recommendations that can be incorporated for future studies in the field of spatial ability and visualization/imagery in sport. Some experiences of the researcher have also been mentioned in this section.

1. The division of participants was supposed to be done randomly, but they were divided according to one group that included juniors and seniors, and another group that contained freshmen and sophomores. Repeating the study by randomly assigning groups would provide better accuracy to the study.

2. Although the sample size was sufficient to conclude that the correlation between the PSVT and the WPT was significant, it would be interesting to see what the results would be if the sample size was increased.
3. An understanding of the PSVT scores with respect to playing position would be interesting to look at. This would provide an idea about the playing positions that incorporate high visualization. It would be intriguing to observe how each position scores on the test, because it might aid in creating a tool to improve the visualization ability of certain positions. Also, the positions that work together in the playing field can be targeted as a focus group to improve their plays.
4. A similar study with NFL athletes can yield much better results. The reason for this being, the level of professional football they exhibit is much higher than the football players tested in this study.
5. The testing did show that the PSVT and the WPT are related to each other significantly, but the factors that both these tests measure need to be taken into account. A more dynamic visualization test can prove to be an accurate measurement of an athlete's visualization ability. Hence, the creation of a dynamic visualization measurement is integral to understanding how an athlete will perform on the field. This measurement instrument can assist coaches and scouts to identify potential players that can be a mainstay in the team over a period of time. Also, looking at the amount of money being spent in buying quality players, a measurement of this kind can help in estimating the true worth of a player.

6. The participants did perform better on the last section of the PSVT. This section measured the spatial orientation ability of the individual. The longer version of the spatial orientation test can be used in order to understand how this ability relates to on-field imagery for the football players.
7. Although it was outside the scope of this research study, age showed a low correlation to PSVT and WPT scores. The result was very interesting and should be looked into in greater detail.

The above recommendations if incorporated might be useful to aid the field of imagery in sport. They may also provide innovative and ingenious ways to develop visualization-based instruments that can be used to not only aid the player, but also the audience who is an important source of revenue for broadcasters.

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APPENDICES

Appendix A Information Sheet

RESEARCH PARTICIPANT CONSENT FORM
Understanding the correlation between the Purdue Spatial
Visualization test (PSVT) and the Wonderlic Personnel test (WPT)
Dr. Craig Miller
Purdue University
Computer Graphics Technology

Purpose of Research

This study focuses on understanding the need for a visualization test in American football, which might be able to predict on-field performances.

Specific Procedures

Prior to participating in this study, you must give consent so that the researcher (Karthik Sukumar) may access your Wonderlic test (WPT) and Purdue Spatial Visualization test (PSVT) scores. You will be asked to give both these tests to the best of your ability.

Duration of Participation

The entire testing process will take up to one hour. The PSVT will be a 30-minute test, while the WPT will be a 12-minute test.

Risks

There is minimal or no risk involved in the study. Anonymity is a risk of this study but classifying you by a participant number provided at the beginning will eliminate your name from the study. Remember, there is a risk to confidentiality, which will be minimized by keeping any data from the study in a secure area as explained in the confidentiality section below.

Benefits

This study may help you understand the process of visualization, which will assist you on the field.

Compensation

A compensation of $40 shall be provided

Confidentiality

The project's research records may be reviewed by departments at Purdue University responsible for regulatory and research oversight. The data obtained from this study will be stored in the office of the Principal Investigator (Dr. Craig Miller) in a filing cabinet. The data will only be accessible by the Principal Investigator and the Co-Investigators (Dr. James Mohler, Dr. Patrick Connolly and Karthik Sukumar). This data includes scores on the Purdue Spatial Visualization Test, scores on the Wonderlic test and the demographic information (age and the playing position). All the data will remain anonymous. Your PSVT and WPT scores will remain confidential and will have no identifying

information associated with them. The data will be stored for a minimum of five years and will be used for research purposes in the future.

Voluntary Nature of Participation

You do not have to participate in this research project. If you agree to participate you can withdraw your participation at any time without penalty.

Contact Information

If you have any questions about this research project, you can contact Dr. Craig Miller (765) 494-8207 and Karthik Sukumar (765) 414-9791. Karthik Sukumar is the main source of contact. If you have concerns about the treatment of research participants, you can contact the Institutional Review Board at Purdue University, Ernest C. Young Hall, Room 1032, 155 S. Grant St., West Lafayette, IN 47907-2114. The phone number for the Board is (765) 494-5942. The email address is irb@purdue.edu.

Documentation of Informed Consent

I have had the opportunity to read this consent form and have the research study explained. I have had the opportunity to ask questions about the research project and my questions have been answered. I am prepared to participate in the research project described above.

Appendix B Demographic Sheet

Participant Number: 1

DEMOGRAPHIC INFORMATION

AFTER READING THE CONSENT FORM, PLEASE FILL IN THE INFORMATION STATED BELOW.

AGE:

ONFIELD PLAYING POSITION:

Appendix C IRB Form

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	CRAIG MILLER KNOY 321
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	05/14/2012
Committee Action:	**Exemption Granted**
IRB Action Date:	05/14/2012
IRB Protocol #:	1205012250
Study Title:	Understanding the correlation between the Purdue Spatial Visulation test and the Wonderlic Person football players

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b)(2) .

If you wish to make changes to this study, please refer to our guidance "**Minor Changes Not Requiring Review**" located on our website at http://www.irb.purdue.edu/policies.php. For changes requiring IRB review, please submit an **Amendment to Approved Study** form or **Personnel Amendment to Study** form, whichever is applicable, located on the forms page of our website www.irb.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not

Appendix D IRB Amendment Form

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	MILLER, CRAIG L
From:	DICLEMENTI, JEANNIE D, Chair Social Science IRB
Date:	07 / 19 / 2012
Committee Action:	Amended Exemption Granted
Action Date:	07 / 19 / 2012
Protocol Number:	1205012250
Study Title:	Understanding the correlation between the Purdue Spatial Visulation test and the Wonderlic Personnel test for American football players

The Institutional Review Board (IRB) has reviewed the above-referenced amended project and has determined that it remains exempt.

If you wish to make changes to this study, please refer to our guidance"**Minor Changes Not Requiring Review**" located on our website at http://www.irb/purdue.edu/policies.php. For changes requiring IRB review, please submit an **Amendment to Approved Study** form or **Personnel Amendment to Study** form, whichever is applicable, located on the forms pages of our website www.irb.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.