A STUDY OF VARIABLES TO HELP PREDICT NAVIGATOR TRAINING SUCCESS AND CLASSIFICATION

THESIS

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This study attempted to build statistical models which could possibly be used to help predict an individual's final outcome of pass or fail from Undergraduate Navigator Training (UNT). Also, the research tried to develop models to help place a potential trainee into one of the three training tracks at UNT. The variables studied were test scores from a computerized testing device which measured psychomotor and cognitive skills of individuals entering training. The Air Force Officers Qualifying Test (AFOQT) scores were also variables considered. Data was from 317 trainees from the years 1988 to 1990. Discriminant analysis was applied in an effort to place an individual accurately into one of the groups of pass or fail and into one of the three tracks based on his/her scores. Logistic regression was performed on the binary response of pass/fail to give models which would predict probability of passing using the test scores. Factor analysis was used to explore the underlying dimensions of all the variables. Some variables were found to be important predictors. Although models were built from the analyses, the study could use more data on individuals who failed from training.

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Abstract

This study attempted to build statistical models which could possibly be used to predict an individual's final outcome of pass or fail from Undergraduate Navigator Training (UNT). Also, the research tried to develop models to help place a potential navigator trainee into one of the three training tracks at UNT. The variables studied were test scores from a computerized testing device which measured psychomotor and cognitive skills of individuals entering training. The Air Force Officer's Qualifying Test (AFOQT) scores were also variables considered. Data was from 317 trainees from the years 1988 to 1990.

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A STUDY OF VARIABLES TO HELP PREDICT NAVIGATOR TRAINING SUCCESS AND CLASSIFICATION

I. INTRODUCTION

General Issue

The Air Force has a continuing need to train new navigators. Navigators currently serve on fighter, bomber, tanker and transport aircraft. The unique missions of these types of aircraft require e special skills of navigators. It is therefore imperative that the Undergraduate Navigator Training (UNT) program produce high quality graduates and in sufficient numbers to meet manpower needs.

According to researchers at the Air Force Human Resources Laboratory (AFHRL), loss of students in the Undergraduate Navigator Training program is a substantial cost to the Air Force (Shanahan, 1986:1). Not only is money wasted but difficulty in meeting the manpower requirement occurs. AFHRL points out that attrition among students in UNT has been a continuing concern. Researchers believe one way to reduce the student loss is to perhaps improve the initial selection of trainees (Shanahan, 1986:1).

In the past, UNT students have been selected mainly on the basis of their performance on the Navigator-Technical composite of the Air Force Officer Qualifying Test (AFOQT)

(Shanahan, 1986:1). The AFOQT is a 16 part written test which produces 5 composite scores (Carretta, 1989,46). Potential officer candidates take this test prior to entering an officer training program. The AFOQT has been used since World War II, and research shows the Navigator-Technical part has been good at predicting success at UNT (Shanahan, 1986:1).

Even though the AFOQT is a valid predictor, there is a continual search for even better prediction instruments. In 1980, research was done at the AFHRL to see if the selection system could be improved or supplemented (Shanahan, 1986:1). An experimental test, the Basic Navigator Battery (BNB) was used in addition to the AFOQT. The BNB was a five-part written test and was administered to the test subjects one week prior to the start of their UNT training (Shanahan, 1986:1-2). The AFOQT, however, was taken by the test subjects several months prior to UNT. The research showed that statistically the predictive validity of the selection system could be improved by using an additional part of the AFOQT along with parts of the BNB (Shanahan, 1986:8).

Specific Problem

Also in the early 1980's, there appeared a renewed interest in using psychomotor testing devices to help select students for flight training (Carretta, 1987:1). Electro-mechanical devices had been used in the past, but the Air

Force discontinued their use in 1955. These devices were also very good at predicting success or failure in flight training. Recent advances in computer technology, along with high attrition rates in Undergraduate Pilot Training (UPT), led the Air Force to look into the feasibility of using psychomotor testing again to select both pilots and navigators. The Air Force is also planning to implement a new pilot training program where students will be identified at the start of UPT whether they will train to be a fighter/bomber pilot or a tanker/transport pilot. Therefore, a means of classifying the students is needed. A computer based device was built for the Air Force and a series of tests called the Basic Attributes Tests (BAT) were developed to be used with the device (Carretta, 1987:1-2). Research conducted by AFHRL showed that certain AFOQT subtests and BAT tests were very useful on a statistical basis in predicting success for pilot training students and could also be used for classification (Carretta, 1989:46-49).

The Air Force has already started a new navigator training program called Specialized Undergraduate Navigator Training (SUNT). In this new program, all the students go through an initial training phase of approximately three months. Then they are classified and placed into one of three training tracks: bomber/fighter, tanker/transport/bomber, or the electronic warfare track (Dupree, 1990). The classification is based mostly on how well the students have performed in flight checks and academic tests up to that point, along with the individual student's aircraft preference (Baker, 1990). In the previous navigator training, all the students would train in a common nine month program before specializing into one of the above tracks. Clearly, it is important to select and classify navigator trainees with the potential for the most success. Similar to its use with pilot candidates, the question is whether these new generation BAT tests can be useful in selecting student navigators.

It is the purpose of this research to develop a statistical model or models that can be used to predict the success of prospective student navigators.

Research Objectives

This study attempts to develop a statistical model which takes information about past navigator trainees and produces an estimate of training success that is close to the actual success rate. Input information will include AFOQT scores and BAT scores. The study will attempt to validate the proposed model so that it can be used to predict success when selecting students for navigator training. It will also be desirable to develop a model for classifying trainees for particular training tracks. To help reach the research objectives, the following investigative questions will be addressed:

1. Are any scores or variables highly correlated with each other?

2. How well do the AFOQT scores predict final training outcome?

3. Which, if any, of the BAT tests are useful at predicting UNT outcome.

4. Is some combination of AFOQT and BAT scores the best predictor?

5. Can individuals in different training tracks be discriminated from each other?

6. Can a statistical model be developed to classify students so as to be placed in a particular training track?

Scope

This study will only deal with test scores obtained on past individuals. Motivational indicators in training will not be addressed as this is extremely difficult to quantify. Individuals who failed from training because of academic or flying deficiencies are the only ones considered as failing. Those who quit or did not graduate because of a fear of flying are not included in the analysis since these reasons involve possible motivation factors. Also, those who were medically eliminated from training are not considered.

II. LITERATURE REVIEW

The following paragraphs will review literature pertinent to this research. Many professional papers and reports documenting previous studies in aircrew selection have been written. Three topics will be covered here. First, the validity of the Air Force Officers Qualifying Test (AFOQT) is examined. Second, a previous navigator selection study is reviewed. Finally, pilot selection research is discussed since current navigator selection research is a logical spinoff of work done in that area.

The AFOQT

The Air Force Officers Qualifying Test, or AFOQT, has been used for several years to select applicants for Air Force pilot and navigator training (Berger, 1990:1). It is used to measure the aptitudes of officer candidates in Air Force Reserve Officer Training Corps (AFROTC) and Officer Training School (OTS). The Air Force Academy does not use the AFOQT in selecting its cadets for flying training. The current test produces five composite scores: Verbal, Quantitative, Academic Aptitude, Pilot, and Navigator-Technical. Minimum qualifying scores on certain composites must be met in order for an applicant to be considered for flying training (Berger, 1990:1). The Navigator-Technical score, or Nav-Tech score, is primarily used in the selection of officers to attend Undergraduate Navigator Training (UNT). The Pilot score is mostly used for pilot selection (Berger, 1990:10-11). The entire AFOQT is validated and revised periodically to ensure that it relates to measures of performance in flight training (Miller, 1966:1;Valentine, 1977:5).

As far back as 1966, the Navigator-Technical composite has been shown to be a good predictor of success in navigator training (Miller, 1966). This study examined data on 2,132 student navigators, and was concerned with the relationship between AFOQT scores, categories of elimination from training, and training grades. Some categories of elimination were: academic, flying deficiency, and motivational. Training grades were the final grades in the academic, flying, and military aspects of the training programs. The Nav-Tech composite was found to be statistically correlated to the dichotomous criterion of graduation/elimination for both academic and flying deficiency elimination. The motivational elimination category, however, was not very predictable from the composite. The final training grades of academic and flying were also related to the AFOQT scores. Academic success in particular for navigator trainees was very predictable from the Nav-Tech scores (Miller, 1966).

Of course, this study is fairly old. A recent study on a more current version of the AFOQT also validated the usefulness of this test (Arth, 1990). This research examined data on 632 navigator and 695 pilot candidates. Similar to other studies on the AFOQT, the pass/fail criterion was the variable of interest. Not only was the validation of the AFOQT composites undertaken, but the study also wanted to see if "the existing Navigator-Technical and Pilot composites could be combined into a single "aircrew" composite" for pilot and navigator selection (Arth, 1990:1). For the navigators, it was found that five of the six subtests in the Nav-Tech composite alone correlated significantly with the pass/fail criterion. Three of the five overall composites - the Pilot, Nav-Tech, and Quantitative composites - when considered together, correlated very well with navigator training performance. As for the question of using a common composite for both pilots and navigators, the researchers found that there was a loss in the ability to predict training success when a common composite was used. Hence, they concluded that the current practice of having separate composites for pilots and navigators is better (Arth, 1990).

Previous Navigator Selection Research

In 1980, an early attempt to help identify factors for navigator training success was a "diagnostic pre-navigation screening test (Pre-Nav test)" (McDaniel, 1984:203). The purpose of the Pre-Nav test was to measure navigator-related skills in students when they first arrived at UNT. Initial research indicated that an individual's score on this test "could be strongly correlated to his or her chances for graduation or elimination" (McDaniel, 1984:204). The Pre-Nav test would become a subtest of the Basic Navigator Battery (BNB) (McDaniel, 1984:204).

Also around 1980, an experimental battery of tests was developed to help supplement or identify alternative selection means to the AFOQT (Shanahan, 1986:1). This study wanted to see if these tests, called the Basic Navigator Battery (BNB), could add significantly to "the overall predictive validity of the Nav-Tech composite of the AFOQT" (Shanahan, 1986:1). Two criterion measures were of interest: the pass/fail criterion, and individual lesson grades. Data for 544 student navigators was used (Shanahan, 1986:2).

Two sets of predictor variables were looked at in this study (Shanahan, 1986:2). The first set was the five composite scores of the AFOQT. The second set was the scores from the five subtests of the BNB. The BNB subtests were all of the paper and pencil variety and were given to the test subjects one week prior to the start of their training class. The subtests involved mathematical reasoning, perceptual reasoning, the ability to follow a set of procedures, and a simulated navigation mission (Shanahan, 1986:2).

The study examined several statistical models involving these test scores (Shanahan, 1986:4-8). Essentially, three prediction models were identified that could be considered in the analysis of pass/fail. The first model consisted only of the AFOQT Nav-Tech scores. The second model added the AFOQT Quantitative composite scores to the first model. Model number 3 added two BNB subtest scores to the second model. Only two of the five BNB tests contributed significantly to this last model, these being the subtests of mathematical reasoning and procedure following. Model 3 gave the best correlation to the pass/fail criterion. As for the prediction of lesson grades, again the best models were those that contained the AFOQT Nav-Tech and Quantitative scores, and the scores from the same BNB subtests (Shanahan, 1986).

The study did not recommend incorporating the BNB into the navigator selection system at that time, however (Shanahan, 1986:8). Further research into the BNB with the development of new forms of this test was recommended. The researchers also recommended that since computerized testing for pilots was being investigated, navigator selection research might benefit from the same. They stated that

> a similar computerized system, adapted specifically for navigator selection, might further increase the accuracy of prediction over that obtainable from conventional paper-and-pencil tests such as the AFOQT and BNB. (Shanahan, 1986:9)

Pilot Selection Research

Current navigator selection research has developed from recent pilot selection work. Aviation psychologists and professionals have recognized that a successful pilot needs very good hand-eye coordination (psychomotor abilities), the ability to rapidly process information, and particular personality characteristics (Kantor, 1988:A33). The problem is how to measure these qualities to select the best candidates for pilot training. To help select Air Force pilots, researchers have developed computer based aptitude testing. Computers have long been used to measure how humans use information and make decisions quickly (Kantor, 1988:A33). Researchers say one of the advantages of computer testing is that "the candidates can be given highly dynamic types of problems to solve and can be timed, down to the thousandth of a second, on how long it takes them to respond" (Kantor, 1988:A33). They add that computer testing and aircrew selection research is a "perfect marriage" and the Basic Attributes System (BAT) featuring a portable microcomputer was developed as a result (Kantor, 1988:A33).

The original BAT system consisted of 15 tests designed to measure "psychomotor abilities, information processing capabilities, and personality characteristics" (Kantor, 1988:A33). The names of some of the tests were Mental Rotation, Time Sharing, Item Recognition, Two-Hand Coordination, and Complex Coordination. Test data was collected on several hundred pilot training candidates during the 1980's to help develop a statistical model to predict training outcome. Subjects were administered the tests at a portable testing laboratory called the PORTA-BAT. The PORTA-BAT features a high speed microcomputer, single and two-axis joysticks for coordination testing, and a data entry keypad (Kantor, 1988:A33-A35).

One recent study involved 478 officer candidates from Air Force Reserve Officer Training Corps (AFROTC) and Officer Training School (OTS) who had been chosen to attend Undergraduate Pilot Training (UPT) "in part, on the basis of their AFOQT scores" (Carretta, 1989:46). All the subjects were tested using the PORTA-BAT system prior to their entrance into training, and they were tracked through UPT until they graduated or were eliminated. This study not only wanted to use the BAT to predict success or failure, but also to see if it could predict those trainees who were selected for fighter aircraft duty. Three statistical models were evaluated against training outcome and fighter aircraft selection. The first model, called simply Model 1, included only AFOQT Pilot and Navigator-Technical composite scores. Model 2 was composed of only the BAT test scores. And Model 3 included both the AFOQT and BAT, which was a total of 42 scores from every single subtest. Model 3 had the highest predictive validity for both outcome and fighter selection, but it was obvious that not all 42 variables were needed in the model. This led to a simpler UPT outcome model of 11 scores from 8 tests. The AFOQT, two psychomotor tests, three cognitive ability tests, and two personality/attitude tests were concluded to be the most important. For the model of fighter aircraft selection, the AFOQT and three BAT tests were the best predictive variables. The study concluded that the BAT battery measuring psychomotor skills, reaction times, and memory efficiency could add significantly to the AFOQT's ability to determine training success (Carretta, 1989).

For navigator selection, a special version of the PORTA-BAT system called the NAV-BAT was prepared (Kantor,1988:A38). Data collected from this system is being used in this thesis. The NAV-BAT has less of a psychomotor emphasis and more of a concentration on information processing (Kantor, 1988:A38). This is logical since the work of a navigator demands less hand-eye coordination than required of pilots.

Summary

This chapter briefly reviewed literature related to past and present research in selecting candidates for flight training. The long used AFOQT continues to be a valid predictor of training success. Various other written and computerized tests have been examined by researchers as possible additions to selection systems. All have generally had some predictive validity for training success or failure. The trend in current pilot selection is to use a computerized psychomotor and cognitive battery of tests along with the AFOQT. Navigator selection studies are shifting toward similar systems.

III. METHODOLOGY

This chapter discusses the methodology used in this research. The data base used is examined and the numerous variables contained in the data are described. Statistical methods used in the conduct of this study are also examined.

The Data

The data was compiled by the Air Force Human Resources Lab (AFHRL) at Brooks AFB, TX. The sample set is 317 navigator candidates in training at Mather AFB, CA in the years 1988 to 1990. The data includes AFOQT and BAT test scores along with miscellaneous data on each individual including age, sex right or left handed, and training class number. The final training outcome of pass/fail is available for most of the trainees as is the particular training track for each person. Appendices A through C give more information on the raw data. The data base was analyzed initially using descriptive statistical procedures found in the computer software package SAS (SAS-BASICS:731).

Test scores will be variables in this research. There are 14 main BAT tests producing a total of 52 scores. The AFOQT contains 5 composite scores along with 16 subtest scores. In all, there are 73 different test scores that could be variables in any model development. For the AFOQT variables in this research, only the 5 composite scores are considered since these 5 scores are formed from the 16 subtests scores (see also Appendix D). Therefore, the 16 subtests scores of the AFOQT will not be separate variables in model development. Not considering these 16 scores is a first attempt to reduce the dimensionality of the problem. Table 1 lists all the tests and the number of scores produced by each.

Table 1

List of Tests

Test	Name	No. of Scores Produced
ANT	Anticipation	1
ABC	Random Character	5
INT	Internal Timing	4
ITM	Item Recognition	3
MKN	Manikin	3
MRT	Mental Rotation	3
M3D	3-D Mental Rotation	3
PAT	Pattern Recognition	3
PSP	Perceptual Speed	3
PS3	Complex Coordination	6
SAA	Scanning and Allocating	6
SDL	Scheduling	3
SMA	Serial Mental Arithmetic	6
VIG	Vigilance	3
AFOQT	Air Force Officers Qual.	21

The data for all 317 trainees is not complete, however. The final training outcome data is available on only 278 of the 317. Additionally, for reasons unknown, some individuals were not given many of the BAT tests. Of the 14 main BAT tests, only 6 of them were given to a large number of trainees in this data base (Appendix E). Also, if the individual's source of commissioning was the Air Force Academy, then that person never took the AFOQT and those scores are nonexistent. A new data base was developed containing only the 278 individuals from the original sample for which a final training outcome is available.

As mentioned, data is available on only 6 of the 14 main BAT tests in a sufficiently large amount. To clarify this, data is available for these 6 BAT tests on about 95% of the individuals. For 7 of the other 8 BAT tests, data is available on only about 20% of the individuals. The one remaining BAT test, Mental Rotation (MRT), had been given to 77% of the sample, however, many of the individuals who had failed from training had not had this test. Since the computer package used in this research excludes observations with missing data in any analytical procedure (SAS-STATS:189,322,753) and since it was desired to have as large a data base as possible, only the 6 tests mentioned above are considered in this research. Data for the AFOQT is available on 88% of the trainees in the sample.

To summarize, because of the missing data as few as 216 of the 278 individuals in the new data base are actually included by SAS in the analysis, and only 27 of the aforementioned 73 variables are considered.

Variable Definitions

This section defines the variables used in the analysis. First, the independent or predictor variables will be presented by describing each BAT test that produces these variables. The AFOQT composite scores are also described. Then the variables or groups to be predicted are defined. All the BAT tests were performed using a computerized testing device. For tests measuring tracking error, rates, or response times, the goal of the test taker is to get as low a score as possible. For all other tests, the goal is to get a high score.

PS3 - Complex Coordination - This BAT test measures psychomotor or hand-eye coordination ability by evaluating tracking ability involving multiple-axis events (Frey, 1990). The test subject uses a right-hand dual-axis joystick to control the horizontal and vertical movement of a cursor on the computer screen. A left-hand joystick controls the left-right movement of a vertical bar of light at the base of the screen. The subject's task is to maintain the cursor centered on a large cross at the center of the screen while simultaneously centering the bar at the base of the screen. The subject completes a three minute practice session and a five minute test. This test produces the variables PS3X1, PS3Y1, PS3Z1, PS3X2, PS3Y2, and PS3Z2. The first three variables are tracking error scores and the last three variables are stick movement rate scores (Frey, 1990).

ITM - Item Recognition - This test measures cognitive or information processing ability, in particular, short term memory storage (Frey, 1990). A string of one to six digits is presented on the screen. The string is removed and followed, after a brief delay, by a single digit. The test subject must press a keypad button marked "yes" if the single digit was one of those presented in the initial string of digits, or they press a button marked "no" if the reverse is true. A total of 48 strings are presented. The subject must work as quickly and accurately as possible. This test produces the variables ITMARTC, ITMARTA, and ITMPER. The first two variables are response times and the other is percent correct (Frey, 1990).

VIG - Vigilance - This test also measures cognitive ability by evaluating perceptual vigilance and resource allocation (Frey, 1990). In this test, a 9 block by 9 block grid appears on the computer screen. Along the side and top of the grid are numbers which serve as the coordinates of each block in the grid. During the test, asterisks (*) will appear within different blocks. The test subject's "routine task" is to cancel the asterisks as quickly as possible by entering the coordinates of the block in which an asterisk appears. Arrows (<) will also appear. The test subject's "emergency task" is to cancel the arrows as quickly as possible in the order of their appearance. When no arrows are present, the subject must resume performing the routine task of cancelling asterisks. This test provides the variables VIGNRT, VIGNPT, and VIGPRT. The first variable, VIGNRT, is the number of routine tasks completed. VIGNPT is the number of priority or emergency tasks completed. VIGPRT is the average response time of the priority tasks (Frey, 1990).

SAA - Scanning and Allocating - This test measures both psychomotor and cognitive ability by assessing time sharing and resource allocation (Frey, 1990). The test subject is presented with a box with a cross within it in the upper left hand corner of the screen. During the test, the cross will move left or right away from its vertical alignment. The subject must maintain the vertical alignment of the cross using the right-hand joystick. An alignment mark at the top of the box is provided to serve as a reference point. After one minute, and each minute thereafter, an additional box will appear in one of the remaining corners of the screen until there are a total of four boxes. The test subject must maintain simultaneous alignment when two or more boxes appear, even though only one box can be controlled, or made active, at a time. To activate a particular box, the subject presses the number of that box (1-4) on the keypad. The active box is identified by its blinking box number on the screen. This test gives the variables SCAATE1, SCAATE2, SCAATE3, SCANS1, SCANS2, AND SCANS3. The first three variables are tracking error scores and the last three variables are number of times the test subject switches to a particular box per minute (Frey, 1990).

MKN - Manikin - This test measures cognitive ability, in particular, spatial transformation ability (Frey, 1990). The subject is presented with an illustration of a man in one of four orientations: front or back view, and right side up or upside down. The "manikin" has a square in one hand and a circle in the other. The hand holding the square or circle varies from trial to trial. During each trial, a "target" square or circle appears beneath the manikin. The test subject must indicate on the keypad which of the manikin's hands the "target" is in. A total of 32 trials are given in the test. This test produces the variables MKNARTC, MKNARTA, and MKNPER. The first two variables are response times and the other is percent correct (Frey, 1990).

ANT - Anticipation - This test measures cognitive ability by assessing velocity estimation (Frey, 1990). In this test, a target moves from left to right on the screen. When the target reaches a point "A" on the screen, it disappears but continues to move to the right. The subject must estimate when the target reaches a point "B" which is located to the right of point "A". When the subject thinks the target has reached point "B", he/she presses a button on the keypad to record the target's actual position. The target then reappears at the point where the subject stopped its movement, thus providing feedback. Target movement rate is constant within a trial but may vary between trials. A total of 50 trials are given. The variable ANTAAERR, which is tracking error, comes from this test (Frey, 1990).

AFOQT - All examinees taking the AFOQT take every part of it (Berger, 1990:34). Hence, even though a subject is applying for pilot training, he will take the navigator part of the AFOQT also. The following are the variables used in this analysis for the AFOQT composite scores. PILOT2 is the Pilot composite score used for predicting pilot training success. NAV2 is the Navigator-Technical composite score used for predicting success in navigator training and other programs which stress mechanical and engineering concepts. The academic aptitude composite score which measures verbal and mathematical skills is ACAD2. VERB2 is the Verbal composite score which measures verbal skills only. Finally, QUAN2 is the Quantitative composite score which measures mathematical skills only (Berger, 1990:10-11).

There are several variables which define the groups to be predicted by this analysis. The first is UNTOUT, which is the navigator training final outcome for an individual. UNTOUT takes on two values; a 0 for failing and a 1 for passing training. The three training tracks an individual can be placed in are defined by separate variables. NV6AA0 is the bomber-fighter or BF track (Dupree, 1990). NV6AB0 is the tanker-transport-bomber or TTB track. The difference in the bombers in each of these tracks is that the aircraft in the BF track are considered "fast-movers" while those in the TTB track are not. The third track is NV6ACO, the Electronic Warfare Officer or EWO track (Dupree, 1990). Appendices F and G show the demographic breakdown of training outcome and training tracks for the individuals in this data.

Dimensionality Assessment

Since the tests are designed to measure different qualities in an individual, it is interesting to see if the set of predictor variables has underlying dimensions that reflect those qualities. This is done with Factor Analysis. Factor analysis attempts to find a smaller number of common dimensions that some of the variables share while still accounting for most of the variation in the data (Dillon, 1984:53). Optionally, if a small number of dimensions or factors can be found, then only those factors need to be dealt with instead of a large number of predictor variables.

This analysis begins by extracting eigenvalues from the data correlation matrix (Bauer, 1990). The number of eigenvalues equals the number of variables. Each underlying factor has an associated eigenvalue. The magnitude of each eigenvalue is proportional to the total variation accounted for by that factor. Hence, there is a point where only a few factors account for most of the variation, and the remaining factors can be discarded. One criterion for the number of factors to keep, Kaiser's criterion, retains only those factors with eigenvalues greater than one (Bauer, 1990).

Each original variable is correlated with a factor and these correlations or factor loadings can be seen in the pattern matrix generated from a factor analysis (Dillon, 1984:63). Therefore, the variables most correlated with a particular factor can be identified and the factor can be "named" based on its highest loading variables. To force each variable to load significantly on only one factor, the concept of factor rotation is sometimes used (Dillon, 1984:69). From the loadings, factor scores for each observation or individual in the data set can be computed (Dillon, 1984:96). These scores can then become the new independent variables for further analysis. The procedure used for factor analysis here is PROC FACTOR (SAS-STATS:335).

Besides factor analysis, another approach to possibly reduce the dimensionality and to help eliminate any multicollinearity present will be to check for highly correlated variables. Multicollinearity occurs when strong correlations exist between the predictor variables and can lead to unstable analyses (Dillon, 1984:271). In this study, if two variables are highly correlated, then the technique of dropping one of the two from the analysis at hand will be used (Dillon, 1984:281). Variables with a correlation coefficient of 0.9 or above will be considered highly correlated (Reynolds, 1991) while those with a coefficient of 0.7 or above (Robinson, 1990) will be considered closely.

Discriminant Analysis

There are distinct groups that an individual can be placed in - these being the two groups of pass or fail, and the three different training track groups. Hence, the statistical method of Discriminant Analysis is used. Discriminant analysis is defined as "a statistical technique for classifying individuals or objects into mutually exclusive and exhaustive groups on the basis of a set of independent variables" (Dillon, 1984:360). This technique can be thought of as assigning to each individual a discriminant score which is actually a weighted average of the values of the variables characterizing the individual. This score is then used to classify the individual into one of the groups. Mathematically, the score is a linear combination (discriminant function) of the original independent variables which minimizes the probability of misclassifying individuals and is given by:

$$\mathbf{Y} = \mathbf{b}^T\mathbf{X} \qquad (1)$$

where

$\mathbf{Y}$ = a 1 x n vector of discriminant scores
$\mathbf{b}^T$ = a 1 x p transpose vector of discriminant weights
$\mathbf{X}$ = a p x n matrix of independent variables
n = the number of observations or individuals
p = the number of independent variables

For two groups, the vector $\mathbf{b}$ is given by:

$$\mathbf{b} = \mathbf{S}^{-1}(\bar{\mathbf{x}}_1 - \bar{\mathbf{x}}_2) \qquad (2)$$

where

> S = the pooled (combined groups) covariance matrix
> $\bar{\mathbf{x}}_1$ = the mean vector for group 1
> $\bar{\mathbf{x}}_2$ = the mean vector for group 2

The mean values ($\bar{Y}_i$), or group centroids, can be computed from the group discrimininant scores (Dillon, 1984:366,. If the distance between the centroids along the discriminant function Y is statistically significant, then the groups do indeed differ from one another. Furthermore, a "point of separation" between the groups can be found (Dillon, 1984:369). An individual is then classified into one of the groups based on where his discriminant score falls in relation to the point of separation. Using this classification rule is good only if the prior probabilities of group membership are equal. If these probabilities are not equal, then the classification rule should take them into account (Dillon, 1984:369-372).

For more than two groups, the analysis is just a generalization of the two-group problem (Dillon, 1984:394). In order for the linear discriminant function to perform at its optimum, certain assumptions must be met:

1. The p variables must have a multivariate normal distribution.
2. The p x p covariance matrix of the variables in the groups must be the same (Dillon, 1984:362).

The procedure PROC DISCRIM in SAS is used to perform the discriminate analysis (SAS-STATS:317). The SAS procedure attempts to find a discriminate function for each group. For an observation to be classified, a discriminate score from each group function is found for that observation. Then the rule is to assign the observation to the respective group with the largest score (Bauer, 1990).

In order to be parsimonious with the predictor variables so as to select the "best" set for discriminanting, an additional step was taken. Usually, when many independent variables are available, some stepwise selection procedure is used to see which variables should enter into the discriminant function (Dillon, 1984:375). This is done with this analysis. The procedure PROC STEPDISC in SAS is used for the stepwise discriminant analysis (SAS-STATS:749).

Logistic Regression

As mentioned, one of the goals of this research is try to build a model which predicts the training outcome of an individual. The outcome is the binary response variable UNTOUT. As seen above, UNTOUT can be treated as two groups, the group of passing and the group of failing. So, discriminant analysis can be used to see which group an individual belongs to, based on his/her test scores. Another method, the technique of Logistic Regression is also used to predict UNTOUT. Logistic regression can be useful when the response variable is binary (Neter, 1985:361). Similiar to linear regression, logistic regression finds a function which gives the mean response for the independent variables.

However, when the dependent variable is binary like UNTOUT, the mean response represents the probability that the response equals 1 for the levels of the independent variables (Neter, 1985:355). Hence, a function found through logistic regression for UNTOUT gives the probability of an individual passing.

With binary responses, the most appropriate response function is usually curvilinear, with asymptotes at 0 and 1 (Neter, 1985:361-362). The response function is called the logistic function and is given by:

$$P = \frac{\exp(B_0 + B_1 X)}{1 + \exp(B_0 + B_1 X)} \qquad (3)$$

where

P = the predicted probability
B_0, B_1 = parameters to be estimated
X = independent variable

Figure 1 illustrates the logistic function.

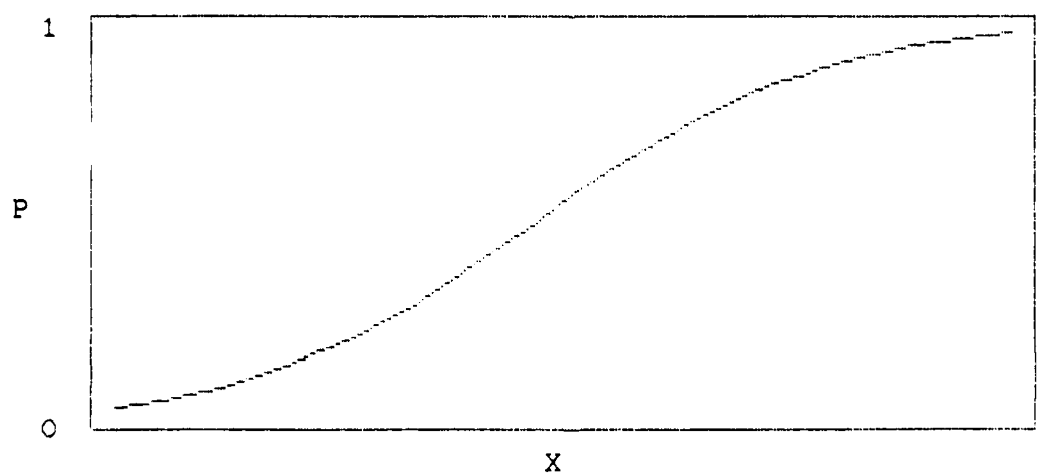


Figure 1. Logistic Function

The equation here is for the special case of only one independent variable. The function can be extended into a logistic function for several independent variables (Neter, 1985:367). For i variables, the quantity in parenthesis in equation (3) would become:

$$B_0 + B_1X_1 + B_2X_2 + \ldots + B_iX_i \qquad (4)$$

In this case, many parameters would have to be estimated from the data. Neter suggests estimating the parameters using weighted least squares (Neter, 1985:359-367), but this appears to be very inefficient. A better way, the method of maximum likelihood (Bauer, 1990), can be used. In SAS, the procedure PROC LOGISTIC uses maximum likelihood for logistic regression (SAS/STAT:1072). This procedure also has a stepwise option for helping select the best variables to be included in the final model (SAS/STAT:1076).

Validation

Models obtained from the above analyses will be considered valid if they can properly discriminate or predict, given the data of future individuals. To help check this validity, a subset of six individuals was selected at random from the initial data base and removed. This subset was made into a validation data base and consists of individuals from different training tracks with different final training outcomes (2 fail and 4 pass). The validation data base is used with any models developed from the analyses to check their validity. In addition, the discriminant procedures will automatically classify observations used to develop the discriminant functions. Therefore, feedback is given on how well the classification models are.

However, there may be a problem with removing some individuals from the data who failed training in order to make a validation data base. As can be seen in Appendix F, the sample of failures is very small (10 out of 278). So removing some of these individuals will probably affect the models developed. Therefore, models developed for predicting outcome will be examined with the validation individuals taken out and also with no data taken out to determine any sensitivity in the data.

Summary

This chapter presented the various methods used to analyze the data. The data bases were discussed and the variables defined. Statistical methods of factor analysis, discriminant analysis, and logistic regression were presented. The next chapter gives the results of the study.

IV. RESULTS

This chapter presents the results of the analyses discussed in the previous chapter. Any deviations from the methodology, assumptions made, or judgemental decisions made will be discussed.

Descriptive Statistics

Appendices H through M present some descriptive statistics of the variables used in this study. Each appendix is devoted to a separate group. For example, appendices I and J give descriptive statistics for individuals failing and individuals passing respectively. Appendices K through M give statistics for individuals in each of the three training tracks. The only real insights that are readily apparent from the statistics are:

1. Individuals failing have much lower mean AFOQT scores than those of the individuals passing.
2. Trainees in the Bomber-Fighter (BF) track generally have the highest AFOQT scores of the three tracks.
3. Trainees in the Tanker-Transport-Bomber (TTB) track have the lowest AFOQT scores of the three tracks.
4. Trainees in the BF track have the better psychomotor scores (lower tracking error scores) than the other tracks.

5. Variables measuring response times are not noticeably different among the three tracks except for VIGPRT, which is much lower for trainees in the BF track.

Correlation Results

A few of the variables are highly correlated with each other. These high correlations are all positive also. As expected, some of the AFOQT composite scores are correlated since many of the same AFOQT subtests contribute to different composites. The very high correlation between ITMARTC-ITMARTA and MKNARTC-MKNARTA suggests that these scores are virtually the same for their respective tests. Table 2 shows the highly correlated variables. The p-value of all of the following coefficients is 0.0001. All other correlation coefficients between variables are less than 0.7. Appendix N presents the entire correlation matrix.

Table 2

Highly Correlated Variables

Variables	Correlation Coefficient
ITMARTC - ITMARTA	0.997
MKNARTC - MKNARTA	0.967
PS3X2 - PS3Y2	0.905
PS3X2 - PS3Z2	0.827
PS3Y2 - PS3Z2	0.844
PILOT2 - NAV2	0.845
ACAD2 - VERB2	0.891
ACAD2 - QUAN2	0.795
NAV2 - QUAN2	0.757
SCANS1 - SCANS2	0.720

Factor Analysis

One reason for performing factor analysis on the variables was to satisfy a curiosity that perhaps there was only two dominant underlying factors to the data - a psychomotor factor and a cognitive factor. However, the factor analysis using the correlation matrix reveals that there are eight factors accounting for 72.6% of the total variation in the data that can be considered. Using the Kaiser's criterion of keeping factors with an eigenvalue greater than one leads to the eight factors. These can be seen in the eigenvalue scree plot in Figure 2.

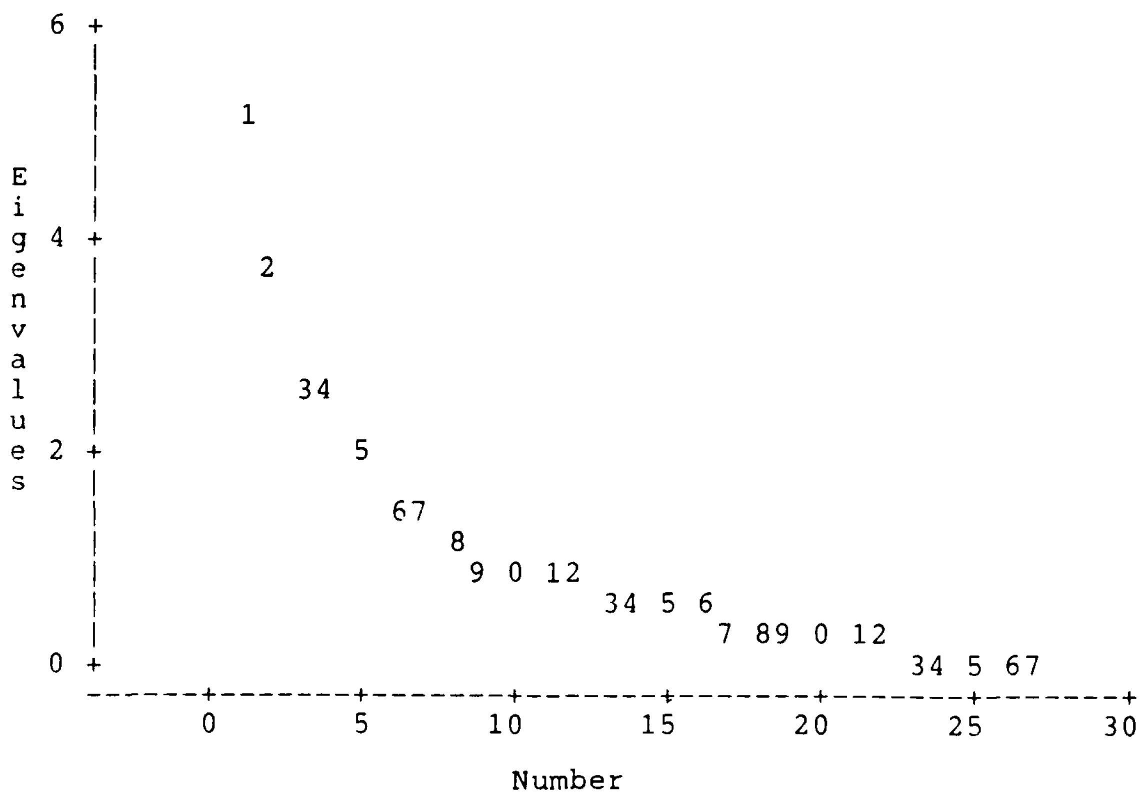


Figure 2. Scree Plot of Eigenvalues from Correlation Matrix

All the eigenvalues and their cumulative proportions of total variation are given in Appendix O. Appendix P shows the factor pattern obtained from SAS.

Rotating the factors using Varimax Rotation leads to the interesting result of each factor being primarily loaded by particular BAT tests. In other words, each factor for the most part appears to be a separate test and can be named accordingly. Appendix Q contains the rotated factor pattern. Table 3 presents the factors and names given to each. Factors 5 and 8 are the only ones "mixed" with variables or scores from two tests. Variables from the SAA test (Scanning and Allocating) are loaded on both factors 4 and 5.

Table 3

Rotated Factor Analysis Results

Factor	Name	Variables with Max Loading
1	PS3	PS3X2, PS3Y2, PS3Z2, PS3Y1, PS3Z1, PS3X1
2	AFOQT	ACAD2, VERB2, QUAN2, NAV2, PILOT2
3	ITM	ITMARTA, ITMARTC, ITMPER
4	SCANS	SCANS2, SCANS1, SCANS3
5	SCAATE	SCAATE2, SCAATE1, SCAATE3, ANTAAERR
6	MKN	MKNARTC, MKNARTA
7	VIG	VIGPRT, VIGNPT
8	VIG/MKN	VIGNRT, MKNPER

The test scores for each individual could have been converted into factor scores for each person. This would have trimmed the original 2/ predictor variables down to only eight factor scores to be dealt with. However, since stepwise procedures are available to help reduce the dimensionality for the analyses to be attempted, the decision was made to stay with the predictor variables.

Stepwise Discriminant Analysis

Since some of the variables are highly correlated, the stepwise analyses were performed with the original 27 variables as input and also with some of the highly correlated variables removed to see if the correlation could affect the results. Seven variables are considered candidates for removal. The variables removed are:

1. ITMARTA
2. MKNARTA
3. PS3Y2
4. PS3Z2
5. PILOT2
6. VERB2
7. QUAN2

Thus the analyses are performed with both 27 and 20 variables as input. SAS default significance levels (0.15) for variables to enter and stay in the model are used (SAS-STAT:751).

Stepwise for UNTOUT. As mentioned in Chapter 3, the sample for individuals failing is very small. So, the plan for removing certain individuals at random for a validation data set (Appendix R) may affect the results for the discriminant analysis for the groups of pass/fail. Hence, results of the stepwise procedure for the data with the validation set removed and for the data with no one removed (N=278) are both reported here in the following tables. The number of individuals taken out is six, two fail and four pass, leaving 272 for SAS to analyze. However, because of missing data for the specific input variables, the actual number analyzed by SAS is lower as indicated in the tables.

The Wilks' Lambda in the following tables is a statistic with a value between 0 and 1 for testing to see if the groups' means are equal (SAS-STAT:754). This statistic should be close to 0 if the groups are well separated. Similarily, the average squared canonical correlation (ASCC) should be close to 1 for well separated groups (SAS-STATS:754).

Table 4

Summary of STEPDISC With 27 Variables as Input
Groups - UNTOUT
N = 219

Step	Variable Entered	Variable Removed	Wilks' Lambda	Prob < Lambda	ASCC
1	PILOT2		0.9319	0.0001	0.0680
2	MKNPER		0.9139	0.0001	0.0860
3	ACAD2		0.9030	0.0001	0.0969

Table 5

Summary of STEPDISC With 20 Variables as Input
Groups - UNTOUT
N = 219

Step	Variable Entered	Variable Removed	Wilks' Lambda	Prob < Lambda	ASCC
1	NAV2		0.9358	0.0002	0.0642
2	MKNPER		0.9183	0.0001	0.0817

Table 6

Summary of STEPDISC With 27 and 20 Variables as Input*
Groups - UNTOUT
N = 225

Step	Variable Entered	Variable Removed	Wilks' Lambda	Prob < Lambda	ASCC
1	NAV2		0.9155	0.0001	0.0845
2	MKNPER		0.8966	0.0001	0.1034
3	SCAATE1		0.8845	0.0001	0.1155
4	PS3X1		0.8738	0.0001	0.1262
5	PS3Y1		0.8555	0.0001	0.1444

* Same results for 27 and 20 variables

Different variables are being selected each time, confirming the suspicion that the sample for individuals failing is so small that the analysis is sensitive to changes in that sample. Also, the test statistics in the preceding tables indicate that the groups of pass/fail are not well separated. So, discriminating between the groups may be difficult.

Stepwise for Training Tracks. The samples for each training track are sufficiently large so the removal of the six validation data points should not affect the training track analysis. The stepwise procedure gave the same results for both 27 and 20 variables as input. Table 7 presents the findings. Again, the test statistics indicate that the groups are not well separated.

Table 7

Summary of STEPDISC With 27 and 20 Variables as Input +
Groups - Training Tracks
N = 216 *

Step	Variable Entered	Variable Removed	Wilks' Lambda	Prob < Lambda	ASCC
1	ACAD2		0.8873	0.0001	0.0564
2	NAV2		0.8650	0.0001	0.0675
3	SCANS2		0.8490	0.0001	0.0767

+ Same results for 27 and 20 variables
* No training track data on 3 individuals

Discriminant Analysis

Discriminant analysis was performed using the variables from the stepwise procedure. After finding discriminant functions, the SAS procedure reports the group where each observation or individual in the data should belong according to the functions (SAS-STAT:318). Thus, any misclassified observations will be pointed out. The following assumptions were used:

1. Pooled covariance matrix used.
2. Prior probabilities of group membership are proportional to the group size.
3. Normality of the variables is assumed.

Discriminant Analysis for UNTOUT. For discriminating between the two groups of pass/fail, again the two data bases of N=272 and N=278 are used. Also because of missing data for the input variables, the actual N number is indicated in the following tables. The small validation data base is used with discriminant functions found only with the N=272 data to test how well the functions can classify observations or individuals not used to develop them.

Table 8

Discriminant Analysis for UNTOUT
Input Variables: PILOT2, ACAD2, MKNPER
N = 228

Coefficients of Linear Discriminant Functions -

	Group	
Variable	Fail	Pass
CONSTANT	-10.98525	-15.30154
PILOT2	0.12037	0.17830
ACAD2	0.03046	0.06060
MKNPER	0.15245	0.19305

Results of Classification -

	Classified Into	
Actual Group	Fail	Pass
Fail	1 (12.5%)	7 (87.5%)
Pass	0 (0.0%)	220 (100.0%)

Results of Classification for Validation Data (N=6) -

	Classified Into	
Actual Group	Fail	Pass
Fail	0 (0.0%)	2 (100.0%)
Pass	0 (0.0%)	4 (100.0%)

Notice from Table 8 that only one individual out of eight who failed was correctly classified as failing. The other seven apparently had high enough PILOT2, ACAD2, and MKNPER scores to place them into the pass group. For the validation data, similiar results are found in that all those who failed are classified into the pass group.

Table 9

Discriminant Analysis for UNTOUT
Input Variables: NAV2, MKNPER
N = 228

Coefficients of Linear Discriminant Functions -

	Group	
Variable	Fail	Pass
CONSTANT	-11.63893	-15.57915
NAV2	0.16861	0.24442
MKNPER	0.14849	0.19019

Results of Classification -

	Classified Into	
Actual Group	Fail	Pass
Fail	0 (0.0%)	8 (100.0%)
Pass	0 (0.0%)	220 (100.0%)

Results of Classification for Validation Data (N=6) -

	Classified Into	
Actual Group	Fail	Pass
Fail	0 (0.0%)	2 (100.0%)
Pass	0 (0.0%)	4 (100.0%)

Again notice in Table 9 that it is difficult to classify correctly the individuals who failed. According to these discriminant functions, everyone should pass. Table 10 gives the discrimination results for the third set of input variables.

Table 10

Discriminate Analysis for UNTOUT
Input Variables: NAV2, MKNPER, SCAATE1, PS3X1, PS3Y1
N = 232

Coefficients of Linear Discriminate Functions -

Variable	Group: Fail	Group: Pass
CONSTANT	-20.78446	-26.70168
NAV2	0.21828	0.30284
MKNPER	0.18008	0.22712
SCAATE1	0.00039	0.00046
PS3X1	0.00021	0.00010
PS3Y1	-0.00003	0.00007

Results of Classification -

Actual Group	Classified Into: Fail	Classified Into: Pass
Fail	2 (20.0%)	8 (80.0%)
Pass	1 (0.45%)	221 (99.5%)

These functions also have a difficult time classifying the individuals who failed. An interesting result here is that one person who passed was placed into the failing group.

Discriminant Analysis for Training Tracks. Table 11 gives the discriminant results for the three training tracks. The validation data (2 individuals from each track) is used to see how well the discriminant functions can classify those individuals.

Table 11
Discriminant Analysis for Training Tracks
Input Variables: ACAD2, NAV2, SCANS2
N = 230

Coefficients of Linear Discriminant Function -

	Group		
Variable	BF	TTB	EWO
CONSTANT	-16.6927	-10.8313	-14.3342
ACAD2	0.0532	0.0287	0.0467
NAV2	0.2717	0.2366	0.2633
SCANS2	0.2700	0.2465	0.2030

Results of Classification -

	Classified Into		
Actual Group	BF	TTB	EWO
Unknown *	0 (0.0%)	3 (100.0%)	0 (0.0%)
BF	9 (23.7%)	23 (60.5%)	6 (16%)
TTB	2 (1.5%)	126 (93.3%)	7 (5.2%)
EWO	2 (3.7%)	42 (77.8%)	10 (19%)

Results of Classification for Validation Data (N=6) -

	Classified Into		
Actual Group	BF	TTB	EWO
BF	1 (50.0%)	1 (50.0%)	0 (0.0%)
TTB	0 (0.0%)	2 (100.0%)	0 (0.0%)
EWO	0 (0.0%)	1 (50.0%)	1 (50%)

* Training Track data missing for 3 individuals

Many of the trainees in the BF and EWO tracks were incorrectly classified into the TTB track. However, almost all the trainees in the TTB track were correctly classified. The three individuals with missing data for their training track were placed into the TTB track.

Logistic Regression

Similiar to the stepwise discriminant analysis, the logistic regression to find a model for probability of passing training was performed using the two data bases. Models were also obtained for 27 and 20 variables as input. The SAS default significance level values (0.05) for variables to enter and stay in the model were used (SAS/STAT:1083). After selecting variables through its stepwise procedure, PROC LOGISTIC automatically estimates the parameters for those variables by maximum likelihood (SAS/STAT:1073).

The validation data set is used for all the models developed to compare results. Table 12 gives the first results with all of the 27 predictor variables as input. The Score Chi-SQ statistic tests the effect of the explanatory variables in the model and the Wald Chi-SQ statistic is used for testing the significance of the parameter estimates (SAS/STAT:1097).

Table 12

Summary of Stepwise Logistic Regression
With 27 Variables as Input
N = 219

Stepwise Procedure -

Step	Variable Entered	Variable Removed	Score Chi-SQ	Prob > Chi-SQ
1	PILOT2		14.9122	0.0001
2	MKNPER		5.9803	0.0145

Parameter Estimation -

Variable	Parameter	Wald Chi-SQ	Prob > Chi-SQ
INTERCEPT	-5.4693	6.025[illegible]	0.0141
MKNPER	0.0543	5.2194	0.0223
PILOT2	[illegible].0921	9.9990	0.0016

Validation Data Results -

Individual	Actual Outcome	Probability of Passing From Logistic Function
1	Fail	0.97
2	Fail	0.68
3	Pass	0.99
4	Pass	0.98
5	Pass	0.97
6	Pass	0.99

It's interesting that individual No. 1 had scores that gave a very high probability of passing but failed from training. Table 13 presents the results from 20 variables as input.

Table 13

Summary of Stepwise Logistic Regression
With 20 Variables as Input
N = 219

Stepwise Procedure -

Step	Variable Entered	Variable Removed	Score Chi-SQ	Prob > Chi-SQ
1	NAV2		14.0540	0.0002
2	MKNPER		5.9245	0.0149

Parameter Estimation -

Variable	Parameter	Wald Chi-SQ	Prob > Chi-SQ
INTERCEPT	-5.5782	5.9000	0.0151
MKNPER	0.0542	5.2288	0.0222
NAV2	0.0909	9.8388	0.0017

Validation Data Results -

Individual	Actual Outcome	Probability of Passing From Logistic Function
1	Fail	0.84
2	Fail	0.80
3	Pass	0.99
4	Pass	0.99
5	Pass	0.94
6	Pass	0.99

Here it appears that if an individual's probability of passing is less than 0.90, then they are candidates for possibly failing training. Table 14 gives the results using the data with the six validation individuals not removed.

The results for the validation data are given but it must be remembered that this data was used to help develop the model.

Table 14

Summary of Stepwise Logistic Regression
With 27 and 20 Variables as Input *
N = 225

Stepwise Procedure -

Step	Variable Entered	Variable Removed	Score Chi-SQ	Prob > Chi-SQ
1	NAV2		19.0117	0.0001
2	MKNPER		7.0653	0.0079
3	SCAATE1		5.2597	0.0218

Parameter Estimation -

Variable	Parameter	Wald Chi-SQ	Prob > Chi-SQ
INTERCEPT	-11.4614	10.9752	0.0009
MKNPER	0.0704	7.6924	0.0055
SCAATE1	0.000109	4.6727	0.0306
NAV2	0.1236	13.6673	0.0002

Validation Data Results -

Individual	Actual Outcome	Probability of Passing From Logistic Function
1	Fail	0.36
2	Fail	0.63
3	Pass	0.99
4	Pass	0.97
5	Pass	0.94
6	Pass	0.99

* Same results for 27 and 20 variables

The general theme with all these logistic models appears that the trainees who passed have a probability of passing close to 1.0.

Summary

This chapter presented the results of the many analyses performed on the data. Different data bases were used with some of the same statistical techniques in order to compare results and check for sensitivity in the data.

V. CONCLUSIONS

Probably the greatest conclusion that can be gleaned from this study is that more data is needed. The sample size for individuals failing from training needs to be much larger to do a good statistical analysis. Missing test scores was a problem also. Obtaining a large sample of failures would likely cause data to be collected over several years of training classes since the failure rate appears to be small. Certainly, it is much smaller than that for pilot training. Since the percentage of failures is small, this begs the question of whether individuals failing from navigator training is a problem anyway.

The following paragraphs will discuss some insights from each of the analyses done.

Key Insights

The factor analysis was interesting in the way that each test being examined ended up being a factor to itself for the most part. This seems to imply that each of the tests are well designed and are measuring separate qualities.

The discriminant analysis for both the final training outcome and the training tracks did not perform well, but, from this, some conclusions can be made. All of the groups involved were not statistically well separated on the basis of the variables examined. Hence, discriminating between groups was difficult. It is extremely hard to tell if a person is going to flunk out of training based on their scores. The small sample size for the failing group did not help matters either.

A couple of variables seemed to be the best discriminators for final outcome. These being the NAV composite test of the AFOQT and the score MKNPER from the Manikin test. Other variables like PILOT2, and ACAD2 from the AFOQT, and SCAATE1 and some PS3 variables came out in the stepwise procedure. However, NAV2 and MKNPER were, for the most part, always selected by the procedure as the most useful variables.

For the training track discrimination, again the variables NAV2 and MKNPER were seen as key. The TTB track was well predicted. For BF and EWO trainees, there were a lot of individuals misclassified into a track that they weren't actually in, but perhaps this is not surprising. Trainees are placed into a track depending on personal preference, Air Force manpower requirements, and their performance while at navigator training. Hence, their performance on the BAT and AFOQT tests taken before they receive actual training may be nonrelated to the track they end up in. Personal preference, which is not included in this analysis, is suspected to be a very good discriminating variable for the different training tracks.

The logistic regression models are perhaps more convenient than discriminant analysis for determining final outcome. Here, a person's probability of passing can be easily computed. If it is not above some predetermined point, they can be closely looked at. Some of the same variables seen in the discriminant analysis are picked here by the stepwise logistic procedure as the best predictors. In particular, NAV2 and MKNPER are selected again as good predictors. The logistic regression analysis also suffers from the small sample size of those failing.

Recommendations for Further Research

As mentioned, more data is needed to perform a good statistical study. Not only is a larger sample needed for individuals who failed, but more data is needed in order to examine all the BAT tests.

However, since the AFOQT seems to be much more important than most of the other BAT tests examined here, perhaps the BAT tests are not needed at all for navigator selection. The AFOQT has historically been a good predictor for training success and that is seen with this study. The PILOT, NAV, and ACAD composite scores were seen in almost all of the results. The fact that the NAV composite score of the AFOQT is an important predictor is good because this is exactly what that composite is designed to do - to predict success in navigator training.

Appendix A: Key to the Data

FLD#	NC	SC	EC	NAME	DESCRIPTION	RANGE	SOURCE
1	6N	1	6	BATDATE	BAT TEST DATE (MMDDYY)	012788 TO 120989	0007.FHEADER
2	9A	7	15	SSAN	SOCIAL SECURITY NUMBER	000000000 TO 999999999	0007.FHEADER
3	20A	16	35	LNAME	LAST NAME		0007.FHEADER
4	20A	36	55	FNAME	FIRST NAME		0007.FHEADER
5	1A	56	56	INITL	MIDDLE INITIAL		0007.FHEADER
6	1A	57	57	SEX	SEX- M=1,F=2	1,2	0007.FHEADER
7	2N	58	59	AGEBAT	AGE AT BAT TESTING	21 TO 28	0007.FHEADER
8	1N	60	60	HAND	HANDEDNESS- R=1 L=2	1,2	0007.FHEADER
9	2N	61	62	BATSTAT	BAT TEST STATION	15,16	0007.FHEADER
10	2N	63	64	FLYHRS	FLYING HOURS CATEGORY	0	0007.FHEADER
11	2N	65	66	AIRSTAT	CURRENT AIRCREW STATUS	0 TO 14	0007.FHEADER
12	2N	67	68	RECAIRC	MOST RECENT AIRCRAFT FLOWN	0 TO 30,99	0007.FHEADER
13	4A	69	72	FILLER1	UNUSED AREA	BLANKS	
14	6A	73	78	COURSE	UNT COURSE NUMBER	NV6AA0 TO NV6AC0	0016.FUNT.
15	1N	79	79	UNTOUT	UNT FINAL OUTCOME(1=PASS,0=FAIL)	0,1,9,' '	0016.FUNT
16	2A	80	81	CLASSYR	UNT CLASS YEAR	88 TO 90,' '	0007.FUNT
17	3A	82	84	CLASSNO	UNT CLASS NUMBER	01 TO 15	0007.FUNT
18	3A	85	87	REASON	UNT PASS/FAIL REASON CODE(SEE NOTE 1)		0007.FUNT
19	1A	88	88	BASE	BASE CODE (SEE NOTE 2)	H,' '	0007.FUNT
20	1A	89	89	TYPE	STUDENT TYPE(SEE NOTE 3)	C,D,H,J,L,1,' '	0007.FUNT
21	1N	90	90	ABCSTAT	ABCD TESTED 1=YES, 0=NO	0 OR 1	0007.FABC
22	1N	91	91	ANTSTAT	ANTICIPATION TESTED 1=YES, 0=NO	0 OR 1	0007.FANT
23	1N	92	92	INTSTAT	INTERNAL TIMING TESTED 1=YES, 0=NO	0 OR 1	0007.FINT
24	1N	93	93	ITMSTAT	ITEM RECOGNITION TESTED 1=YES, 0=NO	0 OR 1	0007.FITM
25	1N	94	94	MKNSTAT	MANIKN TESTED 1=YES, 0=NO	0 OR 1	0007.FMKN
26	1N	95	95	MRTSTAT	MENTAL ROTATION TESTED 1=YES, 0=NO	0 OR 1	0007.FMRT
27	1N	96	96	M3DSTAT	3D MENTAL ROTATION TESTED 1=YES, 0=NO	0 OR 1	0007.FM3D
28	1N	97	97	PATSTAT	PATTERN RECOGNITION TESTED 1=YES, 0=NO	0 OR 1	0007.FPAT
29	1N	98	98	PSPSTAT	NEW PERCEPTUAL SPEED TESTED 1=YES, 0=NO	0 OR 1	0007.FPSP
30	1N	99	99	PS3STAT	2-HAND/COMPLEX COORD TESTED 1=YES, 0=NO	0 OR 1	0007.FPS3
31	1N	100	100	SAASTAT	SCANNING ALLOCATING TESTED 1=YES, 0=NO	0 OR 1	0007.FSAA
32	1N	101	101	SDLSTAT	SCHEDULING TESTED 1=YES, 0=NO	0 OR 1	0007.FSDL
33	1N	102	102	SMASTAT	SERIAL MENTAL ARITH. TESTED 1=YES, 0=NO	0 OR 1	0007.FSMA
34	1N	103	103	VIGSTAT	VIGILANCE TESTED 1=YES, 0=NO	0 OR 1	0007.FVIG
35	1N	104	104	AFQTSTAT	AFOQT TEST DATA 1=YES, 0=NO	0 OR 1	0007.FAFOQT
36	9.2	105	113	ABCDARTC	(ABC)OVERALL CORRECT AVG RESPONSE TIME	7671.91 TO 23020.36	0007.SABC
37	9.2	114	122	ABCDARTA	(ABC)OVERALL AVG RESPONSE TIME	4338.83 TO 22536.04	0007.SABC
38	9.2	123	131	ABCDPER	(ABC)PERCENT CORRECT	18.75 TO 97.92	0007.SABC
39	9.2	132	140	ABCDCONC	(ABC)AVG CONFIDENCE SCORE CORRECTS	2.45 TO 9.00	0007.SABC
40	9.2	141	149	ABCDCONA	(ABC)AVG CONFIDENCE SCORE ALL	1.67 TO 9.00	0007.SABC
41	5N	150	154	ANTAAERR	(ANT)ABSOLUTE TRACKING ERR ALL	699 TO 7948	0007.SANT
42	6.2	155	160	INTAV30	(INT)AVG ABSOLUTE ODOMETER ERR, STOP 30	2.10 TO 27.10	0007.FINT
43	6.2	161	166	INTAV70	(INT)AVG ABSOLUTE ODOMETER ERR, STOP 70	1.00 TO 17.90	0007.FINT
44	6.2	167	172	INTAVA	(INT)AVG ABSOLUTE ODOMETER ERR, ALL	2.65 TO 21.45	0007.FINT
45	6N	173	178	INTNUMA	(INT)NUM-SIDE TASK ANSWERED CORRECTLY	60 TO 191	0007.FINT
46	9.2	179	187	ITMARTC	(ITM)OVERALL CORRECT AVG RESPONSE TIME	-2604.23 TO 2066.38	0007.SITM
47	9.2	188	196	ITMARTA	(ITM)OVERALL AVG RESPONSE TIME	-2722.92 TO 2335.83	0007.SITM
48	9.2	197	205	ITMPER	(ITM)PERCENT CORRECT	54.17 TO 100.000	0007.SITM

49	9.2	206	214	MKNARTC	(MKN)OVERALL CORRECT AVG RESPONSE TIME	226.50 TO 2350.32	0007.SMKN
50	9.2	215	223	MKNARTA	(MKN)OVERALL AVG RESPONSE TIME	473.25 TO 2543.34	0007.SMKN
51	9.2	224	232	MKNPER	(MKN)PERCENT CORRECT	9.38 TO 100.00	0007.SMKN
52	9.2	233	241	MRTARTC	(MRT)OVERALL CORRECT AVG RESPONSE TIME	463.77 TO 3812.67	0007.SMRT
53	9.2	242	250	MRTARTA	(MRT)OVERALL AVG RESPONSE TIME	469.86 TO 4174.60	0007.SMRT
54	9.2	251	259	MRTPER	(MRT)PERCENT CORRECT	45.83 TO 100.00	0007.SMRT
55	9.2	260	268	M3DARTC	(M3D)OVERALL CORRECT AVG RESPONSE TIME	2637.17 TO 8056.71	0007.SM3D
56	9.2	269	277	M3DARTA	(M3D)OVERALL AVG RESPONSE TIME	2653.14 TO 8328.17	0007.SM3D
57	9.2	278	286	M3DPER	(M3D)PERCENT CORRECT	76.56 TO 100.00	0007.SM3D
58	9.2	287	295	PATARTC	(PAT)AVG RESPONSE TIME CORRECTS	2280.92 TO 6288.74	0007.SPAT
59	9.2	296	304	PATARTA	(PAT)AVG RESPONSE TIME ALL	2318.80 TO 6477.83	0007.SPAT
60	9.2	305	313	PATPER	(PAT)PERCENT CORRECT	40.00 TO 100.00	0007.SPAT
61	9.2	314	322	PSPARTC	(PSP)OVERALL CORRECT AVG RESPONSE TIME	1009.13 TO 2043.76	0007.SPSP
62	9.2	323	331	PSPARTA	(PSP)OVERALL AVG RESPONSE TIME	995.70 TO 2087.88	0007.SPSP
63	9.2	332	340	PSPPER	(PSP)PERCENT CORRECT	53.13 TO 85.94	0007.SPSP
64	9.2	341	349	PS3X1	(PS3)X ERROR STICK & RUDDER LAST 2 MINS	1597.00 TO 71995.00	0007.SPS3
65	9.2	350	358	PS3Y1	(PS3)Y ERROR STICK & RUDDER LAST 2 MINS	757.00 TO 67501.00	0007.SPS3
66	9.2	359	367	PS3Z1	(PS3)Z ERROR STICK & RUDDER LAST 2 MINS	1228.00 TO 71992.00	0007.SPS3
67	9.2	368	376	PS3X2	(PS3)X STICK RATE ENTIRE TEST	19383.00 TO 597421.00	0007.SPS3
68	9.2	377	385	PS3Y2	(PS3)Y STICK RATE ENTIRE TEST	19539.00 TO 589362.00	0007.SPS3
69	9.2	386	394	PS3Z2	(PS3)Z STICK RATE ENTIRE TEST	19360.00 TO 759630.00	0007.SPS3
70	9.2	395	403	SCAATE1	(SAA)AVG TRACK ERR MIN 4 BLK 1	7012.75 TO 52737.25	0007.SSAA
71	9.2	404	412	SCAATE2	(SAA)AVG TRACK ERR MIN 4 BLK 2	2156.25 TO 52998.75	0007.SSAA
72	9.2	413	421	SCAATE3	(SAA)AVG TRACK ERR MIN 4 BLK 3	2981.00 TO 53005.00	0007.SSAA
73	2.0	422	423	SCANS1	(SAA)NUM SWITCHES MIN 4 BLK 1	0 TO 32	0007.SSAA
74	2.0	424	425	SCANS2	(SAA)NUM SWITCHES MIN 4 BLK 2	1 TO 34	0007.SSAA
75	2.0	426	427	SCANS3	(SAA)NUM SWITCHES MIN 4 BLK	0 TO 37	0007.SSAA
76	9.2	428	436	SDLTPA	(SDL)TOTAL POINTS ACHIEVED	2923.00 TO 22707.00	0007.SSDL
77	9.2	437	445	SDLTPP	(SDL)TOTAL POINTS POSSIBLE	31808.00 TO 74816.00	0007.SSDL
78	9.2	446	454	SDLTPR	(SDL)RATIO POINTS ACHIEVED TO POINTS POSSIBLE	.05 TO .68	0007.SSDL
79	9.2	455	463	SMAARTC1	(SMA)AVG REPONSE TIME, BLK2, CORRECTS	1673.37 TO 4780.52	0007.SSMA
80	9.2	464	472	SMAARTA1	(SMA)AVG REPONSE TIME, BLK2, ALL	1720.30 TO 4913.32	0007.SSMA
81	9.2	473	481	SMAPER1	(SMA)PERCENT CORRECT,BLK2	57.50 TO 100.00	0007.SSMA
82	9.2	482	490	SMAARTC2	(SMA)AVG REPONSE TIME,BLK 3, CORRECTS	1642.92 TO 5269.63	0007.SSMA
83	9.2	491	499	SMAARTA2	(SMA)AVG REPONSE TIME, BLK3, ALL	1637.45 TO 5935.60	0007.SSMA
84	9.2	500	508	SMAPER2	(SMA)PERCENT CORRECT,BLK3	47.50 TO 100.00	0007.SSMA
85	9.2	509	517	VIGNRT	(VIG)NUMBER OF ROUTINE TASKS COMPLETED	1.00 TO 116.00	0007.SSMA
86	9.2	518	526	VIGNPT	(VIG)NUMBER OF PRIORITY TASKS COMPLETED	0 TO 17.00	0007.SSMA
87	9.2	527	535	VIGPRT	(VIG)AVERAGE REPONSE TIME PRIORITY TASKS	0 TO 240963.00	0007.SSMA
88	6N	536	541	DATE2	AFOQT TEST DATE(LAST ADMINISTRATION, YYMMDD)	821211 TO 900619	0007.FAFOQT
89	2N	542	543	PILOT2	AFOQT PILOT COMPOSITE SCORE(LAST)	19 TO 99	0007.FAFOQT
90	2N	544	545	NAV2	AFOQT NAVIGATOR COMPOSITE SCORE(LAST)	28 TO 99	0007.FAFOQT
91	2N	546	547	ACAD2	AFOQT ACADEMIC COMPOSITE SCORE(LAST)	19 TO 99	0007.FAFOQT
92	2N	548	549	VERB2	AFOQT VERBAL COMPOSITE SCORE(LAST)	15 TO 99	0007.FAFOQT
93	2N	550	551	QUAN2	AFOQT QUANTITATIVE COMPOSITE SCORE(LAST)	11 TO 99	0007.FAFOQT
94	3N	552	554	VA2	AFOQT SUBTEST SCORE(LAST): VERBAL ANALOGIES	007 TO 025	0007.FAFOQT
95	3N	555	557	AR2	AFOQT SUBTEST SCORE(LAST): ARITHMETIC REASONING	005 TO 025	0007.FAFOQT
96	3N	558	560	RC2	AFOQT SUBTEST SCORE(LAST): READING COMPREHENSION	007 TO 025	0007.FAFOQT
97	3N	561	563	DI2	AFOQT SUBTEST SCORE(LAST): DATA INTERPRETATION	004 TO 025	0007.FAFOQT
98	3N	564	566	WK2	AFOQT SUBTEST SCORE(LAST): WORD KNOWLEDGE	003 TO 025	0007.FAFOQT
99	3N	567	569	MK2	AFOQT SUBTEST SCORE(LAST): MATH KNOWLEDGE	006 TO 025	0007.FAFOQT
100	3N	570	572	MC2	AFOQT SUBTEST SCORE(LAST): MECHANICAL COMPREHENSION	002 TO 019	0007.FAFOQT
101	3N	573	575	EM2	AFOQT SUBTEST SCORE(LAST): ELECTRICAL MAZE	000 TO 020	0007.FAFOQT

102	3N	576	578	SR2	AFOQT SUBTEST SCORE(LAST): SCALE READING	011 TO 037	0007.FAFOQT
103	3N	579	581	IC2	AFOQT SUBTEST SCORE(LAST): INSTRUMENT COMPREHENSION	000 TO 020	0007.FAFOQT
104	3N	582	584	BC2	AFOQT SUBTEST SCORE(LAST): BLOCK COUNTING	004 TO 020	0007.FAFOQT
105	3N	585	587	TR2	AFOQT SUBTEST SCORE(LAST): TABLE READING	013 TO 040	0007.FAFOQT
106	3N	588	590	AI2	AFOQT SUBTEST SCORE(LAST): AVIATION INFORMATION	003 TO 020	0007.FAFOQT
107	3N	591	593	RB2	AFOQT SUBTEST SCORE(LAST): ROTATED BLOCKS	003 TO 015	0007.FAFOQT
108	3N	594	596	GS2	AFOQT SUBTEST SCORE(LAST): GENERAL SCIENCE	002 TO 019	0007.FAFOQT
109	3N	597	599	HF2	AFOQT SUBTEST SCORE(LAST): HIDDEN FIGURES	005 TO 015	0007.FAFOQT
110	1N	600	600	COUNTER2	NUMBER OF TIMES AFOQT TEST TAKEN(LAST)	1 TO 4	0007.FAFOQT
111	1A	601	601	FORM2	AFOQT FORM NUMBER(LAST ADMINISTRATION)	0,P	0007.FAFOQT

NOTE 1:

REASON CODES:
E51=FLIGHT TRAINING DEFICIENCY (FTD)
E52=ACADEMIC
E53=MILITARY
E54=MEDICAL
E55=FEAR OF FLYING
E56=SELF INITIATED ELIMINATION (SIE)
E59=OTHER
P52=TRAINING FATALITY
N22=PASSED UPT

NOTE 2:

BASE LOCATION CODES:
G=LAUGHLIN
N=REESE
P=SHEPPARD
R=VANCE
S=COLUMBUS
V=WILLIAMS
H=MATHER

NOTE 3: UNDERGRADUATE NAVIGATOR TRAINING STUDENT TYPE BREAKDOWN: (RE: ATCM 51-230)

	STUDENT TYPE	CODE (NOTE 1)	OR (NOTE2)
1.	AFROTC GRADUATE ON INTITIAL ACTIVE DUTY ASSIGNMENT	C	B
2.	USAFA GRADUATE ON INITIAL ACTIVE DUTY ASSIGNMENT	D	P
3.	USAF HELICOPTER PILOT	E	M
4.	AUSNA USMA GRADUATE ON INITIAL ACTIVE DUTY ASSIGNMENT IN USAF	F	N
5.	OTS GRADUATE ON INITIAL AVTIVE DUTY ASSIGNMENT	H	T
6.	USAF RATED OFFICER	A	R
7.	USAF NONRATED OFFICER NOT SPECIFIED ABOVE	L	S
8.	OFFICER (OTHER THAN USAF)	1	4
9.	CIVILIAN	3	5
10.	FOREIGN ENLISTED MAN	2	2

NOTES:

1. GRADUATE OF FLIGHT SCREENING PROGRAM (FSP), AT HONDO, TEXAS.
2. DID NOT GRADUATE FROM FSP.
3. STUDENTS WHO HAVE BEEN COMPLETING AN ADVANCED DEGREE UNDER AFIT AND HAVE NO OTHER ACTIVE DUTY AFSC ARE CONSIDERED ON INITIAL DUTY ASSIGNMENT FOR UPT.
4. TYPES E AND M FOR HELICOPTER PILOTS BECAME EFFECTIVE WITH FY 82 UPT CLASSES. PRIOR TO 1982, THESE TYPE CODES REPRESENTED USNA GRADS ONLY.
5. REFER TO ATCM 51-230, VOL II, PAGES 45-47 FOR UPT AND ENJJPT ATCM 51-249, PAGES 3-9 AND 3-10 FOR UNT.

**** NOTE: AFOQT DATA IN THIS DATA RECORD REPRESENTS INFORMATION FOR THE MOST RECENT TIME TEST WAS TAKEN BY THE SUBJECT. ***

Appendix B: Example of the Raw Data for Three Individuals
(Names and SSANs have been Removed)

```
 41289[redacted]           [redacted]          [redacted]122116 0 427    NV6AC019
003 N22HC010111000110011                                         1829
                     76558    75481     9375   136284   141053     7813    6963
9    69483     9861
                     2409800   818400  1339500 30525000  7148500  5984400  5254
875  5299875  5300500 0 1 0
                                9300     1300   4915628408287084655076017016016
0120120220080130260080170340070120110131O
 42589[redacted]           [redacted]          [redacted]123115 014 0    NV6AB019
003 N22HC010101000110011                                         1274
                    100481    99273     9792                              12977
5   128169     9306
                     1565900  1353200   434900  5886100  6995600  5459400  3066
075  2574525  2286525 6 8 8
                                3300     1400   44807985111224282224280120080l1
0040090190080060130060090250090070120092C
113089[redacted]           [redacted]          [redacted]127115 0 4 0    NV6AB019
015 N22HH010111000110011                                         1792
                     97440    96167     9375    50425    55734     5000   13974
3   138867     9722
                     1736700  1560700  1805000  4556800  4410500  4831900  3505
250  2885225  2041950 5 6 9
                                2300     1100  14702648811146550849859020010025
019022014010010022013014023014006008009l0
```

Appendix C: Example of the Code for Creating a SAS Data File From the Raw Data

```
OPTIONS NODATE;
libname dat 'gor91m:[ghagler]';
filename stuff 'navdat.sas';
* make a permanent data file on disk;
DATA DAT.FIVE;
INFILE STUFF MISSOVER;
INPUT
SSAN 7-15
NAME $ 16-35
COURSE $ 73-78
UNTOUT 79-79
SEX 57-57
AGE 58-59
HAND 60-60
FLYHRS 63-64
AIRSTAT 65-66
RECAIRC 67-68
REASON $ 85-87
TYPE $ 89-89
ABC 90-90
ANT 91-91
INT 92-92
ITM 93-93
MKN 94-94
MRT 95-95
M3D 96-96
PAT 97-97
PSP 98-98
PS3 99-99
SAA 100-100
SDL 101-101
SMA 102-102
VIG 103-103
AFOQT 104-104
ABCDARTC 105-113
ABCDARTA 114-122
ABCDPER 123-131
ABCDCONC 132-140
ABCDCONA 141-149
ANTAAERR 150-154
INTAV30 155-160
INTAV70 161-166
INTAVA 167-172
INTNUMA 173-178
ITMARTC 179-187
ITMARTA 188-196
ITMPER 197-205
MKNARTC 206-214
MKNARTA 215-223
MKNPER 224-232
```

MRTARTC 233-241
MRTARTA 242-250
MRTPER 251-259
M3DARTC 260-268
M3DARTA 269-277
M3DPER 278-286
PATARTC 287-295
PATARTA 296-304
PATPER 305-313
PSPARTC 314-322
PSPARTA 323-331
PSPPER 332-340
PS3X1 341-349
PS3Y1 350-358
PS3Z1 359-367
PS3X2 368-376
PS3Y2 377-385
PS3Z2 386-394
SCAATE1 395-403
SCAATE2 404-412
SCAATE3 413-421
SCANS1 422-423
SCANS2 424-425
SCANS3 426-427
SDLARTC 428-436
SDLARTA 437-445
SDLPER 446-454
SMAARTC1 455-463
SMAARTA1 464-472
SMAPER1 473-481
SMAARTC2 482-490
SMAARTA2 491-499
SMAPER2 500-508
VIGNRT 509-517
VIGNPT 518-526
VIGPRT 527-535
PILOT2 542-543
NAV2 544-545
ACAD2 546-547
VERB2 548-549
QUAN2 550-551
VA2 552-554
AR2 555-557
RC2 558-560
DI2 561-563
WK2 564-566
MK2 567-569
MC2 570-572
EM2 573-575
SR2 576-578
IC2 579-581
BC2 582-584
TR2 585-587
AI2 588-590
RB2 591-593

```
GS2 594-596
HF2 597-599;
ITMARTC=ITMARTC/100.0;
ITMARTA=ITMARTA/100.0;
ITMPER=ITMPER/100.0;
MKNARTC=MKNARTC/100.0;
MKNARTA=MKNARTA/100.0;
MKNPER=MKNPER/100.0;
MRTARTC=MRTARTC/100.0;
MRTARTA=MRTARTA/100.0;
MRTPER=MRTPER/100.0;
PS3X1=PS3X1/100.0;
PS3Y1=PS3Y1/100.0;
PS3Z1=PS3Z1/100.0;
PS3X2=PS3X2/100.0;
PS3Y2=PS3Y2/100.0;
PS3Z2=PS3Z2/100.0;
SCAATE1=SCAATE1/100.0;
SCAATE2=SCAATE2/100.0;
SCAATE3=SCAATE3/100.0;
VIGNRT=VIGNRT/100.0;
VIGNPT=VIGNPT/100.0;
VIGPRT=VIGPRT/100.0;
DATA DAT.SIX;
SET DAT.FIVE;
IF UNTOUT=0 OR UNTOUT=1;
RUN;
```

Appendix D: Factor Analysis of the AFOQT

The Air Force Officers Qualifying Test (AFOQT) is used to measure the aptitudes of candidates for Air Force Reserve Officer Training Corps (AFROTC) and Officer Training School (OTS) (Berger, 1990:1). The test is also used to measure aptitude for pilot or navigator training. The AFOQT is organized into 16 subtests. These subtests also make up five composite scores; these being Pilot, Navigator-Technical (Nav), Academic Aptitude (Acad), Verbal (Verb), and Quantitative (Quan). A listing of the 16 subtests is presented in Table 15. The names of most of the subtests generally explain what aptitude is being measured by each.

Table 15

AFOQT Subtests

Name	Abbreviation
Verbal Analogies	VA
Arithmetic Reasoning	AR
Reading Comprehension	RC
Data Interpretation	DI
Word Knowledge	WK
Math Knowledge	MK
Mechanical Comprehension	MC
Electrical Maze	EM
Scale Reading	SR
Instrument Comprehension	IC
Block Counting	BC
Table Reading	TR
Aviation Information	AI
Rotated Blocks	RB
General Science	GS
Hidden Figures	HF

(Berger, 1990:2)

The subtests which makeup each composite are presented in Table 16. Notice that some subtests are common to several composites. The Pilot and Nav composites have several tests in common as do the Nav, Acad, and Quan composites. Verb and Acad also share some subtests.

Table 16

Makeup of AFOQT Composites

PILOT	NAV	ACAD	VERB	QUAN
VA	AR	VA	VA	AR
MC	DI	AR	RC	DI
EM	MK	RC	WK	MK
SR	MC	DI		
IC	EM	WK		
BC	SR	MK		
TR	BC			
AI	TR			
	RB			
	GS			
	HF			

(Berger, 1990:2)

Berger reports that a factor analysis of the AFOQT was performed by two researchers named Skinner and Ree in 1987 (Berger, 1990:27). They performed the analysis using a sample of 3,000 test subjects to determine the underlying dimensions of the subtests. This analysis identified five main factors. The names given to each factor and the corresponding subtests with the highest loadings on each factor were as follows (Berger, 1990:27-29):

FACTOR 1 - Verbal - VA, RC, WK
FACTOR 2 - Quantitative - MK, AR, DI
FACTOR 3 - Space Perception - EM, BC, RB, HF, MC
FACTOR 4 - Aircrew Interest/Aptitude - MC, IC, AI, GS
FACTOR 5 - Perceptual Speed - TR, SR

The purpose of my investigation was to see if similar results could be obtained, thus validating the analysis reported by Berger. The sample size was much smaller, consisting of 281 navigator candidates who had taken the AFOQT. Factor analysis with Varimax rotation was performed using SAS.

SAS was allowed to keep the factors which met Kaiser's criterion (eigenvalues greater than 1). Four factors were retained. Looking at the rotated factor pattern, these four factors could possibly be named 1 - Verbal, 2 - Perceptual Speed, 3 - Quantitative, and 4 -Space Perception. Even with four factors, it can be seen that similar results as those above are beginning to take shape.

Next, SAS was forced to keep five factors. The fifth eigenvalue was fairly close to one anyway (0.88). The rotated factor pattern leads to the factor names of:

FACTOR 1 - Verbal - RC, WK, GS, VA
FACTOR 2 - Quantitative - AR, SR, DI, MK
FACTOR 3 - Aircrew Aptitude - AI, IC, MC
FACTOR 4 - Perceptual Speed - TR, BC
FACTOR 5 - Space Perception - HF, EM, RB

This is almost the exact same factor ordering as the one obtained by Skinner and Ree. Each factor is loaded by virtually the same subtests with the exceptions being SR (in the Quantitative factor), GS (in the Verbal factor), and BC (in the Perceptual Speed factor).

Eigenvalues of the subtest correlation matrix and the Rotated Factor Patterns follow.

Eigenvalues of the Correlation Matrix

	1	2	3	4
Eigenvalue	5.1536	1.8841	1.4395	1.1349
Difference	3.2695	0.4446	0.3046	0.2515
Proportion	0.3221	0.1178	0.0900	0.0709
Cumulative	0.3221	0.4399	0.5298	0.6008
	5	6	7	8
Eigenvalue	0.8834	0.8015	0.7662	0.6579
Difference	0.0819	0.0353	0.1082	0.0454
Proportion	0.0552	0.0501	0.0479	0.0411
Cumulative	0.6560	0.7061	0.7539	0.7951
	9	10	11	12
Eigenvalue	0.6125	0.5316	0.4670	0.4172
Difference	0.0809	0.0647	0.0497	0.0241
Proportion	0.0383	0.0332	0.0292	0.0261
Cumulative	0.8334	0.8666	0.8958	0.9218
	13	14	15	16
Eigenvalue	0.3931	0.3225	0.2916	0.2433
Difference	0.0706	0.0309	0.0483	
Proportion	0.0246	0.0202	0.0182	0.0152
Cumulative	0.9464	0.9666	0.9848	1.0000

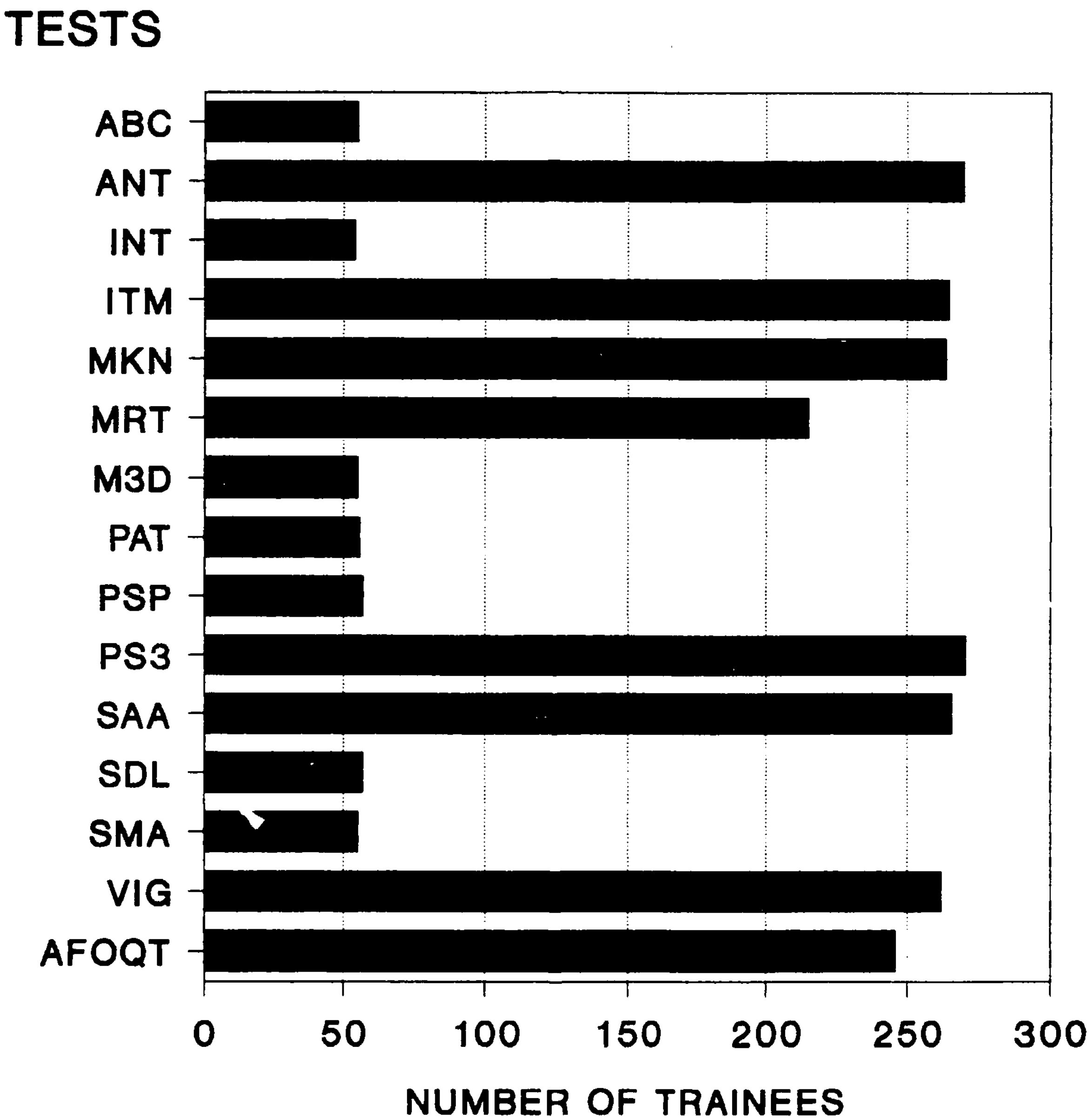
Rotated Factor Pattern (4 Factors Retained)

	FACTOR1	FACTOR2	FACTOR3	FACTOR4
RC2	0.77806	0.02259	0.21578	-0.17479
WK2	0.75805	0.07187	0.27600	-0.17475
GS2	0.74369	-0.14694	0.20811	0.23465
VA2	0.69876	0.25708	0.31191	-0.02675
AI2	0.68236	0.27063	-0.27588	0.20357
MC2	0.59715	0.17242	0.06430	0.33668
TR2	0.04895	0.68306	0.04958	0.01495
SR2	0.05803	0.65916	0.45441	0.03496
BC2	-0.00669	0.64191	0.16544	0.21707
IC2	0.43119	0.58888	-0.23833	0.17926
MK2	0.19481	0.02426	0.74719	0.21563
AR2	0.30812	0.38464	0.70914	-0.01517
DI2	0.45086	0.46595	0.49105	0.00039
EM2	-0.02774	0.15020	-0.09311	0.69214
HF2	0.01585	-0.00019	0.28476	0.66724
RB2	0.21662	0.41880	0.06312	0.46561

Rotated Factor Pattern (5 Factors Retained)

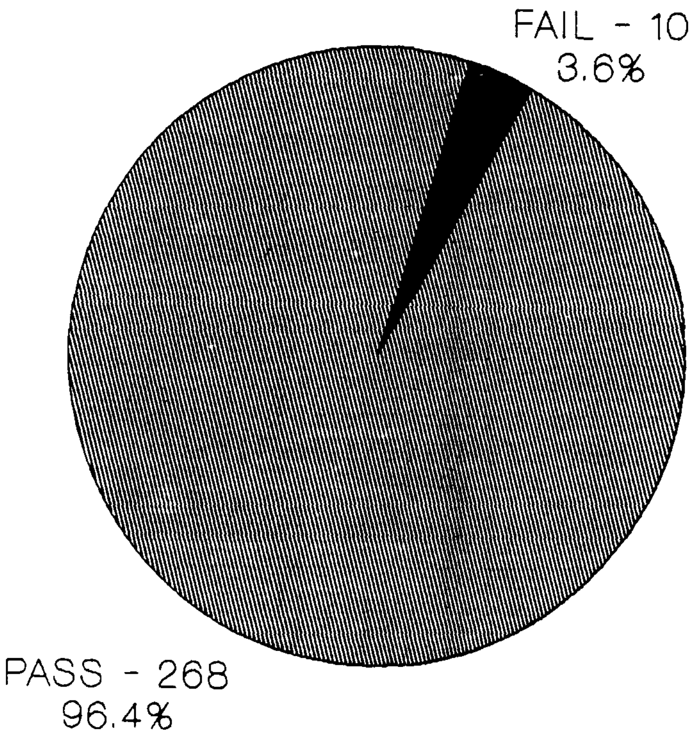
	FACTOR1	FACTOR2	FACTOR3	FACTOR4	FACTOR5
RC2	0.84000	0.09178	0.13319	0.09922	-0.11146
WK2	0.81556	0.17874	0.12829	0.10808	-0.10651
GS2	0.73152	0.05833	0.21557	-0.12829	0.28352
VA2	0.65394	0.36780	0.26830	0.13619	0.01285
AR2	0.33094	0.80947	-0.00104	0.10397	0.08129
SR2	-0.06310	0.79423	0.19100	0.27099	0.04462
DI2	0.35363	0.71186	0.25084	0.13888	0.03826
MK2	0.43161	0.46799	-0.34995	0.07926	0.37816
AI2	0.36704	0.01007	0.72777	0.06931	0.09544
IC2	0.09886	0.18654	0.70907	0.31784	0.05353
MC2	0.32505	0.29846	0.57262	-0.14206	0.28760
TR2	0.12096	0.10705	0.03654	0.84126	0.01186
BC2	-0.02701	0.31029	0.11536	0.60833	0.20793
HF2	0.01692	0.17518	-0.00160	-0.02317	0.70420
EM2	-0.09918	-0.12100	0.17435	0.22690	0.65188
RB2	0.14244	0.12958	0.25693	0.41981	0.44268

Appendix E: Number of Individuals Given Each Test

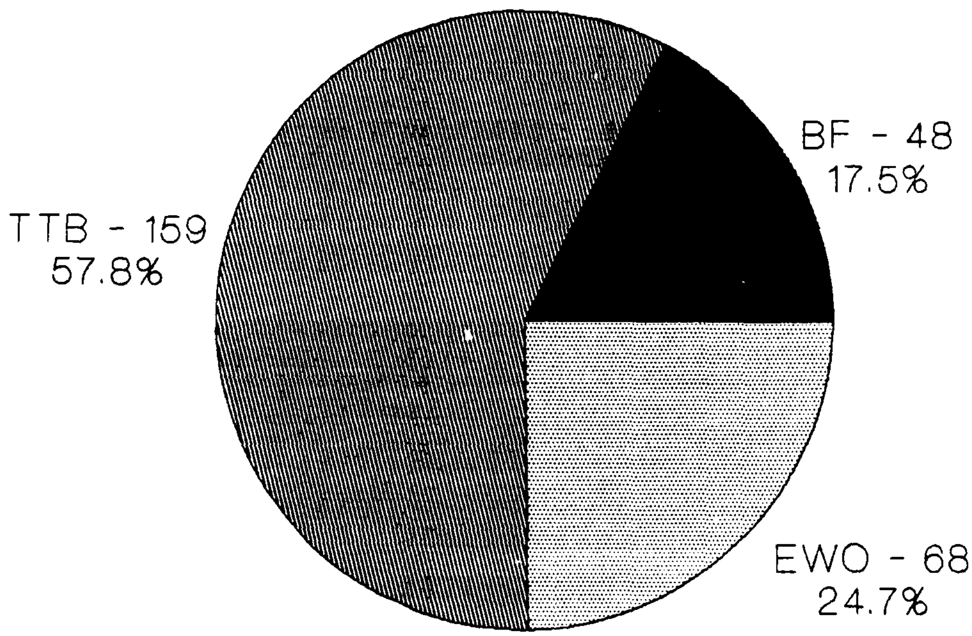


Variable	N	Nmiss
ANTAAERR	270	8
ITMARTC	265	13
ITMARTA	265	13
ITMPER	265	13
MKNARTC	264	14
MKNARTA	264	14
MKNPER	264	14
PS3X1	271	7
PS3Y1	271	7
PS3Z1	271	7
PS3X2	271	7
PS3Y2	271	7
PS3Z2	271	7
SCAATE1	266	12
SCAATE2	266	12
SCAATE3	266	12
SCANS1	266	12
SCANS2	266	12
SCANS3	266	12
VIGNRT	262	16
VIGNPT	262	16
VIGPRT	262	16
PILOT2	246	32
NAV2	246	32
ACAD2	246	32
VERB2	246	32
QUAN2	246	32

Appendix F: Demographic Information on Training Outcome
(N = 278)



Appendix G: Demographic Information on Training Tracks
(N = 275, Frequency Missing = 3)



Appendix H: Descriptive Statistics of the Entire Data Base

Variable	Mean	Std Dev	Minimum	Maximum
ANTAAERR	1368.50	527.85	699.00	7948.00
ITMARTC	796.72	379.11	-2604.23	2066.38
ITMARTA	797.30	390.41	-2722.92	2335.83
ITMPER	95.94	5.79	54.17	100.00
MKNARTC	1777.52	319.20	226.50	2350.32
MKNARTA	1848.95	325.41	473.25	2543.34
MKNPER	71.51	17.63	9.38	100.00
PS3X1	13803.85	11100.83	1597.00	71995.00
PS3Y1	10452.09	9903.14	757.00	67501.00
PS3Z1	10299.72	9722.93	1228.00	71992.00
PS3X2	54151.03	55223.93	19383.00	597421.00
PS3Y2	45111.29	47672.19	19539.00	589362.00
PS3Z2	55726.12	60406.35	19360.00	759630.00
SCAATE1	27808.53	9087.54	7012.75	52737.25
SCAATE2	24134.99	9076.03	2156.25	52998.75
SCAATE3	21405.26	8850.03	2981.00	53005.00
SCANS1	11.30	5.39	0.00	32.00
SCANS2	12.33	5.61	1.00	34.00
SCANS3	12.80	5.20	0.00	37.00
VIGNRT	68.91	22.30	3.00	115.00
VIGNPT	11.73	3.73	0.00	17.00
VIGPRT	9997.19	23217.78	0.0C	240963.00
PILOT2	70.42	18.11	19.00	99.00
NAV2	70.78	16.86	28.00	99.00
ACAD2	65.46	21.68	20.00	99.00
VERB2	63.82	23.97	15.00	99.00
QUAN2	65.34	20.10	19.00	99.00

Appendix I: Descriptive Statistics of Individuals Failing

Variable	Mean	Std Dev	Minimum	Maximum
ANTAAERR	1461.50	256.25	929.00	1808.00
ITMARTC	943.24	284.01	698.39	1623.31
ITMARTA	946.66	281.21	709.60	1623.31
ITMPER	97.50	1.65	95.83	100.00
MKNARTC	1864.32	368.69	1204.89	2282.33
MKNARTA	1954.97	332.89	1257.97	2315.94
MKNPER	54.69	10.23	37.50	68.75
PS3X1	22223.00	20660.66	5277.00	71995.00
PS3Y1	10272.00	6870.46	2149.00	24392.00
PS3Z1	12423.00	8619.84	3223.00	24850.00
PS3X2	61161.30	46556.92	22222.00	170318.00
PS3Y2	41649.10	15684.98	21329.00	62645.00
PS3Z2	57312.40	28067.07	31092.00	124544.00
SCAATE1	25842.00	8502.83	11754.75	40917.25
SCAATE2	24558.30	7440.86	12960.25	33865.75
SCAATE3	26139.75	5644.29	15967.25	34199.25
SCANS1	11.10	4.01	6.00	17.00
SCANS2	12.20	5.41	6.00	26.00
SCANS3	10.10	3.25	6.00	17.00
VIGNRT	54.90	16.68	32.00	82.00
VIGNPT	11.70	3.86	1.00	14.00
VIGPRT	8352.39	4951.14	2621.08	16992.38
PILOT2	48.00	10.10	29.00	63.00
NAV2	49.30	13.47	30.00	79.00
ACAD2	45.00	15.75	21.00	67.00
VERB2	44.70	14.20	26.00	67.00
QUAN2	47.90	17.70	19.00	78.00

Appendix J: Descriptive Statistics of Individuals Passing

Variable	Mean	Std Dev	Minimum	Maximum
ANTAAERR	1363.83	530.29	699.00	7948.00
ITMARTC	791.09	377.83	-2604.23	2066.38
ITMARTA	791.62	389.37	-2722.92	2335.83
ITMPER	95.92	5.83	54.17	100.00
MKNARTC	1774.87	319.49	226.50	2350.32
MKNARTA	1845.78	326.87	473.25	2543.34
MKNPER	72.12	17.42	9.38	100.00
PS3X1	13493.00	10507.94	1597.00	71356.00
PS3Y1	10424.61	9918.02	757.00	67501.00
PS3Z1	10203.23	9717.23	1228.00	71992.00
PS3X2	53876.80	55521.24	19383.00	597421.00
PS3Y2	44908.64	48003.63	19539.00	589362.00
PS3Z2	55363.75	60702.68	19360.00	759630.00
SCAATE1	27705.31	9148.33	7012.75	52737.25
SCAATE2	23934.87	9126.07	2156.25	52998.75
SCAATE3	21131.16	8870.14	2981.00	53005.00
SCANS1	11.35	5.44	0.00	32.00
SCANS2	12.48	5.84	1.00	34.00
SCANS3	12.92	5.25	0.00	37.00
VIGNRT	69.63	22.47	3.00	116.00
VIGNPT	11.77	3.70	0.00	17.00
VIGPRT	9969.40	23389.61	0.00	240963.00
PILOT2	71.29	17.86	19.00	99.00
NAV2	71.58	16.60	28.00	99.00
ACAD2	66.46	21.34	20.00	99.00
VERB2	64.77	23.80	15.00	99.00
QUAN2	66.12	19.92	21.00	99.00

Appendix K: Descriptive Statistics of Individuals in the Bomber-Fighter (BF) Track

Variable	Mean	Std Dev	Minimum	Maximum
ANTAAERR	1303.37	294.27	777.00	2047.00
ITMARTC	803.77	157.95	516.88	1131.00
ITMARTA	801.92	158.21	512.75	1123.67
ITMPER	96.47	2.52	89.58	100.00
MKNARTC	1728.88	323.11	887.47	2277.86
MKNARTA	1789.95	331.05	1045.94	2415.72
MKNPER	74.32	18.36	9.38	100.00
PS3X1	11683.09	8536.21	2534.00	45023.00
PS3Y1	9694.15	8488.61	757.00	37680.00
PS3Z1	8404.83	6406.89	2042.00	32624.00
PS3X2	48172.50	33942.97	19383.00	199752.00
PS3Y2	43387.59	30032.57	19539.00	178170.00
PS3Z2	50951.22	26214.56	19360.00	128728.00
SCAATE1	25466.16	8937.96	7012.75	41089.00
SCAATE2	21060.73	7792.59	6935.75	35212.00
SCAATE3	19135.70	7812.41	6545.50	39877.75
SCANS1	11.96	4.82	4.00	27.00
SCANS2	13.89	5.72	4.00	34.00
SCANS3	14.87	5.09	7.00	27.00
VIGNRT	72.63	22.16	13.00	114.00
VIGNPT	12.04	3.29	0.00	14.00
VIGPRT	6689.64	4887.23	0.00	24303.27
PILOT2	79.05	18.03	35.00	98.00
NAV2	80.53	14.20	43.00	97.00
ACAD2	77.58	19.94	29.00	99.00
VERB2	75.42	23.65	27.00	99.00
QUAN2	76.45	17.33	28.00	96.00

Appendix L: Descriptive Statistics of Individuals in the Tanker-Transport-Bomber (TTB) Track

Variable	Mean	Std Dev	Minimum	Maximum
ANTAAERR	1346.58	357.67	750.00	4073.00
ITMARTC	799.55	461.22	-2604.23	2066.38
ITMARTA	803.86	471.11	-2722.92	2335.83
ITMPER	95.90	5.93	54.17	100.00
MKNARTC	1784.92	338.96	226.50	2291.52
MKNARTA	1857.99	344.33	473.25	2543.34
MKNPER	69.84	16.91	12.50	96.88
PS3X1	14841.61	12152.91	1970.00	71995.00
PS3Y1	11068.80	11026.17	1280.00	67501.00
PS3Z1	11469.25	11514.42	1991.00	71992.00
PS3X2	55179.02	63082.05	21704.00	597421.00
PS3Y2	47168.40	59295.48	19686.00	589362.00
PS3Z2	58807.34	73998.33	20337.00	759630.00
SCAATE1	28432.23	9073.63	7711.50	49486.25
SCAATE2	24929.16	9233.83	4215.00	42931.50
SCAATE3	22239.74	8872.55	2981.00	48908.75
SCANS1	11.34	5.61	1.00	32.00
SCANS2	12.30	5.78	2.00	31.00
SCANS3	12.52	5.22	4.00	37.00
VIGNRT	68.73	21.91	3.00	111.00
VIGNPT	11.68	3.98	0.00	17.00
VIGPRT	10579.91	27542.03	0.00	240963.00
PILOT2	66.39	17.57	19.00	99.00
NAV2	66.53	16.59	28.00	98.00
ACAD2	59.89	20.58	20.00	96.00
VERB2	58.34	23.03	15.00	99.00
QUAN2	60.68	19.36	19.00	99.00

Appendix M: Descriptive Statistics of Individuals in the Electronic Warfare (EWO) Track

Variable	Mean	Std Dev	Minimum	Maximum
ANTAAERR	1465.83	881.81	699.00	7948.00
ITMARTC	777.71	267.42	-322.10	1470.11
ITMARTA	771.04	292.81	-667.56	1464.65
ITMPER	95.59	7.24	56.25	100.00
MKNARTC	1787.47	267.54	881.[illegible]3	2350.32
MKNARTA	1865.21	274.74	1018.59	2457.03
MKNPER	74.06	1[illegible].38	18.75	100.00
PS3X1	12595.73	9775.00	1597.00	53889.00
PS3Y1	9364.75	7859.30	1918.00	53807.00
PS3Z1	8718.69	6135.24	1228.00	31938.00
PS3X2	55370.17	48378.47	21691.00	305250.00
PS3Y2	41227.61	20320.44	20886.00	142323.00
PS3Z2	50665.11	39065.44	19980.00	256084.00
SCAATE1	28151.35	9193.73	12617.00	52737.25
SCAATE2	24500.91	9352.26	2156.25	52998.75
SCAATE3	20826.88	9420.41	3301.75	53005.00
SCANS1	10.83	5.40	0.00	26.00
SCANS2	11.43	5.03	1.00	26.00
SCANS3	12.16	4.97	0.00	28.00
VIGNRT	67.34	23.33	14.00	115.00
VIGNPT	11.60	3.54	0.00	14.00
VIGPRT	11242.47	20818.73	0.00	122043.83
PILOT2	75.61	16.50	41.00	99.00
NAV2	75.65	15.04	39.00	99.00
ACAD2	72.32	20.28	20.00	99.00
VERB2	70.93	22.27	18.00	99.00
QUAN2	70.23	19.48	21.00	99.00

Appendix N: Correlations of Variables

Correlations

	ANTAAERR	ITMARTC	ITMARTA	ITMPER	MKNARTC
ANTAAERR	1.00000	-0.01078	-0.01194	0.01964	-0.07209
ITMARTC	-0.01078	1.00000	0.99686	0.64198	0.02187
ITMARTA	-0.01194	0.99686	1.00000	0.64679	0.00699
ITMPER	0.01964	0.64198	0.64679	1.00000	0.04713
MKNARTC	-0.07209	0.02187	0.00699	0.04713	1.00000
MKNARTA	-0.02455	0.06540	0.05239	0.07661	0.96720
MKNPER	-0.12324	-0.12738	-0.12938	-0.02266	0.04333
PS3X1	0.17039	0.01225	0.01429	0.06240	0.07154
PS3X2	0.06642	-0.06650	-0.06687	0.01143	-0.04685
PS3Y1	0.11188	-0.02969	-0.02867	0.05496	0.03639
PS3Y2	0.05239	-0.03701	-0.03694	0.04060	-0.05454
PS3Z1	0.17282	0.05838	0.05532	0.03194	0.00510
PS3Z2	-0.00352	-0.05923	-0.05831	0.02962	-0.01719
SCAATE1	0.29005	-0.02701	-0.03501	0.03551	0.01539
SCAATE2	0.30524	-0.04588	-0.05058	-0.14383	-0.02229
SCAATE3	0.29816	0.02408	0.02045	0.00316	-0.00120
SCANS1	-0.18885	-0.12722	-0.12464	-0.03535	0.01144
SCANS2	-0.16572	-0.12288	-0.11603	-0.02891	-0.04883
SCANS3	-0.13439	-0.17026	-0.16563	-0.07224	-0.07268
VIGNRT	-0.15268	-0.07551	-0.06963	0.06265	-0.06488
VIGNPT	0.00621	-0.02829	-0.03689	-0.07313	0.11390
VIGPRT	0.04657	0.07500	0.07097	0.07409	0.11422
PILOT2	-0.16117	-0.08120	-0.08297	0.01643	-0.21762
NAV2	-0.13119	-0.08482	-0.08608	-0.00708	-0.15325
ACAD2	-0.00587	-0.08607	-0.08780	-0.01398	-0.09632
VERB2	0.00176	-0.10654	-0.10676	-0.01044	-0.08878
QUAN2	-0.01683	-0.02041	-0.02319	-0.00322	-0.07688

Correlations

	MKNARTA	MKNPER	PS3X1	PS3X2	PS3Y1
ANTAAERR	-0.02455	-0.12324	0.17039	0.06642	0.11188
ITMARTC	0.06540	-0.12738	0.01225	-0.06650	-0.02969
ITMARTA	0.05239	-0.12938	0.01429	0.06687	-0.02867
ITMPER	0.07661	-0.02266	0.06240	0.01143	0.05496
MKNARTC	0.96720	0.04333	0.07154	-0.04685	0.03639
MKNARTA	1.00000	-0.02841	0.07286	-0.02942	0.04081
MKNPER	-0.02841	1.00000	-0.06887	-0.01620	-0.08069
PS3X1	0.07286	-0.06887	1.00000	0.51639	0.63600
PS3X2	-0.02942	-0.01620	0.51639	1.00000	0.54705
PS3Y1	0.04081	-0.08069	0.63600	0.54705	1.00000
PS3Y2	-0.02763	-0.03901	0.45487	0.90490	0.56443
PS3Z1	0.01583	-0.08306	0.57279	0.52439	0.58314
PS3Z2	-0.00089	-0.01267	0.37211	0.82692	0.44925
SCAATE1	0.04272	-0.14241	0.14088	0.21067	0.17475
SCAATE2	0.02430	-0.20013	0.18095	0.21166	0.19528
SCAATE3	-0.01119	-0.14801	0.18876	0.10305	0.14709
SCANS1	-0.00640	0.12801	-0.17741	-0.07648	-0.02276
SCANS2	-0.09113	0.09702	-0.15205	-0.09288	-0.01808
SCANS3	-0.10549	0.14980	-0.14202	-0.09754	-0.02689
VIGNRT	-0.08385	0.18330	-0.10255	-0.06652	-0.09925
VIGNPT	0.10493	0.01888	-0.00445	-0.01398	-0.01612
VIGPRT	0.13021	-0.04566	0.04119	0.00858	0.02046
PILOT2	-0.22019	0.17352	-0.20048	-0.08473	-0.17169
NAV2	-0.14850	0.18704	-0.20215	-0.04427	-0.16168
ACAD2	-0.07493	0.14190	-0.13571	0.02638	-0.10567
VERB2	-0.06538	0.09951	-0.11913	0.02029	-0.09638
QUAN2	-0.06406	0.13777	-0.10975	0.01511	-0.06868

Correlations

	PS3Y2	PS3Z1	PS3Z2	SCAATE1	SCAATE2
ANTAAERR	0.05239	0.17282	-0.00352	0.29005	0.30524
ITMARTC	-0.03701	0.05838	-0.05923	-0.02701	-0.04588
ITMARTA	-0.03694	0.05532	-0.05831	-0.03501	-0.05058
ITMPER	0.04060	0.03194	0.02962	0.03551	-0.14383
MKNARTC	-0.05454	0.00510	-0.01719	0.01539	-0.02229
MKNARTA	-0.02763	0.01583	-0.00089	0.04272	0.02430
MKNPER	-0.03901	-0.08306	-0.01267	-0.14241	-0.20013
PS3X1	0.45487	0.57279	0.37211	0.14088	0.18095
PS3X2	0.90490	0.52439	0.82692	0.21067	0.21166
PS3Y1	0.56443	0.58314	0.44925	0.17475	0.19528
PS3Y2	1.00000	0.49376	0.84373	0.12765	0.13019
PS3Z1	0.49376	1.00000	0.52309	0.25710	0.25199
PS3Z2	0.84373	0.52309	1.00000	0.11585	0.09970
SCAATE1	0.12765	0.25710	0.11585	1.00000	0.54890
SCAATE2	0.13019	0.25199	0.09970	0.54890	1.00000
SCAATE3	0.02328	0.20316	0.03737	0.44611	0.50595
SCANS1	-0.02154	-0.20495	-0.03696	-0.33679	-0.27419
SCANS2	-0.04294	-0.23543	-0.08088	-0.23110	-0.23360
SCANS3	-0.04960	-0.13054	-0.06364	-0.23179	-0.22369
VIGNRT	-0.09177	-0.17558	-0.04781	-0.11845	-0.15219
VIGNPT	-0.03972	-0.01506	-0.01775	-0.06342	0.00806
VIGPRT	0.00374	-0.00802	-0.02135	0.16068	0.02862
PILOT2	-0.05682	-0.15401	-0.03793	-0.15733	-0.22704
NAV2	-0.01769	-0.17189	-0.03464	-0.14461	-0.16611
ACAD2	0.04770	-0.12794	0.02106	-0.01403	-0.02042
VERB2	0.03260	-0.10175	0.01457	0.00336	-0.02267
QUAN2	0.05000	-0.11375	0.00851	-0.05744	-0.02527

Correlations

	SCAATE3	SCANS1	SCANS2	SCANS3	VIGNRT
ANTAAERR	0.29816	-0.18885	-0.16572	-0.13439	-0.15268
ITMARTC	0.02408	-0.12722	-0.12288	-0.17026	-0.07551
ITMARTA	0.02045	-0.12464	-0.11603	-0.16563	-0.06963
ITMPER	0.00316	-0.03535	-0.02891	-0.07224	0.06265
MKNARTC	-0.00120	0.01144	-0.04883	-0.07268	-0.06488
MKNARTA	-0.01119	-0.00640	-0.09113	-0.10549	-0.08385
MKNPER	-0.14801	0.12801	0.09702	0.14980	0.18330
PS3X1	0.18876	-0.17741	-0.15205	-0.14202	-0.10255
PS3X2	0.10305	-0.07648	-0.09288	-0.09754	-0.06652
PS3Y1	0.14709	-0.02276	-0.01808	-0.02689	-0.09925
PS3Y2	0.02328	-0.02154	-0.04294	-0.04960	-0.09177
PS3Z1	0.20316	-0.20495	-0.23543	-0.13054	-0.17558
PS3Z2	0.03737	-0.03696	-0.08088	-0.06364	-0.04781
SCAATE1	0.44611	-0.33679	-0.23110	-0.23179	-0.11845
SCAATE2	0.50595	-0.27419	-0.23360	-0.22369	-0.15219
SCAATE3	1.00000	-0.28019	-0.25789	-0.25913	-0.14665
SCANS1	-0.28019	1.00000	0.71946	0.67221	0.21123
SCANS2	-0.25789	0.71946	1.00000	0.66469	0.20923
SCANS3	-0.25913	0.67221	0.66469	1.00000	0.22177
VIGNRT	-0.14665	0.21123	0.20923	0.22177	1.00000
VIGNPT	-0.05595	0.03539	0.07632	0.09548	0.06348
VIGPRT	0.04568	-0.09065	-0.05566	-0.12139	-0.15325
PILOT2	-0.21956	0.20908	0.12271	0.20299	0.20443
NAV2	-0.21883	0.25125	0.16685	0.23235	0.33042
ACAD2	-0.13311	0.11747	0.14324	0.13352	0.14669
VERB2	-0.07784	0.09574	0.13641	0.10978	0.03478
QUAN2	-0.16718	0.12222	0.10854	0.12163	0.23646

Correlations

	VIGNPT	VIGPRT	PILOT2	NAV2	ACAD2
ANTAAERR	0.00621	0.04657	-0.16117	-0.13119	-0.00587
ITMARTC	-0.02829	0.07500	-0.08120	-0.08482	-0.08607
ITMARTA	-0.03689	0.07097	-0.08297	-0.08608	-0.08780
ITMPER	-0.07313	0.07409	0.01643	-0.00708	-0.01398
MKNARTC	0.11390	0.11422	-0.21762	-0.15325	-0.09632
MKNARTA	0.10493	0.13021	-0.22019	-0.14850	-0.07493
MKNPER	0.01888	-0.04566	0.17352	0.18704	0.14190
PS3X1	-0.00445	0.04119	-0.20048	-0.20215	-0.13571
PS3X2	-0.01398	0.00858	-0.08473	-0.04427	0.02638
PS3Y1	-0.01612	0.02046	-0.17169	-0.16168	-0.10567
PS3Y2	-0.03972	0.00374	-0.05682	-0.01769	0.04770
PS3Z1	-0.01506	-0.00802	-0.15401	-0.17189	-0.12794
PS3Z2	-0.01775	-0.02135	-0.03793	-0.03464	0.02106
SCAATE1	-0.06342	0.16068	-0.15733	-0.14461	-0.01403
SCAATE2	0.00806	0.02862	-0.22704	-0.16611	-0.02042
SCAATE3	-0.05595	0.04568	-0.21956	-0.21883	-0.13311
SCANS1	0.03539	-0.09065	0.20908	0.25125	0.11747
SCANS2	0.07632	-0.05566	0.12271	0.16685	0.14324
SCANS3	0.09548	-0.12139	0.20299	0.23235	0.13352
VIGNRT	0.06348	-0.15325	0.20443	0.33042	0.14669
VIGNPT	1.00000	-0.30751	0.13957	0.17066	0.17134
VIGPRT	-0.30751	1.00000	-0.02460	-0.05751	-0.03917
PILOT2	0.13957	-0.02460	1.00000	0.84498	0.50013
NAV2	0.17066	-0.05751	0.84498	1.00000	0.66203
ACAD2	0.17134	-0.03917	0.50013	0.66203	1.00000
VERB2	0.13041	0.03487	0.43565	0.42910	0.89134
QUAN2	0.17128	-0.12638	0.42474	0.75676	0.79541

Correlations

	VERB2	QUAN2
ANTAAERR	0.00176	-0.01683
ITMARTC	-0.10654	-0.02041
ITMARTA	-0.10676	-0.02319
ITMPER	-0.01044	-0.00322
MKNARTC	-0.08878	-0.07688
MKNARTA	-0.06538	-0.06406
MKNPER	0.09951	0.13777
PS3X1	-0.11913	-0.10975
PS3X2	0.02029	0.01511
PS3Y1	-0.09638	-0.06868
PS3Y2	0.03260	0.05000
PS3Z1	-0.10175	-0.11375
PS3Z2	0.01457	0.00851
SCAATE1	0.00336	-0.05744
SCAATE2	-0.02267	-0.02527
SCAATE3	-0.07784	-0.16718
SCANS1	0.09574	0.12222
SCANS2	0.13641	0.10854
SCANS3	0.10978	0.12163
VIGNRT	0.03478	0.23646
VIGNPT	0.13041	0.17128
VIGPRT	0.03487	-0.12638
PILOT2	0.43565	0.42474
NAV2	0.42910	0.75676
ACAD2	0.89134	0.79541
VERB2	1.00000	0.44527
QUAN2	0.44527	1.00000

Appendix O: Eigenvalues of the Correlation Matrix

	1	2	3	4
Eigenvalue	5.0884	3.6479	2.6024	2.4690
Difference	1.4405	1.0455	0.1334	0.4867
Proportion	0.1885	0.1351	0.0964	0.0914
Cumulative	0.1885	0.3236	0.4200	0.5114

	5	6	7	8
Eigenvalue	1.9823	1.4677	1.3111	1.0538
Difference	0.5146	0.1566	0.2573	0.1358
Proportion	0.0734	0.0544	0.0486	0.0390
Cumulative	0.5848	0.6392	0.6877	0.7268

	9	10	11	12
Eigenvalue	0.9181	0.8507	0.7573	0.7175
Difference	0.0674	0.0933	0.0399	0.0720
Proportion	0.0340	0.0315	0.0280	0.0266
Cumulative	0.7608	0.7923	0.8203	0.8469

	13	14	15	16
Eigenvalue	0.6455	0.5891	0.5423	0.4656
Difference	0.0564	0.0468	0.0767	0.0730
Proportion	0.0239	0.0218	0.0201	0.0172
Cumulative	0.8708	0.8926	0.9127	0.9300

	17	18	19	20
Eigenvalue	0.3926	0.3445	0.3184	0.2952
Difference	0.0481	0.0260	0.0233	0.0577
Proportion	0.0145	0.0128	0.0118	0.0109
Cumulative	0.9445	0.9572	0.9690	0.9800

	21	22	23	24
Eigenvalue	0.2375	0.1504	0.0795	0.0419
Difference	0.0871	0.0709	0.0376	0.0173
Proportion	0.0088	0.0056	0.0029	0.0016
Cumulative	0.9888	0.9943	0.9973	0.9988

	25	26	27
Eigenvalue	0.0246	0.0040	0.0028
Difference	0.0206	0.0012	
Proportion	0.0009	0.0001	0.0001
Cumulative	0.9997	0.9999	1.0000

Appendix P: Unrotated Factor Pattern

Factor Pattern

	FACTOR1	FACTOR2	FACTOR3	FACTOR4
PS3Z1	0.62850	0.41684	0.01381	0.11629
PS3X1	0.59246	0.37073	-0.05462	0.16317
PS3Y1	0.54669	0.47798	-0.13555	0.22281
SCAATE3	0.46600	-0.06015	0.15573	-0.40059
SCAATE1	0.45613	0.08461	0.20997	-0.42416
SCANS3	-0.49367	0.20175	-0.40737	0.29055
SCANS1	-0.51163	0.17626	-0.40803	0.39500
PILOT2	-0.59545	0.39430	0.28626	-0.05838
NAV2	-0.64891	0.49159	0.34087	-0.07477
PS3Y2	0.48493	0.71594	-0.06169	0.27173
PS3X2	0.53860	0.70792	-0.06162	0.19244
PS3Z2	0.46041	0.66613	-0.07968	0.25507
ACAD2	-0.51699	0.55656	0.44753	-0.22312
QUAN2	-0.48389	0.49728	0.41570	-0.12102
VERB2	-0.41523	0.45733	0.35971	-0.23056
ITMARTC	0.15632	-0.30861	0.67983	0.56495
ITMARTA	0.15334	-0.30775	0.67679	0.56988
ITMPER	0.09382	-0.13764	0.55832	0.55500
SCAATE2	0.46589	0.09897	0.13023	-0.48556
MKNARTC	0.13898	-0.21569	-0.10611	0.18090
MKNARTA	0.16849	-0.20871	-0.04357	0.17607
SCANS2	-0.48717	0.15464	-0.39116	0.33879
ANTAAERR	0.30854	0.02465	0.15166	-0.33094
VIGPRT	0.14470	-0.11456	0.12115	-0.01369
VIGNPT	-0.16741	0.14347	0.03334	-0.03304
VIGNRT	-0.37972	0.13915	-0.03698	0.11936
MKNPER	-0.28093	0.13529	-0.10159	0.06797

Factor Pattern

	FACTOR5	FACTOR6	FACTOR7	FACTOR8
PS3Z1	-0.02049	0.01863	-0.10049	0.01632
PS3X1	0.05396	0.03480	-0.08907	0.07070
PS3Y1	0.02088	0.14660	-0.03122	0.03871
SCAATE3	-0.04253	0.36566	-0.04958	0.21698
SCAATE1	0.05595	0.34648	0.12168	0.24810
SCANS3	-0.07928	0.46384	0.02700	0.00983
SCANS1	-0.00020	0.41753	0.10647	-0.02357
PILOT2	-0.05204	-0.14817	0.05406	0.07607
NAV2	0.06610	-0.06434	-0.01337	0.16167
PS3Y2	-0.02636	-0.11402	0.08062	-0.07585
PS3X2	-0.01544	-0.10263	0.04695	0.00027
PS3Z2	-0.00066	-0.18462	0.04455	-0.03487
ACAD2	0.22020	0.08084	0.09232	-0.15484
QUAN2	0.17891	0.03111	-0.09354	0.04653
VERB2	0.19164	0.09913	0.20505	-0.27870
ITMARTC	-0.10597	0.13469	-0.06449	-0.04062
ITMARTA	-0.12170	0.13474	-0.06288	-0.04028
ITMPER	-0.04853	0.15375	0.04072	0.16631
SCAATE2	0.02964	0.40405	-0.07301	0.09635
MKNARTC	0.92505	0.01721	0.00843	0.07021
MKNARTA	0.92466	0.03703	0.02092	0.02577
SCANS2	-0.06197	0.51360	0.11513	-0.05941
ANTAAERR	-0.05086	0.37930	-0.04389	-0.03948
VIGPRT	0.12389	0.00954	0.79576	0.06120
VIGNPT	0.26367	0.10199	-0.69123	-0.23082
VIGNRT	-0.04584	0.01574	-0.21825	0.65693
MKNPER	0.09336	-0.23896	0.01515	0.50555

Appendix Q: Rotated Factor Pattern
(Rotation Method = Varimax)

Rotated Factor Pattern

	FACTOR1	FACTOR2	FACTOR3	FACTOR4
PS3Y2	0.91161	0.08446	-0.02176	-0.00329
PS3X2	0.91081	0.05839	-0.05579	-0.05413
PS3Z2	0.86337	0.05824	-0.04872	-0.05690
PS3Y1	0.74289	-0.12729	0.02315	0.10828
PS3Z1	0.70804	-0.12064	0.06282	-0.13131
PS3X1	0.67385	-0.16309	0.04956	-0.07185
ACAD2	-0.01723	0.95080	-0.03818	0.06936
VERB2	-0.02522	0.81757	-0.07698	0.08223
NAV2	-0.07324	0.81027	-0.00451	0.09517
QUAN2	-0.00182	0.80617	0.03898	0.03738
PILOT2	-0.09566	0.68533	-0.01729	0.04899
ITMARTA	-0.03325	-0.05411	0.95583	-0.09606
ITMARTC	-0.03392	-0.05028	0.95361	-0.10167
ITMPER	0.06179	0.02082	0.82100	0.01435
SCANS2	-0.06992	0.08021	-0.03931	0.88289
SCANS1	-0.04023	0.09181	-0.04833	0.85131
SCANS3	-0.04898	0.09012	-0.09137	0.83562
SCAATE2	0.14287	-0.02285	-0.09495	-0.13215
SCAATE1	0.14304	0.01220	-0.01655	-0.16606
SCAATE3	0.05364	-0.14758	0.01951	-0.16147
ANTAAERR	0.04532	-0.00411	0.01125	-0.04019
MKNARTC	-0.00434	-0.09858	0.00575	-0.02078
MKNARTA	0.00868	-0.06945	0.04808	-0.04299
VIGPRT	-0.01567	0.03606	0.06105	-0.03879
VIGNPT	-0.01387	0.20013	-0.03054	0.03986
VIGNRT	-0.08224	0.12180	0.04013	0.19170
MKNPER	-0.01318	0.11794	-0.11967	0.01103

Rotated Factor Pattern

	FACTOR5	FACTOR6	FACTOR7	FACTOR8
PS3Y2	-0.04807	-0.05071	0.06118	-0.06354
PS3X2	0.04469	-0.04205	0.04675	-0.00789
PS3Z2	-0.08812	-0.02571	0.03828	-0.00933
PS3Y1	0.18870	0.05312	-0.02509	-0.01855
PS3Z1	0.22217	-0.00396	-0.06710	-0.05167
PS3X1	0.19120	0.08590	-0.05341	0.00572
ACAD2	0.02879	0.01297	-0.03526	-0.04226
VERB2	0.02909	0.01523	0.06606	-0.20782
NAV2	-0.13995	-0.11049	-0.07164	0.33384
QUAN2	0.00500	0.00235	-0.16565	0.18024
PILOT2	-0.22102	-0.20464	0.00146	0.23771
ITMARTA	-0.03268	-0.00585	-0.00609	-0.10749
ITMARTC	-0.02818	0.00882	-0.00813	-0.10890
ITMPER	-0.00916	0.04964	0.10340	0.10517
SCANS2	-0.14012	-0.03022	-0.00484	0.02272
SCANS1	-0.23713	0.02811	-0.00780	0.08596
SCANS3	-0.13037	-0.06391	-0.07817	0.11271
SCAATE2	0.77409	0.00967	-0.04295	-0.09884
SCAATE1	0.74501	0.04914	0.17974	0.02300
SCAATE3	0.73381	-0.02087	0.02258	0.00434
ANTAAERR	0.57748	-0.05793	-0.04155	-0.18946
MKNARTC	-0.03661	0.97899	-0.00411	0.02897
MKNARTA	-0.00770	0.97593	0.00295	-0.02742
VIGPRT	0.07547	0.17076	0.80311	-0.12134
VIGNPT	0.00098	0.18355	-0.76128	-0.07620
VIGNRT	-0.03653	-0.06497	-0.13788	0.75906
MKNPER	-0.19814	0.06208	0.07825	0.59692

Appendix R: Validation Data Set

OBS	UNTOUT	REASON	COURSE	ANTAAERR	ITMARTC	ITMARTA	ITMPER
1	0	E51	NV6AB0	1349	1015.17	1015.17	100.00
2	0	E51	NV6AB0	1674	750.43	760.08	97.92
3	1	N22	NV6AA0	1037	726.54	726.79	95.83
4	1	N22	NV6AA0	1191	598.65	600.48	95.83
5	1	N22	NV6AC0	1345	971.96	977.69	95.83
6	1	N22	NV6AC0	1333	747.46	747.46	100.00

OBS	MKNARTC	MKNARTA	MKNPER	PS3X1	PS3Y1	PS3Z1	PS3X2	PS3Y2
1	1204.89	1257.97	59.38	5277	2149	4884	22222	21329
2	2216.76	2264.66	53.13	37380	14333	24850	170318	36996
3	1507.21	1611.22	87.50	10209	10941	8198	35556	37271
4	1961.09	1988.75	68.75	5841	5728	4489	28869	23739
5	2320.35	2423.50	71.88	18430	11549	10600	31399	31311
6	1649.67	1802.63	75.00	8748	9041	4826	35071	32508

OBS	PS3Z2	SCAATE1	SCAATE2	SCAATE3	SCANS1	SCANS2	SCANS3
1	34227	11754.75	12960.25	19062.50	17	26	17
2	67681	24840.75	28511.00	22928.25	7	8	7
3	40791	15529.50	19079.75	10842.25	10	32	18
4	37824	12901.75	10868.25	7778.00	20	26	22
5	43714	29430.75	22904.50	22175.25	8	9	8
6	31402	26303.25	16289.50	22821.75	16	11	9

OBS	VIGNRT	VIGNPT	VIGPRT	PILOT2	NAV2	ACAD2	VERB2	QUAN2
1	53	14	7353.07	63	44	52	64	41
2	32	14	7954.14	36	45	67	67	61
3	116	14	5152.29	94	96	78	50	92
4	85	12	6531.50	63	70	72	64	76
5	83	13	5272.23	55	48	59	74	41
6	85	13	4269.69	94	96	96	97	92

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