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Correlates of Two Experimental Tests with Performance in the FAA Academy Air Traffic Control Nonradar Screen Program

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16. Abstract

This study was designed to determine the relationships among experimental tests, the tests currently used to select entrants into the FAA's Air Traffic Control Specialist (ATCS) Academy Nonradar Screening Program, and Academy success. A battery of paper-and-pencil tests, including the Directional Headings Test (DHT) which was developed at the Civil Aeromedical Institute and subsequently modified for this study, and the Dial Reading Test (DRT) was administered to 1,255 students who entered in 1987. Scores on the current selection measures, the Multiplex Controller Aptitude Test (MCAT) and Abstract Reasoning Test (ART), were obtained from the Office of Personnel Management (OPM).

The pass, fail, and withdrawal rates for the sample were compared to performance levels on the experimental and OPM tests. Several Academy performance criteria and test results were intercorrelated and stepwise multiple regression analyses were conducted to predict overall Academy success and final grades.

Results demonstrated that the DHT and DRT could be used to assess the potential of entrants to successfully complete the Academy Screen. Even though the current ATCS applicant group differs from those entering the Academy a decade ago on several dimensions (e.g., education and experience), the multiple correlation of the DHT, DRT, and MCAT scores with Academy success remained relatively unchanged. Results suggest that there are other test measures which, when combined with the MCAT, would be better predictors than the existing battery of selection tests.

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CORRELATES OF TWO EXPERIMENTAL TESTS WITH PERFORMANCE IN THE FAA ACADEMY AIR TRAFFIC CONTROL NONRADAR SCREEN PROGRAM

INTRODUCTION

The use of a battery of Civil Service Commission (CSC) aptitude tests for Air Traffic Control (ATC) selection was initiated in 1962. Initially, the CSC battery was required only for qualifying individuals without previous experience; however in 1964, the battery was required for all applicants, regardless of experience (Boone, 1979). With some minor modifications, this selection procedure remained in place through August, 1981. The current selection battery, implemented in 1981, is comprised of two aptitude tests, the Multiplex Controller Aptitude Test (MCAT) and the Abstract Reasoning Test (ART), and a job knowledge test, the Occupational Knowledge Test (OKT). Currently, the OPM battery is part of a two-stage selection process. Following qualification on the paper-and-pencil OPM battery, completion of an interview, and medical and security evaluations, applicants are hired as FAA employees. They then enter the second stage of the selection process, a nine week performance-based Screen program (i.e., pass/fail) at the FAA Academy in Oklahoma City.

During the past few years, the FAA has sought to develop more extensive recruitment techniques and more efficient procedures for testing, interviewing, and selecting applicants into the Academy program. As part of this effort, interest has been expressed in the availability of shorter test instruments that could be administered during recruitment efforts to identify individuals who possess high potential for success as Air Traffic Control Specialists (ATCSs). This study was designed to determine the relationships of two shorter instruments, the Directional Headings Test (DHT) and Dial Reading Test (DRT), with performance on tests in the current selection battery. These tests were used in previous Civil Aeromedical Institute (CAMI) investigations by Cobb and Matthews (1972) and Boone (1979) prior to the implementation of the current selection battery. Additionally, results of the comparisons will be used to determine the utility of the two tests, along with tests from the current selection battery, in improving the effectiveness of the selection process.

METHODS

Subjects.

In 1987, the DHT and DRT were administered as part of a battery of experimental tests to 1,255 students who entered the FAA Academy Nonradar Screen Program. Entrants who were repeating the program or those who came from special emphasis programs were excluded from the sample. Women comprised 12.1% and minority group members comprised 6.3% of this sample.

Measures.

OPM Battery. This battery is administered to applicants to determine if they qualify for entry into the Academy Nonradar Screen Program. The MCAT is a timed test that requires the individual to respond to a series of questions by utilizing a) tabular data about aircraft altitude, speed, and course, along with b) a map which contains several aircraft at different locations on various flight paths. This information is used to compute aircraft time-and-distance travel patterns and to determine if there are potential conflicts in the flight paths. The ART is an older, timed Civil Service Commission test (OPM-157) in which applicants are presented a series of figures or letters, and are then asked to select the choice that carries out a principle of logical development. The OKT contains questions about the phraseology and procedures used by airmen and ATCSs.

Weights are applied to the raw scores on the MCAT and ART, to produce a distribution of transformed scores with a mean of 70 and a maximum score of 100. The individual's transformed score is referred to as the Transmuted Composite (TMC). The final OPM rating includes the addition of extra credit points based on their OKT scores and Veteran's

preference points. OPM battery performance measures for this study included scores on the MCAT, ART, and TMC, but excluded the final OPM rating.

DHT. The DHT was developed by Cobb and Matthews (1972) as a paper-and-pencil measure of speeded spatial ability that informal job analyses indicated was a major determinant of ATC performance. Originally, it was comprised of three separate parts. Subjects were given 90 seconds to complete each part of the test. Each item was comprised of one, two, or three bits of information that reflected the cardinal points on a mariner's compass. For example, the letter "E", the symbol " → ", and the notation "90" each denoted "East." Other combinations of letters, symbols, and degrees denoted "West", "North", and "South." In Part I of the test, the subject rapidly determined if the information conflicted or agreed. The item was followed by one of five questions: North?, East?, West?, South?, or Conflict?, to which a yes or no response was given. Part II was similar to Part I except the subject answered whether the presented data represented the exact opposite of the given heading. Part III involved the addition of distraction to Part II questions. Boone (1979) indicated that the DHT was not considered for inclusion in the selection battery since the field testing facilities might be unable to insure that the strict timing and control requirements would be implemented.

Using the basic principles of the DHT, modified procedures were developed that permitted expansion of the testing time to 5 minutes for each of two parts. Each part of the DHT now contains 120 items. In each problem, subjects are presented with three bits of information relating to the cardinal points of a compass. In Part I of the test the subject must rapidly scan the available information and determine either the direction indicated (if all information is consistent), or indicate that the information is inconsistent. In Part II, the task is somewhat more complicated. The determination of direction can be established if at least two of the three types of information are consistent. The inconsistent alternative is selected only when all three bits of information disagree.

DRT. The DRT was developed in the 1950's by the USAF Air Training Command at Lackland Air Force Base for use in the selection of candidates for undergraduate pilot training. Subjects are presented with seven different instrument dials for each set of questions. The questions require the individual to identify and correctly read the appropriate dial in order to select the correct answer from among five choices. The allotted time for completion of the 57 questions is 11.5 minutes. This test has been used in previous research with ATCS subjects (Boone 1979, Marshall-Mies and Colmen 1976, and Brokaw 1957). Tests scores have been found to be predictive of training performance in studies with samples of navigators, ATCSs, and undergraduate pilots.

Criterion Measures.

The Academy ATCS Nonradar Screen Program assesses trainees' ability to learn a set of air traffic procedures and then to apply those procedures during a series of nonradar, laboratory simulations. The performance measures, with their percentage of the final score, include: academic tests (20%); a paper-and-pencil Controller Skills Test (20%); and two evaluations of performance on the best five of six graded laboratory problems - an instructor assessment (30%) and a technical assessment (30%). A final grade of 70.0 is required for successful completion of the ATCS Nonradar Screen. The final status of an entrant can be pass, fail, or withdrawal before completion of the program.

Analyses.

Four series of analyses were conducted in this study:

1) Descriptive statistics for various components of the experimental tests and OPM tests were computed;

2) The relationships of overall Academy success (measured by pass, fail, and withdrawal rates) to the experimental and OPM test scores were examined;

3) Intercorrelations of test results and various Academy performance criteria were calculated; and

4) Stepwise multiple regression analyses were performed, using corrected correlation coefficients to predict Academy performance.

Correlations between the experimental and OPM tests with the criterion measures (Academy performance) were spuriously low, due to the well-known restriction-in-range effect (Thorndike, 1949). Correlation coefficients for the selected sample were lower than would have been the case if the entire applicant group had entered the Academy Nonradar Screen. This occurs as a consequence of the reduction in the range and variances of the test scores in the selected sample. Coefficients were corrected for this restriction using the two-variable equation for the OPM tests. The three-variable equation was employed for the DHT and DRT, since variances for those tests were not available for the ATCS applicant population.

RESULTS AND DISCUSSION

Table 1 presents descriptive statistics for various measures of the two tests for the 1,255 Academy entrants with valid (non-missing) data on both tests. For the Directional Headings Test, the mean of correct item responses on Part II was 57.2, clearly lower than the mean of correct answers for Part I of 72.2. Also, no one achieved the maximum possible score of 120 on Part II, as had occurred on Part I. Since the number of correct responses was so different for the two DHT parts and in order to compensate for possible guessing on the test items, DHT total scores were adjusted. The measure of combined performance for both parts of the DHT in subsequent analyses was based on the product of the number of correct items and the percentage of correct items for Part I, plus the result of the same formula applied to Part II.

The mean correct score on the Dial Reading Test was 43.7, compared to the maximum possible total of 57. Results of a t-test indicated that this value was higher ($p \leq .001$) than the 40.97 average noted in the Boone (1979) study. An adjusted measure of performance on the DRT was computed in a similar manner as was done with the DHT. Specifically, the measure of DRT performance used in this study was represented by the product of the number of correct DRT items and the percentage of correct items.

TABLE 1. Descriptive Statistics for DHT and DRT

Mean	SD	Minimum	Maximum	Test Measure
72.2	15.4	23.0	120.0	Number correct - DHT Part I
57.2	13.6	6.0	103.0	Number correct - DHT Part II
129.4	24.6	33.0	207.0	Total correct - Parts I & II
125.1	25.7	13.2	204.0	DHT adjusted Parts I & II
43.7	8.0	9.0	57.0	Total correct - DRT
38.5	10.0	2.7	57.0	DRT adjusted

Directional Headings Test and Academy Success. The sample was divided into quartiles and the pass, fail, and withdrawal rates (percentages) for the groups were examined using a chi-square statistic (Table 2). Pass rates ranged from 39.6 for those with the lowest DHT scores to 69.3 for the highest DHT quartile. The chi-square comparison of these differences was statistically significant ($p<.001$). The percentages of trainees failing the Screen program or withdrawing before completion of the program were both inversely related to DHT scores. The failure rate was 43.8% for the lowest DHT quartile compared to 25.3% for the

highest quartile of DHT scores. Similarly, 16.6% of those in the lowest quartile withdrew, compared to only 5.4% in the highest quartile.

The final Academy scores for the DHT groups were compared with one-way analyses of variance and the Scheffe test was used for post-hoc comparisons (Table 2). The one-way analysis of variance revealed a statistically significant difference ($p \leq .001$) in the average grades of students based on their DHT scores. Compared to the average of 67.5 for students in the lowest quartile of the DHT, those in the highest quartile had an average score of 74.5. Group comparisons, using the Scheffe test, revealed that the average grade of the fourth quartile students differed significantly ($p \leq .01$) from that of students in the first two quartiles. Also, the third quartile group had a higher Academy final grade average than did the lowest quartile group.

TABLE 2. DHT with Academy Success and Academy Final Score.

ACADEMY PASS, FAIL, WITHDRAWAL RATES

Group	N	Pass	Fail	Withdraw
Quartile 1	313	39.6	43.8	16.6
Quartile 2	314	51.3	38.9	9.8
Quartile 3	315	61.3	29.5	9.2
Quartile 4	313	69.3	25.3	5.4
TOTAL	1255	55.4	34.3	10.3
CHI-SQUARE		62.6**	29.9**	22.0** (D.F.=3)

ACADEMY FINAL SCORE

Group	N*	Mean	SD
Quartile 1	261	67.5	11.8
Quartile 2	283	70.5	10.2
Quartile 3	286	72.8	10.4
Quartile 4	296	74.5	10.2
TOTAL	1126	71.5	11.0

* Excludes those who withdrew before completion of the Screen program.
** $p \leq .001$ F ratio = 22.34**

Dial Reading Test and Academy Success. The sample was divided into quartiles based on DRT performance. Pass, fail, and withdrawal rates for the groups were then examined, using a chi-square statistic (Table 3). Differences in pass rates based on the DRT were similar to those noted for the DHT. The quartile of the sample with a DRT score of 46.2 or higher had a pass rate of 66.3%, compared to a pass rate for the lowest quartile of 40.1%. Failure rates were inversely related to DRT performance with almost one-half (48.4%) of the lowest quartile group failing the Screen. Withdrawal rates did not differ significantly between the groups, although only 7% of the students in the top quartile withdrew, compared with 10.0% to 12.5% for the other quartiles.

Final Academy grades were also compared, using a one-way analysis of variance and Scheffe tests of significance between group means (Table 3). Differences in Academy grades for the DRT performance groups reflected the differences found in pass rates. Mean grades ranged from 67.6 for the first quartile to 74.5 for the fourth quartile. As was the case with the DHT, the mean Academy final score of 74.5 for the highest DRT group was significantly higher ($p \leq .01$) than the Academy scores of the lowest two quartiles of DRT performance.

Also, the group of Academy entrants in the third quartile of DRT performance had significantly higher final scores than those in the first quartile.

TABLE 3. DRT with Academy Success and Academy Final Score.

ACADEMY PASS, FAIL, AND WITHDRAWAL RATES

Group	N	Pass	Fail	Withdraw
Quartile 1	312	40.1	48.4	11.5
Quartile 2	312	54.2	33.3	12.5
Quartile 3	319	60.8	29.2	10.0
Quartile 4	312	66.3	26.7	7.0
TOTAL	1255	55.4	34.3	10.3
CHI-SQUARE		48.8**	39.5**	5.8

(D.F.=3)

ACADEMY FINAL SCORE

Group	N*	Mean	SD
Quartile 1	276	67.6	11.5
Quartile 2	273	70.7	10.2
Quartile 3	287	72.8	10.3
Quartile 4	290	74.5	10.6
TOTAL	1126	71.5	11.0

* Excludes those who withdrew before completion of the Screen program.
** $p \leq .001$ F ratio= 21.64 **

Current Selection Measures and Academy Success. The sample was also divided into quartiles based on Transmuted Composite scores (TMC - used as the primary selection measure of applicants for the job of air traffic controller). The quartile of the sample with TMC scores of 93.7 or greater had a pass rate of 66.1%, compared to the pass rate of 45.4% for the lowest quartile (TMC scores of 87.7 and lower). Lower rates of Academy failure and withdrawal were evidenced as TMC scores increased (Table 4).

The mean Academy score of 74.2 for trainees in the top quartile of the TMC was significantly higher than that for trainees in each of the other TMC groups. None of the remaining comparisons reached statistical significance.

TABLE 4. OPM Selection Test Composite (TMC) with Academy Success and Academy Final Score.

ACADEMY PASS, FAIL, AND WITHDRAWAL RATES

Group	N	Pass	Fail	Withdraw
Quartile 1	315	45.4	40.0	14.6
Quartile 2	301	55.1	32.9	12.0
Quartile 3	320	54.7	37.2	8.1
Quartile 4	319	66.1	27.3	6.6
TOTAL	1255	55.4	34.3	10.3
CHI-SQUARE		27.7***	13.0**	13.6**

(D.F.=3)

ACADEMY FINAL SCORE

Group	N*	Mean	SD
Quartile 1	269	69.7	11.1
Quartile 2	265	71.1	10.3
Quartile 3	294	70.7	11.2
Quartile 4	298	74.2	10.6
TOTAL	1126	71.5	11.0

* Excludes those who withdrew before completion of the Screen program.
** $p \leq .01$
*** $p \leq .001$ F ratio = 9.25***

One possible use of the DHT and DRT would be to employ these tests in conjunction with current selection measures. Table 5 shows the Academy pass rates for the various DHT and DRT performance levels (based on quartile values for the total sample) for the 315 trainees in the lowest quartile of TMC scores (87.7 or lower). Within this group, where the average pass rate was 45.4%, scores on both the DHT and DRT test differentially predicted Academy success. Of the trainees who scored in the upper quartile of the DHT, 68.8% successfully completed the Academy Nonradar Screen Program. A similar percentage (65.6%) of those with higher scores on the DRT were successful. In contrast, of those trainees in the lower quartiles of the DHT, only 29.7% and 39.0% were successful. Percentages of successful trainees in the two lower quartiles of the DRT were 34.4% and 48.0%, respectively. While the utility of using the DHT or DRT to predict the successful Academy performance of trainees with lower scores on the OPM battery needs to be cross-validated with another sample, results suggest that the two tests measure somewhat different aspects of trainee aptitudes than do the OPM scores.

TABLE 5. DHT and DRT Performance and Academy Success for the Lowest Quartile of OPM Test Scores.

	DHT		DRT	
Group	**N**	**% Pass**	**N**	**% Pass**
Quartile 1	111	29.7	128	34.4
Quartile 2	77	39.0	100	48.0
Quartile 3	79	59.5	55	54.5
Quartile 4	48	68.8	32	65.6
TOTAL	315	45.4	315	45.4

Differential Performance on Experimental and OPM Tests. The distribution of the scores of men and women on the DHT, DRT, and TMC did not differ significantly. Comparisons of the distributions for minorities and nonminorities revealed a significant difference on the DRT and TMC, but not the DHT. Of minorities in the sample, 48.1% had DRT scores that fell in the lowest quartile. A higher percentage (39.2%) of the minorities also had TMC scores that fell within the lowest quartile. While these differences do not necessarily mean that there would be corresponding differences in the distributions of the scores between respective applicant subgroups, previous research by Rock, et al, (1984) did demonstrate that women and minorities scored lower than men and nonminorities respectively, on an experimental version of the existing OPM ATCS test battery.

Interrelationships Between Test Results and Academy Performance. First, the Academy entrants' scores on the experimental tests and the scores on the OPM selection tests were correlated using the point-biserial method with the dichotomous criterion measure of Academy pass/not pass. Also, the matrix of Pearson correlation coefficients between the various tests is presented in Table 6. The DRT and DHT exhibited a higher correlation with each other (.45) than with any of the other tests. The TMC had a higher correlation with the DRT than the DHT (.33 and .24, respectively). Following corrections for restriction-in-range, the TMC displayed the highest correlation (.46) with the pass/not pass criterion measure. The corrected correlation of .20 between the criterion measure and the ART was the smallest.

TABLE 6. Matrix of Intercorrelations* of Experimental Tests, OPM Tests, and Academy Success.

	DHT	DRT	ART	MCAT	TMC
DHT	---				
DRT	.45	---			
ART	.17	.26	---		
MCAT	.21	.27	.12	---	
TMC	.24	.33	.49	.92	---
PASS/NOT PASS	.23	.23	.12	.14	.17
PASS/NOT PASS (Corrected for range restriction)	.41	.44	.20	.38	.46

* COEFFICIENTS OF .10 OR GREATER ($p \leq .001$)

Next, experimental test scores and the OPM selection measures were correlated with several measures of Academy performance previously mentioned, including overall final score (NLCOMP), academic tests (NLBA and NLCPT), average technical assessment (AVTA), average instructor assessment (AVIA), average score on laboratory problems (AVL5), and the Controller Skills Test (CST) (Table 7). The sample was now necessarily limited to those trainees who had completed (passed or failed; excluding those who withdrew) the Academy program. Once again, comparisons of the various tests and the criterion measures were corrected for restriction-in-range. Following corrections, correlations between the tests and the overall Academy grade (NLCOMP) were similar to those noted for the pass/not pass criterion. Of the various component measures of the Academy grades, the experimental tests and OPM tests were most closely correlated with performance on the CST (ranging from .32 with the ART to .56 with the TMC and DRT). Correlations with the two measures of laboratory performance (AVTA and AVIA) were very similar. Performance on the two academic tests (NLBA and NLCPT) exhibited relatively low correlations with the various tests (ranging from .03 for the NLBA with the MCAT to .26 for the DHT and TMC with the NLCPT). Correlations between the ART and various measures of Academy performance were, with few exceptions, lower than those of the other predictor tests.

TABLE 7. Correlations* of Experimental Tests and OPM tests with Academy Performance Components.

	NLCOMP	NLBA	NLCPT	AVL5	AVTA	AVIA	CST
DHT	26(47)	17(23)	16(26)	22(38)	22(39)	23(38)	28(49)
DRT	29(52)	09(18)	12(25)	22(42)	21(41)	20(39)	32(56)
MCAT	17(45)	01(03)	06(17)	13(36)	13(36)	12(33)	16(43)
ART	16(26)	13(21)	10(16)	10(16)	11(18)	09(15)	20(32)
TMC	21(54)	06(18)	09(26)	15(41)	16(44)	14(39)	22(56)

N = 1126; COEFFICIENTS OF 11 OR GREATER ($p \leq .001$)
* DECIMAL POINTS OF COEFFICIENTS HAVE BEEN DELETED.
( ) VALIDITY COEFFICIENTS AFTER ADJUSTMENT FOR RESTRICTION-IN-RANGE

Table 8 presents the results of multiple regression analyses which used the OPM and experimental tests as predictors, and Academy success and Academy final scores as criteria. A stepwise method was used in which a test measure was entered into a given model only if it met the significance criterion of $p \leq .01$. The ART was not a significant predictor of Academy success or final score when combined with the experimental tests, or with the experimental tests plus the MCAT. The MCAT, combined with the two experimental tests, was a significant measure, but had lower beta weights than either the DHT or the DRT.

TABLE 8. Multiple Regression Analyses of Validity Coefficients of Test Scores and Academy Performance Criteria.

CRITERION - PASS/NOT PASS ACADEMY SCREEN

MODEL	MULTIPLE R	BETA WEIGHT
1) DRT and DHT	.469	
DRT		.30
DHT		.21
2) DRT, DHT, and ART	.469	
DRT		.30
DHT		.21
3) DRT, DHT, MCAT, and ART	.481	
DRT		.23
DHT		.19
MCAT		.14

CRITERION - ACADEMY FINAL SCORE

MODEL	MULTIPLE R	BETA WEIGHT
1) DRT and DHT	.548	
DRT		.37
DHT		.23
2) DRT, DHT, and ART	.548	
DRT		.37
DHT		.23
3) DRT, DHT, MCAT, and ART	.563	
DRT		.29
DHT		.20
MCAT		.17

Multiple regression models, which included the MCAT, DHT, and DRT produced multiple correlations of .481 (pass/not pass) and .563 (final grade), were similar to those found by Boone (1979), with the exception of the beta weights for the three tests. Boone (1979) performed several multiple regression analyses in order to compare various models comprised of the then current CSC selection tests, the now current selection tests, the DRT, and the earlier version of the DHT. His results for a model containing the MCAT, DHT, and DRT as predictors had a multiple correlation of .566 with the Academy lab score. The beta weights were MCAT (.31), DHT (.14), and DRT (.19).

CONCLUSIONS

Results demonstrate that the DRT and the DHT, each requiring under 15 minutes of administration time, can separately, or in combination be used to assess the potential of individuals to successfully complete the FAA Academy Nonradar Screen Program. The application of these tests during recruitment to provide feedback to individuals concerning their potential for the air traffic profession should be undertaken only after careful consideration and following cross-validation of the results of the present study.

A significant concern associated with this application would be the tendency for recruitment personnel to use the test results as "pre-selection" information and discourage those with low DHT and DRT scores from applying to take the OPM selection battery. Careful training of recruitment personnel in the appropriate use of the test data would be required. Additionally, there are other techniques available to assist in the recruitment of potential applicants that may be less time-consuming than the use of special tests. Research by Collins, Nye, and Manning (1990) evaluated the use of biographical data as one means of identifying applicants who have high potential for successfully completing the Academy Nonradar Screen Program.

Even though the current ATCS applicant group differs significantly from groups entering the Academy a decade ago on selected dimensions (e.g., education and experience), the utility of the DHT, DRT, and MCAT in predicting Academy Screen success remains relatively unchanged. These results do indicate that there are other aptitude measures that, when added to the MCAT, could prove to be better predictors than the existing battery.

Further research, using a greater variety of aptitude measures is needed to more closely identify the combination of those measures that best predicts performance in the Academy Nonradar Screen Program. Determinations of the validity and utility of the various measures must also be expanded to include other criterion measures, such as on-the-job training performance.

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