PROBLEMS IN AIR TRAFFIC MANAGEMENT:

VI. Interaction of Training-Entry Age With Intellectual and Personality Characteristics of Air Traffic Control Specialists

David K. Trites, Ph.D.

Approved by

Stanley R. Mohler

STANLEY R. MOHLER, M.D.
DIRECTOR, CARI

Released by

M. S. White

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Problems in Air Traffic Management VI. Interaction of Training-Entry Age with Intellectual and Personality Characteristics of Air Traffic Control Specialists

DAVID K. TRITES, PH.D.

PREVIOUS RESEARCH HAS conclusively demonstrated that a substantial negative relationship exists between an individual's chronological age at entry into Air Traffic Control Specialist (ATCS) training with the Federal Aviation Agency (FAA) and subsequent performance in training and on the job. It has also been shown that chronological age at entry into ATCS training is related to performance on aptitude tests.[1, 2, 10, 11, 12, 13, 14, 15, 16]

The present investigation represents an exploration of the interaction of training-entry age of Air Traffic Control Specialists with their intellectual and personality characteristics as assessed by paper-and-pencil tests at the time of entry into training. Particular emphasis has been placed upon the identification of decrements in specific aptitudes, or cognitive abilities, which may predispose the older trainees to less effective training and job performance.

In order to present a more meaningful description of the various aptitude tests administered to over 900 Enroute and Terminal ATC trainees, the contents of the tests were examined and matched with the cognitive factor areas described by French[4] and French, Ekstrom and Price.[5] Although some tests could not be matched and others were obviously poor measures of the factor area to which assigned, it was felt that the results might have more usefulness and meaning for other investigators if reported in this frame of reference.

In addition, the literature on aging, as represented, for example, by Dennis' survey[3] and the study of Glanzer, Glaser, and Richlin,[6] was utilized to predict the direction of the relationships expected to obtain between the cognitive factor areas and age. Predictions could not be made for all factors and, for some, examination of the tests assigned to the factor areas suggested that different relationships might occur within a factor area as a function of differences in test content.

Finally, the aptitude and personality differences serving to distinguish three types of training and job performance outcomes were studied. To accomplish this, ATCS trainees were classified as failures in training (*Fail*), passing the training course but leaving the FAA's employment within one year after training (*Pass-Separated*), and passing the training course and still employed by the FAA (*Pass-Retained*).

PROCEDURE

Cognitive Factors and Aptitude Tests:—The paper-and-pencil tests administered to the ATCS trainees were part of an experimental testing program designed to improve selection of Air Traffic Control Specialists. They were administered to the trainees prior to their entry into training at the FAA Academy, Oklahoma City, and yielded 33 discrete scores and 5 composite scores. All but 4 of the 33 individual test scores were assigned to 1 of 12 cognitive factor areas.

Negative relationships were predicted to occur between age and the tests representing 7 of the 12 factor areas. The factor areas were those measured by highly speeded tests (Perceptual Speed, Spatial Scanning, Flexibility of Closure, and Speed of Closure), the Associative Memory Factor, the Induction, or non-verbal abstract reasoning, Factor, and the Number Facility Factor. For the last factor, the negative prediction was based primarily upon the fact that one test was highly speeded (RPM Number Facility Test) even though some studies[6] have suggested that a positive relationship would occur. Based upon the content of the tests entering into the score, the occurrence of a negative relationship with age was also predicted for the CTMM Non-Language Composite.

Intuitively, it was felt that measures related to verbal aptitude might show an increment with age. Unfortunately, the evidence relating to this is contradictory since some studies have found little, or no, decrement with increasing age[3] but other studies have found age-related decrements.[6] This permitted no prediction for the verbal area and suggested that where verbal ability appeared to enter into performance on a particular test assigned to one of the factors with a negative prediction, the direction of the relationship with age would be ambiguous.

From the Federal Aviation Agency, Civil Aeromedical Research Institute, Aeronautical Center, Oklahoma City, Oklahoma.
Dr. Trites is Chief, Selection Section, Psychology Laboratory.
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The descriptions of the factor areas, tests, and the predicted relationships with age are contained in Table I.

A number of the Civil Service Commission (CSC) tests described in Table I, are alternate forms of the tests now being used to select all new ATCS trainees. The specific tests used for actual selection are those which enter into the CSC Composite score (Variable 38 in Table I). These were chosen for an operational battery after intensive evaluation of their usefulness and represented a culmination of the research whose initial stages have been described by Cobb.[1, 2] Accounts of the later research published, to date, appear in a report[15] prepared for internal distribution within the Federal Aviation Agency and in a technical version of the same material published by the Western European Association for Aviation Psychology.[16]

The Composite Score for Commercial Aptitude Tests (Variable 37 in Table I) was initially developed for Enroute trainees in the early phases of our research program.[1] The remaining three CTMM composite scores were computed according to directions given in the Manual for the CTMM tests and can be considered as estimates of "intelligence" in the non-language and language areas as well as an overall estimate of "general intelligence."

Personality Scales:—The personality characteriestics of the ATCS trainees were assessed by the California Psychological Inventory. This inventory was used because its 18 scales purported to measure a number of aspects of personality which were favorable and positive instead of morbid and pathological. No predictions were made for the relationships between the CPI scales and age. Descriptions of the scales are contained in Table II.

Samples:—Three different types of Air Traffic Control Specialists are trained by the FAA. The first of these, the Terminal, or Tower, Controller operates at airports and is concerned primarily with the safe arrival and departure of aircraft from terminal areas. The second type of specialist is found in the Air Route Traffic Control Centers scattered throughout the country. They are referred to as Enroute Controllers and their principal task is to insure the safe transit of aircraft between terminal areas. The final type is the Flight Service Specialist (FSS) who acts as a communications link for all aircraft.

Since the training programs for the three ATCS types differ and because of known differences in demographic characteristics of those entering each kind of training, most of our previous research has treated each speciality as a separate group. In the present study, however, no information about job separation or retention was available for FSS trainees. Consequently, none were included in the analyses. Job separation and retention data were available for large numbers of Terminal and Enroute trainees, but the relatively small number of those separating from the FAA required that these two types of trainees be pooled in order to have a sufficiently large number of cases in the Pass-Separated group.

Also, the tests and scales described in Tables I and II were not administered to all ATCS trainees. Table III contains a listing of the time periods during which each test was administered and the number of cases in each group who took the test, or scale.

Definitions of Criterion Groups and Age:—The three trainee criterion groups mentioned previously were defined in the following manner: (1) Fail: Trainees failing to complete an 8 week ATCS training course at the FAA Academy for reasons pertaining to unsatisfactory performance in the academic or laboratory portions of the course. Those who withdrew from training for reasons beyond their control, such as illness or family problems, were not considered as failures and were eliminated from all analyses. This group was predicted to have the lowest means on the aptitude variables and, on the average to be the oldest group. (2) Pass-Separated: Trainees completing their basic ATCS training course at the FAA Academy and successfully passing the final Air Traffic Control Specialist Certification Examination at the end of the course, but who subsequently left the FAA prior to completion of approximately one year of employment. This group was predicted to have intermediate means on the aptitude variables and be intermediate in mean age. (3) Pass-Retained: Trainees similar in training accomplishments to the Pass-Separated group and who were still employed by the FAA approximately 10 months after completion of FAA Academy training. This group was predicted to have the highest means on the aptitude

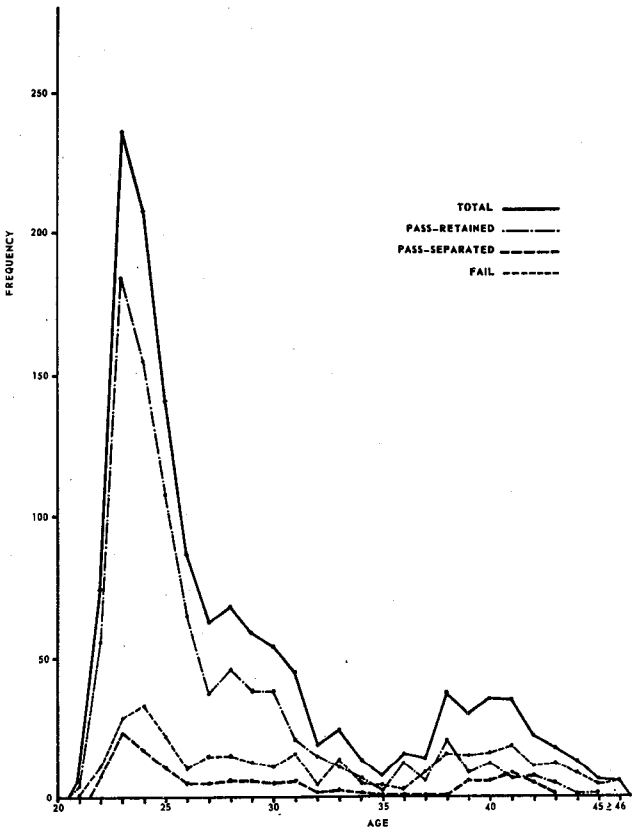

Fig. 1. Age distributions of ATCS trainee criterion groups entering training for the period September, 1960, through June, 1962 (Total N = 1353).

TABLE I—DESCRIPTION OF COGNITIVE FACTORS AND APTITUDE TESTS

Cognitive Factor and Test[1]	Relationship with Age: Predicted	Relationship with Age: Obtained
Induction: "Associated abilities involved in the finding of general concepts that will fit sets of data, the forming and trying out of hypotheses."	—	
1. DAT Abstract Reasoning: Indicate which of a series of choices (figures) properly carries out of a principle of logical development exhibited by a sequence of figures.	—	—**
2. CTMM Analogies: Seven drawings of different objects are presented for each item. The first object has a definite relationship to the second which must be recognized in order to identify, by analogy, the drawing among the last four which is similarly related to the third drawing.	—	—**
3. CTMM Opposites: Select from among several alternatives a pictured object which is most opposite to a stimulus object in terms of its nature, position, or meaning.	—	—
4. CTMM Similarities: Seven drawings of different objects are presented for each item. Select from the last four drawings one which is similar to the first three.	—	—**
5. CTMM Number Series: Indicate which of a series of numbers properly carries out a principle of logical development exhibited by a sequence of numbers.	—	—*
6. CTMM Coins: Manipulate mentally interrelated amounts of money and number of coins.	—	—
7. CSC Abstract Reasoning: Similar to DAT Abstract Reasoning.	—	—
8. CSC Number Series: Similar to CTMM Number Series.		
9. CSC Letter Sequence: Similar to Number Series tests but using letters.	—	—
10. CSC Verbal Analogies: Seven words are presented for each item. Select from the last five words one which is related to the third word in the same way that the first two words are related.	?	+*
Number Facility: "The ability to manipulate numbers in arithmetical operations rapidly."	—	
11. DAT Numerical Ability: Test of arithmetic computational skill.	?	+
12. CTMM Arithmetic: Word problems must be solved involving simple arithmetic and mathematical situations.	?	+**
13. RPM Number Facility: Highly speeded test of ability to add one or two-digit numbers in sets of three.	—	+**
14. CSC Computations: Test of arithmetic computational skill.	?	—
Verbal Comprehension: "The ability to understand the English language."	?	
15. CTMM Verbal Concepts (Vocabulary): Multiple choice vocabulary test.	?	+**
16. DAT Language Usage-Sentences: Indicate all parts of sentences containing errors in grammar, punctuation, or spelling.	?	+*
17. CSC Sentence Arrangement: Rearrange lengthy sentence to form a proper narrative.	?	+
Visualization: "The ability to manipulate or transform the image of spatial patterns into other visual arrangements."	?	
18. DAT Space Relations: Identify solid figures that can be made from an unfolded pattern.	?	—**
19. CSC Spatial Patterns: Identify solid figures that can be made from an unfolded pattern or, from various views of an object, identify the object in a series of alternatives.	?	—
Spatial Orientation: "The ability to perceive spatial patterns or to maintain orientation with respect to objects in space."	?	
20. CTMM Sensing Right and Left: Discriminate between right and left for pictured objects such as various parts of the human anatomy, clothing, etc.	?	+
21. CTMM Manipulation of Areas: Identify three dimensional spatial drawings representing different views of a stimulus object.	?	—
Associative (Rote) Memory: "The ability to remember bits of unrelated material."	—	
22. CTMM Immediate Recall: Series of words are pronounced in pairs. After each series, the first word of each pair is pronounced again, and the word that went with it must be recalled from among three objects pictured in each item.	—	—**
23. CTMM Delayed Recall: Recall facts of a story after an intervening period.	—	+
Mechanical Knowledge: "Knowledge of mechanical principles, devices, and tools, acquired through experience and training."	?	
24. DAT Mechanical Reasoning: Through a study of drawings depicting the operation of physical and mechanical principles determine the correct statement describing a situational outcome resulting from application of the principle.	?	+**
Syllogistic Reasoning: "Ability to reason from stated premises and derive logical conclusions.	?	
25. CTMM Inference: Comprehend statements presenting premises and derive logical conclusions.	?	—
Perceptual Speed: "Speed in finding figures, making comparisons, and carrying out other very simple tasks involving visual perception."	—	
26. RPM Perceptual Speed: Detect and cross out all numbers in a row that are like a circled number at the beginning of each row. Highly speeded.	—	—*
Spatial Scanning: "Speed in visually exploring a wide or complicated spatial field."	—	
27. RPM Visualization: Follow visually the path of lines in a tangled pattern of such lines. Highly speeded.	—	—*
Flexibility of Closure: "The ability to keep one or more definite configurations in mind so as to make identification in spite of perceptual distractions."	—	
28. RPM Copying: Copy four-line geometrical figures onto a matrix of dots. Highly speeded.	—	+

Speed of Closure: "The ability to unify an apparently disparate perceptual field into a single percept."	—	
29. RPM Four-Letter Words: Detect common four-letter words imbedded in lines of letters. This highly speeded test has a high loading on a possible factor called "Verbal Closure."	—	+**
Unknown or Complex Factor Structure		
30. Air Traffic Problems, Part I: Determine whether aircraft may be permitted to change altitude without violating a specified time-separation rule. Unpublished factor analyses indicate high loadings on the Number Facility Factor and Induction Factor.	?	—*
31. Air Traffic Problems, Parts I and II: Twice as long as Air Traffic Problems, Part I.	?	—
32. RPM Aiming: Ability to carry out quickly and precisely a series of movements requiring eye-hand coordination.	—	—
33. CSC Oral Directions: From orally presented information, decisions must be made regarding performance of simple tasks.	?	+
34. CTMM Language Composite: A sum of Variables 12, 15, 23, and 25.	?	+**
35. CTMM Non-Language Composite: A sum of Variables 2, 3, 4, 5, 6, 20, 21, and 22.	—	—**
36. CTMM Language plus Non-Language Composite: An overall estimate of "general intelligence" composed of Variables 33 and 34.	?	+
37. Composite Score for Commercial Aptitude Tests: A sum of Variables 1, 2, 11, 18, and 30, weighted 14, 49, 13, 6, and 18, respectively.	?	—
38. Composite Score for CSC Aptitude Tests: A sum of Variables 7, 9, 14, 19, 31, and 33 each weighted 2, 2, 1, 2, 1, 1, respectively.	?	—

[1] Factor descriptions are quotations from: French, J. W., Ekstrom, Ruth B., & Leighton, A. P. Manual for kit of reference tests for cognitive factors. Educational Testing Service, 1963. Princeton, N. J. Test Names preceded by DAT were part of the Differential Aptitude Test Battery, Form A, 1947, published by the *Psychological Corporation,* New York, N. Y.; those preceded by CTMM were part of California Test of Mental Maturity, Advanced, Form A, 1957, published by the *California Test Bureau,* Los Angeles, California; those preceded by RPM are part of a battery of Repetitive Psychometric Measures developed by Dr. L. J. Moran and published for experimental use in 1959, by the *Hogg Foundation for Mental Health,* The University of Texas, Austin, Texas; those preceded by CSC are issued by the United States Civil Service Commission; and the Air Traffic Problems tests were originally developed by the American Institute for Research, Pittsburgh, Pa., under contract with the Civil Aeronautics Administration in 1950. Forms used in the present research were extensive revisions of the originals tests and were prepared by the Selection Section, Psychology Laboratory, Civil Aeromedical Research Institute, Oklahoma City, Oklahoma.

* Relationship significant at less than the .05 level.

** Relationship significant at less than the .01 level.

[a] Regression lines were significantly heterogenous for these tests.

variables, and, on the average, be the youngest group.

Information used to classify an individual as a Fail was supplied by the FAA Academy. Data used to classify an individual as Pass-Retained or Pass-Separated were obtained, approximately 10 months after completion of FAA Academy training, from the field facility to which the individual had been assigned. For a few individuals, the retention-separation data could

TABLE II. DESCRIPTION OF PERSONALITY SCALES [1]

Scale Name	Description
1. Dominance	To assess factors of leadership ability, dominance, persistence, and social initiative.
2. Capacity for status	To serve as an index of an individual's capacity for status (not his actual or achieved status). The scale attempts to measure the personal qualities and attributes which underlie and lead to status.
3. Sociability	To identify persons of outgoing, sociable, participative temperament.
4. Social presence	To assess factors such as poise, spontaneity, and self-confidence in personal and social interaction.
5. Self-acceptance	To assess factors such as sense of personal worth, self-acceptance, and capacity for independent thinking and action.
6. Sense of well-being	To identify persons who minimize their worries and complaints, and who are relatively free from self-doubt and disillusionment.
7. Responsibility	To identify persons of conscientious, responsible, and dependable disposition and temperament.
8. Socialization	To indicate the degree of social maturity, integrity, and rectitude which the individual has attained.
9. Self-control	To assess the degree and adequacy of self-regulation and self-control and freedom from impulsivity and self-centeredness.
10. Tolerance	To identify persons with permissive, accepting, and non-judgmental social beliefs and attitude.
11. Good impression	To identify persons capable of creating a favorable impression, and who are concerned about how others react to them.
12. Communality	To indicate the degree to which an individual's reactions and responses correspond to the modal ("common") pattern established for the inventory.
13. Achievement via conformance	To identify those factors of interest and motivation which facilitate achievement in any setting where conformance is a positive behavior.
14. Achievement via independence	To identify those factors of interest and motivation which facilitate achievement in any setting where autonomy and independence are positive behaviors.
15. Intellectual efficiency	To indicate the degree of personal and intellectual efficiency which the individual has attained.
16. Psychological-mindedness	To measure the degree to which the individual is interested in, and responsive to, the inner needs, motives, and experiences of others.
17. Flexibility	To indicate the degree of flexibility and adaptability of a person's thinking and social behavior.
18. Femininity	To assess the masculinity or femininity of interest. (High scores indicate more feminine interest, low scores more masculine.)

[1] Descriptions of the scales are quoted from the Manual prepared by Dr. H. G. Gough for the California Psychological Inventory and published by Consulting Psychologist Press, 1960, Palo Alto, Cal.

TABLE III—SAMPLE DESCRIPTIONS AND TESTS ADMINISTERED TO EACH SAMPLE

Sample	Time Period	Tests or Scales	[1] Number of Cases in Pass-Ret.	Pass-Sep.	Fail
1	Sept., 1960-July, 1961	From Table 1, Variables Numbered: 3, 4, 5, 6, 12, 15, 16, 20, 21, 22, 23, 24, 25, 30, 34, 35, 36	458	82	136
2	Sept., 1960-Jan. 1962	From Table 1, Variables Numbered: 1, 2, 11, 13, 18, 26, 27, 28, 29, 32, 37; and all variables in Table 2	626	95	187
3	July, 1961-June, 1962	From Table 1, Variables Numbered: 7, 8, 9, 10, 14, 17, 19, 31, 33, 38	347	33	160

[1] The number of individuals actually administered any particular test may vary slightly from the N's given here as a result of missing data.

not be obtained from a facility. Such individuals were deleted from the study.

The decision to use Retention-Separation after training as the criterion of job performance rather than some index involving ratings by an individual's supervisors was based upon several considerations. First, the fact of retention or separation was completely objective. Second, there can be no doubt that the separation of an individual within less than a year following completion of ATCS training represents a distinct monetary loss to the FAA and can be considered presumptive evidence of unsatisfactory adjustment to the FAA's working environment. Naturally, some separated for reasons not related to performance or adjustment, such as health or a better job opportunity, but the data furnished by facilities indicated that the vast majority of those in the Pass-Separated group were considered deficient in job performance or adjustment. A third consideration was the unavailability of supervisory ratings for many of the separated individuals. Finally, any ratings which were available for separated individuals had to have been made in retrospect; and it is likely that the fact of separation would have given a negative halo to such an individual regardless of the reasons for separation.

Age at entry into training was recorded to the nearest birthdate. The distribution of ages of trainees was skewed with the majority of trainees in the 22 to 26 year age range. The distribution was also definitely bimodal with a secondary peak in the 38 to 41 year range.* Figure 1 contains the frequency polygons for the three trainee-criterion groups and the total of all Enroute and Terminal course trainees coming to the FAA Academy from September, 1960, through June, 1962.

Statistical Methodology:—The analyses of the interaction of training-entry age and the other variables were based upon the covariance analysis techniques described by Snedecor.[9] As programmed for an IBM 1620 computer, the output contained all relevant statistical information, including a test of the homogeneity of the regressions of the criterion groups and a within-groups correlation coefficient. This latter statistic was selected as the appropriate estimate of the correlation between age and the other variables.[7, 8] To test the significance of the differences between adjusted means of the Pass-Retained and Pass-Separated groups on each variable, the adjusted within-groups variance estimate was used in the conventional formula for a t-test.[8] As for the assumptions underlying use of the covariance technique, a survey of the data indicated that all were tenable.

RESULTS

Table IV contains the means and standard deviations of the age distributions for each group of trainees. In every case, the differences between the mean ages were statistically significant in the anticipated direction; i.e., the Fails were oldest, the Pass-Retained the youngest, and the Pass-Separated in between the other two groups.

Aptitude Variables:—Table V contains the criterion group means of all aptitude variables unadjusted and adjusted for their regression on age, the within-groups' correlations between the variables and age, and the F-test values for differences in the unadjusted and adjusted means. Of the 38 individual and composite aptitude variables listed in the table, only two were found to have significantly heterogeneous regressions—DAT Language Usage and RPM Visualization. This precluded the interpretation of their F-tests. Table I contains a summary of the signs and statistical significance of the obtained correlations.

Of the 7 factor areas predicted to have negative

* In a previous study,[11] the age distribution of Enroute trainees was found to contribute most to the bimodality. Unfortunately, several items of information which might have helped in the interpretation of the age distribution and other results of the investigation were not available; e.g., the proportion who were retired military personnel and complete work histories of all trainees.

TABLE IV. MEAN AGES OF THE THREE ATCS TRAINEE CRITERION GROUPS AND THE POOLED MEAN AND STANDARD DEVIATION OF AGE IN EACH SAMPLE [1]

Samples	Pass-Retained $\bar{X}$	N	Pass-Separated $\bar{X}$	N	Fail $\bar{X}$	N	Pooled $\bar{X}$	S.D.	N
1	27.0	458	28.8	82	31.6	136	28.1	6.2	676
2	26.9	626	28.7	95	31.5	187	28.1	6.2	908
3	26.5	347	29.7	33	31.8	160	28.2	6.4	540

[1] Within a sample, the differences between the mean ages of the criterion groups are all significant at less than the .001 level.

TABLE V. CORRELATIONS (r) WITH AGE, ADJUSTED AND UNADJUSTED CRITERION GROUP MEANS (X), AND F-TEST VALUES FOR ALL APTITUDE TEST VARIABLES

Factor and Test	r	Unadjusted Means							Adjusted Means			
		Pass-Ret.		Pass-Sep.		Fail			Pass-Ret.	Pass.-Sep.	Fail	
		$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	F	$\bar{X}$	$\bar{X}$	$\bar{X}$	F
Induction												
DAT Abst. Reas.	—.09 **	36.0	626	34.7	92	29.4	186	17.6 ††	35.7	34.8	30.1	12.0 ††
CTMM Analogies	—.08 **	7.0	626	6.7	95	6.2	187	11.7 ††	7.0	6.7	6.3	7.7 ††
CTMM Opposites	—.05	7.6	458	7.4	82	6.9	136	5.1 **	7.6	7.5	7.0	3.5 *
CTMM Similar	—.15 **	10.2	458	10.3	82	9.7	136	3.2 *	10.2	10.3	9.9	1.1
CTMM Number Series	—.08 *	6.2	458	6.0	82	5.1	136	12.1 ††	6.2	6.0	5.2	8.6 ††
CTMM Coins	—.06	8.5	458	8.5	82	6.7	136	20.3 ††	8.4	8.5	6.8	16.3 ††
CSC Abstract Reas.	—.03	12.7	347	13.4	33	10.5	160	9.4 ††	12.6	13.5	10.5	7.5 ††
CSC Number Series	—.06	2.5	347	2.4	33	1.7	160	10.7 ††	2.4	2.4	1.8	7.1 ††
CSC Letter Sequence	—.07	11.4	347	10.3	33	7.3	160	42.2 ††	11.3	10.4	7.5	31.1 ††
CSC Verbal Analogies	.09 *	10.5	347	10.1	33	9.3	160	8.7 ††	10.6	10.1	9.1	10.8 ††
Number Facility												
DAT Number Ability	.04	23.6	626	22.9	93	18.2	185	9.8 ††	23.8	22.8	17.8	10.6 ††
CTMM Arithmetic	.08 *	8.6	458	8.9	82	7.4	136	14.3 ††	8.7	8.9	7.3	16.3 ††
RPM Number Facility	.10 **	38.4	623	35.8	93	34.7	186	11.4 ††	38.6	35.7	34.1	15.2 ††
CSC Computations	.06	41.7	347	40.5	33	38.0	160	13.3 ††	41.9	40.4	37.7	14.2 ††
Verbal Comprehension												
CTMM Verbal Concepts	.33 **	21.4	458	21.9	81	20.6	136	.9	21.8	21.6	19.2	7.3 ††
DAT Lang. Usage-Sent.	.18 †	37.2	458	38.2	79	34.4	135	2.8 †	37.7	38.0	33.0	6.4 †
CSC Sent. Arrangement	.05	3.7	347	4.0	33	3.3	160	4.8 **	3.7	3.9	3.2	5.4 **
Visualization												
DAT Space Relations	—.09 **	63.0	624	63.1	93	51.0	185	31.0 ††	62.6	63.3	52.0	23.0 ††
CSC Spatial Patterns	—.08	27.7	347	28.6	33	24.4	160	25.8 ††	27.6	28.7	24.7	18.7 ††
Spatial Orientation												
CTMM Sensing R & L	.01	17.2	458	17.1	82	16.2	136	9.8 ††	17.2	17.1	16.2	9.2 ††
CTMM Manip. of Areas	—.07	8.1	458	8.4	82	7.2	136	7.6 ††	8.1	8.4	7.4	5.6 **
Associative (Rote) Memory												
CTMM Immed. Recall	—.11 **	30.4	458	30.3	81	28.7	136	20.2 ††	30.3	30.3	28.8	14.3 ††
CTMM Delayed Recall	.05	17.2	458	17.3	81	15.9	136	14.1 ††	17.2	17.3	15.9	15.1 ††
Mechanical Knowledge												
DAT Mech. Reasoning	.26 **	43.7	458	46.3	79	41.7	135	3.7 *	44.3	46.0	39.9	8.6 ††
Syllogistic Reasoning												
CTMM Inference	—.05	12.0	458	12.1	82	11.1	136	15.0 ††	12.0	12.1	11.1	12.1 ††
Perceptual Speed												
RPM Perceptual Speed	—.08 *	91.8	623	88.4	93	89.8	186	2.3	91.5	88.6	90.6	1.4
Spatial Scanning												
RPM Visualization	—.05 †	34.3	623	32.3	93	31.0	186	18.4 †	34.2	32.4	31.2	14.4 †
Flexibility of Closure												
RPM Copying	.04	10.0	623	9.7	93	8.3	186	10.6 ††	10.0	9.7	8.2	11.4 ††
Speed of Closure												
RPM 4-Letter Words	.17 **	20.6	623	20.5	93	19.1	186	4.3 *	20.8	20.3	18.4	9.6 ††
Unknown or Complex Structure												
Air Traf. Prob.: Pt. I	—.07 *	15.7	626	13.3	93	11.2	186	7.9 ††	15.5	13.4	11.8	5.1 **
Air Traf. Prob.: Pts. I & II	—.08	35.1	347	30.7	33	28.3	160	29.9 ††	34.9	30.9	28.8	20.5 ††
RPM Aiming	—.06	108.	622	104.	93	106.	186	2.9	108.	104.	106.	1.9
CSC Oral Directions	.01	21.4	347	22.1	33	16.9	160	17.9 ††	21.4	22.0	16.9	15.9 ††
CTMM Lang. Compos.	.26 **	95.1	458	94.8	81	55.0	136	9.8 ††	59.7	59.9	53.5	19.5 ††
CTMM Non-Lang. Comp.	—.14 **	95.1	458	94.8	81	86.8	136	34.5 ††	94.8	94.9	87.6	24.7 ††
CTMM Lang. + Non-Lang.	.07	154.	458	155.	81	142.	136	27.4 ††	155.	155.	141.	28.9 ††
Commercial Test Compos.	—.06	178.	625	173.	95	146.	186	64.0 ††	178.	173.	147.	52.7 ††
CSC Test Compos.	—.06	201.	347	198.	33	167.	160	53.7 ††	201.	198.	168.	41.6 ††

† Regression lines were significantly heterogeneous for these tests.
* Significant at the .05 level.
** Significant at the .01 level.
†† Significant at the .001 level.

relationships with age, statistically significant negative correlations were obtained between age and test scores in 3 of the factor areas. These were: (1) The Induction Factor as measured by the DAT Abstract Reasoning test and the CTMM tests of Analogies Similarities, and Number Series; (2) the Associative Memory Factor measured by the CTMM Immediate Recall test; and (3) one highly speeded test representing the Perceptual Speed Factor. Among the 4 remaining factor areas with negative predictions, a negative correlation was obtained for the RPM Visualization test representing the Spatial Scanning Factor. Unfortunately, the regression lines for the three subgroups were heterogeneous which makes interpretation of the age-Visualization test correlation difficult. RPM Copying, a highly speeded test assigned to the Flexibility of Closure Factor, had an insignificant positive correlation with age; and the RPM Four-Letter Words test (Speed of Closure Factor) had a significant positive correlation with age as did two (CTMM Arithmetic and RPM Number Facility) of the four tests assigned to the Number Facility Factor.

Three additional negative and significant correlations between age and test scores were obtained. The first with the total CTMM Non-Language Composite score was predicted. The other two were with the DAT Space Relations test measuring the Visualization Factor and the test of Air Traffic Problems, Part I.

Statistically significant positive correlations were also obtained between age and the DAT Mechanical Rea-

soning test of the Mechanical Knowledge Factor, and between age and the CSC Verbal Analogies test (Induction Factor), the CTMM Verbal Comprehension test of the Verbal Comprehension Factor, and the total CTMM Language Composite score. It would seem then, that the intuitive expectation of a positive relationship between age and Verbal Comprehension has been supported.

Even though the remainder of the variables did not have statistically significant correlations with age, a survey of the algebraic signs of their correlations is of interest. Generally, those tests involving the solution of new types of problems or reasoning (Induction Factor) were negatively related to age; whereas those tests involving verbal aptitude (Verbal Comprehension Factor), numerical aptitude (Number Facility Factor), or other knowledge (Mechanical Knowledge Factor) were positively related to age. Since we are dealing here with statistically insignificant relationships, exceptions to these general trends are to be expected; but overall the findings do seem to be in agreement with the results involving the statistically significant correlations.

With respect to the interactions of age, test performance, and the criterion groups, the mean test performance of the criterion groups differed significantly on all but 3 of the 36 variables having homogeneous regressions, irrespective of the age differences between groups. In all 33 comparisons, the Fail group had the lowest mean score.

Of course, in those covariance analyses involving aptitude variables having a positive relationship with age, the unadjusted mean score for Fails was higher than the adjusted mean. The converse was true for variables having a negative correlation with age. But for only two variables did the regression adjustment lead to pronounced changes in statistical significance or interpretation. These two are illustrated in Figures 2 and 3.

In Figure 2, the unadjusted and adjusted mean scores on the CTMM Verbal Concepts (Vocabulary) test are plotted for each of the three criterion groups. Since there was a positive correlation of .33 between the test score and age, the covariance adjustment produced a relatively large shift in the means. The relationship between the test and criterion groups was changed from a statistically insignificant one to a statistically significant difference having the predicted pattern of Fails with the lowest mean score, the Pass-Retained with the highest mean score, and the Pass-Separated mean score in between the other two.

Figure 3 contains a similar plot of unadjusted and adjusted means for the CTMM Similarities test. Originally the overall difference between the mean test scores was statistically significant but the correction for a negative correlation of −.15 reduced the mean differences to insignificance.

Examination of the differences between the adjusted mean test scores of the Pass-Retained and Pass-Separated groups revealed that on only two tests did the groups differ significantly, with the Pass-Separated group having the smaller mean in each case. These two tests were Air Traffic Problems: Parts I and II and the RPM Number Facility test. Both of these involve highly speeded tasks with the former negatively related to age and the latter positively related to age. A third

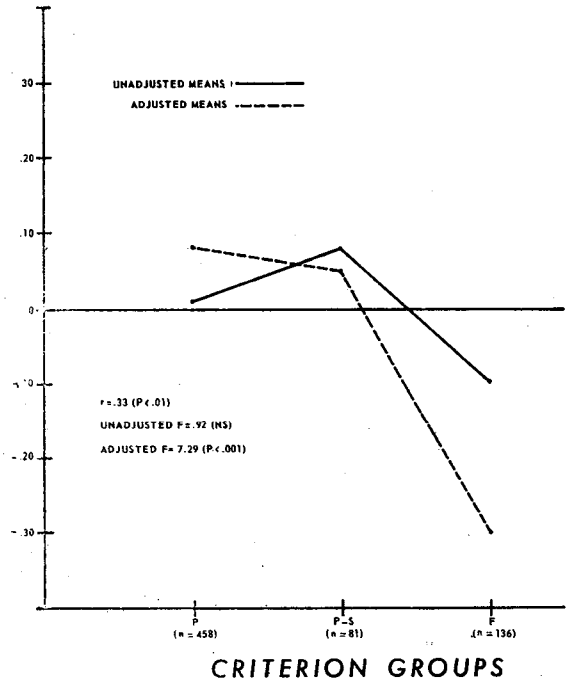

Fig. 2. Unadjusted and adjusted (for age) mean scores of the three ATCS criterion groups on the CTMM verbal concepts (vocabulary) test.

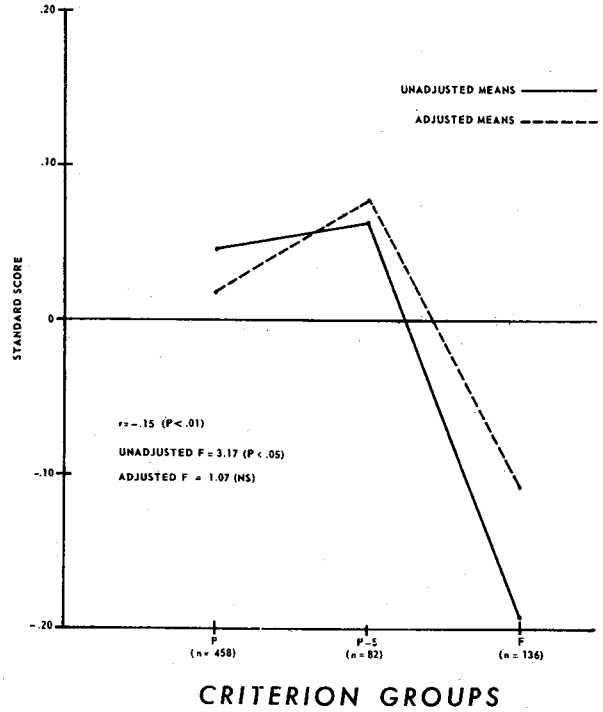

Fig. 3. Unadjusted and adjusted (for age) mean scores of the three ATCS criterion groups on the CTMM similarities test.

test, RPM Visualization measuring the Spatial Scanning Factor, also had a significant difference between the mean scores of the Pass-Retained and Pass-Separated groups but, as mentioned previously, the heterogeniety of the group regressions for that test clouded interpretation of the statistical test of significance.

The remainder of the variables revealed an intriguing pattern of mean differences between the two Pass groups. Mean scores for the majority of spatial tests and tests involving language were higher for the Pass-Separated group. In this context, the tests measuring the Visualization Factor form a logical cluster with the DAT Mechanical Reasoning test since, as pointed out by French, Ekstrom, and Price, "Visualization is important to *Mechanical Movement* and *Mechanical Comprehension* tests . . ."[5] On the other hand, the mean scores for the majority of numerical and induction tests were higher for the Pass-Retained group.

These opposed trends obviously accounted to some extent for the lack of significance between means of the Pass-Retained and Pass-Separated groups on the Commercial Composite score and the CSC Composite score. It should be noted, however, that in spite of all the counteracting trends influencing these two composites, the Pass-Retained group still had the highest adjusted mean score on each.

The other three composite scores, CTMM Language, CTMM Non-Language, and the sum of the two, had relationships with age and the criterion groups which were logical knowing the relationships between age and the individual components of each composite. The Language score was positively correlated with age (.26, $P < .01$), the Non-Language score was negatively correlated (−.14, $P < .01$), and the sum of the two was positively, but insignificantly, correlated with age. For all three composites the adjusted mean scores of the Fails were significantly lower than the Pass groups with the largest relative difference (by standard score conversions) occurring in the Non-Language area prior to correction of the means for the age effect.

Personality Variables:—Table VI contains the criterion group means of the 18 scales of the California Psychological Inventory (CPI) unadjusted and adjusted for their regression on age, the correlations between the scales and age and the F-test values. Eleven of the 18 scales had significant positive correlations with age, the largest of which was only .17. For the remaining 7 scales, all but 1 had insignificant negative correlations with age.

From this, it may be concluded that the older trainees reported themselves as being more intellectually efficient, dependable, interested in leadership and dominance, oriented toward achievement in situations where either conformance or independence are positive behaviors, self-controlled, tolerant and understanding of others, socially oriented, and not preoccupied with worries and self-doubt. In spite of these positive relationships, the statistical tests for the adjusted mean differences revealed that Fails were actually less intellectually efficient, less oriented to achievement in situations where either conformance or independence are positive behaviors, less tolerant of others, less interested in leadership and dominance, less dependable, and more preoccupied with worries and self-doubt than were the Pass-Retained and Pass-Separated individuals. In addition, it was found that among the Fails the adjusted mean of their self reports of social maturity, integrity and rectitude, and the agreement of their responses with the common pattern established for the CPI were significantly lower than means of the two Pass groups. In none of the comparisons of adjusted mean scores were the Pass groups found to differ significantly.

TABLE VI. CORRELATIONS (r) WITH AGE, ADJUSTED AND UNADJUSTED CRITERION GROUP MEANS (X), AND F-TEST VALUES FOR THE PERSONALITY SCALES

		Unadjusted Means							Adjusted Means			
		Pass-Ret.		Pass-Sep.		Fail			Pass-Ret.	Pass-Sep.	Fail	
CPI Scale		$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$	N	F	$\bar{X}$	$\bar{X}$	$\bar{X}$	F
1. Dominance	.13 **	28.7	622	29.1	95	28.0	185	1.4	28.8	29.1	27.6	3.3 *
2. Capacity for Status	.13 **	19.6	622	19.7	93	19.5	184	.1	19.7	19.6	19.2	1.1
3. Sociability	.08 *	25.5	622	25.7	95	25.7	185	.1	25.6	25.7	25.4	.1
4. Social Presence	—.01	35.9	622	35.3	95	35.1	185	2.1	35.9	35.3	35.2	1.7
5. Self-acceptance	—.03	21.3	622	21.1	94	21.1	185	.1	21.2	21.2	21.2	.0
6. Sense of Well-being	.10 **	38.9	622	38.5	94	38.2	185	2.2	39.0	38.4	38.0	4.1 *
7. Responsibility	.17 **	30.8	622	31.1	94	29.6	185	5.4 **	30.9	31.0	29.2	10.6 †
8. Socialization	—.01	37.1	621	37.1	94	35.6	185	5.8 **	37.1	37.1	35.6	5.2 **
9. Self-control	.10 **	30.7	622	31.1	94	31.1	185	.3	30.9	31.0	30.7	.1
10. Tolerance	.13 **	22.0	622	22.1	94	21.4	185	1.3	22.1	22.0	21.0	3.4 *
11. Good Impression	.05	19.7	622	20.1	95	20.4	185	.7	19.8	20.1	20.2	.3
12. Communality	—.02	26.2	622	26.0	93	25.6	184	6.0 **	26.1	26.0	25.6	4.8 **
13. Achievement via Conformance	.13 **	28.6	623	28.4	93	28.0	184	1.0	28.7	28.3	27.7	3.1 *
14. Achievement via Independence	.12 **	17.8	622	18.0	92	17.1	184	2.8	17.8	18.0	16.8	5.2 **
15. Intellectual Efficiency	.08 *	38.6	622	38.9	94	37.3	185	5.6 **	38.7	38.8	37.0	7.4 †
16. Psychological-mindedness	.13 **	11.5	622	11.6	95	11.3	185	.9	11.6	11.6	11.1	2.9
17. Flexibility	—.04	8.2	622	8.2	95	7.9	185	.3	8.2	8.2	8.0	.1
18. Femininity	—.05	16.2	622	16.1	95	16.4	185	.4	16.2	16.1	16.5	.7

* Significant at the .05 level.
** Significant at the .01 level.
† Significant at the .001 level.

DISCUSSION

As in other studies of samples from different populations, the comparison in the present investigation of older versus younger people indicated that older individuals had greater aptitude test decrements in measures of nonverbal reasoning and the solution of novel tasks, immediate memory for new material of an unusual nature, spatial relations, and certain highly speeded tasks.[3, 6] On the other hand, older individuals had greater aptitude test increments in measures of verbal comprehension, numerical operations, and mechanical knowledge. In addition, certain highly speeded tasks were unexpectedly found to be positively correlated with age.

The different relationships between age and highly speeded tests emphasize the need to take test content into account. For example, two highly speeded tests positively related to age involved, in the one case, simple numerical operations (a measure of the Number Facility Factor) and, in the other, identification of common four-letter words (Speed of Closure Factor). This latter test has been shown by several of our unpublished factor analyses to have a high loading on a factor similar to the Verbal Comprehension Factor suggesting that it may be more highly related to a verbal ability than to the Speed of Closure Factor which it was initially thought to measure. Within the framework of this study, then, the expected negative relationships between age and speeded tests were nullified by test content in some instances.

The positive correlations between age and numerical operations are in agreement with the findings of Glanzer, Glaser, and Richlin who, in their study of rated officers of the Air National Guard and commercial airline pilots, reported a positive correlation of .08 ($P < .10$) between a test of numerical operations and age.[6] A contradiction between their study and this one occurred in the area of mechanical reasoning or mechanical principles. They found a significant negative correlation of $-.12$ ($P < .01$), and we found a significant positive correlation of .26 ($P < .01$). Accounting for this discrepancy, be it caused by differences in the tests used to measure the factor or in the characteristics of the samples, certainly calls for additional research since logically one can defend the expectancy of either a positive or negative relationship.

Overall, Failures in ATCS training proved to be an inferior group in terms of the aptitudes assessed when compared with trainees who either passed the training and were retained with the FAA or who passed and were separated from the FAA. The results suggest that the higher training failure rate of older individuals may be partially accounted for by age-related deficiencies in non-verbal abstract reasoning, immediate memory for new and different material, and by the requirements to perform their job tasks rapidly and accurately. Since the Air Traffic Control Specialist must have a good memory, constantly assimilate new information, think in abstract terms and work rapidly, it is not surprising that older individuals coming into the occupation have difficulty adjusting to its demands. This is counterbalanced to some extent by the superior ability of older individuals to handle arithmetic computations more correctly and their superior verbal comprehension as compared to younger trainees, but this is not sufficient to offset their deficiencies.

With respect to job performance as reflected by retention or separation from the FAA within the first year after completing ATCS training, those who separate appear to be deficient primarily in their ability to perform arithmetic operations rapidly and correctly and, to a lesser degree, in non-verbal abstract reasoning. This was indicated by the fact that the two tests, on which performances of the Pass-Retained group were significantly higher than the Pass-Separated group, were a highly speeded test of numerical operations and a highly speeded test designed especially for assessment of aptitude for air traffic control work. Unpublished factor analyses of this latter test revealed that it is highly related to non-verbal abstract reasoning and number facility.

As pointed out previously, the patterning of the mean differences between the Pass-Retained and Pass-Separated groups, even though statistically insignificant, is of some interest. In most cases, the Pass-Retained group had higher mean scores on tests of nonverbal abstract reasoning or number facility, and on highly speeded tasks; whereas the Pass-Separated group had higher mean scores on tests involving spatial orientation, spatial visualization or verbal aptitude.

All in all, the findings in this study give continued support to the appropriateness of the Civil Service Commission Test Battery currently being used to select all new ATCS trainees, insofar as prediction of training failure is concerned. With respect to the discrimination of those who pass and are retained from those who pass and are separated early, the evidence is not as clear. Although the CSC Composite score does discriminate as expected between the Pass-Retained and Pass-Separated individuals, on 3 of the 6 tests (CSC Abstract Reasoning, CSC Spatial Patterns, and CSC Oral Directions) forming the composite score, the Pass-Separated group had a higher mean score than the Pass-Retained group. The differences were not statistically significant but do contribute to the reduction in the difference between means of the Pass-Retained and Pass-Separated groups on the CSC Composite score.

It is tempting to conclude that only the three CSC tests on which the Pass-Retained individuals have higher mean scores than the Pass-Separated (CSC Computations, CSC Letter Sequence and Air Traffic Problems, Parts I and II) should be used in the selection process. This is particularly true in light of the finding that the only tests significantly discriminating these two groups were the air traffic problems test and one of the numerical ability tests. However, this conclusion is not warranted until further research has demonstrated whether the current findings are merely a matter of random variation in the samples of trainees used, what loss in efficiency of prediction of training failures might occur as a result of deletion of the three CSC tests, and what differences in test performance characterize the three different types of ATCS trainees.

With regard to the latter point, it has recently been discovered that measurement of verbal abstract reasoning ability (the CTMM Inference test of the Syllogistic Reasoning Factor in Table I) makes a distinct contribution to prediction of training success of Terminal ATCS trainees.[2] Such was not the case in predicting training success of Enroute ATCS trainees.[1] Since the present study pooled both types of trainees, it is possible that some of the findings may reflect compensatory differences among trainee types.

Until the preceding questions regarding the test battery being used to select ATCS trainees have been answered, no harm can result from its continued operational use, since the value of the component tests for prediction of training failure has been repeatedly demonstrated.

In the personality area, the responses of the older individuals tended to be more positive than responses of the younger; i.e., more intellectually efficient, tolerant, responsible, worrying less, etc. After correcting the mean personality scores for the age differentials, Fails were found to respond less positively in almost every personality dimension than either of the two Pass groups. No significant differences were found between these latter two groups.

It must be emphasized, however, that in the personality realm none of the ATCS groups deviated appreciably from the mean scores of the groups used to establish the inventory's norms. We can conclude from this that, on the average, Air Traffic Control Specialist trainees are essentially normal individuals, insofar as normality is defined and measured by the personality inventory used in the investigation, but that relative to trainees passing the ATCS course, Fails give a more unfavorable assessment of themselves.

From the present study, a fairly clear picture of the successful Air Traffic Control Specialist has emerged. He is one who is relatively young when he enters the occupation, thinks rapidly, reasons correctly, is adept with simple arithmetic, and shows no great deviations from a normal pattern of adjustment.

SUMMARY

By examining the relationships between age at entry into ATCS training and scores on aptitude and personality tests of over 900 Enroute and Terminal ATCS trainees, it was found that: (1) Older trainees had lower test scores than the younger trainees on tests of immediate memory and non-verbal abstract reasoning. (2) Older trainees had higher test scores than the younger trainees on tests of arithmetic and verbal ability. (3) In highly speeded aptitude tests, the type of test (e.g., arithmetic, spatial, vocabulary, etc.) seems to determine whether the older or younger trainees have the higher scores. (4) In the personality area, older trainees were found to be more intellectually efficient, responsible, tolerant, etc., than their younger classmates.

When test scores were examined for groups of trainees classified as failures in training, passing training but leaving the FAA within a year, and passing training and still have the FAA, it was found that: (1) Usually the failure group had the lowest average test scores, the pass but separated group the next lowest, and the pass and retained group the highest average test scores. (2) The pass-separated group was significantly poorer than the pass-retained group in the ability to rapidly and accurately handle arithmetic, and, to a lesser degree, in non-verbal abstract reasoning. (3) With respect to personality, training failures were less intellectually efficient, tolerant, responsible, etc., than the other two groups of trainees. No differences in personality were found between the pass-separated and pass-retained groups.

From the research it was concluded that: (1) The higher training failure rate of the older individuals can be partially accounted for by inferior aptitudes for non-verbal abstract reasoning, memory for new material, and by the inability to work as rapidly and accurately as required in training and on the job. (2) The group of tests presently being used to select ATCS trainees contains measures of those aptitudes shown to be related to retention or separation from the FAA, but further study of the tests is needed. (3) As a group ATCS trainees seem to present an essentially normal picture of their personalities.

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