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16. Abstract

This study examined the interrelationships of age, aptitude measures, and training performance scores for 710 men who entered basic ATC training at the FAA Academy during November 1968 through March 1970. They ranged in age from 21 to 52 years, but less than 12 per cent were over 40. Most of the subjects were former military controllers who possessed sufficient prior ATC experience to be (a) selected for training with an exemption from a qualifying aptitude index, and (b) appointed to trainee status with higher-than-normal pay grades. Age correlated negatively with 21 of the 22 aptitude measures and with training course grades. On most tests, performance means for subjects over age 34 were significantly lower than those obtained for the younger trainees, and their attrition rate for the training course was three times that of their younger classmates. Only one of the 22 aptitude measures failed to correlate positively with the training grades. The results indicated that greater effectiveness in screening such applicants could be attained if eligibility standards were modified to include consideration of both age and aptitudes.

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THE RELATIONSHIP BETWEEN CHRONOLOGICAL AGE AND APTITUDE TEST MEASURES OF ADVANCED-LEVEL AIR TRAFFIC CONTROL TRAINEES

I. Introduction.

The present study concerns the interrelationships of chronological age, numerous aptitude test measures and training-school grades of several different and overlapping samples of ATC trainees. Under selection standards which were instituted in 1968 and because of their highly specialized pre-employment experience, these men were not required to qualify on the CSC ATC Aptitude Screening Test and were appointed to training with higher-than-usual pay grades. Since the major focus of this study concerns age and aptitude measurement, a brief review of material pertinent to both factors is presented below.

A. *Research on Aging Effects.* During the past 20 years scientific estimates of successively longer life expectancies for increasingly larger populations have stimulated psychological research on problems associated with aging. Much of that research, and particularly that accomplished within the last ten years, has been oriented toward establishing the reasons why groups of older individuals perform less well than young adults in a variety of tasks ranging from simple to complex. Considerable evidence supports a theory which holds that deficits in many areas of performance are primarily attributable to neurophysiological effects of aging and the consequent reduction in reaction-time capabilities. Findings also indicate that many age-related performance decrements are a direct outgrowth of such personal factors as environmental background, experience, personality and motivation.

Notwithstanding the issues presented ,the literature clearly reveals that old age is generally distinguished by: trends toward slowness in reaction time; impaired psychomotor abilities; restrictions in behavioral modification to environmental conditions; deficiencies in the reception, integration and use of new or novel information; declines in perceptual and coding abilities; and limitations in learning speed and capacity. However, numerous studies cited by Birren[1] and Talland[14] illustrate that many such age-related deficiencies are not uncommon among subjects only 35–40 years old. This seems particularly true in regard to specific types of speeded tasks involving perceptual discrimination, mental addition or subtraction, handwriting speed, short-term memory, abstract reasoning, word-synonym responses, and information processing. Talland emphasizes that "human capacity to transmit information, as tested by span of immediate recall, diminishes with advancing age between the ages of 20 and 70 years, more under some conditions than under others."[14] He further states that this reduction in capacity, which is crucially related to deficits in learning and memory, seems to occur at a discontinuous rate, "particularly at about 40 and again at about 60 years of age."

The results obtained in a number of other studies suggest that Talland's theory might be extended to include a variety of other abilities. For example, progressively lower performance means for groups over 35 years old have been found in handwriting speed[2] and with a variety of verbal as well as non-verbal intelligence tests.[3,10] Friend and Zubek[11] obtained similar results with *untimed* tests of critical thinking, illustrating that ability to weigh evidence and interpret data generally tends to decline after age 35—irrespective of a time or speed factor. The studies of Brown[5] and Szafran[13] suggest that certain psychomotor abilities are also apt to decline at a relatively early age. Brown discovered

The assistance of Mary Anne Nelson, Alice Weikel, Nancy Jetton, John J. Mathews, Robert Tyson, and Jack Dignum in the collection, processing, and/or analysis of the data is gratefully acknowledged.

that groups of subjects at every age level beyond 40 experienced greater difficulty than the younger groups at grid-matching or congruency-plotting tasks under both *paced* and *unpaced* conditions. The Szafran study, which measured the accuracy with which objects were pitched toward a target under both "direct-vision" and "mirrored" conditions, yielded no appreciable differences between age groups when the task was performed in a straightforward manner. Under conditions involving a mirror, however, the inaccuracy of all groups was much greater than before and rose continuously with age; the largest difference occurred between the age groups "20 to 29" and "30 to 39."

In view of all the experimental evidence, it is now acknowledged that adults of middle age and older tend to perform less well than young adults at many different tasks. However, the reasons for such age-related deficiits have not been fully determined. One of the most commonly accepted doctrines holds that increasing age is accompanied by a trend toward less "flexibility," more cautiousness and greater perseveration in certain tasks but, as Birren points out, the terms "flexibility," "increased cautiousness" and the like "do not directly lead to inferences about the mechanisms involved."[1] Although Birren himself is not immune to this criticism, the following extract from his book, "The Psychology of Aging," constitutes an excellent summary regarding some of the factors presumably bearing upon changes in performance with increasing age.

> The delay of decision sometimes seen in older people, the time taken to review a stimulus, and the apparent conservatism in behavior may not be caused by an increase in the level of certainty required. Rather the difficulty may lie in not being able to attain the same level of certitude as previously, or as compared with a younger person. Limitations in perception and intelligence, age differences in set or expectations, as well as changes in drive, motivation, and caution all interact in providing the psychological basis for the apparent increased behavioral rigidity with advancing age.[1]

B. *FAA Interest in Research on Aging Effects.* The interest of the Federal Aviation Administration in research on aging is not merely incidental. Many of the abilities and skills which have been shown to decline with age may be deemed crucial to satisfactory performance in a number of occupational specialties within the FAA and particularly in the job of an Air Traffic Control Specialist (ATCS). Although ATCS personnel currently number more than 20,000, the rapid growth of aviation in recent years has imposed increasingly heavier traffic loads on both men and equipment of the operation system. Progressive improvements in surveillance gear, communications, and ancillary equipment, supplemented by changes in control procedures and flight regulations and implementation of improved methods of selecting and training control personnel have resulted in a highly efficient air traffic management system.

Yet, the job of a typical ATCS continues to be of a very demanding and critical nature. Maintenance of safety in the expeditious flow of air traffic requires that a controller be resilient to possible effects of variable work-shift patterns, maintain a high degree of compatibility with team or crew members, remain vigilant during all hours of duty with no susceptibility to laxity during periods of light traffic, retain his emotional stability when faced with emergency situations, and always be capable of rendering precise error-free decisions. In order to maintain proficiency, a controller must commit to memory without delay all updated changes in procedures and, when more advanced types of equipment are introduced into the system, is frequently required to undertake additional intensive training. Situations demanding serious study and learning pervade the entire career of each controller. Qualification for appointment to initial, or basic, ATC training is relatively difficult and of those selected only about six of every ten can be expected, on the basis of previous studies,[16 19] to complete successfully all prescribed training phases and attain journeyman status some four to five years after entry into the FAA.

Training records for groups of ATC personnel recruited since 1960 and a number of unpublished studies have consistently revealed a definite relationship between chronological age and attrition probability. In an unpublished six-year follow-up study conducted by CAMI on 688 subjects (who comprised the successive classes of the Academy's basic training courses during August 1961 through March 1963), it was found (a) that 72 per cent of 118 men of age 36 and over failed

their initial training course compared to a failure rate of only 33 per cent for the 570 younger students, and (b) that the older men who did pass the Academy also tended to experience greater difficulty than their younger colleagues in subsequent phases of on-the-job training. The consensus that older controllers generally perform their duties less effectively than younger ATCSs is supported by the results of several studies,[6 17 19] all of which indicate that performance, as evaluated by supervisors or peers, is apt to decline after age 40—regardless of tenure or experience in ATC work. The FAA has submitted for congressional consideration proposals whereby age would be used as a discriminating factor in the selection of recruits for ATC training. Under one such proposal, eligibility for appointment to ATCS training would require that an applicant with highly specialized pre-FAA ATC-related experience be no older than 35 and, if lacking such qualifying experience, to be 30 or younger. Although not intentionally designed to do so, the test battery currently used in the aptitude screening of most applicants has also been found (as will be described later) to have considerable potential in screening from eligibility many of the older applicants, particularly those of age 40 and over. These and other findings have prompted the FAA to maintain continuing interest and participation in research on aging effects.

C. *ATC Trainee Selection Standards.* Since 1960 much of the research conducted by the Psychology Laboratory of the Civil Aeromedical Institute (CAMI) has focused upon the identification of factors associated with measures of training performance and job proficiency ratings of ATC personnel.

One of the early CAMI objectives was achieved in 1963 when a series of analyses and follow-up studies illustrated that a composite score based on six of 27 experimentally administered aptitude tests could have been used to accurately forecast the pass-fail status of approximately 70 per cent of 893 students who enrolled in the Academy's basic ATC training courses during August 1961 through March 1963. These findings prompted a revision in ATC selection procedures. Beginning in January 1964 and continuing through October 1968, a qualifying aptitude index, based on the six tests, constituted a major eligibility requirement of every applicant regardless of pre-FAA experience and other qualifications.

About six months prior to implementation of aptitude screening procedures, however, budgetary limitations necessitated a drastic reduction in the recruitment of ATC personnel and also discontinuance of the standardidzed basic training courses at the Academy. The initial training of each new recruit became the responsibility of officials at the recruit's facility of assignment. Such decentralization of training also resulted in termination of CAMI's experimental testing and validation program. These conditions prevailed for almost half a decade. The few hundred men appointed to training each year were usually selected from among those applicants having both the higher aptitude test scores and greater amounts of ATC-related experience. However, they were not sufficient in number to offset personnel losses and ensure proper growth of the system.

In 1968, the President announced the need for rapid expansion of the air traffic management system and a new program of accelerated recruitment and traiining of control personnel was begun. Under the new selection standards, which became operational in November of 1968, an applicant having an exceptional amount or type of pre-FAA ATC-related experience could be granted an exemption of the aptitude qualification requirement. It was assumed that such highly experienced individuals, after completion of basic training in FAA procedures, would be able to master subsequent phases of training more rapidly and advance to journeyman status more quickly than the less experienced men. With minor exceptions, the selection standards for all other applicants remained essentially the same as those employed during the preceding four years and ten months. Training policies, however, were revised. Basic training courses, similar to those conducted prior to 1964, were again instituted at the Academy and the subsequent availability of training-school grades for use as criteria led to a resumption of CAMI's research and development efforts to improve further ATC selection methods.

The FAA's ATC selection-and-screening programs of various time periods have differed in some respect; yet, they have been remarkably similar. The selection process has always included consideration of an applicant's pre-em-

ployment experience, his educational background, the outcomes of an interview with management officials, and the results of a medical examination. Previous relevant experience, particularly as a military controller, has consistently been viewed as an important asset.

Although the FAA continues to select the majority of its ATC trainees from an applicant pool of former military air traffic controllers, most such applicants usually lack sufficient experience to warrant exemption of the aptitude requirement. Consequently, about two-thirds of all the selectees are moderately experienced men who have attained qualifying scores on the battery of aptitude-screening tests. They are normally hired at a pay grade, or General Service level, of GS–7. Approximately seven per cent, who possess little or no related experience, are selected primarily on the basis of aptitude tests scores and/or educational background and are generally assigned an entry grade of GS–5 or GS–6. Since November 1968, less than one-fourth of the entrants into FAA ATC training have qualified under the standards whereby highly specialized experience has not only permitted exemption of the aptitude requirement but also appointment to training at the GS–8 level or higher. In most instances, they have been appointed as GS–9 trainees.

The six tests currently employed in the aptitude screening of most applicants for ATC training are those which CAMI identified in research of several years ago as the most valid group for prediction of training performance. All six are U. S. Civil Service Commission (CSC) instruments. Operationally, the battery is commonly referred to as "The CSC ATC Aptitude Screening Test" and the six parts, which will be described in later sections of this report, are referred to as "subtests."

D. *The Present Study.* This report pertains to only a small portion of a multi-phase research project which CAMI initiated in November 1968 at the request of the Washington Office of Personnel. In conjunction with the requested research, various aptitude tests were administered, on an experimental basis, to all but three of the successive incoming classes of the Academy's basic ATC training courses during the ensuing 17 months. In order to facilitate the research, the Director of Personnel (PN–1) wrote to all Regions specifying that CAMI be provided a report on each trainee, at time of entry into the Academy, reflecting types and amounts of pre-employment experience, facility of assignment, the overall eligibility rating, pay grade, and other information. It was further directed that the report on each trainee who took the operational CSC ATC Aptitude Test also include all part scores and the composite measure of performance.

In accordance with existing policy, the vast majority of the trainees arrived at the Aeronautical Center for enrollment in either the En-route or Terminal training course within two weeks after being hired by the FAA. Combined enrollments for the Academy's two basic ATC training courses totaled 3,751 for the 17 months encompassed by the study. Records revealed that 3,041 (or about 81.1 per cent) of the trainees entered with pay grades of GS–7 and lower and only 710 at the GS–8 level or higher. Complete information reflecting the specific standards by which each trainee was respectively selected for appointment to training was not available. Based on eligibility standards, however, it was known that *all* of the higher rated trainees possessed pre-FAA ATC-related experience in excess of the minimum, thereby warranting exemption of the aptitude screening requirement. In contrast, it was presumed that only a small, though perhaps significant, proportion of the GS–7's possessed enough experience to permit such a waiver. Almost all other trainees, the majority of whom were also GS–7's, entered under standards which required a qualifying score of at least 210 on the CSC ATC Aptitude Test. For each of these individuals, the test score and evaluations of education and all related experience were weighted in a prescribed manner to derive an eligibility rating for appointment to ATCS training at the GS–5, GS–6, or GS–7 level. In view of the aptitude-screening procedures and the concomitant attenuation effects, these 3,041 lower-rated trainees were deemed rather inappropriate for an investigation of relationships between chronological age and mental abilities. Thus, this study focused upon the 710 men who entered the Academy at the GS–8 level or higher because it was assumed that research based on samples drawn from this group would yield more meaningful results than if accomplished on samples comprised primarily of aptitude-screened trainees.

II. Method.

A. *Testing Sessions.* Thirty-one testing sessions, involving 16 of 17 incoming Enroute classes and 15 of 17 Terminal groups, were conducted during the period 20 November 1968 through 27 March 1970. Because of holiday travel conflicts, three classes of trainees were excluded from the experimental testing program. A total of 2,533 Enroute trainees and 664 Terminal students were examined. However, only 444 (or 17.5 per cent) of the Enroute examinees and 244 (36.7 per cent) of the Terminal participants possessed higher-than-normal pay grades. Among the 444 Enroutes, there were 29 GS–8's, 412 GS–9's, one GS–10 and two GS–11's. The Terminal examinees represented 15 GS–8's, 212 GS–9's, two GS–10's, 14 GS–11's and one GS–12. Aside from these 688 trainees (i.e., 444 plus 244), an additional 22 men of higher-than-normal pay grades entered either the Enroute or Terminal course during this period but were not examined because of illness or tardiness in arriving and enrolling with their scheduled class.

No more than three hours could be allocated for each testing session and adherence to training schedules precluded more than one session per class or group. Inasmuch as the overall project (of which this study is but a part) specified that the predictive potential of many different types of aptitude tests be explored, the groups of tests selected for experimental administration were intentionally varied. At least one week, and sometimes two, intervened between the incoming and alternating Enroute and Terminal classes. Each incoming class was usually administered only five to seven instruments but periodic modification of the battery ultimately resulted in the collection of response data on samples of different size for 14 different tests.

B. *The Present Sample.* Exclusive of overlap, the present sample involves a total of 710 men and represents all students who entered the Academy's basic courses with higher-than-normal pay grades during the period 20 November 1968 through 27 March 1970. Of these, 446 (about 63 per cent) were enrollees of the Academy's 8-week Enroute "T–202" basic training course. The instruction and laboratory problems provided in this course were oriented toward the work required of a controller at an Air Route Traffic Control Center (ARTCC). The remaining 264 were airport tower personnel who took the Terminal, or T–203, 8-week course. The latter was similar to that designed for Center personnel but focused upon basic training in Terminal Area Traffic Control ("TATC") procedures.

C. *Procedure.* CAMI researchers administered no more than seven aptitude tests to any of the incoming classes which included higher-graded ATC trainees. However, examination of the records subsequently received by CAMI revealed that 301 of the 710 trainees of grades GS–8 and above had been administered the operational screening battery although their ATC-related experience was ultimately deemed sufficient to warrant exemption of the aptitude requirement.

Two investigative approaches were therefore adopted. In the first, a series of analyses were undertaken to determine the interrelationships of age, training grades, and the field-reported CSC Test scores for the group of 301 subjects. The second phase of the study pertained only to those samples experimentally tested by CAMI personnel.

The ages of the 301 operatioally examined men, although ranging from 21 to 49 years, yielded a distribution which was markedly skewed—in a positive direction. It was recognized that some of the scheduled correlational analyses would produce more reliable and meaningful results if accomplished on a more "normalized," though appreciably smaller, sample. The age range for the group was therefore divided to establish 13 intervals and attempts were then made to select randomly the cases for each interval in accordance with the proportions dictated by a normal curve of distribution. Since relatively few of the 301 controllers were over age 40, randomness in the selection process was not always possible and considerable difficulty was encountered in attempts to obtain the precise and proportionate numbers of cases desired for the various age brackets. Nevertheless, a sample of 88 cases was established which, though smaller than originally anticipated, appeared sufficiently free of skewnes to permit the valid assessment of the interrelationships of chronological age, part scores and composite scoress on the CSC ATC Test, and training-course performance measures.

After establishing the intercorrelations of all variables for the special sample of 88 cases, a series of multivariate correlational analyses,

based on techniques developed by DuBois,[8] were accomplished to determine the empirical validities (i.e., multiple correlations or "R's") of the various combinations of variables as predictors of three different measures of training course performance. Similar procedures were applied to determine the correlation between age and each of several different composite measures based on various groupings or combinations of test scores and/or training grades. The validities of all test variables with the effects of age partialed out were also computed. Finally, the relationship between age and each of the aptitude measures was assessed by a more conventional technique. In the latter, coarse grouping procedures were applied to establish four age categories: "29 & younger," "30–34," "35–39," and "40 & older." The mean performance score and a measure of variance (s^2) were computed by age group for each variable, tests for homogeniety of variance were accomplished to determine the choice of formulae for computation of the Standard Error of the Difference between the means, and all group mean differences for each variable were then tested for statistical significance.[9]

The second phase of the study, which pertained to performance data collected in CAMI's experimental testing sessions, involved no multivariate correlational analyses. Each of the 14 experimental test variables was dealt with separately. First, the product-moment correlations were obtained between every test variable and chronological age; next, the correlations were computed between the test variables and an overall measure of training course performance; and finally, procedures were employed, as in the first phase of the study, to obtain the mean performance scores of subjects by age group and differences between the group means were then tested for statistical significance.

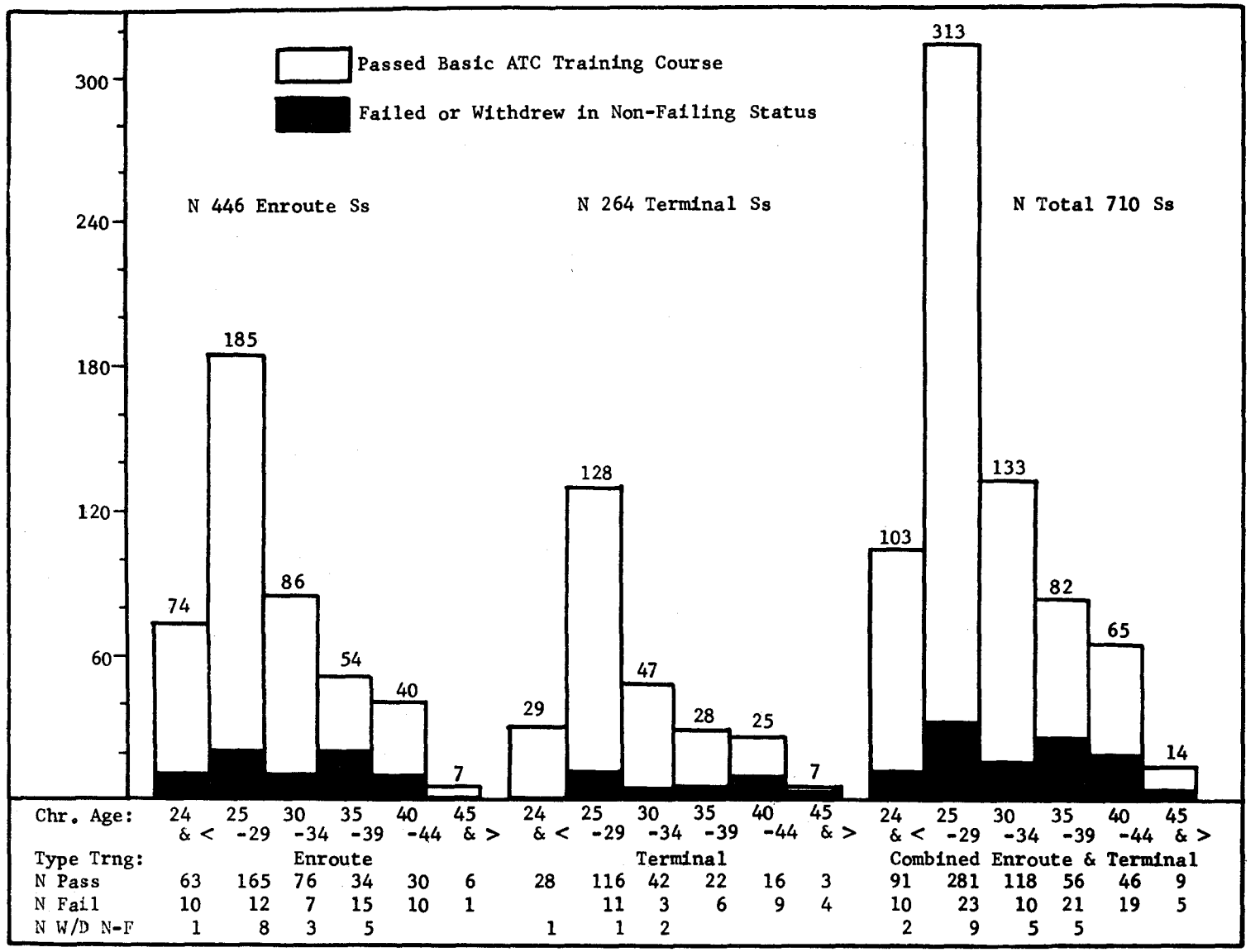
III. Results and Discussion.

PHASE I

A. *The Entire Sample.* The ages of the 710 highly-experienced men who entered ATCS training at the GS–8 level or above ranged from 21 through 52 years. The vast majority, however, were relatively young (see Figure 1). Only seven of the 446 Enroute trainees and seven of the 264 Terminal trainees were over 44 years of age. Of the total group of 710, 103 were 24 years of age or younger, 313 were 25–29 years old and 133 were over 29 but younger than 35. Students in the remaining, older age brackets totaled only 161 and represented 22.7 per cent of the entire sample. However, 50 of these older students either failed or withdrew from Academy basic training. Although not shown in Figure 1, this amonuted to an attrition rate of about 31 per cent whereas the 59 non-graduates among the younger, larger group represented an attrition rate of only 10.8 per cent.

The relationship between chronological age and training course performance is further illustrated in Figure 2. In preparing this figure, all data pertaining to 21 students who withdrew in non-failing status were omitted. Although logic warranted that they be deleted from the analysis, most of them were relatively young and consequently their exclusion from this phase of the study served to magnify somewhat further the findings reflecting an inverse relationship between age and performance. For example, less than nine per cent of the Enroute students in the two categories below age 35 failed, and only about seven per sent of the Terminal students of similar age brackets were unable to attain their basic training certificates. Contrastingly higher failure rates, ranging from approximately 21 to 40 per cent, were found for the trainees of the older age brackets.

A variety of measures, other than pass-fail status, were also available for use as criteria. In the present study, however, only two summary measures and/or a derivative of the two were used. The training records of all graduates traditionally include an "Academic Grade Average," which is the mean of all test grades relating to materials and classroom instruction, and a "Laboratory Grade Average," which is a global measure of performance on all laboratory problems. For research purposes, an arithmetical mean of the two averages was also computed for each subject. A portion of the data presented in Figure 2 pertains to an analysis in which this summary variable, referred to as the "A+L Grade," served as the criterion. More specifically, the median A+L Grade of the non-failing students was determined for the separate Enroute and Terminal groups and the resulting value was used to designate "Upper" and "Lower" categories of training performance.



Chr. Age:	24 & <	25 -29	30 -34	35 -39	40 -44	45 & >	24 & <	25 -29	30 -34	35 -39	40 -44	45 & >	24 & <	25 -29	30 -34	35 -39	40 -44	45 & >
Type Trng:	Enroute						Terminal						Combined Enroute & Terminal					
N Pass	63	165	76	34	30	6	28	116	42	22	16	3	91	281	118	56	46	9
N Fail	10	12	7	15	10	1		11	3	6	9	4	10	23	10	21	19	5
N W/D N-F	1	8	3	5			1	1	2				2	9	5	5		

FIGURE 1. Frequency Distribution of Chronological Age for Enroute and Terminal ATC Trainees Who Entered the FAA Academy During the Period 11/20/68 Through 03/13/70 With Ratings Higher Than GS-7 Level.

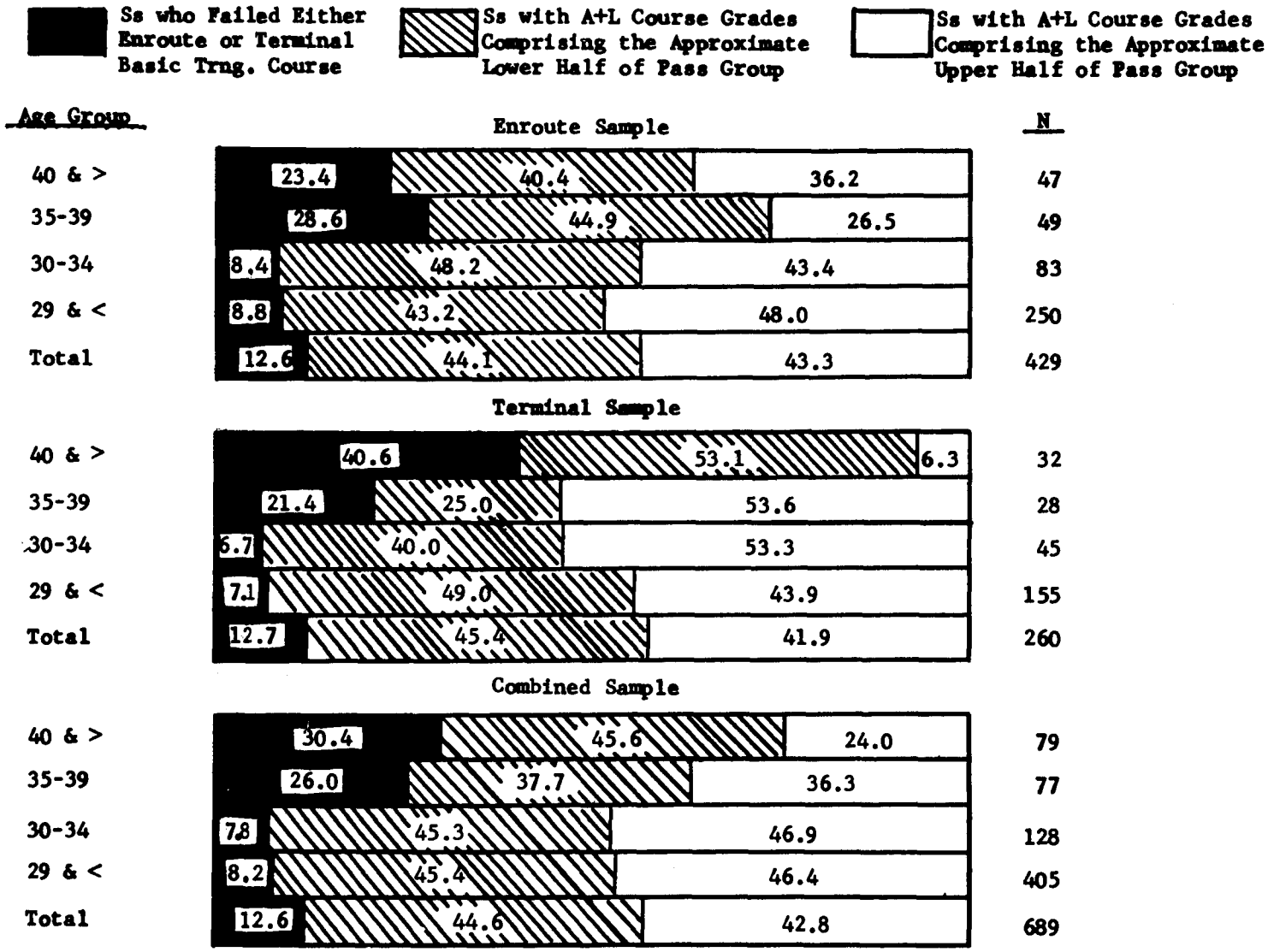


FIGURE 2. Percentage of ATC Trainees* by Age Group Who Failed Academy Basic Training, Passed With Overall A+L (Academic and Laboratory) Grade Averages Comprising the Approximate Lower Half of the A+L Grade Distribution of All Pass Cases, or Passed With Grades Comprising the Upper Fifty Percent.

* Of 710 Ss who entered Academy training with ratings above the GS-7 level during November 1968 through March 1970, twenty-one who withdrew in non-failing status were deleted from the above analysis.

As shown by the top set of bar graphs in Figure 2, somewhat greater proportions of the Enroute students of the age brackets "29 and younger' 'and "30 to 34" were in the upper half of their class than were their older classmates. Of the Terminal trainees, only 6.3 per cent of those over age 39 attained A+L Grades above the median. However, the results obtained for the remaining portions of the Terminal sample were variable from age group to age group and failed to reflect any consistency or trend such as found for the Enroute sample. When the frequencies based on the respective median A+L Grades of the two samples were combined, it was discovered that only 24 per cent of the trainees aged 40 and older and 36.3 per cent of those 35 to 39 years old were in the upper category compared to approximately 46 per cent of those in each of the two younger age brackets.

B. *The Pre-Tested Sample.* The group of 301 trainees for whom operational CSC ATC Test scores were forwarded was highly similar in terms of age characteristics to the total group of 710. Figure 3 follows the same format as Figure 1 and presents the distributions of age, together with training course attrition-graduation status, for the 219 Enroute and 82 Terminal trainees known to have been operationally examined. Unfortunately, insofar as research purposes were concerned, the smaller group included only 28 of the 109 attritions previously found in the total group of 710. Inasmuch as the 109 represented 15.4 per cent of the larger group, a comparable attrition rate for the 301 would have resulted in 46 non-graduates. Moreover, only two of the original 37 Terminal Course failures appeared in the smaller sample. The investigators were unable to determine the reasons why such disparities occurred but strongly suspected that factors other than chance were involved. Although the sample of 301 was not as representative of the 710 as had been anticipated, it was decided to proceed with the study as planned.

The relationship between chronological age and the field-reported CSC Test performance scores of the 301 subjects is reflected in Figure 4. The results depicted in the lower set of bar graphs for the combined Enroute and Terminal groups are rather startling. They indicate that less than 40 per cent of the men in the age brackets "40 and older" and "35 to 39" attained composite scores of 210 or higher on the operational battery. Had these subjects not possessed highly qualifying experience, the aptitude screening standards, under which 210 is considered as the minimum passing score, would have precluded their eligibility for appointment for appointment to training. In contrast, over half of the trainees aged "30 to 34" and "29 and younger" would have qualified. It has been mentioned that during the years 1964 through 1968 a "cutting score" of 190 was used in the screening of all applicants, regardless of types and levels of experience. The results shown in Figure 4 further illustrate that over one-third of the trainees over 34 years of age would not have met this former, and considerably lower, aptitude requirement.

C. *The "Normalized" Sample.* The age distribution for the special sample of 88 cases, which was drawn from the group of 301 for whom CSC Test performance measures were forwarded, was not entirely free of skewness (see Figure 5). As explained earlier, however, considerable difficulty was experienced in selecting many of the cases and the sample represents the largest that could be obtained without further deviation from the proportions dictated by a normal curve of distribution. The youngest man in the sample was 22, the oldest was 49, and the mean age was 33.1 years. Although the modal age bracket, which was "31–32," included 16 cases, the entire distribution was somewhat platykurtic (i.e., relatively flat-topped).

Sixty-seven of the 88 were Enroute and 21 were Terminal trainees. The sample included a total of 13 non-graduates and, as found with the larger groups from which the sample was drawn, most of the attritions were over 34 years old. The youngest of the non-graduates was a 27 year-old student who was killed in an automobile accident and was subsequently designated as "a withdrawal in non-failing status." The remaining 12 non-graduates, all of whom were classified as training-course failures, were over age 32. Incidentally, it was noted that six of the 12 failures possessed 10 years or more experience in pre-FAA ATC work. Although no detailed analysis of the experience backgrounds was attempted, a cursory review of the records suggested that less than five per cent of the 710 men involved in the entire study had had such lengthy experience.

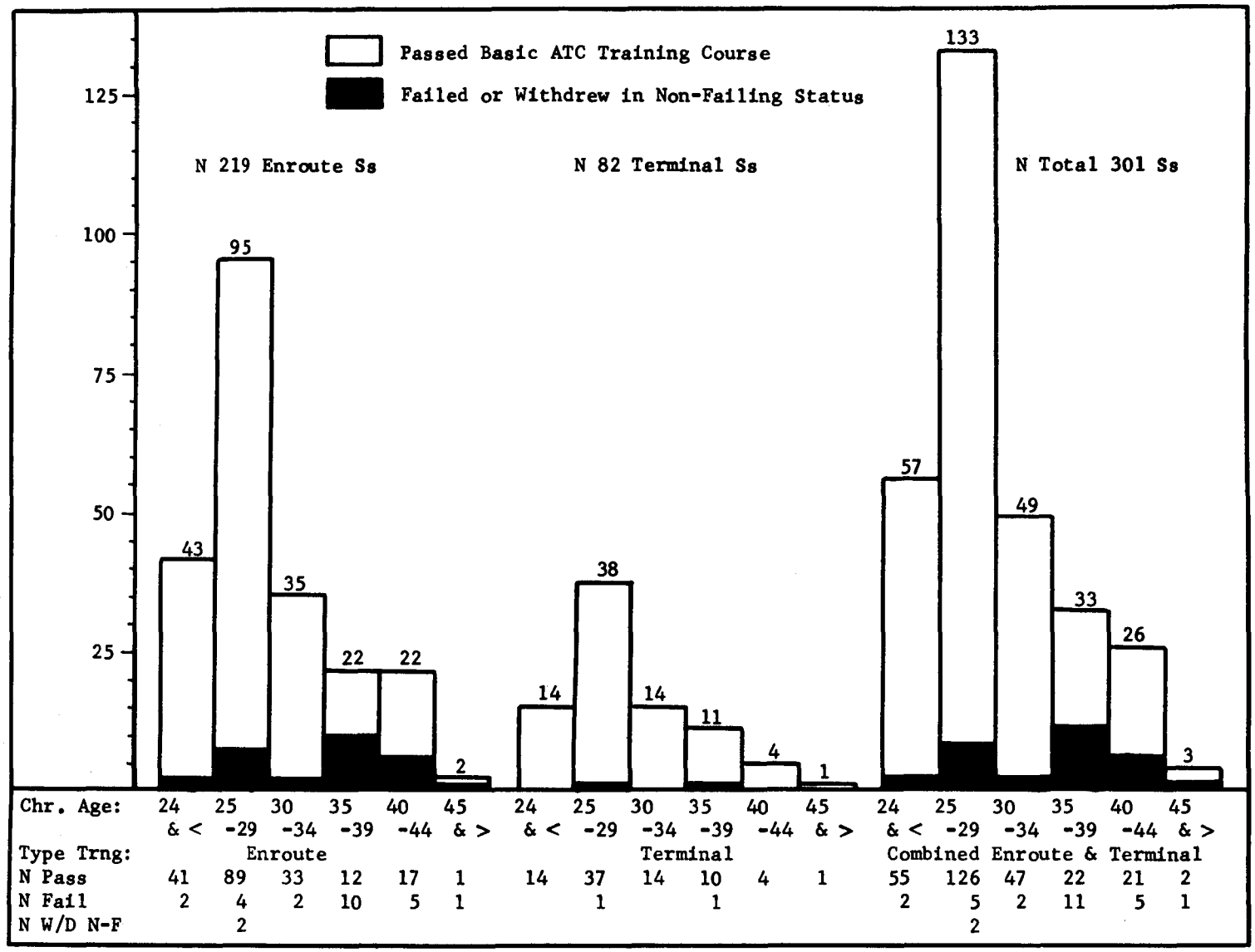


FIGURE 3. Age Distribution of Academy ATC Trainees For Whom Official CSC-ATC-Aptitude-Test-Battery Screening Scores Were Available But Who Were Hired at the GS-8, 9, 10 and 11 Levels on the Basis of Exceptional Types and/or Amounts of Pre-FAA ATC-related Experience Regardless of Aptitude Scores.

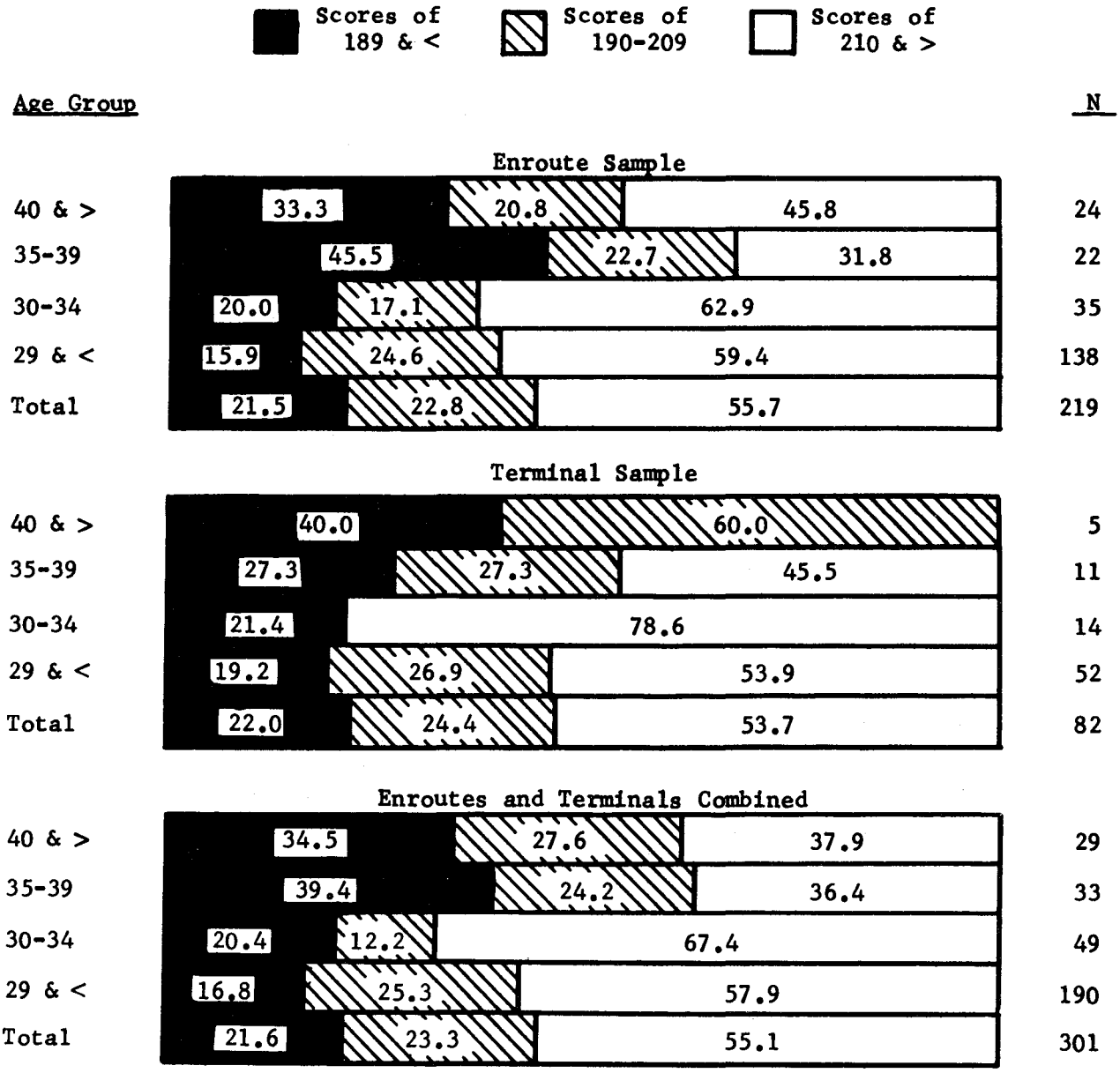
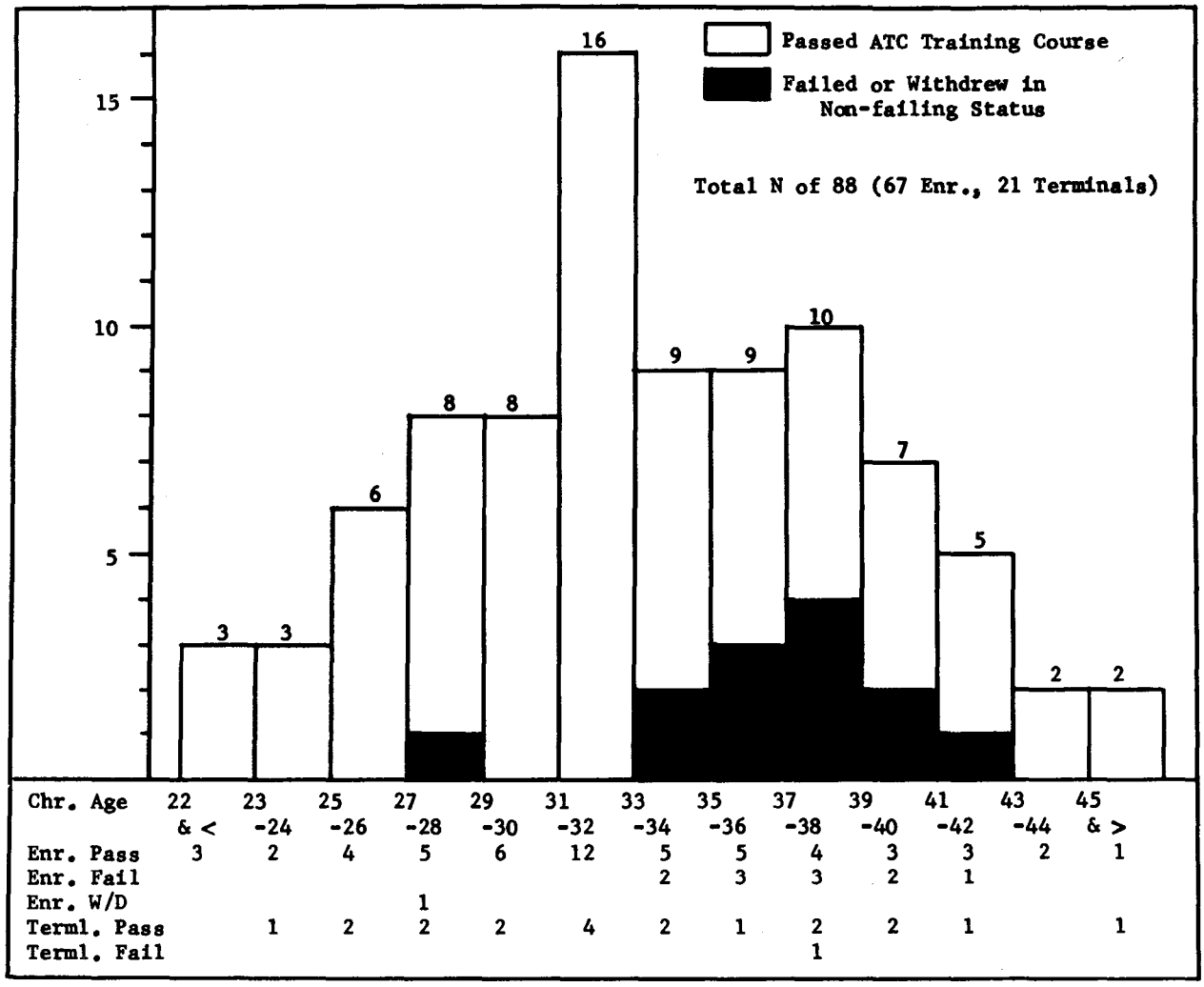


FIGURE 4. Distribution of Composite CSC-ATC-Aptitude Test Scores by Age Group for 219 Enroute and 82 Terminal ATC Trainees Who Were Officially Administered the CSC Test Battery But Were Selected at a Level Higher Than GS-7 on the Basis of Exceptional Types and Amounts of Pre-FAA ATC-related Experience.



Chr. Age	22 & <	23 -24	25 -26	27 -28	29 -30	31 -32	33 -34	35 -36	37 -38	39 -40	41 -42	43 -44	45 & >
Enr. Pass	3	2	4	5	6	12	5	5	4	3	3	2	1
Enr. Fail							2	3	3	2	1		
Enr. W/D				1									
Terml. Pass		1	2	2	2	4	2	1	2	2	1		1
Terml. Fail									1				

FIGURE 5. Age Distribution for 88 ATC Trainees Selected on the Basis of Age for Establishment of a "Non-skewed" Sample With Which to Determine the Relationships Between Age and Five Measures of Performance on the Official, Field-Administered, CSC-ATC-Aptitude Screening Battery.

Relatively complete training-course performance records were available for most of the 88 selected cases. Officials submitted no Academic Grade Average for the Enroute student who had died. Also, the records of the 12 trainees who failed were usually incomplete. However, an Academic Grade Average was submitted for every student who failed although it was generally based on a fewer number of grades than available for each passing student. Similarly, evaluations of performance on laboratory problems were sufficient in number to permit derivation of a Laboratory Grade Average for all but two of the attritions and the deceased student. Thus, for each of 85 subjects in the sample, the A+L Grade represented a simple arithmetical mean of the two summary measures of performance. In order to preclude their deletion from some of the scheduled analyses, each of the two attritions who lacked a Laboratory Grade Average was assigned an A+L Grade based on the Academic Grade Average only.

1. Age and training performance. The relationships between chronological age and the different measures of training performance for the cases of this sample are graphically illustrated in Figure 6. Although the total number of cases within each of the arbitrarily established age groups is relatively small, the results clearly indicate that the trainees over 34 years of age experienced greater difficulty than their younger colleagues in successfully completing their prescribed training course. None of the 23 trainees within the age bracket "29 and younger" failed and only two (i.e., 6.9 per cent) of the 29 in the age group "30 through 34" were attrited. The relationships between age and the other measures of training performance were investigated, in this particular phase, by preparing frequency distributions of the Academic Grade Averages, Laboratory Grade Averages and A+L Grades of all non-failing subjects and, based on the respective median of each array, every student who passed the course was then successively designated as being either in the "Upper" or "Lower" half of the group. Of the trainees under 30 years of age, over 78 per cent were in the upper half of the distribution of Academic Grade Averages, 68.2 per cent obtained Laboratory Grade Averages above the median, and 78.3 per cent possessed "Upper" A+L Grades. In contrast, no more than 42 per cent of the trainees in any

TABLE I.—DESCRIPTION OF CSC-ATC-APTITUDE-SCREENING-TEST VARIABLES

CSC Subtest	Weight	Description
CSC 24 Computations	1	A highly-speeded test of arithmetic skill. The problems involve simple addition, subtraction, multiplication and division. The aptitude factor is referred to as "numerical facility."
CSC 51 Spatial Patterns	2	A test consisting of two different types of spatial items. In one type, the task is to identify solid figures that can be made from unfolded patterns. In each of the other, three different views of an object are presented and the subject must select the correct object from one of four alternatives.
CSC 135 Following Oral Directions	1	In this test the subject must listen carefully to orally-presented directions and information; then discriminate between relevant and irrelevant information in order to proceed toward the proper solution of a series of simple tasks.
CSC 157 Abstract Reasoning and Letter Sequence	2	In the "Abstract Reasoning" portion of the booklet, the task is to indicate which of a series of choices (figures) properly carries out a principle of logical development exhibited by a sequence of figures. In "Letter Sequence" the subject must indicate which of a series of letters properly carries out a principle of logical development exhibited by a sequence of letters.
CSC 540	1	A highly-speeded test consisting of two parts of thirty items each. In each part, the subject is presented a flight data display for several aircraft and must determine whether certain changes in altitude may be directed without violating a specified time-separation rule.
CSC Composite or Total Weighted Scores		Sum of the weighted raw scores for each of the five CSC test booklets (i.e., six subtests).

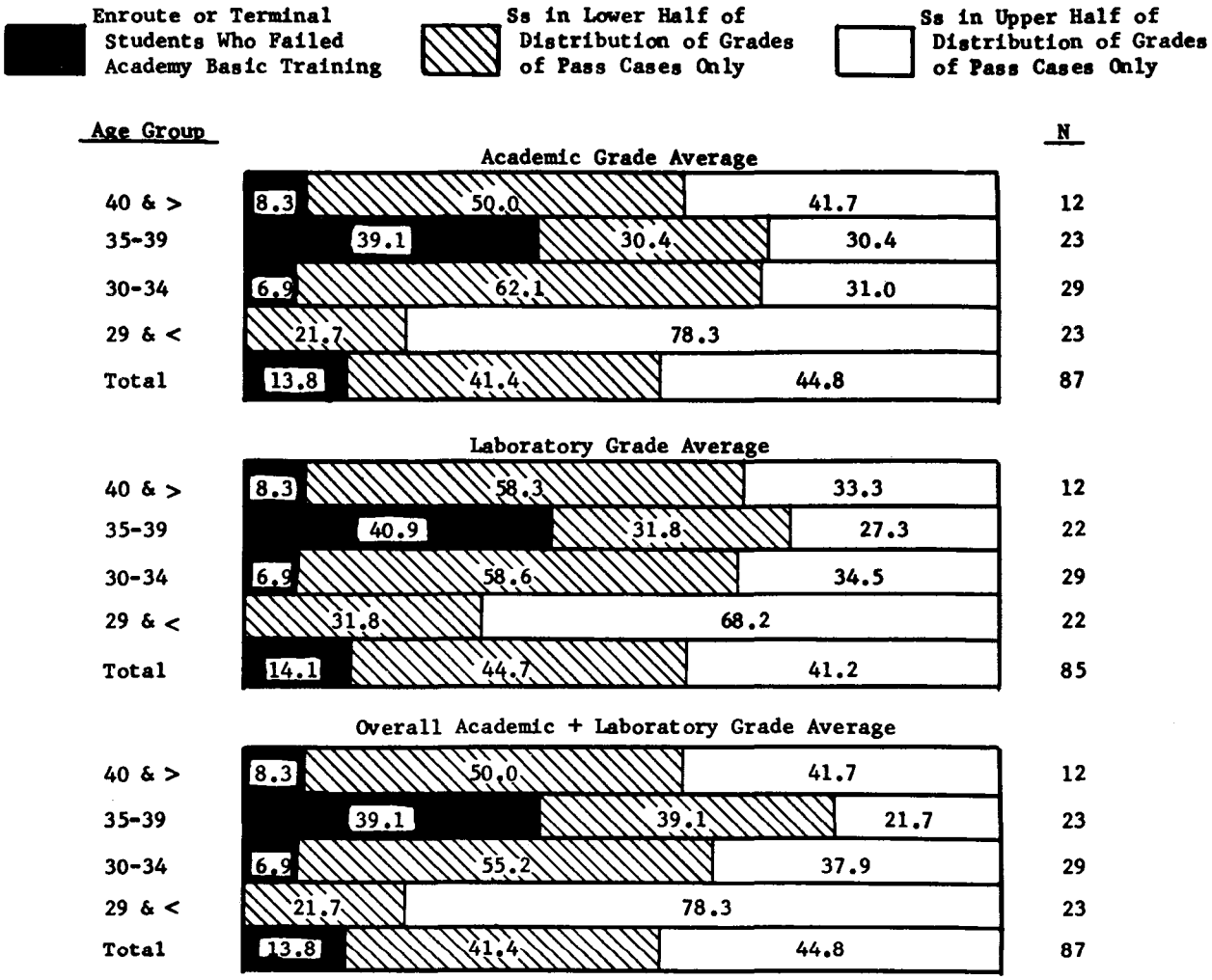


FIGURE 6. Percentages of ATC Trainees* By Age Group Who Failed Academy Training or Passed With Grades Comprising Either the Approximate Lower Half or Approximate Upper Half of the Distributions of Academic, Laboratory, or Combined Academic and Laboratory Grades of the Pass Cases Only.

* The 88 Ss were randomly selected from specific age groups to establish a relatively "normalized" sample. (Note: One S died and laboratory grades were not available for two other Ss; see text.)

TABLE II.—MEANS, STANDARD DEVIATIONS, INTERCORRELATIONS AND VALIDITIES OF CSC-ATC-SCREENING TEST SCORES, TRAINING-COURSE PERFORMANCE MEASURES AND CHRONOLOGICAL AGE

	CSC–24 Number Facility	CSC–51 Space Relations	CSC–135 Fol. Oral Direction	CSC–157 Abst. R. Letr. Sq.	CSC–540 ATC Problems	CSC Composite Score	Academic Grade Average	Lab Grade Average	Overall Acad+ Lab Average	Chron. Age
Max. N	88	88	88	88	88	88	86	85	88	88
Mean	42.7	28.8	27.0	26.5	30.7	210.7	88.1	83.4	85.5	33.1
S.D.	6.7	5.0	5.5	9.3	9.7	34.7	5.6	12.9	8.6	5.8
					Intercorrelations and Validities					
CSC Subtest										
24-Num. F.	---	.06	.23	.22	.30	.42	−.05	−.03	−.06	.09
51-Space R.		---	.43	.40	.16	.60	−.10	.02	.04	−.34
135-Oral Dir.			---	.54	.38	.72	−.10	.33	.24	−.32
157-Ab.R. & L				---	.34	.87	.02	.38	.33	−.34
540-ATC Prbs.					---	.62	.04	.27	.20	−.14
CSC Total Score						---	−.03	.33	.25	−.35
Acad. Grd. Avg.							---	.10	.51	−.11
Lab. Grd. Avg.								---	.91	−.33
Acad + Lab Gr. Av.									---	−.31
Chronolog. Age										---
	R (Multiple correlation) of Specific Combinations of Variables Versus Chronological Age									
CSC–135 and CSC–157										−.38
CSC–135 and CSC–51										−.39
CSC–157 and CSC–51										−.40
CSC–157, CSC–51 and CSC–135										−.42
CSC–157, CSC–51, CSC–135 and Training-Course Lab Grade Averages										−.48

of the older groups were above any of the medians. Aside from the fact that over two-thirds of the trainees comprising the youngest group received above-the-median grades and the finding that most of the failures were 35 or older, all other results obtained in this analysis were of such nature as to suggest only a moderate inverse relationship between age and training performance.

2. Age and performance on CSC subtests. Table I presents a listing and description of the subtests which comprise the CSC ATC Aptitude Screening Test. Operationally, five subscores, rather than six, are generally reported. This procedure is followed because CSC Booklet 157 contains both "Abstract Reasoning" and "Letter Sequence." These two subtests are quite different but, inasmuch as they appear in the same booklet and are both double weighted in derivation of the total score for the CSC ATC Test, the two performance measures are combined and reported as a single subscore by Civil Service Commission officials. CAMI investigators, however, have always chosen to maintain separateness of performance data for these and all other subtests whenever possible. Such was the case in CAMI's previous research wherein the six CSC measures were identified from among 27 variables as yield-the best composite for prediction of training outcomes.

The factor areas covered by the six CSC subtests overlap considerably with those found in many of the so-called "I.Q." tests. In fact, an unpublished CAMI study involving 200 students who entered Academy ATC training during 1963, revealed a correlation of .81 between the Comopsite CSC ATC Score and an "I.Q." based on the 12 subtests of the California Test Bureau's Test of Mental Maturity (CTMM). However, the latter was found to be less effective than the Composite CSC ATC Test Score for prediction of pass-fail status and training grades.

The intercorrelations and validities of the CSC ATC Test measures and their relationship to

chronological age are presented in Table II. Subtest 24, "Computations," which is also sometimes referred to as "Number Facility," is the only one which correlated positively with age. Its magnitude was only .09. Corresponding coefficients for the other four were: −.14 for CSC 540 (Air Traffic Problems); −.34 for CSC 51 (Space Relations); −.32 for CSC 135 (Following Oral Directions); and −.34 for CSC 157 (Abstract Reasoning and Letter Sequence). The latter three were statistically significant ($p<.01$), while those pertaining to CSC 24 and CSC 540 were not significant.

The CSC Total Score (as derived operationally) correlated −.35 with age. A coefficient of this size for a sample of only 88 cases is significant at the .01 level. Moreover, the results of a multiple regression analysis, in which age was retained as the criterion variable, indicated that a validity coefficient of −.42 could be obtained with a composite score based on omission of performance data for both CSC 24 and CSC 540 and application of specific factor weights (other than those dictated for operational use) to the scores on CSC Booklets 51, 135 and 157. Also, an extension of this multiple regression analysis revealed that if the latter three subtests were supplemented by Laboratory Grade Average, and if weights as determined in the analysis were applied to the four measures, the resulting composite measure would have correlated −.48 with chronological age. This coefficient was viewed as being relatively high because (1) the age range, of 22 to 49, was so small and (2) there was no reason to doubt that factors other than those associative with age were also operating in determining performance on the tests and on the laboratory training problems.

3. Validities of CSC test measures. When the Academic Grade Average was considered as the criterion variable, the five subscores and the Total CSC Test Score yielded low and nonsignificant validities—four of which were negative. However, three subtests and the CSC Total Score emerged as significant predictors of Laboratory Grade Average. In this respect, the correlations were: .33 for CSC 135; .38 for the combined parts of Booklet 157; .27 for CSC 540; and .33 for the composite score. Although not presented in the table, the results of a regression analysis indicated that if factor weights as determined by the regression were applied to the scores on Booklets 157, 135 and 540, the resulting composite scores would correlate .43 with the variable reflecting laboratory performance.

Differences between the validities of the tests for the two summary measures of training performance were much greater than expected. However, the Academic Grade Average correlated .10 with Laboratory Grade Average and this was considerably lower than had been anticipated. Unpublished analyses involving the Academy training classes of 1961 through 1963 had resulted in correlations ranging from .47 to .63 between variables of the same name and general type. A question regarding the possibility of "sampling error" therefore arose when a recheck proved the coefficient of .10 to be correct for the sample of 88 cases. This prompted determination of the corresponding correlation for the entire group of highly experienced trainees. The resulting coefficient of .21 was significantly higher than the .10 obtained for the sample, yet significantly lower than any of the correlations based on inputs of earlier years. Moreover, additional analyses pertaining to the groups involved in the present study revealed that the variance of the Laboratory Grade Averages was more than twice that of the Academic Grade Averages. This and other findings suggest that the Academic Grade Averages probably possess less potential than the Laboratory Grades for purposes of individual differentiation and, if so, would partially explain why the aptitude tests are more useful for the prediction of laboratory performance than academic achievement.

The validities of the various CSC Test measures are also shown in Table III. Adjacent to each of the first-order, or original, validity coefficients is one of second order representing the remaining validity of the aptitude measure after statistically partialing out the variance associative with age. Inasmuch as the initial validities of all subtests for prediction of the Academic Grade Average were quite nominal, attention should be directed to a comparison of the two coefficients obtained for each variable when the Laboratory Grade Average served as the criterion. The validity of CSC 135, which was originally .33, dropped to .20. Similarly, the coefficient of .38 for CSC 157 was replaced by a .24, and CSC 540, which had an initial validity of .27 yielded a coefficient of .20 after partialing out the effects of age. Although the residual

TABLE III.—VALIDITIES OF CSC ATC-APTITUDE-SCREENING-TEST MEASURES BEFORE AND AFTER PARTIALING OUT THE EFFECT OF CHRONOLOGICAL AGE

	Academic Grade Average		Laboratory Grade Average		Combined Acad+Lab. Gr. Avg.	
	1st Order r	Partial r	1st Order r	Partial r	1st Order r	Partial r
CSC 24 Number Facility	−.05	−.04	−.03	.00	−.06	−.03
CSC 51 Space Relations	−.10	−.13	.02	−.08	.04	−.06
CSC 135 Following Oral Dir.	−.10	−.13	.33**	.20	.24*	.12
CSC 157 Abst. R. & Ltr. Sq.	.02	−.02	.38**	.24*	.33**	.20
CSC 540 Air Traffic Problems.	.04	.02	.27**	.20	.20	.14
CSC Composite (Total Score)	−.03	−.07	.33**	.19	.25*	.12

*Significant at less than the .05 level.
**Significant at less than the .01 level.

Note: The data above are for a "normalized" age sample of 88 Enroute and Terminal trainees who were selected from among 301 students for whom field-administered CSC Test scores were available but who were hired at a level higher than GS–7 on the basis of pre-FAA ATC-related experience rather than on the basis of test scores.)

validities of these three measures are, in each instance, substantially lower than intially obtained, they are nevertheless of appreciable magnitude and one (the .24 for CSC 157) is statistically significant.

4. Means of CSC subscores by age group. A graphic summary of the relationships between age and each of the CSC measures is presented in Figure 7. An examination of the plotted mean scores for the subjects by age group reveals that the data for three of the five subtests and for the overall test have resulted in highly similar configurations, with the mean performance scores highest for the 23 youngest students and, with one minor exception, progressively lower for each of the older groups. However, the group mean scores for CSC 24 Number Facility and CSC 540 Air Traffic Problems (ATP) follow a unique pattern. In regard to Number Facility, the lowest of the group means is for the youngest trainees and the highest is for the oldest group. A statistical analysis indicated a high degree of variance in the CSC 24 scores about each of the four group means and, although no significant differences were found between any of the groups, the trend in the plotted data suggests that the positive relationship between age and performance on this subtest might be even greater than that indicated by the previously established correlation coefficient of .09.

The findings obtained for CSC 540 were unique in that the trainees of age 40 and older performed almost as well as the two youngest groups, both of which had a mean score of approximately 32. Although the students aged 35–39 represented the only grossly deviant group on CSC 540, none of the differences between group means was statistically significant.

The authors were rather surprised to find a positive relationship, rather than negative, between age and performance on CSC 24 as well as a failure of the plotted means for CSC 540 to reflect a consistent trend (in either direction) insofar as age was concerned. However, both these subtests are highly speeded and, even though the factor content of 540 is somewhat omnibus, good performance on either instrument is largely dependent upon arithmetical skill—

ABLE IV.—LISTING AND DESCRIPTION OF TESTS ADMINISTERED ON AN EXPERIMENTAL BASIS TO STUDENTS WHO ENTERED ACADEMY ATC TRAINING WITH RATINGS HIGHER THAN GS–7

echsler Adult Intell. Scale	An eleven-part intelligence test.
WAIS Digit-Symbol (subtest)	A highly speeded test of encoding digits to symbols in accordance with a nine-unit key.
AMI Symbol-Digit Test	A highly speeded test of decoding symbols to digits in accordance with a nine-unit key.
iff. Test of Mental Maturity	The advanced 1957 edition of the 12-test CTMM.
CTMM–7, Figure Analogies	In each item, the S must recognize the relationship between a pair of drawings (objects) in order to identify, by analogy, one of four choices as being similarly related to a third.
CTMM–8, Inferences	Comprehension of statements presenting premises used in the derivation of logical conclusions.
CTMM–10, Coins	Involves the mental manipulation of interrelated amounts of money and numbers of coins.
CTMM–11 Arithmetic	Solving of word-presented, arithmetic problems.
ess Test, Part III	Involves designating the color of the ink in which the words, "red," "blue," "yellow," and "green" are printed.
own-Carlsen Listening Comprehension Test (Five parts: A, B, C, D & E)	An orally presented test which measures immediate recall, following oral directions, recognizing sentence transitions, word meanings, and lecture comprehension.
AMI Directional Headings	A test requiring the interpretation of letters, symbols and degrees in order to establish true headings (Part I), exact opposites of true headings (Part II), and exact opposites of true headings under conditions of oral distraction (Part III).
AMI Locating Data	A speeded perceptual-precision task of locating blocks of data containing specific groups of numbers and symbols.
SC 540, Air Traffic Prblms.	(As previously described in Table I.)
SC 135, Following Oral Dir.	(As previously described in Table I.)
SC 157, Abstract Reasoning and Letter Sequence	(As previously described in Table I.)

hich is perhaps the most pervasive of all skills volved in air traffic control work. The basic ty of an ATCS is to maintain a safe and peditious flow of air traffic, separating the air- aft in terms of time, altitude, and spacing, gether with a consideration of airspeeds. It is ssible to assume that experience in air traffic ntrol may contribute toward enhancement of thmetic skills and other abilities such as in- ved in CSC 540 and CSC 24. Inasmuch as all subjects of the sample possessed specialized TC experience, with the older individuals gen- ally having the greater amounts, the results tained for these two subtests would, in general, contradict such a hypothesis.

For each of the remaining three subtests and CSC Composite, the plotted mean scores fol- ed a pattern reflecting an inverse relationship ween age and performance. In all instances, the differences between the mean scores of the youngest and oldest groups were statistically significant. Many other differences, particularly between the performance means of the youngest group and those subjects 35–39 years old, were also found to be significant. The consistency, magnitude, and significance of these age-related differences tend to illustrate the potential with which the CSC measures might be used in the screening of older subjects. These and other results obtained in earlier portions of the study for this sample of highly experienced subjects constitute convincing evidence that men over 35 years of age are apt to experience greater difficulty than younger men in satisfactorily completing Academy ATC training and in attaining relatively high performance scores on types of aptitude tests such as CSC 51, CSC 157 and CSC 135.

PHASE II

The second part of this study pertained to a variety of aptitude tests which were administered, on an experimental basis, to trainees at the time they entered Academy basic training. Each incoming class was administered only five to seven tests but successive changes in the groups of tests selected for administration ultimately resulted in the collection of performance data, on samples of varying size, for 14 different instruments. Table IV presents a listing and description of the tests. Seven of the 14 are commercially published instruments; two represent experimental tests constructed by CAMI researchers; one is a revised version of an instrument which the American Institute of Research developed under contractual arrangement for the FAA, and the remaining four are subtests of the CSC ATC Aptitude Screening Test. Classification of every instrument as either a "power" or "speed" test would result in about an equal number being relegated to each category. Should a factor analysis be accomplished on the entire group, factors such as "listening comprehension or following directions," "abstract reasoning or logic," and "speed of perceptual precision" would probably emerge as most predominant.

Although part scores were obtained for many of the tests, they were seldom included in the statistical analyses. Two tests, however, were dealt with in a special manner. Differences in regard to the nature and complexity of the tasks presented in the three parts of the CAMI Directional Headings Test prompted the investigators to maintain separateness of the part scores for this instrument. The other exception pertained to the Press Test. A preliminary analysis of the performance data collected for the three parts of the Press Test had illustrated that Parts I and II were relatively easy and that neither would provide any variance unique from that obtained with Part III. Thus, a total of 16 aptitude measures, including three part scores (but not total score) for CAMI Directional Headings, the Press Test Part III score, and the total scores for the remaining 12 tests, were retained for inclusion in the subsequent analyses.

TABLE V.—CORRELATIONS OF THE EXPERIMENTALLY-ADMINISTERED TESTS WITH CHRONOLOGICAL AGE AND TRAINING-COURSE PERFORMANCE

Test	Number of Ss Administered the Test	Correlation With Age	N Cases for Which Trng. Grades Were Available	Correlation With Acad. + Lab. Grade Avg.
WAIS Digit-Symbol	205	−.19**	199	.37**
CAMI Symbol-Digit	468	−.16**	438	.24**
CTMM–7, Fig. Analogies	184	−.16*	182	.18*
CTMM–8, Inferences	184	−.29**	182	.37**
CTMM–10, Coins	184	−.29**	182	.45**
CTMM–11, Arithmetic	144	−.16*	143	.37**
Press Test, Part III	100	−.03	98	.31**
Brown-Carlsen Test	144	−.16*	142	.23**
CAMI Dir. Headings I	153	−.04	150	.27**
CAMI Dir. Headings II	154	−.19*	151	.27**
CAMI Dir. Headings III	86	−.22*	84	.26*
CAMI Locating Data	313	−19**	306	.30**
CSC 540, ATP	348	−.08	338	.29**
CSC 135, Oral Direc	316	−.23**	307	.29**
CSC 157, Abstr. Reas	291	−.24**	267	.13*
CSC 157, Letter Seq	237	−.15*	230	.25**

*Significant at less than the .05 level.
**Significant at less than the .01 level.

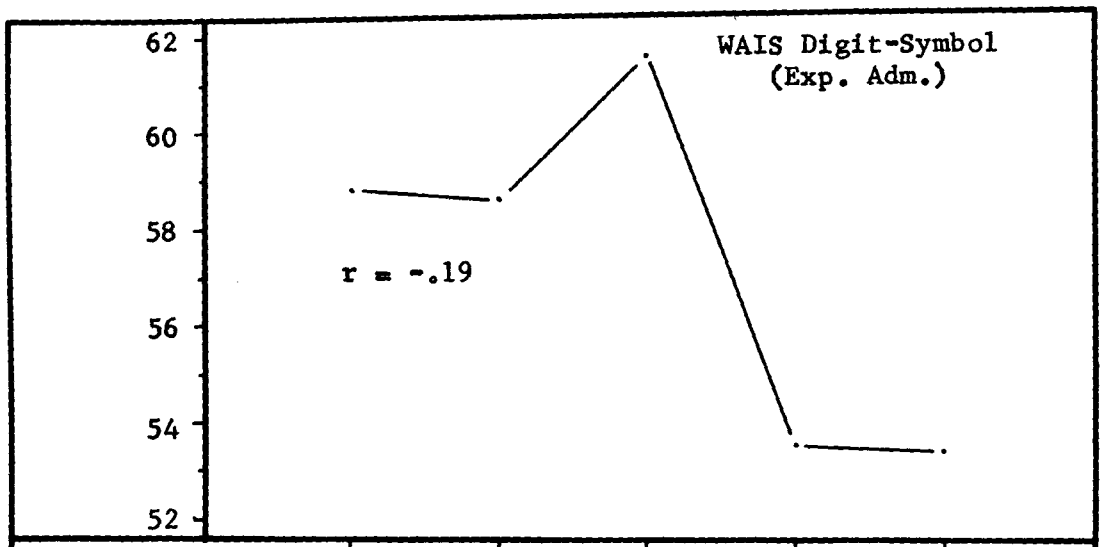
A. *Correlations of Experimentally Administered Tests With Age and Training Grades.* Intercorrelations of the scores for the 16 experimentally administered instruments were not computed because the samples did not overlap sufficiently to permit establishment of a sizable sample based on a "common N." However, product-moment correlations of the 16 performance measures with chronological age and with the A+L Grade Average were obtained. The resulting coefficients are presented in Table V. The samples for which performance data were collected ranged from 86 trainees for Part III of Directional Headings to 468 for the CAMI Symbol-to-Digit Test. Every test correlated negatively with age. The three lowest coefficients were −.03 for Part III of the Press Test, −.04 for Part I of Directional Headings, and −.08 for CSC 540 Air Traffic Problems; all others, ranging from −.15 to −.29 were statistically siignificant at the .05 level or better. Those tests pertaining to abstract reasoning, judgment, logic, and comprehension generally yielded the higher correlations. Next in order of magnitude were those obtained for the speeded-perceptual task measures. Among the latter were scores reflecting performance on CAMI's Locating Data and Symbol-to-Digit Tests and on CTMM–7 Figure Analogies. However, due to attenuation effects stemming from the restriction of range and skewness in the distribution of ages of the subjects comprising the respective samples, each coefficient should be considered as a gross underestimate of the relationship that would have existed had the ages of the trainees been more representative of a general population. Although not shown in Table V, an examination revealed no instance in which the subjects under 20 years of age represented less than 56 per cent of the sample whereas those "40 and older" represented only five to 17.4 per cent of each respective sample.

As an illustration of effects stemming from the lack of "normality" in the age distribution, it should be noted that the correlation of −.23 between age and performance on the experimentally administered CSC 135 Oral Directions subtest is considerably lower than the −.32 obtained in the earlier phase of the study with the operationally reported CSC 135 scores for the special sample of 88 cases (see Table II). Even the latter, however, would probably have been substantially larger had the age range not been so restricted.

The A+L Grade Average was considered as the criterion in the validation of the experimentally administered tests. All 16 measures were found to have significant positive validities. The highest correlation was a .45, which was obtained for CTMM Coins. It should be mentioned that this moderately-speeded test is rather complex and, in addition to unique arithmetical tasks, presents a relatively difficult learning situation which involves the rapid interpretation and use of tabular symbols and other data. The WAIS Digit-to-Symbol Test, CTMM Inferences, and CTMM Arithmetic each yielded a correlation of .37 with the overall training performance measure. Next were the Press Test Part III and CAMI Locating Data with coefficients of .31 and .30 respectively. Validities for eight of the remaining ten tests ranged from .29 for both CSC 540 and CSC 135 to .23 for the composite score on the Brown Carlsen Test. CTMM Figure Analogies yielded a correlation of .18 and CSC 157 Abstract Reasoning ranked last with a coefficient of .13. Failure of the latter to validate more highly was unexpected because it had been identified in previous resarch[7 19] as being among the most valid for prediction of training performance.

The remaining figures, numbered as 8 through 23, further illustrate the relationship between age and performance on the experimentally administered tests. Each figure pertains to a specific test and presents a plot of the mean score for the subjects of the five age groups: "24 & younger," "25–29," "30–34," "35–39," and "40 & older." Although all the findings illustrated by the successive graphs will not be discussed, some seem to warrant special comment.

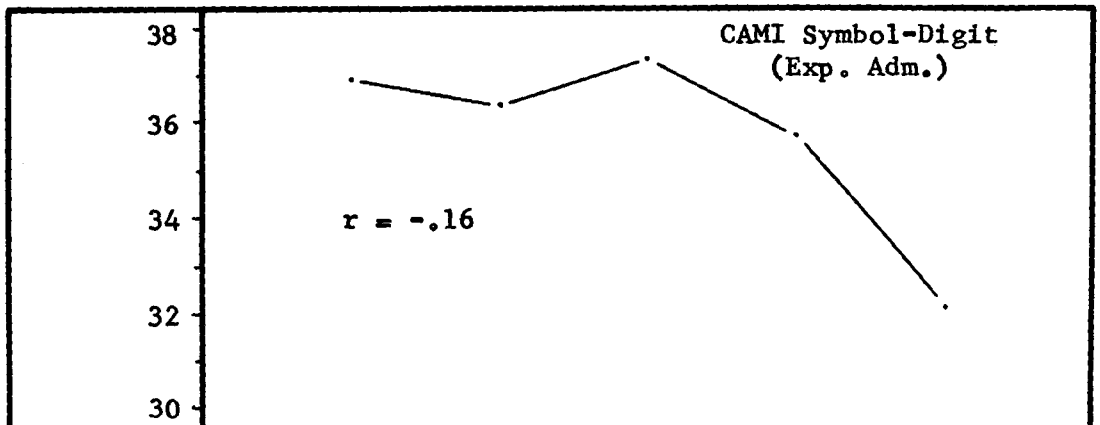
B. *WAIS and CAMI Digit-Symbol Tests.* Figure 8, which pertains to the Digit-to-Symbol subtest of the Wechsler Adult Intelligence Scale (WAIS) is particularly noteworthy because it illustrates dramatic differences between the performance of the three youngest versus the two oldest groups of trainees. Birren and Morrison,[3] in a study based on 933 subjects ranging from 25 to 64 years of age, found this measure to be more inversely related to age than any of the other nine subtest scores of the WAIS. A subsequent study by Birren and Spieth[4] with subjects of



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	30	90	42	21	22
Mean	58.8	58.6	61.6	53.5	53.4
S.D.	8.4	9.2	9.6	9.7	10.1

FIGURE 8. Mean Scores on the WAIS D-S Test by Age Group for 205 ATC Ss Experimentally Tested at Time of Entry into Academy Training.

(Note: The mean performance scores of the Ss in age groups 40 or older and 35–39 are significantly lower than the means of the Ss in the groups aged 24 or younger, 25–29, and 30–34.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	83	198	89	49	49
Mean	36.9	36.4	37.4	35.8	32.2
S.D.	5.7	6.4	6.8	7.1	6.4

FIGURE 9. Mean Scores on CAMI S-D Test by Age Group for 468 ATC Ss Who Took the Test Experimentally Upon Entry into Academy Training.

(Note: The mean performance scores of Ss aged 40 or older is significantly lower than the means of the Ss in each of the groups aged 24 or younger, 25–29, 30–34, and 35–39.)

similar age range reported a correlation of −.42 between age and performance on the WAIS Digit-to-Symbol subtest; this coefficient, which compares favorably with the −.46 obtained by Birren and Morrison, was among the highest of those they obtained for a variety of measures. In the present study, a corresponding coefficient of −.19 was obtained. A coefficient of such magnitude, if derived on a larger sample in which age was more normally distributed and covering a greater range, would reflect an inverse relationship of moderate intensity only. However, it should again be emphasized that this sample, like those for which performance data on the other tests were collected, included no men beyond 52 years of age and, of those subjects within the restricted range, relatively few were over 40. In fact, age was so abnormally distributed that the authors questioned the appropriateness, or legitimacy, of applying correlational formulae to the data. The correlations were computed, however, because it was felt that each coefficient, together with the graphically depicted results would be useful in establishing and projecting general trends in the relationship between age and performance. Also, inasmuch as the experimentally administered batteries included several CSC subtests, it was assumed that correlation coefficients computed by the same method as those in the first phase of the study would be useful for comparative purposes and also illustrate the attenuation effects.

Formulas are available with which to adjust correlation coefficients for restriction-of-range effects, provided the data conform to certain conditions.[12 15] For example, if the correlation of −.19 between age and the WAIS D-S scores had been found for a sample in which the ages were *normally* distributed within a range of 20 to 40, statistical procedures could then have been applied to obtain an estimated correlation of approximately −.36 for a sample in which age was normally distributed within a range of 20 to 60. In each instance, however, the reliability of the estimate would partially depend upon the degree of normality in the distribution of the variables actually being dealt with. Inasmuch as the ages of the examinees of all 16 samples were known to be abnormally distributed, no estimates in this respect were attempted. Nevertheless, it is important to bear in mind that each correlation involving age and listed as being statistically significant would undoubtedly have been of considerably greater magnitude if based on samples in which age was normally distributed over a greater range.

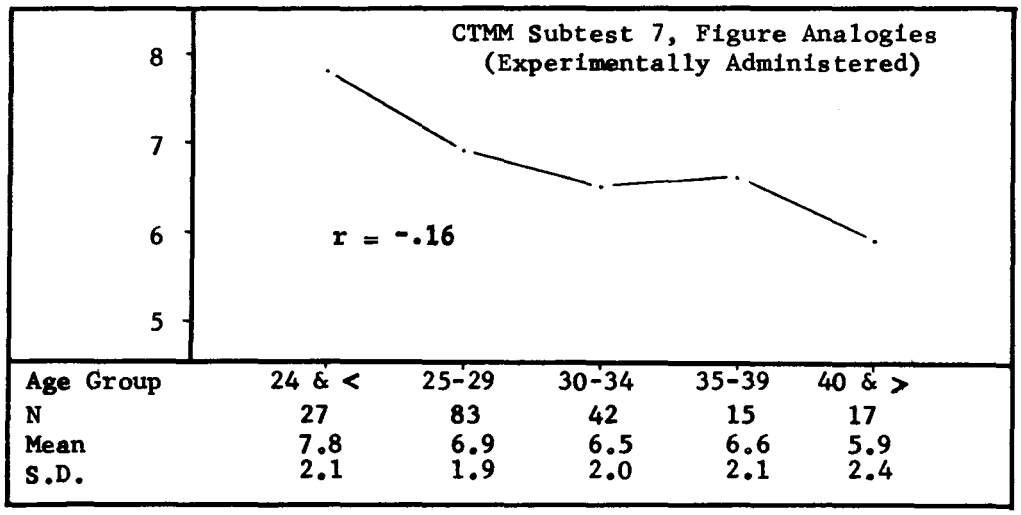
Figure 9 presents the plotted means by age group for the CAMI Symbol-to-Digit Test. This test is a counterpart of the WAIS Digit-to-Symbol Test in that it involves decoding rather than encoding. It is also a more highly speeded test. Although the subjects of the age groups "35 to 39" and "40 & older" performed less well than the younger groups, only the mean performance of those over 39 was found to be significantly lower.

C. *The Four CTMM Subtests, Press Test, and Listening Comprehension.* Figure 10 pertains to CTMM Subtest 7, Figure Analogies. The graph reveals that the youngest group performed best on this test and that the performance means were progressively lower, with one minor exception, for each succeeding age group. Most of the differences were statistically significant. On CTMM Inferences (see Figure 11), the trainees over age 39 performed at a significantly lower level than all younger groups, but differences among the latter were nonsignificant.

In Figure 12, the successive decline in the plotted means from the youngest to the oldest group illustrates the potential with which CTMM Coins, or a similar test, might be used in the screening of older applicants for ATC training. The performance means of both older groups differed markedly, and significantly, from those of the two youngest groups. It may also be recalled that the scores on CTMM Coins correlated .45 with the overall measure of training course performance; this validity coefficient was higher than that obtained with any other test.

Figures 13 and 14 seem to warrant no special comment. Proceeding to Figure 15, it should first be noted that only 12 trainees of age 35 to 39 and only nine subjects of age 40 and above were administered the five-part Brown Carlsen Listening Comprehension Test. In each instance, however, their mean performance level was appreciably below that of the younger groups.

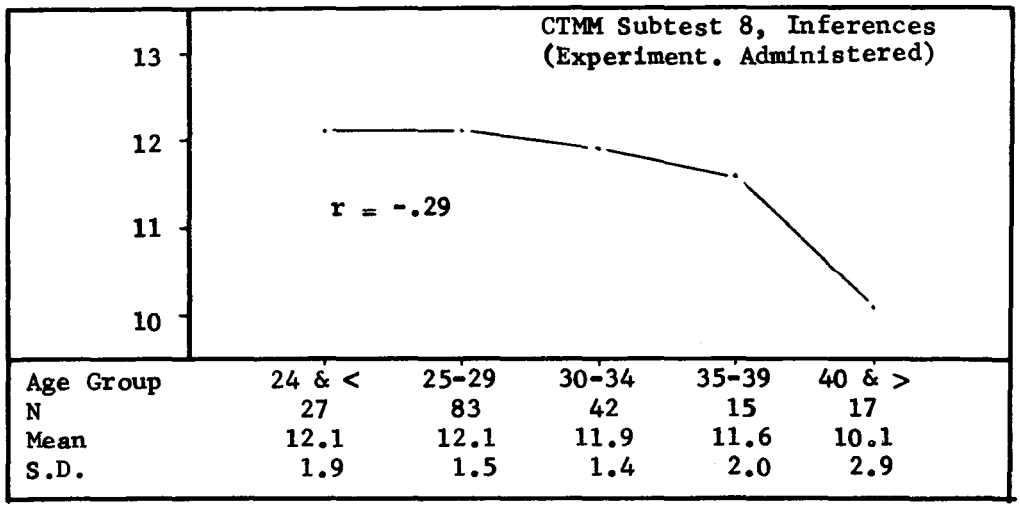
D. *CAMI Directional Headings.* The results for the three parts of the CAMI-developed Directional Headings Test are depicted in Figures 16, 17, and 18. Each part of the test is relatively simple but very highly speeded. Through use



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	27	83	42	15	17
Mean	7.8	6.9	6.5	6.6	5.9
S.D.	2.1	1.9	2.0	2.1	2.4

FIGURE 10. Mean Scores on CTMM Figure Analogies Test by Age Group for 184 ATC Trainees Who Took the Test on an Experimental Basis.

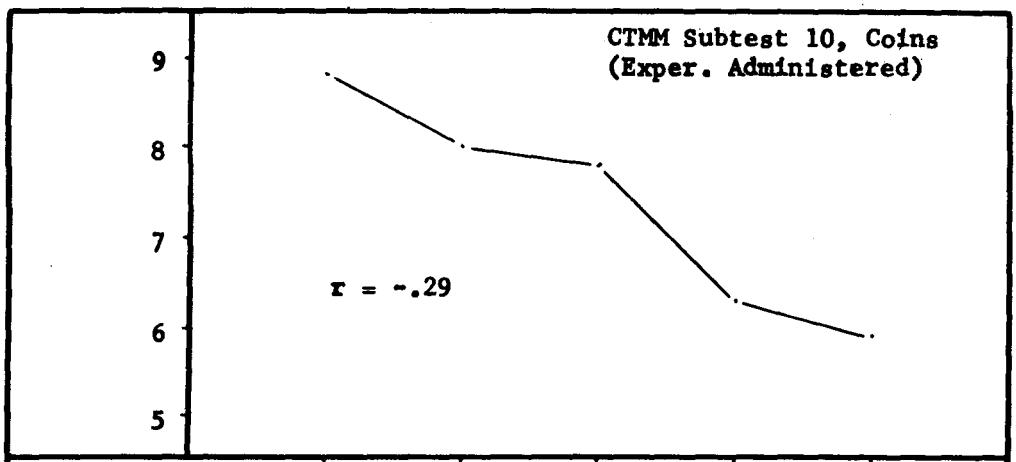
(Note: The mean performance scores of Ss in groups aged 25–29, 30–34, and 40 or older are each significantly lower than the mean for Ss in age group 24 or younger.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	27	83	42	15	17
Mean	12.1	12.1	11.9	11.6	10.1
S.D.	1.9	1.5	1.4	2.0	2.9

FIGURE 11. Mean Scores on CTMM Inference Test by Age Group for 184 Students Who Took the Test Experimentally at Time of Entry into Academy ATC Training.

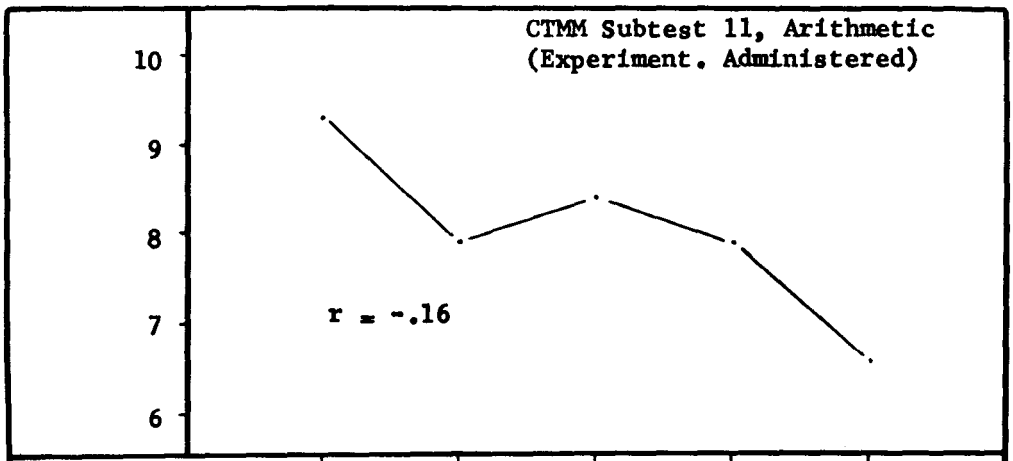
(Note: The mean performance score of Ss in age group 40 or older is significantly lower than each of the means for Ss in groups aged 24 or younger, 25–29, and 30–34.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	27	83	42	15	17
Mean	8.8	8.0	7.8	6.3	5.9
S.D.	2.7	2.6	3.5	3.0	2.6

FIGURE 12. Mean Scores on CTMM Coins Test by Age Group for 184 ATC Students Who Were Experimentally Tested at Time of Entry into Academy Training.

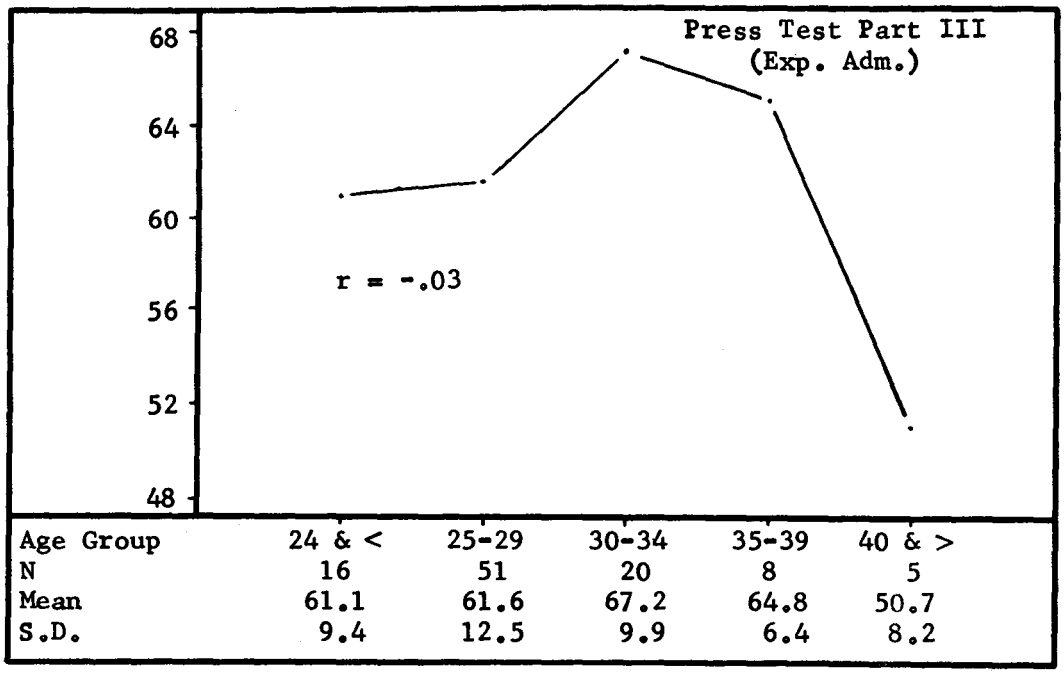
(Note: The mean performance scores of Ss in groups aged 35–39 and 40 or older are each significantly lower than either mean for Ss in age groups 25–29 or 24 and younger.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	19	70	31	12	12
Mean	9.3	7.9	8.4	7.9	6.6
S.D.	1.5	2.7	2.5	3.2	2.5

FIGURE 13. Mean Scores on CTMM Arithmetic Test by Age Group for 144 ATC Trainees Who Were Administered the Test on an Experimental Basis.

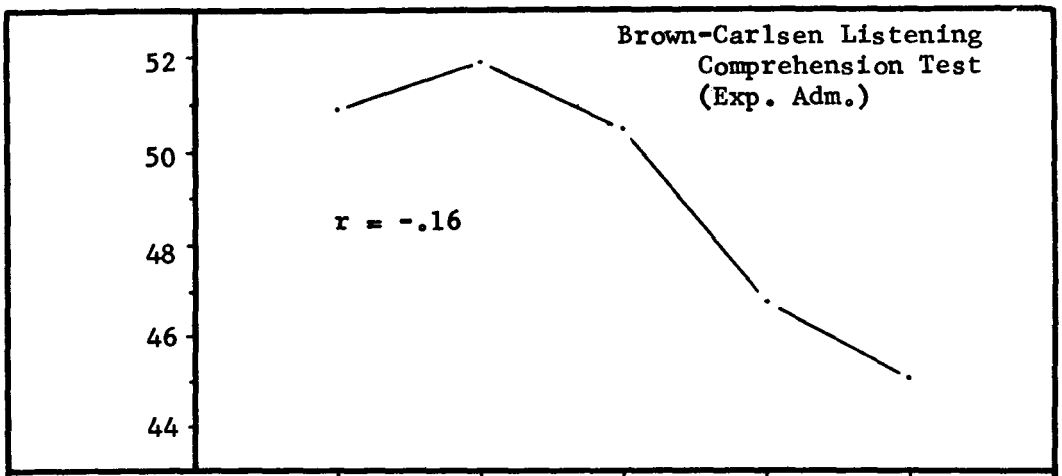
(Note: The mean performance scores of Ss in each of the groups aged 35–39 and 40 or older are significantly lower than the mean of Ss in age group 24 or younger.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	16	51	20	8	5
Mean	61.1	61.6	67.2	64.8	50.7
S.D.	9.4	12.5	9.9	6.4	8.2

FIGURE 14. Mean Performance Scores on Part III of the Press Test by Age Group for 100 ATC Trainees Who Took the Test Experimentally.

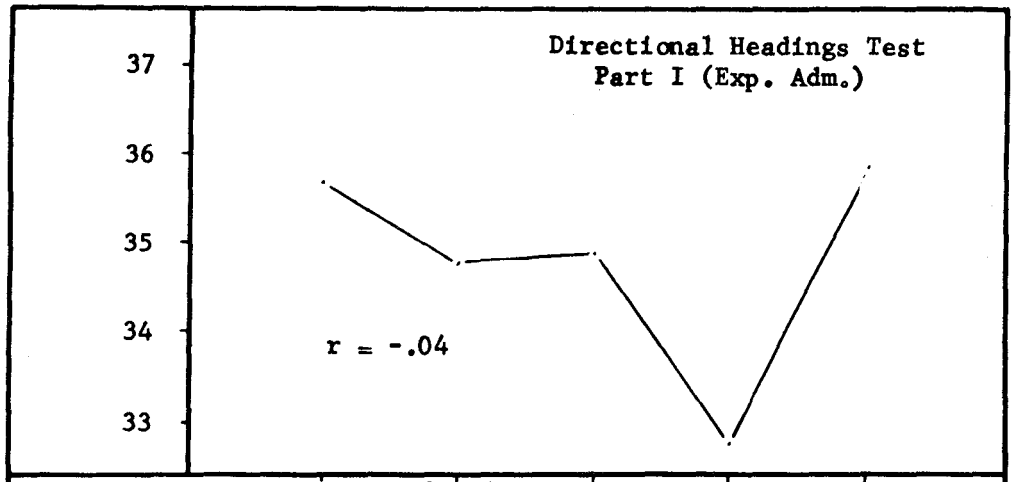
(Note: The mean score for the Ss aged 40 & older is significantly lower than the group means for Ss 24 and younger, 30–34, and 35–39.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	21	74	28	12	9
Mean	50.9	51.9	50.5	46.8	45.1
S.D.	5.9	6.8	6.9	8.2	9.7

FIGURE 15. Mean Performance Scores on the Brown-Carlsen Listening Comprehension Test (Parts A, B, C, D & E Combined) for 144 Ss Experimentally Tested at Time of Entry into Academy ATC Training.

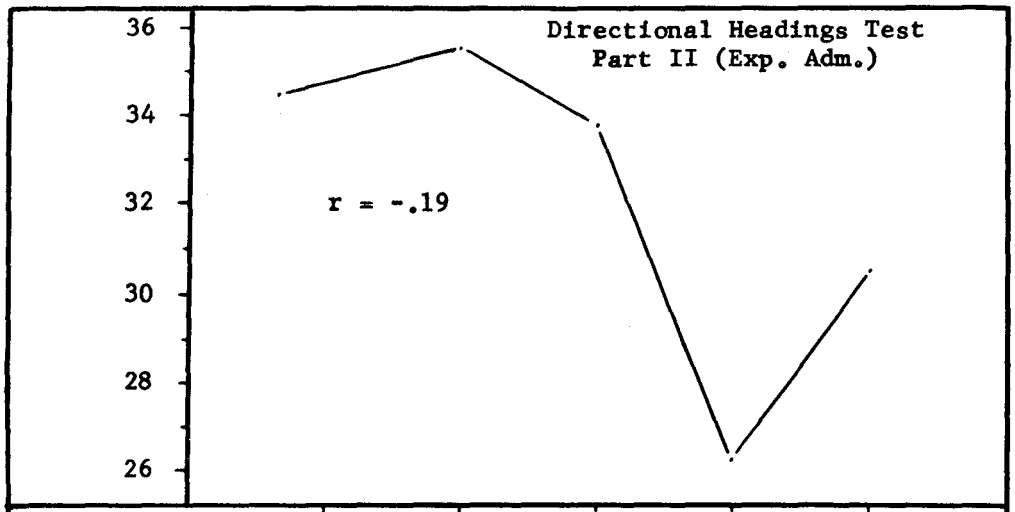
(Note: The mean scores of the Ss aged 40 and older and those 35 to 39 are significantly lower than the mean for Ss aged 25 to 29.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	18	74	26	18	17
Mean	35.7	34.8	34.9	32.8	35.9
S.D.	12.1	10.3	10.0	7.8	8.4

FIGURE 16. Mean Scores on Directional Headings Test Part I by Age Group for 153 ATC Trainees Who Took the Test Experimentally.

(Note: No differences between group means are significant.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	18	74	27	18	17
Mean	34.5	35.3	33.7	26.2	30.6
S.D.	15.3	10.5	11.6	13.3	10.2

FIGURE 17. Mean Scores on Directional Headings Test Part II by Age Group for 154 Students Who Were Administered the Test on an Experimental Basis at Time of Entry Into Academy ATC Training.

(Note: The mean performance level of the Ss 35–39 years old is significantly lower than the means of the trainees 25–29 and 30–34 years of age. Other differences are not significant.)

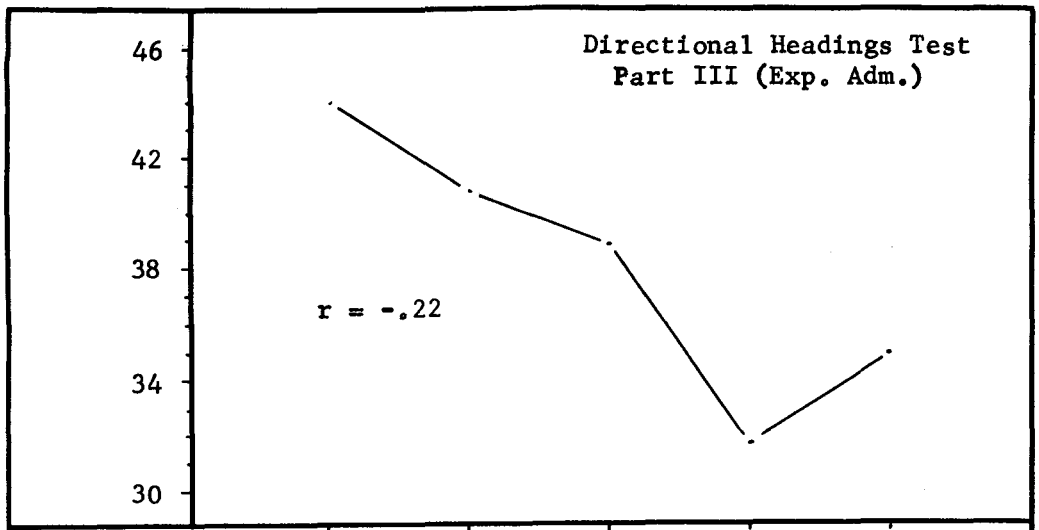
or interpretation of symbols, letters and degrees, the subject's tasks are to establish: true directional headings (Part I), the exact opposites of true headings (Part II), and the exact opposites of true headings while the administrator purposely attempts to disrupt performance by calling aloud the words, "East," "West," "North," and "South" (Part III). In constructing the test, Part I was deemed as a necessary "prelude" to Part II but it was assumed that most of the examinees would find it to be relatively easy and that the performance scores, due to their narrow range, would be of little or no use for purposes of individual differentiation. As expected, the performance scores for the 153 subjects were restricted in range and were negligibly related to age (i.e., −.04). On the other hand, the correlation of .27 between Part I and the A+L Grade Average emerged as a pleasant surprise.

The variance represented in the distribution of scores for Part II of the Directional Headings Test was considerably greater than that obtained for Part I. In general, most of the trainees under 35 years of age performed rather well and the lowest mean was for the group aged "35 to 39" rather than "40 & older." Differences between the performance means of the group aged "35 to 39" and two of the younger groups were statistically significant. However, the pattern of decline in the plotted means from the next-to-the-youngest group was not followed by the oldest group because three of the 17 trainees in the latter attained moderately good scores, resulting in a group mean above that characterizing the performance of those aged 35–39.

Scores on Part III of the Directional Headings Test were even more variable than the scores obtained for Part II. This was presumably due to the "conditions of distraction" under which the third part was administered. Based on a review of the answer sheets and comparisons of part scores attained by each subject, it appeared that some of the trainees of every age group became quite confused and experienced great difficulty in proceeding with the task—which was the same as presented in the second part. However, most of the examinees performed better on Part III than on Part II. In fact, all of the group means shown in Figure 18 are higher than those presented in Figure 17 for Part II. It should also be noted that the plotted group means on Part III reflect a consistent downward trend in performance from the youngest group of trainees to those of age "35 to 39." If three of the 15 oldest students had not attained moderately good scores, the downward trend would have been consistent across all age groups. Contrary to expectations however, no differences between the group means were found to be statistically significant.

E. *Locating Data Test.* Figure 19 reveals a progressive increase in the performance means from the youngest group to those aged "30 to 34" and then a rather sharp decline to the means of the two oldest groups. The authors speculate that the results relating to the Locating Data Test may have been confounded by effects associated with both chronological age and length of experience in military ATC work. The youngest trainees generally possessed less experience than those 25 to 29 years old and this may have been the reason why they experienced greater difficulty with the test. For the same reason, those 25 to 29 may have found the test more difficult than did those of age 30 to 34. Beyond 34, however, it is possible that the effects presumably associated with experience were outweighted by adverse effects associated with age. Although yet unpublished, a current study involving job proficiency measures of 600 journeymen ATCSs at 17 high-density IFR airports has shown that when the mean proficiency ratings are plotted for groups having differential lengths of FAA ATC service, there is an upward progression in the plot from the lesser experienced groups to the group having 12–13 years of experience followed by successively lower means for every group thereafter. The results are highly similar to those previously obtained in a corresponding study[6] of over 600 journeymen engaged in Air Route, or Center, control work. In both instances, the results suggest that, although tenure in FAA ATC work is an important asset, its influence is eventually overcome by adverse effects associated with age; the most notable changes occur at about 40 years of age. Thus, a somewhat corollary theory would explain the results obtained for the Locating Data Test with trainees having different lengths of experience in military control work.

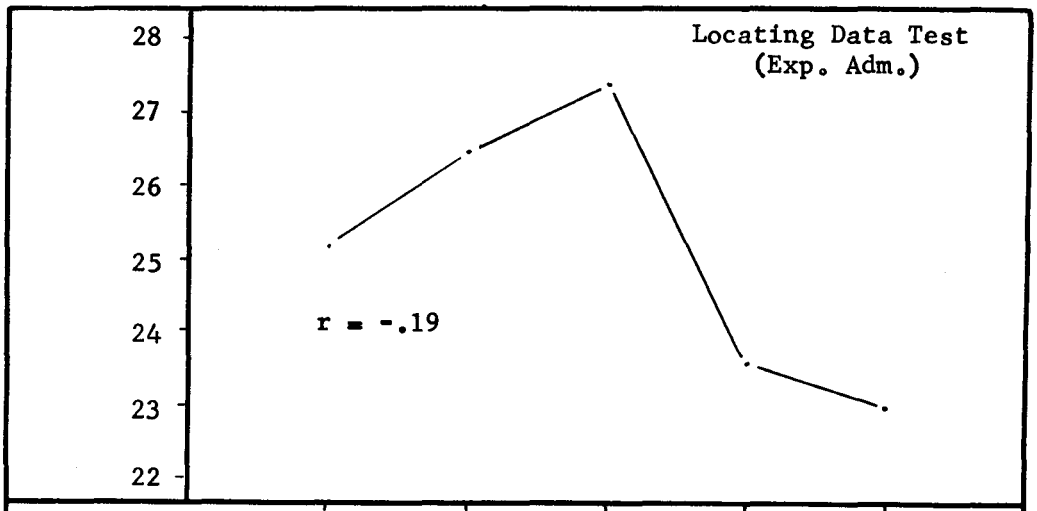
F. *ATP Problems and Following Oral Directions.* Figure 20 presents data for CSC 540 Air Traffic Problems (ATP). The plot closely resembles that previously shown for the Locating Data Test (see Figure 19) and, as before, the



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	8	41	13	9	15
Mean	44.1	40.8	39.0	31.8	35.0
S.D.	20.9	12.9	11.6	16.9	13.6

FIGURE 18. Mean Scores on Directional Headings Test Part III by Age Group for 86 ATC Trainees Who Took the Test Experimentally.

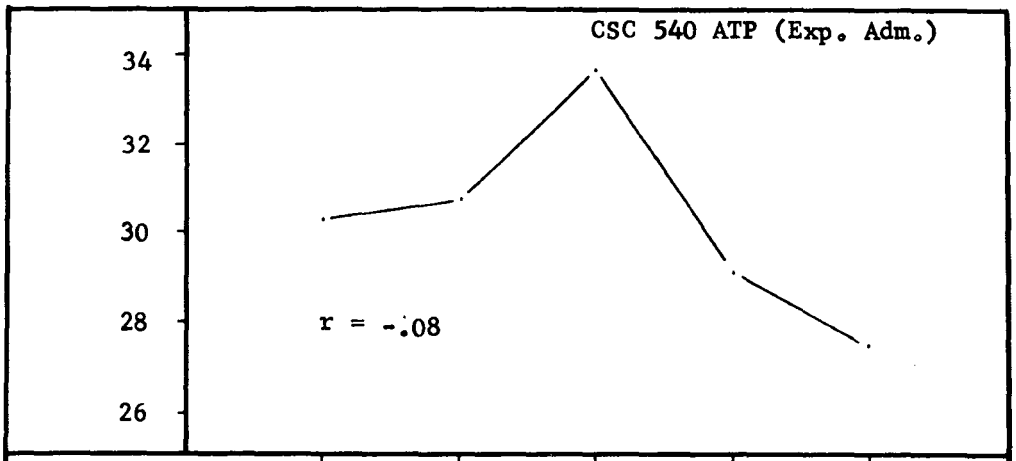
(Note: No differences between group means are significant.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	38	143	57	37	38
Mean	25.3	26.5	27.4	23.6	23.0
S.D.	5.8	4.9	6.1	5.3	5.4

FIGURE 19. Mean Scores on Locating Data Test by Age Group for 313 Students Who Were Administered the Test on an Experimental Basis at Time of Entry into Academy ATC Training.

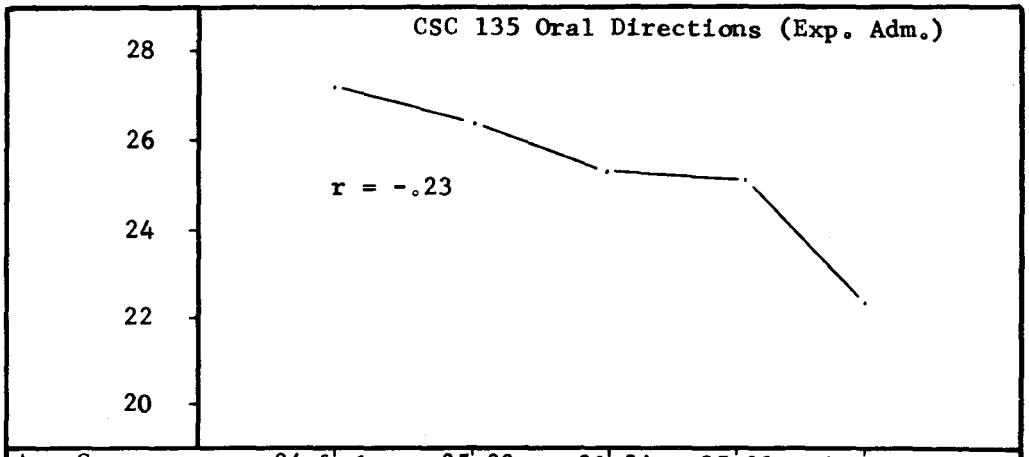
(Note: The mean performance scores of the Ss 35–39 years old and those 40 or over are significantly lower than the means of Ss in age groups 25–29 and 30–34. Other differences are non-significant.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	45	151	65	45	42
Mean	30.3	30.8	33.7	29.1	27.5
S.D.	10.5	10.7	12.1	10.1	12.0

FIGURE 20 Mean CSC 540 ATP Test Scores by Age Group for 348 ATC Trainees Who Took the Test Experimentally Upon Entry Into the Academy.

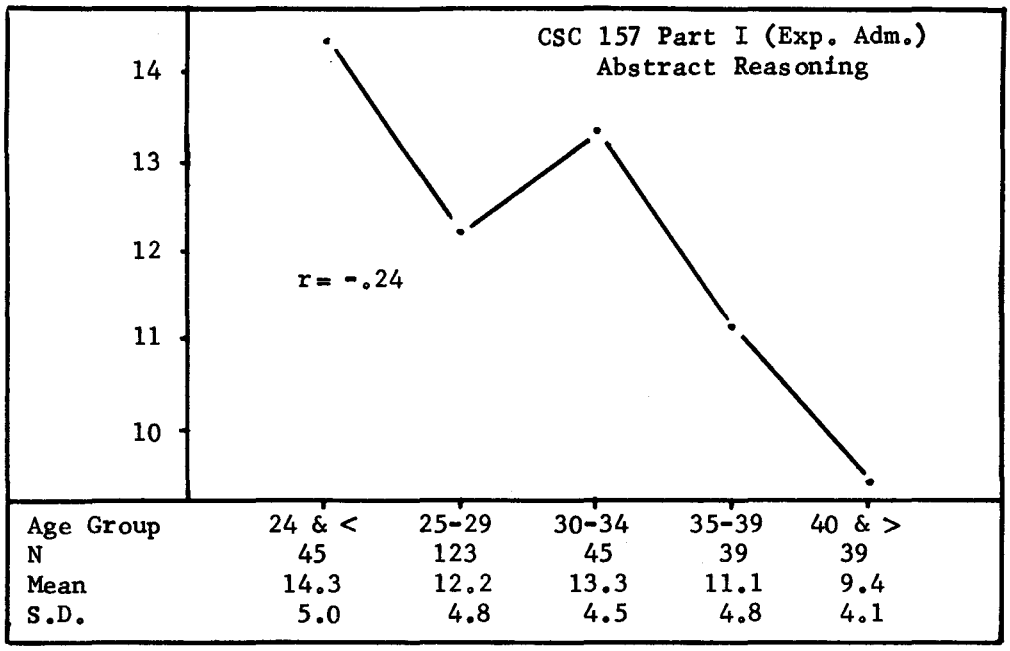
(Note: The mean performance scores of trainees 35–39 years of age and those 40 and older are significantly lower than that of the group 30–34. Other differences are not statistically significant.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	43	140	55	41	37
Mean	27.2	26.4	25.4	25.2	22.4
S.D.	4.1	5.6	4.7	5.9	5.0

FIGURE 21. Mean CSC 135 Oral Directions Test Scores by Age Group for 316 Students Who Were Administered the Test on an Experimental Basis at Time of Entry Into Academy ATC Training.

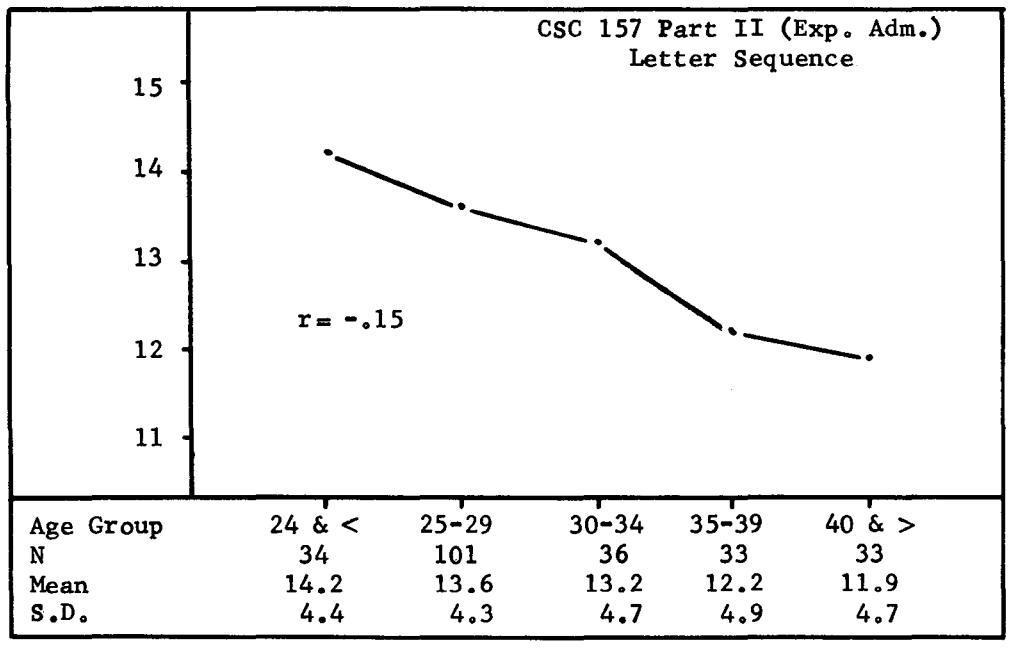
(Note: The mean score of the group 40 and older is significantly lower than the means of all younger groups. Other differences are not significant.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	45	123	45	39	39
Mean	14.3	12.2	13.3	11.1	9.4
S.D.	5.0	4.8	4.5	4.8	4.1

FIGURE 22. Mean CSC 157 Abstract Reasoning Scores by Age Group for 291 ATC Trainees Who Were Administered the Test Experimentally.

(Note: The mean score of the oldest group is significantly lower than the means of all younger groups except those aged 35–39. Other significant differences involve the youngest group versus groups 25–29 and 35–39, and the group 30–34 versus 35–39.)



Age Group	24 & <	25-29	30-34	35-39	40 & >
N	34	101	36	33	33
Mean	14.2	13.6	13.2	12.2	11.9
S.D.	4.4	4.3	4.7	4.9	4.7

FIGURE 23. Mean CSC 157 Letter Sequence Scores by Age Group for 237 ATC Trainees Who Took the Test on an Experimental Basis at Time of Entry Into ATC Training.

(Note: The only statistically significant difference is between the performance means of the youngest and oldest groups.)

authors advance the theory that the results are an outgrowth of interaction effects of age and length of experience in military control work. The performance means of the two oldest groups differed significantly from that of the group aged 30–34; all other differences were nonsignificant.

On CSC 135 Oral Directions, the highest mean score was for the youngest group and, although each older group performed at a successively lower level, the greatest difference between contiguous groups involved the trainees of age 35–39 and the oldest group (see Figure 21). In fact, the mean score of the trainees aged 40 and above was significantly lower than the means of all younger groups.

G. *Abstract Reasoning and Letter Sequence.* Performance measures on both parts of CSC Booklet 157 were also negatively related to chronological age. Figure 22 reveals that the youngest group performed better on Abstract Reasoning than any other group, and that the examinees aged "35 to 39" and those over 39 experienced considerable difficulty. Many of the differences involving the two oldest versus the three youngest groups were statistically significant.

The group means shown in Figure 23 for the Letter Sequence portion of CSC 157 reflect a consistent and moderate decline in performance from the youngest to the oldest group of trainees. Although the correlation of −.15 between age and this aptitude measure is statistically significant, it is not as great as implied by the slope of the plotted means. However, only one difference proved to be statistically significant; it was between the youngest and oldest groups.

IV. Summary.

The results obtained in this study consistently demonstrate that ATC trainees over 34 years of age tend to perform less well than their younger colleagues on a variety of paper-and-pencil aptitude tests. This investigation, in agreement with previous findings[17 18 19] has also shown chronological age to be significantly and inversely related to measures reflecting performance in the prescribed courses of basic training.

Although the subjects over age 34 represented only about 23 per cent of the 710 men involved in the entire study, their failure rate (31.1 per cent) in Academy ATC training was about three times that of the younger trainees. For the 88 subjects selected to constitute a "normalized" sample in terms of age, a correlation of −.31 was obtained between the overall Academic+ Laboratory Grade Average and age. Previous research,[17 18 19] based on samples in which age was not a selection factor, has shown age to correlate as high as −.38, and no lower than −.25, with a similar criterion measure.

The analyses accomplished in the first phase of the present study on the operationally-reported CSC ATC Aptitude Screening Test scores revealed that chronological age was negatively related to four of the five subtest measures and with the composite CSC Test score. Only one of the negative coefficients, the −.14 obtained for CSC 540, failed to be statistically significant. In the second phase, in which 14 different aptitude tests were administered on an experimental basis to subgroups of the 710 subjects, age was found to be negatively correlated with every performance measure, and in most instances, at a statistically significant level.

Based on successive examination and comparison of the mean performance scores of the subjects by age group on each of the various aptitude tests, there seems to be considerable evidence that trainees over age 34 are apt to perform less well than their younger classmates. Beyond age 40, these age-related decrements are likely to be even more pronounced.

All of the experimentally-administered tests, as well as most subtests of the operational screening battery, yielded substantial validities for prediction of training performance. Most notable in this respect were the following: CTMM Coins with a validity coefficient of .45; the WAIS Digit-to-Symbol subtest (r=.37); CTMM Inferences (r=.37); and CTMM Arithmetic (r=.37). The third part of the Press Test, CAMI Locating Data, and the Directional Headings Test also correlated appreciably with the overall measure of training performance. Such findings suggest the feasibility with which these or similar tests might be used in conjunction with some, or all, of the subtests of the CSC battery to further improve ATC-trainee selection procedures.

The findings pertaining to age in this study are pervaded by attenuation effects (the age range was 21–52 years and only 79 of the 710 trainees was over 40), and one may only specu-

late regarding the degree to which the findings *based on extended* age ranges might have been even more pronounced. Moreover, all the trainees possessed considerable pre-FAA ATC-related experience; most of them were former military controllers with exxceptional types or amounts of control experience; all were appointed to FAA ATC training with higher-than-normal pay grades, and although many had taken the operational CSC ATC Aptitude Screening Test before establishing final eligibility, all of them presumably qualified under standards whereby experience warranted exemption of the aptitude requirement.

These standards under which the trainees were recruited were predicated on the assumption that men having specialized experience would generally possess the aptitudes essential for rapid advancement in FAA training. Although results of this study (see Figure 4) indicate that about 45 per cent would have been declared ineligible for appointment had they been screened with the CSC Cbattery, they nevertheless represented a rather select group, both in terms of aptitude levels relative to a general population and in terms of pre-FAA ATC experience relative to that characterizing groups of trainees recruited under conventional standards.

Due to the nature of ATC work and the repetitive involvement of certain perceptual-integrative-mental functions in maintaining temporal and spacial separation of aircraft, the authors contend that, if age and other factors were held constant, experienced controllers would prrobably peform somewhat better than non-controllers on specific types of aptitude tests. In other words, if the effects of age could be legitimately partialed out, a moderate and positive relationship would probably be found between length of control experience and performance measures on many tests and particularly on those such as Numerical Facility, Air Traffic Problems, Locating Data, and Directional Headings.

In contrast with research regarding the relationship between age and performance measures of groups selected from the general population, the present study has pertained to a specific occupational group. Moreover, most of the subjects possessed highly specialized experience and all were relatively young. Although pervaded by attenuation effects, the results generally reflect a consistent negative relationship between age and the types of aptitudes measured.

V. Conclusion.

In view of the obtained interrelationships of age, the aptitude measures, and the training performance grades, it may be concluded that greater effectiveness in the screening and selection of the highly-experienced applicants for FAA ATC training could be attained if the eligibility standards were modified to include consideration of both age and aptitudes. If deemed desirable, the findings obtained in this study could provide the basis for formulation of a revised aptitude test battery which would screen from eligibility many of the older applicants—particularly a large proportion of those over 40 years old. The revised battery would also be more effective than the current battery in identifying the potential training failures at all age levels. It would, in many aspects, be advantageous to reinstate standards whereby a qualifying aptitude index would be required of all applicants, regardless of types and amounts of prior experience.

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