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16. Abstract

This study concerns the development and experimental validation of a novel aptitude test, referred to as "Directional Headings" (or DHT), for the selection of Air Traffic Control Specialist (ATCS) trainees. The test requires the subject to rapidly interpret letters, symbols, and degrees in order to determine: directional headings (Part I), the exact opposites of headings (Part II), and opposites of headings under conditions of aural distraction (Part III). The DHT was administered on an experimental basis to several hundred men as they entered basic ATCS training at the FAA Academy. The vast majority of the subjects had been selected for training on the basis of competitive ratings from among candidates who met exceptionally high qualifying standards in terms of operational aptitude test screening scores and/or evaluations of pre-FAA experience. Despite these pre-screening effects, the DHT scores correlated .41 with an overall measure of training performance. Moreover, over 44 per cent of the 115 examinees who failed the training course scored no higher than 29 on the DHT whereas over 85 per cent of the graduates scored 30 or higher. Reliability of the instrument, as determined by correlating the scores based on even-numbered items versus scores based on odd-numbered items, was .93.

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A PROPOSED NEW TEST FOR APTITUDE SCREENING OF AIR TRAFFIC CONTROLLER APPLICANTS

I. Introduction.

This report pertains to the development and experimental validation of a new, highly-speeded, and rather novel paper-and-pencil type aptitude test and discusses its potential as an additional screening device for improving the validity of the Federal Aviation Administration's (FAA) selection of personnel for training as Air Traffic Control Specialists (ATCSs). The test, referred to as the "Directional Headings Test" (DHT), was developed by the Aviation Psychology Laboratory of the FAA's Civil Aeromedical Institute (CAMI). In seeking to establish whether the findings justify operational implementation of the DHT, it is important first to consider the nature and effectiveness of tests currently being used in the selection process.

The Current ATC Aptitude Test Battery

A. *Validation of CSC Test Battery.* Prior to 1964, the FAA's screening and selection of personnel for ATC training generally involved no formal assessment of an applicant's mental abilities or aptitudes. Beginning in July 1962, and for 18 months thereafter, aptitude measures were considered in the selection of a limited number of trainees who possessed little or no previous job-related experience. From January 1964 through October 1968, a qualifying aptitude index, reflecting performance on a battery of six Civil Service Commission (CSC) tests, constituted a major eligibility requirement of *all* applicants—regardless of their experience and other qualifications. The aptitude screening index was an outgrowth of extensive research conducted by CAMI during 1961 through 1963.[4 18 19]

Specifically, the six CSC tests were identified from among 27 experimentally administered instruments as yielding the best composite measure (of aptitudes) for prediction of training performance. One of the tests, designated as CSC Booklet 24, provided a measure of numerical ability. Others were: CSC 51, which pertained to spatial relationships; CSC 135, "Following Oral Directions"; "Abstract Reasoning" and "Letter Sequence," both of which were parts of CSC Booklet 157; and a special, omnibus test called "Air Traffic Problems" which the American Institute of Research developed in 1950 for the CAA. The latter was ultimately designated as "CSC 540." In that research, the CSC Battery was administered to a total of 893 men as they entered Academy ATC training. The results of subsequent analyses included a product-moment correlation of .51 between the CSC composite scores and a variable which reflected an average of each individual's examination grades and laboratory performance ratings, and a point-biserial correlation of .40 between the CSC measure and Pass-Fail status. More importantly, an examination of the data to determine a "cutting score" for screening purposes revealed that 182 (or 67.1 per cent) of the 271 training-course attritions failed to attain CSC scores of 190 or higher as compared with 222 (or only 37.5 per cent) of the 622 who successfully completed the course. However, in developing the new standards for implementation in January 1964, officials chose to establish 210, rather than 190, as the minimum qualifying score. This relatively high screening hurdle was instituted because records indicated that the number of applicants had, for several months, vastly exceeded the number of ATC trainee positions, and a further reduction in the recruiting of ATC personnel was anticipated. As shown in the upper portion of Appendix A, 576 (or 64.5 per cent) of the 893 trainees involved in the validation study scored less than 210 on the CSC Battery. Although 357 (or 62 per cent) of the 576 passed Academy training, 219 did not, and the 219 represented 81 per cent of the 271 training failures within the entire sample. Selection

fronted in research aimed at progressive improvement of personnel selection procedures. It is commonly referred to as "the problem of creeping criteria" and, inasmuch as officials responsible for training traditionally strive to upgrade their programs, it is a problem that is normally and hopefully anticipated.

The authors of the present report hypothesize that the FAA has also followed much the same pattern: that ATC training programs and performance evaluation standards have been upgraded; that the changes (the exact nature and extent of which would be difficult to determine reliably) are partially attributable to training requirements associated with the increasing complexity of the air traffic management system and in part to the inherent tendency of training personnel to "customize" instructional material, instruction, and/or subjective performance evaluation standards relative to the general level and range of mental abilities characterizing the incoming clases. Moreover, the vast majority of trainees recruited since 1963 have been of exceptional mental calibre and, thereby, comprise groups which would be characterized by substantial restriction of range of aptitudes.

D. *Rationale for Improving Aptitude Screening.* There are a number of reasons why it may be assumed that some improvement in the current aptitude screening process might be achieved. First, the air traffic management system has undergone change in recent years, and it is possible that the job tasks now require certain mental skills supplementary to those currently being assessed.

Moreover, the research in which the six CSC tests were initially validated also yielded appreciable validities for a number of other CSC tests and several commercially-published copyrighted instruments. The latter group included several tests which apparently involved a speeded perceptual-discrimination factor and some which pertained to either coding skills, comprehension, rapid integration or processing of information, or memory. Although none of these tests appeared in the group which the multiple regression analyses indicated most useful for selection purposes, the results led us to suspect that the instruments were measuring important ATC-related aptitudes albeit inadequately. Such findings, supplemented by those obtained for a number of different spatial tests, were interpreted as illustrating the need for development of tests "tailored" to fit the purpose.

While none of the various spatial tests included in CAMI's numerous experimental batteries has failed to validate at statistically significant levels, the validities of each have generally been much more variable from sample to sample than for non-spatial tests. This also applies to CSC Booklet 51 of the operational screening battery. We concluded several years ago that a "visual imagery" type of speeded spatial ability was a major determinant of ATC performance, but we were unable to locate an instrument fully appropriate in this respect. The development of a special test, the complexity of which would have required a major research effort, was not undertaken due to other research commitments having higher priorities.

II. Procedure.

The Directional Headings Test should be considered as a fortuitous outgrowth of developmental efforts which were undertaken on a somewhat intuitive basis rather than a consequence of extensive background research, job activity analyses, and the like. It was developed "in house," within a period of only four weeks by personnel of CAMI's Psychometrics Unit who interpreted the research findings discussed immediately above as indicating that the aptitude screening process might be further improved through more adequate assessment of the applicants' speeded perceptual-discrimination and coding (or decoding) skills. In conceiving the type of task ultimately embodied in Part 1 of the DHT, the initial exploratory effort focused upon the use of diagrams simulating a navigational compass. However, the pictorial approach was abandoned on the hypothesis that if the data pertinent to the solution of each problem were presented in a different format, such as described below, the test would be more difficult and therefore provide better opportunity for individual differentiation.

The DHT is a 3-part test in which the subject is allowed a total of only 90 seconds for the solution of 60 items, or problems, of each part. In each problem, the subject is presented one, two or three "bits" of information relating to the cardinal points on a mariner's compass. For example, the letter "N," the symbol "∧," and

the notation "360°" each denote "North." Similarly, the letter "E," the symbol ">" and "090°," either separately or in combination, denote "East." Other letters, symbols, and degrees correspond to "South" and "West." In Part I of the test, the examinee must rapidly interpret and collate the bits of presented information in order to ascertain whether the data are of a conflicting nature and, if not conflicting, then determine the directional heading to which they correspond; in Part II, he must determine the exact opposite of the heading: and, in Part III, he must ascertain the exact opposite of the directional heading while being subjected to aural distraction. In each item of Form A, the bits of information are followed by one of five questions: "North?", "East?", "South?", "West?", or "Conflict?". The subject is offered two response categories, "Yes" or "No." Approximately one-fourth of the items present "conflicting" data. For example, if the letter "S" were presented in an item of Part I with the symbol ">" and/or "270°" and if the question were "Conflict?", a correct answer would be indicated by marking the space under "Yes." On the other hand, the same conflicting data presented with "West?" (or "North?", "East?", or "South?") would warrant a "No" answer.

The first tentative version of the test consisted of only one part, with the task being essentially the same for all 60 items. Small groups of Academy ATC trainees were examined with the instrument and, although no validation analyses were possible at that time, considerable range and variance were found in the distribution of scores. Moreover, during test sessions, some individuals in every group appeared to become rather confused, or frustrated, when confronted with those items in which "conflicting" bits of information were presented and also hesitant in marking either "Yes" or "No" to many of those items where the questioned direction (e.g., North?") failed to conform to the heading indicated by the data provided. When the CSC battery was being validated some eight years earlier, reactions of much the same type had been noted for many of the trainees during their assessment with CSC 135 Following Oral Directions. Inasmuch as CSC 135 proved to be one of the most valid components of the screening battery, we hypothesized that many of the trainees who had performed poorly on the instrument might have done so because they had a "low frustration tolerance level." Although the latter phrase and the hypothesis to which it alludes are rather loosely formulated, they grossly reflect the reasoning which led to the development of Parts II and III of the DHT.

As mentioned earlier, Part II is similar to Part I except that in each item the subject is asked whether a specified direction represents the direct opposite of the heading. Part III is like Part II but the examinee is subjected to possible distraction by the aural presentation of the randomly arranged words, "West," "South," "East," "North," and "Conflict." The resulting 3-part instrument, in which the examinees were offered no response categories other than "Yes" or "No," was designated as "CAMI Directional Headings Test—*Form A*."

An alternate version of the test, Form B, was eventually developed; it offered five response categories. In each item of the latter, the "bits" of information are presented in the same manner as in Form A but the "question element" does not appear and the examinee merely indicates the answer he deems correct by marking a response space under one of the five columns laeled, "East," "South," "West," "North," and "Conflict."

Form A of the DHT was administered on an experimental basis to a total of 586 students as they enrolled at the FAA Academy during 20 January 1970 through 13 March 1970 in either the basic ARTCC or TATC training course. Form B was administered on a similar basis to 199 trainees, all of whom entered the Air Route course on 27 March 1970. The vast majority of the 785 trainees examined with either Form A or Form B were new hirees and none possessed an FAA ATCS certificate. For purposes of analysis, however, the cases were divided to establish the samples and subsamples described below.

A. *Sample 1.* Form A was administered to 388 ARTCC, or En Route, students who were designated as Sample 1. Of the 388, one entered training at the GS–5 level and 361 at the GS–7 level; the former case was added to the 361 and the group was thereafter referred to as subgroup "1A–En Route–GS–7." The remaining 26 En Route examinees entered at the GS–9 level. They constituted the subgroup "1B–En Route–GS–9."

B. *Sample 2.* The 198 students assessed with Form A of the DHT as they entered the TATC basic training course represented Sample 2. One was a GS–5, 141 were GS–7's, 55 were GS–9's, and one was GS–11. The GS–5 was merged with the GS–7's to establish the subgroup "2A–Terminal–GS–7." The remaining cases comprised the subgroup "2B–Terminal–GS–9."

C. *Sample 3.* Only 199 trainees were examined with Form B of the DHT. They were designated as Sample 3. The subgroups were "3A–En Route–GS–7" and "3B–En Route–GS–9," with N's of 187 and 12, respectively.

The question had arisen during the development of the DHT as to whether past experience in control work would serve as a major determinant of test performance. Unfortunately, official records of the experiential backgrounds were unavailable for many of the trainees who took the test. However, there were reasons to believe that, by maintaining separateness of the test data for the GS–7's and GS–9's, certain phases of the analyses might yield some information bearing upon the issue. It was presumed that most subjects who entered with a pay grade above GS–7 received their appointment to training on the basis of exceptional pre-FAA experience (usually in military air traffic control work) and that, on the same basis, they were automatically exempted from the aptitude screening requirement. Knowledge of FAA recruiting practices suggested that the vast majority of the GS–7 DHT examinees were probably men with moderate-to-appreciable amounts of pre-FAA ATC-related experience who, in establishing their eligibility for selection, were required to pass the CSC ATC Aptitude Screening Test Battery. It was recognized that the experience backgrounds of the GS–7's and GS–9's could not be considered representative of applicant groups. However, it was reasoned that *if* the analysis revealed *no* significant differences between the mean DHT scores of the GS–9's and GS–7's, the issue regarding possible differential effects of lesser amounts of experience (than possessed by most GS–7's) would warrant little concern because the FAA traditionally recruits a very small proportion of its trainees from among those applicants having relatively little or no previous ATC-related experience. On the other hand, if the GS–9's performed at a significantly higher level than the GS–7's, it would then be unwise to recommend that the DHT be used as an operational screening device.

D. *DHT Scoring Procedures.* A formula of "right responses minus wrong" was employed in the scoring of Form A of the DHT because only two response alternatives (i.e., "Yes" and "No") were offered for each item. Form B, with a 5-choice response format, was scored in accordance with the formula "rights minus one-fourth the wrongs." Scores involving fractions were always rounded to the nearest whole number.

Inasmuch as differences, as well as similarities, characterized the tasks presented in Parts I, II, and III, it was postulated that the parts might prove unequal in terms of difficulty and it was also felt that the parts might yield contrastingly different validities. Consequently, the three parts were scored separately. An *arithmetic mean* of each subject's part scores, rather than a sum of the part scores, was obtained to serve as the global measure. The mean score is referred to in the present report as either "The Total Average Score" or simply as "The DHT Score." The latter, as well as the part scores were analyzed to determine their respective relationships with the criteria. In addition, a number of similar analyses were undertaken regarding the differences between the summary DHT measure (i.e., "Average Score") and each of the part scores of the subjects and differences between the part scores themselves.

E. *Criterion Variables.* Academy training officials provided CAMI with an "Evaluation of Performance Record" for each of the trainees who participated in the experimental testing program. The evaluation form for the ARTCC trainees was not identical to that employed in evaluating TATC training-course performance. Nevertheless, each provided grades which permitted derivation of a similar, corresponding measure of performance for each subject, regardless of training option. The summary measure, referred to as the "Combined Academic and Laboratory Grade Average" or "A+L," represented an arithmetical mean of two separate averages; one based on all examination grades relating to academic materials, instruction, and the like, and the other based on performance grades for simulated air-traffic-control work in the laboratory.

The second criterion variable was "Pass-Fail Status" or "P-F." Students whose records bore the notation "Withdrawn in Failing Status" were designated as "Fails"; those who were withdrawn for other reasons were deleted from the study, and all others were considered as "Passes."

In accomplishing some of the analyses, every subject who passed training was categorized either as a "Marginal Pass" or "Non-Marginal Pass." The "Marginal Pass" category was established separately for each sample, irrespective of GS level. First, the "Fail" cases were extracted; next, the A+L Grades of all non-fail subjects in a given sample were arrayed from low to high, and those comprising approximately the lower one-fourth of the grade distribution were designated as "Marginal Passes."

F. *CSC Test Scores.* It was postulated that if the DHT scores of the pre-screened groups of trainees should validate at statistically significant levels for prediction of the training performance measures just described, there would be little doubt that the instrument would validate at higher levels with applicant groups. Nevertheless, additional information bearing upon the interpretation of the attenuated validities could be obtained if the CSC Test Scores and/or evaluations of pre-FAA ATC-related experience were included in the scheduled analyses. Such data were available for a portion of the trainees comprising each validation sample but, as will be discussed, there were reasons to suspect bias in the data.

The development and validation of the DHT was undertaken in conjunction with, and as part of, a comprehensive project which had been initiated in response to a request by the FAA Director of Personnel (PN–1) for updated research on factors associated with successful performance in ATC training. (Other aspects and findings of the latter will be discussed in subsequent reports.) In connection with the requested research, PN–1 wrote to all regions specifying that CAMI be provided a report on each trainee at time of entry into the Academy; the report was to reflect the trainee's overall eligibility rating and other types of information. Most importantly, if the trainee had been assessed with the operational CSC ATC Aptitude Test Battery, the report was to include all subscores (i.e., scores on each CSC test booklet) as well as the complete aptitude measure.

Records were ultimately forwarded to CAMI for about nine-tenths of the 3,579 trainees involved in the larger project but many of them were incomplete. Researchers received CSC Test Scores for less than 52 per cent of the entire group although it was estimated that 70 to 75 per cent had probably been operationally examined with the battery. Unfortunately, insofar as research purposes were concerned, scores on the aptitude screening battery were forwarded for a much smaller proportion of the training failures than for Academy graduates.

In the present study, the 504 GS–7 trainees of Samples 1 and 2 who were administered Form A of the DHT were also administered a questionnaire which included the following two items: (1) "Have you ever been examined with the CSC ATC Aptitude Screening Test Battery?" (2) "If so, please indicate the number of times you took it, and for each time, also indicate the approximate date and the city in which examined." Exactly 95 per cent of the total group of 504 GS–7's indicated that they had been tested one or more times. (Slightly over 97 per cent of the 102 training-course failures within the group claimed they had taken the battery on an operational basis.) However, performance scores on the battery were forwarded to CAMI for only 281 of the 504. Moreover, the 281 represented 62.2 per cent of the 402 pass cases but only 30.4 per cent of the 102 failures. Inasmuch as the CSC Test Scores were available for disproportionately fewer training-course failures than for pass cases, it was presumed that the analyses to be undertaken in this study would yield grossly attenuated validity coefficients for the operationally-derived aptitude measures and that the correlations involving the latter and age and other variables would also be affected.

G. *Pre-FAA ATC-Related Experience.* The questionnaire which CAMI administered to the DHT examinees also contained a section which pertained to ATC-related experience. Specifically, the instructions requested that each trainee indicate whether he had ever held a license, certificate, or rating as a "pilot" and/or in "air traffic control work" and/or in the field of "communications." Although 170 trainees

replied "No" to each of the three areas, the remainder checked one or more. These responses provided the basis for assigning each case to one of eight mutually exclusive categories, with one of the categories reflecting certificated experience in all three fields. An analysis was then scheduled to assess possible effects of experience on DHT scores.

H. *Limited Research on Form B of the DHT.* As pointed out earlier, Form A of the DHT was administered to a total of 586 traineers (Samples 1 and 2) whereas only 199 trainees (Sample 3) were examined with Form B. Academy training schedules were rearranged soon after Form B was developed, thereby precluding further experimental test sessions. Several different analyses accomplished on the data of Form A examinees were not undertaken with Sample 3. Inasmuch as it was determined very early in the study that the two forms were highly comparable in terms of both validity and reliability, it was assumed that if other corresponding analyses of data for the Form A and Form B groups were undertaken, they also would yield comparable findings. Research efforts were therefore focused primarily upon Form A.

III. Results and Discussion.

After scoring the DHT answer sheets, each examinee's scores on Parts I, II, and III were averaged to obtain the overall measure of performance (i.e., "The DHT Score"). The first analysis, which pertained to the Form A examinees only, involved a comparison of the frequency distributions of the DHT Scores of the graduates and non-graduates of the ARTCC and TATC training courses. The distributions are shown in Table I. As may be noted, the graduates of each training course tended to attain higher scores than the non-graduates. The 329 ARTCC graduates averaged 38.5 on the three parts of the test whereas their 59 attrited classmates averaged 31.0. Similarly, the mean score for the 142 TATC graduates was 39.0 while the 56 who failed averaged 31.0. Both differences were statistically significant at the .01 level. Moreover, three of the En Route graduates attained perfect scores of 60 whereas the highest score of any attrited ARTCC trainee was 55; one subject within each subgroup scored only 01. Three of the TATC graduates scored 56 on the test and none scored lower than 13, whereas the scores for the Terminal failures ranged from 50 down to 05. Other differences between the score distributions of the passes and fails, and their bearing upon a recommended screening standard, will be discussed in one of the later sections of this report.

When the frequencies of the Form-A DHT Scores of the passes and fails were merged, the resulting distributions (which are not shown) proved to be much alike. Although that of Sample 1 reflected somewhat greater range and variability of performance, both were slightly skewed in a negative direction. Moreover, the difference between the means of 37.4 and 36.7 (for Samples 1 and 2, respectively) was not statistically significant. Inasmuch as 60 represented the maximum possible (average) score on the three parts, the range and distribution of performance measures for each group were considered quite satisfactory in that they provided no basis for questioning the difficulty level and/or timing of the test.

A. *Intercorrelations and Empirical Validities of DHT and CSC Test Scores.* A point which warrants emphasis is that the three parts of the DHT present different tasks or task situations. Considering these differences, the authors expected that the intercorrelations of the part scores would be of relatively moderate magnitude. The Pearson product-moment correlation coefficients,[11] reflecting the interrelationships, are shown, along with other data, in Table II. The correlations (or "r's") ranged from .46 to .7 for Part I versus Part II, .29 to .69 for I versus III, and from .67 to .88 between the scores on Parts II and III. In each instance, however the lowest of the coefficients pertained to Subsample 2A. Otherwise, the coefficients ranged from .64 to .77 for I versus II, .58 to .69 for versus III, and from .81 to .88 for II versus III. The narrow range of the latter would imply that the test possessed a fair degree of reliability. The authors re-examined all data relating to Subsample 2A but found no computational errors or reasons why the intercorrelations were lower than obtained for any other group.

The hypothesis that examinees would generally experience greater difficulty with Part II than Part I proved rather tenuous. For every sample and subsample, the mean score on Pa

TABLE I.—Distribution of Form-A Directional Headings Test scores for 388 ARTCC and 198 TATC Trainees who were examined upon entry into FAA Academy training.

Form-A D.H. Test Score	Sample 1 Enroute or ARTCC Trainees: Graduates f	Graduates Cum. f	Graduates Cum. %	Non-Graduates f	Non-Graduates Cum. f	Non-Graduates Cum. %	Sample 2 Terminal or TATC Trainees: Graduates f	Graduates Cum. f	Graduates Cum. %	Non-Graduates f	Non-Graduates Cum. f	Non-Graduates Cum. %
56 & >	13	329	100.0		59	100.0	3	142	100.0		56	100.0
54 - 55	1	316	96.0	3	59	100.0	4	139	97.9		56	100.0
52 - 53	10	315	95.7	3	56	94.9	5	135	95.1		56	100.0
50 - 51	17	305	92.7		53	89.8	7	130	91.5	1	56	100.0
48 - 49	17	288	87.5	3	53	89.8	6	123	86.6		55	98.2
46 - 47	19	271	82.4	2	50	84.7	12	117	82.4	2	55	98.2
44 - 45	16	252	76.6	1	48	81.3	5	105	73.9	1	53	94.6
42 - 43	33	236	71.7	4	47	79.7	18	100	70.4	4	52	92.9
40 - 41	32	203	61.8	1	43	72.9	11	82	57.7	6	48	85.7
38 - 39	38	171	52.0	3	42	71.2	12	71	50.0	3	42	75.0
36 - 37	27	133	40.4	2	39	66.1	12	59	41.5	4	39	69.6
34 - 35	27	106	32.2	4	37	62.7	12	47	33.1	2	35	62.5
32 - 33	16	79	24.0	4	33	55.9	6	35	24.7	6	33	58.9
30 - 31	14	63	19.1	3	29	49.2	9	29	20.4	2	27	48.2
28 - 29	10	49	14.9	3	26	44.1	2	20	14.1	4	25	44.6
26 - 27	9	39	11.9		23	39.0	8	18	12.7	3	21	37.5
24 - 25	4	30	9.1	5	23	39.0	3	10	7.0	7	18	32.1
22 - 23	7	26	7.9	5	18	30.5	2	7	4.9	3	11	19.6
20 - 21	2	19	5.8	2	13	22.0		5	3.5	1	8	14.3
18 - 19	2	17	5.2	3	11	18.6	1	5	3.5	3	7	12.5
16 - 17	7	15	4.6	1	8	13.6	2	4	2.8	1	4	7.1
14 - 15		8	2.4		7	11.9	1	2	1.4	1	3	5.4
13 & <	8	8	2.4	7	7	11.9	1	1	.7	2	2	3.6
Mean D.H. Score*												
Graduates:			38.5						39.0			
Non-Grads:						31.0						31.0
Stnd. Deviation												
Graduates:			10.2						9.2			
Non-Grads:						14.3						9.9

*Each mean and S.D. is based on ungrouped test performance data

TABLE II.--Intercorrelations and validities of Directional Headings Test measures and CSC-ATC Test scores.

Sample and Type	Variable	N	Mean	S.D.	Part II	Part III	Total Avg. Score	CSC* ATC Batt. Score	Training Criteria A+L	Training Criteria r pbi** P-F
1A, Enroute GS-7's	DH-A, Part I	362	37.4	9.5	.64	.58	.78	.24	.28	.14
	DH-A, Part II	362	36.6	12.4		.82	.93	.23	.31	.21
	DH-A, Part III	362	39.1	13.9			.93	.30	.36	.25
	DH-A, Avg. Part Score	362	37.5	11.2				.29	.38	.24
	CSC-ATC Test Battery	212	248.2	20.7					.13	.04
	Acad.+Lab Trng. Grade	362	88.1	5.3						.63
1B, Enroute GS-9's	DH-A, Part I	26	35.8	10.7	.77	.59	.80		.64	
	DH-A, Part II	26	34.0	12.4		.84	.95		.46	
	DH-A, Part III	26	37.1	15.8			.93		.35	
	DH-A, Avg. Part Score	26	35.2	12.4					.50	
	CSC-ATC Test Battery*	9	245.8	34.7						
	Acad.+Lab Trng. Grade	26	90.8	4.4						
2A, Terminal GS-7's	DH-A, Part I	142	37.1	8.5	.46	.29	.64	.12	.32	.28
	DH-A, Part II	142	33.9	13.4		.67	.91	.16	.45	.31
	DH-A, Part III	142	37.3	14.6			.85	.11	.45	.28
	DH-A, Avg. Part Score	142	36.2	10.0				.15	.50	.35
	CSC-ATC Test Battery	69	238.1	21.4					.14	-.04
	Acad.+Lab Trng. Grade	142	79.1	8.2						.73
2B, Terminal GS-9's	DH-A, Part I	56	38.0	9.0	.68	.63	.81		.33	.36
	DH-A, Part II	56	36.1	11.6		.88	.96		.33	.28
	DH-A, Part III	56	40.9	11.9			.93		.39	.32
	DH-A, Avg. Part Score	56	38.2	9.9					.38	.34
	CSC-ATC Test Battery	4	231.8							
	Acad.+Lab Trng. Grade	56	80.4	8.9						.86

*Correlation coefficients were not obtained because CSC Test scores were available for only 9 cases of Sample 1B and 4 cases of Sample 2B

**Point-biserial coefficients were not computed for Sample 2 because only 2 of the 26 cases were classified as training-course failures

II was lower than that on Part I, but only one such difference—involving Subsample 2A—was statistically significant. (The performance means pertaining to Form A appear in Table II and those relating to Form B appear in Figure 1.) The authors also hypothesized that a sizable proportion of the trainees would be adversely affected by the "conflicting noise" imposed during administration of Part III. Contrary to expectation, the Part III mean score exceeded that of Part II for every sample and subsample and all mean differences except those relating to Sample 3 and Subsample 1B were statistically significant. Moreover, a review and comparison of each individual's part scores revealed relatively few instances of performance decrements from Part II to Part III. However, no definite conclusions can be made regarding either of the above hypotheses because the results are presumably confounded by learning effects.

Scores on the separate and combined parts of each version of the DHT validated at substantially higher levels for prediction of the A+L Grades than for pass-fail status (see Table II and the tabular data presented with Figure 1). For the four subgroups of Form A examinees, the correlations between the composite DHT scores and the A+L Grades ranged from .38 to .50 while those relating to pass-fail status ranged from .24 to .35. The overall scores of the 187 Form B examinees correlated .44 with the training-course grade averages and only .15 with the alternate criterion.

All such validity coefficients pertaining to the overall scores on either form of the DHT are statistically significant. Each is also significantly higher than the corresponding coefficient obtained for the CSC ATC-Aptitude-Screening Test score. However, the validity indices presented for both the operational screening battery and the two versions of the DHT should be regarded as grossly attenuated because they are based on data pertaining to individuals who had been selected from among those who had fully met the FAA's existing ATC-personnel-screening standards. Had formulae been applied to estimate the correction for restriction-of-range effects, the resulting coefficients would have been larger, and in some instances of much greater magnitude, than those actually obtained. For example, if the correlation of .13 (see Table II) between the CSC ATC Test Score and A+L Grade were adjusted (relative to the ratio of variances in the performance measures of the subjects of the current study and the 893 ATCS trainees who participated in the original validation of the CSC Battery), a coefficient of .25 would result. Such estimated values are not shown in the present report. Instead, the authors have followed a more conservative approach and have presented only the un-corrected validity coefficients.

B. *Correlations Between Scores on Odd- and Even-numbered Items.* Correlations of scores based on odd-numbered items versus scores based on even-numbered items were computed for Form A for the 362 GS–7 En Route trainee subjects only. They were: .92 for Part I; .94 for Part II; .93 for Part III, and .93 for the scores representing an average of the three parts. Similar procedures were employed with the response data of the 187 GS–7 En Route Form B examinees. The resulting correlations were .93, .96, .93, and .95 for Parts I, II, III, and the combined parts, respectively. Such coefficients, however, should be regarded as inflated estimates of reliability because the DHT is admittedly a highly-speeded test and it is known that most speeded tests are apt to yield relatively high correlations between measures reflecting performance on odd- and even-numbered items, particularly when the items, like those of the DHT, do not represent a wide range of difficulty.

C. *Effectiveness of DHT Scores in Predicting "Fail," "Marginal Pass," and "Non-Marginal Pass" Cases.* The effectiveness with which the scores on Form A of the DHT might be used to forecast three categories of performance in the ARTCC training course is illustrated in Figure 2. Prior to undertaking the series of analyses which produced the results depicted in Figures 2, 3, and 4 (which all follow the same format), we inspected the frequency distributions presented in Figure 1 and decided that a DHT Score (i.e., an average of the part scores) of 29 represented the best choice for a "cutting score" or theoretical screening cut. Analyses were then accomplished using score intervals of "29 &<," "30–39," and "40 &>."

Looking first at the upper set of bar graphs in Figure 2, it may be noted that 69 of the 362 En Route GS–7 trainees scored 29 or less on the DHT and that 25 (36.2 per cent) of the 69

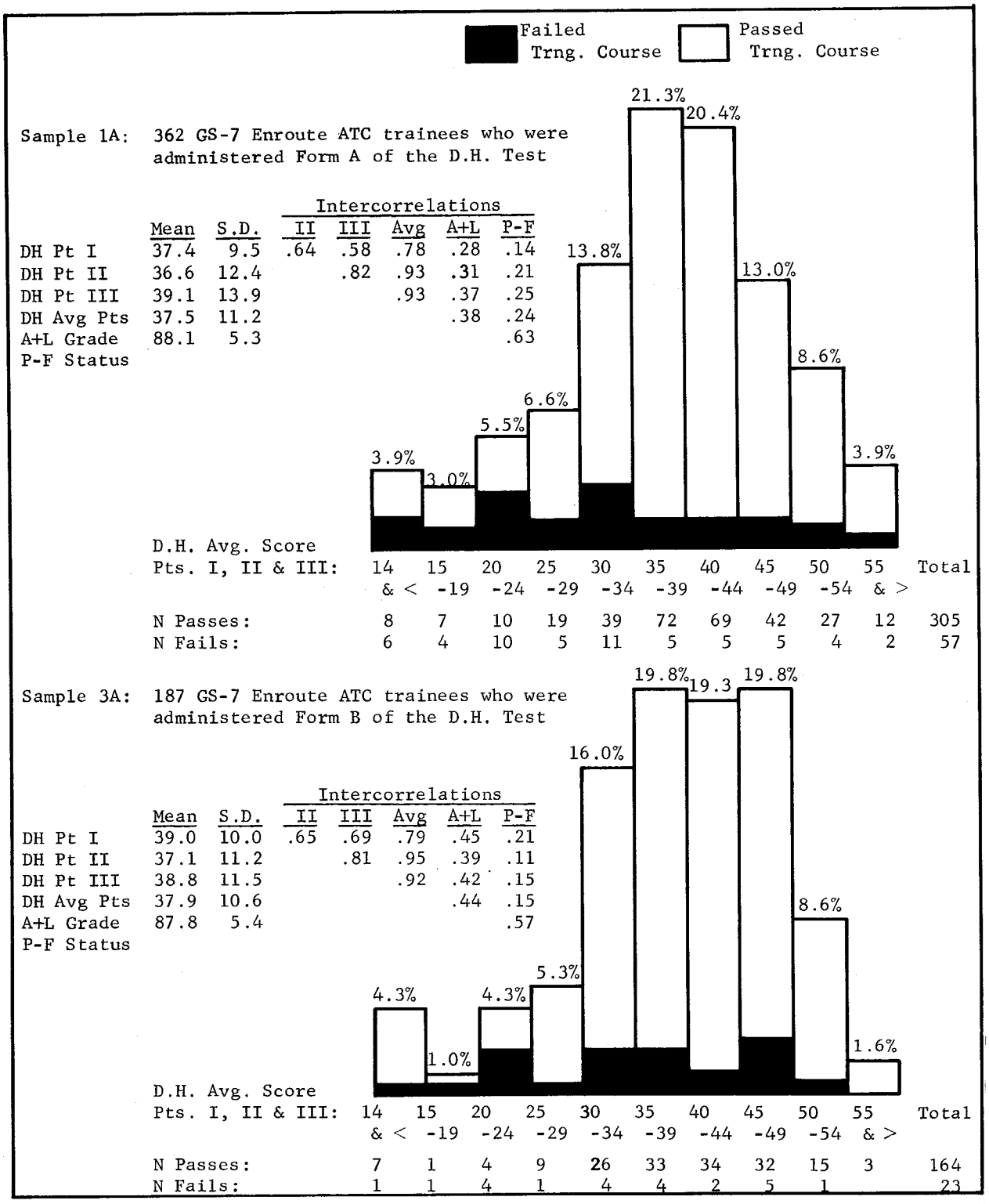
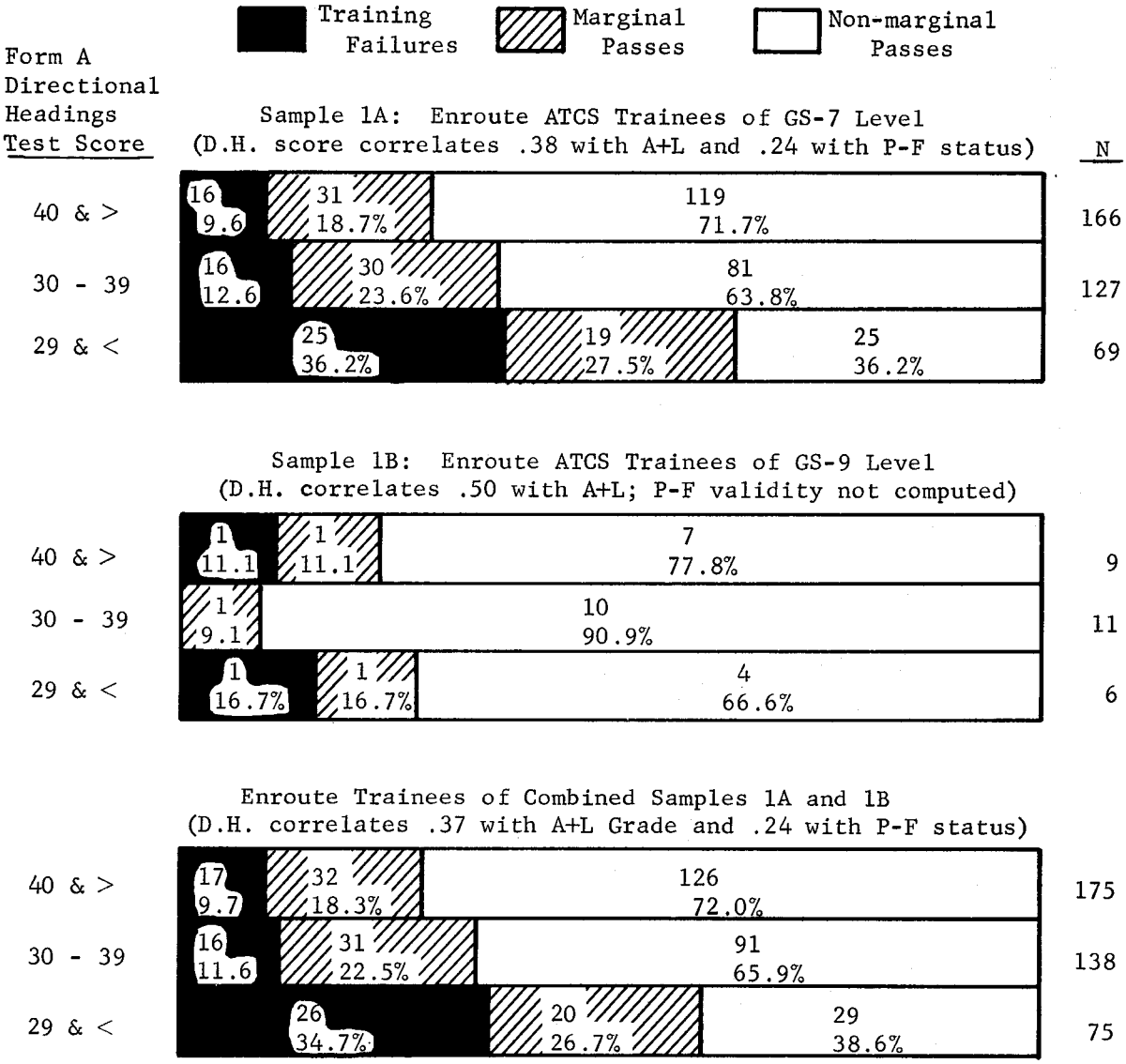


FIGURE 1. Comparison of performance data for groups of En Route GS-7 level ATCS trainees who were administered the Directional Headings Test Form A or B.



IGURE 2. Proportion of En Route ATCS trainees within each of three Directional-Headings-Test-Score groupings who failed the Academy's basic ARTCC training course, "marginally passed," or passed with grades comprising the approximate upper three-fourths of the A+L Grade distribution for the passes only.

ailed to complete training; 19 (27.5 per cent) narginally passed with A+L grades represented n the approximate lower one-fourth of the grade istribution of the passes only, and that only 25 36.2 per cent) completed their course as "non-narginal passes." In contrast, 63.8 per cent of he 127 with DHT scores of 30 to 39 were "non-narginal passes." The results for the 166 GS–7 RTCC trainees who scored 40 and higher on he experimental aptitude test are impressive but nly slightly more so than those pertaining to rainees who scored 30 to 39. No conclusions an be derived on the basis of the results obtained for the 26 ARTCC trainees of GS–9 level. Only two of the 26 failed, three were "marginals," and the other 21 were "non-marginal passes." It is possible that the pre-FAA ATC experience of these trainees enabled them to master more readily the training materials than their less-experienced and lower GS-rated classmates, but such a hypothesis should be viewed as rather tenuous because the sample of En Route GS–9's was so small.

The results of corresponding analyses on the data of the GS–7 and GS–9 Terminal students were much more impressive than obtained for

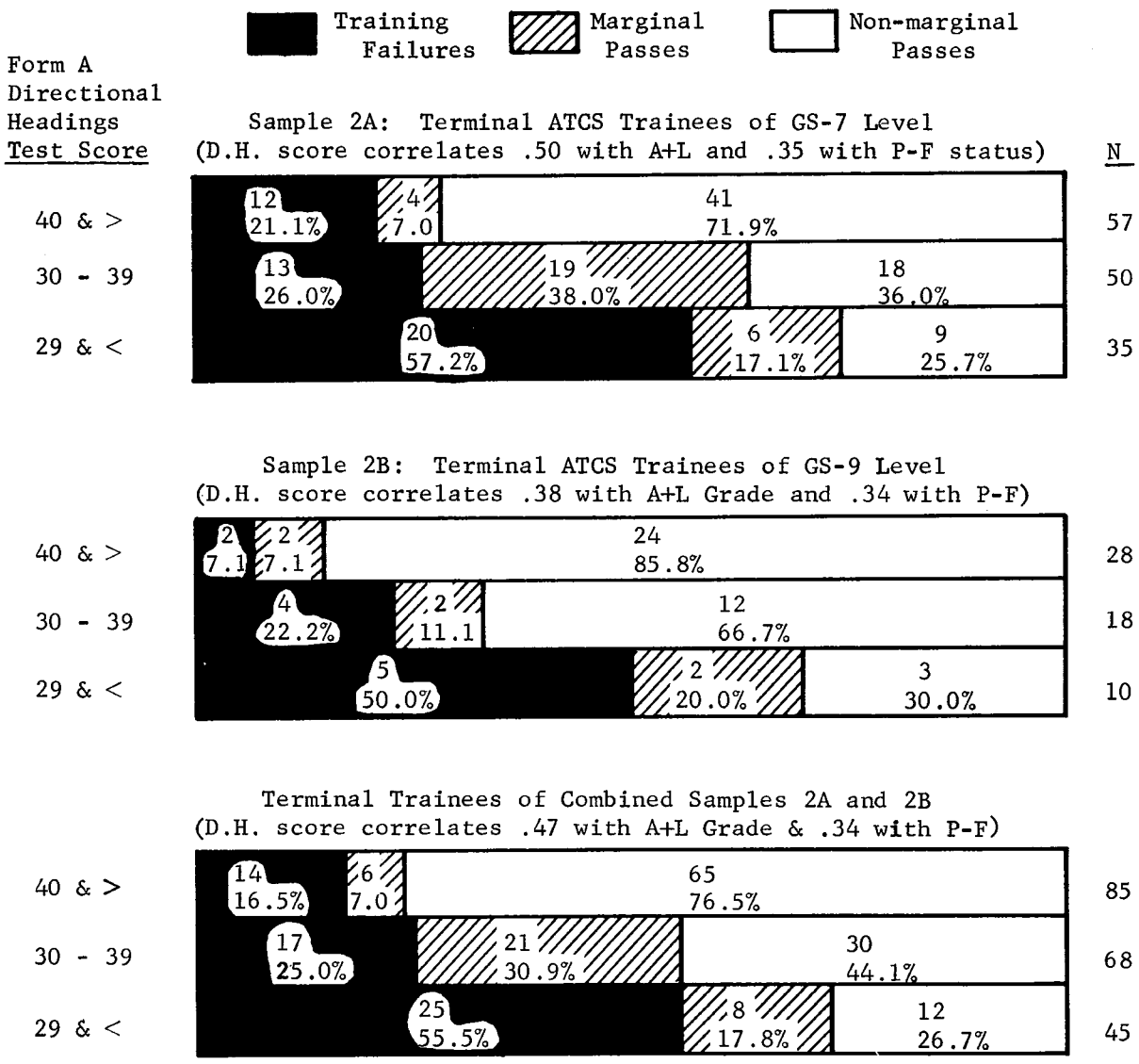


FIGURE 3. Proportion of Terminal ATCS trainees within each of three Directional-Headings-Test-Score grouping who failed the Academy's basic Terminal training course, "marginally passed," or passed with grades comprising the approximate upper three-fourths of the A+L Grade distribution of the passes only.

the groups of En Route trainees. In the upper set of bar graphs shown in Figure 3 for the 142 GS–7 TATC trainees, it should be noted that 57.2 per cent (N=20) of the 35 men having DHT Form-A scores of 29 and less failed training. Of these 35, an additional 17.1 per cent "marginally passed" and only 9 (or 25.7 per cent) passed as "non-marginals." Among the 50 having test scores of 30 to 39, a total of 31 (or 64 per cent) either failed or "marginally passed." In contrast, only 28.1 per cent of the 57 with scores of 40 and above failed or "marginally passed." The findings depicted for Sample 1B (Figure 3) illustrate that the DHT Form-A scores also possess potential for discriminating between the training-performance criteria of the Terminal GS–9's. Seventeen of the 56 TATC GS–9's either failed or passed with "marginal" grades and seven of the 17 scored 29 or less on the DHT, six scored between 30 and 39, and only four attained scores of 40 or above.

Relatively few of the ARTCC trainees who were examined with DHT Form B failed training and consequently the results shown in Figure 4 are not nearly as dramatic as those previously discussed for Form A. Yet, among the 187 GS-

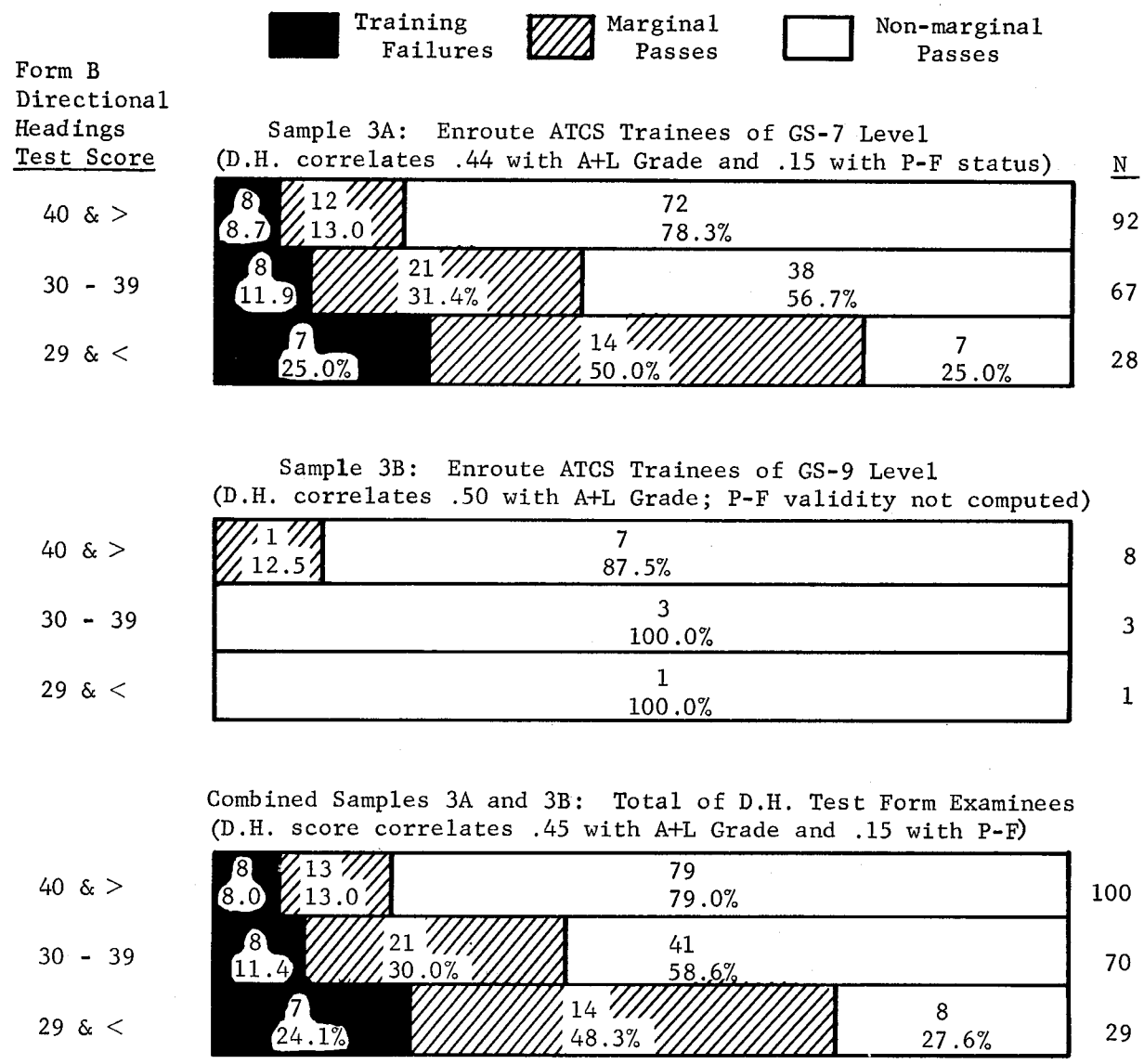


FIGURE 4. Proportion of Directional-Headings-Test Form B examinees (En Route only) within each of three D.H. performance score groupings who failed Academy basic training, "marginally passed," or passed with grades represented in the approximate upper three-fourths of the A+L Grade distribution of passing Ss only.

ARTCC trainees, the 28 with DHT scores of 29 nd less included only 7 "non-marginal passes" nd 21 who either failed or performed "margin-lly." For each of the higher DHT score in-ervals, a progressively higher proportion of the GS–7 subjects were "non-marginals."

D. *Screening Potential of the DHT Versus he CSC Test Battery.* As mentioned earlier, erformance measures on the operational CSC TC Aptitude Test Battery were received for 31, or only 55.8 per cent, of the 504 GS–7 ATCS ainees who were experimentally assessed with DHT Form A. Moreover, the 281 cases included only 31 training-course failures. Inasmuch as the 31 attritions represented only 11 per cent of the sample of 281, whereas 102, or over 20 per cent, of the 504 were known to have failed, the sample should be regarded as biased. The reasons why bias occurred in the collection of the data are unknown. (Over 97 per cent of the 102 non-graduates, like 95 per cent of the 402 graduates, checked "Yes" to an item of the CAMI Questionnaire indicating that they had taken the CSC Battery in the process of establishing eligibility for appointment to training.)

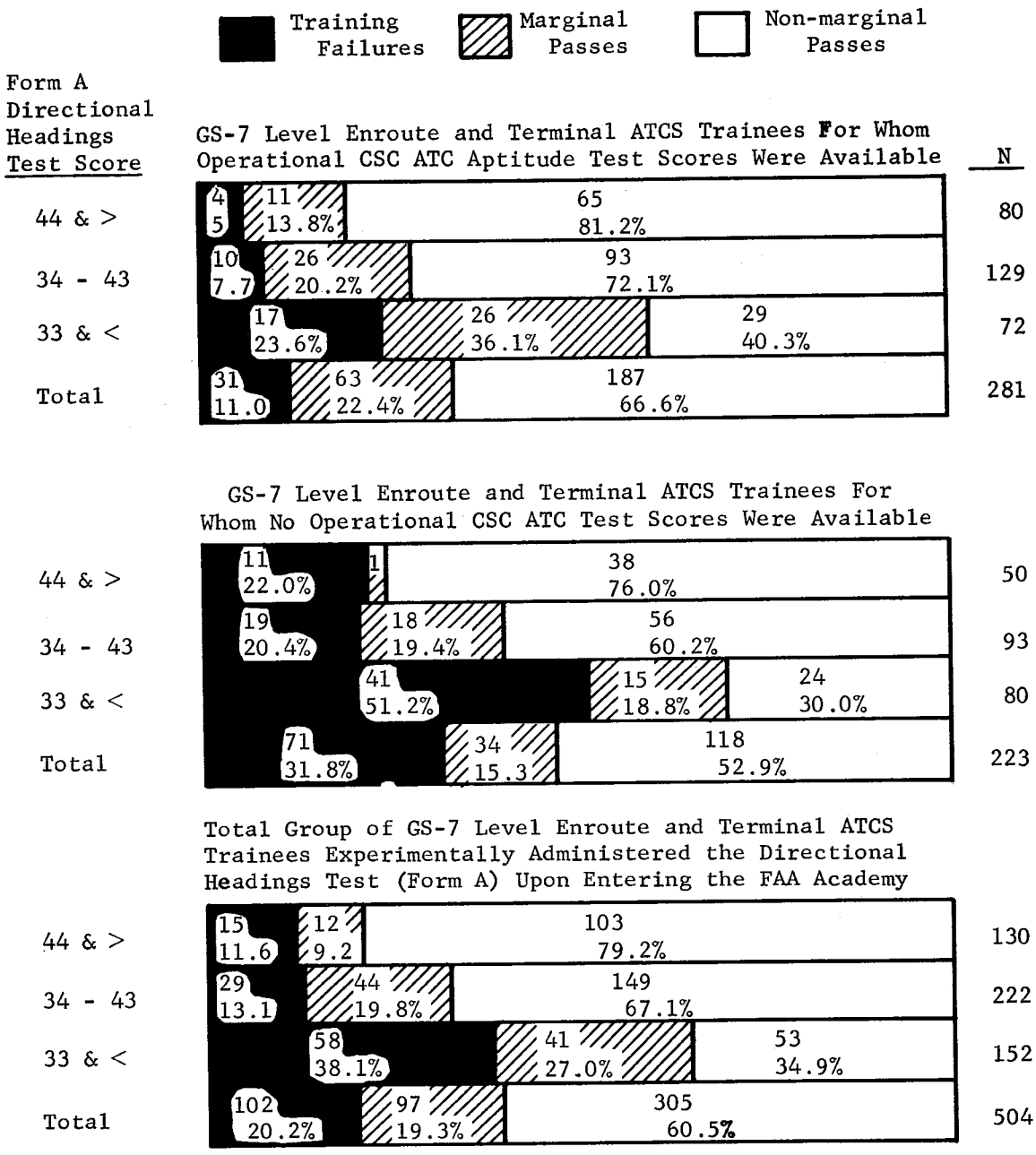


FIGURE 5. Distribution of training-course failures, "marginal" and "non-marginal" passes within each of thre Directional-Headings-Test-Score groupings for 281 GS-7 level ATCS trainees (of Samples 1A and 2A) know to have been operationally examined with the CSC-ATC-Screening Battery and for a similar group of 22 trainees for whom no CSC-Test scores were forwarded.

Notwithstanding the shortcomings of the sample, the authors had no recourse but to deal with the 281 cases in analyses aimed at comparing the screening potential of the DHT with that of the CSC Battery.

The DHT Form A Scores of the 281 GS-ATCS trainees for whom CSC Test data wei available were arrayed from low to high and th resulting distribution was consequently divide into approximate fourths. The lower fourt

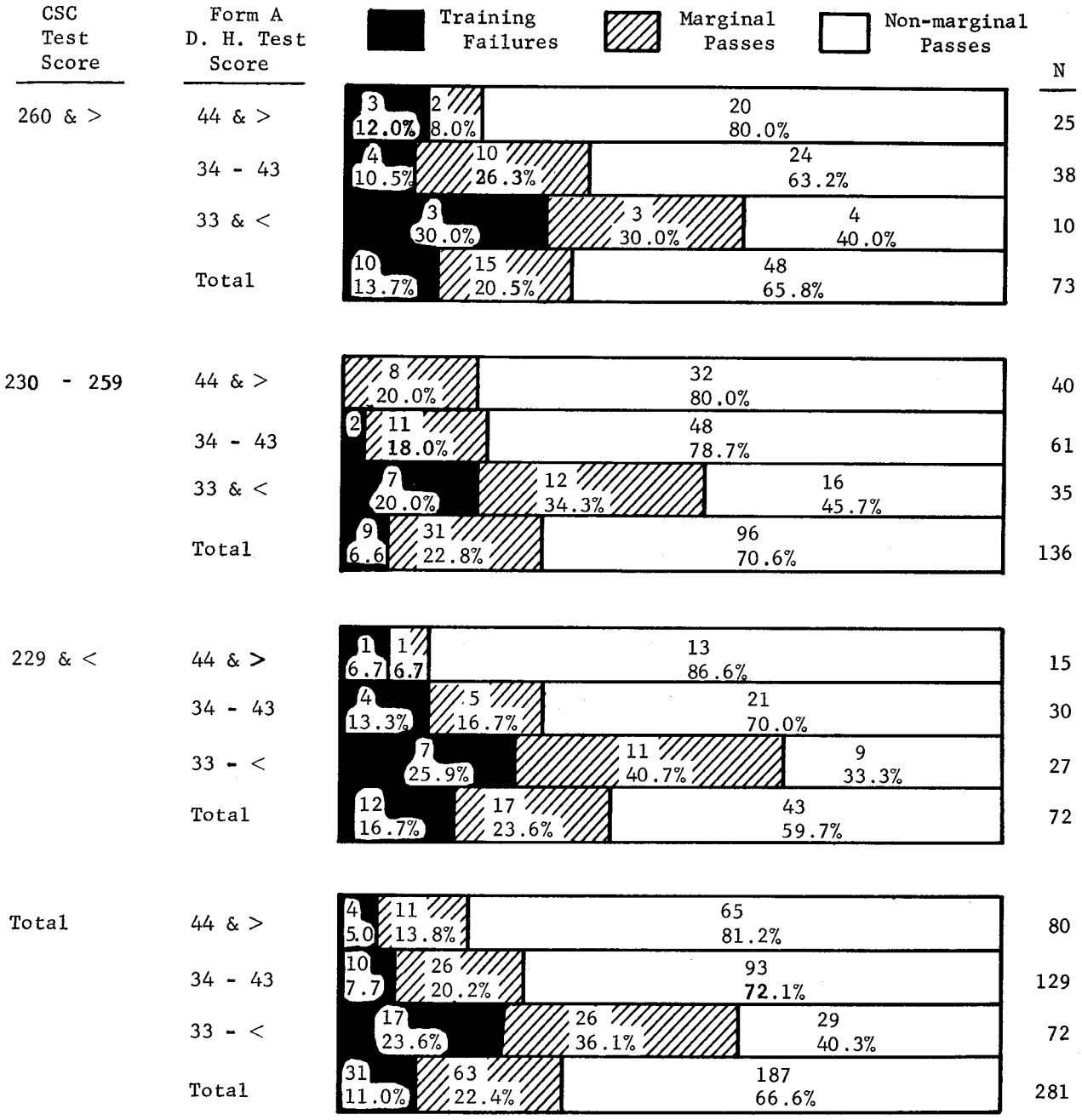


FIGURE 6. Percentages of ATC trainees by CSC-Test-Score and Directional-Headings-Test-Score categories who failed Academy basic training, passed with grades comprising the approximate lower one-fourth of the distribution of "A+L" training grades of the passes only (i.e., "marginals"), or passed with grades in the upper three-fourths (i.e., "non-marginals"). The data pertain to 212 ARTCC trainees of Sample 1A and 69 TATC trainees of Sample 2A, all of GS-7 level and for whom operational CSC-Test-Scores were forwarded to CAMI.

comprised 72 cases, all with scores of 33 or less; 80 cases with scores of 44 and above represented the upper fourth; the remaining 129 cases, with scores of 34 to 43, were designated as the intermediate half. Each of the three subgroups were then reviewed to determine the proportion of cases representing "training failures," "marginal passes," and "non-marginal passes." Retaining the DHT Score intervals established with the group of 281, a similar analysis was accomplished with the group of 223 subjects for whom no CSC Test data were available. In comparing the results obtained for the two groups (see Figure 5), it should first be noted that only 11 per cent of the 281 subjects for whom CSC scores were available failed to successfully complete Academy ATC training, whereas an attrition rate of 31.8 per cent occurred for the 223 for whom no operational aptitude screening measures were available. The latter group also performed less well than the former on the DHT. Although not shown, the mean DHT score was 38.2 for the group of 281 and 35.8 for the smaller group; the mean difference was significant at the .05 level. Over one-half of the training failures in each group scored 33 or less on the DHT. Moreover, over three-fourths of the trainees in either group who attained DHT scores of 44 or greater passed Academy training with "non-marginal" A+L Grades. Also, the majority of subjects within both groups who scored between 34 and 43 on the DHT were "non-marginals" whereas relatively few (i.e., 40.3 per cent and 30.0 per cent) of those with scores of 33 or less were represented in the upper three-fourths of the A+L Grade distribution.

An additional analysis was accomplished on the test data of the 281 GS–7 En Route and Terminal ATCS trainees in order to more fully assess the potential with which the DHT might be used in conjunction with the CSC Battery to further enhance the aptitude screening process. In accordance with a procedure analogous to that just described for the DHT scores, the distribution of CSC scores was examined to determine those cases representing the approximate upper and lower fourths of the array as well as the intermediate half. It was determined that 73 of the 281 subjects scored 260 or higher on the CSC Battery, that 136 scored between 230 and 259, and that the lower fourth consisted of 72 subjects with scores of 229 or less. The cases within each of the three CSC score intervals were then subdivided in terms of the three previously established levels of DHT performance (i.e., score intervals of "33 &<," "34–43," and "44 &>") and also in terms of the three categories of training performance. In reviewing the results (Figure 6), it should first be noted that there is little evidence of any significant relationship between the CSC aptitude scores and training performance; however, previous studies have illustrated that the *power of the CSC Battery is in its successful screening of applicant groups*, whereas the differential scores of those *within the qualifying range* offer little potential for discriminating between levels of training performance. (This is an expected result: See The American Psychologist, 27:236–239, 1972, for discussions of this topic in a different selection context.)

The results depicted by the upper set of bar graphs in Figure 6 for the 73 trainees having CSC scores of 260 and above constitute convincing evidence that the DHT can be used effectively to improve the aptitude screening process. Ten of the 73 subjects represented in the upper fourth of the CSC score distribution scored 33 or less on the DHT and three of the ten failed training, three passed the course with "marginal" A+L Grades and only four were "non-marginals." Disproportionately fewer trainees within the DHT score ranges of "34–43" and "44 &>" failed or marginally passed. Similar results were obtained for the 136 students who had CSC scores of 230 to 259. Thirty-five of the 136 scored 33 or lower on the new test and only 45.7 per cent of the 35 passed with "non-marginal" grades, whereas over three-fourths of those with higher DHT scores did so. Results pertaining to the 72 trainees with CSC scores of 229 and lower follow the same pattern, but in more pronounced degree.

Such findings imply that the DHT is providing measures of certain aptitudes other than those encompassed by the CSC Battery. This was verified by the results of a series of multiple regression analyses. Preparatory to the latter analyses, intercorrelations and validities of the DHT and the various tests of the CSC Battery were first computed for the group of 281 GS–7's for whom CSC scores were available. Although not presented in any table, the correlations between the DHT and the different tests of the

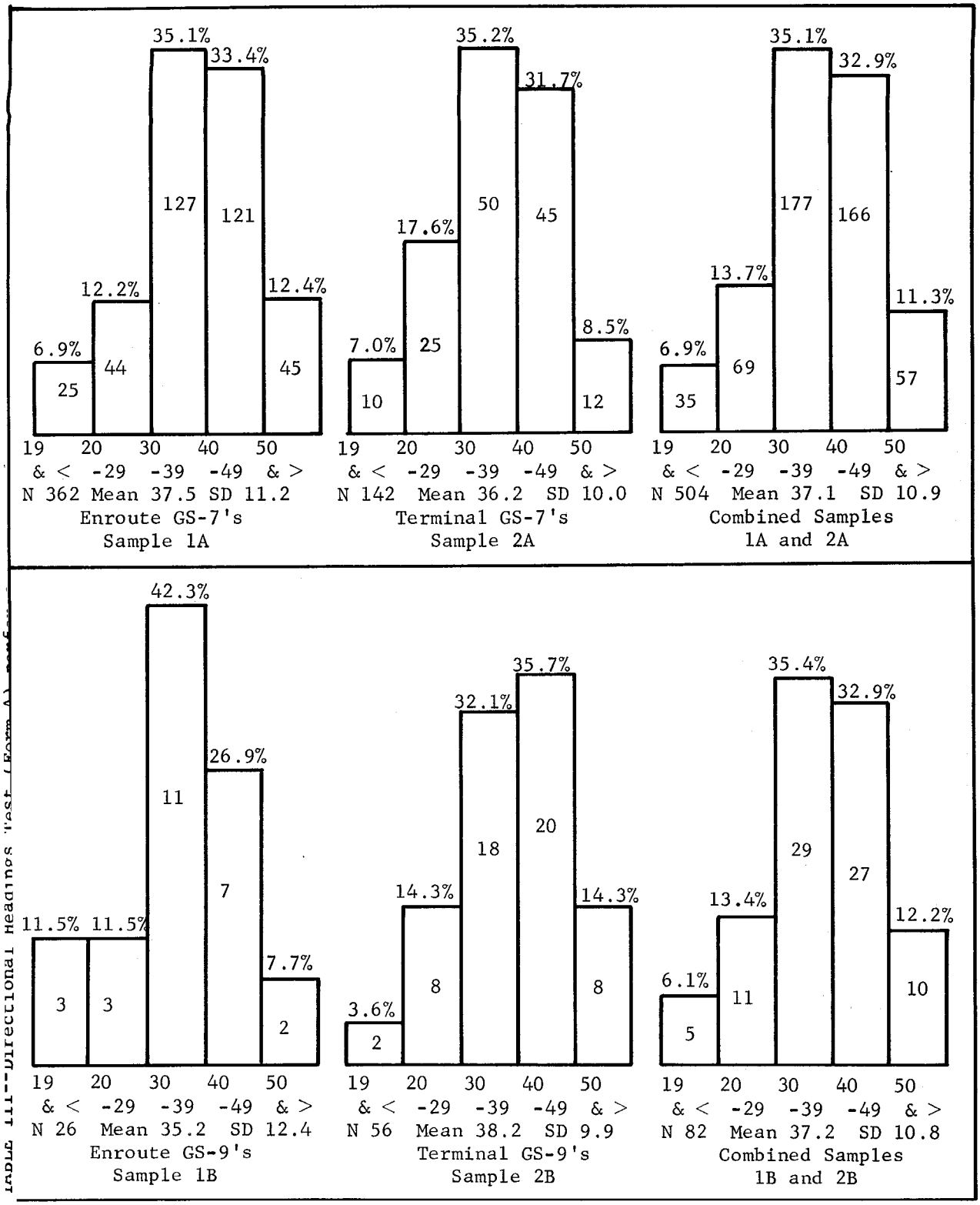


FIGURE 7. Comparison of ATC trainees of GS-7 and GS-9 levels in terms of performance scores on Directional Headings Test Form A.

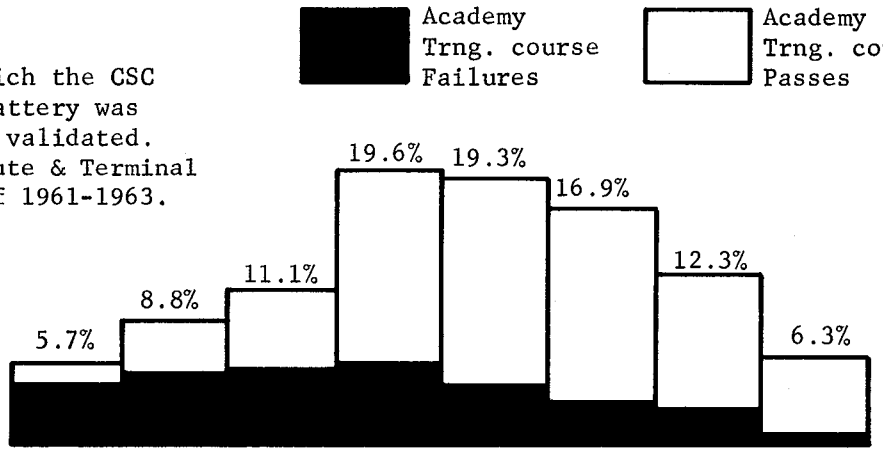
IV. Summary and Conclusions.

This study concerned the development and experimental validation of a novel aptitude test, referred to as "Directional Headings" (or DHT), for the selection of Air Traffic Control Specialist (ATCS) trainees. The test requires the subject to rapidly interpret letters, symbols, and degrees in order to determine: directional headings (Part I), the exact opposites of headings (Part II), and opposites of headings under conditions of aural distraction (Part III). The DHT was administered on an experimental basis to several hundred men as they entered basic ATCS training at the FAA Academy. The vast majority of the subjects had been selected for training on the basis of competitive ratings from among candidates who met exceptionally high qualifying standards in terms of operational aptitude test screening scores and/or evaluations of pre-FAA experience. Despite these pre-screening effects, the DHT scores correlated .41 with an overall measure of training performance. Moreover, over 44 per cent of the 115 examinees who failed the training course scored no higher than 29 on the DHT whereas over 85 per cent of the graduates scored 30 or higher. Reliability of the instrument, as determined by correlating the scores based on even-numbered items versus scores based on odd-numbered items, was .93.

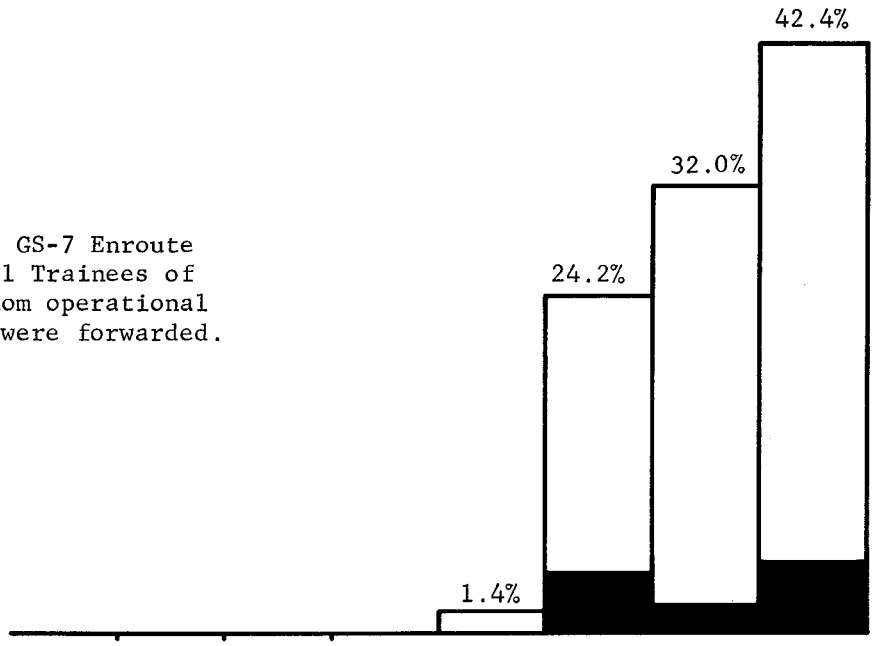
Table IV.--Form-A score distributions by dichotomized age groups for subjects who passed or failed Academy basic training.

Form A DHT Score	Age 35 & <			Age 36 & >			All Ages		
	Pass	Fail	Total	Pass	Fail	Total	Pass	Fail	Total
50 & >	56	4	60	4	3	7	60	7	67
40-49	159	17	176	10	7	17	169	24	193
30-39	157	25	182	16	8	24	173	33	206
29 & <	60	38	98	9	13	22	69	51	120
Total:									
Passes	432			39			471		
Fails		84			31			115	
P + F			516			70			586

APPENDIX A. Distributions of CSC ATC Aptitude Test Battery performance scores for the 893 experimentally-examined entrants into Academy ATC training during 1961–1963 and for 281 operationally-examined trainees who entered during 1970.



CSC Score:	129 & <	130 -149	150 -169	170 -189	190 -209	210 -229	230 -249	250 & >	N Total
N Pass:	13	33	52	124	135	126	87	52	622
N Fail:	38	46	47	51	37	25	23	4	271
N Total:	51	79	99	175	172	151	110	56	893



CSC Score:	129 & <	130 -149	150 -169	170 -189	190 -209	210 -229	230 -249	250 & >	N Total
N Pass:					4	56	85	105	250
N Fail:						12	5	14	31
N Total:					4	68	90	119	281

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