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Measures of cognitive styles, abilities, and aptitudes were obtained for a sample of BE/E School graduates and failures, and used to perform discriminant analyses to determine which linear combination of measures could optimally differentiate the two groups. Classification functions obtained for derived discriminant functions were applied to measures of cognitive characteristics obtained for the study participants to evaluate the effectiveness of the discriminations in predicting group membership (i.e., BE/E

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(19 continued)

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(20 continued)

graduates or failures). Results showed that the two groups differ significantly in certain cognitive characteristics, and that the classification functions were valid predictors of BE/E success or failure.

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ABSTRACT

The objective of this study was to identify those cognitive characteristics that best differentiate the Navy's Basic Electricity and Electronics (BE/E) Preparatory School graduates and failures. Subjects included 207 BE/E students--172 graduates and 35 failures. Before these trainees had commenced BE/E School, they were administered six tests of cognitive styles and six tests of cognitive abilities. Measures of cognitive aptitudes for these students consisted of scores obtained on the Armed Services Vocational Aptitude Battery subtests. Measures obtained were used to perform seven stepwise discriminant analyses to determine which linear combination of measures could optimally differentiate BE/E graduates and failures. The discriminate analyses and their associated statistics indicate that BE/E graduates and failures significantly differ in certain cognitive characteristics. Specifically, graduates tend to have (1) field-independent and/or narrow conceptualizing styles: (2) better verbal comprehension, ideational fluency, general reasoning capacity, and/or inductive abilities: and (3) better quantitative, technical, verbal, and/or general aptitudes. A further analysis of correct classification assuming equal probability of failing and graduating and adjusted probability on a priori basis is also reported. (RAO)

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DISCRIMINATING BETWEEN FAILURES AND GRADUATES IN A COMPUTER-MANAGED COURSE USING MEASURES OF COGNITIVE STYLES, ABILITIES, AND APTITUDES

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FOREWORD

This research and development was undertaken in response to Navy Decision Coordinating Paper, Education and Training Development (NDCP-Z0108-PN) under subproject Z0108-PN.30A, Adaptive Experimental Approach to Instructional Design and the sponsorship of the Director of Naval Education and Training (OP-99). The goal of this subproject is to design and evaluate procedures for facilitating the instructional systems development (ISD) process. This report identifies student characteristics that best differentiate failures and graduates of the Basic Electricity and Electronics (BE/E) School.

The results of this study are intended for use by the Chief of Naval Education and Training, Chief of Naval Technical Training, Technical Program Coordinator for the Navy's BE/E Schools, Commanders of the BE/E Schools, and the Navy's Instructional Program Development Centers.

DONALD F. PARKER
Commanding Officer

SUMMARY

Problem

The implementation of computer-managed instruction (CMI) in the Navy's Basic Electricity and Electronics (BE/E) Preparatory Schools seems to have improved training efficiency and effectiveness. To obtain maximum benefit from CMI, however, adaptive instructional strategies that accommodate alternative teaching treatments to student cognitive characteristics must be designed, developed, and implemented. In filling this need, it will be necessary to identify those cognitive styles, abilities, and aptitudes that differentiate BE/E graduates from failures. Cognitive styles refer to information processing modes used by individuals in problem solving or learning; cognitive abilities, to intellectual capabilities; and cognitive aptitudes, to job-relevant skills.

Objective

The objective of this research and development was to identify those cognitive characteristics that best differentiate BE/E graduates and failures. This information was then used (1) to establish distinct classification functions employing measures of cognitive characteristics to predict student success in BE/E School, and (2) to suggest ways to adapt instruction to students' cognitive characteristics to minimize the BE/E failure rate.

Approach

Subjects included 207 BE/E students--172 graduates and 35 failures. Before these trainees had commenced BE/E School, they were administered six tests of cognitive styles and six tests of cognitive abilities. Measures of cognitive aptitudes for these students consisted of scores obtained on the Armed Services Vocational Aptitude Battery (ASVAB) subtests. Measures obtained were used to perform seven stepwise discriminant analyses to determine which linear combination of measures could optimally differentiate BE/E graduates and failures. These analyses were calculated using (1) indices of cognitive styles, abilities, and aptitudes only, (2) the three two-way interactions of these indices, and (3) the one three-way interaction.

Classification functions obtained for the derived discriminant functions were applied to the measures of cognitive characteristics obtained for the study participants. Two analyses were conducted. In the first, it was assumed that students had an equal probability of failing or graduating. In the second, the probability was adjusted to the a priori probabilities of failing and graduating. By classifying subjects initially used to produce the discriminant functions and comparing predicted group membership with actual group membership, it was possible to determine the proportion of correct classifications and, thus, the adequacy of the discriminations.

Results

1. The discriminant analyses and their associated statistics indicate that BE/E graduates and failures significantly differ in certain cognitive characteristics. Specifically, graduates, as opposed to failures, tend to

have (1) field-independent and/or narrow conceptualizing styles, (2) better verbal comprehension, ideational fluency, general reasoning capacity, and/or inductive abilities, and (3) better quantitative, technical, verbal, and/or general aptitudes. These results confirmed the need for developing procedures for adapting instruction to student cognitive characteristics to minimize the BE/E failure rate.

2. In the classification analysis assuming equal probability of failing or graduating, the percentage of correct classifications of actual failures ranged from 68 to 80 percent; and of actual graduates, from 62 to 80 percent. In the classification analysis adjusting these probabilities to a priori probabilities of failing or graduating, the percentage of current classifications of actual failures ranged from zero to 34 percent; and of actual graduates, from 95 to 99 percent.

Conclusions

1. Measures of cognitive style, ability, and aptitude contributed significantly to the accuracy of prediction of student success or failure in BE/E School.

2. Possible approaches to reducing the BE/E failure rate include (a) excluding students possessing cognitive characteristics associated with failure from BE/E School (assuming a sufficient manpower pool), (b) giving such students special training in deficient areas early in or prior to commencing BE/E School, or (c) developing special instructional strategies based on cognitive characteristics. The latter two alternatives will require additional R&D.

Recommendation

1. Assuming that ASVAB scores are available for all students about to enter BE/E School and that the findings of this study are confirmed on cross validation, the derived classification functions based on aptitudes only should be implemented as predictors of student success or failure.

2. The tests of cognitive styles and abilities used in this study should be administered to students before they commence BE/E School to identify those who may benefit from pretraining in deficient areas or the use of specially designed instructional materials. R&D will be required to develop pretraining and/or special instructional materials.

CONTENTS

LIST OF TABLES

8

INTRODUCTION

Problem

It appears that the implementation of computer-managed instruction (CMI) in the Navy's Basic Electricity and Electronics (BE/E) Preparatory Schools has improved training efficiency and effectiveness. To obtain maximum benefit from the use of CMI, however, adaptive instructional strategies that accommodate alternative teaching treatments to student cognitive characteristics must be designed, developed, and implemented. In filling this need, it will be necessary to identify those cognitive styles, abilities, and aptitudes that differentiate BE/E graduates from failures. Cognitive styles refer to the dominant modes of information processing used by individuals in perceiving, learning, or problem solving; cognitive abilities, to intellectual capabilities; and cognitive aptitudes, to job-relevant skills.

Objective

The objective of this research and development was to identify those cognitive characteristics that best differentiate BE/E graduates and failures. This information was then used (1) to establish distinct classification functions employing measures of cognitive characteristics to predict student success in BE/E School, and (2) to suggest ways to adapt instruction to students' cognitive characteristics to minimize the BE/E failure rate.

APPROACH

Subjects

The original sample consisted of 340 persons who graduated from recruit training at the Naval Training Center, San Diego from 9 May through 2 June 1977 and who were scheduled for training at the BE/E School at that Center. Before beginning BE/E orientation, the subjects were administered 12 tests--six designed to measure their cognitive styles; and six, their cognitive abilities. Test data for 20 of the subjects were discarded, since they failed to follow directions and/or to complete at least 9 of the 12 tests. Of the remaining 320 subjects, 40 failed to graduate from BE/E School--35 for academic reasons and 5 for nonacademic reasons. Thus, test data were available for 315 BE/E trainees--280 graduates and 35 academic failures.

Cognitive aptitudes of all Navy entrants are measured by scores obtained on the 12 subtests of the Armed Services Vocational Aptitude Battery (ASVAB) (MEPCOM Manual 601-1). When attempting to obtain these data for the subjects of this study, 108 of them, all BE/E graduates, either had incomplete or missing ASVAB scores or had been administered the Basic Test Battery (BTB) instead of the ASVAB. (Before ASVAB was adopted, the BTB was used routinely for measuring aptitudes.) Thus, the final sample used in the study consisted of 207 BE/E trainees--172 graduates and 35 failures.

Cognitive Characteristics

The 24 cognitive characteristics measured in this study are listed in Table 1. The six cognitive styles were selected because of their implications for adaptive instruction (Kogan, 1971); and the six cognitive abilities, because they represent various types of information-processing tasks (Carroll, 1974, 1975) and are relevant to the BE/E subject matter. The 12 cognitive aptitudes were selected not only because they are measured by the ASVAB subtests and are therefore readily available for Navy personnel but also because ASVAB scores are used as a basis of assigning personnel to different types of Navy schools. All of the tests used to measure these characteristics are relatively independent, moderate to high in reliability, paper-and-pencil in nature, and fairly short in duration. The 24 cognitive characteristics and the tests used to measure them are described in the appendix.

Analyses

Seven stepwise discriminant analyses were computed to determine which linear combinations of tests optimally differentiate between BE/E failures and graduates. These separate analyses were calculated using (1) indices of cognitive styles, abilities, and aptitudes only, (2) the three two-way interactions of these indices, and (3) the one three-way interaction. In these analyses, multivariate normality and homogeniety of group dispersions were assumed.

Table 1

Cognitive Characteristics Measured

Cognitive Characteristic	Abbreviation	Description	Measurement Instrument
		Cognitive Style	
Field-Independence vs. Field-Dependence	FILDINDP	Analytical vs. global orientation	Hidden Figures Test, Part 1 (Ekstrom, French, Harman, & Dermen, 1976)
Conceptualizing Style	CONCSTY.	Span of conceptual category	Clayton-Jackson Object Sorting Test (Clayton & Jackson, 1961)
Reflectiveness-Impulsiveness	REFLIMPL	Deliberation vs. impulse	Impulsivity Subscale from Personality Research Test, Form E (Jackson, 1974)
Tolerance of Ambiguity	TOLRAMBQ	Inclined to accept complex issues	Tolerance of Ambiguity Scale from Self-Other Test, Form C (Rydell & Rosen, 1966)
Category Width	CATEWIDH	Consistency of cognitive range	Category Width Scale (Pettigrew, 1958)
Cognitive Complexity	COGCOMPX	Multidimensional perceptions of the environment	Group Version of Role Construct Repertory Test (Bieri, Atkins, Briar, Leaman, Miller, & Tripodi, 1966)
		Cognitive Ability	
Verbal Comprehension	VERBCOMP	Understanding the English language	Vocabulary Test, Part 1 (Ekstrom et al., 1976)
General Reasoning	GENLREAS	Solving specific problems	Arithmetic Aptitude Test, Part 1 (Ekstrom et al., 1976)
Associational Fluency	ASSOFLUN	Producing similar words rapidly	Controlled Associations Test, Part I (Ekstrom et al., 1976)
Logical Reasoning	LOGIREAS	Deducing from premise to conclusion	Nonsense Syllogisms Test, Part 1 (Ekstrom et al., 1976)
Induction	INDUCTON	Forming hypotheses to fit certain facts	Figure Classification Test, Part 1 (Ekstrom et al., 1976)
Ideational Fluency	IDEAFLUN	Generating ideas about a specific type	Topics Test, Part 1 (Ekstrom et al., 1976)
		Cognitive Aptitude	
General Information	GENLINFO	Recognizing factual information	General Information Subtest, ASVAB
Numerical Operations	NUMROPER	Completing arithmetic operations	Numerical Operations Subtest, ASVAB
Attention to Detail	ATTNDETL	Finding an important detail	Attention to Detail Subtest, ASVAB
Word Knowledge	WORDKNOL	Comprehending written and spoken language	Word Knowledge Subtest, ASVAB
Arithmetic Reasoning	ARTHREAS	Solving arithmetic word problems	Arithmetic Reasoning Subtest, ASVAB
Space Perception	SPACPERC	Visualizing objects in space	Space Perception Subtest, ASVAB
Mathematics Knowledge	MATHKNOL	Employing mathematical relationships	Mathematics Knowledge Subtest, ASVAB
Electronics Information	ELECINFO	Using electronics relationships	Electronics Information Subtest, ASVAB
Mechanical Comprehension	MECHCOMP	Reasoning with mechanical concepts	Mechanical Comprehension Test, ASVAB
General Science	GENLSCIE	Perceiving relationships between scientific concepts	General Science Subtest, ASVAB
Shop Information	SHOPINFO	Knowing shop tools	Shop Information Subtest, ASVAB
Automotive Information	AUTOINFO	Knowing automotive functions	Automotive Information Subtest, ASVAB

Classification functions obtained for the derived discriminant functions were applied to the measures of cognitive characteristics obtained for study participants. Two analyses were conducted. In the first, it was assumed that students who entered BE/E School had an equal probability of failing or graduating. In the second, this probability was adjusted according to the a priori probabilities of failing and graduating BE/E (Cooley & Lohnes, 1962; Overall & Klett, 1972; Tatsuoka, 1971). Records for BE/E School, San Diego showed that, in the period from 1 April 1977 to 31 March 1978, the base rates of failing and graduating--for all ratings requiring BE/E requisites--were 15 and 85 percent respectively.

By classifying subjects initially used to produce the discriminant functions and comparing predicted and actual group memberships, it was possible to determine empirically the proportion of correct classifications and, thus, the adequacy of the discriminations.

RESULTS

Table 2 compares the performance of BE/E failures and graduates on the 24 tests measuring student cognitive characteristics. As shown, the failures scored significantly lower than the graduates on two of the six cognitive style measures, four of the six cognitive ability measures, and eight of the twelve cognitive aptitude measures. When these measures were intercorrelated, as shown in Table 3, it was found that cognitive style measures appeared to be generally independent of the others, except for field-independence. As was expected, however, ability and aptitude measures appear to be related.

The results of the seven stepwise discriminant analyses computed to determine which linear combinations of measured characteristics optimally differentiate BE/E failures and graduates, along with their associated statistics, are provided in Table 4. As shown, for each analysis, one discriminant function (D) was derived. For example, for the analysis using cognitive styles only, the derived discriminant function is -.81 FILDINDP -.36 CONCSTYL +.26 COGCOMPX. From this function, it can be seen that only three of the six measures of cognitive styles were neede to discriminate significantly between the two groups. The absolute values of the coefficients in the function indicate how much each of the three measures contributes in discriminating between the groups. Once these values have been determined, a set of classification functions (C_f and C_g) can be obtained that will permit the classification of new members into the two groups. For example, the classification functions obtained from the discriminant function derived for cognitive styles are:

$$C_f = .17 \text{ FILDINDP} +.63 \text{ CONCSTYL} +.23 \text{ COGCOMPX} -1.27$$

and

$$C_g = .35 \text{ FILDINDP} +.71 \text{ CONCSTYL} +.22 \text{ COGCOMPX} -13.39.$$

Thus, by inserting the appropriate test scores for a subject into the derived classification equations, a student could be assigned to the group in which he has the highest probability of being a member.

To check the effectiveness of the seven derived discrimination functions, the obtained classification functions were applied to the test scores of the students who participated in this study, since, obviously, actual group membership of these students is known. As indicated previously, separate classification analyses were conducted. In the first, it was assumed that each student who entered BE/E School had an equal probability of failing or graduating. In the second, this probability was adjusted according to the a priori probabilities of failing and graduating BE/E School. Results are provided in Table 5. As shown, in the first analysis (equal probability), the percentage of correct classifications for actual failures ranged from 68.6 to 80.0 percent; and of actual graduates, from 61.6 to 79.1 percent. In the second analysis (adjusted probability), the percentage of correct classifications of actual failures ranged from zero to 34.3 percent; and of actual graduates, from 94.8 to 99.4 percent.

These data show that the hit rate for actual failures is much higher when the equal probability assumption is made. Of prime concern is the capability to identify, as accurately as possible, those students who are likely to fail BE/E School so that corrective action can be taken to reduce the attrition rate. Therefore, it appears that the equal probability assumption is more effective than the adjusted probability assumption. It should be pointed out, however, that adjusting the classification scores of subjects according to prior probabilities is often performed when it is desired to minimize misclassification costs and/or when the size of the actual groups is grossly different.

1.

Table 2

Means, Standard Deviations, and Univariate F-Ratios for BE/E Failures and Graduates on Tests Measuring Cognitive Characteristics

Cognitive Characteristic	Failures (N = 35)		Graduates (N = 172)		Univariate F
	M	SD	M	SD	
Cognitive Style					
FILDINSP	2.34	3.38	5.20	3.82	16.82***
CONCSTYL	11.06	3.63	12.70	4.07	4.90*
REFLIMPL	4.06	2.79	3.33	3.13	1.62
TOLRAMBQ	5.57	2.85	5.70	1.98	0.10
CATEWIDH	32.34	12.61	31.70	9.59	0.12
COGCOMPX	77.20	20.04	72.04	17.71	2.36
Cognitive Ability					
VERBCOMP	7.40	3.49	8.95	3.23	6.54*
GENLREAS	5.00	3.05	8.17	2.95	33.36***
ASSOFLUN	9.31	4.34	10.97	4.91	3.44
LOGIREAS	1.97	4.06	2.76	4.51	0.92
INDUCTON	50.17	15.21	59.72	16.95	9.53**
IDEAFLUN	10.00	3.50	11.59	4.34	4.12*
Cognitive Aptitude					
GENLINFO	55.29	5.44	58.78	6.97	7.81**
NUMROPER	48.60	6.71	53.92	7.45	15.29***
ATTNDETL	49.20	7.49	51.16	9.57	1.30
WORDKNOL	55.80	6.22	59.48	6.30	9.95**
ARTHREAS	53.00	8.37	60.20	8.36	21.54***
SPACPERC	55.60	7.83	56.24	11.15	0.10
MATHKNOL	53.09	5.87	60.44	8.13	25.84***
ELECINFO	57.34	5.30	60.58	6.58	7.48**
MECHCOMP	56.02	6.81	59.62	6.74	8.21**
GENLSCIE	54.80	11.53	60.45	7.66	13.10***
SHOPINFO	56.57	5.84	57.78	6.70	0.98
AUTOINFO	55.97	6.06	57.55	8.02	1.21

*$p < .05$ ($F(1,205) \geq 3.84$).

**$p < .01$ ($F(1,205) \geq 6.64$).

***$p < .001$ ($F(1,205) \geq 10.83$).

Table 3

Intercorrelation Matrix of Cognitive Characteristics Measures

Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1. FILDINDP	1.00																							
2. CONCSTYL	.14	1.00																						
3. REFLIMPL	-.12	-.14	1.00																					
4. TOLRAMBQ	.01	.03	-.00	1.00																				
5. CATEWIDH	.11	-.05	.16	-.06	1.00																			
6. COGCOMPX	-.08	.03	-.13	-.02	-.19	1.00																		
7. VERBCOMP	.13	.08	-.06	.06	.20	-.14	1.00																	
8. GENLREAS	.23*	.11	-.02	.15	.15	-.06	.41*	1.00																
9. ASSOFLUN	.16	.09	-.09	.01	.08	.02	.39*	.17	1.00															
10. LOGIREAS	.12	.05	-.12	.03	.16	.03	.18*	.35*	.11	1.00														
11. INDUCTON	.15	.09	-.11	-.10	.19*	.01	.15	.15	.15	-.00	1.00													
12. IDEAFLUN	.01	.04	-.02	-.00	.05	.03	.20	.14	.38*	.08	.12	1.00												
13. GENLINFO	.04	.01	.07	.03	.06	-.10	.33	.18	.20	.15	.01	.18*	1.00											
14. NUMROPER	.07	.06	-.11	-.02	.11	.07	.18*	.37*	.07	.10	.08	.21*	.13	1.00										
15. ATTNDETL	-.00	.03	-.04	-.11	.08	-.03	.04	.02	-.04	.09	.12	.11	-.02	.28*	1.00									
16. WORDKNOL	-.02	.05	.09	.06	.04	-.06	.52*	.16	.28*	.11	.07	.22*	.41*	.15	-.00	1.00								
17. ARTHREAS	.08	.03	-.05	.06	.05	-.10	.23*	.38*	.07	.22*	.04	.06	.22*	.39*	.08	.35*	1.00							
18. SPACPERC	.15	-.05	.08	.08	.02	-.09	-.03	.09	.10	-.00	.03	.01	.12	.07	-.02	.11	.20*	1.00						
19. MATHKNOL	.27*	.14	-.05	.03	.08	-.03	.29*	.41*	.16	.23*	.12	.11	.19*	.40*	.12	.30*	.50*	.11	1.00					
20. ELECINFO	.24*	.03	-.09	.06	.02	.02	.28*	.24*	.15	.20*	.10	.10	.32*	.11	-.09	.38*	.22*	.24*	.40*	1.00				
21. MECHCOMP	[illegible]	.05	.04	-.01	.11	-.00	.19*	.24*	.15	.18*	.18*	.15	.31*	.12	-.00	.35*	.26*	.34*	.31*	.51*	1.00			
22. GENLSCIE	.04	.02	-.03	.06	.12	-.00	.32*	.16	.17	.17	.09	.12	.33*	.02	-.07	.60*	.30*	.17	.33*	.42*	.40*	1.00		
23. SHOPINFO	.00	-.07	-.11	.04	.05	-.00	.17	.12	.01	.11	-.13	.06	.29*	.10	-.08	.26*	.22*	.17	.14	.35*	.45*	.30*	1.00	
24. AUTOINFO	.12	.05	-.13	.06	.14	-.05	.28*	.18*	.03	.18*	.01	.13	.34*	.12	-.09	.27*	.22*	.14	.19*	.47*	.47*	.29*	.49*	1.00

*$p < .05$, $r(205) \geq .18$.

Table 4

Summary of Stepwise Discriminant Analyses
Using Measures of Cognitive Characteristics

Step Number	Student Cognitive Measure: Entered	Student Cognitive Measure: Removed	F to Enter or Remove	Wilks Lambda (Λ)	p	Rao's V	Change in Rao's V	p of Change
	Cognitive Styles Only							
1	FILDINDP		16.82	.92	.00	16.82	16.82	.00
2	CONCSTYL		2.51	.91	.00	19.55	2.73	.10
3	COGCOMPX		1.46	.91	.00	21.16	1.62	.20

Λ = .91; $\chi^2(3)$ = 19.99; p < .001; λ = .10.

CN_f = .68; CN_g = -.14; R_c = .31.

D = -.81 FILDINDP -.36 CONCSTYL +.26 COGCOMPX.

C_f = .17 FILDINDP +.63 CONCSTYL +.23 COGCOMPX -1.27.

C_g = .35 FILDINDP +.71 CONCSTYL +.22 COGCOMPX -13.39.

Step Number	Entered	Removed	F to Enter or Remove	Wilks Lambda (Λ)	p	Rao's V	Change in Rao's V	p of Change
	Cognitive Abilities Only							
1	CENLREAS		33.36	.86	.00	33.36	33.36	.00
2	INDUCTON		4.40	.84	.00	38.50	5.14	.02

Λ = .84; $\chi^2(2)$ = 35.11; p < .001; λ = .19.

CN_f = -.88; CN_g = .18; R_c = .40.

D = .88 CENLREAS +.35 INDUCTON.

C_f = .43 CENLREAS +.17 INDUCTON -.32.

C_g = .77 CENLREAS +.19 INDUCTON -8.96.

Step Number	Entered	Removed	F to Enter or Remove	Wilks Lambda (Λ)	p	Rao's V	Change in Rao's V	p of Change
	Cognitive Aptitudes Only							
1	MATHKNOL		25.84	.89	.00	25.84	25.84	.00
2	ARTHREAS		5.11	.87	.00	31.62	5.79	.01
3	GENLSCIE		2.[illegible]	.86	.00	34.49	2.86	.10
4	NUMROPER		2.83	.84	.00	37.83	3.35	.07

Λ = .84; $\chi^2(4)$ = 34.38; p < .001; λ = .18.

CN_f = .87; CN_g = -.18; R_c = .40.

D = -.32 NUMROPER -.29 ARTHREAS -.41 MATHKNOL -.33 GENLSCIE.

C_f = .67 NUMROPER +.20 ARTHREAS +.29 MATHKNOL +.61 GENLSCIE -46.17.

C_g = .72 NUMROPER +.24 ARTHREAS +.36 MATHKNOL +.65 GENSCIE -57.46.

Step Number	Entered	Removed	F to Enter or Remove	Wilks Lambda (Λ)	p	Rao's V	Change in Rao's V	p of Change
	Cognitive Styles and Abilities							
1	CENLREAS		33.36	.86	.00	33.36	33.36	.00
2	FILDINDP		6.90	.83	.00	41.42	8.06	.00
3	INDUCTON		3.06	.82	.00	45.13	3.71	.05
4	CATEWIDH		2.66	.81	.00	48.42	3.29	.07
5	COGCOMPX		1.59	.80	.00	50.43	2.01	.16
6	IDEAFLUN		1.15	.80	.00	51.90	1.47	.22

Λ = .80; $\chi^2(6)$ = 45.59; p < .001; λ = .25.

CN_f = .99; CN_g = -.20; R_c = .45.

D = -.09 FILDINDP +.03 CATEWIDH +.01 COGCOMPX -.20 CENLREAS -.02 INDUCTON -.04 IDEAFLUN +1.78.

C_f = .03 FILDINDP +.34 CATEWIDH +.27 COGCOMPX +.31 CENLREAS +.12 INDUCTON +.40 IDEAFLUN -21.68.

C_g = .17 FILDINDP +.30 CATEWIDH -.26 COGCOMPX +.61 CENLREAS +.14 INDUCTON +.45 IDEAFLUN -23.75.

Notes.

1. CN_f and CN_g = Centroids for failure and graduate groups.
2. R_c = Canonical correlation between the derived discriminant function and the set of dummy variables defining membership in the two groups.
3. D = Derived discriminant function.
4. C_f and C_g = Classification functions for failure and graduate groups.

Table 4 (Continued)

Step Number	Student Cognitive Measure: Entered	Student Cognitive Measure: Removed	F to Enter or Remove	Wilks Lambda (Λ)	p	Rao's V	Change in Rao's V	p of Change
	Cognitive Styles and Aptitudes							
1	MATHKNOL		25.84	.89	.00	25.84	25.84	.00
2	FILDINDP		7.02	.86	.00	33.78	7.94	.00
3	ARTHREAS		5.76	.83	.00	40.55	6.77	.01
4	GENLSCIE		2.73	.82	.00	43.87	3.32	.07
5	NUMROPER		3.05	.81	.00	47.65	3.78	.05
6	CATEWIDH		1.81	.80	.00	49.94	2.29	.13
7	COGCOMPX		1.78	.80	.00	52.27	2.28	.13
8	SPACPERC		1.64	.79	.00	54.35	2.13	.14
9		MATHKNOL	.90	.79	.00	53.18	-1.17	1.00
10	CONCSTYL		1.20	.79	.00	54.75	1.57	.21

Λ = .79; $\chi^2(8)$ = 47.58; $p < .001$; λ = .28.

CN_f = -1.02; CN_g = .21; R_c = .46.

D = .45 FILDINDP +.15 CONCSTYL -.22 CATEWIDH -.21 COGCOMPX +.37 NUMROPER +.30 ARTHREAS -.18 SPACPERC +.38 GENLSCIE.

C_f = -.28 FILDINDP +.67 CONCSTYL +.31 CATEWIDH +.28 COGCOMPX +.59 NUMROPER +.33 ARTHREAS +.40 SPACPERC +.53 GENLSCIE -68.14.

C_g = -.10 FILDINDP +.73 CONCSTYL +.27 CATEWIDH +.26 COGCOMPX +.66 NUMROPER +.39 ARTHREAS +.38 SPACPERC +.60 GENLSCIE -76.55.

Step Number	Entered	Removed	F to Enter or Remove	Wilks Lambda (Λ)	p	Rao's V	Change in Rao's V	p of Change
	Cognitive Abilities and Aptitudes							
1	GENLREAS		33.36	.86	.00	33.36	33.36	.00
2	MATHKNOL		7.51	.83	.00	42.13	8.77	.00
3	INDUCTON		3.50	.82	.00	46.39	4.26	.04
4	GENLSCIE		2.76	.80	.00	49.82	3.43	.06
5	LOGIREAS		1.81	.80	.00	52.12	2.30	.13
6	ARTHREAS		1.62	.79	.00	54.20	2.09	.15

Λ = .79; $\chi^2(6)$ = 47.39; $p < .001$; λ = .26.

CN_f = 1.01; CN_g = -.21; R_c = .46.

D = -.56 GENLREAS +.21 LOGIREAS -.25 INDUCTON -.22 ARTHREAS -.25 MATHKNOL -.23 GENLSCIE.

C_f = -.72 GENLREAS -.32 LOGIREAS +.13 INDUCTON +.46 ARTHREAS +.56 MATHKNOL +.51 GENLSCIE -42.46.

C_g = -.45 GENLREAS -.39 LOGIREAS +.16 INDUCTON +.50 ARTHREAS +.61 MATHKNOL +.55 GENLSCIE -52.49.

Step Number	Entered	Removed	F to Enter or Remove	Wilks Lambda (Λ)	p	Rao's V	Change in Rao's V	p of Change
	Cognitive Styles, Abilities, and Aptitudes							
1	GENLREAS		33.36	.86	.00	33.36	33.36	.00
2	MATHKNOL		7.51	.83	.00	42.13	8.77	.00
3	FILDINDP		4.31	.81	.00	47.38	5.25	.02
4	GENLSCIE		3.48	.80	.00	51.72	4.34	.04
5	LOGIREAS		2.30	.79	.00	54.66	2.94	.09
6	CATEWIDH		2.02	.78	.00	57.28	2.63	.10
7	INDUCTON		2.69	.77	.00	60.83	3.54	.06
8	NUMROPER		1.98	.76	.00	63.49	2.66	.10
9		MATHKNOL	.86	.77	.00	62.33	-1.15	1.00
10	COGCOMPX		2.00	.76	.00	65.02	2.69	.10
11	SPACPERC		1.39	.75	.00	66.93	1.90	.17
12	ARTHREAS		1.62	.75	.00	69.18	2.25	.13

Λ = .75; $\chi^2(10)$ = 58.15; $p < .001$; λ = .34.

CN_f = -1.10; CN_g = .23; R_c = .50

D = .33 FILDINDP -.26 CATEWIDH -.17 COGCOMPX +.43 GENLREAS -.16 LOGIREAS +.22 INDUCTON +.21 NUMROPER +.20 ARTHREAS -.17 SPACPERC +.31 GENLSCIE.

C_f = -.07 FILDINDP +.29 CATEWIDH +.28 COGCOMPX -.91 GENLREAS -.26 LOGIREAS +.10 INDUCTON +.29 NUMROPER +.45 ARTHREAS +.37 SPACPERC +.56 GENLSCIE -69.82.

C_g = .08 FILDINDP +.24 CATEWIDH +.26 COGCOMPX -.67 GENLREAS -.32 LOGIREAS +.13 INDUCTON +.74 NUMROPER +.49 ARTHREAS +.35 SPACPERC +.63 GENLSCIE -77.41.

Notes.

1. CN_f and CN_g = Centroids for failure and graduate groups.
2. R_c = Canonical correlation between the derived discriminant function and the set of dummy variables defining membership in the two groups.
3. D = Derived discriminant function.
4. C_f and C_g = Classification functions for failure and graduate groups.

Table 5

Prediction Resu_ts Based on Derived Classification Functions

Classification Function	Actual Failures: Predicted Failures	Actual Failures: Predicted Graduates	Actual Graduates: Predicted Failures	Actual Graduates: Predicted Graduates	χ^2
Equal Probability					
Styles (S)	68.60	31.40	38.40	61.60	10.79**
Abilities (A)	74.30	25.70	26.20	73.80	29.89*
Aptitudes (P)	77.10	22.90	23.30	76.70	38.58*
S x A	71.40	28.60	23.80	76.20	30.33*
S x P	80.00	20.00	22.70	77.30	43.66*
A x P	80.00	20.00	20.90	79.10	47.51*
S x A x P	80.00	20.00	20.90	79.10	47.51*
Adjusted Probability					
Styles (S)	0.00	100.00	0.60	99.40	0.20
Abilities (A)	14.30	85.70	3.50	96.50	6.74**
Aptitudes (P)	11.40	88.60	2.90	97.10	5.08***
S x A	22.90	77.10	3.50	96.50	17.30*
S x P	25.70	74.30	4.10	95.90	19.10*
A x P	28.60	71.40	5.20	94.80	19.00*
S x A x P	34.30	65.70	3.50	96.50	34.74*

*$\chi^2(1) \geq 10.83$; $p < .001$.

**$\chi^2(1) \geq 6.64$; $p < .01$.

***$\chi^2(1) \geq 3.84$; $p < .05$.

2i

DISCUSSION AND CONCLUSIONS

The discriminant analyses and their associated statistics indicated that graduates and failures significantly differed in certain cognitive styles, abilities, and aptitudes. These findings have several implications for the identification of probable student failures and for adapting instruction within BE/E School. First, it was established that BE/E graduates were more field-independent; and failures, more field-dependent. That is, graduates had an information-processing style that was analytical in nature and were inclined to distinguish objects or figures from their backgrounds or contexts in a differentiated manner; and failures had a style that was global in nature and were inclined to perceive objects or figures embedded in their backgrounds or contexts in an undifferentiated manner. In light of the subject matter covered by BE/E School, it seems reasonable to conclude that students who are more analytical are more likely to complete the course. Also, field-independence is associated with an impersonal orientation; and field-dependence, with a personal orientation. Thus, field-independent students should be more successful than field-dependent students in a CMI course, which provides a minimal amount of interpersonal interaction between the instructor--whose new role is that of learning supervisor--and the student, as well as among the students. Field-independent students are more likely to succeed under these circumstances; and field-dependent students, to fail.

It was also found that graduates differed from failures in their conceptualizing style. Graduates tended to organize or sort objects to maximize similarities or differences among them. The fact that they used more categories in an object-sorting task than failures indicated that they usually exercise more critical judgment in recognizing ambiguities among objects or events. Thus, they should be successful in mastering instructional materials--especially subject matter as theoretical and technical as electricity and electronics.

With respect to abilities, graduates were significantly superior to failures in verbal comprehension and ideational fluency as well as in general and inductive reasoning. That is, in comparison with failures, they were more capable of (1) understanding the English language, (2) producing ideas about a specific topic, (3) selecting and organizing information to solve mathematical word problems, and (4) forming and testing hypotheses to fit certain data.

In regard to aptitudes, graduates manifested more quantitative and technical skill than failures, as indicated by their superior performance on tests measuring skills in numerical operations, arithmetic reasoning, mathematical knowledge, electrical knowledge, mechanical comprehension, and general science. Specifically, they surpassed failures in (1) speed and accuracy of performing problems of addition, subtraction, multiplication, and division, (2) facility in producing solutions to arithmetic word problems, (3) use of mathematical relationships involved in algebra, geometry, fractions, decimals, and exponents, (4) capacity to employ electronic symbols, principles, and diagrams, (5) understanding of mechanical and physical concepts and relationships, and (6) skill to perceive relationships between scientific concepts. Also, graduates were superior to failures in word knowledge, which is dependent upon comprehending written and spoken language, and in general knowledge. Considering the course contents of BE/E School, it is not surprising that graduates exceeded failures in these areas.

The above findings suggest several possibilities for developing procedures for adapting instruction to student characteristics (Cronbach & Snow, 1977; Federico, 1978a) to reduce BE/E attrition. Students possessing at least some of those cognitive characteristics associated with probable failure--as identified by this study--theoretically could be treated in one of three ways:

1. Assuming a sufficient manpower pool, they could be excluded from BE/E School and subsequently those ratings for which this preparatory training is a prerequisite, thus saving scarce instructional resources.

2. They could be included in BE/E School with the provision that they be given special training in deficient areas early in or prior to commencing school, thus increasing the likelihood of graduating.

3. They could be admitted to BE/E School with the understanding that special instructional strategies that account for their cognitive characteristics will be developed and implemented, thus minimizing the failure rate.

Before these proposals for accommodating instruction within BE/E School can be implemented, cognitive analyses should be conducted of those characteristics that differentiate graduates and failures to understand the nature of the information processing involved. This will allow the identification of pedagogical strategies and remediation schemes for optimally adapting instruction to reduce the BE/E attrition rate.

Seven different pairs of classification functions were established for predicting the probability of a student failing or graduating from BE/E School. These classification equations require, as input, measures of cognitive styles, abilities, and/or aptitudes. The prediction results based upon these distinct classification functions vary in their precision in terms of hit and miss rates. The derived classification equations also differ in the efficiency of their potential application to BE/E School. The ASVAB is already being given to all newly acquired Navy enlisted personnel; therefore, the set of equations that employs cognitive aptitudes assessed by the ASVAB, as well as those regression equations based on the ASVAB established by Dann (1978), can be implemented immediately. Measures of cognitive styles and abilities, which are integral components of the remainder of the derived classification functions, could be acquired by administering the appropriate tests to students prior to their entry to BE/E School. Information obtained would be used (1) to increase the accuracy of prediction of student failure or success in BE/E School, (2) to identify those students who are deficient in certain cognitive styles and abilities, so that they can be given training to increase their chances of success in BE/E School, and/or (3) to identify those students who should be assigned instructional materials specially designed to accommodate differences in cognitive styles and abilities, to minimize their failure rate within BE/E School. The administration of tests measuring cognitive styles and abilities should require less than 1 hour and should not involve additional school personnel.

RECOMMENDATIONS

1. Assuming that ASVAB scores are available for all students about to enter BE/E School and that the findings of this study are confirmed on cross validation, the derived classification functions based on aptitudes only should be implemented as predictors of student success or failure.

2. The tests of cognitive styles and abilities used in this study should be administered to students before they commence BE/E School to identify those who may benefit from pretraining in deficient areas or the use of specially designed instructional materials that are consistent with their styles and abilities. The development of pretraining and/or special instructional materials will require the following R&D:

a. Information processing analyses of cognitive styles, abilities, and aptitudes identified as important indices of failing or graduating from BE/E School.

b. Multiple-correlational analyses of relationships between performance on BE/E School modules and indices of cognitive characteristics.

c. Studies of student preferences for and perceptions of different instructional techniques and their relationship to measures of cognitive characteristics.

d. Test and evaluation of adaptive instructional strategies desired from the analyses of data resulting from a, b, and c above.

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APPENDIX

COGNITIVE CHARACTERISTICS USED TO DIFFERENTIATE
BE/E FAILURES AND GRADUATES

COGNITIVE CHARACTERISTICS USED TO DIFFERENTIATE BE/E FAILURES AND GRADUATES

Cognitive Styles

1. Field-Independence vs. Field-Dependence (FILDINDP) refers to a predominant manner of approaching the environment in an analytical as opposed to a global fashion. A field-independent person tends to differentiate objects or figures from their embedding backgrounds or contexts; and a field-dependent person, to experience objects or figures as part of their backgrounds or contexts. The former mode of processing reflects competence in analytical functioning together with an impersonal orientation; and the latter, less competence in analytical functioning together with a personal orientation (Witkin, Lewis, Hertzman, Machover, Meissner, & Wagner, 1954; Witkin, Dyk, Faterson, Goodenough, & Karp, 1962; Witkin, Oltman, Cox, Erichman, Hamm, & Ringler, 1973).

This dimension of style was measured by the Hidden Figures Test, Part 1 (Ekstrom, French, Harman, & Derman, 1976), a modification of the Gottschaldt figures-type test specifically designed and developed to study field independence. Within a 12-minute time period, the subject must decide--for each of 16 items--which of five geometrical figures is embedded in a complex pattern. The test score consists of the number of correct items minus a fraction of the numbers of wrong ones. Consequently, the higher the score, the more a subject can differentiate objects from the embedding contexts (i.e., the more field independent).

2. Conceptualizing Style (CONCSTYL) refers to the span of objects or patterns a person tends to consider in one conceptual category. It indicates the way a person organizes or sorts objects to maximize similarities or differences among them; or the range of things he treats as the same or equivalent (Kagan, Moss, & Siegel, 1960, 1963; Sloane, Gorlow, & Jackson, 1963; Wallach, 1962; Wallach & Kogan, 1965). Persons using a few broad categories in sorting tend to perceive that diverse objects are the same or equal; and those using many narrow categories, that they are different or unequal. Persons who use many categories in sorting typically show more critical judgment in recognizing ambiguities among objects or situations than those who use a few categories.

This style was measured by the Clayton-Jackson Object Sorting Test I (Clayton & Jackson, 1961), which consists of a printed sheet containing 50 words--each referring to a familiar object. The objects themselves are heterogeneous in function. The subject's task is to sort those objects by writing down in columns the names of those that appear to go together. He is given 17 minutes to complete the task. The test score is the number of categories formed. The higher the score, the more a subject tends to differentiate when categorizing objects.

3. Reflectiveness-Impulsivity (REFLIMPL) reflects the tendency to act deliberately as opposed to impulsively; that is, the inclination to contemplate a course of action instead of acting on the "spur of the moment." Reflective persons typically are reserved, inhibited, slow, unemotional, and rational; and impulsive persons, spontaneous, uninhibited,

hasty, impetuous, and rash. This cognitive style is primarily concerned with the degree to which a person tends to consider the validity of alternative hypotheses for solutions to problems that contain response uncertainty (Block, Block, & Harrington, 1974; Kagan & Kogan, 1970; Kagan & Messer, 1975; Messick, 1977). That is, reflective persons usually ponder several alternative possibilities prior to deciding and acting; and impulsive persons usually select and exercise the first possibility that occurs to them.

This style was measured by the Impulsivity Subscale from the Personality Research Form, Form E (Jackson, 1974). The subject is presented with a series of 16 true-false statements and asked to indicate whether he feels the characteristic mentioned in each applies to him. He is allowed a maximum of 4 minutes to complete this test. Since the test is keyed for impulsivity, the higher the score, the more impulsive the individual.

4. Tolerance of Ambiguity (TOLRAMBQ) usually refers to the tendency to accept situations or issues that have alternate interpretations and outcomes, or to feel comfortable when confronted with complex issues or circumstances. A person who is tolerant of ambiguity usually perceives such situations or issues as desirable or, at least, not threatening; and a person who is not, as undesirable or threat-inducing. These latter individuals tend to reduce complex issues to simplistic "black-and-white" notions (Frenkel-Brunswick, 1949; Rydell, 1966; Rydell & Rosen, 1966).

This dimension was measured by the Tolerance of Ambiguity Scale, which is included in the Self-Other Test, Form C (Rydell & Rosen, 1966). This scale contains 16 items, each consisting of a statement about a problem or situation, and a corresponding opinion as to its nature. The subject's task is to indicate whether he mostly agrees or disagrees with the opinion. The time limit for this task is 5 minutes. The higher the subject's score, the more tolerant he is of ambiguous situations.

5. Category Width (CATEWIDH) refers to the consistency of the width or range of cognitive categories. When subjects are asked to estimate the two extremes of, say, the speed of birds in flight or the annual rainfall in Washington, D. C., their breadth of categorization tends to be broad, medium, or narrow. This response may be a reflection of their risk-taking behavior. Broad categorizers are inclined to risk negative instances by including a maximum number of positive instances (Type I errors); and narrow categorizers, to risk positive instances by excluding a minimum number of negative instances (Type II errors). That is, broad categorizers tend to tolerate or prefer errors of inclusion; and narrow categorizers, errors of exclusion (Bruner & Tajfel, 1961; Fillenbaum, 1959; Messick & Kogan, 1965).

This cognitive style was measured by the Category Width Scale (Pettigrew, 1958). The scale consists of a series of ten items, each of which states an average value for, say, the length of whales, followed by a series of numbers. The subject's task is to select the two numbers that he feels represent the two extremes of that value. He must complete the test in 8 minutes or less. Items are scored based on the difference between the values of the stated mean and the subject's responses. The higher the total score, the broader the category width.

6. Cognitive Complexity (COGCOMPX) reflects the tendency to perceive the external environment, especially the social environment, in a multidimensional and discriminating manner. A more cognitively complex person perceives this environment in a more differentiated manner than a less cognitively complex person (Bieri, Atkins, Briar, Leaman, Miller, & Tripodi, 1966; Langley, 1971; Kelley, 1955; Schroder, Driver, & Streufert, 1967).

The test used to measure this style was a group version of the Rep Test (Kelley, 1955), which is called the Role Construct Repertory Test (Bieri et al., 1966). The subject is presented with a grid that includes eight columns and eight rows. The columns are labelled by a distinct role type chosen to be indicative of meaningful persons in the subject's social environment; and the rows, by individual traits or characteristics. The subject writes the initials or names of eight persons who correspond to the eight role types, and then rates these persons on a Likert-like scale on all the eight traits. To ensure privacy, the subject is instructed to erase or cross out the names or initials of the persons rated when he has finished the task. This test is scored by comparing the ratings given for each person. If any two ratings agree, a score of 1 is given. The higher the total score, the less cognitively complex the subject since he is evaluating all eight persons in an identical manner.

Cognitive Abilities

1. Verbal Comprehension (VERBCOMP) refers to a person's capacity to understand or comprehend the English language. It has been suggested (Ekstrom et al., 1976) that this dimension may be part of a more pervasive factor that includes reading comprehension, verbal analogies, matching proverbs, grammer and syntax, and verbal relations. Results of two investigations (Haag & David, 1969; Messick & French, 1975) implied that it may be related to the facility to use words in a multiple or flexible manner. Carroll (1974, 1975) mentioned that, within an information-processing framework, this ability is mostly determined by "the lexico-semantic long-term memory store."

The test employed for this cognitive ability was the Vocabulary Test, Part I (Ekstrom et al., 1976). In this 18-item test, the subject is presented with stimulus words, each followed by five other words. The subject selects the one word that has the same or nearly the same meaning as the stimulus word. The maximum time permitted is 4 minutes. The score consists of the number of right responses, minus a fraction of the number of wrong responses. The higher the score, the greater the verbal ability.

2. General Reasoning (GENLREAS) is related to the cognitive capacity to select and organize information pertinent for solving specific problems. Although mathematical reasoning tests are frequently used to measure this ability, they often confound numerical facility with general reasoning ability. Werdelin and Stjernberg (1971) found, in their investigation of tests of arithmetic problems, nonmathematical logical reasoning, and number series, that the more difficult the test, the more it weighted general reasoning. Consequently, this factor could be related to the higher difficulty level of other reasoning factors (Ekstrom et al., 1976).

Carroll (1974, 1975) mentioned that general reasoning was very similar to logical syllogistic reasoning because both include retrieval and serial operations.

The test used to measure this ability was the Arithmetic Aptitude Test, Part I (Ekstrom et al., 1976). In this test the subject is presented with 15 arithmetic word problems, each followed by five alternative answers. The subject's task is to solve the problems in 10 minutes or less. The score consists of the number of correct answers minus a fraction of the number of incorrect answers.

3. Associational Fluency (ASSOFLUN) refers to the capacity to generate rapidly words that have similar meanings or some other common semantic characteristic. Nunnally and Hodges (1965) found separate subfactors for the associations of synonyms, antonyms, and objects usually seen together. Carroll (1974, 1975) indicated that associational fluency involves search of long-term memory, with particular attention directed to its semantic and associational aspects. A subject high in this ability probably has many associations tied to a word and much flexibility in interpreting similarity (Bereiter, 1960).

The test used to measure this ability was the Controlled Associations Test, Part I (Ekstrom et al., 1976). The subject is presented with four stimulus words and asked to write, within 6 minutes, as many words as possible that have the same or similar meanings as these words. The score is the number of correct words. The higher the score, the greater the associational fluency.

4. Logical Reasoning (LOGIREAS) is related to deducing or reasoning syllogistically from premise to conclusion or evaluating logically the correctness of a conclusion. It can be easily confounded with verbal reasoning, especially when the task involves a high level of reading. This factor is quite complex. It involves the retrieval of meanings and algorithms from long-term memory and the performance of serial operations on the materials recovered (Carroll, 1974, 1975).

The test used to measure this factor was the Nonsense Syllogisms Test, Part I (Ekstrom et al., 1976). In this test, the subject is presented with 15 items, each consisting of three statements. Even though all of the statements are really nonsense, the subject is to assume that the first two statements in each item are correct. He must decide whether or not the third statement, which is really a conclusion drawn from the first two statements, demonstrates good reasoning. The subject has 4 minutes to complete the test. The score is the number marked correctly minus the number marked incorrectly. The higher the score, the better the reasoning ability.

5. Induction (INDUCTON) involves forming and testing hypotheses that will fit certain data. It requires producing concepts and evaluating hypotheses and is primarily a synthesizing or unifying process. In information-processing terms, it demands searching long-term memory for pertinent hypotheses in a general logic store. Successful performance depends on whether or not the contents of this store are sufficient to produce the solution (Carroll, 1974, 1975).

The test used to measure this ability was the Figure Classification Test, Part I (Ekstrom et al., 1976). The test includes 14 items, each comprised of two or three groups of three figures, followed by a number of stimulus figures. For each item, the subject's task is to determine (1) what the three figures in any one group have in common (e.g., shaded or unshaded, straight or curved), (2) how the groups of figures differed from one another (e.g., shaded vs. unshaded, straight vs. curved, and (3) which group of figures best corresponded to or matched each of the stimulus figures. He had 8 minutes to complete the task. The score is the number of stimulus figures classified correctly minus a fraction of the number classified incorrectly.

6. Ideational Fluency (IDEAFLUN) refers to the facility to generate a number of ideas about a specific topic or exemplars of a certain class of objects. The emphasis is on the quantity rather than the quality of ideas produced. It is similar to semantic originality and redefinition. According to Carroll (1974, 1975), all of these dimensions involve a search in an experiential store or episodic memory. Ideational fluency involves a rather wide search, whereas semantic originality and redefinition involve restrictions of unusualness or set breaking.

The test used to measure this factor was the Topics Test, Part I (Ekstrom et al., 1976). The subject is given a specific topic and asked to list all the ideas he can about that topic, whether or not they seem important to him. The subject can use a word or a phrase to express each idea. He has a time limit of 4 minutes. The score is the number of appropriate ideas written. The higher the score, the higher the ideational fluency.

Cognitive Aptitudes

Cognitive aptitudes are job-relevant skills that are measured by the ASVAB subtests described below.

1. The General Information Subtest (GENLINFO) is an index of the developed aptitude to recognize factual information that has accumulated from past learning experiences. It is a 20-item test of general knowledge concerning such areas as geography, sports, art, history, and first aid. The subject is instructed to read each item, and to select the best answer from four response alternatives. The time limit for this test is 7 minutes. The subject's score is determined by the number of questions answered correctly. The higher the score, the greater the general knowledge.

2. The Numerical Operations Subtest (NUMROPER) measures how rapidly and accurately a subject can complete arithmetic operations, such as addition, subtraction, multiplication, and division. The subject is instructed to choose the correct response from four response alternatives. This is a 50-item speeded test with a time limit of 3 minutes. The score is the number correct. The higher the score, the greater the numerical facility.

3. The Attention to Detail Subtest (ATTNDETL) was designed to measure the aptitude to perceive simple relationships, to store these relationships mentally, and to decide upon them quickly and accurately. The subject is

presented with 30 items, each comprised of two lines of O's with a varied number of C's mixed in, and asked to indicate, for each item, the total number of C's in both lines. This is a 5-minute speeded test. The subject's score is the number of items marked correctly. The higher the score, the more attentive the subject is to detail.

4. The Word Knowledge Subtest (WORDKNOL) is an index of verbal comprehension that is dependent upon the aptitude to understand written and spoken language. The subject is presented with 30 items, each consisting of an underlined word followed by four other words. For each item, the subject must decide which of the four response words has the same or nearly the same meaning as the underlined word, within a 10-minute period. His score is the number of items answered correctly. Higher scores indicate better word knowledge.

5. The Arithmetic Reasoning Subtest (ARTHREAS) was constructed to measure general reasoning, which is dependent upon the aptitude to solve arithmetic word problems. The subject is required to solve 20 of these problems within a 20-minute period. The score is the number of items answered correctly. Higher scores indicate greater arithmetic reasoning skills.

6. The Space Perception Subtest (SPACPERC) was constructed as an index of a subject's spatial aptitude. It entails the skill to visualize and manipulate objects in space. The subject is presented with 20 pictorial items, each consisting of flat patterns and four drawings of three-dimensional figures. Broken lines on the flat pattern indicate where it is to be folded. The subject must decide which figure could be constructed from each of the flat patterns within a 12-minute period. The score is the number of items answered correctly. The higher the score, the greater the spatial aptitude.

7. The Mathematics Knowledge Subtest (MATHKNOL) was designed as an index of the aptitude to use mathematical relationships involved in solving problems in algebra, geometry, fractions, decimals, and exponents. The subject is required to solve 20 problems in a 20-minute period. The score is the number of correct items. Higher scores signify more mathematical aptitude.

8. The Electronics Information Subtest (ELECINFO) is an index of the cognitive aptitude to use acquired electronic relationships, symbols, principles, and diagrams. The subject is required to answer 30 items involving electronics terminology and computations in a 15-minute period. The score is the number of correct items. Higher scores indicate more electronic aptitude.

9. The Mechanical Comprehension Subtest (MECHCOMP) measures the aptitude to learn, comprehend, and reason with mechanical and physical concepts and principles. Familiarity with ordinary tools and mechanical relations acquired through daily experiences is a prerequisite for adequate performance on this test. The subject is presented with 20 pictorial items and asked to indicate what the drawings represent, within a 15-minute period. The score is based on the number of correct responses. The higher the score, the more the mechanical aptitude.

10. The General Science Subtest (GENLSCIE) measures scientific knowledge of physics and biology, and the reasoning involved to perceive relationships between scientific concepts. The subject is required to respond to 20 items on science within 10 minutes. The score is the number of correct items. Higher scores signify greater knowledge of general science.

11. The Shop Information Subtest (SHOPINFO) is an index of an aptitude that is dependent upon knowledge about and experience with a variety of tools typically found in a shop. The subject is required to answer 20 multiple-choice items about shop practices or tool use within 8 minutes. The score is the number of items marked correctly. Higher scores indicate greater shop knowledge.

12. The Automotive Information Subtest (AUTOINFO) was designed to measure an aptitude pertaining to the diagnosis of automobile malfunctions, the use of specific automotive parts, the operation of particular automobile components, and the knowledge of automobile terminology. The subject is required to answer 20 multiple-choice items dealing with various aspects of automobiles within 10 minutes. The score is the number correct. The higher the score, the greater the automotive knowledge.