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ABSTRACT

This study, the fourth in a series conducted at the Navy's Basic Electricity and Electronics School for a computer managed instruction project, reports the relationships among selected measurements of student cognitive styles, abilities, and aptitudes. Measures of these characteristics for a sample of 166 graduates of BE/E were analyzed to determine the nature and magnitude of their relationships. Canonical analyses established that measures of cognitive styles were significantly related to measures of aptitudes and abilities, but their common variance was not large enough to be of practical value. Measures of aptitudes were significantly related to measures of abilities and the two sets to have a considerable amount of shared variance. When the various measures were factor analyzed, three significant factors--technical aptitude, verbal ability, and problem solving mode--accounted for much of the variability among the measures of cognitive characteristics. Thus it was concluded that cognitive styles are relatively independent of abilities and aptitudes and should be considered in selection of BE/E students, in predicting their performance, likelihood of attrition, and adapting alternative teaching treatments to student attributes. (Author/RAA)

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April 1980

RELATIONSHIPS AMONG SELECTED MEASURES OF COGNITIVE STYLES, ABILITIES, AND APTITUDES

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Measures of cognitive styles, abilities, and aptitudes for a sample of 166 graduates of Basic Electricity and Electronics School were analyzed to determine the magnitude and nature of their relationships. Canonical analyses established that measures of cognitive styles were significantly related to measures of aptitudes and of abilities, but their common variance was not large enough to be of practical value. Measures of aptitudes were significantly related to measures of abilities, and the two sets of measures do have a considerable amount of shared variance. When the various

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) measures were factor analyzed, three significant factors were extracted--which appeared to reflect measures of technical aptitude, verbal ability, and problem-solving mode. These factors accounted for much of the variability among the various measures of cognitive characteristics. Thus, it was concluded that cognitive styles are relatively independent of abilities and aptitudes.

FOREWORD

This research was performed under Advanced Development Project Z1175; subproject PN.05; Improved Effectiveness in Course Design, Delivery, and Evaluation, and the sponsorship of the Deputy Chief of Naval Operations (Manpower, Personnel, and Training). The goal of this subproject is to design and evaluate procedures for facilitating the instructional systems development (ISD) process.

This is the fourth in a series of reports prepared under this subproject. The first (NPRDC TR 79-1) identified measures of student characteristics that may be used to develop individualized instructional procedures; the second (NPRDC TR 79-21), student characteristics that best differentiate failures and graduates of the Basic Electricity and Electronics (BE/E) School; and the third (NPRDC TR 79-30), those characteristics that are predictive of student performance in BE/E School. The purpose of this study was to determine the magnitude and nature of the relationships among selected measures of cognitive styles, abilities, and aptitudes. There is some dispute as to whether cognitive styles can be separated or differentiated from abilities and aptitudes. An important question that must be answered for the ISD process is whether these measures provide complementary or redundant information regarding students' attributes.

The results of this study are primarily intended for the Chief of Naval Education and Training, the Chief of Naval Technical Training, the Instructional Program Development Centers, the Technical Program Coordinators of the Navy's BE/E Schools, and the Department of Defense training and testing research and development community.

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SUMMARY

Problem and Background

It appears that implementation of computer-managed instruction (CMI) in the Navy's Basic Electricity and Electronics (BE/E) Preparatory Schools has improved training efficiency. To obtain maximum benefit from CMI, however, adaptive instructional strategies that accommodate alternative teaching treatments to student cognitive styles, abilities, and aptitudes must be designed, developed, and implemented.

This is the fourth in a series of studies being conducted to address this problem. The first identified measures of student characteristics that may be used to develop individualized instructional procedures; the second, student characteristics that best differentiate BE/E graduates and failures; and the third, those characteristics that are predictive of student performance in BE/E School.

Purpose

The purpose of this research was to determine the magnitude and nature of the relationships among the selected measures of student cognitive styles, abilities, and aptitudes. There is some dispute as to whether cognitive styles can be separated or differentiated from abilities and aptitudes. An important question that must be answered for the ISD process is whether these measures provide complementary or redundant information regarding students' attributes.

Approach

Subjects were 166 BE/E graduates for whom measures of cognitive characteristics had previously been obtained. Using these data as input, three canonical analyses were performed to determine the relationships among (1) styles and abilities, (2) styles and aptitudes, and (3) abilities and aptitudes. Also, to identify those factors that accounted for the variability among cognitive styles, abilities, and aptitudes, a principal factor analysis followed by an orthogonal varimax rotation was computed.

Results

1. Measures of cognitive styles were significantly related to measures of abilities and of aptitudes. The amount of variance shared by measures of cognitive styles and measures of other characteristics, however, is not large enough to be of practical significance.

2. Abilities are significantly associated with aptitudes, and these measures do have a considerable amount of shared variance.

3. Three significant factors--dimensions of technical aptitude, verbal ability, and problem solving--account for much of the variability among the various cognitive characteristics.

Conclusions and Recommendations

The above findings indicate that cognitive styles are relatively independent of abilities and aptitudes. Therefore, they should be considered in selecting BE/E students, in predicting their performance and likelihood of attrition, and in adapting alternative teaching treatments to student attributes. Further R&D will be required to establish the feasibility and practicality of implementing these recommendations for Navy testing and training.

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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 (Orlansky & String, 1979). To obtain maximum benefit from CMI, however, adaptive instructional strategies that accommodate alternative teaching treatments to student cognitive styles, abilities, and aptitudes must be designed, developed, and implemented. In filling this need, it will be necessary to identify those cognitive characteristics that are related to student performance. Cognitive styles refer to the dominant modes of information processing used by individuals in perceiving, learning, or problem solving (e.g., field independence or cognitive complexity); cognitive abilities, to intellectual capabilities (e.g., verbal comprehension or general reasoning); and cognitive aptitudes, to job-relevant skills (e.g., mechanical comprehension or electrical information).

Background

To address this problem, Federico (1978) reviewed the literature concerning adaptive teaching systems, and identified those that could be used to accommodate instruction to student cognitive characteristics. Federico and Landis (1979a) then analyzed measures of cognitive styles, abilities, and aptitudes obtained for a sample of 207 BE/E students--172 graduates and 35 failures--to determine which combination of measures best differentiated members of the two groups. Table 1 lists the characteristics measured by Federico and Landis, and provides an abbreviation, a brief description, and the test measurement instrument used for each. The tests of cognitive styles and abilities were administered to subjects before they had commenced BE/E School. The tests of cognitive aptitudes--the Armed Services Vocational Aptitude Battery (ASVAB) subtests--are routinely administered to all Navy entrants. These tests assess specific skills or knowledge areas, and serve chiefly as classification instruments for making job decisions and school assignments for Navy recruits.

Federico and Landis (1979a) used 24 measures of student characteristics to perform seven stepwise discriminant analyses to determine which linear combinations of tests optimally differentiate between BE/E failures and graduates. These separate analyses were computed using (1) measures of cognitive styles, abilities, and aptitudes only, (2) the three two-way interactions of these sets of indices, and (3) the one three-way interaction. An examination of the discriminant weights corresponding to these functions, together with the univariate F-tests and means and standard deviations for the two groups, revealed that BE/E graduates and failures differed significantly 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 indicated the need for developing procedures for adapting instruction to student cognitive characteristics to minimize the BE/E failure rate.

The effectiveness of each of the seven derived discriminant functions was ascertained by computing a corresponding classification function using the test scores of the BE/E failures and graduates, since their actual group membership was known. Initially, classification functions were calculated assuming that each student who entered BE/E school had an equal probability of failing or graduating. This probability was then adjusted according to a priori probabilities of failing or graduating this school (i.e., .15 and

Table 1

Cognitive Characteristics Measured in Study

Cognitive Characteristic	Abbreviation	Description	Measurement Instrument
		Cognitive Styles	
Field-Independence vs. Field-Dependence	FILDINDP	Analytical vs. global orientation	Hidden Figures Test, Part I (Ekstrom, French, Harmon, & Dermen, 1976)
Conceptualizing Style	CONCSTYL	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 enviroment	Group Version of Role Construct Repertory Test (Bieri, Atkins, Briar, Leaman, Miller, & Tripodi, 1966)
		Cognitive Abilities	
Verbal Comprehension	VERBCOMP	Understanding the English language	Vocabulary Test, Part I (Ekstrom et al., 1976)
General Reasoning	GENLREAS	Solving specific problems	Arithmetic Aptitude Test, Part I (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 I (Ekstrom et al., 1976)
Induction	INDUCTON	Forming hypotheses to fit certain facts	Figure Classification Test, Part I (Ekstrom et al., 1976)
Ideational Fluency	IDEAFLUN	Generating ideas about a specific type	Topics Test, Part I (Ekstrom et al., 1976)
		Cognitive Aptitudes	
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

Note. These cognitive characteristics and the tests used to measure them are described in detail in Federico and Landis (1979a) (Appendix).

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85% respectively). Under the equal probability assumption, the percentage of correct classifications for actual BE/E failures using the seven functions was 68.6 to 80.0 percent; and for actual graduates, 61.6 to 79.1 percent. Adjusting according to prior probability, the percentage of correct classifications of actual BE/E failures was zero to 34.3 percent; and of actual graduates, 94.8 to 99.4 percent.

Finally, Federico and Landis (1979b) used the measures obtained for 166 of the 172 BE/E graduates to identify those characteristics that may be predictive of student performance (i.e., module test scores and times to completion) in the first 11 modules of BE/E School, and to determine whether the predictor pattern changes across these modules. (Performance data were missing for 6 of the 172 BE/E graduates.) They computed 22 stepwise regression analyses and two canonical analyses, using measures of cognitive characteristics as predictors and module test scores or times to completion as criteria. Results indicated that, in 7 of the 11 modules, measures of cognitive styles and/or abilities contributed more to the prediction of student achievement than did measures of cognitive aptitudes. Cognitive styles and aptitudes accounted for more variance in the later modules than the earlier ones; the opposite is true for cognitive abilities.

In all 11 modules, measures of cognitive styles and/or abilities accounted for more of the variance in times to complete the modules than did measures of cognitive aptitudes. Cognitive styles and abilities appear to be approximately equally important predictors of times to complete the earlier as well as the later modules; cognitive aptitudes, however, are more predictive in the second than in the first half of the modules.

Before the discriminant, classification, and regression equations established in these earlier experiments can be implemented, cross-validation studies must be conducted to demonstrate their suitability for different student samples. Also, the relationships among measures of cognitive styles, abilities, and aptitudes should be studied further, particularly since there is some dispute in the relevant research literature (Kogan, 1971; Satterly, 1976; Vernon, 1972) as to whether or not cognitive styles can be separated or differentiated from abilities and aptitudes. An important question that must be answered is whether these measures provide complementary or redundant information regarding students' cognitive characteristics.

Objective

The objective of this research was to determine the magnitude and nature of the relationships among the selected measures of cognitive styles, abilities, and aptitudes.

APPROACH

Subjects

The subjects were the 166 BE/E graduates who participated in the Federico and Landis (1979b) study. As indicated previously, measures of cognitive styles, abilities, and aptitudes had been obtained for these subjects.

Analyses

To determine the magnitude and nature of the relationships among the various cognitive measures, three canonical analyses (Cooley & Lohnes, 1962) were performed. The three sets of variables used in these analyses were (1) cognitive styles and abilities, (2) styles and aptitudes, and (3) abilities and aptitudes.

Also, to identify those factors that accounted for the variability among cognitive styles, abilities, and aptitudes, a principal factor analysis with iteration was computed (Harman, 1967). Since the emerging factors were difficult to interpret because of the nature of their loadings and their bipolarity, the initial principal factor matrix was rotated to achieve a simpler structure and a more meaningful pattern.

RESULTS AND DISCUSSION

The means and standard deviations for the measures of cognitive characteristics are presented in Table 2; the correlation matrix for these measures in Table 3; and results of the three canonical analyses, in Tables 4, 5, and 6.[1] Table 4 shows that cognitive styles are significantly related to abilities; nevertheless, the amount of variance they share is merely 21 percent. The canonical variates indicate that the cognitive style that contributes the most to the relationship is field independence (FILDINDP), followed by category width (CATEWIDH), reflection-impulsivity (REFLIMPL), and conceptualizing style (CONCSTYL). The abilities that contribute most to the relationship are induction (INDUCTON), general reasoning (GENLREAS), and verbal comprehension (VERBCOMP). Except for REFLIMPL, low factor scores on the salient cognitive styles are related to low scores on the salient abilities. These results establish the fact that poor information processing is related, to some extent, to poor reasoning ability. Persons who have difficulty in processing information (1) have difficulty in differentiating objects or figures from their embedding backgrounds or contexts (field dependence), (2) tend to risk positive instances by excluding a minimum number of negative instances (Type II errors) (narrow CATEWIDH), (3) tend to be impetuous, hasty, rash--usually exercising the first possibility that occurs to them to solve problems (impulsivity), and (4) show little critical judgment in recognizing ambiguities among objects or situations (broad CONCSTYL). Persons with poor reasoning ability have difficulty in (1) forming and testing hypotheses to fit certain data (low INDUCTON), (2) selecting and organizing information pertinent to solving specific problems (low GENLREAS), and (3) understanding or comprehending the English language (poor VERBCOMP).

Table 5 shows that cognitive styles are also significantly associated with aptitudes. The amount of variance these two sets of indices have in common, however, is only 19 percent. The cognitive styles that contribute most to this association are FILDINDP and CONCSTYL. The aptitudes that contribute most are mathematics knowledge (MATHKNOL), mechanical comprehension (MECHCOMP), shop information (SHOPINFO), and word knowledge (WORDKNOL). The canonical loadings for these indices suggest that low FILDINDP and CONCSTYL are associated with low MATHKNOL and MECHCOMP and with high WORDKNOL and SHOPINFO. These results show that poor perceptual discrimination, as defined by field dependence and broad CONCSTYL, is somewhat associated with low mathematical and mechanical aptitude and high verbal skills.

Finally, Table 6 shows that cognitive abilities are significantly related to aptitudes, with the two sets of measures having 68 percent of common variance. The loadings of the first canonical variate pair, which accounts for 41 percent of the variance, suggest that the abilities contributing to this association are VERBCOMP and GENLREAS; and that the contributing aptitudes are WORDKNOW and MATHKNOL. Low scores on the salient abilities are related to low scores on the salient aptitudes. These results show that

[1] Because of the large number of tables relative to the amount of text in this section, the tables are included at the end of the section.

persons with low verbal and general reasoning ability tend to be deficient in word and mathematics knowledge.

The loadings of the second variate pair, which is orthogonal to the first and accounts for 27 percent of the variance, indicate that the contributing abilities are GENLREAS VERBCOMP, and INDUCTON; and the contributing aptitudes, WORDKNOL, MECHCOMP, arithmetic reasoning (ARTHREAS), and numerical operations (NUMROPER). The canonical loadings show that high VERBCOMP and low GENLREAS abilities are associated with high WORDKNOL and low MECHCOMP, ARTHREAS, and NUMROPER aptitudes. These results indicate that persons with high verbal and low general reasoning ability tend to have a high verbal aptitude as well as poor mechanical and quantitative skills.

The estimated communalities of the cognitive characteristics for the principal-factor and varimax solutions are presented in Table 7, their associated eigenvalues and other data, in Table 8; and matrices of significant factors obtained, in Table 9.

1. Principal Factor Solution. As shown in Table 7, aptitudes generally have larger communalities than abilities, which, in turn, have larger communalities than styles. Aptitudes seem to have more variance in common with the other cognitive characteristics than do either abilities or styles. Twenty-four factors, which were extracted from the initial unrotated principal factor solution, accounted for 100 percent of the variance. Of these, eight significant factors explained 62.2 percent of the variance. Aptitudes load on factor 1, the most important component, accounting for 21 percent of the variance, more than do abilities, which, in turn, contribute more to this dimension than do styles. Thus, the first factor represents an aptitude-ability underlying dimension. Since the other factors were difficult to interpret because of the nature of their loadings and bipolarity, the initial principal factor matrix was rotated to achieve a simpler structure and more meaningful pattern.

2. Varimax Solution. As shown in Table 7, for the final factor solution, aptitudes have larger communalities than abilities, which, in turn, have larger communalities than styles. Eight rotated factors accounted for 100 percent of the variance of the cognitive characteristics. Of these, three significant factors explained 67.5 percent of the variance. Aptitudes load on factor 1, the most important component, accounting for 43.8 percent of the variance, more than do abilities or styles. The most salient measures contributing to this technical aptitude dimension, in order of prominence, are SHOPINFO, AUTOINFO, MECHCOMP, ELECINFO, GENLSCIE, GENLINFO, and WORDKNOL. Thus, it appears that factor 1 represents a technical aptitude dimension. Abilities load on factor 2, the next important component, explaining 13.7 percent of the variance, more than do aptitudes or styles. Since the most prominent indices loading on this dimension are ASSOFLUN, IDEAFLUN, and VERBCOMP, it appears that factor 2 represents a verbal ability dimension. Finally, some styles, abilities, and aptitudes have large loadings on factor 3, which accounts for 10 percent of the variance. The most important cognitive characteristics contributing to this component, in order of prominence, are FILDINDP, INDUCTON, MATHKNOL, REFLIMPL, CONCSTYL, and GENLREAS. Therefore, it appears that factor 3 denotes a problem-solving-mode dimension.

Since these three factors are orthogonal and have practically no variable overlap among the derived dimensions, they provide complementary--not redundant--information regarding students' cognitive characteristics. Technical aptitude is undoubtedly differentiated and separate from verbal ability as well as from problem-solving mode. No amount of variance seems to be common to these distinct factors.

In this study, the principal factor analysis and varimax rotation established the separability of cognitive style from technical aptitude and verbal ability. Measures of cognitive style, primarily FILDINDP, REFLIMPL, and CONCSTYL, substantially contributed to the problem-solving-mode factor but not the technical aptitude or verbal ability factors. This is somewhat similar to Satterly's (1976) finding from a principal component analysis with varimax rotation, which demonstrated the distinctiveness of cognitive style (FILDINDP, preference for analytical style, speed and flexibility of closure) from the factors of (1) general ability (English comprehension, picture vocabulary, verbal intelligence, and mathematics attainment), (2) spatial ability (spatial dimension, judgment, speed, and flexibility of closure), and (3) perceptual speed (perceptual ability, speed, flexibility of closure, and spatial judgment). The results of the present investigation, however, are different from the findings of Vernon (1972), who demonstrated that measures of cognitive style or FILDINDP do not define a dimension that is distinct from general intelligence and spatial ability factors (which were defined by the following tests--Copying Figures, Paper Formboard, Kohs Blocks, Concealed Figures, Embedded Figures, and Draw-a-Person Body Sophistication).

As indicated previously, two of the canonical analyses showed that the amount of shared variance between cognitive styles and abilities and between cognitive styles and aptitudes is too little to be of practical importance. The small but statistically significant relationships obtained between the linear combinations of these measures indicate the relative independence of cognitive styles from abilities and aptitudes. This was also somewhat manifested by the principal factor analysis and varimax rotation. The distinctiveness or separability of styles from abilities and aptitudes has instructional significance.

Table 2

Means and Standard Deviations of Measures of Cognitive Styles, Abilities, and Aptitudes

Cognitive Characteristic	M	S.D.
Styles:		
FILDINDP	4.74	3.92
CONCSTYL	12.42	4.04
REFLIMPL	3.49	3.10
TOLRAMBQ	5.67	2.17
CATEWIDH	31.83	10.10
COGCOMPX	73.17	18.33
Abilities:		
VERBCOMP	8.77	3.31
GENLREAS	7.70	3.15
ASSOFLUN	10.72	4.89
LOGIREAS	2.65	4.46
INDUCTON	57.99	16.87
IDEAFLUN	11.21	4.05
Aptitudes:		
GENLINFO	58.19	6.84
NUMROPER	53.15	7.60
ATTNDETL	50.84	9.22
WORDKNOL	58.80	6.48
ARTHREAS	59.05	8.88
SPACPERC	56.01	10.72
MATHKNOW	59.27	8.30
ELECINFO	60.05	6.30
MECHCOMP	59.04	6.89
GENLSCIE	59.43	8.71
SHOPINFO	57.60	6.65
AUTOINFO	57.25	7.81

Note. Based on measures obtained for 201 students.

Table 3

Correlation Matrix for Measures of Cognitive Styles, Abilities, and Aptitudes

	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	—																							
2. CONCSTYL	.18	—																						
3. REFLIMPL	-.13	-.15	—																					
4. TOLRAMBQ	.02	.04	-.00	—																				
5. CATEWIDH	.11	-.04	.17	-.06	—																			
6. COGCOMPX	-.12	.02	-.13	-.02	-.18	—																		
7. VERBCOMP	.17	.09	-.08	.08	.21	-.17	—																	
8. GENLREAS	.30	.16	-.06	.15	.15	-.10	.43	—																
9. ASSOFLUN	.18	.10	-.10	.03	.07	.00	.40	.21	—															
10. LOGIREAS	.12	.08	-.13	.03	.10	.02	.20	.35	.12	—														
11. INDUCTON	.21	.10	-.13	-.10	.23	.01	.19	.21	.18	.01	—													
12. IDEAFLUN	.04	.05	-.00	.02	.06	.04	.24	.20	.39	.10	.14	—												
13. GENLINFO	.09	.02	.06	.04	.08	-.12	.35	.23	.22	.18	.03	.18	—											
14. NUMROPER	.13	.09	-.13	-.01	.11	.04	.20	.42	.08	.11	.14	.25	.17	—										
15. ATTNDETL	.03	.02	-.04	-.11	.09	-.03	.05	.07	-.04	.11	.12	.09	-.02	.29	—									
16. WORDKNOL	.04	.09	-.00	.06	.04	-.08	.56	.24	.29	.12	.11	.22	.44	.20	.00	—								
17. ARTHREAS	.15	.07	-.09	.07	.05	-.13	.26	.45	.11	.23	.10	.11	.27	.44	.11	.40	—							
18. SPACPERC	.15	-.04	.09	.08	.03	.19	-.01	.10	.10	-.01	.03	.00	.13	.08	-.02	.11	.20	—						
19. MATHKNOL	.34	.18	-.08	.05	.09	-.07	.32	.48	.19	.25	.19	.16	.24	.45	.15	.36	.55	.12	—					
20. ELECINFO	.26	.04	-.10	.07	.05	-.01	.30	.25	.16	.21	.12	.11	.34	.14	-.06	.42	.25	.24	.42	—				
21. MECHCOMP	.23	.09	.02	-.01	.11	.03	.23	.28	.18	.18	.22	.20	.36	.17	.03	.39	.30	.33	.36	.53	—			
22. GENLSCIE	.19	.05	-.04	.07	.12	-.03	.36	.24	.19	.18	.13	.11	.35	.08	-.05	.62	.36	.16	.39	.44	.43	—		
23. SHOPINFO	.02	-.05	-.11	.04	.05	-.01	.18	.13	.02	.11	-.11	.07	.31	.11	-.07	.27	.23	.17	.16	.37	.45	.31	—	
24. AUTOINFO	.13	.06	-.13	.06	.14	-.06	.29	.19	.04	.18	.03	.14	.35	.13	.07	.28	.23	.14	.21	.47	.47	.28	.50	—

<u>Note</u>. $r(199) \geq .138; p \leq .025.$

$r(199) \geq .181; p \leq .005.$

Table 4

Canonical Variates for Measures of Cognitive Styles and Abilities

Cognitive Styles	Standardized Canonical Loadings	Cognitive Abilities	Standardized Canonical Loadings
FILDINDP	-.58	VERBCOMP	-.26
CONCSTYL	-.25	GENLREAS	-.47
REFLIMPL	.33	ASSOFLUN	-.21
TOLRAMBQ	-.12	LOGIREAS	-.20
CATEWIDH	-.56	INDUCTON	-.50
COGCOMPX	.10	IDEAFLUN	.18

Note. Canonical $R_c = .46$; $R_c^2 = \lambda = .21$; Wilk's $\Lambda = .69$; $\chi^2(36) = 71.07$; $p = .000$.

Table 5

Canonical Variates for Measures of Cognitive Styles and Aptitudes

Cognitive Styles	Standardized Canonical Loadings	Cognitive Aptitudes	Standardized Canonical Loadings
FILDINDP	-.90	GENLINFO	-.05
CONCSTYL	-.27	NUMROPER	.01
REFLIMPL	-.08	ATTNDETL	.04
TOLRAMBQ	-.06	WORDKNOL	.26
CATEWIDH	-.14	ARTHREAS	.07
COGCOMPX	.00	SPACPERC	-.14
		MATHKNOL	-.78
		ELECINFO	-.21
		MECHCOMP	-.38
		GENLSCIE	.06
		SHOPINFO	.38
		AUTOINFO	-.14

Note. Canonical $R_c = .43$; $R_c^2 = \lambda = .19$; Wilk's $\Lambda = .61$; $\chi^2(72) = 94.04$; $p = .039$.

Table 6

Canonical Variates for Measures of Cognitive Abilities and Aptitudes

Cognitive Abilities	Standardized Canonical Loadings: First Variate	Standardized Canonical Loadings: Second Variate	Cognitive Aptitudes	Standardized Canonical Loadings: First Variate	Standardized Canonical Loadings: Second Variate
VERBCOMP	-.64	.89	GENLINFO	-.18	.07
GENLREAS	-.36	-.90	NUMROPER	-.23	-.37
ASSOFLUN	.03	-.01	ATTNDETL	-.05	.11
LOGIREAS	-.14	-.05	WORDKNOL	-.45	.88
INDUCTON	-.08	-.27	ARTHREAS	-.07	-.41
IDEAFLUN	-.22	-.01	SPACPERC	.14	-.07
			MATHKNOL	-.30	-.23
			ELECINFO	-.02	-.01
			MECHCOMP	-.08	-.46
			GENLSCIE	-.04	-.08
			SHOPINFO	.11	.18
			AUTOINFO	-.21	.22

Note. For the first canonical variate, $R_c = .64$; $R_c^2 = \lambda = .41$; Wilk's $\Lambda = .33$; $\chi^2(72) = 213.19$; $p = .000$. For the second canonical variate, $R_c = .52$; $R_c^2 = \lambda = .27$; Wilk's $\Lambda = .56$; $\chi^2(55) = 112.55$; $p = .000$.

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Table 7

Estimated Commonalities of the Cognitive Characteristics for the Principal Factor and Varimax Solutions

Cognitive Characteristic	Estimated Commonalities: Initial Unrotated Principal Factor Solution	Estimated Commonalities: Terminal Rotated Orthogonal Varimax Solution
Styles:		
FILDINDP	.24	.31
CONCSTYL	.11	.10
REFLIMPL	.27	.47
TOLRAMBQ	.12	.20
CATEWIDTH	.21	.30
COGCOMPX	.17	.21
Abilities:		
VERBCOMP	.51	.71
GENLREAS	.37	.51
ASSOFLUN	.36	.51
LOGIREAS	.23	.21
INDUCTON	.25	.32
IDEAFLUN	.27	.41
Aptitudes:		
GENLINFO	.33	.33
NUMROPER	.39	.55
ATTNDETL	.19	.25
WORDKNOL	.58	.76
ARTHREAS	.41	.48
SPACPERC	.21	.24
MATHKNOL	.47	.59
ELECINFO	.50	.56
MECHCOMP	.60	.71
GENLSCIE	.55	.61
SHOPINFO	.50	.67
AUTOINFO	.45	.53

Note. Communalities, the amount of variance of a measure that is shared by at least one other measure being considered, were initially estimated based on the squared multiple correlation between a specific measure and the rest of the measures in the correlation matrix. The communality estimates obtained were then improved using an iteration procedure. In this procedure, the number of factors to be extracted from the original correlation matrix was determined, and the entries in the main diagonal were then replaced by the initial communality. Next, the same number of factors was generated from the reduced matrix, and the variances accounted for by these dimensions became the new communalities estimates. The diagonal entries were subsequently replaced with these new communalities. This procedure continued until the differences between two successive communality estimates were negligible.

Table 8

Associated Eigenvalues, Percent Variance Accounted for, and Cumulated Percent Variance for the Principal Factor and Varimax Solutions

Factor	Associated Eigenvalue	Percent Variance Accounted for	Cumulated Percent Variance
	Initial Unrotated Principal Factor Solution		
1	5.03	21.0	21.0
2	1.97	8.2	29.2
3	1.56	6.5	35.7
4	1.51	6.3	41.9
5	1.41	5.9	47.8
6	1.29	5.4	53.2
7	1.15	4.8	58.0
8	1.02	4.3	62.2
9	.93	3.9	66.1
10	.85	3.6	69.7
11	.81	3.4	73.0
12	.80	3.3	76.4
13	.74	3.1	79.5
14	.69	2.9	82.4
15	.64	2.6	85.0
16	.60	2.5	87.5
17	.52	2.2	89.7
18	.47	2.0	91.6
19	.43	1.8	93.4
20	.38	1.6	95.0
21	.35	1.5	96.4
22	.34	1.4	97.8
23	.28	1.2	99.0
24	.24	1.0	100.0
	Terminal Rotated Orothogonal Varimax Solution		
1	4.60	43.8	43.8
2	1.44	13.7	57.5
3	1.05	10.0	67.5
4	.90	8.5	76.1
5	.82	7.8	83.8
6	.66	6.3	90.2
7	.58	5.6	95.7
8	.45	4.3	100.0

Note. The eigenvalue associated with a factor represents the amount of total variance it accounts for.

Table 9

Matrices of Significant Factors Obtained by the Principal Factor and Varimax Solutions

Cognitive Characteristic	Factor[a] 1	2	3	4	5	6	7	8
Initial Unrotated Principal-Factor Solution								
Styles:								
FILDINDP	.21	.16	-.01	.36	.31	-.06	.08	-.04
CONCSTYL	.09	.15	-.01	.20	-.05	-.12	.07	-.05
REFLIMPL	-.07	-.12	.24	-.46	.40	.11	.11	.03
TOLRAMBQ	.19	.01	.16	.05	.06	-.30	.06	.26
CATEWIDH	.23	.17	.12	-.05	.32	.10	-.20	-.21
COGCOMPX	-.08	-.00	-.13	.22	-.34	.07	.07	.10
Abilities:								
VERBCOMP	.60	.21	.41	-.02	-.17	-.16	-.24	-.17
GENLREAS	.45	.33	-.06	.02	.21	-.10	-.16	.24
ASSOFLUN	.34	.27	.47	.14	-.10	.14	.11	.19
LOGIREAS	.32	.17	-.10	.04	.04	-.19	-.18	.02
INDUCTON	.17	.30	.03	.33	.09	.23	.07	-.17
IDEAFLUN	.28	.29	.21	-.07	-.15	.34	-.04	.24
Aptitudes:								
GENLINFO	.52	-.13	.17	-.18	.01	.01	-.05	.00
NUMROPER	.37	.41	-.37	-.21	-.14	.16	-.08	.07
ATTNDETL	.01	.34	-.24	-.15	-.06	.19	-.06	-.13
WORDKNOL	.70	-.06	.22	-.22	-.29	-.01	.21	-.21
ARTHREAS	.51	.11	-.30	-.28	.02	-.14	.11	.02
SPACPERC	.26	-.15	-.05	-.01	.26	.12	.20	.14
MATHKNOL	.57	.28	-.28	-.01	.06	-.13	.20	-.04
ELECINFO	.65	-.25	-.05	.24	.03	.02	.10	-.05
MECHCOMP	.70	-.26	-.13	.15	.17	.29	.07	.04
GENLSCIE	.70	-.16	.03	-.06	-.13	.18	.21	-.04
SHOPINFO	.55	-.46	-.13	-.03	-.12	.07	-.27	.11
AUTOINFO	.56	-.33	-.05	.14	.02	.05	-.29	-.01
Terminal Rotated Orthogonal Varimax Rotation[b]								
Styles:								
FILDINDP	.08	-.00	.51	.19	.07	-.05	.11	.11
CONCSTYL	-.04	.01	.25	-.10	.06	.03	-.08	.07
REFLIMPL	-.13	.05	-.29	.52	-.11	.04	.30	.02
TOLRAMBQ	-.01	.05	.03	.01	.03	.05	.01	.44
CATEWIDH	.12	.19	.20	.45	.11	-.01	-.07	-.12
COGCOMPX	-.00	.05	.02	-.45	-.03	-.04	.03	-.06
Abilities:								
VERBCOMP	.24	.36	.29	.27	.16	.40	-.41	.15
GENLREAS	.16	.18	.24	.18	.51	-.03	-.03	.30
ASSOFLUN	.02	.63	.22	.01	-.03	.21	-.00	.18
LOGIREAS	.18	.01	.15	.06	.34	.04	-.16	.14
INDUCTON	.01	.20	.49	-.00	.04	.00	.02	-.21
IDEAFLUN	.06	.61	-.02	-.01	.17	.03	.03	-.07
Aptitudes:								
GENLINFO	.31	.16	-.05	.19	.13	.31	.04	.07
NUMROPER	.06	.20	-.01	-.07	.66	.06	.01	-.25
ATTNDETL	-.14	.06	.02	.01	.33	-.03	-.06	-.34
WORDKNOL	.31	.25	-.01	.06	.13	.76	-.01	-.03
ARTHREAS	.18	-.05	-.03	.07	.56	.32	.15	.04
SPACPERC	.20	.03	.06	.11	.05	.06	.41	.07
MATHKNOL	.13	.00	.30	-.00	.56	.33	.16	.03
ELECINFO	.57	.01	.21	-.05	.07	.33	.19	.06
MECHCOMP	.66	.12	.21	.05	.14	.19	.39	-.09
GENLSCIE	.40	.05	.07	-.02	.20	.60	.17	.18
SHOPINFO	.75	.01	-.20	-.05	.11	.12	.02	.03
AUTOINFO	.71	.02	.07	.05	.07	.09	-.04	.03

[a] Only factors with associated eigenvalues greater than or equal to 1.0 are tabulated. This minimum eigenvalue criterion ensures that only factors accounting for at least the amount of total variance of a single cognitive characteristic are significant.

[b] Only the first three factors are significant in this solution.

CONCLUSIONS AND RECOMMENDATIONS

From the above findings, it is concluded that (1) cognitive styles are relatively independent of abilities and aptitudes, and (2) the information provided by these distinct measures is complementary rather than redundant to that provided by measures of students' abilities and aptitudes. Consequently, all three types of measures--styles, abilities, and aptitudes--should be considered in selecting BE/E students, in predicting their performance and likelihood of attrition, and in adapting alternative teaching techniques to student cognitive characteristics. By designing distinct instructional strategies to take into account the differences among students in their cognitive characteristics, it seems likely that they may (1) learn facts, concepts, principles, and rules more readily, (2) retain these specific types of knowledges more easily, and (3) retrieve material from memory with more facility. Consequently, not only may student school performance measurably improve, but also their subsequent on-the-job performance.

Before special instruction techniques can be developed, additional research and development is required. This should include:

1. Information-processing analyses of the cognitive styles, abilities, and aptitudes investigated in this study.

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

3. Test and evaluation of pretraining in specific cognitive styles, abilities, and aptitudes as well as adaptive instructional strategies.

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