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AN EVALUATION OF COMPUTERIZED TESTS AS PREDICTORS OF JOB PERFORMANCE IN THREE NAVY RATINGS:
I. DEVELOPMENT OF THE INSTRUMENTS

Charles H. Cory

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Charles H. Cory

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Martin F. Wiskoff

Approved by
James J. Regan
Technical Director

Navy Personnel Research and Development Center
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The potential usefulness of computerized tests for supplementing paper-and-pencil measures for predicting job performance abilities was the objective of a series of studies. This report covers the initial test development and analysis research.

Eight computerized tests were constructed to measure five personal attributes identified in previous research as being important for job performance. The experimental battery also contained nine previously developed tests. The

20. ABSTRACT (cont'd)

battery was administered to 385 enlisted personnel and test results and interrelationships were analyzed in conjunction with operational written test and biographical variables. Correlational and factor analyses were carried out.

Computerized tests were particularly important for measuring sequential information processing, movement detection and short-term memory skills. They offered no advantage over paper-and-pencil measures of perceptual speed, and findings relative to perceptual closure were ambiguous.

Computerized and paper-and-pencil tests of perceptual closure apparently measured different abilities.

The two separate, short-term memory abilities found corresponded to faculties for high associational and low associational (rote) stimuli.

FOREWORD

This research was performed under Task Area Number RR042-04-01 (Job Element Approach to the Validation of Perceptual Measures) and Work Unit Number NR 150-335. It was supported by Personnel and Training Research Programs of the Office of Naval Research.

The research was carried out to investigate a proposal originally developed by Dr. Rebecca Bryson, who, at the time, was assigned to the then-existing Personnel and Training Research Laboratory, San Diego. The author wishes to thank Dr. Bryson for her many suggestions concerning the approach and methodology of the study.

SUMMARY

Problem

Considerable evidence exists that the low validities frequently found for paper-and-pencil tests against job performance criteria may be consequences of ability requirements for job performance which are too varied to be completely measurable by written tests. Thus other modes of test administration may provide useful measures for some types of jobs. Computerized testing permits the assessment of many additional skill characteristics beyond those measurable in most paper-and-pencil tests, of which some abilities may be useful for classification and assignment purposes. This report summarizes the first of two studies intended to evaluate computerized tests as predictors of on-job performance. It covers the statistical characteristics and factor structure of a set of experimental and operational tests.

Approach

Eight computerized tests were constructed to measure five personal attributes identified in previous research as being important for job performance. The experimental battery also included previously developed tests, a number of which were paper-and-pencil tests from factor reference batteries. The 17 experimental tests were administered to 385 enlisted personnel who were in training for the Electrician's Mate, Personnelman, or Sonar Technician ratings, or were unassigned recruits. Scores were analyzed in conjunction with operational biographical and test variables.

Findings and Conclusions

1. Computerized tests were particularly important for measuring sequential information processing, movement detection, and short term memory skills. They offered no advantage over paper-and-pencil measures of perceptual speed, and findings relative to perceptual closure were ambiguous. (Pages 12, 13, and 14.)

2. Despite apparent similarity of format, computerized and paper-and-pencil tests of perceptual closure apparently measured different abilities. Additional research should be carried out to investigate more specifically the characteristics of these closure tests. (Pages 11, 12, 15, and 16.)

3. Two separate, short term memory abilities were found, corresponding to faculties for high associational and for low associational (rote) stimuli. (Pages 14 and 15.)

4. Considerable diversity of coverage existed among tests, even tests ostensibly measuring the same personal attributes. Measures of movement detection and dealing with concepts/information were more diffuse than those of short term memory and perceptual speed. (Pages 12 and 13.)

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BACKGROUND

Despite more than a half century of development and improvement of tests used for the selection and assignment of personnel to jobs, the level of test validity achieved remains disappointingly low. Rundquist (1967), among others, has pointed out that there is no evidence that selection techniques have improved during the past six decades.

Furthermore, as Ghiselli (1959) has noted, there is frequently little consistency in validity coefficients even for the same type of job from company to company. Thus in one series of studies he found that validity coefficients of intelligence tests for general clerical positions ranged from -.40 to +.80, with the middle 50 percent of the correlation coefficients covering a range of 50 correlation points. Similar variations in correlation coefficients were observed for other test-occupation combinations.

Ghiselli suggested that part of the difficulty in achieving consistent relationships can be attributed to differences in job content from company to company. Other probable causes include differences among supervisors in rating standards and biases, e.g., halo effects. Rundquist attributed similar findings to the multidimensional character of abilities required for performance on jobs. Because of the lack of one-to-one correspondences between abilities and performance on jobs, deficiencies in one ability may frequently be counteracted by strengths in other abilities. For example, good performance on a memory task might result from a superior memory, or efficient grouping techniques, or from combinations of these abilities.

These considerations suggest that despite extensive test-job performance validation research, personnel experts at the present time have only a hazy understanding of the predictive relationships between tests and subsequent job performance. Since most test validations have utilized global performance ratings as criteria, there is little understanding of which elements within the total job are predictable and which are unpredictable. Furthermore, the types of tests which are predictive of individual job elements are also essentially unknown.

Studying the predictive relationships of tests to individual job elements would shed light on these relationships. In addition, studying the test-job element predictive relationships might provide a means of counteracting the well known deficiencies in the global criterion rating resulting from halo effect and varying supervisory standards.

Global ratings have long been known to be unduly influenced by halo effects. By confining the attention of raters to more narrowly defined and highly specifiable criteria--such as are contained in the individual job elements--the ratings are more likely than are global ratings to conform to actual performance differences on the criteria. In addition, differences in supervisory perceptions of the importance of specific job elements for global performance can be made manifest in a study focussed on predictability of job elements. By forming the global evaluation as a composite of the relatively accurate job element evaluations, some of the effects of halo should be counteracted.

Furthermore, if reliable relationships between test scores and specific job elements can be found, it may be possible to build more valid selection batteries by using those tests which relate significantly to important elements of individual jobs. Thus the prediction battery would vary in conjunction with variations in the job elements present. One obvious advantage of this procedure would be that positions formally in the same job classification but having different job elements could have different selection batteries.

Synthetic Validity

Lawshe (1952) originally described such a procedure which he called "synthetic validity." The term was intended to describe a process of combining individual test-job element validities to compute the estimated validity of the selection battery for the total job. However, predictions of job suitability for individual personnel were based on combinations of scores on only those tests which were most predictive of each of the job elements important to the total job.

Lawshe suggested that synthetic validity would be ideally suited for validation research in small companies. For these companies the numbers of individuals in the same jobs are usually so small that empirically derived validity coefficients are not reliable. If pooling of data across administrative units (to increase the total N) is resorted to, there is the likelihood that differences in job content will adulterate the actual validity. A situation which has recently assumed importance, in which the synthetic validity technique might also be useful is in the development of selection batteries for specific minority groups; the Ns available for validation studies on these groups are frequently very small.

Only a few studies using synthetic validities have been reported during the 20 years since the technique was originally proposed (Lawshe & Steinberg, 1955; Guion, 1965; Drewes, 1961), and none of these has constituted a full-scale evaluation of the potential of the technique. Lawshe and Steinberg found that personnel in clerical positions, requiring proficiency in spelling, scored higher on a spelling test than incumbents in other jobs. This was interpreted as indicating self selection had occurred on those jobs for clerical personnel having skill in spelling. The Drewes and Guion studies produced evidence favoring synthetic validity over traditional techniques of test validation. However, the Drewes study, using subject matter of very narrow scope (psychomotor tests), and the Guion study, based on an *N* of 13, constitute very limited demonstrations of the technique's feasibility.

Since estimates of overall synthetic validity are based on a combination of measures of test-job element relationships, two elements which are critical for the technique are accurate job analysis and accurate estimates of test-job element relationships. At the present time, both of these estimates are provided from the judgments of experts and thus the accuracy of individual estimates is largely dependent on the experience and good judgment of their originators. In addition, the usefulness of estimates is restricted by a proliferation of ad hoc job element categorizations, resulting in a considerable lack of transferability of findings. For synthetic validity to be a technique of broad applicability, a simple, scientifically developed set of classification categories which can be applied by supervisors and non-specialists in personnel is needed.

The Position Analysis Questionnaire (PAQ)

Such a set of classification categories may be provided in the Position Analysis Questionnaire (PAQ), which has been developed from a series of studies of job characteristics by McCormick and his associates (McCormick, Jeanneret & Mecham, 1969a; McCormick, Jeanneret & Mecham, 1969b; Mecham & McCormick, 1969a; Mecham & McCormick, 1969b; Mecham & McCormick, 1969c; and McCormick, Jeanneret & Mecham, 1972). The PAQ was intended as an empirically derived instrument for use in job classification and designed for use in computing synthetic validitities.

The questionnaire was used to collect job analysis data in broadspectrum studies of occupations--some of which covered 536 widely varied jobs. For one study (McCormick et al., 1969a) ratings of the relevance of 68 personal attributes to each job element characteristic in the PAQ were collected from experts. Separate principal component analyses of the job analysis and the personal attribute data developed from the study produced factor structures which were very similar. The six major dimensions extracted from the personal attribute data were the same as six of the seven major dimensions extracted from the job analysis data, suggesting that major job dimensions had been identified.

These major job dimensions suggest a possible reason for the low validities typically found between selection batteries and job performance criteria. The dimensions identified are: information input, mediation processes, work output, interpersonal activities, work situation and job context, and miscellaneous. Of these, only two, information input and mediation processes, and parts of a third, work output, appear to relate to abilities which are testable by means of written tests, the usual method of assessment. Thus, based on these job dimensions, at most only half of the elements defining job performance appear to be predictable from written test data. This fact, combined with the less than perfect reliabilities of written tests, could mean that the low predictor-job performance validities typically found reflect the actual effective limits for predicting job performance from test batteries as presently constituted. However, it is also possible that the dimensions for which the tests appear to be appropriate are also the ones which are either entirely or primarily responsible for differentiation in level of overall performance evaluations. To examine these possibilities further it is desirable to expand the types of abilities measured in a job selection battery.

Computerized Testing for Perceptual and Reasoning Elements

One potentially promising area for additional types of selection tests is visual perception. The best predictors of job performance have frequently been found to be tests of clerical and perceptual abilities (Lucier, 1958; Kipnis, 1962; Phillips, 1966; Ghiselli, 1966; and Curtis, 1971). In addition, many of the perceptual elements among the personal attribute data of the studies of McCormick, et al. (Mecham and McCormick, 1969a, Appendix B) were rated by classification experts as of extreme or substantial relevance to performance in a wide variety of job elements.

For measuring certain visual perceptual abilities, the use of computerized testing equipment seems to offer important advantages over written tests. Some of the features unique to a computerized testing system and not available in regular paper-and-pencil tests are: exact determination of stimuli exposure times, moving stimuli, exact control of the sequence of stimuli presentation, successive modification of components of stimuli, determination of response latencies, and sophisticated classification and scoring of responses. These characteristics of computerized testing equipment also appear to offer advantages for testing other areas of ability identified in the research of McCormick et al., such as those dealing with concepts/information and visual short term memory.

Previous usage of computers has included a variety of tasks in the collection and interpretation of psychometric data. Common uses have been interpreting MMPI profiles and collecting and processing averaged evoked responses for the analysis of brain-wave patterns. A number of studies have found that computerized training offered definite advantages over traditional instructor-directed classroom training (Hickey, 1968; Hansen, Dick & Lippert, 1968; Long, O'Neil & Schwartz, 1969; and Longo, 1969). Two such studies conducted at this Center (Ford & Slough, 1970; Hurlock, 1971) found A-School training to require between 40 and 50 percent less time with improved retention when computerized instruction is substituted for typical classroom instruction. Students preferred the self-paced computerized instruction method by a wide margin.

The few investigations of adapting computers to ability testing have in the main focussed on the potential of computerized branching techniques for improving the efficiency and accuracy of ability testing (Cleary, Linn, & Rock, 1968; Linn, Rock, & Cleary, 1969; Bayroff & Seeley, 1967; Bryson, 1971). Dunn, Lushene, & O'Neil (1971) used computerized testing to study the concomitants of the variation of latencies on the MMPI. However, no comprehensive investigation of the potential usefulness of measures of ability based on utilization of the capabilities peculiar to computerized testing equipment has been found in the literature.

The equipment available in the Center's computer-assisted instruction system included computer consoles, each containing a cathode ray tube (CRT) display unit, a typewriter, and a self-contained projector-screen for film presentation. Subjects could indicate their answers to questions on the CRT by typing or by touching a light pen target on the screen.

Research Objectives

This study was initiated to investigate a number of questions concerned with the empirical relationships among predictors and criteria (defined both globally and in terms of individual job elements), the consistency of such relationships within and across ratings, and finally, the predictive accuracy for small samples of the synthetic validity technique in comparison with the commonly used multiple linear regression technique.

Data produced from the study are intended to provide information and conclusions concerning the following topics:

a. The predictive validities of tests within three ratings for both global and specific job element performance criteria.

b. The consistency of the predictive relationships of tests and job elements across ratings. Do tests which have statistically significant relationships with a job element in one rating correlate significantly with the same job element in other ratings?

c. Comparison of written and computerized tests designed to measure the same attribute in terms of (1) areas of measurement, and (2) predictive validity for job performance criteria.

d. The accuracy of opinions of personnel experts concerning the types of personal attributes required for the performance of specific job elements.

e. Comparison of the predictive accuracy of synthetic validity and multiple regression techniques.

f. The usefulness of ratings of importance of job elements and percentage of time spent on job elements as moderator variables for the validation of test scores against global and specific performance ratings.

PROCEDURE

Variables

Experimental Tests. The attributes shown in the study of McCormick, et al. (1969a) which appeared to be most relevant to the Navy ratings selected for the study (Personnelman, Electrician's Mate, and Sonar Technician), and to the specific characteristics of the computer-assisted testing equipment were: Short Term Memory, Perceptual Speed, Perceptual Closure, Movement Detection, and Dealing with Concepts/Information. To measure these attributes, eight computerized tests were constructed, supplemented by one auditorially administered test, one motion picture test, and seven paper-and-pencil tests previously developed at this Center or elsewhere. To provide a method of orientation for defining the personal attributes measured by particular tests, wherever possible, the experimental battery for an attribute was selected to include one or more factor reference tests for the attribute which had been identified in previous research. Most of these reference tests were selected from the battery developed at Educational Testing Service (ETS) as a result of the research of French, Ekstrom & Price (1963).

These 17 experimental tests are described below. Samples of items from the eight computerized tests are shown in the Appendix.

(1) Short Term Memory

- Memory for Objects--A computer-administered test consisting of five frames, each frame containing pictures of from four to nine objects with simple one-word names. The set of frames, arranged in ascending level of difficulty, is shown twice using the same sequence, with exposure times approximately one-half second per object in a frame. For the first showing subjects respond by typing the names of the objects that they can remember. For the second showing, the objects are identified from word lists.

- Memory for Words--A computerized test similar to Memory for Objects in format, presentation, and exposure time for the individual stimuli, except that words are used instead of pictures as in Memory for Objects. Five frames of three-letter words and five frames of five-letter words, with each set of frames shown in order of difficulty, are presented. Each three-letter stimulus frame has a five-letter frame which corresponds to it in number of words.

- Visual Memory for Numbers Test--A computer-administered test composed of four-to-13 digit numbers. The stimuli were adapted from the Ms-2 test (Digit Span-Visual), which is a factor reference test for Memory Span in the ETS factor battery (French, et al.).

  For some of the numbers, the digits are flashed consecutively on the screen, one per second, with answers to be recorded after the last digit of the number has been shown. The digits in the other number series are presented simultaneously, in sets of 5 to 13 digits.

. Auditory Memory for Numbers--A previously developed test which consists of aural presentation of number series by tape recording. The four to ten digits in each series are read aloud at about one digit per second. Subjects record the digits they recall after each series has been read.

. Object Number Test (Ma-2 of the Kit of Reference Tests of Cognitive Factors [KRT], French, et al.)--A factor reference test for associative memory. Subjects are given three minutes to examine and memorize word-number pairs; then, with the words presented in a different order, the subjects must fill in the matching numbers.

(2) Perceptual Speed

. Comparing Figures--A computer-administered test in which the frames are composed of sets of squares or circles presented as rows, vertical columns, and right and left slant columns. Three to six stimulus pairs are shown on the CRT at one time. Each stimulus has a cross bar oriented either vertically or horizontally. Subjects are asked to record as true-false answers whether the cross bars of all corresponding pairs in the sets have the same orientations or some have different orientations. Two item exposure modes are used. For the first subtest, items are shown only at fixed exposures consisting of approximately one-third second for each stimulus in a set. Exposures of items in the second part are not timed, and each stimulus frame is shown until the subject records his answer.

. Counting Numbers--This paper-and-pencil speed test is an adaptation of Test 4 in the Air Force Factor Reference Battery II (AFPTRC-TN-57-104). The test involves scanning rows of numbers to identify and count specified digits.

(3) Perceptual Closure

. Recognizing Objects--A new, computerized test in which partially blotted out pictures of common objects are presented. The first presentation shows 90 percent of the detail and more detail is added in increments of 10 until 90 percent of the picture is exposed. Subjects may attempt to type the name of the object after each stimulus frame has been presented. The measure recorded for this test consisted of the total number of frames shown before the objects were identified. Thus, the lower the score, the better the performance.

. Gestalt Completion Test (Cs-1 of the KRT)--A factor reference test for Speed of Closure. This is a two-part written test in which partially blotted-out pictures of objects are shown and subjects must name the objects. The stimuli of the test are similar to individual stimulus frames of the Recognizing Objects test, but the test does not permit determination of recognition limens as does the Recognizing Objects test.

- Concealed Words Test (Cs-2 of the KRT)--A factor reference test for Speed of Closure. This two-part written test consists of common words with parts of their letters missing. Subjects attempt to identify the words.

- Hidden Patterns Test (Cf-2 of the KRT)--A factor reference test for Flexibility of Closure. This two-part written speed test consists of 400 patterns, each of which is to be inspected to determine if it contains a test pattern.

(4) Movement Detection

- Memory for Patterns--A new, computerized test in which patterns are formed by sequentially blinking dots. Subjects are asked to report whether or not two consecutive patterns are identical or they are asked to reproduce given patterns.

- Drift Direction (Gibson, 1947)--A motion picture test in which each item consists of a dot moving slowly next to a line. Subjects must tell whether the dot moves away from, toward, or parallel to the line.

(5) Dealing with Concepts/Information

- Twelve Questions--This computer-administered test is similar to the Twenty Questions game in that subjects are asked to guess the name of an object based on yes-no answers supplied by the computer to questions. It differs from Twenty Questions in that the questions are supplied in the test rather than being posed by the subject. The subject's objectives are to select those questions that will provide the quickest identification of the object and to avoid questions which are redundant or useless. As selecting questions and guessing the name of the object proceed, questions more specific to the object are given.

- Password--This computer-administered test resembles the regular "Password" game in that sets of words are shown which suggest a target word. Five separate words are shown as clues. After the first two clues and each succeeding one, subjects may attempt to identify the object by typing its name on the keyboard.

- Nonsense Syllogisms Test (Rs-1 of the KRT)--A factor reference test for Syllogistic Reasoning. The items in this two-part written test consist of formal syllogisms in which the terms are nonsense words. Subjects must indicate whether the conclusions shown are correct or incorrect.

- Inference Test (Rs-3 of the KRT)--A factor reference test for Syllogistic Reasoning. This two-part written test consists of 40 items, each containing a statement and five possible conclusions which might be drawn from the statement. Subjects indicate whether or not the conclusions are logically justified.

Operational Tests and Biographical Variables

- Armed Forces Qualification Test (AFQT)--A measure of vocabulary, arithmetic reasoning, spatial reasoning, and mechanical knowledge. Scores are recorded as percentiles for a large sample of eligibles for military service and range from 10 to 99.

Scores of the following classification tests are reported as Navy Standard Scores and have means for an unrestricted Navy sample of about 50 and standard deviations of about 10.

- General Classification Test (GCT)--A test involving ability to comprehend and define words and to reason verbally.

- Arithmetic Reasoning Test (ARI)--A test of quantitative aptitude involving mathematical reasoning and problem solving.

- Mechanical Test (MECH)--A test of basic mechanical and electrical knowledge and comprehension of mechanical principles and relationships.

- Clerical Test (CLER)--A test of perceptual speed and accuracy which involves checking whether pairs of numbers are the same or different.

- Sonar Pitch Memory Test (SONAR)--A test of ability to detect and remember small differences in tonal pitches.

- Radio Code Aptitude Test (RADIO)--A test, administered by phonographic recording, measuring ability to learn International Morse Code.

- Electronic Technician Selection Test (ETST)--A test of knowledge of mathematics, science, electricity, and electronics.

- Shop Practices (SHOP)--A test of knowledge of the use of tools and other shop equipment.

Also extracted from the military records for use as biographical variables were Years of Education and Year of Birth.

Sample

The experimental battery was administered to a total of 385 students at the Naval Training Center (NTC), San Diego during May and June of 1972. Subjects were chosen from personnel in the first two weeks of A-School for three ratings having widely varied duties. Also tested, in order to increase the sample sizes of the two ratings having relatively small *N*'s, were recruits in their final week of training, who were eligible for A-School but had not yet received post-recruit assignments. The sample contained the following rating group subsamples:

A-School students in first two weeks of training:

Personnel Man	82
Electrician's Mate	107
Sonar Technician	58
Recruits in the upper half of the recruit distribution of ability	138
Total	385

It was anticipated that some of the 138 subjects in the recruit sample would receive assignments for training in one of the three ratings and could thus be added to the sample during the on-job validation phase. Meanwhile the additional recruits tested would produce more stable statistics on the experimental tests.

Analysis

Intercorrelations of the operational and experimental tests and the biographical variables were computed and correlations of tests intended to measure the same attribute were compared. Particular attention was given to the relationships between computer-administered and factor-reference tests.

To gain further perspective concerning interrelationships in the predictive battery, a principal components analysis was performed, using 1's in the diagonal. By limiting the factors extracted to those having eigenvalues greater than one, seven principal components were extracted. They were rotated by the varimax method.

Correlations. That the sample was highly restricted may be seen from the means and standard deviations of the operational tests, as shown in Table 1. As expected, the sample had larger means and smaller standard deviations than typical samples of Navy enlisted recruit input. The means of the classification tests ranged between a third and a whole standard deviation above 50, the general mean, and the standard deviations ranged from 70 to 90 percent of the usual size. These restrictions resulted in intercorrelations among the operational tests which were 20 to 25 points lower than those usually computed for unrestricted samples.

A large number of the correlations among the predictor variables are statistically significant. Significant intercorrelations are particularly common among the operational tests. The computerized tests also tend to show significant correlation with each other.

The correlations in Table 1 indicate the extent to which the computerized tests overlap the reference tests for the attribute they were both designed to measure.

TABLE I

Descriptive Statistics For Operational And Experimental Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Mean	S.D.	N
1. AFQT	--	58	50	52	05	27	22	51	40	-08	36	50	27	17	04	19	36	11	25	18	-02	07	18	22	18	18	14	18	-18	72.39	16.60	320
2. GCT		--	44	32	09	28	17	50	30	-08	27	04	27	02	06	30	58	23	03	15	03	05	32	30	19	27	40	19	-27	60.78	6.20	319
3. ARI			--	13	26	08	34	42	06	-14	29	21	03	16	17	22	40	20	10	26	04	10	12	22	23	22	19	14	00	56.24	6.66	319
4. MECH				--	-07	20	08	35	69	-05	20	-05	19	-01	-13	14	15	-03	14	07	-01	00	09	01	-03	09	06	06	-15	53.25	6.90	319
5. CLER					--	-05	20	08	-12	-21	26	48	10	28	12	08	18	07	06	37	12	-11	00	05	05	17	03	00	-05	54.88	8.60	319
6. SONAR						--	31	21	16	-02	15	02	13	06	03	07	13	14	10	15	08	07	14	19	25	18	14	18	-09	59.46	9.25	317
7. RADIO							--	26	-03	-08	32	24	05	18	08	12	15	23	15	27	17	23	08	25	26	31	11	20	-04	59.74	8.99	313
8. ETST								--	36	-10	21	09	13	04	02	25	38	08	15	16	00	12	18	18	09	37	17	14	-25	59.54	6.74	313
9. SHOP									--	-12	08	-04	04	-17	-19	03	17	-04	02	02	00	-02	19	01	12	10	10	-05	-10	54.60	6.78	313
10. Year of Birth										--	-19	-19	01	-07	-03	-08	-13	-12	-07	-13	-12	-04	-10	01	-13	-05	-04	10	04	52.26	1.56	373
11. Hidden Patterns											--	30	32	29	10	14	22	14	19	28	14	22	15	14	17	29	26	11	-14	63.91	20.05	301
12. Counting Numbers												--	02	22	05	02	13	10	06	27	11	10	01	13	16	18	07	04	-06	30.00	6.25	370
13. Gestalt Completion													--	29	05	09	12	05	13	21	-01	10	10	14	04	06	18	15	-24	16.42	3.31	360
14. Concealed Words														--	08	14	52	14	10	11	09	12	03	13	08	06	02	11	-11	23.39	5.64	369
15. Object Number															--	11	20	16	05	10	04	16	13	10	16	03	08	09	05	12.48	6.66	370
16. Nonsense Syllogisms																--	34	22	09	12	00	09	17	10	12	08	12	06	-12	5.43	6.84	366
17. Inference																	--	21	08	17	05	10	28	22	19	25	31	16	-17	11.28	4.38	369
18. Aud. Memory for Numbers																		--	06	13	02	13	10	32	52	10	16	13	-08	117.45	14.65	347
19. Drift Direction																			--	12	01	11	03	10	12	13	10	13	-13	13.13	7.41	368
20. Comparing Figures, Spd.[a]																				--	33	07	11	16	24	27	15	09	-15	34.02	8.39	373
21. Comparing Figures, Unstructured[a]																					--	04	05	12	16	13	14	14	-14	13.92	2.54	373
22. Memory for Patterns, T-F[a]																						--	00	15	28	24	04	10	-04	5.13	3.58	367
23. Twelve Questions[a]																							--	24	19	18	33	18	-13	23.90	28.00	336
24. Memory for Words[a]																								--	40	26	28	50	-25	32.09	8.79	373
25. Vis. Memory for Numbers[a]																									--	24	25	21	-11	82.46	17.38	373
26. Memory for Patterns, Free Response[a]																										--	20	24	-28	16.53	8.03	367
27. Password[a]																											--	24	-25	22.24	5.72	358
28. Memory for Objects[a]																												--	-19	38.22	8.96	373
29. Recognizing Objects [a]																													--	15.95	4.13	373

Note.--

1. Decimal points have been omitted from the correlation coefficients.
2. Coefficients significant at $p < .05$ and $p < .01$ have been identified by single (—) and double (═) underlines, respectively.

[a]Computer-administered tests.

(1) Short Term Memory

The visual and auditory Memory for Numbers Tests are well suited as reference tests for the Memory Span factor. The Object-Number Test has been shown to measure a somewhat different ability, associative memory.

Intercorrelations among the four short term memory tests (variables 18, 24, 25, and 28) ranged from .20 to .50, with Memory for Words having the highest intercorrelations with the other tests. As would be expected from the factor structures determined in previous studies (French, et al., p. 22) correlations of the Object-Number Test with the Memory Span tests were considerably lower and were barely significant. Correlation of the two memory for numbers tests, .52, is an estimate of the association between tests which measure the same factor.

(2) Perceptual Speed

The Counting Numbers test from the Air Force Factor Reference Battery correlated .48 with CLER, confirming that CLER is a measure of perceptual speed. The lower correlation of Comparing Figures with Counting Numbers (.27) indicates that the computer-administered test is not as pure a measure of perceptual speed as CLER.

(3) Perceptual Closure

The three paper-and-pencil reference tests for perceptual closure intercorrelated about .30 with one another. Correlations of Recognizing Objects with these tests, in general, were much lower. Surprisingly, Recognizing Objects correlated only .24 with Gestalt Completion, a test which it appears to closely resemble, and its correlations with Hidden Patterns and Concealed Words were barely significant. This indicates that the differences between the computer and the paper-and-pencil modes for tests of perceptual closure are greater than they appear to be.

(4) Movement Detection

Because of the nature of the Movement Detection abilities, paper-and-pencil factor reference tests were not available. Furthermore, the experimental tests for this attribute have little in common. It is clear from the low correlation of Memory for Patterns and Drift Direction (which barely approached significance) and the differences between the correlations of these tests with others in the battery that the two tests are not measuring the same ability.

(5) Dealing with Concepts/Information

Although reference tests were not available for this attribute as such, Nonsense Syllogisms and Inference are reference tests for syllogistic reasoning, a similar type of ability.

Dealing with Concepts/Information is apparently less focused and more diffuse than the first three attributes. Intercorrelations among the Inference, Twelve Questions and Password tests were about .30. Correlations of Twelve Questions and Password with Nonsense Syllogisms were about ten to fifteen points lower.

Although correlations among most of the tests for particular attributes were significant and substantial, the communalities were generally low. Even for reference tests for the same factor, the uncorrelated variance was larger than the covariance.

Factor Loadings. Rotated loadings for the seven principal components derived from 26 operational and experimental variables are shown in Table 2.[1] In Table 2 loadings of about .30 or greater were considered significant.

These factors are no doubt somewhat distorted from those derivable from a full range sample. An obvious distortion is a "g" factor which is underdefined as a result of the low intercorrelations among operational tests, mentioned in the Correlations section. However, many of the relationships emerging from the factoring are consistent with past findings. Therefore, the factor structure of the battery may be generally applicable to full range samples.

(1) Factor 1

With the AFQT, GCT, ARI, Nonsense Syllables, and Inference tests loading heavily on this factor, it clearly measures the broad-based cognitive ability originally identified by Spearman as "g." It is consistent that Object Number, a reference test for associative or rote learning, should load positively on this basic academic ability.

(2) Factor 2

The heavy loadings of CLER and Counting Numbers and the absence of significant loadings for these tests on other factors indicate that Factor 2 is a measure of perceptual speed. Comparing Figures loaded significantly but less heavily on this factor, serving as an additional indication that the test is less pure as a measure of perceptual speed than CLER. Whether the non-perceptual speed elements in Comparing Figures will prove of value for predicting on-job performance is to be determined in the follow-up portion of the study.

---

[1]Preliminary factoring of the complete battery of operational and experimental tests suggested that inclusion of all of the tests would serve to distort the interrelationships between tests and principal components. Therefore, elimination of the Auditory Memory for Numbers, Comparing Figures, Unstructured and Memory for Patterns, T-F tests from the final factoring was done to clarify and to more accurately present the factor structure.

TABLE 2

Rotated Factor Loadings of Twenty-Six Operational and Experimental Variables (N = 373)

Variable	Factor 1	2	3	4	5	6	7	h^2
AFQT	5640	0097	0533	4675	3108	-0160	3027	73
GCT	6628	0157	2438	3046	0856	3192	0575	70
ARI	7112	2989	0324	0054	-0245	-0978	2510	67
MECH	1940	-0856	-0404	7907	2077	-0062	1269	73
CLER	1683	7418	-0060	-1544	1489	-0670	-1185	64
SONAR	0271	-0570	0815	2285	1066	1270	6289	48
RADIO	1962	3542	1604	-0107	0322	-1660	6051	58
ETST	5784	1396	2712	4377	-0234	-0447	1088	63
SHOP	1133	-0441	-0770	8351	-0876	1831	0510	76
Year of Birth	-0003	-4631	3828	-1587	0289	-3589	-0619	52
Hidden Patterns	1825	4300	0050	1441	4673	1355	2072	52
Counting Numbers	0221	7395	0545	-0661	0341	-0195	0540	56
Gestalt Completion	0561	-0052	1502	1053	7669	1737	-0603	66
Concealed Words	1083	2473	0272	-2018	6482	-1332	0553	56
Object Number	3343	-0225	-2096	-4606	1136	2216	2084	47
Nonsense Syllogisms	5488	-0050	-0426	-0535	1572	1553	-0452	36
Inference	6966	1371	1197	0439	-0146	3340	-0258	63
Drift Direction	0123	0620	0334	1100	3610	-0260	3107	24
Comparing Figures[a]	0730	5451	1085	0396	1506	1370	1942	40
Twelve Questions[a]	2034	-0118	0669	0569	0104	6638	1047	50
Memory for Words[a]	1448	0298	5643	-1273	0589	2640	3777	57
Visual Memory for Numbers[a]	0569	1738	1290	-1220	-0536	3995	5753	56
Memory for Patterns[a]	1503	3876	5416	1620	-1090	0656	1877	54
Password[a]	1707	0675	2982	0176	0888	6242	0429	52
Memory for Pictures[a]	0100	-1054	6060	-1341	1468	0941	3416	55
Recognizing Objects[a]	-0046	-1287	-5796	-2288	-2526	-2587	2092	58
Eigenvalue	5.33	2.41	1.81	1.48	1.34	1.23	1.08	
Percentage of Variance	20.50	9.28	6.97	5.68	5.18	4.72	4.17	
	(Total Percentage = 56.50)							

Note.—

1. Decimal points are omitted from the factor loadings and the communalities.
2. Factor loadings $\sim \geq |.3000|$ are underlined.
3. Small percentages of missing data were present for some of the operational variables.

[a]Computer-administered test.

Speed of performance, which is important for both ARI and Hidden Patterns, may be the reason these tests load significantly on Factor 2. The precise and rapid perceptual processes required for RADIO may be the reason for inclusion of this test in the factor. For this sample, age was associated positively with perceptual speed, a finding also reported in previous research (Cory, 1971, p. 11).

(3) Factor 3

Factor 3, as well as Factor 7, measures a short term memory ability. However, the abilities are primarily distinguished by their degree of associational content. Thus the memory tests loading most heavily on Factor 3 require the direct recall of stimuli having high associational values or substantial verbal mediation--i.e., words, patterns, and the names of objects. Interestingly, Recognizing Objects has its only significant loading on this factor rather than on perceptual closure, suggesting a possible close association between memory and closure. Factor 3 was negatively associated with age.

(4) Factor 4

This factor, with MECH and SHOP having the highest loadings, primarily represents mechanical reasoning and tool knowledge. Thus it consists of a crystallized ability having primarily practical rather than academic content. However, measures of more academic crystallized abilities, AFQT, ETST, and GCT, also load significantly on it.

Factor 4 is the second crystallized ability factor on which the Object-Number test--clearly a measure of fluid ability--loaded significantly. However, the Object-Number test was negatively associated with Factor 4, in contrast to the positive loadings of the test on Factor 1, a generalized factor of academic aptitude.

(5) Factor 5

The heavy loadings of Gestalt Completion, Concealed Words, and Hidden Patterns on Factor 5 indicate it to be a measure of perceptual closure. Drift Direction and AFQT probably loaded significantly on this factor by virtue of their visual elements.

This analysis confirms the diversity of focus of the two tests selected for Movement Detection, since the tests loaded on different principal components. Memory for Patterns loaded on Perceptual Speed and Memory for high Associative Stimuli while Drift Direction loaded on Perceptual Closure and Memory for low Associative Stimuli.

(6) Factor 6

This sequential reasoning factor is primarily defined by computer-administered tests, with the tests loading most heavily being Password and

Twelve Questions. It is somewhat similar to the factor identified as Serial Integration by Siebert & Snow (1965, p. 61), who used a motion picture rather than a computer terminal mode of administration. Factor 6 involves primarily serial, deductive reasoning requiring frequent updates of the information pool. The high verbal content of GCT apparently accounts for its significant loading on this factor. Age is positively related to performance on Factor 6.

(7) Factor 7

This short term memory factor is primarily defined by stimuli requiring rote reproduction, with little if any associational content. Thus SONAR, RADIO, and Visual Memory for Numbers, requiring as they do reproduction of musical pitches, sound patterns, and numeric digits have the heaviest loadings on Factor 7, and tests involving more associative stimuli have lower loadings. Perceptual elements apparently account for the significant loadings of Drift Direction and AFQT on this factor.

DISCUSSION

It is clear that the experimental battery represents a considerable increase in the breadth of abilities covered beyond those in the operational battery. Three of the seven factors were defined wholly or principally by experimental tests. For two of these factors, 3 and 6, computerized administration appears to represent the difference between measuring and not measuring the ability.

Computer administration of the Memory for Numbers Test offers advantages over written but not over aural administration by a monitor. Computerized administration of tests of perceptual speed does not appear to offer any advantage over the traditional paper-and-pencil measures for this attribute.

Results from the Recognizing Objects test suggest that memory elements may have important influences on the recognition threshold for indistinct visual stimuli. To clarify these relationships additional studies are needed in which computer-administered and written tests of perceptual closure can be compared.

Although short term memory tests were the major defining elements in two factors, in general the study was in agreement with the findings of Christal (1958) and Thurstone (1946), among others, in failing to find clear cut evidence for memory factors defined by contents specific to the data. The different memory abilities which emerged, corresponded with the high and low associational characteristics of the stimuli.

Collection of on-job performance marks from supervisors of the subjects eight to ten months after their completion of A-School has been completed and is now being processed. A report will shortly be prepared covering the additional topics mentioned in the Research Objectives section.

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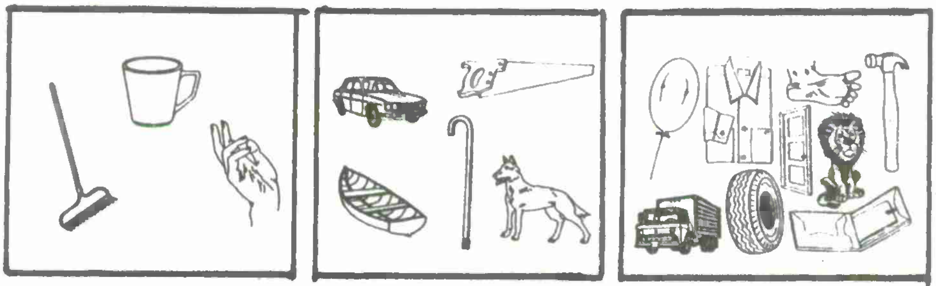
APPENDIX

ILLUSTRATIVE ITEMS FROM THE EIGHT COMPUTERIZED TESTS

1. MEMORY FOR OBJECTS



2. MEMORY FOR WORDS

BIN MAN OWL

PRIZE IVORY TABLE
STOVE MUSIC SOLID

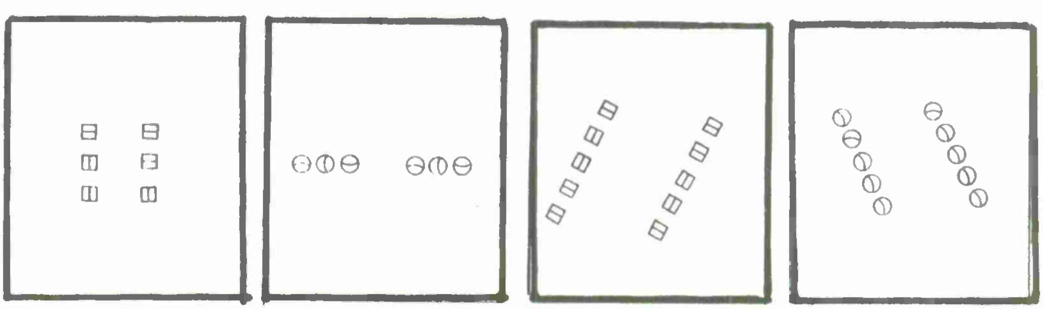
FIR TEA HAT KID ART
EYE CAT RIB BAT

3. VISUAL MEMORY FOR NUMBERS TEST

2 5 1 6*

124956387*

4. COMPARING FIGURES

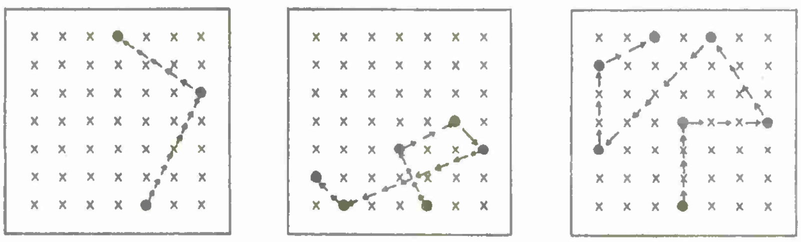


5. RECOGNIZING OBJECTS

90% 80% 60%

90% 80% 60%

6. MEMORY FOR PATTERNS



7. COMPUTERIZED 12 QUESTIONS

Mineral
Frequently larger than a glove

1. Is it often used as clothing?
2. Is it made of a soft material?
3. Is it often used at meals?
4. Do people often wear it?
5. Does it have moving parts?
6. Does it have a hard surface?
7. Is it always found on an auto?
8. Is it made at least partly of glass?
9. Does it have more than one use?
10. Does it use electricity?

Mirror

11. Is it sometimes used by magicians?
12. Do men and women use it equally often?
13. Is it often used before a person goes out?
14. Can one use it with his eyes closed?
15. Must one touch it to use it?

16. Does it appear dark in the light?
17. Can it be used to send messages?
18. Can it improve one's appearance?

8. COMPUTERIZED PASSWORD

Metal Finger	Circle	Shiny	Wedding
Soaring Emblem	Feathers	Large	Bald

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Washington, DC 20360

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Naval Air Systems Command
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Falls Church, VA 22042

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NAVAIR 415C
Naval Air Systems Command
5600 Columbia Pike
Falls Church, VA 22042

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OASN (M&RA)
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ATTN: Dr. R. Dusek

1 Mr. Edmund F. Fuchs
U.S. Army Research Institute
1300 Wilson Boulevard
Arlington, VA 22209

1 Commander
U.S. Theater Army Support
Command, Europe
ATTN: Asst. DCSPER (Education)
APO New York 09058

1 Dr. Stanley L. Cohen
Work Unit Area Leader
Organizational Development
Work Unit
Army Research Institute for
Behavioral and Social Science
1300 Wilson Boulevard
Arlington, VA 22209

1 Superintendent
U. S. Military Academy
West Point, NY 10996

Air Force

1 Headquarters, U.S. Air Force
Chief, Personnel Research and
Analysis Division (AF/DPSY)
Washington, DC 20330

1 Research and Analysis Division
AF/DPXYR Room 4C200
Washington, DC 20330

1 AFHRL/AS (Dr. G. A. Eckstrand)
Wright-Patterson AFB
Ohio 45433

1 AFHRL/MD
701 Prince Street
Room 200
Alexandria, VA 22314

1 Dr. Robert A. Bottenberg
AFHRL/PES
Lackland AFB, TX 78236

2 Personnel Research Division
AFHRL
Lackland Air Force Base
Texas 78236

1 AFOSR(NL)
1400 Wilson Boulevard
Arlington, VA 22209

1 Commandant
USAF School of Aerospace Medicine
Aeromedical Library (SUL-4)
Brooks AFB, TX 78235

1 CAPT Jack Thorpe, USAF
Department of Psychology
Bowling Green State University
Bowling Green, OH 43403

1 LT COL Henry L. Taylor, USAF
Military Assistant for Human
Resources
OAD(E&LS) ODDR&E
Pentagon, Room 3D129
Washington, DC 20301

1 Superintendent
U. S. Air Force Academy
Colorado 80840

Marine Corps

1 Commandant, Marine Corps
Code A01M-2
Washington, DC 20380

1 COL George Caridakis
Director, Office of Manpower
Utilization
Headquarters, Marine Corps (A01H)
MCB
Quantico, VA 22134

1 Dr. A. L. Slafkosky
Scientific Advisor (Code Ax)
Commandant of the Marine Corps
Washington, DC 20380

1 Mr. E. A. Dover
Manpower Measurement Unit (Code
A01M-2)
Arlington Annex, Room 2413
Arlington, VA 20370

1 Headquarters
U. S. Marine Corps (Code MPI)
Washington, DC 20370

Coast Guard

1 Mr. Joseph J. Cowan, Chief
Psychological Research Branch (P-1)
U.S. Coast Guard Headquarters
400 Seventh Street, SW
Washington, DC 20590

1 Superintendent (P)
U. S. Coast Guard Academy
New London, CT 06320

1 Commandant (Code B-5)
U. S. Coast Guard
Washington, DC 20591

Other DOD

1 LT COL Austin W. Kibler, Director
Human Resources Research Office
Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209

1 Mr. Helga Yeich, Director
Program Management, Defense
Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209

1 Director for Manpower Research
Office of Secretary of Defense
The Pentagon, Room 3C980
Washington, DC 20301

Other Government

1 Dr. Lorraine D. Eyde
Personnel Research and Development
Center, Room 3458
U.S. Civil Service Commission.
1900 E. Street, N.W.
Washington, DC 20415

1 National Research Council
Division of Anthropology
and Psychology
Washington, DC 20418

1 National Science Foundation
Washington, DC 20550

1 Dr. Vern Urry
Personnel Research and
Development Center
U.S. Civil Service Commission
Washington, DC 20415

Miscellaneous

1 Dr. Scarvia B. Anderson
Educational Testing Service
17 Executive Park Drive, N.E.
Atlanta, GA 30329

1 Dr. Richard C. Atkinson
Stanford University
Department of Psychology
Stanford, CA 94305

1 Dr. Bernard M. Bass
University of Rochester
Management Research Center
Rochester, NY 14627

1 Mr. H. Dean Brown
Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, CA 94025

1 Mr. Michael W. Brown
Operations Research, Inc.
1400 Spring Street
Silver Spring, MD 20910

1 Dr. Ronald P. Carver
American Institutes for Research
8555 Sixteenth Street
Silver Spring, MD 20910

1 Century Research Corporation
4113 Lee Highway
Arlington, VA 22207

1 Dr. Kenneth E. Clark
University of Rochester
College of Arts and Sciences
River Campus Station
Rochester, NY 14627

1 Dr. Rene' V. Dawis
University of Minnesota
Department of Psychology
Minneapolis, MN 55455

1 Dr. Norman R. Dixon
Associate Professor of Higher
Education
University of Pittsburgh
617 Cathedral of Learning
Pittsburgh, PA 15213

1 Dr. Robert Dubin
University of California
Graduate School of Administration
Irvine, CA 92664

1 Dr. Marvin D. Dunnette
University of Minnesota
Department of Psychology
N492 Elliott Hall
Minneapolis, MN 55455

1 Dr. Victor Fields
Department of Psychology
Montgomery College
Rockville, MD 20850

1 Dr. Edwin A. Fleishman
American Institutes for Research
8555 Sixteenth Street
Silver Spring, MD 20910

1 Dr. Robert Glaser, Director
University of Pittsburgh
Learning Research and Development
Center
Pittsburgh, PA 15213

1 Dr. Albert S. Glickman
American Institutes for Research
8555 Sixteenth Street
Silver Spring, MD 20910

1 Dr. Henry J. Hamburger
University of California
School of Social Sciences
Irvine, CA 92664

1 Dr. Harry H. Harman
Educational Testing Service
Division of Analytical Studies
and Services
Princeton, NJ 08540

1 Dr. Richard S. Hatch
Decision Systems Associates, Inc.
11428 Rockville Pike
Rockville, MD 20852

1 Human Resources Research
Organization, Division #3
P.O. Box 5787
Presidio of Monterey, CA 93940

1 Human Resources Research Organization
Division #4, Infantry
P. O. Box 2086
Fort Benning, GA 31905

1 Human Resources Research Organization
Division #5, Air Defense
P.O. Box 6057
Fort Bliss, TX 79916

1 Human Resources Research Organization
Division #6, Library
P.O. Box 428
Fort Rucker, AL 36360

1 Dr. Lawrence B. Johnson
Lawrence Johnson and Associates, Inc.
200 S Street, N.W., Suite 502
Washington, DC 20009

1 Dr. David Klahr
Carnegie-Mellon University
Graduate School of Industiral
Administration
Pittsburgh, PA 15213

1 Dr. Frederick M. Lord
Educational Testing Service
Princeton, NJ 08540

1 Dr. E. J. McCormick
Purdue University
Department of Psychological Sciences
Lafayette, IN 47907

1 Dr. Robert R. Mackie
Human Factors Research, Inc.
6780 Cortona Drive
Santa Barbara Research Park
Goleta, CA 93017

1 Mr. Edmond Marks
109 Grange Building
Pensylvania State University
University Park, PA 16802

1 Dr. Leo Munday
Vice President
American College Testing Program
P.O. Box 168
Iowa City, IA 52240

1 Dr. Donald A. Norman
University of California,
San Diego
Center for Human Information
Processing
La Jolla, CA 92037

1 Mr. Luigi Petrullo
2431 North Edgewood Street
Arlington, VA 22207

1 Dr. Diane M. Ramsey-Klee
R-K Research & System Design
3947 Ridgemont Drive
Malibu, CA 90265

1 Dr. Joseph W. Rigney
Behavioral Technology Laboratories
University of Southern California
3717 South Grand
Los Angeles, CA 90007

1 Dr. George E. Rowland
Rowland and Company, Inc.
P.O. Box 61
Haddonfield, NJ 08033

1 Dr. Arthur I. Siegel
Applied Psychological Services
Science Center
404 East Lancaster Avenue
Wayne, PA 19087

1 Dr. Benton J. Underwood
Northwestern University
Department of Psychology
Evanston, IL 60201

2 Dr. David J. Weiss
University of Minnesota
Department of Psychology
Minneapolis, MN 55455

1 Dr. Anita West
Denver Research Institute
University of Denver
Denver, CO 80210

1 Dr. John Annett
The Open University
Milton Keynes
Buckinghamshire
ENGLAND

1 Dr. Milton S. Katz
MITRE Corporation
Westgate Research Center
McLean, VA 22101

1 Dr. Charles A. Ullmann
Director, Behavioral Sciences
Studies
Information Concepts, Inc.
1701 N. Ft. Myer Drive
Arlington, VA 22209

1 Dr. Alfred F. Smode,
Staff Consultant
Training Analysis and
Evaluation Group
Naval Training Equipment Center
Code N-00T
Orlando, FL 32813

1 Dr. Clifford E. Lunneborg
Director, Bureau of Testing
University of Washington
Seattle, WA 98195

1 Commanding Officer
Navy Schools Command
ATTN: Educational Advisor
Treasure Island, CA 94130

1 Forces Armees
Centre de Recherches
Des Facteurs Humains
83 Chausee de Chaxleroi
1060 Bruxelles
BELGIQUE

1 Dr. E. Gary Joselyn
University of Minnesota
3008 University Ave SE
Minneapolis, MN 55414

1 Dr. Richard E. Snow
School of Education
Stanford University
Stanford, CA 94305

1 Dr. William M. Meredith
Department of Psychology
University of California
Berkeley, CA 94720

1 Dr. Charles L. Thomas
Department of Educational Psychology
Indiana University
Bloomington, IN 47401

#16 1079