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AUTHOR Hansen, Duncan N.; And Others
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ABSTRACT

A review of the literature on automated psychological testing shows that most research and development in this area is based on a one-test, one-psychologist model. In this model, the functions of test administration, scoring, and interpretation are thought out in terms of specific tests presented on an individualized basis. However, more complete and sophisticated psychological assessment can take place with a multi-test, multi-team model. This model makes extensive use of time-sharing, interactive, terminal-oriented computer systems. Methodological investigations and research and development work on automated testing in the last decade are reviewed in terms of the three dimensions of testing: administration, scoring, and interpretation. A computerized information management system for the storage and retrieval of student evaluation files appears to be necessary. Such a system would allow varying and appropriate reports to be generated for psychologists, teachers, counselors, etc. The capability of computers to analyze and accept natural language input must be further developed before testing can become fully automated. (JK)

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TECH MEMO

REVIEW OF AUTOMATED TESTING

Duncan N. Hansen, John J. Hedl, Jr., and Harold F. O'Neil, Jr.
The Florida State University

Tech Memo No. 30
February 26, 1971

Project NR 154-280
Sponsored by
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Duncan N. Hansen
Director
CAI Center

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REVIEW OF AUTOMATED TESTING[1]

Duncan N. Hansen, John J. Hedl, Jr., and Harold F. O'Neil, Jr.
Florida State University

Introduction

The active investigation of the use of automated equipment for psychological testing spans the past decade. Numerous forces have contributed to this active investigation of the methodological requirements to automate psychological testing. First, and foremost, the amount of psychological and educational evaluation has increased many orders of magnitude. It is quite common to find both state and national testing programs as well as increased psychological and guidance services being executed within most major school systems. Secondly, there is an ever increasing demand for professional manpower which grossly fails to match the requirements for diagnostic and evaluative assessment (Arnhoff, 1968; Boneau, 1968a; Boneau, 1968b). Lastly, our assessment programs are becoming much more sophisticated in the sense of using multiple tests and preparing more sophisticated reports which have more prescriptive characteristics in terms of affecting the future course of a student's passage through our educational enterprise.

In regard to the methodological investigations, review of the literature indicates that the predominant model has been the one test-one psychologist focus. In essence, the functions of test administration, scoring, and interpretation have been conceptualized, analyzed and explored in terms of specific tests presented on an individualized basis. As will be pointed out in this paper, there are some serious problems found in such a limited model of the one test-one psychologist (OTOP) focus. The major deficiencies have been threefold in nature. First, the goal of increased sophisticated psychological assessment has contributed to the growing trend for the use of test batteries with multiple requirements ranging from cognitive through personality assessment; this trend is obviously counter to the OTOP approach. Second, the OTOP model more directly relates to the clinical approach which has an operational deficiency in terms of bridging the hiatus between diagnostic assessment and prescriptive guidance. Lastly, we would conjecture that methodological investigations of the OTOP model are far too constrained in that the opportunity to consider the full domain of a multi-test, multi-team (MTMT) psychological testing service opens up many new possibilities for the use of time-sharing interactive terminal-oriented computing systems.

During the past decade, the team model for multiphasic psychological testing and educational intervention has become a more predominant theme. Psychologists, counselors, teachers, and professionals are realizing the need for an extension of the diagnostic, interpretation, and intervention process. Thus, one could conjecture that the MTMT model will lead to a better representation of the psychological assessment process. Primary considerations of this model involve information gathering and processing of specified behaviors, critical decisions based on the most reliable and valid behavioral samples, and, most importantly, the collation of this data for the generation of alternative hypotheses regarding the interpretation and implied educational treatments to be offered. The MTMT model offers a broader context in which to adequately evaluate the potential use of computer resources to reduce the manpower requirements and to extend the sophistication of the psycho-educational testing process.

We turn now to a consideration of the methodological investigations of automated testing and their associated R and D problems carried out in the last decade. The paper will be organized to cover the domains of test administration, test scoring, and test interpretation. Most importantly, a strong emphasis will be placed on the information processing and multi-functional characteristics implied by the MTMT model so that a broader range of R and D issues and subgoals can be considered.

Test Administration

Automated test administration concerns the interaction between the student and the automated equipment being used for the test presentation. There appear to be four areas of methodological activity in this area: 1) terminal equipment, 2) the interactive testing process, 3) reliability and validity issues, and 4) the collection of multiple response indices.

Terminal Equipment. In reference to the availability of automated terminal equipment, it is quite common to find typewriters, cathode ray tubes, and slide projectors being used for test item presentation. Since the creation of inexpensive terminal equipment is one of the dynamic areas in computer technology, one can anticipate more sophisticated terminal devices as well as a significant decrease in the cost. On the other hand, progress with respect to the operation of appropriate audio presentation units and natural speech analyzers has been discouraging. Although digitalized speech as well as speech analysis devices are being investigated at Stanford and Haskins Laboratory respectively, the generic problems involved in natural speech analysis are delaying developments of new equipment.

In regard to psycho-motor/manipulative presentations, cost seems to be one of the greatest deterrents to any extensive development. It should be anticipated, though, that this may be overcome within the coming decade.

Interactive Test Process. Turning to the characteristics of the student-terminal interaction, several investigators have provided indirect evidence that this man-machine dialogue may be characterized as unbiased, non-stressful, and nearly human in nature. For example, Smith (1963) points to a "confession machine effect" which appears to enhance the data acquisition in particular content areas such as the subject's personal experience or his perceived personality characteristics. Evans and Miller (1969) found that students responded with greater honesty and candor to highly personal items of a social science questionnaire when administered by a computer as opposed to a conventional administration. Cogswell and Estavan (1965) have also reported similar findings on the apparent confidentiality of the computer interview.

This neutral nature of the computer evaluation experience may also be inferred from CAI research dealing with Trait-State Anxiety Theory (Spielberger, Lushene, and McAdoo, 1971). In this CAI anxiety research, a conceptual distinction is made between state anxiety, which consists of feelings of apprehension that vary in intensity and fluctuate over time, and trait anxiety which refers to individual differences in anxiety proneness.

In two studies (O'Neil, Spielberger, & Hansen, 1969; O'Neil, Hansen, & Spielberger, 1969) the CAI learning experience did not seem to differentially affect state anxiety responses for high and low trait anxiety Ss, although there was a significantly higher response by high trait anxiety Ss. An analysis of the CAI situation revealed a possible explanation for the absence of any relationship between trait anxiety and differential increases in state anxiety within this CAI setting. In the CAI task, the computer did not evaluate the adequacy of the S's performance relative to others, and therefore, did not pose a threat to self-esteem. These two studies, because they did not find differential shifts on A-State results for low and high trait anxious Ss, lend indirect evidence for the implied impersonal nature of a computer task.

More direct evidence for the non-threatening nature of a computer-based evaluation comes from a study by Gallagher (1970). He investigated the relationship of instructional treatments and learner characteristics in a terminal oriented computer-managed instruction course. Computer evaluation and instructor evaluation of term projects resulted in some rather interesting findings. Trait anxiety scores were negatively related to performance ($r = -.51$) in the instructor evaluated group, but were not related in the computer evaluated group ($r = -.03$). If one assumes that the treatment group which emphasized human interaction (instructor-evaluated group) would result in a greater threat to the individual's self-esteem, then these results would be consistent with Trait-State Anxiety Theory. In addition, these results provide some evidence that the interactive computer process may be less threatening, and, therefore, may be more neutral in nature, at least in the situations studied to date.

Reliability and Validity. In addition to these considerations, computer-based evaluation may have important reliability and validity implications. Computer-based administration of psychological tests should increase the reliability and validity of the test information due to the more neutral features of its interaction. Since the computer may be conceptually objective and neutral, its use to administer tests should eliminate certain possible human biases resulting from the typical dyadic interaction between examiner and student. The reduction of these affective error variance components should lead to increased reliability of the tests (Cronbach, 1960).

Reliability and validity studies concerning automated administration procedures have demonstrated from an empirical standpoint, the feasibility of a technological approach and have paved the way for further research and developmental efforts. For example, Elwood (1969) developed a non-computerized automated testing booth to administer the Wechsler Adult Intelligence Scale (WAIS). Orr (1969) reported favorable results for this approach from a comparison of an automated WAIS presentation with a traditional WAIS presentation (r = .93). However, this system only provides scoring capabilities for 2 of the 11 subtests (Digit Span and Digit Symbol). Recent computer methodology (Hedl, O'Neil, & Hansen, 1971) to be reported in an associated paper will describe how the administration of intelligence test items can be programmed to allow for repetition and expansion of verbal responses. Th. more contingent, interactive elicitation of responses appears to yield equivalent reliability and validity indices to those found for human presentation.

In a study of computer-based sequential testing, Hansen (1969) found a significant improvement in internal consistency reliability for computer presentation ($r = .80$) in comparison with a conventional classroom achievement test ($r = .43$). More interestingly, the computer-based test yielded a significant relationship ($r = .76$) with a college entrance aptitude score.

Parenthetically, one is surprised at the sparseness of the studies that directly compare reliability and validity of computer approaches with conventional administration. Obviously, considerable empirical study remains to be performed.

Multiple Response Collection. In reference to multiple response collection, the MMPI research at Florida State University (Dunn, Lushene, & O'Neil, 1971) represents an attempt at the total automation of the MMPI. The inventory items are presented on a cathode-ray tube. Latency is recorded as the student responds to each item. Immediately following the completion of the tests, the system prints out its interpretation of the data. These latency results will be reported later in an associated report.

As a part of the computer-based sequential test, Hansen (1969) found the addition of subjective confidence responses yielded improved validity coefficients. Massengill and Schuford (1967) have reported similar results. Obviously, the full potential of multiple dependent measures remains to be empirically explored within automated testing.

The R & D efforts concerning the automation of psychological testing have focused essentially on the OTOP model. In essence, these research applications attempted to simulate standard clinical testing procedures. A standard psychometric test was automated in terms of test administration and the results were then compared with traditional testing procedures. Although most of the results have demonstrated the feasibility of the computer methodology, the research has been limited in scope. For example, there has been no attempt to develop test items specifically for a computer-based approach. Given the increases in psychological assessment problems in our nation's schools, broader conception and implementation of computer testing applications are needed to extend the diagnostic interpretation and intervention process.

On the other hand, the goal of the MTMT model is to expedite the information gathering of psychological and cognitive data to provide for sufficient intervention and treatment programs. This goal can only be achieved through a broader conception of the assessment process. First, research should focus on the computer aspects centering around input and output of natural language during on-line communication between the student and the system. Starkweather (1965), Colby, Watt, & Gilbert (1966), and Weizenbaum (1966) have developed computer techniques to conduct psychotherapeutic dialogues with patients. These natural language processing techniques could be utilized to extend and enrich the interviewing and test-interactive aspects of a test battery. Hedl, O'Neil, & Hansen (1971) have shown that an interactive dialogue is possible with the automated administration of an individualized intelligence test.

A second emphasis implied by the MTMT model would be the determination of the optimal psychologist-computer-student interaction. Questions of student interest and motivation are of primary concern here. Efficient and reliable data gathering can only be achieved if the student places the appropriate confidence in the psychologist and the computer. In essence, one needs to plan and study from a systems viewpoint the adaptive aspects of the total assessment process.

Third, the number and variety of psycho-educational and psychological tests to implement within the MTMT model would, of necessity, need to be quite extensive. In addition, the decisions for test administration should possibly stress the increased use of subtest scales within test batteries. Specific findings determined from an initial test battery could be immediately followed up with in-depth evaluation to more precisely determine the nature and scope of a particular aptitude or disability.

This multi-testing procedure reveals new possibilities for computer applications in the assessment process. It could extend the variety of information available on a student and provide the differential data for the psychologist, teacher, and counselor. Given that the information needs are different for these professionals, the concept of the multi-test battery approach dictates the need for precise determination of the information requirements for each professional. Thus, an automated approach could allow for far greater flexibility in the composition of the test battery as well as possibly individualized subtest sequences that would maximize motivation and adaptation by the student. Obviously, these issues flowing from the MTMT model remain to be investigated.

Automated Scoring

The case of an automated approach to test scoring appears to vary along a structured/unstructured response dimension. For example, multiple-choice test item formats can be considered highly structured and, therefore, extremely easy to computer process using either optical scanners or on-line terminals. On the other hand, natural language inputs are quite unstructured as to vocabulary and grammatical characteristics as well as semantic content, and thus are more difficult to process.

This structured/unstructured dimension has been identified in order to provide a framework by which to consider the methodological process found in automated scoring techniques. This section will briefly mention conventional test scoring via optical scanners and then evaluate the research developments in natural language processing of verbal responses, use of multiple index scores, and finally sequential testing.

Test Scoring. Although the employment of computers to calculate test scores and to carry out statistical analyses and summaries of test data has been common for many years, the volume has been growing at a considerable rate. The advent of test scoring machines and the more sophisticated optical scanners has provided commercial testing services such as Educational Testing Service, Measurement Research Center, California Test Bureau, Science Research Associates, etc. with the capability for processing millions of student tests. Woods (1970) presents a comprehensive survey of the general uses of such data processing techniques in school testing programs. However, the application of these response analysis techniques to on-line terminal oriented computer testing systems is a recent advance. We turn now to the consideration of the use of natural language processing for test responses.

Natural Language Processing. One of the most significant developments for the analysis of language has been the General Inquirer System, a system of computer programs for content analysis of English tests (Stone, Dunphy, Smith, & Ogilvie, 1966). Using special "dictionaries" of words precategorized for specific research purposes, the system automatically tallies frequencies of category usage for a body of text material. The materials which have been analyzed range from suicide notes (Stone et al., 1966) to Thematic Apperception Test narratives (Smith, 1968). Bhusham and Ginther (1968) have reported using this system to analyze essays.

Most applications of the General Inquirer have ignored the problems of syntax. Goldberg (1966), for instance, applied the system to sentence completions with some success. Other researchers in the field of automated content analysis have evaded syntax problems by restricting the responses of the subject in one manner or another. In developing a computer-based system for scoring responses to the Holtzman Ink-Blot Test, Gorham (1967) restricted subjects to the use of six words for each blot. Even with this restriction, the correlations between hand and computer scoring equalled or exceeded interscorer reliability for the computer scoring for 15 of the 17 variables.

Peck and Veldman (1961) of the University of Texas have been developing a computer-based system for presenting and scoring responses to a sentence completion test. The problems of syntax were reduced due to the restriction on the subject to use a single word in responding to each sentence stem. The most recent system (Veldman, 1967) produces 40 scores from a 36-item form and employs a complex word-root data reduction system. This prototypic tailored inquiry method offers many of the benefits of a traditional interview, and might serve as a basis of future programs which could conduct intensive assessment interviews.

Recently, Archambault (1970) developed a computerized program to score verbal responses to three of the seven subtests of the Torrance Tests of Creative Thinking. The subtests considered were the Ask and Guess subtests (Activities 1, 2, and 3) in which subjects ask questions about a drawing and make guesses about the causes and consequences of a pictured event. Subject responses to each of these subtests are scored for fluency, flexibility, and originality.

For each of these categories a dictionary of entries was constructed by analyzing the model responses given by Torrance for key words and phrases in Roget's International Thesaurus (1962) and Soule's Dictionary of English Synonyms (1966). The test was administered in traditional fashion and the student responses were keypunched on standard IBM cards, one response to a card. These responses were then analyzed in a batch process mode. A word/phrase lookup procedure was performed to determine the frequency of categories which were used.

Archambault's data indicated that creativity, as defined by Torrance, was judged accurately by a computer. The syntax problems were reduced by only analyzing the frequency of word usage. However, this frequency word usage or word phrase look up procedure produced significant correlation ranging from .52 to .99 between the computer and the pooled scores of four trained judges. It appears that the use of a computer to score open-ended responses to standardized test items is feasible and should be further investigated.

The above-mentioned studies employed word dictionaires for their natural language programs. Essentially, the input data was compared against the dictionary entries in order to detect the presence or absence of certain word usage categories. Based upon the occurrence or non-occurrence of matches with the dictionary, scoring and branching decisions were made concerning the students' responses. The tests were administered in traditional fashion and the resultant data were then key-punched and analyzed in a batch process mode. The responses were not evaluated on a real-time basis. The automated Slosson Intelligence Test (Hedl, et. al., 1971) also employs a word dictionary approach; however, the input responses are immediately analyzed for their correctness.

One of the major problems in implementing computer analysis of natural language pertains to an economically feasible input system. This difficulty should be solved with the development of better interactive terminal devices and time-sharing computing systems.

Multiple Index Scores

The interactive testing approach exemplified by the two following papers illustrates new dimensions in the analysis of heretofore unexamined response characteristics. Multiple dependent measures such as latency, subjective confidence, and anxiety can be incorporated to improve both the diagnostic power and efficiency of the psychometric instruments. Research with the MMPI (Dunn, et al., 1971) has shown that the information processing time (latency) for a given item is partially a function of the number of characters in the item, the ambiguity of the item, and the social desirability value of the item. Massengill and Schuford (1967) have shown that subjective confidence ratings significantly increase test reliability. Hansen (1969) reported an improved predictive relationship for a college entrance aptitude measure if confidence scores are included with the right/wrong CAI scores.

Confidence or subjective probability scores may have great potential for improving diagnostic procedures, in that this additional subjective information approximates more closely many clinical assessment procedures. Moreover, a procedure for calculating factor scores recommended by Cattell (1965) could be implemented within the overall system.

Sequential Testing. As on-line scoring becomes more frequently utilized, the concept of sequential testing is likely to become part of the scoring methodology. Sequential testing is a procedure by which the selection of each item is contingent on the prior performance. In addition, subtest sequences can be altered according to real-time behavioral data samples, and according to the objective of the testing procedure as specified by the psychologist, teacher, or counselor. Sequential selection of tests to be administered can also be incorporated with the overall system. In this respect, sequential testing is necessary to solve the logistic problems presented by implementation of an MTMT model that strives for in-depth differential student assessment. The concept of mass test administrations would be eliminated (Cleary, Linn, & Rock, 1968) by a widescale adoption of this procedure with the MTMT model.

Sequential testing is also being employed for criterion performance assessment within individually prescribed instruction (IPI). Ferguson (1970) has described a model for computer-assisted criterion-referenced testing. The essential assumption of the approach is a hierarchical sequence of skill performance levels. Items are presented within a given skill area until sufficient information is available to formulate a mastery or non-mastery decision on the particular skill. The Pittsburgh IPI project is currently utilizing this form of sequential testing to facilitate the assessment/management aspects of their instructional program.

In summary, as methodological advances occur in natural language processing, in multiple dependent measures for combination or factor scores, and in sequential testing, the potential of the MTMT model will become a reality. In essence, the full array of student scores will be stored in learning history vectors and become an operational component in the educational process.

As developments in natural language processing become more sophisticated, the structured vs. unstructured distinction of response processing will not be a major consideration. Natural language processing and multiple dependent measures will become integrated in the student's score file and ultimately far more useful in the instructional process.

Automated Interpretation

The challenge of automated interpretation of test results consists of converting quantitative indices or profiles into meaningful verbal statements. While the R & D effort in this area is quite limited, one can foresee a great need for methodological development because of the extensive manpower required to provide for this phase of the testing process. As to reasons for the limited R & D efforts to date, one should recognize that an essential characteristic of a psychologist's role consists of providing human dialogue and interpretation regarding the outcomes of the testing process. Moreover, the interpretation of quantitative scores has always been a problem, due to the lack of sophistication of the varying clientele audience. In turn, generating professionally appropriate interpretations for psychological colleagues, guidance counselors, classroom teachers, and parents varies as to both the depths of interpretation as well as the use of quantitative concepts. Given these reasons for the limited progress in automated interpretation of test results, this section will review the major progress in the personality domain because of the more substantial methodological progress that has been demonstrated in comparison with the aptitude area. A brief discussion of preliminary research in the aptitude and achievement area is made. The section will conclude with a review of beginning efforts to develop an information management system for test result interpretations.

Personality Test Interpretation. The first operational system for the MMPI was developed at the Mayo Clinic (Rome, Swenson, Mataya, McCarthy, Pearson, and Keating, 1962) for routine use on medical and surgical patients. Glueck and Reznikoff (1965) have modified the Mayo program for application to a psychiatric in-patient population. More complex scoring and interpretative systems for the MMPI have been developed by Finney (1967) and Fowler (1969).

A number of less-than-complete interpretative efforts have been made in that many programs are available to provide interpretive statements based upon some limited aspect of the profile or to examine the test scores for congruence with some specified profile type. Thus, there are programs to examine MMPI scores for the Gilberstadt-Duker and Marks-Seeman code types, to apply the Meehl-Dahlstrom profile discrimination rules, or to identify maladjusted college students generally (Kleinmuntz, 1963). These lead to category descriptions if a student is positively identified.

The above mentioned programs involve both scoring and interpretative routines. In contrast, the Rorschach Test has only an interpretative system to analyze the obtained scores (Piotrowski, 1964). Agreement found between program and clinical diagnosis was 86 percent.

Essentially, both the MMPI and Rorschach programs examine the configuration of certain test scales or scores and then locate appropriate sentences or paragraphs stored in the computer memory system depending upon the scale elevations. The interpretative statements are then combined and a report produced.

Recent efforts by Fowler with the MMPI exemplify the concept of variable interpretative reports that are intended for different but specifiable audiences. Unlike his earlier work, and the work of others in the interpretation research area, which dealt extensively with clinical interpretation of score profiles, Fowler is currently designing a program to write varied psychological reports depending upon the nature of the intended audience. Implicit in this work is the need for a concise specification of the informational needs of the personnel who will eventually read, process, and further act upon the interpreted results. Using an audience rating methodological approach, each version is up-dated according to readability, audience relevancy, and professional utility criteria. One can anticipate that these methodological techniques will be utilized to extend the automated interpretive efforts of the future.

<u>Aptitude Test Interpretation</u>. Two examples of purely interpretative type programs for aptitude and achievement tests are available. These systems require test scores as input and provide for minimal interpretation of the patterns of scores. Within the area of aptitude and achievement measures, Helm (1965) has programmed the evaluation of a battery of individual scores per student. Sixty-five classes of sentences were generated from written psychological reports. The rule classifications incorporated approximately 90 percent of the information in the psychological reports. The output report consisted basically of simple sentences designed as direct translations of scores although some provision was made for compound sentences to handle contrasts or similarities between two or more profile scores.

In the area of counseling, Cogswell and Estavan (19[illegible]) have developed a program to evaluate student folders containing such input information as grades, aptitude test scores, etc. Applying the rules derived from previous counselor judgments, the computer program would select appropriate output statements such as: "Student's grades have gone down quite a bit. Ask about this in an interview." There was 75 percent agreement between the computer statements and the evaluative behavior of two counselors.

<u>Information Management Systems</u>. In stressing the multi-test multi-professional approach to assessment, an information management system (IMS) for storage and retrieval of student evaluation files appears to be necessary. In this way, varying but appropriate reports can be generated for psychologists, teachers, counselors, etc. Implicit in the MTMT model is the conception of a continuous record system with automated interpretative capability. All too often, the school psychologist or

classroom teacher perceives instructional problem cases within the framework of symptom disorders, either achievement or psychological in nature. A totally automated diagnostic system with interpretive capability could be preventative in nature in that continuous information would be available on each student and would be processed by the appropriate personnel at their level of information capability.

This IMS should also be able to suggest treatment possibilities for identified problem disorders. In addition, probabilistic statements could be presented concerning possible causative or treatment alternatives for each student. A constant cybernetic approach to the IMS would up-date the current interpretation and treatment statements. In other words, the effect of different treatments would be stored in the IMS and compared to the previous predictions for the purpose of actuarial up-dating. Thus, more valid and yet more precise statements of diagnostic and instructional activities would be readily available. One can anticipate that R and D efforts in automated interpretation of test results will follow the trend towards incorporation within IMS developments.

Summary

Given the rapid distribution of computer terminals, one can anticipate extensive empirical automated testing research during the 70's. We contend that the trends found in the MTMT model will influence those efforts. We anticipate extensive efforts on the natural language, dialogue aspect of test administration. Both test scoring and interpretation will be influenced by the growing availability of IMS for education. Thus, this decade will undoubtedly represent the full flowering of the automated testing area.

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FOOTNOTES

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MILITARY MAILING LIST

Col. Ray Alvord
FR 19995
Air Force Institute of Technology
SLG
Wright-Patterson Air Force Base,
Ohio 45433

Dr. Ray Berger
Electronic Personnel Research Group
USC
Los Angeles, California 90007

Chief of Naval Research
Code 458
Department of the Navy
Arlington, Va. 22217

Director
ONR Branch Office
219 Dearborn Street
Chicago, Illinois 60604
Att: Dr. Morton Bestin

Office of Naval Research
Area Office
207 West Summer Street
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Director
Naval Research Laboratory
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Attn: Technical Information Div.

Commanding Officer
Service School Command
U.S. Naval Training Center
San Diego, California 92133

Commanding Officer
Naval Medical Neuropsychiatric
Research Unit
San Diego, California 92152

Dr. James J. Regan
Code 55
Naval Training Device Center
Orlando, Florida 32813

Col. Walt Murphy
AFHRL (TT)
Human Resources Lab.
Lowry Air Force Base, Colorado

Mr. Norman B. Carr
Educational Advisor
U.S. Army
Southeastern Signal School
Ft. Gordon, Georgia 30905

Director
ONR Branch Office
495 Summer Street
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Att: Dr. Charles Starsh

Director
ONR Branch Office
1030 East Green Street
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Office of Naval Research
Area Office
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San Diego, California 92152

Commanding Officer
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Jacksonville, Florida 32213

Chief, Naval Air Reserve Training
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Ohio 45433

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ERIC Clearinghouse
Stanford University
Palo Alto, California 94305

ERIC Clearinghouse
Educational Media and Technology
Stanford University
Stanford, California 94305

Commander
Operational Test and
Evaluation Force
U.S. Naval Base
Norfol, Virginia 23511

Chief of Naval Operations, OP-07TL
Department of the Navy
Washington, D.C. 20350

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Naval Ship Systems Command
Code 03H
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Washington, D.C. 20360

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Alexandria, Virginia 22314

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Norfol, Virginia 23511
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Army Institute of Research
Walter Reed Army Medical Center
Washington, D.C. 20012

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Wright-Patterson Airforce Base
Ohio 45433

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Division #5, Air Defense
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Fort Bliss, Texas 79916

Director
Human Resources Research Office
George Washington University
300 North Washington Street
Alexandria, Virginia 22314

Chief
Training and Development Division
Office of Civilian Personnel
Department of the Army
Washington, D.C. 20310

Behavioral Sciences Division
Office of Chief of Research
and Development
Department of the Army
Washington, D.C. 20310

Headquarters, Electronic System Div.
ESVPT
L.G. Hanscom Field
Bedford, Massachusetts 01730

6570th Personnel Research Lab.
Aerospace Medical Division
Lackland Air Force Base
San Antonio, Texas 78236

AFOSR (SRLB)
1400 Wilson Boulevard
Arlington, Virginia 22209

Mr. Joseph Cowan
Chief, Personnel Research Ranch (P-1)
U.S. Coast Guard Headquarters
400 7th St. S.W.
Washington, D.C. 20226

Dr. Lee J. Cronbach
School of Education
Stanford University
Stanford, California 94305

Dr. M. D. Ha-ron
Human Sciences Research, Inc.
Westgate Industrial Park
7710 Old Springhouse Road
McLean, Virginia 22101

Dr. Joseph W. Rigney
Behavioral Technology Laboratories
University of Southern California
University Park
Los Angeles, California 90007

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

Dr. Mats Bjorkman
University of Umea
Department of Psychology
Umea 6, Sweden

Executive Secretariat
Interagency Committee on
Manpower Research, Room 251-A
1111 20th St., N.W.
Washington, D.C. 20036
Attn: Mrs. Ruth Relyea

Naval Undersea R. & D. Center
3202 E. Foothill Boulevard
Pasadena, California 91107

Lt. Col. Donald F. Ford
AF HRL (HRD)
Lowry AFB, Colorado 80230

Headquarters, U.S. Air Force
Washington, D.C. 20330
Attn: AFPTRD

Executive Officer
American Psychological Association
1200 Seventeenth Street, N.W.
Washington, D.C. 20036

Dr. Philip H. Dubois
Department of Psychology
Washington University
Lindell & Skinker Boulevards
St. Louis, Missouri 63130

Dr. Robert R. Mackie
Human Factors Research, Inc.
6780 Cortona Drive
Santa Barbara Research Park
Goleta, California 93107

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

Dr. Alvin E. Goins, Exec. Sec
Behavioral Sciences Res. Branc
National Institute of Mental He
5454 Wisconsin Avenue, Room 10
Chevy Chase, Maryland 20203

LCDR J.C. Meredith, USN (Ret.)
Institute of Library Research
University of California, Berk
Berkeley, California 94720

Dr. Marshall Farr
Office of Naval Research (Code
800 N. Quincy Street, Room 711
Arlington, Virginia 22217

Technical Information Exchange
Center for Computer Sciences
and Technology
National Bureau of Standards
Washington, D.C. 20234

Dr. Tom Jeffrey
Besrl, Behavioral Science
Research Laboratory
207 Commonwealth Bldg.
Arlington, Virginia 22209

Dr. Glen Finch
AFOSR, Air Force Office
of Scientific Research
1400 Wilson Blvd.
Arlington, Virginia 22209

Director, Education & Trng. Sciences
Naval Medical Research Institute
Building 142
National Naval Medical Center
Bethesda, Maryland 20014

Dr. George S. Harker, Director
Experimental Psychology Division
U.S. Army Medical Research Lab.
Fort Knox, Kentucky 40121

U.S. Army Air Defense School
Office of Director of Instruction
Attn' Mr. Wayne O. Aho
Fort Bliss, Texas 79916

Mr. Charles W. Jackson
5009 Holmes Ave., N.W.
Redstone Arsenal
Huntsville, Alabama 35805

Research Director, Code 06
Research and Evaluation Dept.
U.S. Naval Examining Center
Building 2711 - Green Bay Area
Great Lakes, Illinois 60088
Attn. C. S. Winiewicz

Dr. Ralph R. Canter
Military Manpower Research Coordinator
CASD (M&RA) MR&U
The Pentagon, Room 3D960
Washington, D.C. 20301

U.S. Army Behavior and Systems
Research Laboratory
Commonwealth Building, Room 239
1320 Wilson Boulevard
Arlington, Virginia 22209

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Computers and Automation
815 Washington Street
Newtonville, Massachusetts
02160

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Aerospace Crew Equipment Department
Naval Air Dev. Center, Johnsville
Warminster, Pennsylvania 18974

Commander
Submarine Development Group Two
Fleet Post Office
New York, New York 09501

Dr. Henry S. Odbert
National Science Foundation
1800 G. Street, N.W.
Washington, D.C. 20550

Education & Training Develop. Staff
Personnel Research & Develop. Lab.
Bldg. 200, Washington Navy Yard
Washington, D.C. 20390

Dr. A. L. Slafkosky
Scientific Advisor (Code AX)
Commandant of the Marine Corps
Washington, D.C. 20380

Lt. Col. F. R. Ratliff
Office of the Ass't. Secretary
of Defense (M&RU)
The Pentagon, Room 3D960
Washington, D.C. 20301

Director
Behavioral Sciences Laboratory
U.S. Army Research Institute of
Environmental Medicine
Natick, Massachusetts 01760

Dr. Bernard M. Bass
University of Rochester
Management Research Center
Rochester, New York 14627

Dr. Donald L. Bitzer
Computer-Based Education Research
University of Illinois
Urbana, Illinois 61801

Dr. C. Victor Bunderson
Computer Assisted Instruction Lab.
University of Texas
Austin, Texas 78712

Dr. Robert Dubin
Graduate School of Administration
University of California
Irvine, California 02650

Mr. Wallace Feurzeig
Bolt, Beranek and Newman, Inc.
50 Moulton Street
Cambridge, Mass. 02138

Dr. John C. Flanagan
American Institutes for Research
Post Office Box 1113
Palo Alto, California 94302

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

Dr. Carl E. Helm
Dept. of Educational Psychology
City U. of N.Y. - Graduate Center
33 West 42nd Street
New York, New York 10036

Dr. Lloyd G. Humphreys
Department of Psychology
University of Illinois
Champaign, Illinois 61820

Dr. Gabriel D. Ofiesh
Center for Ed. Technology
Catholic University
4001 Harewood Rd., N.E.
Washington, D.C. 20017

Dr. Paul Slovic
Oregon Research Institute
P. O. Box 3196
Eugene, Oregon 97403

Dr. John Annett
Department of Psychology
Hull University
Yorkshire, ENGLAND

Dr. F. J. Divesta
Pennsylvania State University
320 Reackley Building
University Park,
University Park, Pennsylvania 16802

Dr. Marvin D. Dunnette
University of Minnesota
Department of Psychology
Elliot Hall
Minneapolis, Minnesota 55455

S. Fisher, Research Associate
Computer Facility, Graduate Center
33 West 42nd Street
New York, New York 10036

Dr. Robert Glaser
Learning Research and Development
Center
University of Pittsburgh
Pittsburgh, Pennsylvania 15213

Dr. Bert Green
Department of Psychology
Johns Hopkins University
Baltimore, Maryland 21218

Dr. Albert E Hickey
ENTELEK, Incorporated
42 Pleasant Street
Newburyport, Massachusetts 01950

Dr. Richard Myrick, President
Performance Research, Inc.
919 Eighteenth St., N.W., Suite 425
Washington, D.C. 20036

Mr. Luigi Petrullo
2431 N. Edgewood Street
Arlington, Virginia 22207

Dr. Arthur W. Staats
Department of Psychology
University of Hawaii
Honolulu, Hawaii 96822

Dr. M.C. Shelesnyak
Interdisciplinary Communications
Smithsonian Institution
1025 15th St., N.W./Suite 700
Washington, D.C. 20005

Educational Testing Service
Division of Psychological Studies
Rosedale Road
Princeton, New Jersey 08540

Dr. George E. Rowland
Rowland and Company, Inc.
P. O. Box 61
Haddonfield, New Jersey 08033

Department of the Navy
Office of Naval Research
Arlington, Virginia 22217
Code 458

Dr. Harold Gulliksen
Department of Psychology
Princeton University
Princeton, New Jersey 08540

Dr. Marty Rockway
AFHRL (TT)
Human Resources Lab.
Lowry Air Force Base, Colorado