ED 315 455 TM 014 489

AUTHOR Kieras, David E.
TITLE Learning about Equipment from Technical Documentation: A Basic Comprehensible Writing Aid. Final Report. Technical Report No. 31.
INSTITUTION Michigan Univ., Ann Arbor. Technical Information Design and Analysis Lab.
SPONS AGENCY Office of Naval Research, Arlington, Va.
REPORT NO FR-89-ONR-31
PUB DATE 10 Jan 90
CONTRACT N00014-85-K-0138
NOTE 14p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Comprehension; *Computer Assisted Instruction; Computer Uses in Education; *Documentation; *Learning Processes; Models; Reading Comprehension; *Scientific and Technical Information; Technical Education; *Technical Writing; Writing (Composition)
IDENTIFIERS *Equipment Operation; *Mental Models

ABSTRACT

Theoretical and empirical work was conducted on the role of the "mental model," or how-it-works information, in learning to operate equipment. The original project was concerned with empirical and cognitive modeling studies of how people learn to operate equipment from the kind of information contained in technical documentation. The goal was to understand how knowledge about equipment could be presented effectively and how knowledge about the equipment should be conveyed to the reader. These studies were described in prior publications, which are listed in this final report. The second part of the project was a separate line of work on a computerized aid for comprehensible writing, a computer program intended to provide feedback to the writers of technical documents about comprehensibility problems. A general conclusion of the project was that high-quality training on specific procedures is generally superior to training limited to system knowledge. The developed feedback system was sophisticated and fast. Future work on this topic might best be focused on documenting the redundancy and insignificance of much mental model content. The reports and publications of this portion of the project are also listed. Applications of the work of both parts of the project and the problems encountered are summarized. (SLD)

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release: distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): TR-89 / ONR-31	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: University of Michigan; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: Cognitive Science, Office of Naval Research (Code 1142CS)
6c. ADDRESS (City, State, and ZIP Code): Technical Communication Program, Ann Arbor, MI 48109-2108	7b. ADDRESS (City, State, and ZIP Code): 800 N. Quincy Street, Arlington, VA 22217
8a. NAME OF FUNDING/SPONSORING ORGANIZATION; 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: N00014-85-K0138
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO.
61153N	RR04206	RR04206-0A	NR667-543

11. TITLE (Include Security Classification)
Learning About Equipment from Technical Documentation: A Basic Comprehensible Writing Aid: FINAL REPORT

12. PERSONAL AUTHOR(S)
David Kieras

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Report	FROM 2/1/85 TO 9/30/89	1/10/90	8

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Mental Models, Procedure Learning & Comprehensibility
05	09		

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

This is the final report for a two part project. Theoretical and empirical work was conducted on the topic of the role of "mental model," or how-it-works information, in learning to operate equipment. A general conclusion is that high-quality training on specific procedures is generally superior to training limited to system knowledge, which was relatively difficult to learn and to apply. Additional work was also done on learning procedures from text, which further extended production-system models as an account of procedural learning. The second part of the project was further work on a computer-based aid for comprehensible writing of technical materials. Applications of the project work and various problems encountered are summarized.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION
22a. NAME OF RESPONSIBLE INDIVIDUAL: Susan Chipman	22b. TELEPHONE (Include Area Code): (202) 696-4318; 22c. OFFICE SYMBOL

DD Form 1473, JUN 86 — Previous editions are obsolete. — SECURITY CLASSIFICATION OF THIS PAGE: Unclassified

S/N 0102-LF-014-6603

LEARNING ABOUT EQUIPMENT FROM TECHNICAL DOCUMENTATION

A BASIC COMPREHENSIBLE WRITING AID

FINAL REPORT

Contract No. N00014-85-K0138, NR 667-543
David Kieras, Principal Investigator
University of Michigan

ABSTRACT

This is the final report for a two part project. Theoretical and empirical work was conducted on the topic of the role of "mental model," or how-it-works information, in learning to operate equipment. A general conclusion is that high-quality training on specific procedures is generally superior to training limited to system knowledge, which was relatively difficult to learn and to apply. Additional work was also done on learning procedures from text, which further extended production-system models as an account of procedural learning. The second part of the project was further work on a computer-based aid for comprehensible writing of technical materials. Applications of the project work and various problems encountered are summarized.

Project Goals

This research contract actually encompassed two projects. The original one, under the title *Learning about Equipment from Technical Documentation*, was concerned with empirical and cognitive modeling studies of how people learn to operate equipment from the kind of information contained in technical documentation, namely, information about operating procedures, and information about how the device works. The goal was to understand how knowledge about equipment could be effectively presented, both in terms of what the user is supposed to do procedurally, and what about the equipment itself should be conveyed. The second portion of the project was added later for administrative reasons; this was a separate line of work on a computerized aid for comprehensible writing, a computer program intended to provide feedback to the writers of technical documents concerning comprehensibility problems. This sub-project was sponsored by the Navy Personnel Research and Development Center.

Work Accomplished

The Role of Mental Model Information

Questions from earlier work. This project started where earlier work left off (see Kieras & Bovair, 1984) on the topic of the role of mental model information about how the device works. At that point we had demonstrated empirically that training in mental model information for a simple control panel device resulted in much improved performance in paradigms where people were explicitly taught or had to infer procedures for operating the device. A simulation model had been constructed of the mental model reasoning process, (see Kieras, 1984; Kieras, in press) and some work was done during the period of this project showing that the model accounted for some aspects of the data. This work was submitted to two different journals with negative outcomes. Overall the reviewers did not seem to agree that the approach was worthwhile and did not consider that the comparison of the model to the data was adequately impressive. The data in question were individual inter-response latencies for elementary actions on the device (e.g. pushing a button) where each subject where each subject contributed one trial on each problem. Since the model was a model only of correct performance, only about half of the response sequences in the data could be compared to the model. Of these, quantitative predictions made from the model and various nuisance variables could account for roughly 40% of the variance in the inter-response latencies for individual subjects, which as it happens is close to the maximum variance that could be accounted for given the reliability of the data. Thus, it would appear that perhaps the reviewers simply did not appreciate that accounting for problem-solving data in such detail was an accomplishment, or perhaps there has been a shift in paradigm where simply being able to model some data is not considered publishable anymore. But in any event, because new data were being collected, I felt that further effort to publish an admittedly limited set of results was not worthwhile compared to work using more comprehensive and reliable data sets.

So a new line of studies was begun, with the idea that the modeling of mental model processes would be done in service of a larger scale goal, rather than just demonstrating that such models were possible. A set of such larger goals appeared during work on my contribution to the ONR- and ETS-sponsored conference on "Diagnostic monitoring of skill and knowledge acquisition" (Kieras, in press). The mental models trained in the earlier studies were in fact logically incomplete, and contained highly specific rather than generic information. This differed sharply from the assumptions that I had made in the cognitive simulation model, and so it was clear that the content of the mental model training did not agree with the logically complete specification of the mental model represented by the simulation. Perhaps a cleaner set of data, and better fit of the model would be obtained under conditions where subjects were trained in the same mental model content as the simulation.

Furthermore, during the same work I realized that the earlier studies had compared mental model training to conditions in which subjects either inferred the procedures on a trial and error basis, or were given training in rather sub-optimal procedures. That is, the original study in Kieras and Bovair (1984, Exp. 1) trained subjects in procedures that were highly overlapping and highly redundant, but this was not made explicit to the subjects. Our transfer work (Kieras and Bovair, 1986) was based on the realization that this overlap explained the rote training data. Thus, the procedure training that subjects received was rather sub-optimal. It turns out that a complete and accurate procedure for the control panel device can be stated in almost the same number of steps as just one of the ten procedures that subjects were trained on.

So, a better view of the Kieras and Bovair (1984) studies is that mental model training was shown to be superior to both trial and error and grossly inferior procedure training. The problem is that military training practices correspond to neither one of these radically inferior conditions, however much their need for improvement. The new studies compared mental model training to *high-quality* procedure training.

A final goal of the new line of studies was to get performance up to a higher level than previously so that a larger subset of the behavior sequences could be compared to the simulation models.

New control panel device studies. A series of three careful studies on the control panel device were undertaken; these studies were quite sound methodologically and produced very high-quality data. In these studies different forms of mental model training were compared to a high-quality rote procedure training condition. The results were ambiguous for understanding the value of mental model-based training. Throughout all of the studies, the rote procedure training was by far the best condition in terms of speed of learning and quality of performance. The different mental model conditions proved to be indistinguishable, except in the earliest trials, generally poor in overall learning, and showed a rapid convergence to the same execution time characteristics as the rote procedure condition.

One of the goals for the studies was to demonstrate that more complete and comprehensive mental model training would be superior to the sketchier training used in the original studies. Thus, the best condition was predicted to be one in which subjects studied the same generic inference rules and strategy as in the original simulation model. But this turned out to be the worst condition! Overall, the results were that the more complete and elaborate the mental model training, the longer it took people to learn it and to learn how to apply it.

A second goal was to get more stable, reliable time data by having the subjects repeat the problems, rather than solve them just one time, as before. Most frustrating was that initially, the training conditions could be distinguished, but performance was poor, and as the subjects gained experience, performance improved substantially, but the training conditions became indistinguishable. Thus the only effects of the mental model training were in the first few trials, and on these trials, the performance was generally no better in these experiments than they had been with the original ones. The procedure training condition was superior on these initial trials, and remained at least equal to all other conditions thereafter.

In summary, these studies suggest that subjects in the mental model conditions quickly construct a *procedure* for operating the device; they do this by making inferences from the mental model training materials, which can be difficult to do depending on the amount, complexity, and abstractness of the material. On the other hand, subjects given the procedure *directly* are far better off. Hence, acquiring procedures from text is superior to inferring them from a mental model.

Scaled-up mental model study. Another study was done in which the effects originally observed with the control panel device were sought in a scaled-up version. A computer-based version of the control panel device system was defined and implemented. Instead of operating switches and observing indicator lights, the subjects typed in commands and viewed status information on a video terminal. The three training conditions compared were (1) rote procedure training; (2) additional training in the syntax and semantics of the command language, which is most like traditional computer training; and (3) additional training on the underlying dynamic characteristics of the system, which directly supported inferences of correct operating procedures for novel situations.

The results showed a moderately strong overall benefit of more complete training, but this effect, contrary to expectation, failed to be specific to the individual problem solving situations. Furthermore, in a *post hoc* analysis of the procedural content of the training and testing, it appeared that to a good first approximation, the time taken to execute the task was a function of how much procedural knowledge the subjects had acquired in their previous experience with the device. This very powerful effect apparently masked many of the benefits that training in system knowledge might have provided.

Conclusions on mental model training. The overall conclusion from these studies is that high-quality training on procedures is probably the most efficient training approach. We have yet to see a case where training in mental model content is of definite benefit above and beyond high-quality procedure training. Perhaps there are situations where good procedure training is impractical. But otherwise, these studies imply that the benefits of understanding how a system works will be limited to very transitory first-time or one-of-a-kind situations. Once a subject has successfully problem-solved through a situation, the mental model content is of little value thereafter. These results are being prepared as a technical report.

Certainly further work on the value of mental models in training is needed, but we should probably be prepared for the outcome of this research being very different from what we would have previously imagined. For example, it could be that most mental model training in military equipment systems is simply a waste of time, given that in the actual work situation the procedures for interacting with most equipment have been made explicit, and when these procedures are not adequate to cover the situation, there is little that can be done other than to wait for an expert to repair the equipment. An example of this appears in some of the actual Navy training and job aid materials that I have examined, in which even emergency malfunction procedures are spelled out in considerable detail. In contrast, the training includes classroom and textbook principles of systems such as steam turbines that are dwelt on at some length, even though nowhere in the trainee's job (or several grades above it) could this knowledge ever possibly be applied. Perhaps the major effect of such training is only to convey terminology and a knowledge of system components (e.g. types of valves and bearings) and certain elementary basic principles, such as why bearings can not be allowed to get too hot. Thus future work on this topic might best be focussed on documenting the redundancy and insignificance of much mental model content for many military jobs, rather than further attempts to demonstrate its usefulness.

Acquiring Procedures from Text

This work was carried on mostly by Susan Bovair. Extensions of this work and the simulation modeling of the data will be the subject of her dissertation.

Major papers. Two major papers on this topic were published with Bovair first author on both; the first was accepted at *Human-Computer Interaction*, with the data originally collected under IBM sponsorship. ONR support for the preparation of this paper was acknowledged. This paper concerned the learning and execution of procedures for operating a text editor. The second paper was an important theoretical paper on the acquisition of procedures from text for the new *Handbook of Reading Research*. This is a key paper because it is the first time a theoretically sophisticated treatment of this topic has been prepared and presented in a place where a variety of reading researchers will see it. One function of the paper is to emphasize the lack of research in this area; it is drastically under-explored. The paper also presents our framework for a model of how procedures are acquired, based on the construction of production rule representations for procedures using the information presented in the text. The preparation of this paper was an important activity in this project.

"Overload" study. Susan Bovair conducted an experiment on the "overload effect" noted in our earlier work on procedure acquisition. In this earlier experiment (Kieras and Bovair, 1986) we observed that one of the procedures, when it was the first one learned, took much more time than was predicted by the production rule model. Our hypothesis was that this was due to a working memory overload during procedure learning; this one procedure when learned first involved a total number of production rules that was substantially larger than that in any other situation in the experiment. If a representation of the entire procedure had to be constructed in working memory, then subjects presumably would have to engage in considerable extra processing to make up for the fact that they could not maintain the entire procedure at once in memory. This hypothesis was tested with a very carefully designed experiment that manipulated the degree of overload with a complex set of procedures defined on the control panel device. The experiment was designed using the simulation model of procedure acquisition to predict the number of new rules and overload effect *a priori*. A set of procedures and a set of training orders was defined so as to produce a predicted overload effect under conditions where it would not be confounded with other factors, such as being the very first trial in the experiment.

The basic results were that the putative overload effect occurred, but only early in the experiment; no overload effect occurred in the second half of the procedures. This initially very puzzling result fell into place when, as a result of the thinking involved in preparing the review paper, Bovair realized that there are a whole set of low-level procedures that subjects would have to learn in the experiment. For example, if one of the steps in the procedure was *Set S2 to X* then the subjects had to learn a whole set of production rules for carrying out what had appeared to us to be a single step. For example, first they have to locate the control S2, then grasp it, then rotate it in one direction or the other, and stop when the pointer is at the position X. Thus, there is in fact a set of lower-level production rules that must be learned in order to operate the equipment. Since these same basic activities are used repeatedly in all of the procedures, they only have to be learned early in the experiment.

Bovair was able to describe these low-level procedures and make quantitative predictions of training time using this expanded set of production rules. The fit to the data is very good. She has reanalyzed our earlier data from Kieras and Bovair (1986) with similar results. These results are also being prepared as a technical report.

Conclusions on procedure acquisition. The work done in this project on procedure acquisition has been largely theoretical, but with some important empirical results that show that the basic approach of modeling procedure learning in terms of the acquisition of production rules is both more robust and simpler than originally expected. Bovair's dissertation work, in which she will construct a comprehensive simulation model of the procedure acquisition process, should be a key piece of work in capturing the theoretical insights that we have accumulated thus far.

Comprehensibility System

Several versions of the comprehensibility system were delivered to NPRDC. This system has evolved considerably during its tenure as part of this project. The parser is now very sophisticated and very fast, and the set of criticism rules incorporated in the model have expanded into a fairly large and comprehensive set. This software was also repeatedly revised and improved both for efficiency and speed, but also for ease of future revision and updating. Additionally, the software was designed so that portions of it could be easily used in cognitive modeling projects such as Bovair's dissertation work. A chapter on the system appeared in the key Britton and Glynn volume on computer writing environments, ensuring its visibility to a wider audience.

At this point the major remaining problem with the comprehensibility system is that its output is still too verbose. The last work to be done on this version is to complete final work in extensions to the grammar, and simplify the output. One more version of the system is slated to be delivered to NPRDC, along with a technical report that provides maintenance and extension information for NPRDC staff.

Reports and Publications

Technical Reports

Kieras, D.E. (1987). The role of cognitive simulation models in the development of advanced training and testing systems (Tech. Rep. No. 23, TR-87/ONR-23). Ann Arbor: University of Michigan, Technical Communication Program. (DTIC AD A178268)

Kieras, D.E. (1987). What mental model should be taught: Choosing instructional content for complex engineered systems (Tech. Rep. No. 24, TR-87/ONR-24). Ann Arbor: University of Michigan, Technical Communication Program. (DTIC AD A178392)

Bovair, S., Kieras, D.E., & Polson, P.G. (1988). The acquisition and performance of text editing skill: A production system analysis (Tech. Rep. No. 28). Ann Arbor: University of Michigan, Technical Communication Program.

Bovair, S. & Kieras, D.E., (1989). Toward a model of acquiring procedures from text (Tech. Rep. No. 30, TR-89/ONR-30). Ann Arbor: University of Michigan, Technical Communication Program.

Reports In Preparation

Bovair, S. High- and low-level procedure transfer effects in learning to operate a device (Tech. Rep. No. 32, TR-90-ONR-32). Ann Arbor: University of Michigan, Technical Communication Program.

Kieras, D.E. Rote procedure versus mental model training in operating equipment (Tech Rep. No. 33, TR-90-ONR-33). Ann Arbor: University of Michigan, Technical Communication Program.

Kieras, D.E. Programmers' guide for the computerized comprehensibility system (Tech. Rep. No. 34, TR-90-ONR-34). Ann Arbor: University of Michigan, Technical Communication Program.

Publications

Kieras, D.E. (1987). Cognitive Modelling. In *Encyclopedia of Artificial Intelligence*, New York: Wiley.

Kieras, D.E. Mental models for engineered systems and computers. In the proceedings of *Workshop on the Role of Mental Models in User-Centered System Design*, under Army Research Institute sponsorship, hosted by University of Colorado Institute for Cognitive Science, Breckenridge, CO, January 13-16, 1988.

Kieras, D.E. (1988). What mental model should be taught: Choosing instructional content for complex engineered systems. In J. Psotka, L.D. Massey, and S. Mutter (Eds.), *Intelligent Tutoring Systems: Lessons Learned* (pp. 85-111). Hillsdale, NJ: Erlbaum.

Bovair, S. & Kieras, D.E. (1989). Toward a model of acquiring procedures from text. In Barr, Kamil, Rosenthal and Pearson (Eds.), *Handbook of Reading Research,* Vol. II. Longman

Kieras, D.E. (1989). An advanced computerized aid for the writing of comprehensible technical documents. In B. Britton & S. Glynn (Eds.), *Computer Writing Environments: Theory, Research, and Design.* Hillsdale, NJ: Erlbaum.

Bovair, S., Kieras, D.E., & Polson, P.G. (In press). The acquisition and performance of text editing skill: A cognitive complexity analysis. *Human-Computer Interaction.*

Problems Encountered

The productivity of this project was impaired by many administrative and managerial problems. They are summarized here by way of explanation, and in hopes that they might be instructive for future projects. This project was initiated while I was still at the University of Arizona; then the project was moved to the University of Michigan. Of course there was the normal disruption due to the various problems of moving. But an especially serious one was that a new laboratory computer, a VAX 730, was installed. Although supplied at no cost to the project, considerable project resources during the first year were consumed in getting software converted and implemented. Given the obsolescence of the machine at this time, this large effort is not likely to pay off in the long run. It appears at this time an almost ideal environment for training experiments is a large screen Macintosh II with software packages such as HyperCard or Course of Action, which reduce the software programming requirements to a very low level, even though far more features and power are available.

Another computer-related problem was that at the time of the move, we had just received a set of Xerox 1108 AI Workstations, and a substantial effort was made to implement all cognitive modeling software on these machines and pursue other related work such as the comprehensibility system in this environment as well. These were very difficult machines to use, and consumed a very large amount of time. However, our actual computational needs were much simpler; we simply needed a high performance LISP implementation, and many of the features of the workstations that made them useful for intelligent tutoring system work were simply a distraction for us. A very large amount of software work was discarded after these machines were replaced with general purpose workstations (Apollos) which have proved to be far more satisfactory.

The most serious problem was a massive over-commitment of the Principal Investigator. In addition to the complications of moving to a different university and dealing with new lab equipment, I had too many projects active during the period of this project. In addition to this project, I was P.I. on a major IBM-sponsored project, a medium-sized project sponsored by NASA, the original comprehensibility system project, an additional ONR project that started later, and a substantial applied project for NPRDC. This over-commitment resulted in a lack of focus and erratic management of the staff. The most serious manifestation was that I had to take over the programming for the comprehensibility system. A more substantive effect of this over-commitment is that there were many promising research leads that opened up during this project that simply could not be followed up.

Accomplishments

Two items to mention under this heading involved aspects of this work making a transition towards application. The first was that the research on mental models was directly applied to work done for NASA on diagrammatic displays for engineered systems. The basic thrust was that diagrams, and especially computer-generated animated and color-coded diagrams, can be used to convey mental model information to the user. If this is done in a form that directly facilitates the inferences that the user needs to perform, problem solving ability with a system should be improved. These effects, along with some important limitations, were demonstrated both for the simple control panel device, and also for a complex piece of actual spacecraft equipment. The following is the reference for the report on this topic:

Kieras, D.E., (1988). Diagrammatic displays for engineered systems: Effects on human performance in interacting with malfunctioning systems (Tech. Rep. No. 29). Ann Arbor: University of Michigan, Technical Communication Program.

At the request of Dr. Gerald Laabs of NPRDC, we conducted a set of analyses of a test battery for job performance. These tests consisted of actual procedure executions for a variety of tasks involving ship machinery. Our analysis dealt with both the procedural and mental model content of the tasks and their relationship to the background knowledge and training of the personnel. The result was a suggestion for simple methods for ensuring non-redundant task selection. The reference for the report on this project is as follows:

Kieras, D.E. A cognitive analysis of the relations between a set of hands-on job performance test tasks. Tech. Rep. prepared for the Navy Personnel Research and Development Center, Gerald Laabs, Scientific Monitor, under Scientific Services Program Contract No. DAAL03-86-D-0001, Delivery Order 694. March 3, 1989.

References

Kieras, D.E. (1984). A simulation model for procedure inference from a mental model for a simple device (Tech. Rep. No. 15, UARZ/DP/TR-84/ONR-15). Tucson: University of Arizona, Department of Psychology. (DTIC AD A143909)

Kieras, D.E., & Bovair, S. (1984). The role of a mental model in learning to operate a device. *Cognitive Science, 8,* 255-273.

Kieras, D.E., & Bovair, S. (1986). The acquisition of procedures from text: A production-system analysis of transfer of training. *Journal of Memory and Language, 25,* 507-524.

Kieras, D.E. (In press). The role of cognitive simulation models in the development of advanced training and testing systems. To appear in N. Frederiksen, G. Glaser, A. Lesgold, & M. Shafto (Eds.), *Diagnostic Monitoring of Skill and Knowledge Acquisition.* Hillsdale, NJ: Erlbaum.

Defense Technical Information Center
Cameron Station, Bldg. 5
Alexandria, VA 22314
Attn: TC

Office of Naval Research,
Code 1142CS
800 N. Quincy Street
Arlington, VA 22217-5000

Dr. James D. Baker
Director of Automation and Research
Allen Corporation of America
209 Madison Street
Alexandria, VA 22314

Dr. Meryl S. Baker
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Thomas G. Bever
Department of Psychology
University of Rochester
River Station
Rochester, NY 14627

Dr. Arthur S. Blaiwes
Code N712
Naval Training Systems Center
Orlando, FL 32813-7100

Dr. Joanne Capper, Director
Center for Research into Practice
1718 Connecticut Ave., N.W.
Washington, DC 20009

Dr. Ruth W. Chabay
CDEC, Hamburg Hall
Carnegie Mellon University
Pittsburgh, PA 15213

Dr. Charles Clifton
Tobin Hall
Department of Psychology
University of
Massachusetts
Amherst, MA 01003

Brian Dallman
Training Technology Branch
3400 TCHTW/TTGXC
Lowry AFB, CO 80230-5000

Margaret Day, Librarian
Applied Science Associates
P.O. Box 1072
Butler, PA 16003

Dr. Sharon Derry
Florida State University
Department of Psychology
Tallahassee, FL 32306

Dr. Thomas M. Duffy
Communications Design
Center, 160 BH
Carnegie-Mellon University
Schenley Park
Pittsburgh, PA 15213

Dr. Richard Duran
Graduate School of Education
University of California
Santa Barbara, CA 93106

ERIC Facility-Acquisitions
4350 East-West Hwy., Suite 1100
Bethesda, MD 20814-4475

Dr. Debra Evans
Applied Science Associates, Inc.
P. O. Box 1072
Butler, PA 16003

Dr. Beatrice J. Farr
Army Research Institute
PERI-IC
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Elizabeth Fennema
Curriculum and Instruction
University of Wisconsin
225 North Mills Street
Madison, WI 53706

Dr. Michael Flaningam
Code 52
NPRDC
San Diego, CA 92152-6800

Dr. J. D. Fletcher
Institute for Defense Analyses
1801 N. Beauregard St.
Alexandria, VA 22311

Dr. Linda Flower
Carnegie-Mellon University
Department of English
Pittsburgh, PA 15213

Department of Humanities and
Social Sciences
Harvey Mudd College
Claremont, CA 91711

Dr Robert Glaser
Learning Research
& Development Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15260

Dr. Sam Glucksberg
Department of Psychology
Princeton University
Princeton, NJ 08540

Dr. Susan R. Goldman
Dept. of Education
University of California
Santa Barbara, CA 93106

Dr. Sherrie Gott
AFHRL/MOMJ
Brooks AFB, TX 78235-5601

Dr. T. Govindaraj
Georgia Institute of Technology
School of Industrial and Systems Engineering
Atlanta, GA 30332-0205

Dr. Cheryl Hamel
NTSC, Code 711
Orlando, FL 32813

Janice Hart
Office of the Chief of Naval Operations
OP-111J2
Department of the Navy
Washington, D.C. 20350-2000

Dr. Melissa Holland
Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

Ms. Julia S. Hough
110 W. Harvey Street
Philadelphia, PA 19144

Dr. Steven Hunka
3-104 Educ. N.
University of Alberta
Edmonton, Alberta
CANADA T6G 2G5

Dr. Janet Jackson
Rijksuniversiteit Groningen
Biologisch Centrum, Vleugel D
Kerklaan 30, 9751 NN Haren
The NETHERLANDS

Dr. Michael Kaplan
Office of Basic Research
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

Dr. Charlotte Linde
Structural Semantics
P.O. Box 707
Palo Alto, CA 94320

Dr. Jack Lochhead
University of Massachusetts
Physics Department
Amherst, MA 01003

Dr. Elaine Marsh
Naval Center for Applied Research
in Artificial Intelligence
Naval Research Laboratory
Code 5510
Washington, DC 20375-5000

Dr. James L. McClelland
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

Dr. Kathleen McKeown
Columbia University
Department of Computer Science
450 Computer Science Building
New York, NY 10027

Dr. James McMichael
Technical Director
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Arthur Melmed
Computer Arts and Education Laboratory
New York University
719 Broadway, 12th floor
New York, NY 10003

Dr. George A. Miller
Dept. of Psychology
Green Hall
Princeton University
Princeton, NJ 08540

Dr. Jason Millman
Department of Education
Roberts Hall
Cornell University
Ithaca, NY 14853

Dr. Lynn Misselt
HQM-222
Control Data Corporation
Box O
Minneapolis, MN 55440

Dr. William Montague
NPRDC Code 13
San Diego, CA 92152-6800

Dr. Allen Munro
Behavioral Technology Laboratories - USC
1845 S. Elena Ave., 4th Floor
Redondo Beach, CA 90277

Dr. Judith Orasanu
Basic Research Office
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Glenn Osga
NOSC, Code 441
San Diego, CA 92152-6800

Dr. Nancy N. Perry
Naval Education and Training
Program Support Activity
Code-047
Building 2435
Pensacola, FL 32509-5000

Dept. of Administrative Sciences
Code 54
Naval Postgraduate School
Monterey, CA 93943-5026

Dr. Mary C. Potter
Department of Brain and
Cognitive Sciences
MIT (E-10-039)
Cambridge, MA 02139

Dr. Charles M. Reigeluth
330 Huntington Hall
Syracuse University
Syracuse, NY 13244

Mr. William A. Rizzo
Code 71
Naval Training Systems Center
Orlando, FL 32813

Nuria Sebastian
Dep. Psicologia Basica
Univ. Barcelona
Adell Florensa s.n.
08028 Barcelona
SPAIN

Dr. Judith W. Segal
OERI 555 New Jersey Ave., NW
Washington, DC 20208

Dr. Robert J. Seidel
US Army Research Institute
5001 Eisenhower Ave.
Alexandria, VA 22333

Dr. Randall Shumaker
Naval Research Laboratory
Code 5510
4555 Overlook Avenue, S.W.
Washington, DC 20375-5000

Dr. Robert Smillie
Navy Personnel R&D
San Diego, CA 92152-6800

Dr. Alfred F. Smode
Code 7A
Research and Development Dept.
Naval Training Systems Center
Orlando, FL 32813-7100

Dr. Marian Stearns
SRI International
333 Ravenswood Ave.
Room B-S124
Menlo Park, CA 94025

Dr. Thomas Sticht
Applied Behavioral and Cognitive
Sciences, Inc.
P.O. Box 6640
San Diego, CA 92106

Dr. David E. Stone
Computer Teaching Corporation
1713 South Neil Street
Urbana, IL 61820

Dr. M. Martin Taylor
DCIEM
Box 2000
Downsview, Ontario
CANADA M3M 3B9

Dr. Douglas Towne
Behavioral Technology Labs
University of Southern California
1845 S. Elena Ave.
Redondo Beach, CA 90277

Dr. Frank L. Vicino
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Jerry Vogt
Navy Personnel R&D Center
Code 51
San Diego, CA 92152-6800

Dr. Thomas A. Warm
Coast Guard Institute
P. O. Substation 18
Oklahoma City, OK 73169

Dr. Beth Warren
BBN Laboratories, Inc.
10 Moulton Street
Cambridge, MA 02238

Dr. Douglas Wetzel
Code 51
Navy Personnel R&D Center
San Diego, CA 92152-6800

Dr. Barbara White
BBN Laboratories
10 Moulton Street
Cambridge, MA 02238

Dr. Robert A. Wisher
U.S. Army Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

Dr. Frank B. Withrow
U.S. Department of Education
Room 504D, Capitol Plaza
555 New Jersey Avenue, N.W.
Washington, DC 20208

Dr. Merlin C. Wittrock
Graduate School of Education
UCLA
Los Angeles, CA 90024

Dr. Wallace Wulfeck, III
Navy Personnel R&D Center
Code 51
San Diego, CA 92152-6800

Frank R. Yekovich
Dept. of Education
Catholic University
Washington, DC 20064

Dr. Joseph L. Young
National Science Foundation
Room 320
1800 G Street, N.W.
Washington, DC 20550

Dr. Uri Zernik
General Electric:
Research & Development Center
Artificial Intelligence Program
P.O. Box 8
Schenectady, NY 12301

Office of Naval Research
Resident Representative
Ohio State University Research Ctr.
1314 Kinnear Rd.
Columbus, OH 43212