A Rand Note

preparing for the

OFFICE OF NAVAL RESEARCH
HEURISTICS FOR KNOWLEDGE ACQUISITION FROM MAPS

Perry W. Thorndyke

A Rand Note
prepared for the
OFFICE OF NAVAL RESEARCH

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED
Heuristics for Knowledge Acquisition from Maps

Perry W. Thorndyke

The Rand Corporation
1700 Main Street
Santa Monica, California 90406

Office of Naval Research (Code 458)
Arlington, Virginia 22217

Approved for Public Release; Distribution Unlimited

No Restrictions

Maps
Learning

The reverse side
Acquiring knowledge from a map depends upon procedures for focusing attention, encoding information, and integrating diverse knowledge. This paper describes the heuristics people use to study and learn maps. Verbal protocols obtained from eight subjects suggested four categories of procedures that were invoked during learning: attention, encoding, evaluation, and control. The use of certain heuristics in each category was highly predictive of learning success. Good learners differed from poor learners in their ability to encode spatial information, to evaluate their learning progress, and to focus their attention in accordance with a learning plan. Many of the successful heuristics appear to be readily trainable.
PREFACE

This paper was prepared for presentation at the Sixth International Joint Conference on Artificial Intelligence, to be held in Tokyo, Japan, in August 1979. The research summarized here was funded by the Office of Naval Research under Contract N00014-78-C-0042. It is reported in more detail in Rand Report R-2375-ONR, Individual Differences in Knowledge Acquisition from Maps.
SUMMARY

Acquiring knowledge from a map depends upon procedures for focusing attention, encoding information, and integrating diverse knowledge. This Note describes the heuristics people use to study and learn maps. Verbal protocols obtained from eight subjects suggested four categories of procedures that were invoked during learning: attention, encoding, evaluation, and control. The use of certain heuristics in each category was highly predictive of learning success. Good learners differed from poor learners in their ability to encode spatial information, to evaluate their learning progress, and to focus their attention in accordance with a learning plan. Many of the successful heuristics appear to be readily trainable.
ACKNOWLEDGMENTS

I gratefully acknowledge the contribution of Cathleen Stasz, whose collaboration on the experimental studies made this Note possible.
## CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREFACE</td>
<td>iii</td>
</tr>
<tr>
<td>SUMMARY</td>
<td>v</td>
</tr>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>vii</td>
</tr>
<tr>
<td>Section</td>
<td></td>
</tr>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. THE KNOWLEDGE ACQUISITION PROCESS</td>
<td>2</td>
</tr>
<tr>
<td>III. ANALYSIS OF LEARNING HEURISTICS</td>
<td>4</td>
</tr>
<tr>
<td>IV. ANALYSIS OF INDIVIDUAL DIFFERENCES</td>
<td>8</td>
</tr>
<tr>
<td>V. CONCLUSIONS</td>
<td>12</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>14</td>
</tr>
</tbody>
</table>
Any image processing system, whether human or machine, must translate the information in the sensory display into a meaningful internal description of the sensory image [1, 3]. This paper investigates how humans acquire knowledge from geographic maps. Artificial intelligence studies of map learning [2] have emphasized the use of cartographic knowledge to guide segmentation and interpretation of map features. The present study, in contrast, focuses on the high-level procedures that people use to select, combine, and encode map information in memory. I shall refer to these procedures as heuristics to emphasize the variety of available techniques and the lack of prescriptive learning methods. The research goal is to develop a theory of expertise in map learning by analyzing differences between good and poor learners in terms of differences in their learning heuristics.
Figure 1 schematizes the knowledge acquisition process. The maps used in this study contain a variety of conceptual "elements" (e.g., buildings, roads, parks). Each element has both spatial extent (shape and location relative to adjacent elements) and a linguistic label. Because map learning is an active, intentional process, it resembles a problem-solving task. The goal state corresponds to a complete memory description of the map (shown at the top of the figure), and the problem-solving operators are the heuristics the learner applies to produce the memory representation. These heuristics regulate the flow of information and determine how it will be encoded in memory.

Attentional heuristics restrict the set of information on the map that the learner focuses on at any point in time, as illustrated in the lower portion of the figure. Encoding heuristics elaborate the information currently in focus and integrate it with other information from the map and knowledge already in memory. For example, one such procedure (P27) might form a semantic association between the names Aspen Road and Forest Road using knowledge about their common property, "trees."

Since the processing capacity (i.e., the upper bound on processing effort, size of working memory, communication channel capacity, etc.) is limited [4], only a subset of the available procedures are concurrently active. Therefore, control heuristics oversee the selection, activation, and scheduling of competing encoding and attentional procedures.
Figure 1. A schematic view of map learning
III. ANALYSIS OF LEARNING HEURISTICS

To identify the heuristics that people actually use, Cathleen Stasz and I [5] collected verbal protocols from eight subjects attempting to learn real maps. On each of six trials, subjects would first study a map for two minutes and then attempt to reconstruct the map from memory. During the study period, subjects thought out loud, describing their attentional focus, their study heuristics, and their evaluations of their learning progress.

Four general types of processes emerged from the protocols: attention, encoding, evaluation, and control. These processes and the heuristics subjects used to implement them are described briefly below.

Attentional processes included those by which subjects restricted eye fixations to a particular subset of the map (focus of attention) and shifted their focus of attention to a new location (attention switching). Two types of attentional heuristics were observed. The first of these, partitioning, was a procedure for focusing attention on a subset of the map information. Since a map contained too much information to be assimilated on any one trial, partitioning the map enabled a learner to attend selectively to a well-defined aspect of the map. Subjects partitioned the map either by (a) spatial region (e.g., by attending only to elements in the north of Market...
Street) or by (b) conceptual category (e.g., by attending only to the streets on the map).

The second type of attentional process comprised sampling heuristics. These procedures determined shifts in a subject's focus of attention among various map elements. **Systematic sampling** involved shifting attention according to a subject-defined algorithm (e.g., studying elements from west to east). **Stochastic sampling** involved shifting the focus of attention to an immediately adjacent element, but in no systematic or consistent direction. In **random sampling**, the focus of attention jumped haphazardly around the map, with the new focus seemingly independent of the previous focus in both location and content. **Memory-directed sampling** occurred when a subject decided to study particular elements that had not yet been learned. For example, at the beginning of a new study trial, a subject might study the location of a river because she or he could not remember it on the previous recall trial.

When information was in a subject's focus of attention, various heuristics could be used to elaborate and encode the information in memory. These heuristics may be divided into those that operated primarily on verbal or linguistic information and those that operated primarily on shapes and location information.

Three verbal learning heuristics were observed. **Counting** helped subjects to cluster several elements sharing a particular property (e.g., "there are two parks on Victory Avenue").
Mnemonics were used to generate easily memorable retrieval cues for a set of names, such as "BUD," the order of the three structures on Market Street (bank, undertakers, and department store). The association heuristic involved the elaboration of the map information by association to or embellishment with some related prior knowledge. For example, one subject noted that Forest and Aspen Roads were both names for "trees."

Similarly, several heuristics for learning spatial information were observed. Visual imagery was a learning technique in which subjects constructed mental images of portions of the map. During study, some subjects closed their eyes and attempted to draw shapes or name elements in a mental image and reported attempts to form a mental picture of some portion of the map. Labeling involved the generation of a verbal label for a complex spatial configuration. For example, a subject might notice that the three streets in the northwest corner of the map resembled the mathematical symbol pi. In pattern encoding, a subject would notice a particular low-level shape or spatial feature of an element, such as Victory Avenue curving to the east. Finally, the relation encoding heuristic refers to the creation of a spatial relation between two or more elements. For example, one subject stated that Victory Avenue is "below the golf course" and is "parallel to Johnson."

The third type of process evident in the protocols was evaluation. Subjects would monitor their learning progress by considering what they had already learned and what they still needed to study. In particular, they would focus on an element
and then determine whether or not they had learned it well enough to recall it later. This evaluation required a search and retrieval of information from memory and a comparison of that information to the representation on the map of the target element. When subjects decided they had not learned the information, they might then decide to study the element using one of the elaboration heuristics.

Finally, control or executive processes presumably directed the overall flow of processing. Since processing capacity is limited, only a subset of the processes can be active simultaneously. The control processes include a mechanism for selecting from a set of available heuristics those to be activated (selection) and a mechanism for deciding when to deactivate a heuristic and switch to a new one (switching). For example, several subjects began to study a map with an unrestricted random-sampling heuristic and then switched to a more selective partitioning heuristic.
IV. ANALYSIS OF INDIVIDUAL DIFFERENCES

For each subject, the accuracy of the maps reproduced after each of the six study trials was computed as the proportion of map elements whose name and location were correctly recalled. Performance ranged widely, from 94% of the map elements correct after only four trials to 39% correct after six trials.

The protocols of the successful learners (three subjects who recalled at least 90% of the elements correctly) were directly contrasted with those of the other five learners. For each subject, the number of occurrences of each heuristic in the subject's six study protocols was computed. While subjects did not vary in how many heuristics they used, they did vary in which heuristics they used. The major differences between good and poor learners' use of heuristics are summarized below for each processing category.

Attention. When good learners used the partitioning heuristic, it was accompanied by either systematic or stochastic sampling. Once they had decided to focus on a defined subset of the map information, they would sample only elements in the partitioned set. In contrast, poor learners either (a) did not use the partitioning strategy, (b) used random sampling to accompany partitioning, or (c) were unable to restrict attention to elements in the partitioned set.

On later trials, when the basic framework of the map had been learned, good learners relied on memory-directed sampling to
determine their focus of attention. That is, good learners knew which details were as yet unlearned and searched for and focused on that particular information. Their heuristic for selecting attentional focus was thus goal-directed. Poor learners, on the other hand, rarely used this sampling heuristic.

**Encoding.** All subjects successfully learned the linguistic information; however, subjects varied in their success at learning the spatial information. Effective learners used frequent and varied spatial-learning heuristics, while poor learners did not. Good learners reported constructing in memory and rehearsing a visual image of the map. They would also refine their knowledge of spatial location by noticing and encoding explicit shapes (pattern encoding) or spatial relations (relation encoding) among two or more map elements. These heuristics were used significantly more often by good learners than by poor learners. Poor learners frequently reported that they could not think of a technique for learning the spatial information in their focus of attention.

**Evaluation.** All learners extensively evaluated their learning progress after each recall trial, but both the accuracy and content of subjects' evaluations differed between good and poor learners. An evaluation resulted in a decision that the subject either did or did not "know" the evaluated information. Good learners evaluated primarily unlearned elements (82% of all evaluation statements), ignoring information they had already learned. Poor learners evaluated a significantly smaller proportion (62%) of unlearned elements, and instead spent some of
their study time confirming that they knew certain information. As noted above, good learners appeared to be goal-directed during studying. They would bring to each new learning trial knowledge of what information they had not yet learned, find that information on the map, and then study it using an appropriate encoding strategy. Poor learners seemed more data-driven: they would first focus on a randomly selected map element and then evaluate the element in memory to decide whether or not it had been learned.

When subjects assessed whether or not they knew an element, they could be either correct or incorrect in the evaluation. (Accuracy was assessed by comparing the subjects' statements about the elements with the accuracy of the reproductions on the previous trial.) Good learners were significantly more accurate in their evaluations (96% correct) than poor learners (82%). That is, good learners were superior at determining their current state of learning and "knowing what they know."

**Control.** When good learners adopted a particular heuristic, they would continue to use it until it had achieved its purpose. For example, when good learners used partitioning, they would sample only information in the partitioned set until all elements had been considered. In contrast, poor learners frequently abandoned this heuristic abruptly and prematurely. This typically occurred when subjects could think of no heuristic for learning the sampled information.
Poor learners also failed to select and use heuristics effectively following evaluations. When a decision had been made that an element had not yet been learned, good learners immediately studied the element. However, poor learners would frequently shift their focus of attention to a new element without studying the unlearned information.
These analyses suggest that the use of powerful heuristics is principally responsible for differences in learning success. We have completed another study that demonstrates directly the utility of using these heuristics [6]. Three groups of subjects, equivalent in map learning ability, were given differential training in the use of learning heuristics. One group learned six of the effective heuristics reported here: three spatial-learning strategies (imagery, relation encoding, pattern encoding), two feedback-monitoring strategies (evaluation, memory-directed sampling), and partitioning. A second group learned six heuristics that were uncorrelated with learning success. The third group received no instruction. Subjects trained to use effective heuristics improved their performance on a new map significantly more than subjects in the other two groups. Further, the magnitude of the improvement was a function of the frequency with which subjects used the trained heuristics.

These studies exemplify a growing body of research in cognitive studies of expertise and individual differences. Psychologists are beginning to view expertise as a collection of well-tuned information processes that combine to produce complex task performance. This analytic approach has, of course, been successfully applied in the construction of knowledge-based AI systems. Based upon the early successes of this approach in
cognitive psychology, it would appear to have a promising future in that area as well.
REFERENCES


SPECIAL COPIES FOR THE NAVY

1  Office of Naval Research
   Code 1021P
   Department of the Navy
   Arlington, Virginia  22217

2  Scientific Officer
   Director, Personnel & Training
   Research Programs, Psychological
   Sciences Division
   Office of Naval Research
   Department of the Navy
   Arlington, Virginia  22217

   FOR Mr. Henry M. Halff

3  Administrative Contracting Officer
   Office of Naval Research
   Arlington, Virginia  22217

   FOR Mr. W. Grant

4  4000-28500
   Chief Scientist
   Office of Naval Research
   Branch Office
   Pasadena, California  91106

   FOR Dr. Eugene E. Gloyo

5  4000-29000
   Naval Research Laboratory
   Attn: Code 2627

6  Office of Naval Research
   Code 200
   Arlington, Virginia  22217

DEPARTMENT OF THE NAVY

7  Dr. Jack Adams
   Office of Naval Research Branch
   221 Old Marylebone Road
   London, NW 15th
   ENGLAND

8  4100-18000
   Naval Postgraduate School
   Attn: Library (Code 1424)

   FOR Dr. Jack R. Borsting
<table>
<thead>
<tr>
<th>Page 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 4100-10500</td>
</tr>
<tr>
<td>FOR Dr. Robert Breaux</td>
</tr>
<tr>
<td>FOR Mr. James S. Duva</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>13</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>FOR Dr. Pat Federico</td>
</tr>
<tr>
<td>FOR Dr. Ed Aiken</td>
</tr>
<tr>
<td>FOR Dr. John Ford</td>
</tr>
<tr>
<td>FOR Dr. James McBride, Code 301</td>
</tr>
<tr>
<td>FOR Dr. James McGrath, Code 306</td>
</tr>
<tr>
<td>FOR Dr. William Montaque</td>
</tr>
<tr>
<td>FOR A. A. Sjoholm, Code 2C1</td>
</tr>
<tr>
<td>FOR Library</td>
</tr>
<tr>
<td>FOR Persis Sturgis</td>
</tr>
<tr>
<td>FOR Robert Richards</td>
</tr>
<tr>
<td>FOR John Wolfe</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>Number</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>18</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>19</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>21</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>22</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>23</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>24</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>No.</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>26</td>
</tr>
<tr>
<td>27</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>28</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>29</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>31</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>32</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
33 4000-34000 Director, R&D Plans Div. (NCP-987)
Office of Research, Development,
Test & Evaluation
Office, Chief of Naval Operations
FOR Mr. Robert Smith

34 Dr. Alfred F. Smode
Training Analysis & Evaluation
Group (TAFG)
Department of the Navy
Orlando, Florida 32813

35 4100-09000 Technical Information Division
(Code 8131)
Naval Air Development Center
Warminster, Pennsylvania 18974
FOR Cdr. Charles J. Theisen, Jr.

36 4000-55000 Naval Ocean Systems Center
Research Library, Code 4473B
FOR W. Gary Thomson

DEPARTMENT OF THE ARMY

37 ARI Field Unit-Leavenworth
P. O. Box 3122
Fort Leavenworth, Kansas 66027

38 Office, ECS/Operations
USAAREUR Director of GPD
HQ USAREUE & 7th Army
APO New York C9403

39 3300-00600 U.S. Army Infantry School Library
Fort Benning, Georgia 31905
FOR Capt. Hinton, ATSH-I-V-IT
46 2305-02500  Research Branch (MFCYPF)  
Hq, AF Manpower & Personnel Center  
Randolph AFB, Texas  78148

47  
Maj. Eric K. Waters  
Chief, Instructional Tech. Branch  
AF Human Resources Laboratory  
Lowry AFB, Colorado  80230

DEPARTMENT OF THE MARINES

48  
Director, Office of Manpower  
Utilization  
Hq Marine Corps (MPU)  
BCB, Ptg. 2009  
Quartico, Virginia  22134

49  
Dr. A. I. Slifkosky  
Scientific Advisor (Code RI-1)  
Hq U.S. Marine Corps  
Washington, D.C.  20380

DEPARTMENT OF THE COAST GUARD

50  
Mr. Joseph J. Cowan, Chief  
Psychological Research (G-E-1/62)  
U.S. Coast Guard Hq  
Washington, D.C.  20590

DEPARTMENT OF DEFENSE

51 1100-05000  Defense Advanced Research Projects  
Agency  
Attn: Fred A. Koether  
FOR Dr. Dexter Fletcher  
FOR Dr. Stephen Andricle

52  
Military Assistant for Human  
Resources  
Office of the Under Secretary of  
Defense for Research & Engineering  
Washington, D.C.  20301

53  
Director, Research & Data  
Office, Asst. Secretary of Defense  
(Human, Reserve Affairs and  
Logistics)  
Washington, D.C.  20301
OTHER GOVERNMENT AGENCIES

54  5800-61000  Central Intelligence Agency
    FOR  Dr. Joseph Markowitz

55  5500-58000  Basic Skills Program
    National Institute of Education
    1200 19th Street, N.W.
    Washington, D. C. 20208
    FOR  Dr. Thomas G. Sticht
    FOR  Dr. Susan Chipman
    FOR  Lawrence Frase

56  5600-59000  Dr. Joseph L. Young, Director
    Memory & Cognitive Processes
    National Science Foundation
    Washington, D. C. 20550

56a 1300-01000  Defense Documentation Center

57  1300-05000  Professor Earl A. Alluisi
    Department of Psychology
    Old Dominion University
    Norfolk, Virginia 23508

58  1500-18000  Dr. John B. Andersen
    Department of Psychology
    Carnegie-Mellon University
    Pittsburgh, Pennsylvania 15213

59  1900-22000  Dr. Michael Atwood
    Science Applications Institute
    40 Denver Tech. Center West
    7935 E. Frentice Avenue
    Englewood, Colorado 80110

60  2300-26000  1 Psychological Research Unit
    Dept. of Defense (Army Office)
    Campbell Park Office
    Canberra, ACT 2600
    AUSTRALIA
<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Department/Institution</th>
<th>Address</th>
<th>Zip Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>61</td>
<td>Dr. Nicholas A. Bond</td>
<td>Dept. of Psychology</td>
<td>Sacramento State College</td>
<td>95819</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>600 Jay Street</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sacramento, California</td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>Dr. Lyle Bourne</td>
<td>Department of Psychology</td>
<td>University of Colorado</td>
<td>80302</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Boulder, Colorado</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>Dr. John Seeley Brown</td>
<td>Bolt Beranek &amp; Newman, Inc.</td>
<td>50 Moulton Street</td>
<td>02138</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cambridge, Massachusetts</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Dr. John P. Carroll</td>
<td>Psychometric Lab</td>
<td>Univ. of North Carolina</td>
<td>27514</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Davie Hall 013A</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chapel Hill, North Carolina</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Dr. William Chase</td>
<td>Department of Psychology</td>
<td>Carnegie-Mellon University</td>
<td>15213</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pittsburgh, Pennsylvania</td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>Dr. Micheline Chi</td>
<td>Learning R&amp;D Center</td>
<td>University of Pittsburgh</td>
<td>15213</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3939 C'Hara Street</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pittsburgh, Pennsylvania</td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>Dr. Allan M. Collins</td>
<td>Bolt Beranek &amp; Newman, Inc.</td>
<td>50 Moulton Street</td>
<td>02138</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cambridge, Massachusetts</td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>Dr. John J. Collins</td>
<td>Essex Corporation</td>
<td>201 N. Fairfax Street</td>
<td>22314</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Alexandria, Virginia</td>
<td></td>
</tr>
<tr>
<td>69</td>
<td>Dr. Meredith Crawford</td>
<td></td>
<td>5605 Montgomery Street</td>
<td>20015</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Chevy Chase, Maryland</td>
<td></td>
</tr>
</tbody>
</table>
Dr. Ruth Lay  
Center for Advanced Study in Behavioral Sciences  
202 Junipero Serra Blvd.  
Stanford, California  
94305

Dr. Hubert Dreyfus  
Department of Psychology  
University of California  
Berkeley, California  
94720

Major I. N. Evonic  
Canadian Forces Pers. Applied Research  
1107 Avenue Road  
Toronto, Ontario  
CANADA

Dr. Ed Feigenbaum  
Dept. of Computer Science  
Stanford University  
Stanford, California  
94305

Dr. Victor Fields  
Dept. of Psychology  
Montgomery College  
Rockville, Maryland  
20850

Dr. Edwin A. Fleishman  
Advanced Research Resources Orgr.  
4330 East West Highway, Suite 900  
Washington, D. C.  
20014

Dr. John R. Frederiksen  
Bolt Beranek & Newman, Inc.  
50 Moulton Street  
Cambridge, Massachusetts  
02138

Dr. Robert Glaser  
LRDC  
University of Pittsburgh  
3939 O'Hara Street  
Pittsburgh, Pennsylvania  
15213

Dr. Ira Goldstein  
Xerox Palo Alto Research Center  
3333 Coyote Road  
Palo Alto, California  
94304
Dr. Donald A. Norman
Dept. of Psychology C-009
University of California
La Jolla, California 92037

Dr. Jesse Orlansky
Institute for Defense Analysis
400 Army-Navy Drive
Arlington, Virginia 22202

Dr. Seymour A. Papert
Massachusetts Inst. of Technology
Artificial Intelligence Lab
545 Tech Square
Cambridge, Massachusetts 02139

Mr. Luigi Petrullo
2411 N. Edgewood Street
Arlington, Virginia 22207

Dr. Peter Polson
Dept. of Psychology
University of Colorado
Boulder, Colorado 80302

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

Dr. Peter B. Read
Social Science Research Council
605 Third Avenue
New York, New York 10016

Dr. Mark D. Reckase
Educational Psychology Dept.
University of Missouri
12 Hill Hall
Columbia, Missouri 65201

Dr. Fred Reif
SESAME
c/o Physics Department
University of California
Berkeley, California 94720
115 Dr. Albert Stevens  
Bolt Beranek & Newman, Inc.  
50 Moulton Street  
Cambridge, Massachusetts 02138

116 Dr. Patrick Suppes  
Institute for Mathematical Studies in the Social Sciences  
Stanford University  
Stanford, California 94305

117 Dr. Kikumi Tatsuoka  
Computer Based Education Research Laboratory  
257 Engineering Research Laboratory  
University of Illinois  
Urbana, Illinois 61801

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

119 Dr. Thoras Wallston  
Psychometric Laboratory  
Davie Hall 013A  
University of North Carolina  
Chapel Hill, North Carolina 27514

120 Dr. Claire E. Weinstein  
Educational Psychology Dept.  
University of Texas  
Austin, Texas 78712

121 Dr. David J. Weiss  
N667 Elliott Hall  
University of Minnesota  
75 E. River Road  
Minneapolis, Minnesota 55455

122 Dr. Susan F. Whitely  
Psychology Department  
University of Kansas  
Lawrence, Kansas 66044
131 Amos Tversky
Psychology Department
Stanford University
Stanford, California 94305

132 Dr. John Jonides
Human Performance Center
University of Michigan
310 Packard Road
Ann Arbor, Michigan 48104

133 William Brewer
Psychology Department
University of Illinois
Champaign, Illinois 61820

134 Geography Department
Pennsylvania State University
University Park, Pennsylvania 16802

PCR Peter Gould
FOR Roger Downs

135 Alex Siegel
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, Pennsylvania 15213

136 PACE DEPOSIT LIBRARIES
137 ADDRESSES
190 TOTAL COPIES