

AD-A084 754

CARNEGIE-MELLON UNIV PITTSBURGH PA DEPT OF PSYCHOLOGY
ACQUISITION OF A MEMORY SKILL.(U)
MAY 80 W G CHASE, K A ERICSSON, S FALLOON

F/6 5/10

N00014-79-C-0215

NL

UNCLASSIFIED

AD
A084 754

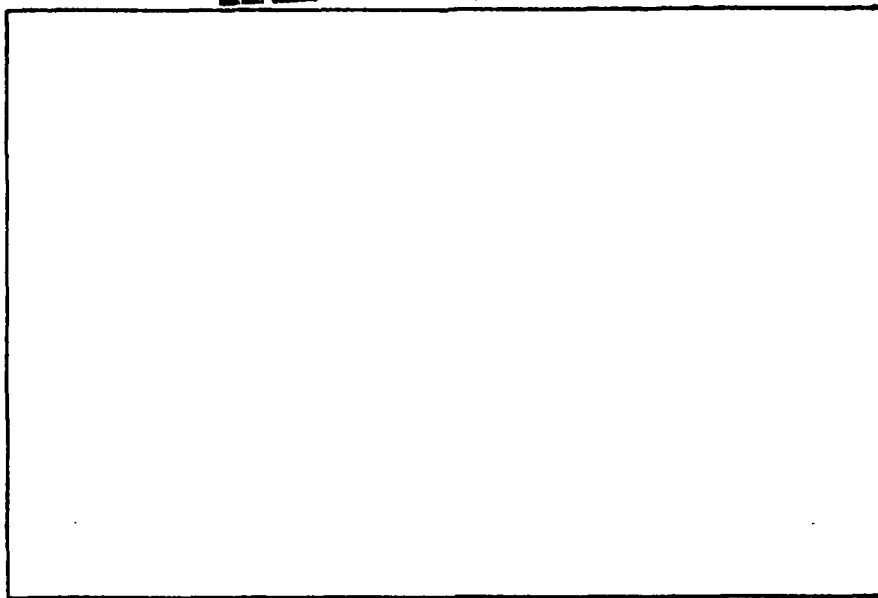


END
DATE
FILMED
6-80
DTIC

LEVEL ~~II~~

①
K

ADA 084754



DEPARTMENT
of
PSYCHOLOGY

DTIC
ELECTE
S MAY 28 1980 D
C

DDC FILE COPY



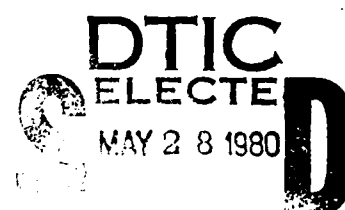
This document has been approved
for public release and sale; its
distribution is unlimited.

Carnegie-Mellon University

80 5-27-161

ACQUISITION OF A MEMORY SKILL

William G. Chase, K. Anders Ericsson
and Steve Faloan
Carnegie-Mellon University



This research is sponsored by the Personnel and Training Research Programs, Psychological Science Division, Office of Naval Research, under Contract No. N00014-79-0215, Contract Authority Identification No., NR157-430.

Reproduction in whole or in part is permitted for any purpose of the United States Government.

Approved for public release; distribution unlimited.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A084754	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED	6. PERFORMING ORG. REPORT NUMBER
(6) Acquisition of a Memory Skill .	(9) Technical rept.	
7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)	
(15) William G. Chase, K. Anders Ericsson and Steven Faloon	(15) N00014-79-C-0215 NR 157-430	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Psychology Carnegie-Mellon University Pittsburgh, PA 15213	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 157-430	
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel and Training Research Programs Office of Naval Research Arlington, VA 22217	11. REPORT DATE May 80	12. NUMBER OF PAGES 9
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) unclassified	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
(12) 23		
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES In press, <u>Science</u>		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Memory span Short-term memory Mnemonics		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) After more than 230 hours of practice in the laboratory a subject was able to increase his memory span from 7 to 79 digits. His performance on other memory tests with digits equaled that of memory experts with life-long training. With an appropriate mnemonic system, there is seemingly no limit to memory performance with practice.		

387876 Am

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

One of the most fundamental and stable properties of the human memory system is the limited capacity of short-term memory. This limit places severe constraints on the human's ability to process information and solve problems (1). On the other hand, this limit (about seven unrelated items) stands in apparent contrast to documented feats of memory experts (2). Whether these memory skills are the result of extensive practice or of exceptional ability has often been disputed. The goal of this research is to analyze how a memory skill is acquired.

An undergraduate (SF) with average memory abilities and average intelligence for a college student engaged in the memory span task for about 1 hour a day, 3 to 5 days a week, for more than $1\frac{1}{2}$ years. S.F. was read random digits at the rate of 1 digit per second; he then recalled the sequence. If the sequence was reported correctly, the next sequence was increased by 1 digit; otherwise it was decreased by 1 digit. Immediately after half the trials (randomly selected), S.F. provided verbal reports of his thoughts during the trial. At the end of each session, he also recalled as much of the material from the session as he could. On some days, experiments were substituted for the regular sessions.

During the course of 20 months of practice (more than 230 hours of laboratory testing), S.F.'s digit span steadily improved from 7 to almost 80 digits (Fig. 1). Furthermore, his ability to remember digits after the session also improved. In the beginning, he could recall virtually nothing after an hour's session; after 20 months of practice, he could recall more than 80 percent of the digits presented to him. On one occasion (after 4 months of practice), we tested S.F.'s memory after the session with a recognition test (because recognition is a much more sensitive measure of retention than recall is); he not only recognized perfectly 3- and 4-digit sequences from the same day, but recognized sequences from earlier in the week.

With only a few hundred hours of practice, S.F. would be classified as a beginner at most skills. However, in his field of expertise, memory for random digits, he compares favorably with the best-known mnemonists, such as Luria's S. and Hunt and Love's V.P. (2). For example, after about 6 months of practice, we set S.F. the task of recalling a matrix of 50 digits because data on this task are available for both S. and V.P. S.F.'s study times and recall times were at least as good as those of the lifetime memory experts.

The key to understanding this skill comes from analyses of S.F.'s verbal reports and his

performance on various experimental tests. We will first describe two essential components of this skill: (i) his mnemonic associations, and (ii) his retrieval structures. Then we will address the question of whether or not S.F. was able to increase his short-term memory capacity.

The most essential part of S.F.'s skill is his mnemonic associations, which he described in great detail in his verbal reports. The principle of a mnemonic is to associate unknown material with something familiar; the advantage is that it relieves the burden on short-term memory because recall can be achieved through a single association with an already-existing code in long-term memory. What S.F. did was to categorize 3- and 4- digit groups as running times for various races (3). For example, 3492 was recoded as "3 minutes and 49 point 2 seconds, near world-record time" (4). During the first 4 months, S.F. gradually constructed an elaborate set of mnemonic associations based initially on running times, and then supplemented with ages (893 was "89 point 3, very old man") and dates (1944 was "near the end of World War II") for those sequences that could be categorized as times. Running times (62 percent) and ages (25 percent) account for almost 90 percent of S.F.'s mnemonic associations.

There are several lines of evidence concerning the mnemonic associations. On the basis of S.F.'s verbal reports, we were able to simulate his mnemonic associations, that is, to abstract a set of rules that categorizes a sequence of digits as 3- and 4-digit running times. When we compared the simulation to the verbal reports, between 85 to 95 percent of the time the computer categorized the digit sequences as S.F. did. By means of the simulation, we were also able to determine which sequences of digits would be categorized as running times and which would not. On the basis of this analysis, we presented S.F. with sequences that could not be associated with running time categories. (This was before S.F. started to use ages to supplement his running times, after about 2 months of practice.) When S.F. was faced with these uncodable sequences, his performance dropped almost to his beginning level. In another experimental session we did the opposite: we presented him with sequences that could all be coded in terms of running times. His performance jumped by 22 percent (from an average of 16 to an average of 19.5 digits).

The mechanism whereby S.F. recodes single digits into 3- and 4-digit units is not sufficient to account for his performance. If S.F. originally had a digit span of 7 digits, and he then learned to recode digits into 4-digit groups, how could he remember the order of more than seven groups of

digits, that is, more than 28 digits? The answer to this question comes from an analysis of his retrieval structures.

Like most people, S.F. initially tried to hold everything in a rehearsal buffer, which stored material in a phonetic code. When he first used his mnemonic associations (session 5), he demonstrated the first rudimentary use of a retrieval structure. He recoded the first 6 digits as two running times, if possible, and he held the last 4 to 6 digits in his rehearsal buffer. He then tried to recall the two running times in order while rehearsing the last few digits. This strategy worked well, and he gradually perfected it over the course of the first 30 sessions until he could recall as many as 18 digits by recoding three groups of 4 digits each as running times and holding the last 6 digits in his rehearsal buffer. At this point, he began to experience real difficulty in keeping the order straight for more than three or four running times (Fig. 1, blocks 8 and 9).

The next important advance came when S.F. introduced organization into his retrieval structure by segmenting his groups into supergroups: he used two 4-digit groups followed by two 3-digit groups and the rehearsal group. From this point, S.F. improved his performance rapidly by increasing the number of groups within each supergroup, until he began to experience the same difficulty as before. The second plateau in his performance curve (around block 21 in Fig. 1) is associated with difficulty in remembering the order of more than four groups within a supergroup. Introducing another level of organization by subdividing these supergroups allowed S.F.'s performance to improve rapidly so that he now averages almost 80 digits. His current retrieval organization can be described as a hierarchy with three levels, and his retrieval structure for 80 digits can be illustrated in the following way, with spaces corresponding to levels in the hierarchy:

444 444 333 333 444 333 444 5

Besides the verbal descriptions, there is a great deal of additional evidence that S.F. uses hierarchical retrieval structures. Probably the most straightforward evidence comes from his speech patterns during recall, which almost invariably follow the same pattern. Digit groups are recalled rapidly at a normal rate of speech (about 3 digits per second) with pauses between groups (about 2 seconds between groups, on average, with longer pauses when he has difficulty remembering). At the end of a supergroup, however, there is a falling intonation, generally followed by a longer pause (5).

In several experiments, we verified that groups are retrieved through the hierarchical structure rather than through direct associations between groups. In one experiment, instead of asking for recall after presenting the digits, we presented S.F. with a 3- or 4-digit group and asked him to name the group that preceded it or followed it in the sequence. He required more than twice as long, on the average, if the preceding or following group crossed a supergroup boundary (10.0 seconds) than if it did not (4.4 seconds). In another experiment, after an hour's session, we presented S.F. with 3- and 4-digit groups from that session and asked him to recall as much as he could about each group. He invariably recalled the mnemonic associations he had generated, and he often recalled a great deal about the location of the group within the hierarchy, but he was virtually never able to recall the preceding or following group.

After all this practice, can we conclude that S.F. increased his short-term memory capacity? There are several reasons to think not. (i) The size of S.F.'s groups were almost always 3 and 4 digits, and he never generated a mnemonic association for more than 5 digits (6). (ii) He almost never allowed his rehearsal group to exceed 6 digits. (iii) He generally used three groups in his supergroups, and, after some initial difficulty with five groups, never allowed more than four groups in a supergroup. (iv) In one experimental session, S.F. was switched from digits to letters of the alphabet after 3 months of practice and exhibited no transfer: His memory span dropped back to about six consonants.

These data suggest that the reliable working capacity of short-term memory is about three or four units, as Broadbent has recently argued (7), and that it is not possible to increase the capacity of short-term memory with extended practice. Rather, increases in memory span are due to the use of mnemonic associations in long-term memory. With an appropriate mnemonic system and retrieval structure, there is seemingly no limit to improvement in memory skill with practice.

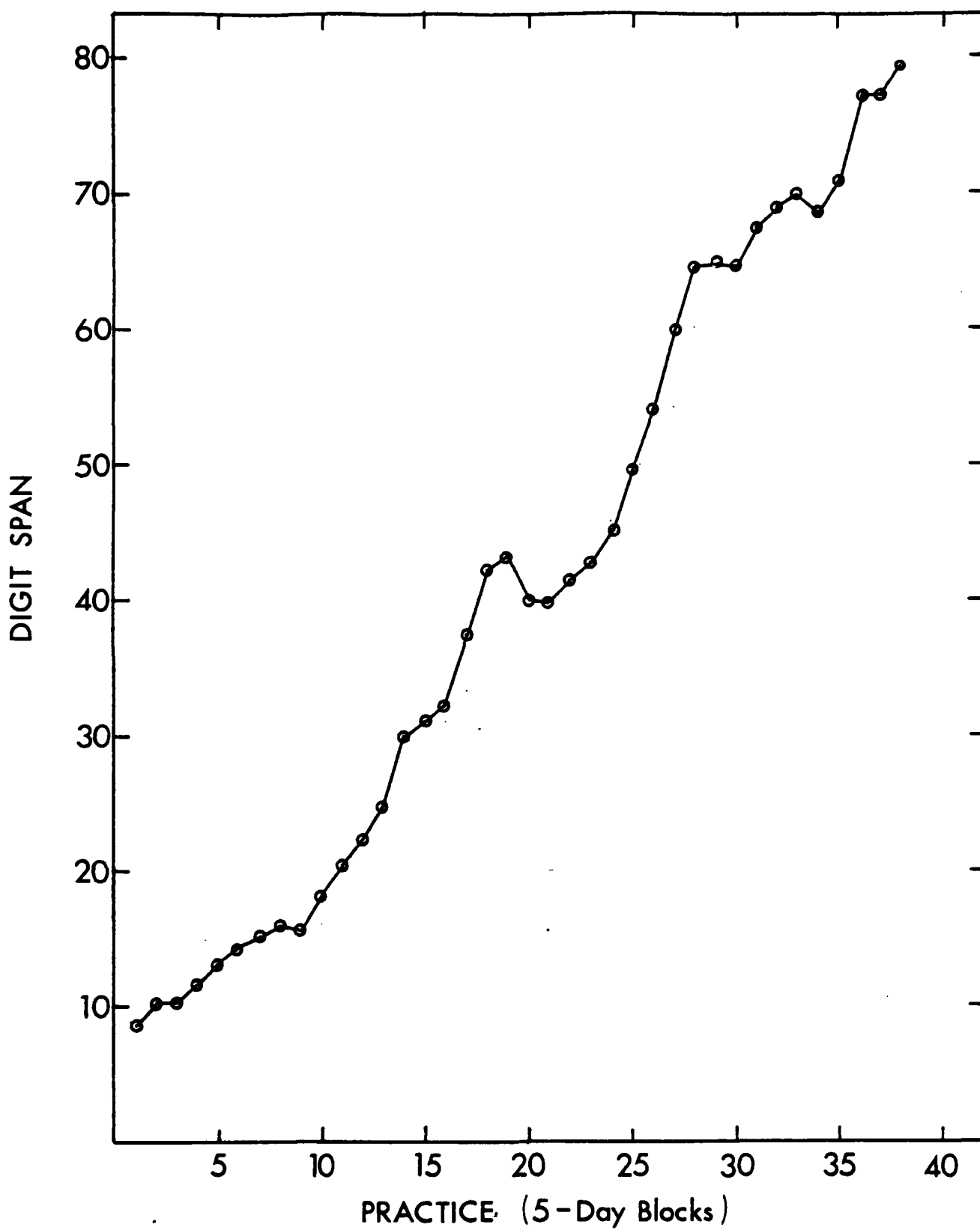
References and Notes

1. G.A. Miller, Psychol. Rev., 63, 81 (1956); A. Newell and H.A. Simon, Human Problem Solving (Prentice-Hall, Englewood Cliffs, N.J., 1972).
2. A.R. Luria has documented the case history of one exceptional person, S., who seemed to remember large amounts of trivial information for years by means of visual imagery [The Mind of a Mnemonist, (Avon, New York, 1968)], and E. Hunt and T. Love have described another exceptional person, V.P. who could remember large amounts of material by means of elaborate linguistic associations in several languages [in A.W. Mellon and E. Martin, Eds., Coding Processes in Human Memory (Winston, Washington D.C., 1972), p. 237].
3. S.F. is a good long-distance runner who competes in races throughout the eastern United States. He classifies running times into at least 11 major categories, from half-mile to marathon, with several subcategories within each.
4. The category label by itself was not sufficient to retrieve the exact digits presented. A complete understanding of the precision of mnemonic associations will require an answer to the more general question of how meaningful associations work.
5. Pauses, intonation, and stress patterns are well-known indicators of linguistic structures [M.A.K. Halliday, Intonation and Grammar in British English (Mouton, The Hague, 1967); K. Pike, The Intonation of American English (Univ. of Michigan Press, Ann Arbor, 1945)]. In one memory span study, we compared the grouping patterns indicated by the prosodic features in recall with the grouping patterns reported by S.F. in his verbal protocols, and agreement was virtually perfect.
6. The mnemonic associations of lighting calculators appear to be limited to 3 or 4 digits [G.E. Müller, A. Psychol. Ergänzungsband, 5, (1911)].
7. D.A. Broadbent, in Studies in Long Term Memory, A. Kennedy and A. Wilkes, Eds., (Wiley, New York, 1975), p. 3].
8. Supported by contract N00014-78-C-0215 from the Advanced Research Projects Agency and By Grant MH-07722 from the National Institute of Mental Health. We thank J.R. Anderson, M.T.H. Chi, W. Jones, M. W. Schustack, and H.A. Simon for their valuable comments.

Accession For	
NTIS GRA&I	☒
DOC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist.	Avail and/or special
A	

Figure 1.

Average digit span for S.F. as a function of practice. Digit span is defined as the length of the sequence that is correct 50 percent of the time; under the procedure followed, it is equivalent to average sequence length. Each day represents about 1 hour's practice and ranges from 55 trials per day in the beginning to 3 trials per day for the longest sequences. The 38 blocks of practice shown here represent about 190 hours of practice; interspersed among these practice sessions are approximately 40 hours of experimental sessions (not shown).



Navy

- 1 Dr. Ed Aiken
Navy Personnel R&D Center
San Diego, CA 92152
- 1 Dr. Robert Blanchard
Navy Personnel R&D Center
Managment Support Department
San Diego, CA 92151
- 1 Chief of Naval Education and Training
Liason Office
Air Force Human Resource Laboratory
Flying Training Division
WILLIAMS AFB, AZ 85224
- 1 DR. PAT FEDERICO
NAVY PERSONNEL R&D CENTER
SAN DIEGO, CA 92152
- 1 Dr. John Ford
Navy Personnel R&D Center
San Diego, CA 92152
- 1 LT Steven D. Harris, MSC, USN
Code 6021
Naval Air Development Center
Warminster, Pennsylvania 18974
- 1 Dr. Patrick R. Harrison
Psychology Course Director
LEADERSHIP & LAW DEPT. (7b)
DIV. OF PROFESSIONAL DEVELOPMMENT
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402
- 1 LCDR Wade Helm
Psychology Department
University of South Dakota
Vermillion, SD 57069
- 1 CDR Robert S. Kennedy
Head, Human Performance Sciences
Naval Aerospace Medical Research Lab
Box 29407
New Orleans, LA 70189

Navy

- 1 Dr. Norman J. Kerr
Chief of Naval Technical Training
Naval Air Station Memphis (75)
Millington, TN 38054
- 1 Dr. William L. Maloy
Principal Civilian Advisor for
Education and Training
Naval Training Command, Code 00A
Pensacola, FL 32508
- 1 Dr. Kneale Marshall
Scientific Advisor to DCNO(MPT)
OP01T
Washington DC 20370
- 1 CAPT Richard L. Martin, USN
Prospective Commanding Officer
USS Carl Vinson (CVN-70)
Newport News Shipbuilding and Drydock Co
Newport News, VA 23607
- 1 Dr. James McBride
Navy Personnel R&D Center
San Diego, CA 92152
- 1 Dr. George Moeller
Head, Human Factors Dept.
Naval Submarine Medical Research Lab
Groton, CN 06340
- 1 Dr William Montague
Navy Personnel R&D Center
San Diego, CA 92152
- 1 Commanding Officer
U.S. Naval Amphibious School
Coronado, CA 92155
- 1 Library
Naval Health Research Center
P. O. Box 85122
San Diego, CA 92138
- 1 Naval Medical R&D Command
Code 44
National Naval Medical Center
Bethesda, MD 20014

Navy

- 1 Ted M. I. Yellen
Technical Information Office, Code 201
NAVY PERSONNEL R&D CENTER
SAN DIEGO, CA 92152
- 1 Library, Code P201L
Navy Personnel R&D Center
San Diego, CA 92152
- 5 Technical Director
Navy Personnel R&D Center
San Diego, CA 92152
- 1 Director, Navy Personnel R&D Center
Washington Liason Office
Building 200, 2N
Washington Navy Yard, DC 20374
- 6 Commanding Officer
Naval Research Laboratory
Code 2627
Washington, DC 20390
- 1 Psychologist
ONR Branch Office
Bldg 114, Section D
666 Summer Street
Boston, MA 02210
- 1 Psychologist
ONR Branch Office
536 S. Clark Street
Chicago, IL 60605
- 1 Office of Naval Research
Code 437
800 N. Quincy Street
Arlington, VA 22217
- 1 Office of Naval Research
Code 441
800 N. Quincy Street
Arlington, VA 22217
- 5 Personnel & Training Research Programs
(Code 458)
Office of Naval Research
Arlington, VA 22217

Navy

- 1 Psychologist
ONR Branch Office
1030 East Green Street
Pasadena, CA 91101
- 1 Office of the Chief of Naval Operations
Research, Development, and Studies Branch
(OP-102)
Washington, DC 20350
- 1 Captain Donald F. Parker, USN
Commanding Officer
Navy Personnel R&D Center
San Diego, CA 92152
- 1 LT Frank C. Petho, MSC, USN (Ph.D)
Code L51
Naval Aerospace Medical Research Laboratory
Pensacola, FL 32508
- 1 DR. RICHARD A. POLLAK
ACADEMIC COMPUTING CENTER
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402
- 1 Dr. Gary Poock
Operations Research Department
Code 55PK
Naval Postgraduate School
Monterey, CA 93940
- 1 Roger W. Remington, Ph.D
Code L52
NAMRL
Pensacola, FL 32508
- 1 Dr. Bernard Rimland (03B)
Navy Personnel R&D Center
San Diego, CA 92152
- 1 Mr. Arnold Rubenstein
Naval Personnel Support Technology
Naval Material Command (08T244)
Room 1044, Crystal Plaza #5
2221 Jefferson Davis Highway
Arlington, VA 20360

Navy

- 1 Dr. Worth Scanland
Chief of Naval Education and Training
Code N-5
NAS, Pensacola, FL 32508
- 1 Dr. Sam Schiflett, SY 721
Systems Engineering Test Directorate
U.S. Naval Air Test Center
Patuxent River, MD 20670
- 1 Dr. Robert G. Smith
Office of Chief of Naval Operations
OP-987H
Washington, DC 20350
- 1 Dr. Alfred F. Smode
Training Analysis & Evaluation Group
(TAEG)
Dept. of the Navy
Orlando, FL 32813
- 1 Dr. Richard Sorensen
Navy Personnel R&D Center
San Diego, CA 92152
- 1 W. Gary Thomson
Naval Ocean Systems Center
Code 7132
San Diego, CA 92152
- 1 Dr. Robert Wisher
Code 309
Navy Personnel R&D Center
San Diego, CA 92152

Army

- 1 Technical Director
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333
- 1 HQ USAREUE & 7th Army
ODCSOPS
USAREUE Director of GED
APO New York 09403
- 1 Col Gary W. Bloedorn
US Army TRADOC Systems Analysis Activity
Attn: ATAA-TH
WSMR, NM 88002
- 1 DR. RALPH DUSEK
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
- 1 Dr. Beatrice J. Farr
Army Research Institute (PERI-OK)
5001 Eisenhower Avenue
Alexandria, VA 22333
- 1 Col Frank Hart
Army Research Institute for the
Behavioral & Social Sciences
5001 Eisenhower Blvd.
Alexandria, VA 22333
- 1 Dr. Ed Johnson
Army Research Institute
5001 Eisenhower Blvd.
Alexandria, VA 22333
- 1 Dr. Michael Kaplan
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
- 1 Dr. Milton S. Katz
Training Technical Area
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Army

- 1 Director
U.S. Army Human Engineering Labs
Attn: DRXHE-DB
Aberdeen Proving Ground, MD 21005
- 1 Dr. Harold F. O'Neil, Jr.
Attn: PERI-OK
Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333
- 1 LTC Michael Plummer
Chief, Leadership & Organizational
Effectiveness Division
Office of the Deputy Chief of Staff
for Personnel
Dept. of the Army
Pentagon, Washington DC 20301
- 1 Dr. Robert Sasnor
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333
- 1 Commandant
US Army Institute of Administration
Attn: Dr. Sherrill
FT Benjamin Harrison, IN 46256
- 1 Dr. Frederick Steinheiser
U. S. Army Reserch Institute
5001 Eisenhower Avenue
Alexandria, VA 22333
- 1 Dr. Joseph Ward
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Air Force

- 1 Air Force Human Resources Lab
AFHRL/MPD
Brooks AFB, TX 78235
- 1 Air University Library
AUL/LSE 76/443
Maxwell AFB, AL 36112
- 1 Dr. Earl A. Alluisi
HQ, AFHRL (AFSC)
Brooks AFB, TX 78235
- 1 DR. T. E. COTTERMAN
AFHRL/ASR
WRIGHT PATTERSON AFB
OHIO 45433
- 1 Dr. Genevieve Haddad
Program Manager
Life Sciences Directorate
AFOSR
Bolling AFB, DC 20332
- 1 Dr. Ronald G. Hughes
AFHRL/OTR
Williams AFB, AZ 85224
- 1 Dr. Ross L. Morgan (AFHRL/LR)
Wright -Patterson AFB
Ohio 45433
- 1 Research and Measurment Division
Research Branch, AFMPC/MPCYPR
Randolph AFB, TX 78148
- 1 Dr. Marty Rockway (AFHRL/TT)
Lowry AFB
Colorado 80230
- 1 Dr. Frank Schufletowski
U.S. Air Force
ATC/XPTD
Randolph AFB, TX 78148
- 1 Jack A. Thorpe, Maj., USAF
Naval War College
Providence, RI 02846

Air Force

- 1 Brian K. Waters, Lt Col, USAF
Air War College (EDV)
Maxwell AFB, AL 36112

Marines

- 1 H. William Greenup
Education Advisor (E031)
Education Center, MCDEC
Quantico, VA 22134
- 1 Special Assistant for Marine
Corps Matters
Code 100M
Office of Naval Research
800 N. Quincy St.
Arlington, VA 22217
- 1 DR. A.L. SLAFKOSKY
SCIENTIFIC ADVISOR (CODE RD-1)
HQ, U.S. MARINE CORPS
WASHINGTON, DC 20380

Other DoD

- 12 Defense Documentation Center
Cameron Station, Bldg. 5
Alexandria, VA 22314
Attn: TC
- 1 Dr. Craig I. Fields
Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, VA 22209
- 1 Dr. Dexter Fletcher
ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BLVD.
ARLINGTON, VA 22209
- 1 Military Assistant for Training and
Personnel Technology
Office of the Under Secretary of Defense
for Research & Engineering
Room 3D129, The Pentagon
Washington, DC 20301

Civil Govt

- 1 Dr. Susan Chipman
Learning and Development
National Institute of Education
1200 19th Street NW
Washington, DC 20208
- 1 Mr. James M. Ferstl
Bureau of Training
U.S. Civil Service Commission
Washington, D.C. 20415
- 1 Dr. Joseph I. Lipson
SEDR W-638
National Science Foundation
Washington, DC 20550
- 1 Dr. John Mays
National Institute of Education
1200 19th Street NW
Washington, DC 20208
- 1 William J. McLaurin
Rm. 301, Internal Revenue Service
2221 Jefferson Davis Highway
Arlington, VA 22202
- 1 Dr. Arthur Melmed
National Institute of Education
1200 19th Street NW
Washington, DC 20208
- 1 Dr. Andrew R. Molnar
Science Education Dev.
and Research
National Science Foundation
Washington, DC 20550
- 1 Personnel R&D Center
Office of Personnel Management
1900 E Street NW
Washington, DC 20415
- 1 Dr. H. Wallace Sinaiko
Program Director
Manpower Research and Advisory Services
Smithsonian Institution
801 North Pitt Street
Alexandria, VA 22314

Civil Govt

- 1 Dr. Frank Withrow
U. S. Office of Education
400 Maryland Ave. SW
Washington, DC 20202
- 1 Dr. Joseph L. Young, Director
Memory & Cognitive Processes
National Science Foundation
Washington, DC 20550

Non Govt

- 1 Dr. John R. Anderson
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213
- 1 Anderson, Thomas H., Ph.D.
Center for the Study of Reading
174 Children's Research Center
51 Gerty Drive
Champaign, IL 61820
- 1 Dr. John Annett
Department of Psychology
University of Warwick
Coventry CV4 7AL
ENGLAND
- 1 DR. MICHAEL ATWOOD
SCIENCE APPLICATIONS INSTITUTE
40 DENVER TECH. CENTER WEST
7935 E. PRENTICE AVENUE
ENGLEWOOD, CO 80110
- 1 1 psychological research unit
Dept. of Defense (Army Office)
Campbell Park Offices
Canberra ACT 2600, Australia
- 1 Dr. R. A. Avner
University of Illinois
Computer-Based Educational Research Lab
Urbana, IL 61801
- 1 Dr. Alan Baddeley
Medical Research Council
Applied Psychology Unit
15 Chaucer Road
Cambridge CB2 2EF
ENGLAND
- 1 Dr. Patricia Baggett
Department of Psychology
University of Denver
University Park
Denver, CO 80208

Non Govt

- 1 Ms. Carole A. Bagley
Minnesota Educational Computing
Consortium
2354 Hidden Valley Lane
Stillwater, MN 55082
- 1 Mr Avron Barr
Department of Computer Science
Stanford University
Stanford, CA 94305
- 1 Dr. Jackson Beatty
Department of Psychology
University of California
Los Angeles, CA 90024
- 1 Dr. John Bergan
School of Education
University of Arizona
Tuscon AZ 85721
- 1 Dr. Nicholas A. Bond
Dept. of Psychology
Sacramento State College
600 Jay Street
Sacramento, CA 95819
- 1 Dr. Lyle Bourne
Department of Psychology
University of Colorado
Boulder, CO 80309
- 1 Dr. Kenneth Bowles
Institute for Information Sciences
University of California at San Diego
La Jolla, CA 92037
- 1 Dr. John S. Brown
XEROX Palo Alto Research Center
3333 Coyote Road
Palo Alto, CA 94304
- 1 Dr. Bruce Buchanan
Department of Computer Science
Stanford University
Stanford, CA 94305

Non Govt

- 1 DR. C. VICTOR BUNDERSON
WICAT INC.
UNIVERSITY PLAZA, SUITE 10
1160 SO. STATE ST.
OREM, UT 84057
- 1 Dr. Anthony Cancelli
School of Education
University of Arizona
Tuscon, AZ 85721
- 1 Dr. John E. Carroll
Psychometric Lab
Univ. of No. Carolina
Davie Hall 013A
Chapel Hill, NC 27514
- 1 Charles Myers Library
Livingstone House
Livingstone Road
Stratford
London E15 2LJ
ENGLAND
- 1 Dr. William Chase
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213
- 1 Dr. Micheline Chi
Learning R & D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15213
- 1 Dr. William Clancey
Department of Computer Science
Stanford University
Stanford, CA 94305
- 1 Dr. Allan M. Collins
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, Ma 02138

Non Govt

- 1 Dr. Lynn A. Cooper
Department of psychology
Uris Hall
Cornell University
Ithaca, NY 14850
- 1 Dr. Meredith P. Crawford
American Psychological Association
1200 17th Street, N.W.
Washington, DC 20036
- 1 Dr. Kenneth B. Cross
Anacapa Sciences, Inc.
P.O. Drawer Q
Santa Barbara, CA 93102
- 1 Dr. Emmanuel Donchin
Department of Psychology
University of Illinois
Champaign, IL 61820
- 1 LCOL J. C. Eggenberger
DIRECTORATE OF PERSONNEL APPLIED RESEARC
NATIONAL DEFENCE HQ
101 COLONEL BY DRIVE
OTTAWA, CANADA K1A OK2
- 1 ERIC Facility-Acquisitions
4833 Rugby Avenue
Bethesda, MD 20014
- 1 Dr. A. J. Eschenbrenner
Dept. E422, Bldg. 81
McDonnell Douglas Astronautics Co.
P.O.Box 516
St. Louis, MO 63166
- 1 Mr. Wallace Feurzeig
Bolt Beranek & Newman, Inc.
50 Moulton St.
Cambridge, MA 02138
- 1 Dr. Victor Fields
Dept. of Psychology
Montgomery College
Rockville, MD 20850

Non Govt

- 1 Dr. Edwin A. Fleishman
Advanced Research Resources Organ.
Suite 900
4330 East West Highway
Washington, DC 20014
- 1 DR. JOHN D. FOLLEY JR.
APPLIED SCIENCES ASSOCIATES INC
VALENCIA, PA 16059
- 1 Dr. John R. Frederiksen
Bolt Beranek & Newman
50 Moulton Street
Cambridge, MA 02138
- 1 Dr. Alinda Friedman
Department of Psychology
University of Alberta
Edmonton, Alberta
CANADA T6G 2E9
- 1 Dr. R. Edward Geiselman
Department of Psychology
University of California
Los Angeles, CA 90024
- 1 DR. ROBERT GLASER
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213
- 1 Dr. Marvin D. Glock
217 Stone Hall
Cornell University
Ithaca, NY 14853
- 1 Dr. Daniel Gopher
Industrial & Management Engineering
Technion-Israel Institute of Technology
Haifa
ISRAEL
- 1 DR. JAMES G. GREENO
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213

Non Govt

- 1 Dr. Harold Hawkins
Department of Psychology
University of Oregon
Eugene OR 97403
- 1 Dr. Barbara Hayes-Roth
The Rand Corporation
1700 Main Street
Santa Monica, CA 90406
- 1 Dr. Frederick Hayes-Roth
The Rand Corporation
1700 Main Street
Santa Monica, CA 90406
- 1 Dr. Dustin H. Heuston
Wicat, Inc.
Box 986
Orem, UT 84057
- 1 Dr. James R. Hoffman
Department of Psychology
University of Delaware
Newark, DE 19711
- 1 Dr. Lloyd Humphreys
Department of Psychology
University of Illinois
Champaign, IL 61820
- 1 Library
HumRRO/Western Division
27857 Berwick Drive
Carmel, CA 93921
- 1 Dr. Earl Hunt
Dept. of Psychology
University of Washington
Seattle, WA 98105
- 1 DR. KAY INABA
21116 VANOWEN ST
CANOGA PARK, CA 91303
- 1 Dr. Wilson A. Judd
McDonnell-Douglas
Astronautics Co.-St. Louis
P.O. Box 30204
Lowry AFB, CO 80230

Non Govt

- 1 Dr. Steven W. Keele
Dept. of Psychology
University of Oregon
Eugene, OR 97403
- 1 Dr. Walter Kintsch
Department of Psychology
University of Colorado
Boulder, CO 80302
- 1 Dr. David Kieras
Department of Psychology
University of Arizona
Tuscon, AZ 85721
- 1 Dr. Mazie Knerr
Litton-Mellonics
Box 1286
Springfield, VA 22151
- 1 Dr. Stephen Kosslyn
Harvard University
Department of Psychology
33 Kirkland Street
Cambridge, MA 02138
- 1 Dr. Jill Larkin
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213
- 1 Dr. Alan Lesgold
Learning R&D Center
University of Pittsburgh
Pittsburgh, PA 15260
- 1 Dr. Michael Levine
210 Education Building
University of Illinois
Champaign, IL 61820
- 1 Dr. Charles Lewis
Faculteit Sociale Wetenschappen
Rijksuniversiteit Groningen
Oude Boteringestraat
Groningen
NETHERLANDS

Non Govt

- 1 Dr. Robert Linn
College of Education
University of Illinois
Urbana, IL 61801
- 1 Dr. Frederick M. Lord
Educational Testing Service
Princeton, NJ 08540
- 1 Dr. Robert R. Mackie
Human Factors Research, Inc.
5775 Dawson Avenue
Goleta, CA 93017
- 1 Dr. Mark Miller
Computer Science Laboratory
Texas Instruments, Inc.
Mail Station 371, P.O. Box 225936
Dallas, TX 75265
- 1 Dr. Allen Munro
Behavioral Technology Laboratories
1845 Elena Ave., Fourth Floor
Redondo Beach, CA 90277
- 1 Dr. Donald A Norman
Dept. of Psychology C-009
Univ. of California, San Diego
La Jolla, CA 92093
- 1 Dr. Seymour A. Papert
Massachusetts Institute of Technology
Artificial Intelligence Lab
545 Technology Square
Cambridge, MA 02139
- 1 Dr. James A. Paulson
Portland State University
P.O. Box 751
Portland, OR 97207
- 1 Mr. A. J. Pesch, President
Eclectech Associates, Inc.
P. O. Box 178
N. Stonington, CT 06359
- 1 MR. LUIGI PETRULLO
2431 N. EDGEWOOD STREET
ARLINGTON, VA 22207

Non Govt

- 1 Dr. Martha Polson
Department of Psychology
University of Colorado
Boulder, CO 80302
- 1 DR. PETER POLSON
DEPT. OF PSYCHOLOGY
UNIVERSITY OF COLORADO
BOULDER, CO 80309
- 1 DR. DIANE M. RAMSEY-KLEE
R-K RESEARCH & SYSTEM DESIGN
3947 RIDGEMONT DRIVE
MALIBU, CA 90265
- 1 Dr. Mark D. Reckase
Educational Psychology Dept.
University of Missouri-Columbia
4 Hill Hall
Columbia, MO 65211
- 1 Dr. Fred Reif
SESAME
c/o Physics Department
University of California
Berkely, CA 94720
- 1 Dr. Andrew M. Rose
American Institutes for Research
1055 Thomas Jefferson St. NW
Washington, DC 20007
- 1 Dr. Ernst Z. Rothkopf
Bell Laboratories
600 Mountain Avenue
Murray Hill, NJ 07974
- 1 Dr. David Rumelhart
Center for Human Information Processing
Univ. of California, San Diego
La Jolla, CA 92093
- 1 PROF. FUMIKO SAMEJIMA
DEPT. OF PSYCHOLOGY
UNIVERSITY OF TENNESSEE
KNOXVILLE, TN 37916

Non Govt

- 1 DR. WALTER SCHNEIDER
DEPT. OF PSYCHOLOGY
UNIVERSITY OF ILLINOIS
CHAMPAIGN, IL 61820
- 1 Dr. Alan Schoenfeld
Department of Mathematics
Hamilton College
Clinton, NY 13323
- 1 DR. ROBERT J. SEIDEL
INSTRUCTIONAL TECHNOLOGY GROUP
HUMRRO
300 N. WASHINGTON ST.
ALEXANDRIA, VA 22314
- 1 Committee on Cognitive Research
% Dr. Lonnie R. Sherrod
Social Science Research Council
605 Third Avenue
New York, NY 10016
- 1 Robert S. Siegler
Associate Professor
Carnegie-Mellon University
Department of Psychology
Schenley Park
Pittsburgh, PA 15213
- 1 Dr. Robert Smith
Department of Computer Science
Rutgers University
New Brunswick, NJ 08903
- 1 Dr. Richard Snow
School of Education
Stanford University
Stanford, CA 94305
- 1 Dr. Kathryn T. Spoehr
Department of Psychology
Brown University
Providence, RI 02912
- 1 Dr. Robert Sternberg
Dept. of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520

Non Govt

- 1 DR. ALBERT STEVENS
BOLT BERANEK & NEWMAN, INC.
50 MOULTON STREET
CAMBRIDGE, MA 02138
- 1 Mr. William Stobie
McDonnell-Douglas
Astronautics Co.
P. O. Box 30204
Chico, CA 95926
- 1 Dr. David Stone
ED 236
SUNY, Albany
Albany, NY 12222
- 1 DR. PATRICK SUPPES
INSTITUTE FOR MATHEMATICAL STUDIES IN
THE SOCIAL SCIENCES
STANFORD UNIVERSITY
STANFORD, CA 94305
- 1 Dr. Kikumi Tatsuoka
Computer Based Education Research
Laboratory
252 Engineering Research Laboratory
University of Illinois
Urbana, IL 61801
- 1 Dr. David Thissen
Department of Psychology
University of Kansas
Lawrence, KS 66044
- 1 Dr. John Thomas
IBM Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598
- 1 DR. PERRY THORNDYKE
THE RAND CORPORATION
1700 MAIN STREET
SANTA MONICA, CA 90406
- 1 Dr. Walt W. Tornow
Control Data Corporation
Corporate Personnel Research
P.O. Box 0 - HQN060
Minneapolis, MN 55440

Non Govt

- 1 Dr. Douglas Towne
Univ. of So. California
Behavioral Technology Labs
1845 S. Elena Ave.
Redondo Beach, CA 90277
- 1 Dr. J. Uhlaner
Perceptronics, Inc.
6271 Variel Avenue
Woodland Hills, CA 91364
- 1 Dr. Benton J. Underwood
Dept. of Psychology
Northwestern University
Evanston, IL 60201
- 1 DR. THOMAS WALLSTEN
PSYCHOMETRIC LABORATORY
DAVIE HALL 013A
UNIVERSITY OF NORTH CAROL
CHAPEL HILL, NC 27514
- 1 Dr. Phyllis Weaver
Graduate School of Education
Harvard University
200 Larsen Hall, Appian Way
Cambridge, MA 02138
- 1 Dr. David J. Weiss
N660 Elliott Hall
University of Minnesota
75 E. River Road
Minneapolis, MN 55455
- 1 DR. GERSHON WELTMAN
PERCEPTRONICS INC.
6271 VARIEL AVE.
WOODLAND HILLS, CA 91367
- 1 Dr. Keith T. Wescourt
Information Sciences Dept.
The Rand Corporation
1700 Main St.
Santa Monica, CA 90406
- 1 DR. SUSAN E. WHITELY
PSYCHOLOGY DEPARTMENT
UNIVERSITY OF KANSAS
LAWRENCE, KANSAS 66044

Non Govt

- 1 Dr. Christopher Wickens
Department of Psychology
University of Illinois
Champaign, IL 61820
- 1 Dr. J. Arthur Woodward
Department of Psychology
University of California
Los Angeles, CA 90024
- 1 Dr. Karl Zinn
Center for research on Learning
and Teaching
University of Michigan
Ann Arbor, MI 48104