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Donald R. Gentner
Jonathan Grudin
Eileen Conway

# FINGER MOVEMENTS IN TRANSCRIPTION TYPING





CENTER FOR HUMAN INFORMATION PROCESSING
LA JOLLA, CALIFORNIA 92093
UNIVERSITY OF CALIFORNIA, SAN DIEGO

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High speed films and key press latencies of a skilled typist show that finger movements usually overlap in time. The starting time of these movements is highly variable, even when comparing identical sentences. Often movements toward keys were initiated out of the order in which the letters were eventually typed. These results conflict with current models of rapid, well-learned motor movements.

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# Finger Movements in Transcription Typing

Donald R. Gentner

Jonathan Grudin

Eileen Conway



CENTER FOR HUMAN INFORMATION PROCESSING
LA JOLLA, CALIFORNIA 92093

UNIVERSITY OF CALIFORNIA, SAN DIEGO

*This research was supported by the Advanced Research Projects Agency and the Office of Naval Research, Personnel and Training Research Programs and was monitored by ONR under Contract N00014-79-C-0323, NR 157-437, under terms of ARPA Order No. 3767. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Advanced Research Projects Agency, of the Office of Naval Research, or the United States Government.*

## Abstract

Skilled transcription typing is normally thought to involve highly routinized, sequential movements. However, high-speed films show that a typist's finger movements usually overlapped in time, and the starting times of these movements were highly variable, even when comparing identical sentences. Movements toward keys were often initiated out of the order in which the letters were eventually typed. These results conflict with current models of rapid, well learned motor movements and suggest instead a multi-level control of movement utilizing feedback or prediction.

Rapid, precise, malleable motor activity as demonstrated in speech and manual tasks is an important human characteristic. The task of typing, because it is an extremely rapid skill (a good office typist will average seven or eight keystrokes per second) and has a well defined output, has been the subject of speculation and some investigation (Lashley, 1959; Shaffer, 1973; Sternberg, Monsell, Knoll & Wright, 1973). Typing has typically been thought of as a sequential, automatic process. Models of the motor output generally involve a series of motor commands, often one for each letter, which are placed in a buffer and then sequentially executed. The actual finger movement is assumed to be ballistic with no feedback control once the movement is initiated. Accordingly, studies of typing have been almost exclusively based on records of the keys pressed and the inter-keypress latencies (Sternberg et al., 1978; Shaffer, 1976).

A proper test of the ballistic sequential model requires a more detailed examination of the typing process. In order to study how skilled motor movements are programmed and controlled, we filmed a transcription typist and analyzed the finger movements in the resulting motion picture. The data reported here are based on a high-speed (100 frames per second) film of an expert typist. The typist transcribed English sentences on the typewriter-like keyboard of a computer terminal at approximately 90 words/minute. For each such keystroke, we determined the time at which the finger started a smooth movement toward the key. During the filming, the keypresses and inter-keypress latencies were recorded by computer .[1]

We found that 96% of the finger movements were initiated before the previous key was pressed. The mean time for a complete finger movement was 261 msec, while the mean inter-keypress latency was 124 msec. Thus two or three fingers are often in motion simultaneously.

---

Insert Figure 1 about here

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These data are expanded in Figure 1 which shows the distribution of the starting and ending times of finger movements, both measured relative to the time when the previous key was pressed. This figure shows that the starting times of finger movements are more variable than their ending times (the keypresses). The starting times have a standard deviation of 103 msec, while the ending times have a standard deviation of 26 msec.

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Insert Figure 2 about here

---

Figure 2 illustrates this result, showing the timing of keystrokes for two words from a pair of repeated sentences. Figure 2 also shows two cases where the keystrokes are initiated in an order different from the final keypresses. Overall, 21% of the movements were initiated out of order (although the movements always ended with keypresses in the correct order). There were several cases where the finger movements were initiated out of order by 150 msec or more. Movements were initiated out of order for sequences of letters occurring both within hands (24% of the time) and across hands (13% of the time). One case, shown in the top portion of Figure 2, extended over two words: In typing the

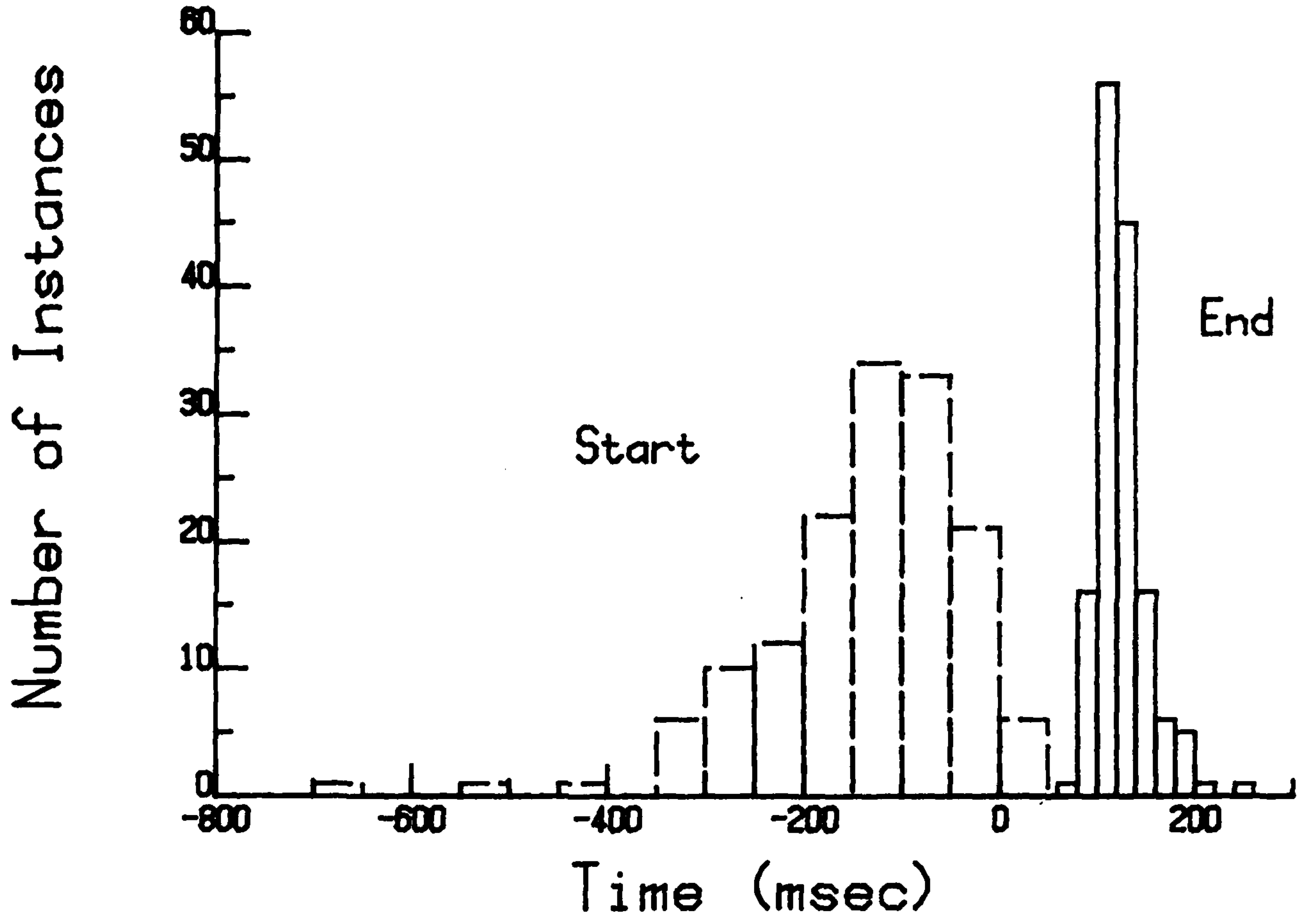


Figure 1. The distribution of starting and ending times of keystrokes, measured relative to the time of the previous keypress. Most keystrokes overlap, with the second finger movement starting before the keypress at the end of the previous movement. The starting times of movements show much more variability than the ending times.

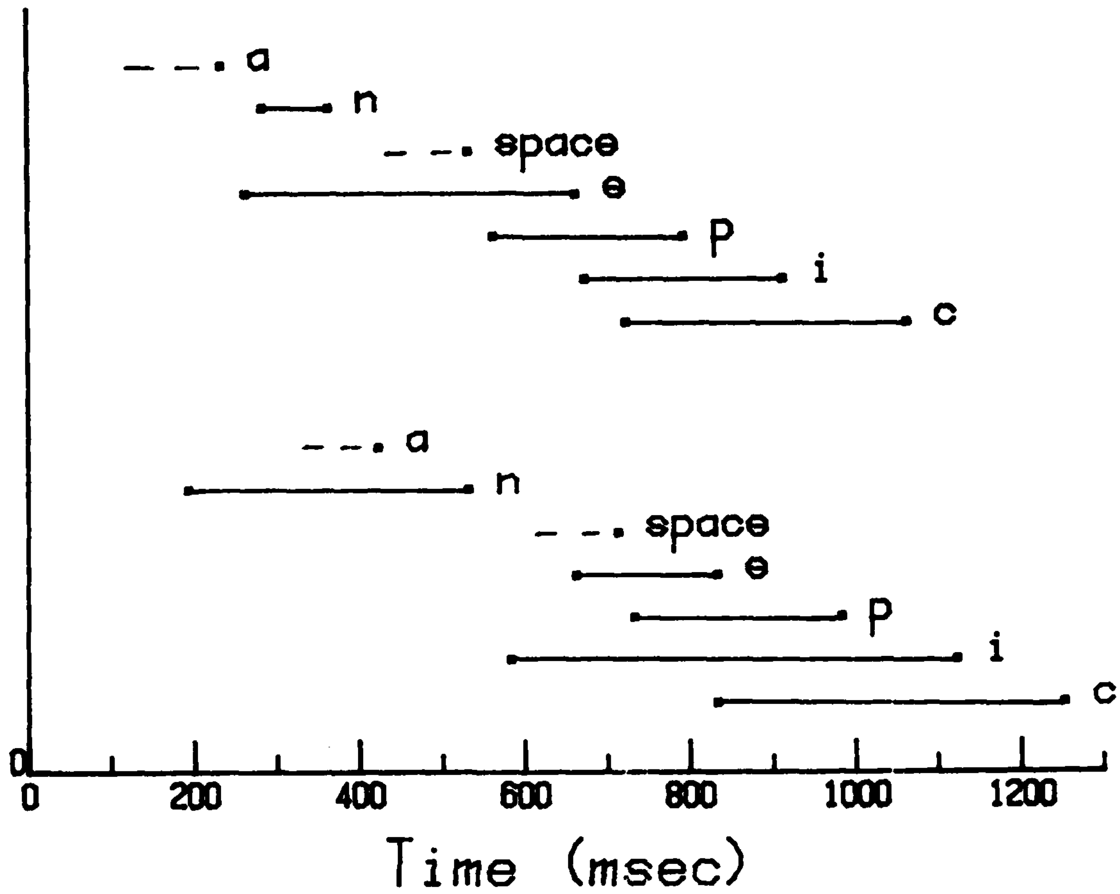


Figure 2. Relative timing of keystrokes for the phrase "... an epic ..." on repeated typing of the same sentence. The left ends of the horizontal lines represent the initiation time of the keystrokes, and the right ends of the lines represent the time of the keypresses. Initiation times were not measured for the letter a and the space bar; this is indicated by the dashed lines to the left of the keypress times. Note that successive keypresses are more regularly timed than the corresponding initiations. In two cases, although the keys were pressed in the proper order, the keystrokes are initiated out of order: in the first sentence the e keystroke was initiated before that of n in the previous word; in the second sentence the keystrokes for the word epic were initiated in the order i, e, p, c.

sequence <u>an</u> <u>epic</u>, the movement to type the <u>e</u> was initiated before the movement to type the <u>n</u>.

These data raise two questions: 1) What is responsible for the large variation in movement times? 2) How are the movements controlled so that the inter-keypress latencies are much more regular than the starting times of the movements?

We found that the movement times were partly determined by the length of time that the corresponding hand and finger had been free. Depending on the sequence of letters being typed, a given hand may be free for varying times before it presses a key, and we found that the longer the hand was free the earlier the keystrokes were initiated. This is undoubtedly related to the common observation that sequences of letters which alternate between the hands are typed faster than sequences which are typed with a single hand. However, we found that finger movements within one hand can also overlap. In 51% of the cases where successive keys were typed by two fingers on the same hand, the second keystroke was initiated while the first keystroke was still in progress. Early initiation of the second keystroke was positively correlated with the length of time that finger had been free. The analyzed film included two repeated sentences. Comparison of these sentences demonstrated that the particular letter or pattern of letters being typed accounts for only part of the variation in movement times. The movement times to type a given letter in identical contexts had a correlation coefficient of 0.60; that is, only about 35% of the variance is related to the letter being typed and the sentence context. The portion of the variance associated with the letter being typed and its context can be traced almost entirely to the length of time that the corresponding finger and hand have been free.

The remaining variance in movement time (65%) indicates that the automated finger movements in touch typing are not entirely stereotyped or preprogrammed; the movement appears to be controlled during its execution. Just as we observed with the overall data, the variation in movement times on repeated typing is due primarily to variation in starting times. Measured relative to the previous keypress, the median difference in starting times was 58 msec, while the the median difference in ending times (the inter-keypress latency) was 10 msec. Figure 2, which shows the timing for repeated typing of the phrase, an epic, illustrates this finding by contrasting the irregularity of the initiations of finger movements with the regularity of the keypresses. Overall, comparing corresponding letters in the repeated sentences, earlier starting times for a movement were not correlated with shorter inter-keypress latencies (r = 0.05). An analysis of corresponding keystrokes in the repeated sentences showed that there can be significant variation in the finger's position at the start of the keystroke. In particular, keystrokes which start with the finger closer to the target key are initiated later than keystrokes starting farther away.

There is precedent for the notion that highly skilled sequential movements can overlap. An analogous phenomenon is well known in phonology, where the articulatory movements required for a sequence of phonemes often overlap in time (Perkell, 1969). The great variability in initial finger position, initiation and movement times, and the existence of frequent initiations out of order, however, present difficulties for existing models which call for sequential keystroke initiation. Models which view the output process in typing as the execution of a series of motor programs, one for each letter, cannot account for these observations. Our results indicate that the motor program must be considerably more general, perhaps specifying only the key to be pressed, the finger, and its sequential relation to the other keypresses (Saltzman, 1979). Thus at this level the program appears quite abstract.

The actual initiation and timing of the movement and control of its trajectory might then be determined by a lower level of processing which takes into account the position of the fingers and the other competing activities. These processes controlling finger movement presumably utilize detailed information about the location and activities of the fingers. Sensory information and proprioceptive feedback from the muscles controlling the fingers could play a role. Neural impulses take about 70 msec to travel from muscle sensors through the cerebellum and back to the finger (Bizzi, 1979), an appreciable fraction of the movement times. Other control mechanisms are possible, however: For instance, control could be based on central monitoring of motor commands, rather than feedback from the fingers.

Regardless of the specific interface between the high-level program and the sequence of muscle movements, the picture of typing which emerges is very different from that of a stereotyped, ballistic movement.

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## Footnotes

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1. The film which we have analyzed in detail covers 310 keystrokes (about 40 seconds of typing). Because we were primarily interested in the possibility of overlapping keystrokes, this analysis does not include keystrokes where successive keys are typed by the same finger, since the finger movements are necessarily sequential; in addition, the initiation of a movement toward a home row key is ambiguous, as it may simply be a return of the finger to a home position. Thus, we restricted our analysis of the film to the 147 keystrokes to letters on the upper or lower rows of the keyboard where the previous keystroke was not made by the same finger. Other films of the same typist and video tapes of other typists show results similar to those reported here, but they have not been analyzed quantitatively.

Navy

1 Dr. Arthur Bachrach
Environmental Stress Program Center
Naval Medical Research Institute
Bethesda, MD 20014

1 CDR Thomas Berghage
Naval Health Research Center
San Diego, CA 92152

1 Dr. Robert Blanchard
Navy Personnel R&D Center
Managment Support Department
San Diego, CA 92151

1 Dr. Jack R. Borsting
Provost & Academic Dean
U.S. Naval Postgraduate School
Monterey, CA 93940

1 Dr. Robert Breaux
Code N-711
NAVTRAEQUIPCEN
Orlando, FL 32813

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 Dr. Richard Gibson
Bureau of medicine and surgery
Code 3C13
Navy Department
Washington, DC 20372

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Code 6021
Naval Air Development Center
Warminster, Pennsylvania 18974

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Navy Personnel R&D Center
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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 Mr. Arnold Rubenstein
Naval Personnel Support Technology
Naval Material Command (08T244)
Room 1044, Crystal Plaza #5
2221 Jefferson Davis Highway
Arlington, VA 20360

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

1 Mr John H. Wolfe
Code P310
U. S. Navy Personnel Research and
Development Center
San Diego, CA 92152

1 Dr. Patrick R. Harrison
Psychology Course Director
LEADERSHIP & LAW DEPT. (7b)
DIV. OF PROFESSIONAL DEVELOPMENT
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

1 Dr. Lloyd Hitchcock
Human Factors Engineering
Division (6022)
Naval Air Development Center
Warminster, PA 18974

1 CDR Charles W. Hutchins
Naval Air Systems Command Hq
AIR-340F
Navy Department
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1 Dr. Norman J. Kerr
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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. 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 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

1 Psychologist
ONR Branch Office
1030 East Green Street
Pasadena, CA 91101

1 Office of the Chief of Naval Operations
Research, Development, and Studies Branc
(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 Laborat
Pensacola, FL 32508

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ACADEMIC COMPUTING CENTER
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

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Code 55PK
Naval Postgraduate School
Monterey, CA 93940

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Code L52
NAMRL
Pensacola, FL 32508

1 Dr. Bernard Rimland (03B)
Navy Personnel R&D Center
San Diego, CA 92152

Army

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 Sasmor
U. S. Army Research Institute for the
Behavioral and Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

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
USAAREUE Director of GED
APO New York 09403

1 Mr. J. Barber
HQS, Department of the Army
DAPE-ZBR
Washington, DC 20310

1 DR. RALPH DUSEK
U.S. ARMY RESEARCH INSTITUTE
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. 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

1 Director
U.S. Army Human Engineering Labs
Attn: DRXHE-DB
Aberdeen Proving Ground, MD 21005

1 Dr. Harold F. O'Neil, Jr.
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WRIGHT PATTERSON AFB
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AFOSR
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AFHRL/OTR
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Lowry AFB
Colorado 80230

1 Dr. Frank Schufletowski
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ATC/XPTD
Randolph AFB, TX 78148

2 3700 TCHTW/TTGH Stop 32
Sheppard AFB, TX 76311

1 Jack A. Thorpe, Maj., USAF
Naval War College
Providence, RI 02846

Marines

1 H. William Greenup
Education Advisor (E031)
Education Center, MCDEC
Quantico, VA 22134

1 Major Howard Langdon
Headquarters, Marine Corps
OTTI 31
Arlington Annex
Columbia Pike at Arlington Ridge Rd.
Arlington, VA 20380

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

CoastGuard

1 Chief, Psychological Reserch Branch
U. S. Coast Guard (G-P-1/2/TP42)
Washington, DC 20593

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. Joseph L. Young, Director
Memory & Cognitive Processes
National Science Foundation
Washington, DC 20550

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 Intitute 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 Dr. H. Wallace Sinaiko
Program Director
Manpower Research and Advisory Services
Smithsonian Institution
801 North Pitt Street
Alexandria, VA 22314

1 Dr. Frank Withrow
U. S. Office of Education
400 Maryland Ave. SW
Washington, DC 20202

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

1 Dr. Lynn A. Cooper
Department of psychology
Uris Hall
Cornell University
Ithaca, NY 14850

1 Thomas L. Crandell
35 Leslie Avenue
Conklin, NY 13748

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 Dr. Hubert Dreyfus
Department of Philosophy
University of California
Berkely, CA 94720

1 LCOL J. C. Eggenberger
DIRECTORATE OF PERSONNEL APPLIED RESEARC
NATIONAL DEFENCE HQ
101 COLONEL BY DRIVE
OTTAWA, CANADA K1A 0K2

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 Dr. Marvin D. Glock
217 Stone Hall
Cornell University
Ithaca, NY 14853

1 Dr. Frank E. Gomer
McDonnell Douglas Astronautics Co.
P. O. Box 516
St. Louis, MO 63166

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

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

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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. Michael Levine
210 Education Building
University of Illinois
Champaign, IL 61820

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. 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. LUIGI PETRULLO
2431 N. EDGEWOOD STREET
ARLINGTON, VA 22207

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. 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

1 DR. ALBERT STEVENS
BOLT BERANEK & NEWMAN, INC.
50 MOULTON STREET
CAMBRIDGE, MA 02138

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. John Thomas
IBM Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, NY 10598

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

1 Dr. John R. Anderson
Department of Psychology
Carnegie Mellon University
Pittsburgh, PA 15213

1 Thomas H. Anderson, Ph.D.
Center for the Study of Reading
174 Children's Research Center
51 Gerty Drive
Champiagn, 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

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. Pat Carpenter
Department of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Dr. John B. 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

1 Dr. Ed Feigenbaum
Department of Computer Science
Stanford University
Stanford, CA 94305

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

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 Glenda Greenwald, Ed.
"Human Intelligence Newsletter"
P. O. Box 1163
Birmingham, MI 48012

1 Dr. Earl Hunt
Dept. of Psychology
University of Washington
Seattle, WA 98105

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 Mr. Marlin Kroger
1117 Via Goleta
Palos Verdes Estates, CA 90274

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. 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 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. PERRY THORNDYKE
THE RAND CORPORATION
1700 MAIN STREET
SANTA MONICA, CA 90406

1 Dr. Douglas Towne
Univ. of So. California
Behavioral Technology Labs
1845 S. Elena Ave.
Redondo Beach, CA 90277

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

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

1 Dr. Christopher Wickens
Department of Psychology
University of Illinois
Champaign, Ill 61820