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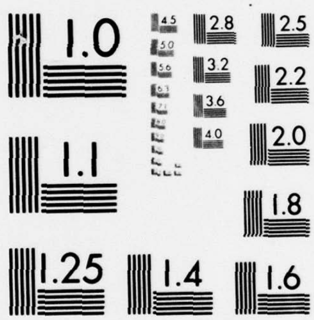

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University of Oregon
Eugene, Oregon 97403

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INDIVIDUAL DIFFERENCES IN ATTENTIONAL FLEXIBILITY

Steven W. Keele, W. Trammell Neill & Suzanne M. de Lemos
University of Oregon

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Abstract

This report describes a preliminary study that attempts to develop the concept of attentional flexibility. Flexibility refers to the rapidity with which set or attention can be switched from one signal requiring attention to another. If a trait exists, then people that can rapidly switch set on one task should also be able to rapidly switch set in a different kind of setting. The existence of such a trait could ultimately be very useful as a predictor of performance on a variety of skilled tasks, and some evidence for that has been found by Kahneman, Gopher, and colleagues. We studied flexibility on four tasks: (1) The difficulty in dealing with an unexpected signal after just being primed for another; (2) The difficulty in dealing with a rarely occurring event that occurs in the context of much more frequent events; (3) The ability to prepare for signals in another category immediately after responding to a signal in a different category, even when the need for preparation is predictable; and (4) The ability to switch attention from one dichotic message to another. This preliminary study provides some promise for the concept of flexibility, so we are currently engaged in follow-up studies.

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Introduction

The last few years have generated considerable interest in an information-processing approach to the study of individual differences. What is meant by an information-processing approach? There are two closely related ideas. One idea bases the study of individual differences on current theory regarding cognitive processes. In the past much investigation of individual differences was rather distant from the mainstream of experimental psychology and its theory; indeed, some people argue that much past study of individual differences had little basis in any theory of how the mind operates.

The second idea underlying an information-processing approach involves the measurement of processes that comprise task performance. Usually in past studies of individual differences, whole task scores from a variety of tasks were correlated with each other to determine whether the tasks had processes in common. Such correlations tend to be low because although two tasks may have processes in common that produce a correlation, they also involve different processes that reduce the correlation. An information-processing approach, in contrast, attempts to derive process scores, not task scores, and correlate such scores derived from different tasks to infer a common process. To the extent that theory has postulated appropriate processes and to the extent the measurement methods isolate the processes, correlations should be higher than traditional correlations between tasks.

Basically, Donders' historic subtractive method is used to isolate process scores. Theory is used to select two or more conditions of the same task to reflect different levels of difficulty on a single process. Subtracting the two scores from each other yields a derived measure of the process. Sometimes several conditions that manipulate difficulty along a single process are run, and a function is fit to the results and used to estimate a parameter that reflects the process. But a parameter estimate from a function is basically an estimate derived from subtracting conditions, except that more than two conditions are used. Two examples of the subtractive method are: (1) The subtraction of physical match reaction times in Posner's letter matching paradigm (Posner & Mitchell, 1967) from name match reaction times yields a measure of the relative speed of access to a name code; (2) Fitting the equation RT = a + bH to reaction time (RT) as a function of stimulus uncertainty (H) yields a parameter b that estimates choice time.

We have begun a project using information-processing analysis to study individual differences in attentional flexibility. This project is still underway; the data we have to report are from a preliminary study that yielded promising results but at the same time clearly indicates needed changes in our studies to firmly establish a trait of attentional flexibility.

The germination point for our research came from studies by Gopher and Kahneman (1971) and Kahneman, Ben-Ishai, and Lotan (1973). They devised a dichotic listening task that involved two parts in each trial. In Part 1 a high or low tone occurred informing subjects whether to report digits from the left or right ear. Then a series of word pairs or digit and word pairs occurred at a rapid rate and subjects reported back only the digits that occurred in the indicated ear. After several pairs another tone occurred with no pause in the rate to initiate Part 2. In Part 2 three digit pairs were presented, and subjects reported the three digits from the ear cued by the second tone. Number of errors on Part 2 correlated modestly with accident ratings of Israeli bus drivers, with flight school success of student pilots, and with skill assignment of professional pilots. Part 1, on the other hand, correlated less well with the criterion tasks.

Why did Part 2 but not Part 1 correlate with flying and driving skills? Kahneman and colleagues suggested that Part 2 requires switching attention (or set) from an already committed state. Part 1 does not. Ease of switching attention in the dichotic task may be related to flying and driving because they can benefit from flexible changes in set. For example, an accident in bus driving may more likely be avoided by a person that can quickly switch attention from the task at hand to an unexpected event.

If this notion is correct, it implies that people reliably differ on a trait of attentional flexibility, and that trait is common both to Part 2 of the dichotic listening task and both flying and driving. The present study was devised to determine in a more fundamental manner whether a trait of flexibility exists.

In general flexibility may be identified with the ease with which one can switch set from one expectation to another. Moreover, we concerned ourselves with situations in which set is changed in a time range of milliseconds to perhaps a second. Our eventual hope is that this type of flexibility might be predictive of performance in fast action motor skills such as driving, flying, or many dynamic sports.

Switching of set can occur in two different manners. In one case people may expect a particular signal type and then get an unexpected signal. Posner and Snyder (1975) and LaBerge (1973) have extensively analyzed this paradigm. People typically are fast in responding to an expected signal--i.e., they show RT benefit compared to neutral expectations. But RT to unexpected signals exhibits cost compared to the neutral signal. Our initial notion was that RT cost is a measure of flexibility. People that suffer little cost can rapidly switch set to deal with an unexpected event. We devised two different situations that involved switching set from one signal to an unexpected signal and measured both RT costs and benefits of expectations.

The other case of interest is one in which set is switched in a predictable manner. In essence one can ask whether flexibility refers to dealing with unexpected signals (i.e., cost) or whether it refers simply to switching of set regardless of whether the switch is predictable or not. We devised one situation that required constant switching of set but the signal source to which attention should be directed was perfectly predictable.

Finally we examined a version of Kahneman and colleagues' dichotic listening task.

If a general trait of flexibility exists, then the various derived measures of cost and benefit should correlate with one another. Let's turn to consider in more detail the actual tasks used.

Tasks

A total of 15 subjects were run through four tasks extending over several sessions. Each task was designed to yield one or more measures of flexibility. Then these measures of flexibility were correlated with each other. Most of the measures involved subtracting one condition from another. Several of the measures were prompted by Posner and Snyder's theoretical treatment of attention switching in terms of costs and benefits.

The Priming Task

One task was closely analogous to the cost-benefit paradigm of Posner and Snyder. On each trial a warning signal occurred. On half the trials the warning was a neutral plus indicating that any of four possible signals was equally likely. Those signals were a red light, a square, triangle, or trapezoid. The red light required a toggle switch press with the left hand and the forms required key-press responses with the right hand. Both the red light and the forms were centered on a scope face. On the other half of the trials the warning signal was the word red, cueing the subjects that the red light would follow with a probability of .70. If the red light failed to occur, the forms occurred with equal probability. These two trial types, cued and noncued, were randomly intermixed. The warning signal occurred 500 msec before a signal requiring a response.

Benefit was calculated by subtracting reaction times to the red light when it was cued from reaction times to the red light under neutral expectations. Cost was calculated by subtracting reaction time to neutral forms from reaction time to unexpected forms.

Rare Event Task

The second task used the same stimuli--red light, square, trapezoid, and triangle--and the same response assignments. On 99% of all trials, one of the three forms occurred. Response to one signal was followed 20 msec later by another stimulus. On only 1% of the trials, averaging once every two blocks of trials and 12 times a session, did a red light occur. Because in the context subjects were expecting forms, reaction time to red lights suffered large cost. Half the trials were preceded by a plus sign warning for any of the three forms and the other trials were preceded by a word warning for a particular one of the three forms. Although cost to the red light was larger when subjects were prepared for a particular form than for any form, the variable had little effect on other results and will be ignored.

Cost to the red light can be calculated by subtracting the neutral reaction time to red lights in the priming study from reaction time to the red light when it rarely occurred in the rare event task. Cost calculated in this manner tended to be four or five times larger than cost in the priming study.

Alternation Task

Both preceding tasks measured flexibility by the additional time required to respond to an unexpected signal. The alternation task required switching set but not in an unpredictable manner. Subjects were presented with six signals. Three colored lights--red, green, and yellow--were assigned to keys operated by the left hand and three forms--square, triangle, and trapezoid--were assigned to keys operated by the right hand.

In pure blocks subjects expected and responded only to colors or only to forms. In alternating blocks subjects responded to both colors and forms, but the two signal types strictly alternated. Response to a color was followed by a form and vice versa.

One way of viewing the difference between the two conditions is this: Should alternating blocks be viewed as six-choice or three-choice? If subjects efficiently switch attention, then the alternating condition is like three-choice. But if they fail to constantly use the predictability inherent in the situation and alternate attention, the task is like six-choice. In general alternating reaction time minus pure block reaction time yields a measure of flexibility.

In this task no warning signals were employed, but two different response-stimulus intervals were used. At the fast rate only 50 msec transpired between one response and the next stimulus. At the slow rate 750 msec transpired. The slow rate provides time for switching set, but even at that rate all subjects had slower RTs in the alternating condition than in the pure block condition. This suggested it would be useful to try two measures of flexibility. One measure was simply alternation reaction times at the fast rate minus pure block reaction times at the <u>fast</u> rate. The other measure adjusted the first one by additionally subtracting <u>slow</u> rate alternating RTs minus pure RTs. The rationale of the adjustment was that some people do not alternate attention very effectively even at slow rates where ample time should be available. The adjusted measure therefore reflects flexibility that was due to the high rate of action rather than one's reluctance to optimally prepare set.

Dichotic Listening Task

Our final task was a version of the Gopher and Kahneman dichotic listening task. This version was constructed by Dick Pew at Bolt, Beranek and Newman and kindly lent to us. Pairs of words, either pairs of color names or a color name and a digit, were presented at two pairs per second with one member of a pair directed to each ear through earphones. A high or low tone indicating from which ear to report the digits started a string of pairs, and then as the input progressed the subjects spoke the indicated digits aloud. After three, four, five, or six pairs another tone occurred at the same timing interval as the pairs. Altogether four tones occurred in a block before subjects were given a brief rest pause before another block.

The primary measure of flexibility is simply number of errors in reporting the correct digits. The measure combines both errors of digit omission and of reporting the wrong digit.

Expectations

If people differ from one another on a general trait of flexibility, then we would expect the various measures of flexibility derived from the different tasks to correlate with one another.

Results

The flexibility scores for each reaction time task can be derived from either reaction times or errors. When both scores are used a large number of correlations exist. Correlations involving error scores generally were smaller than correlations involving only reaction time scores, so to simplify the data presentation only reaction time correlations are shown in Table 1.

The priming task yields two scores, cost and benefit. The rare event task yields a single score of cost. Two measures were derived from the alternating colors and forms task, one in which alternation minus pure block reaction times at the fast rate were measured and one in which that score was adjusted by the alternation minus pure block scores at the slow rate. A single error score was used for the dichotic listening task.

The major diagonal in the table lists the reliability of the tasks. The reliabilities were all quite good except for very low reliability of the priming cost measure. The other correlations are between tasks, and they adopt the convention that positive correlations fit the hypothesis and negative correlations do not.

In general the correlations are not large, but several encourage us that we are tapping a common factor of flexibility.

One surprise is that priming task cost did not correlate with the scores from other tasks. This may partly be due to the extremely low reliability of the prime cost score. On the other hand, prime benefit showed some tendency to correlate with the other scores and that also was unexpected. Why might benefit, which one would think measures preparation, correlate with the other scores that measure ability to switch attention? One clue is that the priming

Table 1

Correlations Between Derived Scores of Flexibility

	Prime benefit	Prime cost	Rare event	A-P fast	A-P fast minus A-P slow	Dichotic Listening
Prime benefit	.89					
Prime cost	.75*	.32				
Rare event	.45*	-.20	.96			
A-P fast	.44	-.01	.31	.87		
A-P fast minus A-P slow	.59*	-.20	.61*	.77*	.80	
Dichotic listening	.43	-.22	.21	.47*	.45*	.92

Underlined values are reliabilities.

* $p < .05$

study is itself a rather fast moving task that requires one to attend to a new prime about every second. People that are relatively inflexible may be deficient is using the prime and hence show low benefit. They also would tend to show low prime cost because a prerequisite of cost is that the prime cue is effectively used. Although flexibility may show up in benefit on the priming task, it would show up on cost on the rare event task. On the rare event task subjects have the context of hundreds of trials all with the same expectation for forms. They do not have to drive attention to expect a form in response to a priming cue. Since no person should have difficulty in expecting the likely source of signals, everyone should have large benefit, and flexibility then would show up only in dealing with unexpected signals--i.e., in cost.

Both measures on the alternating task also correlated moderately well with some of the other scores, and this was particularly true for the fast rate flexibility score adjusted for slow rate use of the predictability inherent in alternation. The important conclusion to be derived from these observations is that flexibility appears to reflect the proficiency with which one can switch set, whether switching is predictable or not, and not just the proficiency of dealing with unexpected signals.

Performance on the dichotic listening task also correlated with other tasks, though generally to a lesser degree. However, another problem occurred in conjunction with that task. Not only did the derived scores shown in Table 1 correlate with dichotic performance, but straight reaction time, which measures overall speed and not cost or benefit, correlated even more highly with the dichotic listening scores. When reaction time was partialed out, little or no predictability of the flexibility scores for dichotic listening remained. This was not true for correlations among other measures: Overall reaction speed had little influence on the correlations between the flexibility data. Some reflection reveals a possible reason why the dichotic task is influenced by speed, and flexibility scores offer little beyond that. The dichotic task is forced in pace and errors result when subjects have insufficient time to deal with a signal. People that are relatively slow in encoding one signal on the dichotic task may have less time available for dealing with a succeeding signal whether that signal is a word or tone. Problems in dealing with the dichotic task may therefore derive not from being slow in attention shifts but from having inadequate time for a shift even if one is relatively fast in shifting.

The data presentation here is rather cursory, ignoring details of error rates on most of the tasks, alternate scoring systems, and partial correlations. More detailed analysis, however, would not clarify issues. The correlations between tasks are sufficiently large to indicate promise for the concept of attentional flexibility as a trait. However, the correlations are not as large or consistent as we would desire so that clearly further investigation is required. This report constitutes a preliminary presentation of what we are attempting and the promise shown. In our ongoing work we have tried to improve individual paradigms to eliminate some problems with each. We have dropped the dichotic listening task as a good one for tapping flexibility because of its correlations with speed. And we have added new tasks.

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Navy

4 DR. JACK ADAMS
OFFICE OF NAVAL RESEARCH BRANCH
223 OLD MARYLEBONE ROAD
LONDON, NW, 15TH ENGLAND

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

1 DR. JOHN F. BROCK
NAVY PERSONNEL R& D CENTER
SAN DIEGO, CA 92152

1 DR. MAURICE CALLAHAN
NODAC (CODE 2)
DEPT. OF THE NAVY
BLDG. 2, WASHINGTON NAVY YARD
(ANACOSTIA)
WASHINGTON, DC 20374

1 Dept. of the Navy
CHNAVMAT (NMAT 034D)
Washington, DC 20350

1 Chief of Naval Education and
Training Support)-(01A)
Pensacola, FL 32509

1 Dr. Charles E. Davis
ONR Branch Office
536 S. Clark Street
Chicago, IL 60605

1 Mr. James S. Duva
Chief, Human Factors Laboratory
Naval Training Equipment Center
(Code N-215)
Orlando, Florida 32813

5 Dr. Marshall J. Farr, Director
Personnel & Training Research Programs
Office of Naval Research (Code 458)
Arlington, VA 22217

1 DR. PAT FEDERICO
NAVY PERSONNEL R&D CENTER
SAN DIEGO, CA 92152

Navy

1 CDR John Ferguson, MSC, USN
Naval Medical R&D Command (Code 44)
National Naval Medical Center
Bethesda, MD 20014

1 Dr. John Ford
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. Eugene E. Gloye
ONR Branch Office
1030 East Green Street
Pasadena, CA 91101

1 CAPT. D.M. GRAGG, MC, USN
HEAD, SECTION ON MEDICAL EDUCATION
UNIFORMED SERVICES UNIV. OF THE
HEALTH SCIENCES
6917 ARLINGTON ROAD
BETHESDA, MD 20014

1 MR. GEORGE N. GRAINE
NAVAL SEA SYSTEMS COMMAND
SEA 047C112
WASHINGTON, DC 20362

1 CDR Robert S. Kennedy
Naval Aerospace Medical and
Research Lab
Box 29407
New Orleans, LA 70189

1 Dr. Norman J. Kerr
Chief of Naval Technical Training
Naval Air Station Memphis (75)
Millington, TN 38054

1 Dr. Leonard Kroeker
Navy Personnel R&D Center
San Diego, CA 92152

1 Dr. James Lester
ONR Branch Office
495 Summer Street
Boston, MA 02210

^L

Navy

1 Dr. William L. Maloy
Principal Civilian Advisor for
Education and Training
Naval Training Command, Code 00A
Pensacola, FL 32508

1 Dr. Sylvia R. Mayer (MCIT)
HQ Electronic Systems Div.
Hanscom AFB
Bedford, MA 01731

1 Dr. James McBride
Code 301
Navy Personnel R&D Center
San Diego, CA 92152

2 Dr. James McGrath
Navy Personnel R&D Center
Code 306
San Diego, CA 92152

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 Commanding Officer
Naval Health Research
Center
Attn: Library
San Diego, CA 92152

1 CDR PAUL NELSON
NAVAL MEDICAL R& D COMMAND
CODE 44
NATIONAL NAVAL MEDICAL CENTER
BETHESDA, MD 20014

1 Library
Navy Personnel R&D Center
San Diego, CA 92152

6 Commanding Officer
Naval Research Laboratory
Code 2627
Washington, DC 20390

Navy

1 OFFICE OF CIVILIAN PERSONNEL
(CODE 26)
DEPT. OF THE NAVY
WASHINGTON, DC 20390

1 JOHN OLSEN
CHIEF OF NAVAL EDUCATION &
TRAINING SUPPORT
PENSACOLA, FL 32509

1 Office of Naval Research
Code 200
Arlington, VA 22217

1 Office of Naval Research
Code 441
800 N. Quincy Street
Arlington, VA 22217

1 Scientific Director
Office of Naval Research
Scientific Liaison Group/Tokyo
American Embassy
APO San Francisco, CA 96503

1 SCIENTIFIC ADVISOR TO THE CHIEF
OF NAVAL PERSONNEL
NAVAL BUREAU OF PERSONNEL (PERS OR)
RM. 4410, ARLINGTON ANNEX
WASHINGTON, DC 20370

1 DR. RICHARD A. POLLAK
ACADEMIC COMPUTING CENTER
U.S. NAVAL ACADEMY
ANNAPOLIS, MD 21402

1 Mr. Arnold I. Rubinstein
Human Resoureces Program Manager
Naval Material Command (0344)
Room 1044, Crystal Plaza #5
Washington, DC 20360

1 Dr. Worth Scanland
Chief of Naval Education and Training
Code N-5
NAS, Pensacola, FL 32508

Navy

1 A. A. SJOHOLM
TECH. SUPPORT, CODE 201
NAVY PERSONNEL R& D CENTER
SAN DIEGO, CA 92152

1 Mr. Robert Smith
Office of Chief of Naval Operations
OP-987E
Washington, DC 20350

1 Dr. Alfred F. Smode
Training Analysis & Evaluation Group (TAEG)
Dept. of the Navy
Orlando, FL 32813

1 CDR Charles J. Theisen, JR. MSC, USN
Head Human Factors Engineering Div.
Naval Air Development Center
Warminster, PA 18974

1 W. Gary Thomson
Naval Ocean Systems Center
Code 7132
San Diego, CA 92152

1 DR. MARTIN F. WISKOFF
NAVY PERSONNEL R& D CENTER
SAN DIEGO, CA 92152

Army

1 HQ USAREUE & 7th Army
ODCSOPS
USAAREUE Director of GED
APO New York 09403

1 Commandant
U.S. Army Infantry School
Ft. Benning, GA 31905
Attn: ATSH-I-V-IT (Cpt. Hinton)

1 DR. JAMES BAKER
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333

1 DR. RALPH DUSEK
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333

1 DR. FRANK J. HARRIS
U.S. ARMY RESEARCH INSTITUTE
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333

1 Col. Frank Hart, Director
Training Development Institute
ATTNG-TDI
Ft. Eustis, VA 23604

1 Dr. Milton S. Katz
Individual Training & Skill Evaluation Technical Area
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Harold F. O'Neil, Jr.
ATTN: PERI-OK
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333

1 Director, Training Development
U.S. Army Administration Center
ATTN: Dr. Sherrill
Ft. Benjamin Harrison, IN 46218

Army

1 Dr. Joseph Ward
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Air Force

1 Air Force Human Resources Lab
AFHRL/PED
Brooks AFB, TX 78235

1 Air University Library
AUL/LSE 76/443
Maxwell AFB, AL 36112

1 DR. G. A. ECKSTRAND
AFHRL/AS
WRIGHT-PATTERSON AFB, OH 45433

1 Dr. Alfred R. Fregly
AFOSR/NL, Bldg. 410
Bolling AFB, DC 20332

1 CDR. MERCER
CNET LIAISON OFFICER
AFHRL/FLYING TRAINING DIV.
WILLIAMS AFB, AZ 85224

1 Dr. Ross L. Morgan (AFHRL/ASR)
Wright -Patterson AFB
Ohio 45433

1 Research Branch
AFMPC/DPMYP
Randolph AFB, TX 78148

1 Dr. Marty Rockway (AFHRL/TT)
Lowry AFB
Colorado 80230

1 Brian K. Waters, Maj., USAF
Chief, Instructional Tech. Branch
AFHRL
Lowry AFB, CO 80230

^L

Marines

1 Director, Office of Manpower Utilization
HQ, Marine Corps (MPU)
BCB, Bldg. 2009
Quantico, VA 22134

1 DR. A.L. SLAFKOSKY
SCIENTIFIC ADVISOR (CODE RD-1)
HQ, U.S. MARINE CORPS
WASHINGTON, DC 20380

CoastGuard

1 MR. JOSEPH J. COWAN, CHIEF
PSYCHOLOGICAL RESEARCH (G-P-1/62)
U.S. COAST GUARD HQ
WASHINGTON, DC 20590

^L

Other DoD

1 Dr. Stephen Andriole
ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BLVD.
ARLINGTON, VA 22209

12 Defense Documentation Center
Cameron Station, Bldg. 5
Alexandria, VA 22314
Attn: TC

1 Dr. Dexter Fletcher
ADVANCED RESEARCH PROJECTS AGENCY
1400 WILSON BLVD.
ARLINGTON, VA 22209

1 Military Assistant for Human Resources
Office of the Director of Defense
Research & Engineering
Room 3D129, the Pentagon
Washington, DC 20301

1 Director, Research & Data
OSD/MRA&L (Rm. 3B919)
The Pentagon
Washington, DC 20301

Civil Govt

1 Dr. Susan Chipman
Basic Skills Program
National Institute of Education
1200 19th Street NW
Washington, DC 20208

11 Mr. James M. Ferstl
Bureau of Training
U.S. Civil Service Commission
Washington, D.C. 20415

1 Dr. William Gorham, Director
Personnel R&D Center
U.S. Civil Service Commission
1900 E Street NW
Washington, DC 20415

1 William J. McLaurin
Rm. 301, Internal Revenue Service
2221 Jefferson Davis Highway
Arlington, VA 22202

1 Dr. Andrew R. Molnar
Science Education Dev.
and Research
National Science Foundation
Washington, DC 20550

1 Dr. Thomas G. Sticht
Basic Skills Program
National Institute of Education
1200 19th Street NW
Washington, DC 20208

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

Non Govt

1 PROF. EARL A. ALLUISI
DEPT. OF PSYCHOLOGY
CODE 287
OLD DOMINION UNIVERSITY
NORFOLK, VA 23508

1 Dr. John R. Anderson
Dept. of Psychology
Yale University
New Haven, CT 06520

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 MR. SAMUEL BALL
EDUCATIONAL TESTING SERVICE
PRINCETON, NJ 08540

1 Dr. Gerald V. Barrett
Dept. of Psychology
University of Akron
Akron, OH 44325

1 Dr. Nicholas A. Bond
Dept. of Psychology
Sacramento State College
600 Jay Street
Sacramento, CA 95819

1 Dr. John Seeley Brown
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, MA 02138

1 DR. C. VICTOR BUNDERSON
WICAT INC.
UNIVERSITY PLAZA, SUITE 10
1160 SO. STATE ST.
OREM, UT 84057

Non Govt

1 Dr. John B. Carroll
Psychometric Lab
Univ. of No. Carolina
Davie Hall 013A
Chapel Hill, NC 27514

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. Kenneth E. Clark
College of Arts & Sciences
University of Rochester
River Campus Station
Rochester, NY 14627

1 Dr. Norman Cliff
Dept. of Psychology
Univ. of So. California
University Park
Los Angeles, CA 90007

1 Dr. Allan M. Collins
Bolt Beranek & Newman, Inc.
50 Moulton Street
Cambridge, Ma 02138

1 Dr. John J. Collins
Essex Corporation
201 N. Fairfax Street
Alexandria, VA 22314

1 Dr. Meredith Crawford
5605 Montgomery Street
Chevy Chase, MD 20015

1 Dr. Donald Dansereau
Dept. of Psychology
Texas Christian University
Fort Worth, TX 76129

^L

Non Govt

1 Dr. Ruth Day
Center for Advanced Study
in Behavioral Sciences
202 Junipero Serra Blvd.
Stanford, CA 94305

1 ERIC Facility-Acquisitions
4833 Rugby Avenue
Bethesda, MD 20014

1 MAJOR I. N. EVONIC
CANADIAN FORCES PERS. APPLIED RESEARCH
1107 AVENUE ROAD
TORONTO, ONTARIO, CANADA

1 Dr. Richard L. Ferguson
The American College Testing Program
P.O. Box 168
Iowa City, IA 52240

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

1 Dr. Edwin A. Fleishman
Advanced Research Resources Organ.
8555 Sixteenth Street
Silver Spring, MD 20910

1 Dr. John R. Frederiksen
Bolt Beranek & Newman
50 Moulton Street
Cambridge, MA 02138

1 Dr. Frederick C. Frick
MIT Lincoln Laboratory
Room D 268
P. O. Box 73
Lexington, MA 02173

1 DR. ROBERT GLASER
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213

Non Govt

1 DR. JAMES G. GREENO
LRDC
UNIVERSITY OF PITTSBURGH
3939 O'HARA STREET
PITTSBURGH, PA 15213

1 Dr. Ron Hambleton
School of Education
University of Massechusetts
Amherst, MA 01002

1 Dr. Barbara Hayes-Roth
The Rand Corporation
1700 Main Street
Santa Monica, CA 90406

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 Mr. Gary Irving
Data Sciences Division
Technology Services Corporation
2811 Wilshire Blvd.
Santa Monica CA 90403

1 DR. LAWRENCE B. JOHNSON
LAWRENCE JOHNSON & ASSOC., INC.
SUITE 502
2001 S STREET NW
WASHINGTON, DC 20009

1 Dr. Wilson A. Judd
McDonnell-Douglas
Astronautics Co. East
Lowry AFB
Denver, CO 80230

1 Dr. Arnold F. Kanarick
Honeywell, Inc.
2600 Ridgeway Pkwy
Minneapolis, MN 55413

^L

Non Govt

1 Dr. Roger A. Kaufman
203 Dodd Hall
Florida State Univ.
Tallahassee, FL 32306

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

1 LCOL. C.R.J. LAFLEUR
PERSONNEL APPLIED RESEARCH
NATIONAL DEFENSE HQS
101 COLONEL BY DRIVE
OTTAWA, CANADA K1A OK2

1 Dr. Robert R. Mackie
Human Factors Research, Inc.
6780 Cortona Drive
Santa Barbara Research Pk.
Goleta, CA 93017

1 Dr. Richard B. Millward
Dept. of Psychology
Hunter Lab.
Brown University
Providence, RI 82912

1 Dr. Donald A Norman
Dept. of Psychology C-009
Univ. of California, San Diego
La Jolla, CA 92093

1 Dr. Melvin R. Novick
Iowa Testing Programs
University of Iowa
Iowa City, IA 52242

1 Dr. Jesse Orlansky
Institute for Defense Analysis
400 Army Navy Drive
Arlington, VA 22202

1 Dr. Seymour A. Papert
Massachusetts Institute of Technology
Artificial Intelligence Lab
545 Technology Square
Cambridge, MA 02139

Non Govt

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

1 DR. PETER POLSON
DEPT. OF PSYCHOLOGY
UNIVERSITY OF COLORADO
BOULDER, CO 80302

1 Dr. Frank Pratzner
Cntr. for Vocational Education
Ohio State University
1960 Kenny Road
Columbus, OH 43210

1 DR. DIANE M. RAMSEY-KLEE
R-K RESEARCH & SYSTEM DESIGN
3947 RIDGEMONT DRIVE
MALIBU, CA 90265

1 MIN. RET. M. RAUCH
P II 4
BUNDESMINISTERIUM DER VERTEIDIGUNG
POSTFACH 161
53 BONN 1, GERMANY

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

1 Dr. Joseph W. Rigney
Univ. of So. California
Behavioral Technology Labs
3717 South Hope Street
Los Angeles, CA 90007

1 Dr. Andrew M. Rose
American Institutes for Research
1055 Thomas Jefferson St. NW
Washington, DC 20007

^L

Non Govt

1 Dr. Leonard L. Rosenbaum, Chairman
Department of Psychology
Montgomery College
Rockville, MD 20850

1 Dr. Ernst Z. Rothkopf
Bell Laboratories
600 Mountain Avenue
Murray Hill, NJ 07974

1 PROF. FUMIKO SAMEJIMA
DEPT. OF PSYCHOLOGY
UNIVERSITY OF TENNESSEE
KNOXVILLE, TN 37916

1 DR. WALTER SCHNEIDER
DEPT. OF PSYCHOLOGY
UNIVERSITY OF ILLINOIS
CHAMPAIGN, IL 61820

1 DR. ROBERT J. SEIDEL
INSTRUCTIONAL TECHNOLOGY GROUP
HUMRRO
300 N. WASHINGTON ST.
ALEXANDRIA, VA 22314

1 Dr. Robert Singer, Director
Motor Learning Research Lab
Florida State University
212 Montgomery Gym
Tallahassee, FL 32306

1 Dr. Richard Snow
School of Education
Stanford University
Stanford, CA 94305

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

Non Govt

1 Mr. D. J. Sullivan
c/o Canyon Research Group, Inc.
741 Lakefield Road
Westlake Village, CA 91361

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

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 CAROLINA
CHAPEL HILL, NC 27514

1 Dr. Claire E. Weinstein
Educational Psychology Dept.
Univ. of Texas at Austin
Austin, TX 78712

1 Dr. David J. Weiss
N660 Elliott Hall
University of Minnesota
75 E. River Road
Minneapolis, MN 55455

1 DR. SUSAN E. WHITELY
PSYCHOLOGY DEPARTMENT
UNIVERSITY OF KANSAS
LAWRENCE, KANSAS 66044

^L