AD-A050 774 STANFORD UNIV CALIF SCHOOL OF EDUCATION F/G 5/10
CORRELATION OF SELECTED COGNITIVE ABILITIES AND COGNITIVE PROCE--ETC(U)
DEC 76 R E SNOW, B MARSHALEK, D F LOHMAN N00014-75-C-0882
UNCLASSIFIED TR-3 NL

1 OF 1
AD A050774

END
DATE
FILMED
4 -78
DDC

(12)

CORRELATION OF SELECTED COGNITIVE ABILITIES AND COGNITIVE PROCESSING PARAMETERS: AN EXPLORATORY STUDY

RICHARD E. SNOW

BRACHIA MARSHALEK

AND

DAVID F. LOHMAN

TECHNICAL REPORT NO. 3
APTITUDE RESEARCH PROJECT
SCHOOL OF EDUCATION
STANFORD UNIVERSITY

DECEMBER 1976

CORRELATION OF SELECTED COGNITIVE ABILITIES AND COGNITIVE PROCESSING PARAMETERS: AN EXPLORATORY STUDY

RICHARD E. SNOW

BRACHIA MARSHALEK

AND

DAVID F. LOHMAN

TECHNICAL REPORT NO. 3

APTITUDE RESEARCH PROJECT

SCHOOL OF EDUCATION

STANFORD UNIVERSITY

DECEMBER 1976

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 3
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): Correlation of selected cognitive abilities and cognitive processing parameters: An exploratory study.
5. TYPE OF REPORT & PERIOD COVERED: Technical Rep[redacted]t #3
6. PERFORMING ORG. REPORT NUMBER: TR-3
7. AUTHOR(s): Richard E./Snow, Brachia/Marshalek and David F./Lohman
8. CONTRACT OR GRANT NUMBER(s): NØØ14-75-C-Ø882
9. PERFORMING ORGANIZATION NAME AND ADDRESS: School of Education, Stanford University, Stanford, California
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: NR 154-376
11. CONTROLLING OFFICE NAME AND ADDRESS: Personnel and Training Research Programs, Psychological Sciences Division, ONR, 458
12. REPORT DATE: Dec[redacted]76
13. NUMBER OF PAGES: 38 (42p.)
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

UNLIMITED

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

UNLIMITED

18. SUPPLEMENTARY NOTES

This research was jointly sponsored by the Office of Naval Research and the Defense Advanced Research Projects Agency.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Individual differences, cognitive processes, information processing, aptitudes, cognitive abilities, experimental and correlational research methodology, short-term memory.

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

This pilot study investigated some relationships between tested ability variables and processing parameters obtained from memory search and visual search tasks. The 25 undergraduate Stanford students who participated in this study had also participated in a previous investigation by Chiang and Atkinson. Slope and intercept parameters for the search tasks and digit span scores were available from that study on all subjects. A battery of traditional ability tests and several film tests previously developed by the senior (cont over)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

391 909

author were administered to all students. One of the film tests was designed to produce an "erasure" or backward masking effect in short term visual memory. Factor scores were computed separately for ability tests and the short term visual memory test. These factor scores and other raw variables were then correlated with the slope, intercept and digit span parameters from the Chiang and Atkinson study. Multiple regression methods were also employed to regress ability variables on parameters and parameters on ability measures. In general, the correlations between parameters and ability variables were low, and the regression of parameters on ability variables yielded larger R's than the regressions of abilities on the parameters. The short term visual memory film test did not correlate more substantially with the processing parameters than it did with the ability factors. The data did provide further support for some of the implications derived from previous studies of ability-process parameter relations. The overall pattern of correlation was interpreted in terms of an information processing model in which general ability is viewed as the executive function that selects, creates and implements programs that process and store information. The results of this study are discussed in terms of their implications for future research in this area.

The previous reports in this series reviewed the present state of research on aptitude for instructional learning, and the need for combined experimental and correlational analyses aimed at process theories of aptitude (Snow, 1976a, 1976b). An outline for a laboratory science of aptitude was sketched. It was suggested that one line within this general approach would be to examine interrelations between mental tests representing the major distinctions in factor theories of ability organization and parameters reflecting features of cognitive information processing models. The present report describes a first exploratory study toward this end.

Early studies by Hunt and his associates (Hunt, Frost, & Lunneborg, 1973; Lunneborg, 1975; Hunt & Lansman, 1975) have begun to spell out some relationships of the sort needed to connect individual differences in tested aptitudes to measures of processing in short-term memory. This initial research has relied on a rather restricted conception of human aptitudes and the appropriate methods of studying them correlationally (Snow, 1976b). Nonetheless, one important hypothesis that has taken shape through Hunt's work relates verbal ability to speed of processing in short-term memory. Among other findings, it was shown that college students in a high scoring verbal ability group displayed faster memory search (i.e., lower slope scores) in the Sternberg (1969) task, better maintenance of temporal order information (i.e., more release from proactive inhibition when data are scored for order), and faster access to name information in the (Posner, et al, 1969) name match/physical match task than did students in a lower scoring verbal ability group. In the analysis, it was not possible to distinguish verbal ability from a more general ability construct in this hypothesis.

Chiang and Atkinson (1976) pursued the Hunt findings by administering memory search, visual search, and memory span tasks to college students for whom verbal and quantitative ability scores were available. The present study administered an additional battery of ability tests to the same students used by Chiang and Atkinson so that this and related hypotheses could be explored further. Specifically, the purposes of the present investigation were the following:

1. Examine the Chiang-Atkinson tasks in relation to tests representing fluid-analytic, spatial, and visual perceptual and memory abilities, as well as verbal and quantitative abilities.
2. Replicate earlier findings by Seibert and Snow (1965) on individual differences in visual backward masking and their relation to visual perceptual and verbal abilities.
3. Explore distributions and correlational patterns among all these test and task variables, and between them and indices of sex and cerebral laterality, in a sample of Stanford University undergraduates. It was hoped that certain ability factors of interest in the project's further work would be discernable, even with a small initial sample. It was also planned to test some alternative conceptions of how task parameters and mental tests might combine as predictors of one another. The data would in addition serve a pilot function in deciding whether Stanford students would be appropriate as subjects in the further research.

Background

To understand the present findings, it is necessary that we report in some detail the procedure and results of both the Chiang-Atkinson investigation and the earlier Seibert-Snow study on visual masking. In both cases we have pursued further analysis of the data to advance our own thinking. These analyses were used as methodological examples in the previous discussion by Snow (1976b).

The Chiang-Atkinson Study. Chiang and Atkinson (1976) used 33 Stanford University students and one high school student as subjects. Half the sample were males, half females. Subjects performed the Sternberg (1966, 1969) Memory Search Task, the Visual Search Task (Neisser, 1964; Atkinson, Holmgren, & Juola, 1969), and a digit span task of standard design. The experiment was controlled by an IMLAC PDS-1 computer. All trials were displayed on a CRT unit; subjects typed their responses on a keyboard.

In the memory search task, a memory set of from one to five consonants was presented sequentially, followed by a probe letter. The subject's task was to indicate whether or not the probe was contained in the memory set.

Each character in the memory set appeared in the same centered position on the CRT for 800 msec. with a 200 msec. break between characters. The probe letter appeared two seconds after the last memory set character. Since performance on this task is virtually error-free, the dependent variable was reaction time (RT). Each trial was either positive (probe contained in memory set) or negative (probe not contained in memory set). Memory set size varied from one to five, yielding ten different item types. During the four one-hour experimental sessions, each subject received 30 trials of each type, or 300 trials in all. The task produced two scores for each subject; a slope representing increase in RT as a function of increasing memory set size, and an intercept representing RT at zero set size. The model typically adopted for this task interprets the slope parameter as a measure of the time required for a single comparison in memory, and the intercept parameter as the sum of times required for stimulus encoding, binary decision, and response production (Sternberg, 1969).

In the visual search task, a target letter was presented for 800 msec. followed 200 msec. later by a linear display of from one to five consonants. The subject's task was to indicate whether or not the target letter was contained in the display set. Both positive and negative trials at each display set size were given. Each subject received a total of 300 trials over the four experimental sessions. Again, the dependent variable was RT, with two scores computed for each subject; slope across increasing display set size and an intercept at zero set size. The model for this task assumes that the slope parameter displays time required for stimulus encoding plus a single comparison, and the intercept parameter represents time for binary decision and response production.

In the digit span task, a memory set of four to twelve randomly generated digits was presented sequentially. The subject's task was to recall the digits in the order of their presentation. Each digit appeared for 800 msec. in the center position of the CRT, with a 200 msec. wait between digits. Each series of five trials progressed from four to twelve digits by increments of two. The dependent variable was the average number of digits recalled in correct order. This score entered the analysis directly. In all, each subject received 150 digit span trials.

The findings of principal interest here concerned 30 subjects (15 males, 15 females) for whom Scholastic Aptitude Test Verbal (SAT-V) and Quantitative (SAT-Q) scores had been obtained from university files. Chiang and Atkinson first intercorrelated all measures in this sample. These data showed high intercorrelations among the slope parameters, and also among the intercept parameters of the two search tasks.

Using reliability estimates provided by Chiang and Atkinson, it was possible to correct these intercorrelations for attenuation and thus to examine the adequacy of the processing models underlying each task. While the correlations gave evidence supporting the construct validity of the two parameter measures, it was shown that the models required some revision to bring them in line with the correlational data. Contrary to previous theory, variance due to individual differences in stimulus encoding seemed to be present in the intercept parameters for both the memory search and the visual search tasks (Snow, 1976b).

Chiang and Atkinson found no significant correlation between the parameters and scores on SAT-V or SAT-Q. This appeared to contradict Hunt's finding. When data for like parameters were combined and analyzed separately by sex, however, relations consistent with Hunt's hypothesis were found for males but not for females. Among males, the combined slope measure correlated negatively with both SAT-V (-0.36) and SAT-Q (-0.44), indicating that higher ability subjects showed shallower slopes (i.e., relatively short RT on larger memory sets) compared with lower ability subjects. For females, the corresponding correlations were +0.72 and +0.33! The memory span measure displayed the opposite interaction with sex: higher memory span scores were associated with steeper slopes in males, and with shallower slopes in females. Given the small sample and the fact that the sex differences had been unanticipated, Chiang and Atkinson drew no solid conclusions. Also, because both the verbal and the quantitative ability score were implicated, interpretation would have to be based on a more general ability construct such as crystallized ability (Gc), not verbal ability alone. Both the ability and the sex implication needs to be checked further.

The Seibert-Snow Study

An earlier project of one of the present authors investigated the use of motion picture tests to obtain measures of cognitive abilities not measurable via printed media. The results of these studies were given in a series of unpublished reports (Seibert & Snow, 1965; Snow and Seibert, 1966; Seibert, Reid, & Snow, 1967).

One aspect of that research was of particular importance in the present program. A series of motion picture tests had been constructed to approximate the laboratory conditions used by Averbach and Coriell (1961) to demonstrate an "erasure" or backward masking effect in the visual system. The films, called Short Term Visual Memory (STVM) I, II, and III were composed of items each of which presented a randomly constructed eight-letter array, with some form of marker appearing on the screen at a variable delay interval before or after the array to mark one of the letters. In each item the array appeared on the screen for 31 msec.; the marker appeared either 52 msec. before the array, or 10, 94, 177, 260, 344, 428, or 510 msec. after the array had left the screen. The subject's task in each item was to record the designated letter on an answer sheet. Each of eight letter positions was randomly paired with each of the eight delay intervals, producing 64 items for each of the three tests and a possible score of 0 to 8 at each delay interval for each test. STVM I used a bar marker appearing adjacent to the letter it marked, STVM II used a circle marker around the letter position it marked, and STVM III used a bar marker appearing simultaneously with the letter array and a circle marker around the marked position at one of the delay intervals. It was this third test that was planned to yield the characteristic curve that has since come to be designated a Type B curve for meta-contrast in more recent literature (Kahneman, 1968; Turvey, 1973).

The principal finding was described by Snow (1976b). Briefly, average performance showed the expected curve, with a pronounced masking effect in the vicinity of the 94 msec. delay interval. But individual differences were large at each of the delay intervals. An ability factor largely based on other film tests and called "perceptual integration" correlated significantly with STVM III performance at delays less than 94 msec., while a verbal facility factor accounted for more individual difference variance at later delay intervals. The results were interpreted as supporting a two-stage conception of initial information processing, with different abilities associated with each stage.

Procedure

Subjects. Of the 34 subjects who participated in the Chiang-Atkinson experiment, 25 (11 males, 14 females) also participated in the present experiment as paid volunteers. Of the 9 subjects who did not participate in both studies, 4 had either graduated or were overseas, 3 could not be contacted, and 2 were unwilling to participate.

Reference test battery. Ten printed tests and five motion picture tests were administered to all subjects. Five printed tests came from the ETS Kit (French, Ekstrom, & Price, 1963). These were: Identical Pictures, Hidden Figures, Card Rotations, Paper Folding, and Surface Development. Other printed tests were: Group Embedded Figures Test (Oltman, Roskin, & Witkin, 1969), an adaptation of Matching Familiar Figures (Zelniker, Jeffrey, Ault, & Parsons, 1972), Ravens Progressive Matrices (Series E; Raven, 1938), Camouflaged Words (Guilford, 1967), and Word Transformations (Guilford, 1967).

The film tests originated in earlier research of the senior author, as previously noted. The Short Term Visual Memory tests were described above. STVM I was used here primarily as practice. Only the first 16 items were administered. STVM II was not used. STVM III, which is intended to provide the masking curve was administered in its entirety. In addition, the following three film tests were included.

Film Memory III is a short silent film showing two young adults interacting on a city street. Subjects view the film with instructions to "pay attention to what happens in the film. You will be asked questions about it later." They are then given a page of true-false questions about events in the film and their spatial and temporal relationships, and are told that the questions follow the time sequence in the film and must be answered in that order.

In Sequential Words, each item presents a six letter adjective, one letter after another. Letters appear in a fixation box at the center of the screen. The letters of each word are thus temporally spaced, but not spatially separated. Each letter appears on the screen for 31 msec. separated by 62 msec. of blank screen.

In Successive Perception III, each item presents a still photograph of some common object which the subject must identify by writing its name. On any given frame, portions of the picture are obscured by one of a series of eight overlay mats. Each mat represents a 16 x 16 grid from which 32 cells have been identified randomly and removed. With a mat change every 42 msec, the subject never sees the complete photograph at one point in time, but over one second (three complete mat change cycles), all details of the photo appear three times.

Handedness was assessed by a questionnaire distributed at the beginning of the group session. Eyedness was determined by asking subjects to hold a pencil about 20 inches in front of their faces and then to align it with a vertical line drawn on the blackboard at the front of the auditorium. Subjects were instructed to close one eye and then the other and record under which condition the pencil appeared to be more significantly out of alignment.

Another questionnaire asked for self-report of corrected vision and whether glasses or contact lenses were worn. Subjects were also asked to rate their effort in the previous Chiang-Atkinson experiment and general performance expectations for tests they were about to take in the present experiment. At the close of the group session, subjects again rated their effort and performance on the tests. The motivational data are not examined in this report, however.

Testing sessions. Each subject participated in a three-hour group session and a one-hour individual session. In all, four group sessions were conducted to accommodate subjects' schedules. Ravens Progressive Matrices, Matching Familiar Figures, Surface Development, and Camouflaged Words were administered during the individual session. All other tests were given during the group session. Standard instructions were used with all tests.

The group sessions were held in a large group instruction room with fixed seating and a graded floor. Subjects were assigned randomly to every other seat near the center of the room in the fourth, fifth, and sixth rows. Maximum viewing angle was four seats from the centerline. Viewing angle and viewing distance were taken as individual difference measures for each subject.

Results

The data analysis aimed first at describing the pattern of relationships among the tests administered by this project and then at their relation to measures available from the Chiang-Atkinson work. Multiple regression and factor analytic techniques were used in addition to simple correlations for these purposes. It was recognized of course that analyses of this sort on a sample of 25 subjects would not provide stable estimates of population values and could not sustain conclusions. It was hoped, however, that the data would display some of the expected patterns and might provide new clues. Processed data and basic scatterplots can serve as checks on one another, even in small samples. The basic plots would in addition show some of the distributional characteristics to be expected in further Stanford samples.

Analysis of the reference test battery. Table 1 shows order of administration and descriptive statistics. Table 2 provides the matrix of intercorrelations for the reference tests, and Table 3 gives the results of a factor analysis of this matrix. The analysis used a principal components solution, selecting factors with eigenvalues greater than 1.00, followed by varimax rotation. Part scores for the STVM III delay intervals were not included here.

- - - - - - - - - - - - - -

Tables 1, 2, & 3 about here

- - - - - - - - - - - - - -

The tests were chosen primarily to represent the nonverbal side of a general hierarchical model of ability organization. That model posits the division of general mental ability, at the top of the hierarchy, into crystallized-verbal ability (G_c), fluid-analytic ability (G_f) and visualization ability (G_v). One or another of these constructs accounts for many of the aptitude-instructional treatment interactions found in previous literature (Snow, 1976a). Lower in the hierarchy the more specialized abilities appear, such as memory span, perceptual speed, visual memory, and the like. These deserve attention here, along with the more general factors, because they seem relatively close to the kinds of tasks often used in research on cognitive processes. Accordingly, the test battery was composed of four tests requiring some form of disembedding analysis of figural or verbal stimuli in addition to the Raven abstract reasoning task (G_f), three spatial tests (G_v), two perceptual speed tests, the Chiang-Atkinson digit span measure, and motion picture tests thought to represent several other aspects of short-term visual processing and memory.

Table 1

Tests, Order of Administration,
Means, Standard Deviations (SD), and Reliabilities (N=25)

Test	Order	Mean	SD	Reliability
Raven Matrices, Series A-E	12	56.04	3.81	.78[a]
Embedded Figures	7	16.40	2.08	.68
Hidden Figures	5	15.56	6.40	.82
Surface Development	14	49.12	11.42	.90
Card Rotation	2	170.32	38.08	.88
Paper Folding	8	14.56	3.93	.88
Match. Famil. Figs., errors	13	4.88	3.66	.79[b]
Identical Pictures	1	87.40	8.57	.78
Camouflaged Words	15	10.60	3.85	.41
Word Transformations	11	16.16	3.17	.80[b]
Sequential Words	10	19.56	8.51	.59
Successive Perception III[c]	6	0.00	.77	.68
Film Memory III	9	24.36	2.99	.81[b]
Short Term Visual Memory I[c]	3	0.00	.77	.66
Short Term Visual Memory III	4	47.00	6.80	
Delay 1 -52 msec.		6.92	1.15	.46[b]
Delay 2 10 msec.		5.48	1.78	.58[b]
Delay 3 94 msec.		3.20	1.19	.71[b]
Delay 4 177 msec.		4.92	1.80	.63[b]
Delay 5 260 msec.		6.20	1.38	.53[b]
Delay 6 344 msec.		6.56	1.00	.60[b]
Delay 7 428 msec.		6.88	1.20	.57[b]
Delay 8 510 msec.		6.84	1.14	.69[b]

Note. Reliabilities not superscripted are parallel forms estimates stepped up by Spearman-Brown.

[a]Mean intercorrelation among the five parts corrected by Spearman-Brown.

[b]Communalities as lower bound estimates of reliability. See Tables 3 and 4.

[c]Residualized for differences in seating distance.

Table 2

Matrix of Intercorrelations Among Administered Tests (N=25)

Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Embedded Figures	--	60	50	41	58	31	36	-36	-06	42	39	20	-08	23	14
2 Hidden Figures		--	38	42	41	55	40	-32	-06	46	25	04	-17	23	34
3 Card Rotations			--	51	70	44	08	-60	28	12	23	-03	-36	21	02
4 Paper Folding				--	73	36	46	-30	23	49	14	05	-23	55	10
5 Surface Development					--	30	40	-42	16	34	22	09	-43	37	14
6 Camouflaged Words						--	22	-35	10	46	02	-12	08	10	18
7 Word Transformations							--	-28	11	77	39	16	12	39	18
8 Match. Famil. Figs., Errors								--	-09	-35	-57	-24	11	-26	-23
9 Identical Pictures									--	-02	-04	-24	01	09	-36
10 Raven Matrices										--	20	15	28	37	12
11 Digit Span											--	23	-10	40	20
12 Sequential Words												--	05	42	38
13 Film Memory III													--	-38	-14
14 Short Term Visual Memory I															39
15 Successive Perception III															

NOTE: Decimals omitted
r of 0.40 is significant at .05 level.

Table 3

Results of Factor Analysis of the Matrix of Table 2 (N=25)

Variable	Unrotated Factors I	II	III	IV	V	h^2	Rotated Factors F1	F2	F3	F4	F5
Embedded Figures	-71	00	-05	-23	-13	58	18	22	57	40	11
Hidden Figures	-70	02	-16	-43	18	73	17	24	75	10	26
Card Rotations	-66	-53	24	-18	-23	87	51	-12	56	44	-29
Paper Folding	-75	-25	-02	27	33	81	59	55	36	03	-17
Surface Development	-78	-33	20	06	14	78	66	26	45	23	-12
Camouflaged Words	-54	-21	-40	-44	09	70	-03	17	82	00	-04
Word Transformations	-64	27	-42	37	07	80	01	85	19	21	01
Match. Famil. Figs., Errors	66	-02	-11	09	58	79	-12	-08	-35	-80	02
Identical Pictures	-10	-61	-14	51	-16	69	19	17	-06	07	-78
Raven Matrices	-65	25	-60	15	11	88	-13	82	41	11	04
Digit Span	-51	31	20	14	-57	74	06	19	-01	83	14
Sequential Words	-25	65	27	14	-10	59	08	26	-25	40	54
Film Memory III	25	28	-76	02	-28	81	-85	28	00	-01	-11
Short Term Visual Mem. I	-60	27	34	44	26	81	61	55	-13	23	26
Successive Perception III	-35	57	28	-32	25	68	19	11	16	10	77

Note: Decimals omitted.

As expected then, the unrotated factor matrix showed a general factor dominated by the spatial tests, and by the disembedding measures and the Raven (G_f and G_v combined). The rotation procedure then distributed these among three smaller factors. The first of these is bipolar, reflecting the negative correlations between Film Memory III and the spatial ability and STVM tests seen also in the original correlation matrix. This suggests some kind of opposition among the skills required in those tests. The second factor is defined by the Raven and Word Transformation tests, and appears peculiarly specific. It derives from the single highest correlation in the original matrix. Factor 3 includes three of the four disembedding tests, with high loadings for Camouflaged Words, Hidden Figures, and Embedded Figures. The relatively low loading of the Embedded Figures Test could be explained as a result of a ceiling effect noticeable in Table 1. This factor also includes significant loadings from the spatial tests and the Raven. The fact that the general unrotated factor was split in these three ways is perhaps unimportant. The separation of Raven and Word Transformation from the other spatial and disembedding tests was not expected, but varimax rotation can capitalize on one or two aberrant relations, as seems to be the case here. The rest of the correlations in the fluid-analytic cluster do not seem to justify this separation.

On the other hand, it may be that Raven requires reasoning skills or strategies differing somewhat from those required in the spatial and disembedding tests. This deserves further check. The analysis of the spatial tests definitely seems worth pursuing. The close association of spatial tests and disembedding tests, together with the negative relation of these to the film memory measure, may suggest a network of complementary and opposing processes. This pattern was expected, based on reports of Witkin's research on field-independence-field dependence (Witkin, 1973) and on some prior data of the authors. The film memory test was constructed to obtain a relatively passive, global and incidental kind of nonverbal memory, akin to memory for faces and other incidental learning tasks associated by Witkin with field dependence. Film Memory III and Hidden Figures defined the two aptitudes shown by Koran, Snow, and McDonald (1971) to interact with video versus transcript-based training treatments in an experiment on the acquisition of teaching skills. In that experiment, the Hidden Figures Test (Part 1) was correlated -0.10 with Film Memory III. The multiple factor representation of spatial measures obtained here could imply a division of their variance between abstract reasoning skills involved in apatial analysis and active-selective visual imaging processes which stand in contrast to the passive visual imaging presumed to be involved in Film Memory III. The negative correlations that dominate this division will need closer inspection in more substantial samples.

Factor 4 is defined by MFF errors and visual Digit Span, and is best thought of as visual memory span. Factor 5 is another bipolar factor, arising from the negative correlations of Identical Pictures with Successive Perception III and Sequential Words. The latter two tests helped define the factor called "Perceptual Integration" in the Seibert-Snow studies described earlier. The factor here may contrast the rapid sequential perception forced upon the subject by these film tests with performance when speed is under the subject's control. These factors were both expected, though it was thought that Identical Pictures would relate positively to Factor 4 rather than negatively to Factor 5.

Descriptive analysis of backward masking measures. Table 4 shows the intercorrelations and factor matrices for the eight subtests of STVM III, each representing a different delay interval. Again, the factor analysis was by principal components, with factors showing eigenvalues greater than 1.00 rotated using varimax. The solution is easily understood in terms of the test design, and prior data on it.

- - - - - - - - - -

Table 4 about here

- - - - - - - - - -

Factor 1 reflects performance before and after the masking effect, while Factor 2 shows high loadings for the delay intervals in the region where masking is presumably strongest. It is important to note that the means and standard deviations of STVM 1, 5, 6, 7, and 8 are comparable, while the means and the standard deviations of STVM 2, 3, and 4 differ substantially from these. (See Table 1.) STVM III-3 and III-4 have lower means than the other delay intervals, while STVM III-2 and III-4 have higher standard deviations than the other delay conditions. The factor scores derived from the two factors appear in subsequent analyses as STVM-F1 and STVM-F2. (See Snow, 1976b, Figure 9, for a comparison of the average masking curve found in this sample with those obtained in two previous samples.)

Descriptive analysis of parameters and other measures. Means and standard deviations for the task parameters and other variables not entered into the factor analyses are given in Table 5. Intercorrelations among the parameters are presented in Table 6. Corresponding values for the total sample of 30 subjects reported by Chiang and Atkinson are shown in parentheses. Differences

Table 4

Correlations and Factor Analysis of Number Correct Scores at Each of Eight STVM III Delay Intervals (N=25)

	1	2	3	4	5	6	7	8	Unrotated I	Unrotated II	Unrotated h^2	Rotated F1	Rotated F2
Delay 1 (-52 msec.)	--	16	19	45	14	32	35	49	61	-29	46	68	-01
Delay 2 (10 msec.)		--	50	27	22	-04	41	24	52	55	58	23	72
Delay 3 (94 msec.)			--	33	30	-20	22	08	45	71	71	10	83
Delay 4 (177 msec.)				--	70	25	39	43	79	-01	63	72	32
Delay 5 (260 msec.)					--	15	41	49	72	06	53	62	36
Delay 6 (344 msec.)						--	16	29	33	-70	60	59	-49
Delay 7 (428 msec.)								68	75	-01	57	69	31
Delay 8 (510 msec.)								--	78	-28	69	82	07

Note: Decimals omitted.

between the values reflect changes in the sample size from 30 to 25 subjects. There are a few notable discrepancies between the two sets of correlations. First, the two digit span variables were more highly intercorrelated here than they were in the full sample (.87 versus .46). Second, differential correlations between the digit span measures and other parameters observed in the full sample were reduced in the present sample. Finally, the visual search intercept and slope correlated slightly negatively in the full sample but positively in the present sample. However, neither correlation is significantly different from zero. The other correlations were quite similar to those reported for the full Chiang-Atkinson sample.

- - - - - - - - - - - - -
Tables 5 & 6 about here
- - - - - - - - - - - - -

Correlations between parameters and ability measures. Correlations between the ability factor scores, STVM factor scores, other subject classification variables (such as sex, eyedness, and handedness), ability measures not included in the factor analysis, and the task parameters from the Chiang-Atkinson study are shown in Table 7. Since interpretation of the factor scores is tenuous in this small sample, raw correlations between individual tests or subject classification variables and each of the three average parameters are given separately in Tables 8, 9, and 10. In each table, the correlations are rank ordered. Since faster performance is indicated by lower scores on the intercept and slope parameters, correlations with these variables are ordered from negative to positive.

- - - - - - - - - - - - - - - - -
Tables 7, 8, 9, & 10 about here
- - - - - - - - - - - - - - - - -

The pattern of correlations with average slope in Table 8 suggests that rapid processing of tachistoscopically presented alphabetic characters is negatively related to the slope parameter. This is consistent with Hunt's results, and implies that individual differences in stimulus encoding and matching are involved in these film tests as well as in the memory search slope. On the other hand, the large positive correlation between SAT-V and the slope contradicts Hunt's finding. This correlation was not unexpected, as Chiang and Atkinson found a correlation of .72 between SAT-V and average slope for females in the full sample, and this subsample contained 14 females

Table 5

Means and Standard Deviations of Parameters and Variables

Not Entered Into the Factor Analysis (N=25)

Test	Mean	S.D.
Scholastic Aptitude Test-Verbal[a]	617.09	69.66
Scholastic Aptitude Test-Quantitative[a]	661.43	76.56
Average Intercept	455.16	76.60
Average Slope	44.00	20.03
Raven Time	26.06	9.78
Matching Familiar Figures Time	236.40	121.56
Sex	-0.12	1.01
Handedness Questionnaire	2.24	3.49
Eyedness	0.80	1.65
Memory Search Intercept	463.28	81.72
Memory Search Slope	44.36	21.10
Visual Search Intercept	466.68	71.84
Visual Search Slope	43.20	20.63
Digit Span, Total Correct	30.34	3.16
Digit Span, Ave. Set Size	7.42	0.86
Seating Distance	1.76	0.83
Seating Angle	0.00	0.82

[a]For all calculations involving SAT-V and SAT-Q, N=23 due to missing data on these variables for two subjects.

Table 6

Intercorrelations of Chiang-Atkinson Parameters (N=25)

		Visual Search		Memory Search		Average		Digit Span	
		Intercept	Slope	Intercept	Slope	Intercept	Slope	Total	Avr. Set Size
Visual Search	Intercept		22 (-29)	87 (97)	05 (04)	88	14	-46 (-04)	-52 (-35)
	Slope			38 (43)	84 (83)	31	96	-13 (15)	-26 (-08)
Memory Search	Intercept				09 (10)	92	24	-33 (00)	-54 (-33)
	Slope					06	96	-16 (13)	-16 (04)
Average	Intercept						19 (24)	-37	-54 (-30)
	Slope							-15	-21 (-06)
Digit Span	Total								87 (46)
	Avr. Set Size								

<u>Note</u>. Values in parentheses are from Chiang and Atkinson (1976; N=30) Decimals omitted.

Table 7

Intercorrelations of Ability Factors with Task Parameters and Other Variables (N=25)

Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1 Short Term Visual Memory-F1		00	28	29	12	-11	04	00	24	04	-19	03	-09	-16	00	01	-01	-07	06	-30	-19	-15	-15	25
2 Short Term Visual Memory-F2			-03	18	-30	38	38	06	28	-30	-19	15	23	17	-12	-07	-16	-18	-33	-16	24	32	-31	-15
3 F1				00	00	00	00	28	25	50	-13	-20	01	16	-04	-04	46	-15	45	-10	18	06	10	-03
4 F2					00	00	00	07	23	-32	-02	-02	-06	02	14	04	-14	08	-09	-12	07	19	16	10
5 F3						00	00	39	34	-26	29	11	29	30	37	-17	-29	36	-26	19	11	-01	34	10
6 F4							00	-17	20	-40	-21	05	50	42	-27	06	-44	-20	-51	-21	77	83	-34	-14
7 F5								-13	19	-01	-08	22	-10	16	-25	-13	-01	-05	-01	-09	06	14	-01	24
8 Scholastic Aptitude Test-Verbal[a]									37	11	50	-13	16	11	46	08	24	38	04	59	01	-13	33	-12
9 Scholastic Aptitude Test-Quantitative[a]										-12	15	03	30	43	33	36	-07	17	-23	13	35	23	00	-38
10 Average Intercept											19	-36	-18	-39	-08	12	92	06	88	31	-37	-54	18	19
11 Average Slope												-02	29	-17	50	06	24	96	14	96	-15	-21	00	10
12 Raven Time													26	23	05	-27	-37	04	-42	-08	05	-02	-40	-10
13 Matching Familiar Figures Time														41	20	-13	-10	31	-33	25	48	24	-23	08
14 Sex															13	06	-34	-14	-43	-18	75	62	06	-30
15 Handedness Questionnaire																17	01	52	-18	45	02	-16	16	-22
16 Eyedness																	06	02	-06	08	05	08	-10	-15
17 Memory Search Intercept																		09	87	38	-33	-54	27	18
18 Memory Search Slope																			05	84	-16	-16	-04	15
19 Visual Search Intercept																				22	-46	-52	34	20
20 Visual Search Slope																					-13	-26	04	05
21 Digit Span, Total Correct																						87	-16	-24
22 Digit Span, Avr. Set Size																							-21	-24
23 Seating Distance																								00
24 Seating Angle																								

Note: Decimals omitted; r = 0.40 significant at .05 level

[a] For all calculations involving SAT-V and SAT-Q, N-23 due to missing data on these two variables for two subjects.

Table 8

Ordered Correlations of Average Slope with Ability Variables (N=25)

Variable	Average Slope
STVM III- Delay 1	-44
STVM III- Delay 4	-33
Sequential Words	-27
STVM III- Delay 3	-26
STVM III- Delay 5	-24
Sex	-17
Identical Pictures	-13
STVM III- Delay 8	-09
Successive Perception III	-09
STVM III- Delay 2	-07
Short Term Visual Memory I	-05
Word Transformation	-05
Card Rotations	-04
Raven Time	-02
MFF Errors	-02
Embedded Figures	02
Surface Development	02
Raven	06
Eyedness	06
STVM III- Delay 6	06
STVM III- Delay 7	08
Hidden Figures	11
Paper Folding	13
SAT-Q	15
Film Memory III	18
Camouflaged Words	25
MFF Time	29
Total Left	50
SAT-V	50

Note: Decimals omitted

Table 9

Ordered Correlations of Average Intercept with Ability Variables (N=25)

Variable	Average Intercept
Film Memory III	-47
Raven	-45
Hidden Figures	-42
Word Transformations	-39
Sex	-39
Raven Time	-36
STVM III- Delay 3	-36
Embedded Figures	-27
Camouflaged Words	-27
STVM III- Delay 5	-20
MFF Time	-17
STVM III- Delay 2	-13
SAT-Q	-12
STVM III- Delay 4	-10
Successive Perception III	-09
Total Left	-08
Sequential Words	-05
STVM III- Delay 8	-04
Identical Pictures	-04
Card Rotation	-02
STVM III- Delay 7	03
STVM III- Delay 6	04
Paper Folding	05
Short Term Visual Memory I	08
Eyedness	10
SAT-V	11
Surface Development	13
STVM III- Delay 1	24
MFF Errors	26

Note: Decimals omitted

Table 10

Rank Ordered Correlations of Digit Span with Ability Variables (N=25)

Variable	Total Correct	ASSLC
Sex	75	62
Embedded Figures Test	49	39
MFF Time	48	24
Surface Development	46	22
SAT-Q	35	23
Card Rotation	33	23
Word Transformation	30	39
STVM III- Delay 3	29	37
Hidden Figures	24	25
Paper Folding	18	14
Sequential Words	17	23
Successive Perception III	15	17
Raven	13	20
Short Term Visual Memory I	11	19
Camouflaged Words	06	02
Eyedness	05	08
Raven Time	05	-02
STVM III- Delay 4	05	18
STVM III- Delay 2	03	05
Total Left	02	-16
SAT-V	01	-13
STVM III- Delay 5	01	05
Identical Pictures	-02	-04
STVM III- Delay 7	-12	-16
STVM III- Delay 1	-14	-10
STVM III- Delay 6	-14	-22
Film Memory III	-22	-16
STVM III- Delay 8	-26	-10
MFF Errors	-59	-57

Note: Decimals omitted

and 11 males. However, this correlation and the comparable correlation between total left and the slope parameter both dropped to .35 when one left-handed female outlier was removed from this sample.

The correlations with the average intercept shown in Table 9 display another interesting pattern. None of the positive correlations is significantly different from zero, but those negative correlations that are significant, and several others that are moderately high, come mainly from two types of tests, and all are complex tests. However, Film Memory III seems to be a distinctly different test psychologically from the others, all of which can be interpreted as reflecting fluid-analytic ability (as noted in discussing Factors 1, 2, and 3 in Table 3). The correlations between Film Memory III and these other tests were close to zero. Yet each gave a strong negative relation with the intercept parameter. This implies that the intercept measure is composed of at least two independent components, and that these two types of tests differ in their emphasis on these components. It is also to be noted that Digit Span correlated -.54 with average intercept in this sample, but showed little relation to the other ability tests in these two clusters. This implies still a third component in the intercept scores.

Perhaps a "workbench" model of short-term memory is relevant here (cf. Klatzky, 1975). According to this model, the tradeoff between work space and storage space on a workbench is analogous to the tradeoff between processing space and storage space in short term memory. With more (or "bigger") items in storage, the processing capacity is reduced for a short term memory of a given size. A subject with a large capacity (high digit span score) would have more processing "space" available than a subject with a smaller capacity for a given task. Thus, greater short term memory capacity would be associated with faster responses (i.e., lower intercepts); hence, the negative correlation between intercept and digit span.

The correlations between average digit span score and the other ability variables shown in Table 10 lend some support to this model, although there are a number of puzzling discrepancies. The correlation between sex and digit span reflects a mean difference of 4.6 points in average digit span score ($\bar{X}$ males = 32.9, $\bar{X}$ females = 28.3) or a one point differential in the corresponding maximum digit span scores ($\bar{X}$ males = 8.0, $\bar{X}$ females =

negative correlation between MFF errors and Digit Span (that produced Factor 4 in Tables 4 and 5) can be viewed as additional support for the workbench model noted above. This test requires that the subject compare a stimulus line drawing with six very similar alternatives, only one of which is exactly the same as the stimulus. There is a multitude of details which must be encoded and compared across figures, and errors can result from a failure to encode and compare relevant features or a failure to remember which alternatives have already been eliminated. Thus, students with a larger memory span would be expected to perform better on the test. As one goes down the list in Table 10, it does appear that each test in turn seems to require less processing space, or less storage space, or both, at least until Film Memory III and the long delay trials of STVM III. These would seem to require more storage space, if less processing.

Multiple regression analyses of parameter measures. The correlation patterns observed above can be summarized by entering selected ability tests (and other measures) into multiple prediction equations for each parameter. The slope and intercept parameters are of principal interest here. Table 11 shows the results of such analyses with each of these parameters taken as the criterion to be predicted. Results for the slope show again the involvement of sex and left sidedness along with SAT-V in individual differences in slope scores. The equation for the intercept parameter shows the three relatively independent components mentioned earlier, each accounting for appreciable variance. The theoretical model for the intercept parameter does posit three independent process components: stimulus encoding, binary decision, and response production (See Chiang & Atkinson, 1976; Snow, 1976b). One could hypothesize that the Digit Span, HFT-Raven and Film Memory III tests reflect individual differences in speed in stimulus encoding, decision, and response production, respectively. But it is not clear on the face of it that these three types of tests correspond in any direct way to these three model components.

- - - - - - - - - -

Table 11 about here

- - - - - - - - - -

Table 11

Step-wise Multiple Regressions predicting Average Slope, and Average Intercept from Abilities and Other Subject Variables

Dependent Variable Average Slope						Dependent Variable Average Intercept					
Variable	Order	R	ΔR^2	r	b	Variable	Order	R	ΔR^2	r	b
SATV	1	.50	.25	.50	.10	DSASSLC	1	.54	.29	-.54	-45.63
TOTLEFT	2	.59	.09	.50	1.88	Film Mem III	2	.75	.28	-.47	-14.25
SEX	3	.64	.07	-.17	-7.62	HFT	3	.84	.14	-.41	-4.02
MFFTIME	4	.70	.09	.29	.05	RAVTIME	4	.88	.06	-.36	-2.07
Constant					-34.13	Constant					1259.39

Note. Table includes multiple correlation (R), increment to R^2 (ΔR^2), regression coefficients (b) and Order of variable entered into the equation

Multiple regression analyses of ability tests and factors: Illustrative examples. It is also possible to use processing parameters as predictors of ability scores, and this can illustrate how one might examine an important assumption about the form of processing model needed to account for ability differences. Most information processing models assume a sequence of independent process components or stages. Ability variance then would be accounted for by a sum of independent variances from different components. But it is also possible that different components interact. This possibility can be checked by including multiplicative terms in the prediction equations. Each analysis fits an equation of the form

$$Y = b_1(S) + b_2(I) + b_3(D) + b_4(S \times I) + b_5(S \times D) + b_6(D \times I) + \text{constant}$$

where: Y = an ability test or factor score to be predicted

S = average slope parameter

I = average intercept parameter

D = digit span score (DSASSLC)

b = regression coefficients for variables entered into the equation.

Thus, two-way interactions among the parameters are entered into the regression equations after the main effects of each parameter. The linear additive assumption would be untenable if interactions among the parameters accounted for more variance in the dependent ability variable than did main effects. A similar question would arise if interactions among ability measures were found to be substantial predictors of processing parameters. It is the case that aptitude variables have been found to show complex interactive effects of this sort in predicting learning outcome in instructional experiments (See Cronbach & Snow, 1977; Snow, 1976a).

In Table 12 ten such analyses are shown. In most cases the amount of ability variance accounted for by parameter main effects and interactions was not high. There were, however, several instances in which interactions were better predictors than main effects. For example, in the regression of Identical Pictures on the parameters, parameter main effects accounted for only 2.6 percent of the variance while their two-way interactions accounted for 33 percent of the variance. This was also the pattern for prediction of Factor 5 scores. Similarly, in the regression of SAT-V on the parameters, the interaction between the intercept and digit span scores accounted for more variance than either did when entered into the equation by itself.

- - - - - - - - - -

Table 12 about here

- - - - - - - - - -

Table 12

Forced Stepwise Multiple Regression of Some Abilities and Ability Factors on the Processing Parameters and Their Interactions

		Factor 1			Factor 2			Factor 3			Factor 4[a]		
Variable	Order	R	ΔR^2	b	R	ΔR^2	b	R	ΔR^2	b	R	ΔR^2	b
Slope	1	.13	.02	.31	.01	.00	.13	.29	.08	.12	.21	.04	-.01
Intercept	2	.56	.29	.05	.33	.10	-.02	.43	.10	.02	.42	.12	-.01
Digit Span	3	.67	.13	3.66	.33	.00	.27	.45	.02	1.23			
S x I	4	.68	.02	.00	.33	.00	.00	.45	.00	.00	.42	.00	.00
S x D	5	.68	.01	-.03	.36	.02	-.02	.45	.00	-.01			
D x I	6	.73	.06	-.01	.39	.02	.00	.48	.02	.00			
Constant				7.56			3.10			-9.16			3.98

		Factor 5			Identical Pictures			SATV			SATQ		
Variable	Order	R	ΔR^2	b	R	ΔR^2	b	R	ΔR^2	b	R	ΔR^2	b
Slope	1	.08	.01	.03	.13	.02	2.40	.50	.25	-4.18	.15	.02	7.79
Intercept	2	.08	.00	.05	.13	.00	-.37	.54	.04	-3.46	.21	.02	-1.79
Digit Span	3	.16	.02	3.21	.16	.01	-13.81	.54	.00	-124.83	.31	.05	9.45
S x I	4	.23	.02	.00	.30	.06	.00	.54	.00	.02	.33	.01	.01
S x D	5	.23	.00	.00	.44	.10	-.28	.55	.01	-.54	.38	.04	-1.54
D x I	6	.48	.17	-.01	.60	.16	.06	.62	.09	.34	.41	.02	.19
Constant				-24.78			174.85			1913.00			777.91

		Factor 1 STVM			Factor 2 STVM		
Variable	Order	R	ΔR^2	b	R	ΔR^2	b
Slope	1	.20	.04	.35	.19	.03	-.02
Intercept	2	.21	.01	.06	.33	.07	-.03
Digit Span	3	.28	.03	3.64	.37	.03	-1.08
S x I	4	.28	.00	.00	.37	.00	.00
S x D	5	.37	.05	-.03	.37	.00	.00
D x I	6	.51	.13	-.01	.42	.04	.00
Constant				-31.15			9.94

<u>Note</u>. Table includes Multiple correlation (R), increment to R^2 (ΔR^2), Regression coefficient (b), and order in which the variables were forced into the regression. Regression coefficients were recomputed after all the variables were forced in.

a. See text.

In these analyses of course, only the slope and intercept parameters are assumed to reflect independent stages of the same processing model, so combinations involving digit span do not test the additive assumption directly. But it is interesting that digit span combines multiplicatively with other parameters in several analyses. Because of the small sample size and the number of variables involved in these computations, these regressions are perhaps best viewed as illustrative examples of a data analytic technique rather than as substantive findings.

Multiple regression analyses of the sort shown in Tables 11 and 12 display two contrasting theoretical perspectives. Correlational research has typically treated ability measures as independent variables to be used to "account for" individual differences in some learning or performance task of interest. The Seibert-Snow (1965) analysis of backward visual masking was of this form. Two ability factors accounted for variance at different delay intervals; they interpreted this as supporting a two-stage model of visual masking. Similar work in the psychomotor area has been reported by Fleishman (1975) who has interpreted patterns of ability-trial intercorrelations as reflecting changes in underlying ability requirements at different stages of practice in motor learning. Experimental research, on the other hand, usually assumes that parameters derived from a model of the experimental task are the basic elements and that cognitive abilities can be explained by reducing them to a set of processing parameters. The work of Hunt, et al. (1973) and R. Sternberg (1977) takes this form. Hunt explains verbal ability as reflecting more basic differences in speed of encoding, etc., while Sternberg dissects reasoning ability into a series of component parameters.

These two theoretical perspectives imply two corresponding ways of analyzing data, but the two need not be mutually exclusive. Alternatively treating abilities as basic and parameters as the variables to be explained, and then reversing the logic and treating parameters as basic and ability constructs as complex variables can yield a richer understanding of both sets of variables.

Analysis of visual masking. One further aspect of the data needs to be explored in this pilot venture. In earlier research with the STVM III task, it was shown that two separate abilities ("perceptual integration" and "verbal facility") related to individual differences in performance at different delay intervals. Rather different mean curves over delay intervals were obtained for subjects labelled high or low on these two abilities (see Snow 1976b).

Using Successive Perception III and SAT-V to mark these two abilities, respectively, it might be possible to replicate the curves obtained earlier, even with this small sample. Further, one can explore comparable relationships between slope and intercept parameters and STVM III performance. This would provide, as well, an illustration of scatterplotting methods in this kind of research.

Males and females were treated separately. For each sex, scores on Successive Perception III and SAT-V were used to form bivariate plots. In Figure 1a, 10 males (one male in the sample had no SAT-V score) are shown divided roughly into four groups, labelled high or low on each ability. The division into these clusters must be made subjectively, but at least scatterplots can be compared across studies; labels cannot. Subjects are identified by number in the plots to facilitate comparison within this study. Figure 1b shows means for these four ability groups separately, across the eight delay interval conditions. The curves do appear to replicate those reported by Seibert and Snow (1965) for an undergraduate male sample. Those high on perceptual integration ability perform relatively well under short delay conditions, while those low on this ability but high on verbal ability do relatively better at later delays. The curves cross at a point near the 94 msec. delay interval, both here and in the earlier study. Also, the one low-low subject shows the poorest performance throughout, as expected.

- - - - - - - - - - -

Figures 1 and 2 here

- - - - - - - - - - -

Figure 2a and 2b provide a comparable analysis of slope and intercept scores for the males with N = 11. In Figure 2a three groups of subjects seem discernable in the scatterplot. Figure 2b shows mean curves on STVM III for these groups. The three subjects with the lowest slopes (i.e., who are fast in memory search and matching regardless of set size) and higher intercepts (LH) show a curve similar to that obtained for subjects low in perceptual integration and high in verbal ability in Figure 1b. Those with high slopes and low intercepts (HL) give a curve similar to the high perceptual integration-low verbal ability curve of Figure 1b. Note that the two groups are not composed of exactly the same subjects in the two figures. The high slope-high intercept group (HH) in Figure 2a produces a curve that is misleading. If this group is divided further into two groups of two subjects each, the resulting curves bound the others; subjects #14 and #22 give the lowest average curve while subjects #24 and #25 show a curve indistinguishable from that of the HL group.

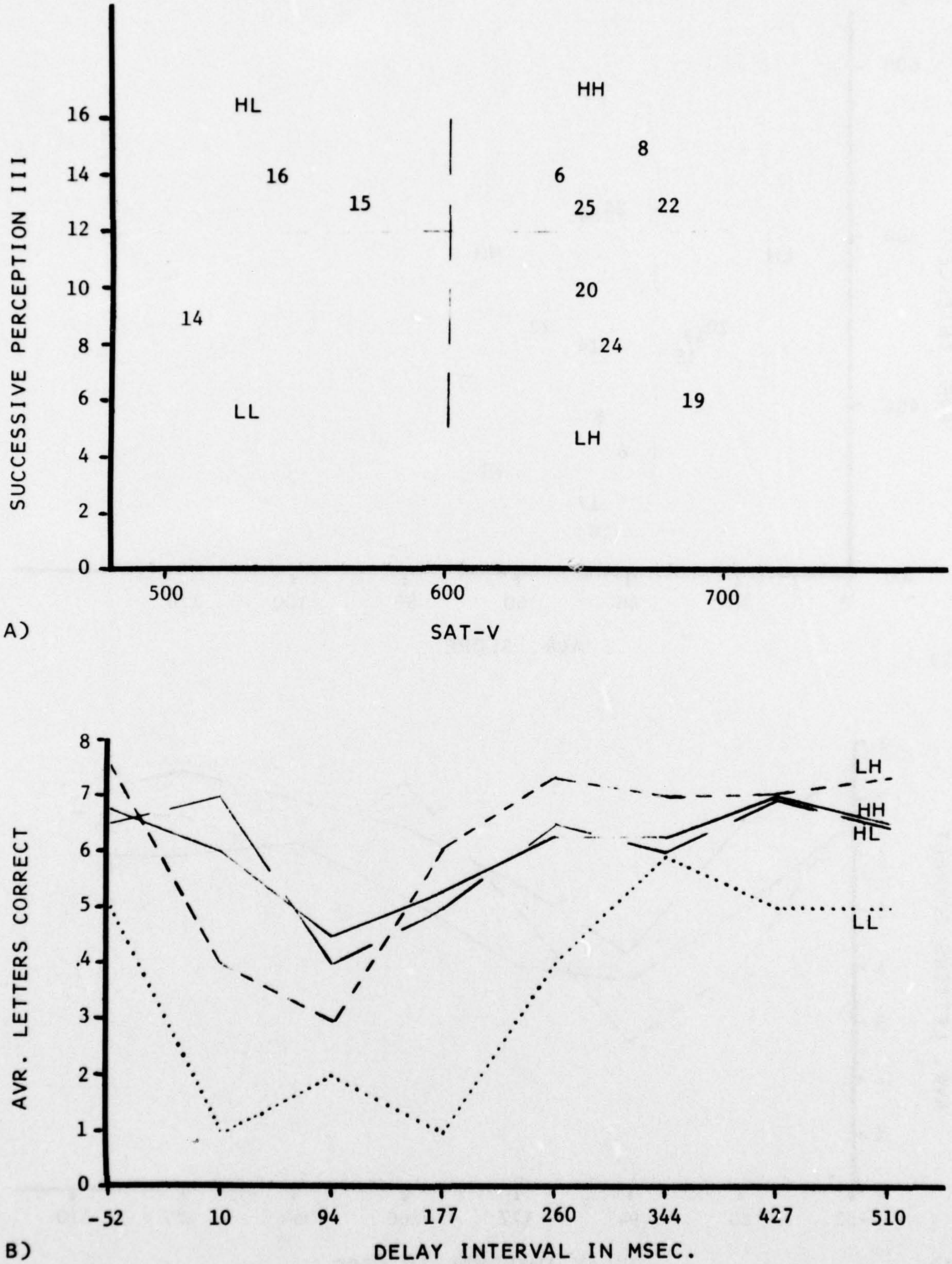

Figure 1. **Bivariate scatterplot identifying groups of male subjects as high or low on Successive Perception III and SAT-V ability scores a) and mean performance of these groups as a function of marker delay interval on the STVM III task b).**

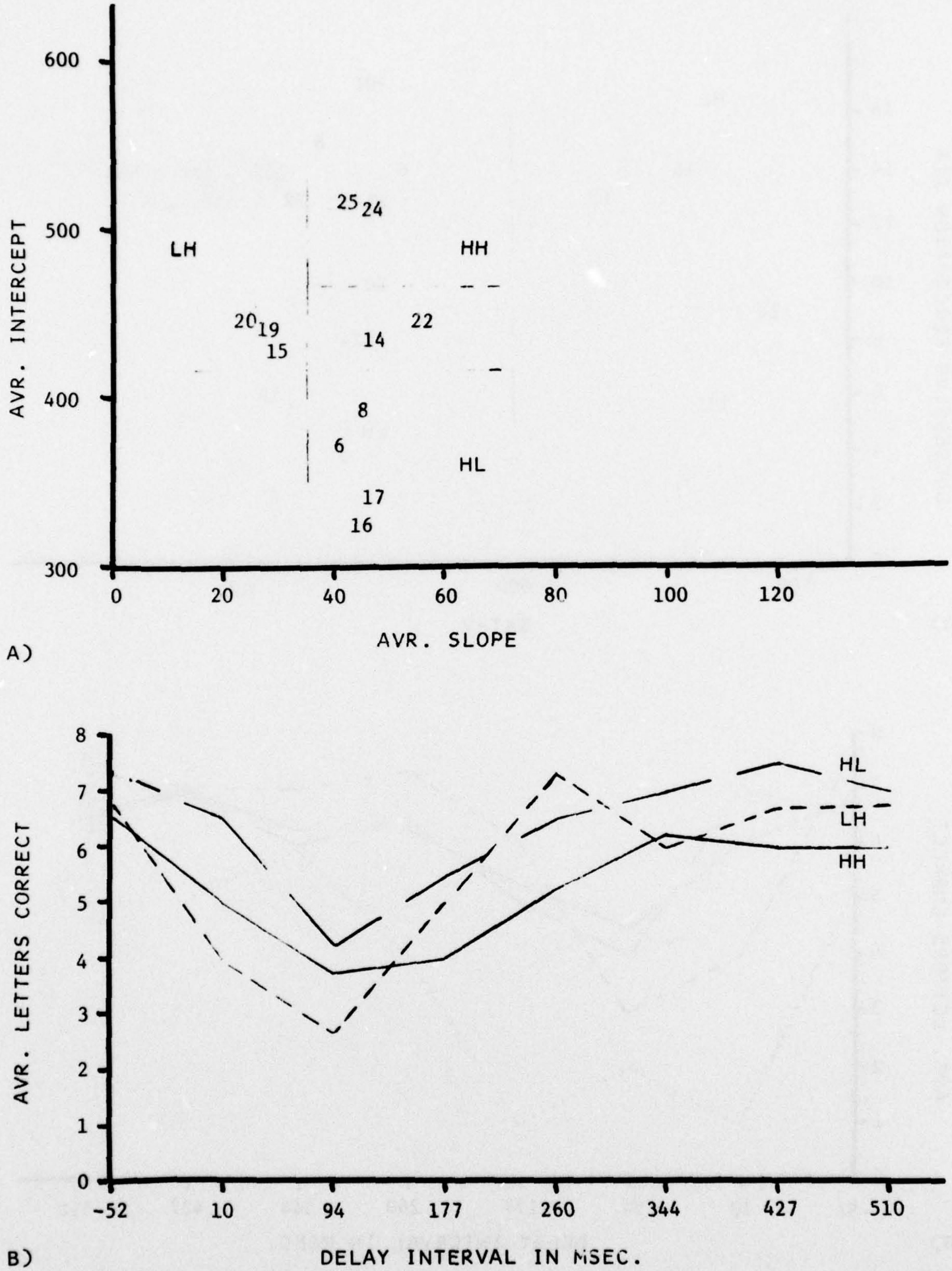

Figure 2. Bivariate scatterplot identifying groups of male subjects as high or low on slope and intercept parameter scores a) and mean performance of these groups as a function of marker delay interval on the STVM III task b).

It is not clear exactly what to make of these results. The data reinforce the suggestion from earlier work that two distinct ability factors account for performance in two regions of the visual masking curve and that the slope and intercept parameters from the Chiang-Atkinson study give partially similar results, for males at least. But a much larger sample and an improved visual masking task will probably be needed to probe these relationships more deeply.

The data for females gave no similar trends. While there are differences in the STVM III curves for different groups of subjects (see Figures 3ab and 4ab), there does not seem to be much that can be said as a result. This does, however, underscore the implication from Chiang and Atkinson that sex differences in this domain deserve further consideration. Note that in Figure 3a females did not fall neatly into quadrants; there were two clusters (ML and MH) in the middle range of scores on Successive Perception III. (Subjects #5 and #18 were not included in the means in Figure 3b.) Also it was clear that the slope x intercept bivariate distributions for males and females were quite different. (Compare Figures 2a and 4a.)

- - - - - - - - - - - -
Figures 3 and 4 here
- - - - - - - - - - - -

Discussion

Correlational analysis in small samples cannot be counted upon to sustain conclusions. So we shall draw none. The methodology used here is otherwise sound, however, and illustrates how correlational and scatterplotting techniques can be used for exploratory purposes in future research. Moreover, even with this small sample, some of the correlation patterns obtained suggest hypotheses worth further study. The following observations may help to guide that work.

1. The slope parameter defined by Hunt and Chiang-Atkinson from visual memory search tasks shows moderate relation to verbal ability among males. Faster search rates seem associated with higher verbal ability. Individual differences on this parameter also show relation to other ability tests involving rapid short term processing of discrete symbols. The fact that data for females in the Chiang-Atkinson sample seem not to show these relations may imply an important sex difference, but may also arise from distributional anomalies in this small sample of females.

2. The intercept parameter derived from such search tasks appears more complex than the slope parameter, as the underlying model for these tasks would predict. Individual differences in intercept scores seem to include

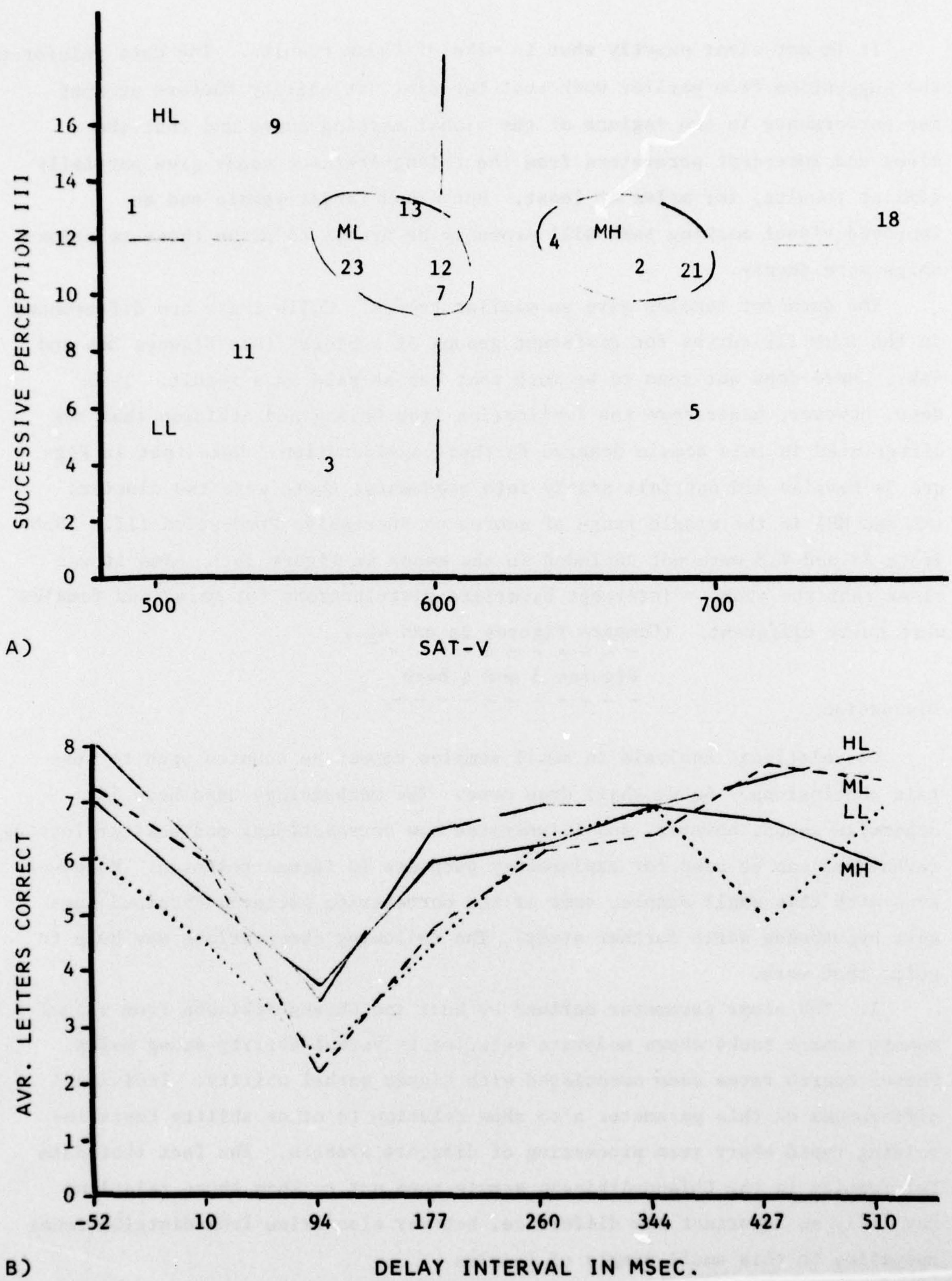

Figure 3. Bivariate scatterplot identifying groups of female subjects as high or low on Successive Perception III and SAT-V ability scores a) and mean performance of these groups as a function of marker delay interval on the STVM III task b).

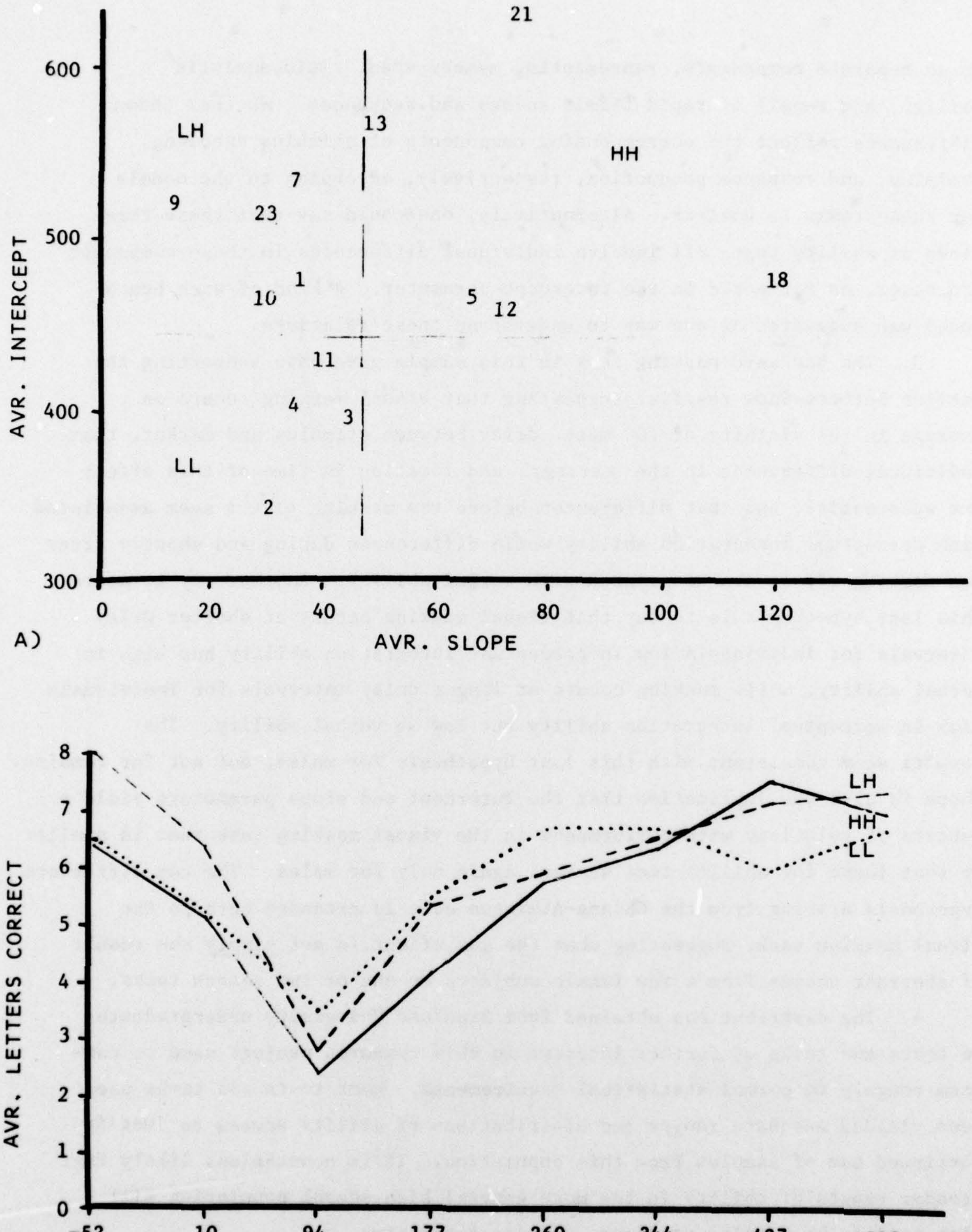

Figure 4. Bivariate scatterplot identifying groups of female subjects as high or low on slope and intercept parameter scores a) and mean performance of these groups as a function of marker delay interval on the STVM III task b).

three separate components, representing memory span, fluid analytic ability, and recall of rapid filmic scenes and sequences. Whether these differences reflect the corresponding components of stimulus encoding, decision, and response production, respectively, according to the models for these tasks is unclear. Alternatively, one could say that these three kinds of ability tests all involve individual differences in these component processes, as reflected in the intercept parameter. A kind of work bench model was suggested as one way to understand these relations.

3. The backward masking task in this sample gave data supporting the earlier Seibert-Snow results, suggesting that visual masking occurs on average in the vicinity of 100 msec. delay between stimulus and marker, that individual differences in the strength and location in time of this effect are substantial, and that differences before the masking effect seem associated with perceptual integration ability while differences during and shortly after the masking effect are associated with verbal ability. Another way to state this last hypothesis is to say that visual masking occurs at shorter delay intervals for individuals low in perceptual integration ability but high in verbal ability, while masking occurs at longer delay intervals for individuals high in perceptual integration ability but low in verbal ability. The results seem consistent with this last hypothesis for males, but not for females. There is also the implication that the intercept and slope parameters yield a pattern of relations with performance in the visual masking task that is similar to that found for ability test scores, again only for males. The sex difference hypothesis arising from the Chiang-Atkinson data is extended here to the visual masking task, suggesting that the sex effect is not simply the result of aberrant scores from a few female subjects on one or two search tasks.

4. The distributions obtained from Stanford University undergraduates on tests and tasks of further interest in this research project seem to conform roughly to normal statistical requirements. Most tests and tasks used here yielded adequate ranges and distributions of ability scores to justify continued use of samples from this population. It is nonetheless likely that broader ranges of ability in the more general high school population will also need to be sampled to assure representativeness.

5. Finally, it appears that regression models of ability test performance using processing component parameters as predictors, and similar models of processing component parameters using ability scores as predictors, can

readily be built to promote understanding of ability-process relations. These models may well need to include terms reflecting the interaction of predictors as well as their main effects.

This last decision, to avoid a priori commitments as to whether task parameters or ability constructs are more psychologically fundamental seems particularly important. It may be that traditional ability tests tap higher-order cognitive processes than do the task parameters, and there was some indication of this in the present data. On the other hand, ability tests are usually short and sample only a few items, while the information processing tasks used in this study involved hundreds of trials on a particular type of item. It may be that if the ability tests were extended to a comparable length, performance would no longer depend on general test-taking strategies and adaptation; correlations with the parameters might then increase. In information processing terms, the cognitive processes tapped by the traditional ability test may relate more to "executive" functions than processing functions of the model. Constructing (or selecting) the program to process the data, or deciding where and in what form to store data in order that it may be later retrieved and manipulated with the greatest ease--these and similar functions of the "executive" in information processing models are similar to the presumed functions of test strategy and experience. This analogy may also shed light on why heterogeneous ability test batteries usually yield a substantial "g" factor.

Further, the experimental parameters employed in information processing models derive from simple, automatic tasks that rely on relatively specific, lower-order processes. If the correlation among ability tests is due to efficient "executive" functions that are responsible for setting strategies (or selecting and assembling the performance programs), then it is to be expected that correlations among dissimilar tasks that require little programming will be low. The failure of the task parameters to correlate more substantially with the STVM III factor scores than they did with the ability factor scores is a case in point. Group factors tend to appear in factor analyses of ability variables when both the content and processing requirements of the tasks are similar. It is quite possible that content similarity is increasingly important for task intercorrelations as one moves down the ability hierarchy. Also to be noted is the importance for exploratory purposes of examining the scatterplots underlying particular correlations. Important intricacies in ability-parameter relations may not come to light in routine correlational analysis.

Finally, in further research on ability-process relations, we believe that multifaceted experiments that systematically vary task requirements on a number of dimensions will prove superior to simple correlational work with paradigmatic information processing tasks yielding only one or two within-task parameters. Attempts to relate the domains of correlational and information processing psychology will profit from a clarification of the cognitive complexity and generalizability of both task parameters and ability constructs. Such research requires large samples, abundant psychometric information on each subject, facet designed experimental tasks, and a better understanding of individual strategic, as well as process differences in test performance.

References

Atkinson, R. C., Holmgren, J. E. & Juola, J. F. Processing time as influenced by the number of elements in a visual display. Perception & Psychophysics. 1969, 6, 321-326.

Averbach, E., & Coriell, A. S. Short-term memory in vision. Bell System Technical Journal, 1961, 40, 309-328.

Chiang, A., & Atkinson, R. C. Individual differences and interrelationships among a select set of cognitive skills. Memory & Cognition, 1976, 4, 661-672.

Cronbach, L. J., & Snow, R. E. Aptitudes and instructional methods: A handbook for research on interactions. New York: Irvington, 1977.

Fleishman, E. A. Toward a taxonomy of human performance. American Psychologist, 1975, 30, 1127-1149.

French, J. W., Ekstrom, R., & Price, L. Kit of reference tests for cognitive factors. Princeton, NJ: Educational Testing Service, 1963.

Guilford, J. P. The nature of human intelligence. New York: McGraw-Hill, 1967.

Hunt, E. B., Frost, N., & Lunneborg, C. E. Individual differences in cognition: A new approach to intelligence. In G. Bower (Ed.), Advances in learning and memory (Vol. 7). New York: Academic Press, 1973.

Hunt, E. B., & Lansman, M. Cognitive theory applied to individual differences. In W. K. Estes (Ed.), Handbook of learning and cognitive processes (Vol. 1) Hillsdale, NJ: Erlbaum, 1975.

Kahneman, D. Method, findings, and theory in studies of visual masking. Psychological Bulletin, 1968, 70, 404-425.

Klatsky, R. L. Human Memory: Structures and Processes. San Francisco: W. H. Freeman, 1975.

Koran, M. L., Snow, R. E., & McDonald, F. J. Teacher aptitude and observational learning of a teaching skill. Journal of Educational Psychology, 1971, 62, 219-228.

Neisser, U. Visual search. Scientific American, 1964, 210, 94-102.

Oltman, P. K., Raskin, E., & Witkin, H. A. The group imbedded figures test. Palo Alto, CA: Consulting Psychologists Press, 1971.

Posner, M. I., Boies, S. J., Eichelman, W. H., & Taylor, R. L. Retention of visual and name codes of single letters. Journal of Experimental Psychology, 1969, 79, 1-16.

Raven, J. C. Progressive matrices: A perceptual test of intelligence, 1938, individual form. London: Lewis, 1938

Seibert, W. F., Reid, J. C., & Snow, R. E. Studies in cine-psychometry II: Continued factoring of audio and visual cognition and memory. Lafayette, IN: Purdue University Audio Visual Center, 1967.

Seibert, W. F., & Snow, R. E. Studies in cine-psychometry I: Preliminary factor analysis of visual cognition and memory. Final Report, USOE Grant Number 7-12-0280-184. Lafayette, Ind.: Audio Visual Center, Purdue University, 1965.

Snow, R. E. Research on Aptitudes: A progress report. Technical Report No. 1. Aptitude Research Project, School of Education, Stanford University, 1976a.

Snow, R. E. Theory and method for research on aptitude processes. Technical Report No. 2. Aptitude Research Project, School of Education, Stanford University, 1976b.

Snow, R. E., & Seibert, W. F. Exploratory factor analysis in cine-psychometry. Paper presented at the meeting of the American Psychological Association, New York, September 1966.

Sternberg, R. J. Intelligence, information processing, and analogical reasoning: The componential analysis of human abilities. Hillsdale, NJ: Erlbaum, 1977.

Sternberg, S. High-speed scanning in human memory. Science, 1966, 153, 652-654.

Sternberg, S. Memory-scanning: Mental processes revealed by reaction-time experiments. American Scientist, 1969, 57, 421-457.

Turvey, M. T. On peripheral and central processes in vision: Inferences from an information-processing analysis of masking with patterned stimuli. Psychological Review, 1973, 80, 1-52.

Witkin, H. A. The role of cognitive style in academic performance and in teacher-student relations. Princeton, NJ: Educational Testing Service, 1973.

Zelniker, T., Jeffrey, W. E., Ault, R., & Parsons, J. Analysis and modification of search strategies of impulsive and reflective children on the Matching Familiar Figures Test. Child Development, 1972, 43, 321-335.

DISTRIBUTION LIST

Navy

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

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

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

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

1 Dr. M. A. Bertin, Scientific Director
Office of Naval Research
Scientific Liaison Group/Tokyo
American Embassy
APO San Francisco 96503

1 Office of Naval Research
Code 200
Arlington, VA 22217

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

1 Director, Human Resource Management
Naval Amphibious School
Naval Amphibious Base, Little Creek,
Norfolk, VA 23521

1 LCDR Charles J. Theisen, Jr., MSC, USN
4024
Naval Air Development Center
Warminster, PA 18974

1 Commanding Officer
U.S. Naval Amphibious School
Coronado, CA 92155

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

1 Chairman, Leadership & Law Dept.
Div. of Professional Development
U.S. Naval Academy
Annapolis, MD 21402

1 Scientific Advisor to the Chief
of Naval Personnel (Pers Or)
Naval Bureau of Personnel
Room 4410, Arlington Annex
Washington, DC 20370

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

1 Mr. Maurice Callahan
NODAC (Code 2)
Dept. of the Navy
Bldg. 2, Washington Navy Yard
(Anacostia)
Washington, DC 20374

1 Office of Civilian Personnel
Code 342/02 WAP
Washington, DC 20390
Attn: Dr. Richard J. Niehaus

1 Office of Civilian Personnel
Code 263
Washington, DC 20390

1 Superintendent (Code 1424)
Naval Postgraduate School
Monterey, CA 93940

1 Mr. George N. Graine
Naval Sea Systems Command
SEA 047C12
Washington, DC 20362

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

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

1 Dr. Alfred F. Smode, Director
Training Analysis & Evaluation Group
Department of the Navy
Orlando, FL 32813

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

1 Capt. H. J. Connery, USN
Navy Medical R&D Command
NNMC, Bethesda, MD 20014

1 Navy Personnel R&D Center
Code 01
San Diego, CA 92152

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

5 A. A. Sjoholm, Head, Technical Support
Navy Personnel R&D Center
Code 201
San Diego, CA 92152

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

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 LCDR J. W. Snyder, Jr.
F-14 Training Model Manager
VF-124
San Diego, CA 92025

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

1 Dr. Worth Scanland
Chief of Naval Education & Training
NAS, Pensacola, FL 32508

1 Dr. Richard A. Pollak
Academic Computing Center
U.S. Naval Academy
Annapolis, MD 21402

Army

1 Technical Director
U.S. Army Research Institute for the
Behavioral & Social Sciences
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Armed Forces Staff College
Norfolk, VA 23511
Attn: Library

1 Commandant
U.S. Army Infantry School
Fort Benning, GA 31905
Attn: ATSH-I-V-IT

1 Commandant
U.S. Army Institute of Administration
Attn: EA
Fort Benjamin Harrison, IN 46216

1 Dr. Beatrice Farr
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 Dr. Ralph Dusek
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. Leon Nawrocki
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

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

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

1 Col. G. B. Howard
U.S. Army
Training Support Activity
Fort Eustis, VA 23604

1 Col. Frank Hart, Director
Training Management Institute
U.S. Army, Bldg. 1725
Fort Eustis, VA 23604

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

1 ARI Field Unit - Leavenworth
P.O. Box 3122
Ft. Leavenworth, KS 66027

1 DCDR, USAADMINCEN
Bldg. #1, A310
Attn. AT21-OED Library
Ft. Benjamin Harrison, IN 46216

1 Dr. Edgar Johnson
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

1 Dr. James Baker
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Air Force

1 Research Branch
AFMPC/DPMYP
Randolph AFB, TX 78148

1 AFHRL/AS (Dr. G. A. Eckstrand)
Wright-Patterson AFB
Ohio 45433

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

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

1 Instructional Technology Branch
AFHRL
Lowry AFB, CO 80230

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

1 Dr. Sylvia R. Mayer (MCIT)
HQ Electronic Systems Division
LG Hanscom Field
Bedford, MA 01730

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

1 Dr. T. E. Cotterman
AFHRL/ASR
Wright Patterson AFB
Ohio 45433

1 Dr. Donald E. Meyer
U.S. Air Force
ATC/XPTD
Randolph AFB, TX 78148

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

1 Dr. William Strobie
McDonnell Douglas Astronautics Co. East
Lowry AFB
Denver, CO 80230

Marine Corps

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

1 Dr. A. L. Slafkosky
Scientific Advisor (Code RD-1)
HQ, U.S. Marine Corps
Washington, DC 20380

1 AC/S, Education Programs
Education Center, MCDEC
Quantico, VA 22134

Coast Guard

1 Mr. Joseph J. Cowan, Chief
Psychological Research Branch (G-P-1/62)
U.S. Coast Guard Headquarters
Washington, DC 20590

Other DoD

1 Dr. Harold F. O'Neil, Jr.
Advanced Research Projects Agency
Cybernetics Technology, Room 623
1400 Wilson Blvd.
Arlington, VA 22209

1 Dr. Robert Young
Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209

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

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

1 Director, Management Information
Systems Office
OSD, M&RA
Room 3B917, The Pentagon
Washington, DC 20301

Other Government

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

1 Dr. Andrew R. Molnar
Science Education Dev. & Res.
National Science Foundation
Washington, DC 20550

1 Dr. Marshall S. Smith
Associate Director
NIE/OPEPA
National Institute of Education
Washington, DC 20208

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

1 Dr. H. Wallace Sinaiko, Director
Manpower Research & Advisory Services
Smithsonian Institution
801 N. Pitt Street
Alexandria, VA 22314

1 Dr. James M. Ferstl
Employee Development: Training
Technologist
Bureau of Training
U.S. Civil Service Commission
Washington, DC 20415

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

Miscellaneous

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

1 Dr. Scarvia B. Anderson
Educational Testing Service
Suite 1040
3445 Peachtree Road NE
Atlanta, GA 30326

1 Professor Earl A. Alluisi
Dept. of Psychology
Old Dominion University
Norfolk, VA 23508

1 Dr. Daniel Alpert
Computer-Based Education
Research Laboratory
University of Illinois
Urbana, IL 61801

1 Ms. Carole A. Bagley
Applications Analyst
Minnesota Educational
Computing Consortium
1925 Sather Ave.
Lauderdale, MN 55113

1 Mr. Samuel Ball
Educational Testing Service
Princeton, NJ 08540

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

1 Dr. John Brackett
SofTech
460 Totten Pond Road
Waltham, MA 02154

1 Dr. Robert K. Branson
1A Tully Bldg.
Florida State University
Tallahassee, FL 32306

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

1 Dr. Victor Bunderson
Institute for Computer Uses in Education
355 EDLC
Brigham Young University
Provo, UT 84601

1 Dr. Ronald P. Carver
School of Education
University of Missouri-Kansas City
5100 Rockhill Road
Kansas City, MO 64110

1 Don Ely, Director
ERIC Clearinghouse on Information Resources
School of Education
Syracuse University
Syracuse, NY 13210

1 Century Research Corporation
4113 Lee Highway
Arlington, VA 22207

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

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

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

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

1 Dr. Rene V. Dawis
Dept. of Psychology
University of Minnesota
Minneapolis, MN 55455

1 Dr. Ruth Day
Dept. of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. John D. Carroll
Psychometric Lab
Davie Hall 013A
University of North Carolina
Chapel Hill, NC 27514

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

1 Dr. John Eschenbrenner
McDonnell Douglas Astronautics Company-East
P.O. Box 30204
St. Louis, MO 80230

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

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

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

1 Dr. Larry Francis
University of Illinois
Computer-Based Educational Research Lab
Champaign, IL 61801

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

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

1 Dr. Vernon S. Gerlach
College of Education
146 Payne Bldg. B
Arizona State University
Tempe, AZ 85281

1 Dr. Robert Glaser, Co-Director
University of Pittsburgh
R&D Center
3939 O'Hara Street
Pittsburgh, PA 15213

1 Dr. M. D. Havron
Human Sciences Research, Inc.
7710 Old Spring House Road
West Gate Industrial Park
McLean, VA 22101

1 Dr. Duncan Hansen
School of Education
Memphis State University
Memphis, TN 38118

1 CDR Mercer
CNET Liaison Officer
AFHRL/Flying Training Div.
Williams AFB, AZ 85224

1 HumRRO/Western Division
27857 Berwick Drive
Carmel, CA 93921
Attn: Library

1 HumRRO/Columbus Office
Suite 23, 2601 Cross Country Drive
Columbus, GA 31906

1 HumRRO/Ft. Knox Office
P.O. Box 293
Fort Knox, KY 40121

1 Dr. Lawrence B. Johnson
Lawrence Johnson & Associates, Inc.
Suite 502
2001 S Street NW
Washington, DC 20009

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

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

1 Dr. Steven W. Keele
Dept. of Psychology
University of Oregon
Eugene, OR 97403

1 Dr. David Klahr
Dept. of Psychology
Carnegie-Mellon University
Pittsburgh, PA 15213

1 Mr. W. E. Lassiter
Data Solutions Corp.
Suite 211, 6849 Old Dominion Drive
McLean, VA 22101

1 Dr. Frederick M. Lord
Educational Testing Service
Princeton, NJ 08540

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

1 Dr. William C. Mann
University of So. California
Information Sciences Institute
4676 Admiralty Way
Marina Del Rey, CA 90291

1 Dr. Leo Munday
Houghton Mifflin Co.
P.O. Box 1970
Iowa City, IA 52240

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

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. Kenneth A. Polycyn
PCR Information Sciences Co.
Communication Satellite Applications
7600 Old Springhouse Rd.
McLean, VA 22101

1 Dr. Steven M. Pine
N 660 Elliott Hall
University of Minnesota
75 East River Road
Minneapolis, MN 55455

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

1 R. Dir. M. Rauch
P II 4
Bundesministerium der Verteidigung
Postfach 161
53 Bonn 1, GERMANY

1 Dr. Joseph W. Rigney
University of So. California
Behavioral Technology Laboratories
3717 South Grand
Los Angeles, CA 90007

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

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

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

1 Dr. Robert J. Seidel
Instructional Technology Group, HumRRO
300 N. Washington St.
Alexandria, VA 22314

1 Dr. Persis Sturgis
Dept. of Psychology
California State University-Chico
Chico, CA 95926

1 Mr. Dennis J. Sullivan
c/o Canyon Research Group, Inc.
32107 Lindero Canyon Road
Westlake Village, CA 91360

1 Mr. Walt W. Tornow
Control Data Corporation
Corporate Personnel Research
P.O. Box 0--HQN060
Minneapolis, MN 55440

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

1 Dr. Carl R. Vest
Battelle Memorial Institute
Washington Operations
2030 M Street NW
Washington, DC 20036

1 Dr. David J. Weiss
Dept. of Psychology
N660 Elliott Hall
University of Minnesota
Minneapolis, MN 55455

1 Dr. Keith Wescourt
Dept. of Psychology
Stanford University
Stanford, CA 94305

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

1 Dr. Anita West
Denver Research Institute
University of Denver
Denver, CO 80201

1 Mr. Thomas C. O'Sullivan
TRAC
1220 Sunset Plaza Drive
Los Angeles, CA 90069

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

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

1 Prof. Fumiko Samejima
Dept. of Psychology
Austin Peay Hall 304C
University of Tennessee
Knoxville, TN 37916

1 Dr. William S. Vaughan
W. V. Associates
3308 Dodge Park Road
Landover, MD 20785

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

1 Dr. Nicholas A. Bond
Dept. of Psychology
Sacramento State College
6000 Jay Street
Sacramento, CA 95819

1 Dr. James Greeno
Learning R&D Center
University of Pittsburgh
3939 O'Hara Street
Pittsburgh, PA 15213

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

1 Dr. Robert Sternberg
Dept. of Psychology
Yale University
Box 11A, Yale Station
New Haven, CT 06520

1 Dr. Walter Schneider
Dept. of Psychology
University of Illinois
Champaign, IL 61820

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