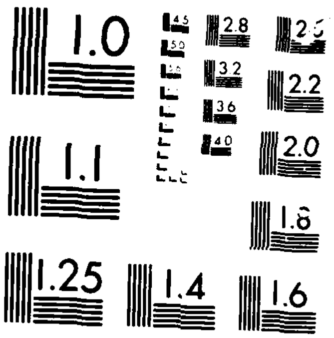
AD-A169 205 SPEED OF INFORMATION PROCESSING AND INDIVIDUAL DIFFERENCES IN INTELLIGENCE(U) NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER SAN DIEGO CA 1/1

UNCLASSIFIED D P SACCUZZO ET AL. JUN 86 NPRDC-TR-86-23 F/G 5/10 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.8
3.2
3.6
4.0

NPRDC-TR 86-23

JUNE 1986

SPEED OF INFORMATION PROCESSING AND INDIVIDUAL DIFFERENCES IN INTELLIGENCE

NAVY PERSONNEL RESEARCH AND DEVELOPMENT CENTER
SAN DIEGO, CALIFORNIA

NAVY PERSONNEL RESEARCH
AND
DEVELOPMENT CENTER
San Diego, California 92152

NPRDC TR 86-23

June 1986

SPEED OF INFORMATION PROCESSING AND INDIVIDUAL DIFFERENCES IN INTELLIGENCE

Dennis P. Saccuzzo
Gerald E. Larson
Bernard Rimland

Reviewed by
John J. Pass

Approved by
Martin F. Wiskoff

Released by
H. S. Eldredge
Captain, U.S. Navy
Commanding Officer

Navy Personnel Research and Development Center
San Diego, California 92152-6800

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A169205

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S) NPRDC TR 86-23	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Navy Personnel Research and Development Center 6b OFFICE SYMBOL (If applicable) Code 62	7a NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) San Diego, CA 92152-6800	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO.	WORK UNIT ACCESSION NO.
62763N	F63521	804	042.1

11 TITLE (Include Security Classification)

SPEED OF INFORMATION PROCESSING AND INDIVIDUAL DIFFERENCES IN INTELLIGENCE

12 PERSONAL AUTHOR(S)

Saccuzzo, Dennis P.; Larson, Gerald E., & Rimland, B.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Interim	FROM FY 84 TO FY 85	1986 June	25

16 SUPPLEMENTARY NOTATION

17 COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	
05	09		Cognitive speed; inspection time; reaction time; information processing, scholastic aptitude intelligence.

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

A battery of tachistoscopic, auditory, reaction time, and microcomputer generated measures of information processing speed was administered to 96 college students between 18 and 22 years of age. In addition, each subject was given a battery of tests designed to evaluate right and left cerebral hemisphere functioning. Criterion measures included a verbal (Vocabulary) and nonverbal (Block Design) measure of intelligence. Results revealed a general processing speed factor in addition to task specific sources of variability. Moreover, the processing speed tasks loaded on the same second order factor as did traditional measures of I.Q. The findings support the theoretical view that processing speed may be a partial source of individual differences in intelligence. An important objective for future work in this area is to separate and evaluate the common and specific sources of variability on information processing tasks.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED
22a NAME OF RESPONSIBLE INDIVIDUAL Gerald E. Larson	22b TELEPHONE (Include Area Code) (619) 225-6722 22c. OFFICE SYMBOL Code 62

DD FORM 1473, 84 MAR

83 APR edition may be used until exhausted
All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

UNCLASSIFIED

FOREWORD

The present research is an outgrowth of the Cognitive Speed project at the Navy Personnel Research and Development Center, under which the lead author, Dr. Dennis Saccuzzo of San Diego State University, served as an expert consultant during FY 1985. Funding was provided under Future Technologies for Manpower and Personnel (PE62763, RF63-521-804).

The primary objectives of this effort were to determine the relationship between various measures of speed of information processing, and to follow up an earlier NPRDC study indicating that speed of processing is related to mental aptitude and performance in a technical training program (NPRDC TR 85-3). The battery of cognitive speed tests will be further developed and evaluated in upcoming research in both military and civilian settings.

H. S. ELDREDGE
Captain, U.S. Navy
Commanding Officer

J. W. TWEEDDALE
Technical Director

SUMMARY

Problem

Current intelligence/aptitude tests for the military and the private sector seem to have reached the upper limit of their predictive validity. Recent developments in the cognitive and computer sciences may offer new hope for better measures of mental ability. Chronometric tests, which evaluate how fast a person makes simple judgments, typically in a second or less, have become increasingly feasible over the past 10 years. Computerized testing makes precise measurement possible, but attempts to relate processing speed to complex cognitive performance have produced conflicting and sometimes discouraging findings.

Purpose

The present effort probed beyond the available data to gain insight into seemingly inconsistent findings and to evaluate several microcomputer tests of processing speed. We were interested in whether fast reaction times and rapid processing of visual and auditory information were characteristics of people who also score high on conventional IQ tests. Such a relationship would indicate a fundamental information processing capacity underlying intelligence. We also sought to determine the characteristics of information processing tests (such as complexity and sensory modality) that affect score overlap with conventional tests.

Approach

A set of reaction time, auditory, and visual measures of processing speed was administered to 96 university students between 18 and 22 years of age. As criteria, the students were given the Vocabulary and Block Design subtests of the Wechsler Adult Intelligence Scale--Revised (WAIS-R), and scores on the Scholastic Aptitude Test, freshman grade point average, and high school grade point average were obtained from college records. Subjects were also given the Gordon Laterality Battery, which provides an assessment of left and right cerebral hemispheric functioning that is presumably related to verbal and spatial skills, respectively. Correlational and factor analytic procedures were used to test the presence of a general intelligence factor that underlies performance on all types of tests, chronometric or conventional, and to evaluate the strength of visual or auditory task differences.

Results

Conventional IQ tests and measures of processing speed share some common variance, indicating that processing speed is part of general intelligence. The relationship between the conventional and experimental measures appears to be a modest one, however. Analyses also revealed that processing speed differed somewhat according to the nature of the task, indicating that each of the experimental tests provides unique information about ability in addition to information about general aptitude.

Discussion and Conclusions

1. The modest overlap between processing speed and traditional measures of intelligence indicates that chronometric tests have potential for adding predictive power to the Armed Services Vocational Aptitude Battery (ASVAB).

2. Because there is task-specificity in processing speed, some chronometric tests will add more unique variance to ASVAB than others. Chronometric items that contain no linguistic content, such as the reaction time and visual inspection time measures employed in the present study, are promising candidates for research.

Recommendations

Future research should be directed toward determining whether a "general processing speed" subtest or a set of task-specific subtests might contribute most to the ASVAB. Such work should include comparisons to training grades and job performance measures, in addition to comparisons to conventional ability test scores.

CONTENTS

LIST OF TABLES

INTRODUCTION

Paper and pencil tests of ability, such as the Armed Services Vocational Aptitude Battery (ASVAB), appear to have reached their peak in predicting training and job performance. Consequently, there has been a search for new methods of assessing aptitude. One such approach, referred to as chronometric measurement, attempts to evaluate an individual's speed of information processing, hypothetically a critical underlying process of cognition. Chronometric tests are promising areas for research, because they are likely to provide information beyond the aptitudes currently measured by ASVAB. ASVAB subtests appear to measure four primary ability factors: verbal, mathematical, technical knowledge, and clerical speed (Ree, Mullins, Matthews, & Massey, 1982). While ASVAB is knowledge oriented, chronometric tests are process oriented, that is, performance is thought to be largely independent of prior learning.

The potential of chronometric measurement for use in military settings is unclear due to a limited data base and some seemingly conflicting evidence. Most studies have restricted themselves to only one or two sets of processing speed tasks. Results have varied. Though most studies have revealed a small but significant correlation between processing speed tasks and those involving complex cognitive behavior, the meaning of such findings is a matter of controversy.

Empirical support for a relationship between processing speed and individual differences in intelligence has come from reaction time studies that manipulate the level of uncertainty to which a subject must respond (Jensen, 1979; Jensen & Munro, 1979; Lunneborg, 1978; Smith & Stanley, 1983; Vernon, 1981). Using parameters such as median reaction time, slope of reaction time as a function of the number of bits, and intraindividual standard deviations of reaction time performance, investigators have reported large differences between retarded persons and those of normal IQ, as well as between vocational-college students and university students (Jensen 1980b; 1982). Based on his own findings and a survey of the literature, Jensen (1982) estimates the correlation between reaction time and individual differences on IQ tests to be between -.3 and -.4. The correlations vary widely across samples, however (Lunneborg, 1978).

A second line of investigation, the study of speed of visual information processing, has also supported a relationship between processing speed and performance on complex cognitive tasks. In the typical visual paradigm, the subject makes a discrimination for a briefly exposed "target" stimulus, such as identifying which of two lines presented to the right and left of central fixation is longer. The target stimulus is followed by a spatially overlapping noninformational mask (e.g., two uniform lines that completely superimpose the lines of the target stimulus). An extensive literature on the masking task itself reveals that it limits the duration that the informational impulse is available for processing in the nervous system (Felsten & Wasserman, 1980). Speed of processing, or "inspection time" as it is sometimes called (Vickers, Nettelbeck, & Willson, 1972), is estimated by systematically varying the exposure duration of the target and estimating the minimum duration needed for criterion accuracy (Lally & Nettlebeck, 1977; Nettelbeck & Lally, 1976) or by keeping the stimulus duration constant and varying the interval between target and mask (Saccuzzo, Kerr, Marcus, & Brown, 1979; Saccuzzo & Marcus, 1983).

Numerous studies have reported a statistically significant difference between mentally retarded and non-retarded (average IQ) individuals in speed of visual information processing as evaluated in a backward masking paradigm. Such differences occur in spite of wide variations in the nature of the stimuli, method of stimulus presentation, and technique used to estimate visual processing speed (Saccuzzo & Michael, 1984). There are, moreover, clear-cut developmental differences. The general finding is a direct relationship between chronological as well as mental age and performance (Blake, 1974; Liss & Haith, 1970; Saccuzzo et al., 1979). Finally, the evidence supports a significant relationship between degrees of normal intelligence and visual processing speed, though the magnitude of the relationship remains controversial (Mackintosh, 1981; Nettelbeck, 1982).

Though an early study reported an astonishing -.92 correlation between scores on the Performance Scale of the Wechsler Adult Intelligence Scale (WAIS) and inspection time (Nettelbeck & Lally, 1976), most subsequent investigations found a less spectacular, but significant, relationship between inspection time and intelligence, with a median correlation of about -.45. These positive findings have been criticized, however, on methodological grounds--small sample sizes (usually no more than 25 subjects); the inclusion of mentally retarded persons, which greatly inflates the correlation due to the extremely disparate range of performance relative to the sample size; and analyses based only on extreme scoring subjects, which, again, is well-known to inflate correlations (Irwin, 1984; Nettelbeck, 1982).

Nettelbeck (1982) took a sober look at his own and others' work in the area. His analyses revealed a small but relatively consistent association between intelligence and inspection time. Irwin (1984) similarly found modest but significant correlations between inspection time and intelligence test performance.

The relationship between individual differences in intelligence and processing speed has also been evaluated in studies using auditory masking techniques. Compared to the use of a visual paradigm, however, there have been relatively few auditory studies. Brand (1981) reported correlations of -.70 and -.66 between a measure of auditory inspection time and the Raven Progressive Matrices test and the Mill-Hill vocabulary tests, respectively. Raz, Willerman, Ingmundson, and Hanlon (1983) found significant differences between high- and low-scoring college students on the SAT test and auditory processing speed as measured in a backward masking paradigm, but their study was limited by a small sample size (N = 7 per group) and the possibility of a confounding due to an inordinate number of females in the low SAT group. Irwin (1984) evaluated auditory processing speed in order to determine whether Brand's (1981) reported correlations of -.7 and -.66 could be replicated. Results showed a far smaller but statistically significant relationship in the predicted direction.

In the present study, we obtained visual, auditory, and reaction time measures of processing speed for the same subjects. We also explored the feasibility of using microcomputer controlled tasks to evaluate processing speed, as suggested by Cory, Rimland, and Bryson (1977). Finally, we attempted to probe more deeply into the meaning of performance on a processing speed task, especially as it might relate to the functioning of the right and left cerebral hemispheres.

METHOD

Subjects

The subjects were 96 volunteer San Diego State University students from an introductory course in psychology. All subjects were between 18 and 22 years of age. Fifty-three were male; forty-three were female. Eighty were Caucasian; the remaining

16 were black, Hispanic, and Asian. The sample was representative of the total population of San Diego State students in the 18-22 age range.

Procedure

Each subject was tested on tasks designed to estimate speed of visual, auditory, and reaction time processing. Subjects were also given the Vocabulary and Block Design subtests of the Wechsler Adult Intelligence Scale, Revised (WAIS-R) and the Cognitive Laterality Battery (Gordon, 1983).

Visual Processing Tasks

Two types of visual tasks were used, with the order of presentation alternating between subjects. The first type involved tachistoscopic presentations in a paradigm that followed the general procedures used by Saccuzzo et al. (1979). In this paradigm, which differed from Saccuzzo et al. (1979) only in terms of the test stimuli (arrows instead of letters) and the use of a fixed rather than variable stimulus duration, stimuli are presented in a three-field Gerbrands tachistoscope. The test stimuli are constructed by mounting black paratype arrows in the center of white stimulus cards. Half of the arrows point to the left and half point to the right. They are presented for a display duration of 4 milliseconds in a prearranged random sequence. The arrows are followed at varying intervals by a masking stimulus that completely superimposes the target stimulus. The subject is asked to fixate on a small cross presented in a dimly lit field by the tachistoscope. After 10-20 warm-up practice trials, the stimulus is presented. After a 1 millisecond interval following termination of the stimulus, the mask is presented. The subject's task is to point to the right or to the left to indicate the direction of the target. An index called the Critical Interstimulus Interval (ISIc) is calculated in the following fashion. For each interval between off-set of the target and on-set of the mask, a subject must obtain at least six out of seven correct responses. When this criterion is not achieved, the interval between target and mask is increased by 2 milliseconds.

Testing continues until the subject reaches the criterion. Then the stimulus duration is decreased in increments of 1 millisecond until the subject obtains at least two errors out of seven. The lowest stimulus-mask interval at which the subject achieves at least six out of seven correct responses is designated as the subject's ISIc for that trial. After a 5 minute rest period, the procedure is repeated and the ISIc is determined a second time. Feedback is not given. Luminances of the target and masking field are equated and held constant at 51.39 cd/m throughout the experiment. Luminance of the fixation field is held at 3.43 cd/m. The fixation field is off-set prior to stimulus presentation and is on-set 1 second after termination of the mask. There is a 2-3 second interval between trials and rest as needed. Total testing time is approximately 30 minutes.

A microcomputer presented battery of five tests for estimating processing speed (inspection time) provided the second set of experimental tasks. For all five tasks, two lines (one 12.7mm, the other 15.9mm) were presented at central fixation. The five tasks differed in line orientation (vertical versus horizontal) and line composition (dashed lines versus solid lines).

Subjects indicated which of the two lines was longer by pressing an appropriate key on the microcomputer keyboard. Inspection time was evaluated in an adaptive modified staircase method. The mask was always presented immediately following off-set of the target stimulus. The initial stimulus presentations were relatively long. Two consecutive correct responses led to a proportional decrease in the stimulus duration compared to the original duration. An error led to a proportional increase in the duration. Testing proceeded until subjects achieved two consecutive correct responses and the fastest possible speed permitted by the microcomputer, which was scored zero, or obtained seven errors. The score of zero, or the stimulus duration achieved after seven errors, was called inspection time.

Each of the five tasks was presented twice to each subject: once via a TRS-80 and once via an Apple II. Half of the subjects were tested first on the Apple, the other half first on the TRS. Testing time for all tasks on both microcomputers was a total of approximately 45 minutes.

Auditory Processing Tasks

Auditory speed of processing was measured by the Repetition Test developed by Tallal and Piercy (1973). Dr. Tallal trained the experimenters responsible for collecting the data for this research. The Repetition Test is a measure of auditory processing that uses two tones, which are presented in different combinations and with varied interstimulus intervals (ISI). For the purpose of this study, the two sequencing tasks for short and long ISIs, in which the subject indicates detection and differentiation between tones in a two-element pattern, were used to estimate speed of auditory processing. Stimuli were presented on a tape recorder. Processing speed was evaluated by the number of errors for long and short ISIs. Total testing time was approximately 1/2 hour. About half the subjects received the auditory task last. The other half took the auditory task either before receiving any of the visual processing tasks or following their participation in one of the two visual tasks (tachistoscope and microcomputer).

Reaction Time

The reaction time task was presented on the TRS-80 computer and keyboard and given immediately after the subject had completed the TRS-80 visual processing task. Subjects were presented with one, three, or five boxes along the bottom of the screen. Specified keys on the top row of the keyboard, corresponding to the boxes, were used for responding. The task was to press the appropriate numbered key as quickly as possible after a box was illuminated. At the beginning of each of the 11 consecutive trials for each of the various choice conditions, the subject held down the space bar until one of the boxes was lighted. The number of milliseconds between the onset of the stimulus and the instant the space bar was released provided a measure of reaction time. Each subject's median reaction time was used as the index for the one (RT1), three (RT2), and five (RT3) choice tasks.

Cognitive Laterality

The Cognitive Laterality Battery (CLB), developed by Gordon (1983) to evaluate individual differences in hemispheric asymmetries, was administered to subjects in small groups (8-16 subjects) after all processing tasks had been completed. The CLB is a slide projected battery of eight individual subtests. Presentation of the battery is driven by cues embedded in cassette tapes which contain instructions and auditory test items. Presentation of the battery is thus almost completely automated. Subjects record their response on answer sheets. The experimenter was blind to subjects' previous scores. Of the eight subtests, four are nonverbal and purportedly related to right hemisphere functioning, the other four are related to left hemisphere functioning. Table 1 summarizes the eight subtests and provides a brief description of the task. An overall

Right Hemisphere (RH) score is the average of the Z-scores for the four right-hemisphere-related subtests; an overall Left Hemisphere (LH) score is the average of the Z-scores for the four left-hemisphere-related tasks.

Table 1

Summary of the Cognitive Laterality Battery

Subtest	Hemisphere	Task
Serial sounds	Left	Identify in order familiar sounds (e.g., baby cries) presented in sequences of increasing length.
Localization	Right	Locate points in space.
Serial numbers	Left	Repeat strings of digits presented in increasing lengths.
Orientation	Right	Determine which two of three 3-dimensional geometric figures rotated in space are the same.
Word production (letters)	Left	Write as many words as possible that begin with a given letter.
Form completion	Right	Identify a well-known object or scene from a partially erased silhouette.
Word production (categories)	Left	Write as many words as possible for a presented category (e.g., animal names).
Touching blocks	Right	Given a stack of blocks, subject must indicate, for specified blocks in the stack, how many others are touching.

Criterion Measures

Five criterion measures were used to evaluate intelligence and academic achievement: high school GPA (HSGPA), freshman GPA (FRGPA), total score on the Scholastic Aptitude Test (SAT), and scaled scores on WAIS-R Vocabulary and Block Design. Vocabulary and Block Design scores were administered immediately before or after administration of the tachistoscope visual processing task. HSPGPA, FRGPA, and SAT scores were taken directly from a student's official record in the registrar's office. Table 2 presents a summary of all the variables and their abbreviations.

Table 2

Summary of All Variables and Abbreviations

HSGPA	High School Grade Point Average
FRGPA	Freshman Grade Point Average
SAT	Scholastic Aptitude Test
VOCAB.	Vocabulary Subtest of the WAIS-R
BD	Block Design Subtest of the WAIS-R
AUDLG	Auditory Processing--Long ISIs
AUDST	Auditory Processing--Short ISIs
TSA[a]	Tachistoscopic Visual Processing--First Administration
TSA[b]	Tachistoscopic Visual Processing--Second Administration
TRAV	TRS-80 Inspection Time Composite
APAV	Apple Microcomputer Inspection Time Composite
RT1	Reaction Time (one choice)
RT2	Reaction Time (three choice)
RT3	Reaction Time (five choice)
G Left	Score for Left Hemisphere Performance on Gordon Laterality Battery
G Right	Score for Right Hemisphere Performance on Gordon Laterality Battery

[a]ISIc1 Critical Interstimulus Interval based on first administration of tachistoscopic visual proacessing measure.

[b]ISIc2 Critical Interstimulus Interval based on scored administration of tachistoscopic visual processing measure.

RESULTS

Preliminary Analyses

Three preliminary analyses were conducted.

Order Effects

A t-test was performed on each of the computer presented inspection time tasks comparing subjects whose initial stimulus presentations were from the TRS-80 to those who received the TRS-80 second, and to compare those who received the Apple II presentations first to those who received them second. None of the differences in the group means reached statistical significance.

Microcomputer Measures

Inspection times (IT) for each of the five TRS and five Apple tasks were factor analyzed separately for the TRS and Apple microcomputers using the principal components method (Hotelling, 1933) with unities in the major diagonal as the initial estimate of commonality. Results for the two microcomputers were analogous, with the first unrotated factor for both analyses dominated by significant loadings on at least four of the five IT estimates. Similar results were obtained when the IT variables were factor analyzed in conjunction with the criterion or the CLB scores. The IT tasks for each type of microcomputer loaded together. Consequently, the Z scores for each set of five microcomputer tasks were added to form a composite score. Thus, there was a TRS-80 composite and a separate Apple II composite, each based on the average five Z scores. Since a few subjects, either due to misunderstanding of instructions or an error in task administration, did not have valid scores for one or more IT task, composites were obtained only for those subjects who had validly completed all 10 IT tasks.

Gender Differences

Males and females did not differ significantly for any of the five criterion variables or either of the composite microcomputer IT scores. There were also no significant gender differences for any of the scores on the CLB.

Significant gender differences in favor of males were found, however, for the short ISI version of the auditory task (AUDST), $t\,(84) = 2.23$ $p < .029$ and for the three-choice, $t\,(84) = -2.97$, $p < .004$, and five-choice $t\,(84) = -4.08$, $p < .001$, reaction time tests.

Analysis of Criterion and Processing Speed Measures

Table 3 presents the intercorrelations among the five criterion variables for the total sample. The observed correlations closely correspond to those reported for these variables by McCornack (1982) for a larger stratified sample drawn from the same population at the same university.

Table 3

Intercorrelations Among the Criterion Variables

	HSGPA	FRGPA	SAT	VOCAB	BD
HSGPA	1.0	.37**	.23*	.33*	.23*
FRGPA		1.0	.19*	.30**	.01
SAT			1.0	.55*	.34**
VOCAB				1.0	.12
BD					1.0
Mean	3.01	2.51	889	8.87	11.83
SD	0.42	0.68	138	1.96	2.63

*$p < .05$.
**$p < .01$.

Table 4 presents the intercorrelations and first unrotated factor for the various measures of processing speed. The correlations were generally modest but significant except for the tachistoscopicly obtained indices. The unrotated factor suggested the presence of a general speed factor, which we confirmed through a hierarchical factor analysis.

Table 5 shows the results of a Schmid and Leiman (1957) hierarchical factor analysis. As the table shows, a second-order factor, Mental Speed, emerged, which accounted for 28 percent of the total variance. First-order factors unambiguously labeled Reaction Time Processing, Auditory Processing, and Visual Processing are also present. These three first-order factors are residualized and orthogonalized by the Schmid-Leiman method. Hence, they are uncorrelated with one another and with the mental speed factor.

Examination of Table 6 indicates that most of the correlations between the various measures of processing speed and scholastic achievement, scholastic aptitude, and intelligence are either nonsignificant or quite modest. Although it might be validly argued that the correlations reported in Table 6 are artifically lowered due to a restriction of the range of talent, the absence of a significant relationship between Vocabulary and any of the processing speed variables is quite striking. Block Design, by contrast, correlated significantly with all three reaction time scores and both microcomputer inspection time composites. Thus, the correlations in Table 6 appear to reflect a fundamental difference in the relationship between vocabulary and processing speed and that of Block Design and processing speed. Moreover, the first unrotated factor suggests the presence of a general factor on which the criterion measures and speed of processing measures both load. This possibility was further explored in a hierarchical factor analysis.

Table 7 presents the results of a Schmid-Leiman hierarchical factor analysis in which all factors are orthogonalized and first-order factors are residualized (i.e., their correlated variance is "absorbed" into the second-order general factor). As the analysis shows, the processing speed tasks and the criterion variables loaded together on a second-order factor, which was labeled General Mental Speed. Four first-order factors, Reaction Time, Auditory Speed, Psychometric Intelligence, and Visual Speed, also emerged.

Table 8 presents the correlations and first unrotated factor for the measures of processing speed and those for left and right hemispheric functioning. The pattern of correlations, consistent with the Verbal-Spatial dichotomy reported in Table 6, reveals a different pattern of correlation between the processing speed measures and the measures of hemispheric functioning.

Table 4

Intercorrelations and Unrotated Factor for Measures of Processing Speed

	AUDLG	AUDST	ISIc1	ISIc2	TRAV	APAV	RT1	RT3	RT5	Factor Loading[a]
AUDLG	1.0	.59**	.06	.16	.15	.22*	.29**	.39**	.14	<u>.66</u>
AUDST		1.0	.01	.09	.20*	.27**	.07	.20*	.15	<u>.53</u>
ISIc1			1.0	.12	-.14	-.15	-.05	.13	.08	.04
ISIc2				1.0	-.14	.04	.19	.15	.00	<u>.22</u>
TRAV					1.0	.32**	.35**	.09	.24**	<u>.45</u>
APAV						1.0	.01	.04	.17	<u>.35</u>
RT1							1.0	.65**	.37**	<u>.71</u>
RT2								1.0	.65**	<u>.80</u>
RT3									1.0	<u>.66</u>
Mean	1.24	13.96	15.21	18.13	0.00	0.00	0.28	0.36	0.41	
SD	2.04	8.07	16.05	16.69	0.61	0.53	0.07	0.09	0.10	

[a]Factor loadings for first factor of unrotated factor matrix for Principal Components factor analysis (total variance accounted for equals 29.8%). Salient loadings are underlined.

*$p < .05$.

**$p < .01$.

Table 5

Hierarchical Factor Analysis of Measures of Processing Speed
(Level One Factor Structure)

	Factor 1 (Second-order) Mental Speed	Factor 2 Reaction Time Processing	Factor 3 Auditory Processing	Factor 4 Visual Processing
AUDLG	.69	.06	.59	-.01
AUDST	.62	-.06	.62	.01
ISIc1	.23	-.02	-.06	.30
ISIc2	.36	.00	-.02	.35
TRAV	.45	.10	.00	.32
APAV	.44	-.07	.08	.40
RT1	.57	.56	.02	.02
RT2	.66	.64	.07	-.05
RT3	.55	.57	-.05	.03
Total Variance	28%	11%	8%	5%

Note. Salient factor loadings are underlined.

Table 6

Correlations and Unrotated Factor for Criterion Variables
and Measures of Processing Speed

	AUDLG	AUDST	ISIc1	ISIc2	TRAV	APAV	RT1	RT2	RT3	Factor Loading[a]
HSGPA	.05	-.02	.21*	-.17	.15	-.12	.00	.09	.09	.28
FRGPA	.24*	.23*	.15	.11	.18*	.01	-.10	-.03	.09	.30
SAT	.14	.25*	-.05	.00	.10	.11	.14	.25*	.19*	.56
VOCAB	.00	.05	.07	-.05	.15	.11	.03	.00	.03	.29
BD	.13	.12	.03	.09	.30**	.24*	.39**	.28**	.24*	.58
Factor Loadings[a]	.58	.51	.05	.15	.49	.35	.63	.71	.61	

Note. Correlations have been reflected so that good performance has been positively correlated with all variables.

[a]Factor loadings for first unrotated factor matrix for Principal Components analysis (total variance accounted for equals 22.6). Salient loadings are underlined.

*$p < .05$.

**$p < .01$.

Table 7

Hierarchical Factor Analysis for Criterion Variables and Measures of Processing Speed

	Factor 1 (Second-order) General Mental Speed	Factor 2 Reaction Time	Factor 3 Auditory Speed	Factor 4 Psychometric Intelligence	Factor 5 Visual Speed
AUDLG	.63	.07	.64	-.02	-.01
AUDST	.58	-.07	.67	.02	.01
ISIc1	.23	-.03	-.07	.02	.32
ISIc2	.29	.01	-.01	-.11	.38
TRAV	.47	.09	-.01	.11	.33
APAV	.40	-.08	.09	-.03	.43
RT1	.52	.61	-.02	-.03	.03
RT2	.61	.68	.08	.00	-.06
RT3	.52	.61	-.06	.03	.03
HSGPA	.30	-.01	-.07	.56	-.07
FRGPA	.40	-.15	.12	.44	.06
SAT	.47	.08	.06	.56	-.11
VOCAB	.32	-.12	-.07	.60	.02
BD	.50	.19	-.05	.37	.10
Total Variance	21%	9%	7%	10%	4%

Note. Salient factor loadings underlined. Correlations in the original matrix were reflected so that good performance has been positively correlated with all other variables.

Table 8

Correlations and First Unrotated Factor for Measures of Processing Speed and Hemispheric Functioning[a]

	Left Hemisphere	Right Hemisphere	Factor Loadings[b]
AUDLG	.25**	.04	.66
AUDST	.21*	.07	.54
ISIc1	.16	-.19*	.03
ISIc2	-.03	.10	.21
TRAV	-.04	.22*	.45
APAV	-.05	.23*	.36
RT1	.01	.24**	.70
RT2	.15	.07	.77
RT3	.14	.08	.65
Factor Loadings[b]	.26	.30	
Mean	.095	-.034	
SD	.56	.52	

[a]Correlations have been reflected.

[b]Factor loadings for first unrotated factor matrix for Principal Components factor analysis (total variance accounted for equals 25.4%). Salient loadings are underlined.

*$p < .05$.
**$p < .01$.

DISCUSSION AND CONCLUSIONS

A set of processing speed (inspection time and reaction time) tasks loaded on the same second-order factor, derived from a hierarchical analysis, as did a set of traditional measures of intelligence and aptitude. (This finding reveals that performance on complex cognitive tasks such as Block Design and the SAT is related to performance on tasks that have little or no knowledge content and require no complex problem solving strategy.) The findings thus support the theoretical view that processing speed may be a general factor in individual differences in performance on complex intellectual tasks.

The data further reveal two major components to the variability of processing speed: a general component that accounts for roughly half the variance, and task-specific components that account for the other half. The task-specific components are reaction time, auditory speed, and visual speed. These task-specific components account for substantial variability and cannot be ignored when considering the correlations between measures of processing speed and measures involving complex cognitive processing.

For instance, the pattern of correlations revealed that the visual tasks tended to be related to the right hemisphere-related tasks on the Gordon Battery; the auditory tasks, by contrast, were related to the Gordon Battery left-hemisphere tasks. Hypothetically, it would be feasible to construct one set of processing time tasks to measure general intelligence (through obtaining a composite score in which individual differences due to task-specific abilities average out, as in the Wechsler Intelligence Scales) and to measure more specific group factors that are relatively independent of each other. The specific factors can help provide a more precise evaluation of an individual's particular talents or pattern of talents.

In sum, present findings confirm that the correlation between processing speed and complex cognitive skill are quite modest, but they support the utility of processing speed for exploring questions of theoretical importance. Moreover, the data suggest a strategy for enhancing the practical application of processing speed measures. The most critical task for research in this area is to separate the common variance from the task-specific and to determine more precisely what each of these components measures. As of now, we are left with the following conclusions:

1. Inspection and reaction time tasks, which contain little or no intellectual content and involve little or no complex problem solving skills, share common variance with conventional psychometric tests that contain a high degree of intellectual content and involve complex problem solving skill.

2. Processing speed may be multi-dimensional. Though a general processing speed factor emerges from a hierarchical analysis of diverse inspection and reaction time tasks, more specific factors emerge as well. Therefore, measurement of Spearman's "g" factor of mental ability by means of speed-of-processing tasks will most likely depend on using a test battery with sufficient diversity in specific task features to permit the "averaging out" of task specific variance. The composite score would predominantly reflect the general ability factor that is common to all tasks.

3. An alternative to conclusion 2, above, is to exploit, rather than average out, task specificity. For example, some measures of processing speed will add more unique variance to ASVAB than others. Since most ASVAB subtests rely to some extent on verbal skills, chronometric test items which contain no linguistic content are perhaps the most promising candidates for research on improved personnel selection and classification.

4. Inconsistent findings across inspection time studies may be due to differences in task requirements, which may favor one subgroup over another.

RECOMMENDATIONS

Future research should be directed toward determining the circumstances under which a "processing speed subtest" would add predictive power to the ASVAB. More specifically, further determination of the dimensionality of processing speed must be made, to clarify whether a single test or brief set of tests of processing speed would be the best way to boost the validity of the ASVAB for selection and/or classification purposes. Such work should use occupational training and job performance as criterion measures.

REFERENCES

Blake, J. (1974). Developmental changes in visual information processing under backward masking. Journal of Experimental Child Psychology, 17, 133-146.

Brand, C. R. (1981). General intelligence and mental speed: Their relationship and development. In M. P. Friedman, J. P. Dos, & N. O'Conner (Eds.), Intelligence and learning (pp. 589-593). New York: Plenum Press.

Cory, C. H., Rimland, B., & Bryson, R. H. (1977). Using computerized tests to measure new dimensions of abilities: An exploratory study. Applied Psychological Measurement, 1, 101-110.

Felsten, G., & Wasserman, G. S. (1980). Visual masking: Mechanisms and theories. Psychological Bulletin, 88, 329-353.

Gordon, H. W. (1980). Cognitive asymmetry in dyslexia families. Neuropsychologia, 18, 645-656.

Gordon, H. W. (1982). Learning disabled are cognitively right. In M. Kinsbourne (Ed.), Topics in learning disabilities. New York: Academic Press.

Gordon, H. W. (1983). Cognitive Laterality Battery. Pittsburg: Western Psychiatric Institute and Clinica, University of Pittsburg, School of Medicine.

Hotelling, H. (1933). Analysis of a complex of statistical variable into principal components. Journal of Educational Psychology, 24, 417-441 and 498-520.

Irwin, R. J. (1984). Inspection time and its relation to intelligence. Intelligence, 8, 47-65.

Jensen, A. R. (1979). g-Outmoded theory or unconquered frontier? Creative Science and Technology, 2, 16-29.

Jensen, A. R. (1980a). Bias in mental testing. New York: The Free Press.

Jensen, A. R. (1980b). Chronometric analysis of mental ability. Journal of Social Biological Structures, 3, 26.

Jensen, A. R. (1982). Reaction time and psychometric g. In H. J. Eysenck (Ed.), A model for intelligence (pp. 93-132). New York: Springer-Verlag.

Jensen, A. R. (in press). The g beyond factor analysis. In J. C. Conoley, J. A. Glover, & R. R. Ronning (Eds.), The influence of cognitive psychology on testing and measurement Hillsdale, NJ: Erlbaum.

Jensen, A. R., & Munro, E. (1979). Reaction time, movement time, and intelligence. Intelligence, 3, 121-126.

Lally, M., & Nettelbeck, T. (1977). Intelligence, reaction time, and inspection time. American Journal of Mental Deficiency, 82, 273-281.

Liss, P. H., & Haith, M. M. (1970). The speed of visual processing in children and adults: Effects of backward and forward masking. Perception and Psychophysics, 8, 396-398.

Lunneborg, C. (1978). Some information-processing correlates of measures of intelligence. Multivariate Behavioral Research, 13, 153-161.

Mackintosh, N. J. (1981). A new measure of intelligence? Nature, 289, (No. 5798), 529-530.

McCornack, R. L. (1982). Predicting freshman grades and the analysis of prediction errors in four groups of minority students. Institutional Research, San Diego State University, San Diego, CA.

Mohan, J., & Jain, M. (1983). Intelligence and reaction time. Indian Psychological Review, 24, 6-11.

Nettelbeck, T. (1982). Inspection time: An index for intelligence? Quarterly Journal of Experimental Psychology, 34A, 299-312.

Nettelbeck T., & Lally, M. (1976). Inspection time and measured intelligence. British Journal of Psychology, 67, 17-22.

Raz, M., Willerman. L., Ingmundson, P., & Hanlon, M. (1983). Aptitude-related differences in auditory recognition masking. Intelligence, 7, 71-90.

Ree, M. J., Mullins, C. J., Matthews, J. J., & Massey, R. H. (1982). Armed Services vocational Aptitude Battery: Item and factor analysis of forms 8, 9, and 10 (AFHRL-TR-81-55). Brooks Air Force Base, TX: Air Force Human Resources Laboratory.

Saccuzzo, D. P., Kerr, M., Marcus, A., & Brown, R. (1979). Visual information-processing in mental retardation. Journal of Abnormal Psychology 83, 341-345.

Saccuzzo, D. P., & Marcus, A. (1983). Speed of visual information processing improves with practice in mental retardation. Paper presented at the 91st Annual Convention of the American Psychological Association, Anaheim, CA.

Saccuzzo, D. P., & Michael, B. (1984). Speed of information-processing and structural limitations in retarded and dual diagnosis retarded-schizophrenic persons. American Journal of Mental Deficiency, 89, 187-194.

Schmind, J., & Leiman, J. M. (1957). The development of hierarchical factor solutions. Psychomentrika, 22, 53-61.

Smith, G. A., & Stanley, G. (1983). Clocking g: Relating intelligence and measures of timed performance. Intelligence, 7, 353-358.

Tallal, P., & Piercy, M. (1973). The Repetition Test. Neuropsychologia, 11, 389-398.

Vernon, P. A. (1981). Reaction time and intelligence in the mentally retarded. Intelligence, 5, 345-355.

Vickers, D., Nettelbeck, T., & Willson, R. J. (1972). Perceptual indices of performance: The measurement of "inspection time" and "noise" in the visual system. Perception, 1, 263-295.

Wechsler, D. (1981). Manual for Wechsler Adult Intelligence Scale-Revised. San Diego: Hartcourt, Brace, & Janovich.

DISTRIBUTION LIST

Deputy Under Secretary of Defense for Research and Engineering (Research and Advanced Technology)
Deputy Assistant Secretary of the Navy (Manpower)
Chief of Naval Operations (OP-01B6), (OP-01B7) (2), (OP-987H)
Director of Navy Laboratories (ONT 0722)
Commander, Navy Recruiting Command (Code 20)
Commanding Officer, Naval Aerospace Medical Research Laboratory, Pensacola
Chief of Naval Research (Code 270), (Code 440), (Code 442), (Code 442PT)
Officer of Naval Research, London
Chief of Naval Education and Training (Code 00A), (Code N-21)
Chief of Naval Technical Training (Code 00)
Commandant of the Marine Corps (MPI-20)
Mr. Greenup, Education Center MCDEC, Quantico
Commander, Army Research Institute for the Behavioral and Social Sciences, Alexandria (PERI-POT-I), (PERI-SZ)
HQ USMEPCOM/MEPCPAT-A, North Chicago
Commander, Air Force Human Resources Laboratory, Brooks Air Force Base (AFHRL/MO Manpower and Personnel Division), (Scientific and Technical Information Officer), TSRL/Technical Library FL 2870)
Commander, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base (AFHRL/LR-TDC)
Commander, Air Force Human Resources Laboratory, Lowry Air Force Base (AFHRL/ID)
Commanding Officer, U.S. Coast Guard Research and Development Center, Avery Point
Superintendent, Naval Postgraduate School
Director of Research, U.S. Naval Academy
Center for Naval Analyses
Canadian Forces Personnel, Applied Research Unit, Canada
Ministry of Defense, Senior Psychologist, Naval, England
D. Dennison, Army Personnel Research Establishment, Personnel Psychological Division, England
Science 3 (RAF), Lacon House, England
1 Psychological Research Unit, NBH 3-44, Australia
Directorate of Psychology, AF, Department of Defense (Air for CE), Australia
Navy Psychology, Australia, (2)
Defense Psychology Unit, Defense HQ, New Zealand (2)
Dr. Regan
Mr. Ramras
Defense Technical Information Center (DDAC) (2)

END

DTIC

7-86