INTELLIGENCE 7, 253–269 (1983)

Convergence betweeen Attention Variables and Factors of Psychometric Intelligence in Older Adults*

STEVEN W. CORNELIUS
Cornell University
SHERRY L. WILLIS
The Pennsylvania State University
JOHN R. NESSELROADE
The Pennsylvania State University
PAUL B. BALTES
Max Planck Institute for Human Development and Education

The purpose of the present study was to examine the hypothesis that individual differences on measures of attention would converge with select factors of psychometric intelligence, especially fluid intelligence and short-term acquisition and retrieval. A sample of 83 elderly adults ($\bar{X}$ = 71 years) was administered a battery of 17 psychometric ability tests. Tests were selected to mark four psychometric ability factors (Cattell and Horn's dimensions of fluid and crystallized intelligence, short-term acquisition and retrieval, and perceptual speed). Also, seven tasks representing four aspects of attention—decoding processes, selective attention, attention switching, and concentration—were administered. A confirmatory factor analysis was conducted to examine the relationships among the four psychometric ability factors and 11 variables obtained from the attention tasks. Results were only partially consistent with the hypothesized pattern of convergence. Two attention measures had significant loadings on a fluid-type intelligence factor, and one had a marginally significant loading on a short-term memory factor. In general, the greatest convergence occurred between attention variables and the ability factor of Perceptual Speed. Results were discussed with respect to previous research on psychometric abilities and cognitive processes, the theory of fluid-crystallized intelligence, and their implications for understanding intellectual aging.

*This research was supported by a grant from the National Institute of Aging (5-R01-AG004403) to Paul B. Baltes and Sherry L. Willis, co-investigators. The authors would like to acknowledge the assistance of Margie Lachman, Avron Spiro, Myrtle Williams, Carolyn Nesselroade, Rudolph Kafer, and Manfred Schmitt in various phases of this study, and to Geoffrey Loftus for his thoughtful comments on an earlier version of this paper. Correspondence and requests for reprints should be sent to Steven W. Cornelius, Department of Human Development and Family Studies, Cornell University, Ithaca, NY 14853, or Sherry L. Willis, College of Human Development, The Pennsylvania State University, University Park, PA 16802.

The division between experimental and individual difference traditions in psychological theory and research has been a topic of substantial concern and discussion (e.g., Cronbach, 1957, 1975; Sternberg & Detterman, 1979; Underwood, 1975a). During the last decade, efforts to bridge these approaches in the area of cognition and intelligence are reflected in attempts to integrate cognitive information processing models and factor theories of intelligence (e.g., Carroll, 1976; Carroll & Maxwell, 1979; Hunt, 1978; Sternberg, 1977). Initial findings suggest that individual differences among college students on indices of intelligence may reflect variability in processes, such as accessing overlearned codes, attentional capacity, accessing and manipulating information in active memory, and resistance to interference or susceptibility to distraction (e.g., Hunt, 1978; Hunt, Frost, & Lunneborg, 1973; Hunt, Lunneborg, & Lewis, 1975).

The design of the present research was guided by dual foci. First, this study examined the relation between performance on information processing tasks and major factors of psychometric abilities, using the measurement framework of Cattell (1971) and Horn's (1970, 1978) theory of fluid and crystallized intelligence. A second aim was to examine the role of attentional processes as they may be related to individual differences in older adults' intellectual functioning. Accounting for large individual differences among elderly adults' intellectual performance is a critical concern in gerontological research (e.g., Baltes & Willis, 1979; Krauss, 1980). The present study focuses on attentional processing variables that may elucidate characteristics of individual differences in intellectual aging.

Although significant correlations between a number of information processing indices and several psychometric tests of intellectual abilities have been documented in previous research (e.g., Carroll, 1976; Hunt, 1978; Snow, 1979), the theoretical relations between these domains are still relatively imprecise. Hunt (1978), however, suggested that mechanistic information processes are conceptually similar to the psychometric abilities identified as fluid intelligence and short-term acquisition and retrieval (e.g., Horn, 1978). Support for Hunt's (1978) hypothesis is not compelling in previous research. At the level of simple correlations, relations between individual differences in information processing and verbal or quantitative achievement tests have been documented (for reviews, see Carroll, 1979; Hunt, 1978; Snow, 1979). These tests probably reflect Cattell (1971) and Horn's (1978) crystallized intelligence dimension. Moreover, in factor analytic research (e.g., Hunt et al., 1975), the results suggest that the correspondence between information processing and psychometric measures is limited. Primarily, psychometric indices of perceptual speed have been linked to processes involving the access of overlearned codes (e.g., Stroop color naming test, Posner's letter matching task, and intercept values in Sternberg's short-term memory task). However, methodological shortcomings in the design (e.g., small sample sizes; use of extreme groups; small numbers of ability variables to mark specific intellectual dimensions), and analysis (e.g., use of principal components rather than principal axes factoring methods; orthogonal rather than oblique factor rotations; reliance on simple rather than multivariate correlational analyses) of previous research preclude firm conclusions (for critiques, see Carroll, 1979; Snow, 1979). Indeed, Hunt (1978) noted that research was needed to "map out the relation between specific information-processing functions and Gf (fluid intelligence) and SAR (short-term acquisition and retrieval) measures. Such studies would be most useful if they were conducted using populations that are known to vary widely on Gf measures, such as persons in middle and later years" (p. 125).

The design of the present research avoids many of the methodological pitfalls discussed in critiques of previous research in this area (e.g., Carroll, 1979; Snow, 1979). A sample of older adults was administered a broad battery of psychometric ability tests and a number of information-processing type tasks. Psychometric tests were chosen to identify seven primary abilities representing the general dimensions of fluid intelligence and short-term acquisition and retrieval, as well as the dimensions of crystallized intelligence and broad speediness (see Table 1). This selection of psychometric tests was based on previous research with older adults (e.g., Baltes, Cornelius, Spiro, Nesselroade, & Willis, 1980) and affords a more precise identification on the factor level of the psychometric ability domain than has been possible in prior research. In addition, seven information-processing tasks were included in the present study to identify four aspects of attention: decoding processes, selective attention, attention switching or reorientation, and concentration. Several of these tasks have been in previous research by Hunt and his colleagues (e.g., Hunt, 1978; Hunt et al., 1973; Hunt et al., 1975; Lansman, 1977; Lansman, Donaldson, Hunt, & Yantis, in press; Poltrock, 1977). Measures of concentration or vigilance involving sustained attention over an extended time (12.5 to 15 minutes) were also included to explore the relation between fluctuation in this function and psychometric ability performance.

METHOD

Subjects

The sample consisted of 83 community-dwelling older adults from rural locales in central Pennsylvania. The mean age of subjects (19 males, 64 females) was 70.58 years (SD = 6.86; range = 61–90). Male subjects were significantly older ($\bar{M}$ = 74.68, F = 69.36 years; F (1,81) = 9.76, $p < .03$). The mean educational level of the sample was 12.12 years (SD = 3.14; range = 6–19) with no significant sex differences. The self-reported health of subjects was good, and subjects reported no substantial auditory or visual impairments.

TABLE 1

Schematic Design of Psychometric Measurement Battery[a]

General Dimension	Primary Ability	Test[b]	Source
Fluid Intelligence	CFR	Culture Fair Test (Scale 2, Form A), Power Matrices (Scale 3, Form A, 1963 ed., and Form B, 1961 ed.)	Cattell & Cattell (1957, 1961, 1963)
	CFR	ADEPT Figural Relations Test (Form A)	Plemons, Willis, & Baltes (1978)
	CFR	Raven's Progressive Matrices	Raven (1962)
Fluid Intelligence	I	ADEPT Induction Diagnostic Test	Blieszner, Willis, & Baltes (1981)
	I	Induction Standard Test	Ekstrom, French, Harman, & Derman (1976); Thurstone (1962)
Fluid/Crystallized Intelligence	CMR	Verbal Analogies I	Guilford (1969a)
	CMR	Word Matrix	Guilford (1969b)
Crystallized Intelligence	EMS	Social Translations (Form A)	O'Sullivan & Guilford (1965); O'Sullivan, Guilford, & deMille (1965)
	EMS	Social Situations (EP03A)	Horn (1967)
Crystallized Intelligence	V	Verbal Meaning (9–12)	Thurstone (1962)
	V	Vocabulary (V-2, V-3, V-4)	Ekstrom et al. (1976)
Short-term Acquisition and Retrival/Fluid Intelligence	MS	Visual Number Span	Ekstrom et al. (1976)
	MS	Auditory Number Span	After Ekstrom et al. (1976)
	MS	Auditory Number Span—Delayed Recall	After Ekstrom et al. (1976)
Broad Speediness	P	Finding A's	Ekstrom et al. (1976)
	P	Number Comparison	Ekstrom et al. (1976)
	P	Identical Pictures	Ekstrom et al. (1976)

[a]Hypothesized relationships are based primarily on Cattell (1971) and Horn (1970, 1975, 1978). Hypothesized primary mental abilities include Figural Relations (CFR), Induction (I), Semantic Relations (CMR), Experiential Evaluation (EMS), Verbal Comprehension (V), Memory Span (MS), and Perceptual Speed (P). Several of the marker tests were shortened for administration.

[b]Induction and Vocabulary are composites of several subtests (see text). The Induction Diagnostic and Standard subtests include Letter Sets (Blieszner et al., 1981; Ekstrom et al., 1976) Number Series, and Letter Series (Blieszner et al., 1981; Thurstone, 1962). Vocabulary is a composite of subtests V–2, V–3, and V–4 (Ekstrom et al., 1976).

Measurement Battery

Psychometric Tests. The battery of psychometric intelligence tests (see Table 1) was selected to mark the four general, second-stratum dimensions of fluid and crystallized intelligence, short-term acquisition and retrieval, and broad speediness (Cattell, 1971; Horn, 1970, 1978). One or more relatively "pure" primary abilities representing these dimensions were identified (e.g., Horn, 1975, 1978), and multiple tests were included in the battery to mark each primary mental ability.

Attention Variables. Information processing tasks were chosen to obtain measures of four aspects of attention: decoding processes, selective attention, attention switching, and concentration. A conceptual framework involving the four attention dimensions, representative tasks, and dependent variables is presented in Table 2.

1. *Decoding processes* involved in accessing overlearned codes. A paper and pencil version of Posner's letter identification task developed by Lansman et al. (in press) was used. Pairs of letters were judged as same or different under two conditions. In a physical identity condition (sections 2 and 4 of the tasks), letter pairs are the same only if the letters are exact duplicates (e.g., AA). In a name identity condition (sections 3 and 5), letter pairs are the same if they are different visual symbols for the same letter name (e.g., Aa). There are 120 problems in

TABLE 2
Schematic Design for Attention Measures

Aspect of Attention	Task	Variable	Original Source
Decoding Processes	Letter Identification	(a) Name identity (b) Name minus Physical Identity	Lansman (1977)
Selective Attention	Stroop Color Naming	(a) Word condition (b) Word minus Color Naming	Stroop (1935)
	Number Counting	(a) Digit Counting (b) Digit minus Letter Counting	Underwood (1975b)
Attention Switching	Proactive Interference in Semantic Recall	(a) Trial 4 total (b) Trial 4 minus Trial 1	Wickens (1972)
	Continuous Paired-Associate Recall	Total number recalled	Atkinson & Shiffrin (1968)
Concentration	Concentration Performance Test	Total number correct	Düker (1959)
	Word Recognition Test	Total number correct	ADEPT (1979)

each section with 1.25 minutes allotted per section; section 1 was a practice condition.

2. *Selective attention* was assessed in two measures: modified version of the Stroop (1935) color naming task and Underwood's (1975b) number counting task. The Stroop task involved two conditions. In the color condition (Parts 1 and 3), subjects were shown a color swatch of one of five colors (red, orange, blue, green, or yellow) and asked to write the first letter of the color (R, O, B, G, Y) as quickly as possible. In the word condition (Parts 2 and 4), color names were printed in an incongruous color of ink (e.g., "red" was printed in blue ink). The subject was to write as quickly as possible the first letter of the ink color. There were 120 problems in each part with a time limit of 2 minutes per part. Two scores were obtained: (a) total number of correct responses in the word condition (split-half reliability estimate = .91), and (b) a difference score derived by subtracting an individual's score in the color condition from the score in the word condition (reliability estimate = .39).

A number counting task (based on Underwood, 1975b) involved two conditions. In the letter condition (Parts 1 and 3), subjects were shown rows of the letter Q and asked to count the number of Qs in each row as quickly as possible. In the digit condition (Parts 2 and 4), subjects were shown rows of identical digits of incongruous span lengths (e.g., eight 2s) and required to count the number of digits in each row. There were 108 problems in each part with a time limit of 1 minute 50 seconds per part. Two scores were obtained: (a) total number of correct responses in the digit condition (split-half reliability estimate = .96), and (b) a difference score derived by subtracting an individual's score in the letter condition from the score in the digit condition (reliability estimate = .41).

3. *Attention switching* was assessed in a semantic recall task and a continuous paired-associate task. A semantic recall task, sensitive to proactive interference, was developed based on Wickens's (1972) procedure. This task involved five blocks of trials with four trials per block. In each trial block, subjects were shown successively four cards each containing three semantically related words (e.g., Trial 1: apple, orange, peach). After each card presentation, subjects were asked to remember the words while performing a distraction task (writing numbers forward by 3s for 15 seconds). Subjects then recalled the three words. In the four successive trials per block, additional words from the same semantic category (e.g., Trial 2: banana, cherry, plum) were presented. Subject's recall was expected to become increasingly impaired as a result of proactive interference. Two scores were obtained: (a) Number of words recalled on the fourth trial, summed across five trial blocks (alpha reliability estimate = .81), and (b) a difference score derived by subtracting scores on the first trial from scores on the fourth trial summed across five blocks of trials (reliability estimate = .40).

A continuous paired-associate task, modelled after Atkinson and Shiffrin's (1968) procedure, involved eight practice trials and 30 test trials. Initially, subjects were shown two cards involving letter-number pairs (e.g., A = 3; B = 7).

In the probe trial (e.g., A = ?), the subject was to write the number paired with the probe letter. Following the probe trial, the letter was re-paired with a different number (e.g., A = 9). Thirty trials were presented. One score was computed: total number correct responses for 30 probe trials (alpha reliability estimate = .92).

4. *Concentration* or vigilance was assessed in two tasks. Concentration was conceptualized as sustained attention in tasks involving a time period of much longer duration than in the tasks described above. The Concentration Performance task was an adaptation of Düker's (1959) Konzentrations-Leistungs-Test. Subjects computed two arithmetic problems (e.g., 3 + 6 − 8= ; 9 + 1 + 7 =) and then were instructed to subtract the smaller sum from the larger sum (e.g., 16). Subjects were told to solve as many problems as possible. After 7.5 minutes, subjects circled the problem they were working on and continued. One score was computed: total number of correct responses (split-half reliability estimate = .94).

A word recognition task was developed by research staff as an additional index of concentration. This task was divided into 10 sections. In each section, subjects were to identify the 50 three-letter words among 200 three-letter syllables (consonant-vowel-consonant). For each section, 1.25 minutes were allotted. One score was computed: total number correct responses (reliability estimate = .99).

Procedure

A young white woman administered the psychometric tests and information-processing tasks with the assistance of a test proctor(s). Testing sites were community organization facilities (e.g., senior citizen centers). Subjects were tested during the summer of 1979 in groups of 4 to 12 persons per group. Subjects had previously participated in 1977 in a study of the structure of psychometric abilities in old age (Baltes et al., 1980).

The test battery was administered in three sessions (2.5–3 hours per session). Within each session, psychometric and information-processing tasks, and personality/demographic questionnaires were administered.

Scoring and Descriptive Statistics

In the psychometric battery, a total score was computed for each ability test. For two primary abilities, a combined score was computed from several highly correlated tests assumed to measure them. Composite Induction scores were computed for Induction Diagnostic and Induction Standard tests by summing the standardized scores of the three respective subtests: Letter Sets, Number Series, and Letter Series tests. Likewise, a composite Vocabulary score was obtained for the sum of scores on three vocabulary subtests (V–2, V–3, V–4; Ekstrom, French, Harman, & Derman, 1976).

A basic score was obtained for each of the attention tasks. A derived score was also computed for the Letter Identification, Stroop Color Naming, Number Counting, and Semantic Recall tasks. It is problematic to select from among many possible scores that may be obtained from such tasks (cf. Carroll, 1979; Hunt, 1978). From a measurement view, the basic scores have better measurement properties (e.g., the estimated reliabilities of the basic scores are higher than those of the derived scores). However, from a theoretical view, the derived scores are presumably better indices of specific attentional processes. Since several of the tasks are highly speeded, the basic variables probably measure both a specific attentional process as well as general speed of processing. The derived scores should control for such extraneous influences, since they are obtained by subtracting an individual's score in a control condition of the task. Because methodological and theoretical considerations lead to somewhat different conclusions, both basic and derived scores for four attention tasks were included in the following analyses.

Correlations among the psychometric ability tests and attention measures are presented in Table 3.

Method of Data Analysis

Data analyses were conducted in two stages. First, a structural, factor analytic representation of the domain of psychometric ability variables was established. Three structural ability models investigated by Baltes et al. (1980) were used as target models to examine their fit to the present data. A confirmatory factor analysis program (Jöreskog & Sörbom, 1978) was used to examine the fit of the three structural models (seven factors; four factors; and a general and three group factors). For each model, hypothesized salient factor loadings were estimated and hypothesized nonsalient factor loadings were fixed equal to zero. Factor variances were fixed equal to unity to establish a metric for each factor. Factor correlations were estimated, and the unique variances of the variables were left free to be estimated.

Results of this stage of analyses provide a reference framework for the second stage of analyses investigating the structural convergence between the domains of psychometric intelligence factors and attention variables. An extension-type factor analysis (e.g., Dwyer, 1937; Gorsuch, 1974) was conducted. A fixed structural solution for the domain of psychometric ability variables was employed (i.e., the factor loadings and unique variance for psychometric variables and factor intercorrelations were fixed equal to numerical values obtained from the first stage of analysis of psychometric ability variables). Then, the model of psychometric ability factors was extended to the domain of attention variables. Basic and derived variables obtained from the attention tasks were allowed to load freely on each of the four factors. Unique variances for the attention variables were estimated. In addition, covariances among the unique factors of the

TABLE 3

Correlations Among Psychometric Ability and Attention Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1. Culture Fair	—																											
2. Figural Relations Diagnostic	.70	—																										
3. Raven's Progressive Matrices	.62	.69	—																									
4. Induction Diagnostic	.71	.63	.65	—																								
5. Induction Standard	.67	.68	.73	.77	—																							
6. Verbal Analogies	.55	.61	.54	.60	.63	—																						
7. Word Matrix	.56	.47	.43	.64	.63	.52	—																					
8. Social Translations	.50	.50	.47	.46	.43	.54	.32	—																				
9. Social Situations	.52	.57	.45	.51	.50	.50	.44	.56	—																			
10. Verbal Meaning	.60	.63	.60	.59	.66	.63	.55	.53	.67	—																		
11. Vocabulary	.55	.53	.59	.55	.59	.59	.50	.46	.58	.90	—																	
12. Visual Number Span	.37	.43	.37	.43	.49	.44	.39	.30	.43	.57	.56	—																
13. Auditory Number Span	.32	.34	.36	.38	.44	.24	.35	.24	.24	.34	.32	.37	—															
14. Number Span—Delayed Recall	.52	.44	.54	.44	.53	.34	.42	.24	.35	.46	.49	.53	.64	—														
15. Finding A's	.42	.46	.38	.46	.49	.33	.28	.20	.35	.50	.48	.50	.04	.26	—													
16. Number Comparison	.45	.60	.48	.53	.57	.45	.37	.27	.53	.54	.54	.44	.20	.32	.53	—												
17. Identical Pictures	.50	.63	.52	.48	.53	.40	.42	.42	.55	.48	.40	.41	.11	.34	.51	.62	—											
18. Name Identity	.59	.69	.49	.57	.55	.48	.42	.43	.56	.56	.54	.46	.19	.42	.64	.66	.75	—										
19. Name Minus Physical Identity	−.28	−.09	−.18	−.20	−.14	−.08	−.12	−.19	−.16	−.13	−.09	−.09	−.10	−.21	−.10	−.23	−.32	−.16	—									
20. Stroop Word Naming	.64	.64	.52	.56	.55	.49	.42	.47	.51	.57	.56	.38	.24	.40	.40	.53	.61	.73	−.23	—								
21. Word minus Color Naming	−.06	−.08	−.08	−.14	−.22	−.15	−.23	.05	−.09	−.12	−.17	−.24	.03	−.04	−.25	−.39	−.28	−.20	.14	.00	—							
22. Digit Counting	.60	.70	.69	.61	.69	.59	.50	.45	.55	.66	.59	.50	.25	.49	.47	.71	.76	.76	−.28	.72	−.24	—						
23. Digit minus Letter Counting	.14	.14	.26	.29	.36	.11	.21	.20	.18	.14	.09	.23	.14	.19	.20	.06	.06	.09	.03	.04	−.09	.12	—					
24. Trial 4 Semantic Recall	.43	.43	.45	.39	.44	.35	.40	.27	.46	.59	.61	.36	.26	.47	.30	.33	.44	.55	−.14	.54	−.15	.52	.00	—				
25. Trial 4 minus Trial 1 Recall	.16	.24	.21	.16	.24	.12	.23	.06	.15	.30	.33	.15	.18	.25	.17	.14	.20	.26	−.04	.19	−.10	.22	.02	.61	—			
26. Cont. Paired-Associate Recall	.56	.64	.64	.63	.59	.46	.47	.56	.50	.52	.50	.36	.36	.45	.40	.44	.50	.60	−.22	.64	.01	.64	.33	.47	.23	—		
27. Concentration Performance	.45	.56	.52	.47	.50	.45	.34	.31	.43	.55	.50	.51	.31	.40	.45	.47	.43	.52	−.09	.53	−.07	.57	.16	.38	.23	.50	—	
28. Word Recognition	.59	.62	.52	.56	.55	.50	.39	.38	.60	.65	.61	.51	.12	.35	.56	.63	.77	.77	−.32	.70	−.30	.78	−.01	.58	.14	.51	.54	—

Note: $N = 83$ subjects.

attention variables were left free to be estimated in order to minimize relations among attention variables on the outcome. Convergence between psychometric ability factors and attention variables was examined in terms of the pattern of factor loadings (regressionlike weights of attention variables on ability factors) rather than factor structure coefficients (correlations between attention variables and ability factors).[1]

RESULTS

Stage One: Structural Models of Psychometric Ability Factors

In the first analysis, a seven-factor model was constructed to represent the primary abilities of Figural Relations, Induction, Semantic Relations, Experiential Evaluation, Verbal Comprehension, Memory Span, and Perceptual Speed. Results from the present analysis of this model were similar to the earlier outcome (Baltes et al., 1980). The overall statistical fit of the model was $\chi^2(98) = 134.34$, $p = .0087$. However, the factor correlations were quite high with three exceeding .88, indicating some redundancy among the seven factors. Less differentiated models with fewer factors were then investigated to determine whether they might yield viable and more parsimonious representations.

The second model examined consisted of a general factor with loadings for all psychometric ability variables and three group factors identified by the marker variables of Verbal Comprehension, Memory Span, and Perceptual Speed. The overall statistical fit of this model was $\chi^2(108) = 159.84$, $p = .0009$.

Finally, a four-factor model was examined. Marker variables of the fluid abilities Figural Relations, Induction, and Semantic Relations were combined with the marker variables of the crystallized ability Experiential Evaluation to define a Broad Reasoning factor. A Crystallized Knowledge factor was loaded by the Social Situations test and Verbal Comprehension markers. A Memory Span factor was loaded by visual and auditory tests of digit span recall. Finally, a Perceptual Speed factor was loaded by three speed tests of perceptual discrimination.[2] The fit of this was $\chi^2\ (112) = 160.32$, $p = .0019$. The standardized solution for the four-factor model is presented in the upper half of Table 4.

---

[1]The decision to focus on the factor-loading pattern rather than the factor structure coefficients was made, because available evidence on older adults has indicated substantial intercorrelations among ability factors (e.g., Baltes et al., 1980). The factor loading pattern treats the psychometric ability factors as an interrelated system. The estimated factor loadings provide a description of the factorial composition of the attention variables using available evidence on psychometric ability factors as a standard. In this sense, the loading coefficients take into account the magnitude of factor correlations among psychometric abilities.

[2]The modified four-factor model reported by Baltes et al. (1980) included loadings of the ADEPT Induction test on the Perceptual Speed factor and Identical Pictures test on the Memory Span factor. When this modified model was analyzed using the present data, neither of these loadings differed significantly from zero; they were fixed at zero in the four-factor solution presented here.

TABLE 4
Standardized Solution for Extension Analysis Model of Psychometric Ability Factors and Attention Variables

Variable	Factor: Broad Reasoning	Factor: Crystallized Knowledge	Factor: Memory Span	Factor: Perceptual Speed	Unique Variance
	Factor Loadings[a]				
Psychometric Ability					
Culture Fair	.80				.35
Figural Relations Diagnostic	.82				.33
Raven's Progressive Matrices	.79				.37
Induction Diagnostic	.83				.31
Induction Standard	.87				.24
Verbal Analogies	.72				.48
Word Matrix	.67				.55
Social Translations	.58				.67
Social Situations	.30	.44			.51
Verbal Meaning		.99			.02
Vocabulary		.91			.18
Visual Number Span			.62		.61
Auditory Number Span			.70		.51
Number Span—Delayed Recall			.87		.24
Finding A's				.66	.56
Number Comparison				.80	.37
Identical Pictures				.78	.39
Attention					
Name Identity	−.14	−.09	.12	1.02**	.16
Name minus Physical Identity	.17	.16	−.19	−.46*	.88
Stroop Word Naming	.36	.06	.00	.37**	.46
Word minus Color Naming	.46	.13	−.05	−.85**	.73
Digit Counting	.13	.01	.11	.72**	.19
Digit minus Letter counting	.62**	−.18	.06	−.28	.87
Trial 4 Semantic Recall	−.15	.45**	.28*	.17	.59
Trial 4 minus Trial 1 Recall	−.17	.27	.20	.34*	.89
Cont. Paired-Associate Recall	.75**	−.12	.05	.05	.46
Concentration Performance	.05	.16	.20	.34*	.57
Word Recognition	−.17	.21*	−.02	.88**	.22
Factor	Intercorrelations				
Broad Reasoning	—				
Crystallized Knowledge	.77	—			
Memory Span	.68	.58	—		
Perceptual Speed	.80	.68	.49	—	

[a]Factor loadings, unique variances, and factor intercorrelations for psychometric ability variables were fixed equal to the values underlined; blanks in each column indicate loadings fixed equal to zero.

*.05 < p < .10.

**p < .05.

The four-factor model was adoped to define a multidimensional structure for psychometric ability variables in the second stage of analyses. This choice was guided by considerations of both statistical and theoretical criteria (see Baltes et al., 1980, for a discussion of the relative merits of alternative representations of ability structures). In the present context, the four-factor model has an acceptable fit to the psychometric ability data. Moreover, it exhibits high similarity to the second-stratum dimensions of the fluid-crystalized theory (cf. Horn, 1978), and, thus, is more appropriate than the models with seven factors or a general and three group factors for investigating the hypothesis that attentional processes are most highly related to the dimensions of fluid intelligence and short-term acquisition and retrieval (factors labeled Broad Reasoning and Memory Span, respectively, in this model).

Stage Two: Convergence Between Ability Factors and Attention Variables

The standardized solution for the extension-type model is presented in Table 4. The overall goodness of fit is χ^2 (296) = 339.39, p = .0418. The primary concern in this solution is the pattern of significant loadings of attention variables on psychometric ability factors.

The results listed in Table 4 indicate only partial support for the hypothesized convergence between attention variables and ability factors of fluid intelligence (Factor 1: Broad Reasoning) or short-term acquisition and retrieval (Factor 3: Memory Span). Two attention variables (the derived score from Underwood's counting task and Continuous Paired-Associate Recall) have significant loadings on the Broad Reasoning factor and one attention variable (Trial 4 Semantic Recall) has a marginally significant loading on the Memory Span factor. However, the major convergence occurs between the Perceptual Speed factor (Factor 4) and attention variables. Five attention variables have significant loadings on this factor, and an additional two have marginally significant loadings on it. Because Name Identity, Stroop Word Naming, and Digit Counting tasks were speeded and scores on them were computed using the number correct in a fixed time limit, higher scores for these variables reflect faster reaction times. Two attention variables (derived scores from the Posner letter identification and Stroop color naming tasks) have significant negative loadings on this factor. This result may occur because the psychometric speed variables have larger covariances with performance in the "control" condition of these attention tasks, which is subtracted in the computation of derived scores. Similar results have been obtained in previous research using derived scores from these tasks (e.g., Hunt et al., 1975). Finally, two attention variables, both involving semantic content, load the Crystallized Knowledge factor (Factor 2). In summary, only three of the eleven attention variables have significant loadings on the fluid intelligence or short-term memory dimensions. In general, the results indicate that the attention variables included in this analysis are more highly related to the ability factor of Perceptual Speed.[3]

DISCUSSION

The present research examined the convergence between major factors of psychometric intelligence and several attention variables. The specific aim was to assess the hypothesis that processes involved in attention would be most highly related to ability dimensions of fluid intelligence and/or short-term acquisition and retrieval in the theory of fluid-crystallized intelligence. The analytic strategy of the present research paralleled the logic of extension analysis and involved two stages of analyses.

In the first stage of analyses, the fits of three structural models of psychometric abilities differing in the number of factors and pattern of loadings were evaluated (e.g., Baltes et al., 1980). Outcomes of the present analyses were quite similar to earlier results. Although a highly differentiated seven-factor model had an acceptable statistical fit to the data, the magnitude of factor intercorrelations indicated substantial overlap among some of the factors. Consequently, less differentiated models with a general and three group factors and four factors were evaluated. The four-factor model was selected for use in further analyses for theoretical reasons. This model includes factors labeled Broad Reasoning, Crystallized Knowledge, Memory Span, and Perceptual Speed. These four factors are similar to but not identical with four second-stratum dimensions of fluid intelligence, crystallized intelligence, short-term acquisition and retrieval, and broad speediness, respectively, in Cattell (1971) and Horn's (1978) theory.

In the second stage of analyses, the four-factor model of psychometric intellectual abilities was extended to the domain of attention variables to examine the relationships among the ability factors and attentional processing measures. It was expected that selected measures of attention would have significant loadings on the fluid-type factor of Broad Reasoning and/or Memory Span factor. Factor loadings of attention variables on psychometric ability factors provided scant support for this hypothesis. Two attention variables had significant loadings on

[3]One reviewer (John B. Carroll) reanalyzed the data and provided us with his results. An exploratory factor analysis of the psychometric abilities yielded five factors according to his criteria for extraction. Factors of Crystallized Knowledge, Memory Span, and Perceptual Speed were similar to those reported here. A Social Intelligence factor loaded by Social Translations and Situations tests was distinguished from a Broad Reasoning factor which was loaded by the first seven tests listed in Table 4. A traditional extension analysis was then performed. The pattern of results for the attention variables was quite similar to that reported in Table 4, based on an examination of salient loadings in the two solutions. The absolute magnitude of the factor loadings reported in Table 4 was somewhat larger than those obtained in Professor Carroll's analysis. Both analyses suggest that the majority of the attention variables have their largest convergence with a Perceptual Speed factor. Copies of Professor Carroll's results may be obtained from the authors upon request.

the Broad Reasoning factor. Contrary to the expected pattern of convergence, two attention variables loaded on the Crystallized Knowledge factor, and seven variables loaded on the Perceptual Speed factor. Thus, these results indicate that the attention variables included in the present study converge chiefly with the ability factor of Perceptual Speed rather than with factors of Broad Reasoning or Memory Span.

These results should not be misinterpreted as suggesting that the attention variables loading on the Perceptual Speed factor are unrelated to the other three psychometric ability factors. Indeed, most of the simple correlations between the marker tests of these other factors and the attentional variables are moderate in size and significant (see Table 3). However, all of these ability factors evidence significant and substantial intercorrelations (e.g., see the factor intercorrelations in Table 4. In the extension-type factor analysis conducted in the present study, the correlations among ability factors are taken into account in that the factor loadings of the attention variables on the ability factors are regression-type weights with the effects of other factors partialled. Thus, within the context of a multidimensional structure of interrelated intellectual abilities, most of the attention variables appear to be more highly related to the Perceptual Speed than other ability factors.

Data in the present study were obtained from a sample of elderly adults, and it is questionable whether they are generalizable to other age groups. Although the findings should be interpreted with caution due to our sampling only of older adults, the results of the present study are in accord with the outcomes of similar research examining the relations between psychometric abilities and cognitive information processing variables in adolescent and young adult samples. For example, Hunt et al. (1975) obtained a factor with positive loadings for two psychometric tests of clerical (perceptual) speed and negative loadings for derived scores from the Posner letter-matching and Stroop color-naming tasks. Similar to the present results, however, the variables derived from these two tasks had negligible loadings on the factors which were loaded by traditional psychometric measures of fluid and crystallized abilities. Likewise, Lunneborg (1977) found that the difference score on the Stroop task was a significant predictor of performance on two perceptual speed tests but not on various tests of fluid or crystallized abilities. Finally, Lansman et al. (in press) reported a confirmatory factor analysis indicating that letter-matching speed in the Posner task was highly correlated with a psychometric factor of clerical–perceptual speed but uncorrelated with factors of fluid and crystallized intelligence and spatial visualization.

Moreover, the results are consistent with the identification of a broad dimension of speediness in gerontological research (e.g., Birren, Woods, & Williams, 1980) and the theory of fluid-crystallized intelligence (e.g., Horn, 1978). In the present study, all of the attention variables loading on the Perceptual Speed factor were based on performance in speeded tasks. Although it is possible that the present results are in part an artifact of this measurement procedure, measures obtained from speeded tasks do not necessarily load a single factor (e.g., Horn & Donaldson, 1980; Hunt et al., 1975).[4] In addition, even the derived scores for the Letter Matching and Stroop tasks (i.e., Name minus Physical Identity and Word minus Color Naming) loaded on the Perceptual Speed factor. Since general individual differences in speed should be minimized by subtracting individuals' scores in the control condition of a task, results for the derived scores are not consistent with an interpretation that the findings are a simple result of the measurement procedures employed.

Substantively, the outcomes of the present research contribute to a further understanding of the role of speed in intellectual aging. Horn (1980), for example, suggested that traditional psychometric tests of speed probably reflect attentional processes such as a capacity for dividing attention and focusing concentration. In the present study, neither of the tasks selected to tap attention switching loaded on the speed factor, but it was loaded by measures designed to tap decoding processes, selective attention, and concentration. This finding identifies some attentional processes that are highly related to individual differences in performance on perceptual speed tests. Moreover, the results suggest that these attentional processes should be distinguished from other major individual-difference dimensions of abilities. Although it is possible that age-related deficits in processes of decoding, selective attention, and concentration are related to performance on psychometric tests of intellectual abilities, the present results do not support an interpretation that such deficits are chiefly involved in the aging of fluid or crystallized abilities or short-term memory. Results from a recent study designed to examine the modifiability of attention in older adults (Willis, Cornelius, Blow, & Baltes, 1983) provide corroborative evidence for this view. Although significant training effects in the study were obtained on several measures of attention, these effects were not paralleled by transfer effects to any of the posttest measures of fluid or crystallized intelligence or memory span.

In concert, the results of both correlational and experimental research with older adults yields little support for the view that individual differences in attentional processes are primarily related to individual differences in reasoning, knowledge, or short-term memory abilities. Consistent with other findings from previous research with younger adults, the present results indicate that individual differences on several types of attentional processes are more highly related to individual differences on the ability factor of Perceptual Speed than to other major factors psychometric intelligence.

---

[4]In separate analyses, the dimensionality of the attention variables was examined independent from the psychometric intelligence variables. In these analyses, only the basic scores from the attention tasks were analyzed. Results were consistent with a unidimensional model [$\chi^2(11) = 7.37, p = .77$] and did not match our conceptual differentiation among four distinct attentional dimensions.

REFERENCES

Adult Development and Enrichment Project. *Word recognition test.* The Pennsylvania State University, College of Human Development, 1979.

Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its component processes. In K. W. Spence & J. T. Spence (Eds.), *Advances in the psychology of learning and motivation: Research and theory* (Vol. 2). New York: Academic Press, 1968.

Baltes, P. B., Cornelius, S. W., Spiro, A., Nesselroade, J. R., & Willis, S. L. Integration vs. differentiation of fluid-crystallized intelligence in old age. *Developmental Psychology,* 1980, *16,* 625–635.

Baltes, P. B., & Willis, S. L. The critical importance of appropriate methodology in the study of aging: The sample case of psychometric intelligence. In F. C. Hoffmeister & C. Müller (Eds.), *Brain function in old age.* Heidelberg: Springer, 1979.

Baltes, P. B., & Willis, S. L. Enhancement (plasticity) of intellectual functioning in old age: Penn State's Adult Development and Enrichment Project (ADEPT). In F. I. M. Craik & S. E. Trehub (Eds.), *Aging and cognitive processes.* New York: Plenum Press, in Press, 1982.

Birren, J. E., Woods, A. M., & Williams, M. V. Behavioral slowing with age: Causes, organization, and consequences. In L. W. Poon (Ed.), *Aging in the 1980s: Psychological issues.* Washington, DC: American Psychological Association, 1980.

Blieszner, R., Willis, S. L., & Baltes, P. B. Training research in aging on the fluid ability of inductive reasoning. *Journal of Applied Developmental Psychology,* 1981, *2,* 247–265.

Carroll, J. B. Psychometric tests as cognitive tasks: A new "Structure of Intellect." In L. B. Resnick (Ed.), *The nature of intelligence.* Hillsdale, NJ: Erlbaum, 1976.

Carroll, J. B. How shall we study individual differences in cognitive abilities?—Methodological and theoretical perspectives. In R. J. Sternberg & D. K. Detterman (Eds.), *Human intelligence: Perspectives on its theory and measurement.* Norwood, NJ: Ablex, 1979.

Carroll, J. B., & Maxwell, S. E. Individual differences in cognitive abilities. *Annual Review of Psychology,* 1979, *30,* 603–640.

Cattell, R. B. *Abilities: Their structure, growth, and action.* Boston, MA: Houghton-Mifflin, 1971.

Cattell, R. B., & Cattell, A. K. S. *Test of g: Culture fair* (Scale 2, Form A). Champaign, IL: Institute for Personality and Ability Testing, 1957.

Cattell, R. B., & Cattell, A. K. S. *Measuring intelligence with the Culture-Fair tests: Manual for Scales 2 and 3.* Champaign, IL: Institute for Personality and Ability Testing, 1961.

Cattell, R. B., & Cattell, A. K. S. *Test for g: Culture Fair* (Scale 3, Form A and B). Champaign, IL: Institute for Personality and Ability Testing, 1963.

Cronbach, L. J. The two disciplines of scientific psychology. *American Psychologist,* 1957, *12,* 671–684.

Cronbach, L. J. Beyond the two disciplines of scientific psychology. *American Psychologist,* 1975, *30,* 116–127.

Düker, H. *Konzentrations-Leistungs-Test.* Göttingen: Hogrefe, 1959.

Dwyer, P. S. The determination of the factor loadings of a given test from the known factor loadings of other tests. *Psychometrika,* 1937, *2,* 173–178.

Ekstrom, R. B., French, J. W., Harman, H., & Derman, D. *Kit of factor-referenced cognitive tests* (Rev. ed.). Princeton, NJ: Educational Testing Service, 1976.

Gorsuch, R. L. *Factor analysis.* Philadelphia, PA: Saunders, 1974.

Guilford, J. P. *Verbal analogies test, I.* Beverley Hills, CA: Sheridan Psychological Services, 1969. (a)

Guilford, J. P. *Word matrix test.* Beverley Hills, CA; Sheridan Psychological Services, 1969. (b)

Horn, J. L. Social situations—EP03A. Unpublished test, University of Denver, Department of Psychology, 1967.

Horn, J. L. Organization of data on life-span development of human abilities. In L. R. Goulet & P. B. Baltes (Eds.), *Life-span developmental psychology: Research and theory.* New York: Academic Press, 1970.

Horn, J. L. Psychometric studies of aging and intelligence. In S. Gershon & A. Raskin (Eds.), *Aging* (Vol. 2). New York: Raven Press, 1975.

Horn, J. L. Human ability systems. In P. B. Baltes (Ed.), *Life-span development and behavior* (Vol. 1). New York: Academic Press, 1978.

Horn, J. L. Concepts of intellect in relation to learning and adult development. *Intelligence*, 1980, *4*, 285–317.

Horn, J. L., & Donaldson, G. Cognitive development in adulthood. In O. G. Brim, Jr. & J. Kagan (Eds.), *Constancy and change in human development*. Cambridge, MA: Harvard University Press, 1980.

Hunt, E. Mechanics of verbal ability. *Psychological Review*, 1978, *85*, 109–130.

Hunt, E., Frost, N., & Lunneborg, C. Individual differences in cognition. In G. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 7). New York: Academic Press, 1973.

Hunt, E., Lunneborg, C., & Lewis, J. What does it mean to be high verbal? *Cognitive Psychology*, 1975, *7*, 194–227.

Jöreskog, K. G., & Sörbom, D. *LISREL IV: A general computer program for estimation of linear structural equation systems by maximum likelihood methods*. Chicago, IL: International Educational Resources, 1978.

Krauss, I. Between- and within-group comparisons in aging research. In L. W. Poon (Ed.), *Aging in the 1980s: Psychological issues*. Washington, DC: American Psychological Association, 1980.

Lansman, M. Paper and pencil measures of cognitive processes (Tech. Note). Seattle, WA: University of Washington, Department of Psychology, 1977.

Lansman, M., Donaldson, G., Hunt, E., & Yantis, S. Ability factors and cognitive processes. *Intelligence*, in press.

Lunneborg, C. E. Choice reaction time: What role in ability measurement? *Applied Psychological Measurement*, 1977, *1*, 309–330.

O'Sullivan, M., & Guilford, J. P. *Social translations, Form A*. Beverley Hills, CA: Sheridan Psychological Services, 1965.

O'Sullivan, M., Guilford, J. P., & de Mille, R. *Measurement of social intelligence* (Tech. Rep. No. 34). Los Angeles: University of Southern California, Psychology Laboratory, 1965.

Plemons, J., Willis, S. L., & Baltes, P. B. Modifiability of fluid intelligence in aging: A short-term longitudinal training approach. *Journal of Gerontology*, 1978, *33*, 224–231.

Poltrock, S. E. Individual differences in attentional processes. Paper presented at the meeting of the Western Psychological Association, Seattle, April 1977.

Raven, J. C. *Standard progressive matrices, Set II* (1962 Rev.). London: H. K. Lewis, 1962.

Snow, R. E. Theory and method for research in aptitude processes. In R. J. Sternberg & D. K. Detterman (Eds.), *Human intelligence: Perspectives on its theory and measurement*. Norwood, NJ: Ablex, 1979.

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

Sternberg, R. J., & Detterman, D. K. (Eds.). *Human intelligence: Perspectives on its theory and measurement*. Norwood, NJ: Ablex, 1979.

Stroop, J. R. Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 1935, *18*, 643–662.

Thurstone, T. G. *Primary mental abilities for Grades 9–12* (Rev. ed.). Chicago: Science Research Associates, 1962.

Underwood, B. J. Individual differences as a crucible in theory construction. *American Psychologist*, 1975, *30*, 128–134. (a)

Underwood, G. *Attention and memory* (1st ed.). New York: Pergamon Press, 1975. (b)

Wickens, D. Characteristics of word encoding. In A. Melton & E. Martin (Eds.), *Coding processes in human memory*. Washington, DC: Winston, 1972.

Willis, S. L., Cornelius, S. W., Blow, F., & Baltes, P. B. Training research in aging: Attentional processes. *Journal of Educational Psychology*, 1983, *75*, 257–270.