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Age Difference Patterns of Psychometric Intelligence in Adulthood: Generalizability Within and Across Ability Domains

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Cross-sectional data from the 5th (1984) wave of the Seattle Longitudinal Study are reported with regard to the generalizability of age differences in psychometric intelligence within and across ability domains. Ss were 1,628 community-dwelling individuals drawn from a Pacific Northwest health maintenance organization. Age difference patterns of 9 groups with mean ages from 29 to 88 years are examined for the ability domains of verbal ability, spatial orientation, inductive reasoning, numeric ability, verbal memory, and perceptual speed. Each ability is marked by 3 or 4 observed variables.

The extensive literature on the course of psychometric intelligence over the adult life span has informed researchers that most abilities tend to peak in early midlife, plateau until the late 50s or early 60s, and then show decline, initially at a slow pace but accelerating as the late 70s are reached (Botwinick, 1977; Cunningham, 1987; Labouvie-Vief, 1985; Schaie, 1980). There remains some controversy, however, on the specific age at which certain abilities peak and on the ages at which significant decline can first be detected (Botwinick, 1977; Schaie, 1983; Willis, 1985). Data from cross-sectional studies usually lead to relatively pessimistic conclusions for those variables where positive cohort trends have been observed and to unduly optimistic conclusions for those variables where cohort trends have been negative. Longitudinal studies may also yield under- or overestimates of mean age changes, depending on whether the longitudinal panel has been exposed to favorable or unfavorable attrition and reactivity effects (Schaie, 1988a).

Most of the major existent longitudinal studies of adult development (e.g., Eichorn, Clausen, Haan, Honzik, & Mussen, 1981; Schaie, 1983; Schmitz-Scherzer & Thomae, 1983; Shock et al., 1984; Siegler, 1983) thus far have only very limited data that speak to the issues of generalization of findings within and across domains in the area of intellectual functioning. On this matter, cross-sectional data may actually be quite instructive because such data allow researchers to draw concurrent comparisons of age difference patterns within and across domains, without requiring attention to the thorny methodological issues of comparisons across time (cf. Schaie, 1977, 1988a).

Although we have argued repeatedly that group comparisons submerge the vast individual differences within age/cohorts that exceed age differences across age/cohorts by far, our discussion is confined here to patterns that depict group averages. We do so because the study of intraindividual differences requires repeated measurement data that as yet are not available for all of the ability markers to be considered in this article. Moreover, individual-differences data on those observed variables for which longitudinal data are at hand have been reported elsewhere (cf. Schaie, 1990). The position taken in this article, one that is documented with empirical data, is that there are likely to be substantial life stage differences in adulthood in the degree to which levels of performance for different ability markers are equivalent both within and across ability domains. To document this, we first examine the extent to which patterns of age differences are congruent within a particular ability domain by examining age difference patterns for the operational definitions of six psychometric abilities. The abilities we examine, in turn, broadly sample higher order constructs such as those espoused by Horn (1982). Thus, fluid intelligence is represented by inductive reasoning, whereas verbal ability and numeric ability stand as representatives of crystallized intelligence. Mental rotation is represented by our spatial ability construct. Verbal memory and perceptual speed are examined as ability samplers for the memory and speed domains, respectively. We therefore also consider the degree to which age difference patterns are similar across the various ability domains.

What is at issue is the question of whether patterns of age differences in ability remain invariant for multiple markers of the primary mental abilities. We have previously examined this issue by means of structural analyses (Schaie, Willis, Jay, & Chipuer, 1989) and have shown that configural invariance (i.e., number of factors and factor patterns) is preserved across widely differing age groups. However, the magnitude of the regression of the latent constructs on the observed variables differed markedly across age. These findings imply that the

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relevance of a particular marker variable may shift at different life stages, a fact observed a long time ago in cross-sectional studies of the Wechsler Adult Intelligence Scale (Cohen, 1957). The reasons for such shift may be sought in such contextual variables as shifts in educational exposure to the skills embodied in a particular marker variable or latent construct and the impact of slowing in perceptual or motor speed that may differentially effect various markers. For example, researchers know that conditions of instructions and speededness imposed by time limits differentially affect performance on the Primary Mental Abilities (PMA) and Educational Testing Service (ETS) vocabulary tests (Hertzog, 1989, 1991). Likewise, researchers know that there have been generational shifts in instruction in quantitative skills that should affect numerical performance for different cohorts. For other abilities, researchers would expect congruence across the entire life span until the 80s are reached. At that late stage, the differential memorization demands as well as the relative motor complexity of an answer-sheet format as compared with a disposable-booklet format might result in differential efficiency of a given marker.

Although age difference patterns appear generally invariant across sex within domains (albeit there is strong evidence for overall gender differences in level of performance), it is not a foregone conclusion that such invariance holds for all abilities or for all markers of a given ability. We therefore examine gender differences and report results separately by gender where warranted.

The issue of the generalizability of markers within domains is particularly important for age-comparative studies. For valid cross-sectional comparisons, we must show that an observed variable provides a reasonable representation of the developmental trajectory of the latent construct to be marked. If this is the case, then a single marker may suffice. However, if there is wide discrepancy in developmental trajectories for multiple markers, we would then be forced to multiply mark the construct, providing differential weights for the markers at different life stages. The data presented here provide guidance on these matters.

Method

Subjects

Our inquiry into adult cognitive functioning began about 35 years ago by randomly sampling 500 subjects equally distributed by sex and age, ranging from 20 to 70 years, from the then approximately 18,000 members of a health maintenance organization in the Pacific Northwest (Schaie, 1983; Schaie & Hertzog, 1986). The survivors of the original sample were retested, and additional panels were added in 7-year intervals. The sampling frame represents a broad distribution of educational and occupational levels, covering the upper 75% of the socioeconomic spectrum. The population frame from which we have been sampling repeatedly has grown to a membership of over 400,000 individuals, but the general demographic characteristics of the sampling frame remain quite comparable. The primary data examined here include the 1,628 community-dwelling individuals (743 men and 885 women) who were examined in the fifth Seattle Longitudinal Study (SLS) cycle during 1983–1985 (see Table 1 for a breakdown by age/cohort). These individuals had a mean educational level of 14.3 years (SD = 3.06, range = 1–20 years); their family income averaged $23,200 ($SD$ = $9,606, range = $1,000–$50,000+). Occupational levels were rated on a scale from 0 (*unskilled*) to 9 (*professional occupations*). Those individuals gainfully employed at the time of assessment averaged an occupational level of 6.8 (SD = 1.87). Most frequent occupations represented involved skilled trades, clerical sales, managerial jobs, and semiprofessional jobs (also see Schaie, 1988b).

Measurement Variables

The original SLS psychometric ability battery was expanded to permit structural analyses that require multiple measures to mark each ability factor. The longitudinal markers included in this battery of necessity (i.e., for consistency across successive test administrations) use the test booklet and answer-sheet format used since the beginning of the SLS (Thurstone & Thurstone, 1949). All other forms use disposable booklets on which answers are marked directly (cf. Ekstrom, French, Harman, & Derman, 1976; Schaie, 1985). Table 2 lists the measures, the primary ability that they mark, their sources, and their test–retest correlations over a 2-week interval for a group of 172 subjects (Schaie, Willis, Hertzog, & Schulenberg, 1987). A brief description of the primary abilities and the measures marking them is given in the following paragraphs.

Inductive reasoning. This is the ability to deduce novel concepts to relationships.

1. *PMA Reasoning test.* The subject is shown a series of letters (e.g., a, b, c, b, a, d, e, f, e) and is asked to identify the next letter in the series.
2. *Adult Development and Enrichment Project (ADEPT) Letter Series test.* This is a parallel form to the PMA Reasoning test.
3. *Word Series test.* The subject is shown a series of words (e.g., January, March, May) and is asked to identify the next word in the series. Positional patterns used in this test are identical to the PMA Reasoning test.
4. *Number Series test.* The subject is shown a series of numbers (e.g., 6, 11, 15, 18, 20) and is asked to identify the next number in the series.

Spatial orientation. This is the ability to visualize and mentally manipulate spatial configurations, to maintain orientation with respect to spatial objects, and to perceive relationships among objects in space.

1. *PMA Space test.* The study participant is shown an abstract figure and is asked to identify which of six other drawings represents the model in two-dimensional space.
2. *Object Rotation test.* The subject is shown a line drawing of a meaningful object (e.g., an umbrella) and is asked to identify which of six other drawings represents the model rotated in two-dimensional space.
3. *Alphanumeric Rotation test.* The subject is shown a letter or number and is asked to identify which of six other drawings represents the model rotated in two-dimensional space.

Test stimuli in the Object and Alphanumeric Rotation tests have the same angle of rotation as the abstract figures in the PMA Space test.

4. *Cube Comparison test.* For each item, two drawings of a cube are presented; the subject is asked to indicate whether the two drawings are of the same cube rotated in three-dimensional space.

Numeric ability. This is the ability to understand numerical relationships and compute simple arithmetic functions.

1. *PMA Number test.* The subject checks whether additions of simple sums shown are correct or incorrect.
2. *Addition test.* This is a test of speed and accuracy in adding three single- or two-digit numbers.
3. *Subtraction and Multiplication test.* This is a test of speed and accuracy with alternate rows of simple subtraction and multiplication problems.

Verbal ability. Language knowledge and comprehension is measured by assessing the scope of a person's recognition vocabulary.

Table 1
Subsamples Entering the Age Differences Analyses

Group	SLS cohort	Date of birth	No. of men	No. of women	Total	Mean age
1	1–2	1886–1899	18	23	41	88
2	3	1900–1906	63	74	137	81
3	4	1907–1913	120	140	260	74
4	5	1914–1920	137	154	291	67
5	6	1921–1927	127	135	262	60
6	7	1928–1934	92	102	194	53
7	8	1935–1941	62	92	154	46
8	9	1942–1948	53	71	124	39
9	10–11	1949–1962	71	94	165	29
Total sample			743	885	1,628	59

Note. Following the convention used in all reports from the Seattle Longitudinal Study (SLS), lower cohort numbers represent earlier born (older) subjects.

1. *PMA Verbal Meaning test.* This is a four-choice synonym test that is highly speeded.

2. *ETS Vocabulary II test.* This is a five-choice synonym test.

3. *ETS Vocabulary IV test.* This is a five-choice synonym test consisting mainly of difficult items.

Perceptual speed. This is the ability to find figures, make comparisons, and carry out other simple tasks involving visual perception with speed and accuracy.

1. *Identical Pictures test.* The subject identifies which of five numbered shapes or pictures in a row are identical to the model at the left of the row.

2. *Finding A's test.* In each column of 40 words, the subject must identify the 5 words containing the letter *a*.

3. *Number Comparison test.* The subject inspects pairs of multidigit numbers and indicates whether the two numbers in each pair are the same or different.

Verbal memory. This is the ability to encode, store, and recall meaningful language units.

Table 2
Psychometric Intelligence Measurement Battery

Primary ability	Test	Source	Test–retest correlation
Inductive reasoning	PMA Reasoning (1948)	Thurstone & Thurstone (1949)	.884
	ADEPT Letter Series (Form A)	Blieszner, Willis, & Baltes (1981)	.839
	Word Series	Schaie (1985)	.852
	Number Series	Ekstrom, French, Harman, & Derman (1976)	.833
Spatial orientation	PMA Space (1948)	Thurstone & Thurstone (1949)	.817
	Object Rotation		.861
	Alphanumeric Rotation	Willis & Schaie (1983)	.820
	Cube Comparison	Ekstrom et al. (1976)	.951
Numeric ability	PMA Number (1948)	Thurstone & Thurstone (1949)	.875
	ETS Addition (N-1)	Ekstrom et al. (1976)	.937
	ETS Subtraction and Multiplication (N-3)	Ekstrom et al. (1976)	.943
Verbal ability	PMA Verbal Meaning (1948)	Thurstone & Thurstone (1949)	.890
	ETS Vocabulary II	Ekstrom et al. (1976)	.928
	ETS Vocabulary IV	Ekstrom et al. (1976)	.954
Perceptual speed	Identical Pictures	Ekstrom et al. (1976)	.814
	Finding A's	Ekstrom et al. (1976)	.860
	Number Comparison	Ekstrom et al. (1976)	.865
Verbal memory	Immediate Recall	Zelinski, Gilewski, & Schaie (1979)	.820
	Delayed Recall	Zelinski et al. (1979)	.732
	PMA Word Fluency	Thurstone & Thurstone (1949)	.896

Note. PMA = Primary Mental Abilities; ADEPT = Adult Development and Enrichment Project; ETS = Educational Testing Service.

1. *Immediate Recall test.* The subject studies a list of 20 words for 3½ min. The subject is then given an equal period of time to recall the words in any order.

2. *Delayed Recall test.* The subject is asked to recall the same list of words as in the Immediate Recall test after 1 hr of intervening activities (other psychometric tests).

3. *PMA Word Fluency test.* The subject freely recalls as many words as possible according to a lexical rule within a 5-min period.

Assessment Procedure

The measures described in the previous paragraphs were administered to small groups of subjects as part of a broader battery that originally required approximately 2 hr in a single session but has since grown to a 5-hr battery spread over two sessions. The tests were administered by an examiner, who was assisted by a proctor. Testing locations were at familiar sites close to the homes of our participants. Subjects entered the study in 1956, 1963, 1970, 1977, and 1983–1985. During the first three cycles, subjects were assessed only on the five basic PMA tests (Verbal Meaning, Space, Reasoning, Number, and Word Fluency). In 1977, the Finding A's test and the Identical Pictures test from the ETS kit were added, whereas the remaining multiple markers were first introduced in the 1983–1985 cycle. Only data collected in the latter cycle are included in the analyses reported in this article.

Statistical Procedures

All scores on the observed variables were rescaled into *T*-score form ($M = 50$, $SD = 10$), using parameters for the total sample ($N = 1{,}628$) at first test. Factor scores for the six intellectual abilities were then computed with factor regression weights that were based on a previously determined best-fitting factor model (Schaie, Dutta, & Willis, 1991; also cf. Schaie et al., 1987; Schaie et al., 1989). These regression weights are reported in Table 3.

We applied a repeated measure analysis of variance (ANOVA) approach to the categorization of age rather than treating age as a continuous variable. We did this because we were interested in testing the hypothesis of whether generalization across markers differs depending on life stage and then to identify the life stage at which there is divergence from a common trend. Also, maintaining age/cohort categories previously used in the SLS facilitates comparison of these analyses with those previously published (e.g., Schaie, 1983). Effect sizes were calculated separately for between and within effects by means of the Dodd and Schultz (1973) method of estimating ω^2 in designs with unequal cell sizes. Although we did not believe that multiple testing would substantially affect the within-subject comparisons, all findings reported were covaried on how many times a particular subject had previously participated in the study. For post hoc comparisons we used Tukey's method, controlling experimentwise for the α level of multiple tests with a computational algorithm developed by Games, Yancey, Howell, and Serapiglia (1987).

Table 3
Normalized Regression Weights for the Ability Factor Scores

Variable	R	S	N	V	Ps	M
Inductive reasoning						
PMA Reasoning	.267					
ADEPT Letter Series	.261					
Word Series	.265					
Number Series	.207					
Spatial orientation						
PMA Space		.276				
Object Rotation		.307				
Alphanumeric Rotation		.276				
Cube Comparison		.141				
Numerical ability						
PMA Number			.292			
ETS Addition			.388			
ETS Subtraction and Multiplication			.311			
Verbal ability						
PMA Verbal Meaning				.085	.251	
ETS Vocabulary II				.460		
ETS Vocabulary IV				.455		
Perceptual speed						
Identical Pictures					.399	
Finding A's					.159	
Number Comparison			.030		.191	
Verbal memory						
Immediate Recall						.392
Delayed Recall						.388
PMA Word Fluency						.220

Note. R = inductive reasoning; S = spatial orientation; N = numeric ability; V = verbal ability; Ps = perceptual speed; M = verbal memory; PMA = Primary Mental Abilities; ADEPT = Adult Development and Enrichment Project; ETS = Educational Testing Service.

Results

We first consider the congruence of age difference patterns within the specific ability domains and then examine the generalizability of age difference patterns for the latent ability factors.

Age Difference Patterns Within Ability Domains

Repeated measures ANOVAs, covaried for number of times individuals had been previously tested, were used to determine whether the age/cohort patterns for the observed variables differed significantly within each ability construct. We also examined the question of whether there were significant differences in patterns by gender. Results for these analyses are reported in Table 4. It should be noted that there were no statistically significant Test × Age/Cohort × Gender interactions for any of the ability domains. Hence, our analysis of the age difference patterns within domains can proceed using age/cohort data aggregated across gender. We did observe, however, statistically significant Test × Gender interactions for all domains examined: these interactions are described in conjunction with the Test × Age/Cohort interactions. Because scales within factors were equated across measures, main effects for tests must by definition be zero. However, the interactions of tests with the other independent variables reflect within-subject variance differentially affecting different levels of these variables.

The age difference patterns within the six primary ability factors (in standardized form) are reported in Table 5. Because of the significant Test × Gender interactions, means are provided separately by gender, and means and standard deviations are given for the total age/cohort groupings. Results with respect to congruence among the patterns for the different operations measuring the ability constructs are described in the following paragraphs.

Table 4
Repeated Measures Analyses of Variance for Age/Cohort, Gender, and Tests by Ability Domain

Ability domain	Inductive reasoning		Spatial orientation		Numeric ability		Verbal ability		Perceptual speed		Verbal memory	
	F	ω^2	F	ω^2	F	ω^2	F	ω^2	F	ω^2	F	ω^2
Between effects												
Age/cohort	129.31**	.41	124.66**	.39	15.74**	.09	22.44**	.10	110.74**	.36	78.31**	.29
Gender	0.01	—	52.87**	.02	0.25	—	2.45	—	46.38**	.02	48.18**	.02
Age/Cohort × Gender	0.91	—	1.39	—	2.75*	.01	1.90	—	1.05	—	0.87	—
Within effects												
Tests[a]	—	—	—	—	—	—	—	—	—	—	—	—
Age/Cohort × Tests	4.54**	.02	3.60**	.01	4.78**	.01	48.02**	.20	18.39**	.08	3.63**	.01
Gender × Tests	47.75**	.03	13.63**	.01	13.95**	.01	10.42**	.01	18.42**	.01	3.79**	.01
Age/Cohort × Gender × Tests	1.51	—	1.47	—	0.92	—	1.98	—	1.11	—	1.04	—

[a] Because all tests were scaled to T-score metric (M = 10, SD = 10), the main effect for tests must be zero by definition.
* p = .01. ** p = .001.

Inductive reasoning. This fluid ability has consistently shown the most dramatic cohort effects (cf. Schaie, 1983, 1990). However, age differences between youngest and oldest cohorts in our study vary from approximately 1.6 standard deviations for the Number Series to 2.3 standard deviations for the Word Series test. Although there is close convergence among the different measures from the mid-40s to the mid-70s, statistically significant differences occur for both the two youngest and two oldest age/cohorts. The Number Series test appears to be significantly more difficult than the Word Series test for the young adults, whereas the reverse situation occurs in advanced old age, with the two measures involving letter series falling in between. For the two youngest age/cohorts it is actually the ADEPT Letter Series test that is the easiest (see Figure 1).

No significant overall gender difference was observed at the construct level. However, women performed significantly better than men on the PMA Reasoning test and the Word Series test ($p < .01$). Men performed significantly better than women on the Number Series test ($p < .001$), whereas there were no gender differences on the ADEPT Letter Series test. There was no significant Age/Cohort × Gender interaction.

Spatial orientation. Extreme age differences on this visualization ability also differ from about 1.4 standard deviations for the three-dimensional Cube Comparison test to approximately 2.2 standard deviations for the Alphanumeric Rotation test, which contains the most familiar stimuli among the measures involving two-dimensional rotation. No statistically significant differences were found within age/cohorts, except for the two oldest groups. Here average performance remained relatively higher for the most complex representation of the ability, the three-dimensional Cube Comparison test (cf. Figure 2).

On this ability, men performed significantly better than women throughout ($p < .01$) on all observed measures except for the Alphanumeric Rotation test. Men did significantly better on the three-dimensional Cube Comparison test than on all the two-dimensional tests, whereas women performed significantly better on the Alphanumeric Rotation test than on the Object Rotation test ($p < .01$).

Numeric ability. Differential age patterns for markers are also seen between indicators of numeric ability. Although the age differences between the youngest and oldest age/cohort is roughly equivalent across the three measures, approximately 1 standard deviation, there are noteworthy discrepancies between the two operational definitions of addition and the measure of subtraction and multiplication. The latter measure attains a significantly higher level ($p < .01$) in early middle age (ages 39–46), whereas it appears to be relatively more difficult than checking simple addition for the three oldest groups (cf. Figure 3).

Gender differences in numeric ability are confined to the PMA Number test, on which men performed significantly better ($p = .01$) than women. However, there was also a significant Gender × Age interaction, with the age difference from young adulthood to old age being significantly less for women on the PMA Number test (SD = 0.6 for women vs. SD = 1.1 for men) and on the ETS Subtraction and Multiplication test (SD = 0.7 for women vs. SD = 1.5 for men).

Verbal ability. Substantial differences among measures are observed for this crystallized ability. The PMA Verbal Meaning test shows age differences exceeding 2 standard deviations, but age differences for the vocabulary tests from the ETS amount to less than ⅓ standard deviation. For the highly speeded PMA measure, the negative age/cohort trend begins in the 50s, whereas for the more difficult vocabulary tests from the ETS factor kit, a peak is actually observed for the 67-year-old group. Statistically significant differences between these measures are observed for all groups. The younger groups (until age 60) performed relatively better on the speeded measure, whereas the older groups (beginning with age 67) did better on the power tests of verbal ability (see Figure 4). Note also that the increase with age in within-group variability was greater for the power tests than for the speeded vocabulary measure.

Women performed better than men ($p < .01$) on only the ETS Level II Vocabulary test, the easier of the two power tests. However, within gender, men performed best on the more difficult Level IV Vocabulary test, whereas women performed best on the Level II Vocabulary test.

Perceptual speed. We also found wide age differences for the

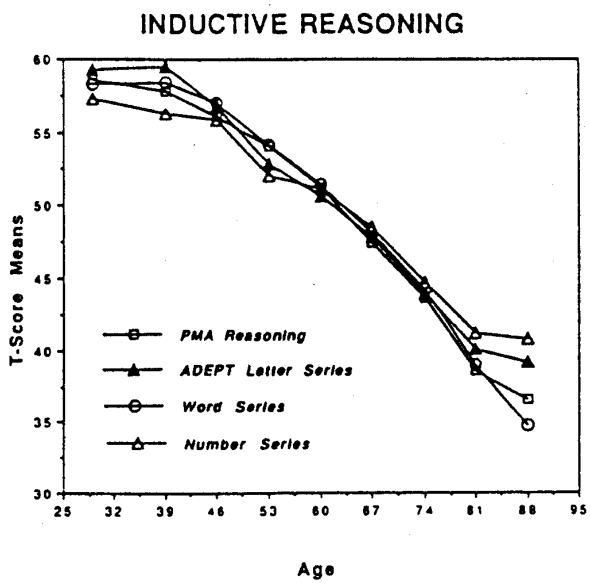

Figure 1. Age difference patterns for markers of inductive reasoning ability. (PMA = Primary Mental Abilities; ADEPT = Adult Development and Enrichment Project.)

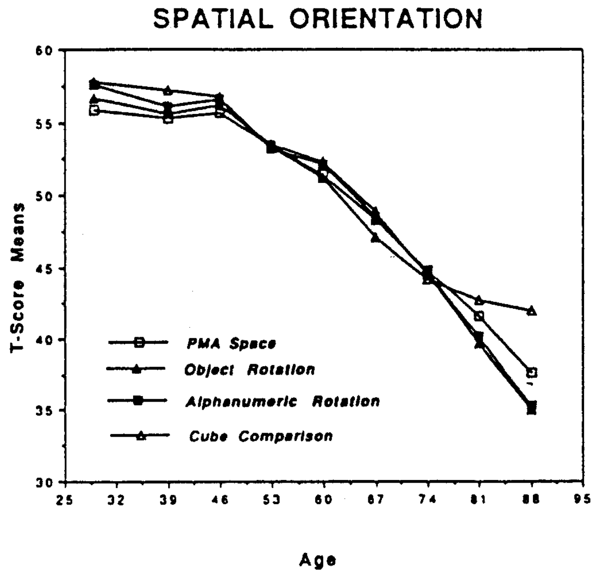

Figure 2. Age difference patterns for markers of spatial orientation ability. (PMA = Primary Mental Abilities.)

measures of perceptual speed, ranging from little over 1 standard deviation for the Finding A's test to $2\frac{3}{4}$ standard deviations for the Identical Pictures test. Performance on the Finding A's test was significantly higher than that for the other markers for the four oldest age/cohorts (age 67 and above). By contrast, significantly higher performance was shown on the Identical Pictures test for the youngest four age/cohorts (see Figure 5).

In this domain, women performed significantly better throughout than men ($p = .001$) on the Finding A's test and the Number Comparison test. There were no gender differences on the Identical Pictures test; however, this test was the easiest marker for the women and the most difficult marker for the men.

Verbal memory. Age differences for this ability ranged from about 1½ standard deviations for the word recall measure to approximately 2 standard deviations for the measures involving list learning. The PMA Word Fluency test appears to have been significantly more difficult for the youngest age/cohort, whereas it was relatively easier for the three oldest age/cohorts ($p < .01$; see Figure 6).

Women performed significantly better than men on all markers; however, the gender difference is greater for the list learning tasks than for the word recall measure.

Age Difference Patterns Across Abilities

Substantial variations in age difference patterns were also observed for the derived ability factor scores. Their means are provided separately by gender, and the means and standard deviations for the total gender/cohort groupings are reported in Table 6. The magnitude of the age difference between the youngest and oldest age/cohort varies from about ¾ standard deviation for verbal ability to over 2½ standard deviations for perceptual speed. Differences are also observed in the ages of the cohort obtaining peak performance levels. Performance is highest for the youngest age/cohort for inductive reasoning,

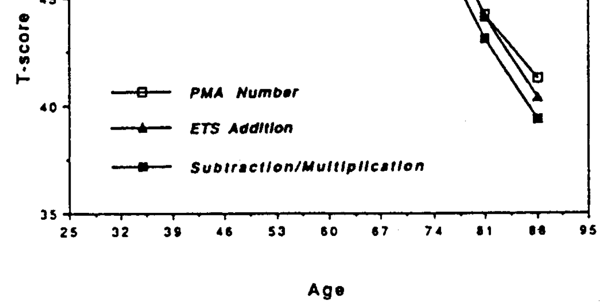

Figure 3. Age difference patterns for markers of numeric ability. (PMA = Primary Mental Abilities; ETS = Educational Testing Service.)

Table 5

Means and Standard Deviations for Six Psychometric Ability Domains for Mean Ages 29–88 Years in T-Score Units (M = 50, SD = 10)

Variable	Age 29	39	46	53	60	67	74	81	88
Inductive reasoning									
PMA Reasoning									
Men	58.22	57.28	55.00	52.40	51.28	45.97	42.36	38.16	36.08
Women	58.83	58.10	56.85	55.61	51.30	48.63	44.32	38.97	37.76
Total									
M	58.57	57.75	56.10	54.09	51.29	47.38	43.61	38.60	36.58
SD	7.76	6.95	7.68	8.10	8.02	8.17	7.49	6.25	6.24
ADEPT Letter Series									
Men	59.82	59.54	57.07	52.31	51.52	47.46	43.19	39.14	39.76
Women	58.74	59.41	56.53	53.41	49.86	48.30	44.45	40.80	39.20
Total									
M	59.30	59.46	56.74	52.90	50.68	47.86	43.87	40.07	39.18
SD	8.65	8.19	8.00	7.95	9.03	8.26	7.03	6.40	5.25
Word Series									
Men	58.09	56.81	56.35	52.62	51.26	47.02	43.33	37.33	33.94
Women	58.43	59.59	57.34	55.49	51.56	48.99	45.81	40.28	37.22
Total									
M	58.25	58.40	56.95	54.15	51.42	48.11	44.23	38.98	34.76
SD	7.71	7.37	7.16	7.00	7.47	8.52	8.44	7.99	6.74
Number Series									
Men	59.20	59.20	58.06	53.99	53.75	50.31	44.96	41.28	40.56
Women	55.48	55.48	54.30	50.22	48.69	47.02	44.48	41.03	41.21
Total									
M	57.29	56.30	55.84	52.02	51.16	48.51	44.71	41.14	40.76
SD	8.29	8.60	8.91	9.26	8.92	9.24	8.40	6.48	5.52
Spatial orientation									
PMA Space									
Men	57.48	57.74	57.95	54.75	54.06	49.96	46.19	42.35	39.53
Women	54.63	53.35	54.04	52.31	48.94	46.72	43.45	41.05	37.52
Total									
M	55.86	55.23	55.62	53.47	51.42	48.26	44.71	41.65	38.28
SD	9.27	10.42	9.50	9.33	8.79	8.66	7.65	6.43	5.56
Object Rotation									
Men	58.85	57.79	57.64	54.53	54.08	50.40	45.47	40.74	36.17
Women	54.64	54.10	55.19	52.62	50.63	47.47	43.61	38.75	35.12
Total									
M	56.68	55.58	56.18	53.53	52.31	48.85	44.46	39.67	35.57
SD	7.75	8.24	7.47	7.91	8.20	8.72	8.64	8.53	6.77
Alphanumeric Rotation									
Men	58.79	57.62	56.88	54.42	52.72	49.09	44.60	39.05	36.53
Women	56.30	54.83	56.29	52.30	51.62	47.95	44.45	41.20	35.65
Total									
M	57.58	56.03	56.52	53.28	52.16	48.50	44.52	40.24	36.02
SD	6.45	7.79	6.60	8.24	8.19	8.99	8.90	9.05	7.98
Cube Comparison									
Men	60.07	61.69	59.56	56.45	54.54	48.46	45.10	42.87	44.88
Women	55.38	53.84	54.09	50.64	47.97	45.79	43.38	42.59	40.83
Total									
M	57.78	57.21	56.76	53.32	51.22	47.07	44.16	42.71	42.49
SD	10.11	10.19	9.25	8.64	8.19	8.03	7.10	7.62	8.30
Numeric ability									
PMA Number									
Men	52.31	50.42	53.39	50.86	55.19	50.72	49.58	44.69	41.00
Women	48.37	52.07	50.72	51.06	49.56	50.60	48.14	43.82	42.68
Total									
M	50.07	51.36	51.79	50.96	52.29	50.70	48.80	44.22	41.24
SD	10.04	9.33	7.88	10.54	10.77	9.67	9.23	9.19	8.70
ETS Addition									
Men	51.77	49.98	53.40	49.62	52.77	49.09	49.88	42.95	39.11
Women	49.36	52.86	52.22	51.51	50.56	51.57	48.88	45.06	43.38
Total									
M	50.52	51.63	52.70	50.61	51.63	50.42	49.34	44.09	40.38
SD	9.05	8.75	10.64	9.90	9.79	10.12	9.06	10.11	8.64

Table 5 (*continued*)

Variable	Age 29	39	46	53	60	67	74	81	88
				Numeric ability (*continued*)					
ETS Subtraction–Multiplication									
Men	52.63	52.60	56.35	50.63	53.05	49.29	48.07	42.29	37.53
Women	48.83	55.36	52.86	52.29	50.44	50.72	47.43	43.67	41.48
Total									
M	50.78	54.18	54.24	51.52	51.72	50.02	47.72	43.05	39.37
SD	10.00	8.86	10.20	9.49	9.72	9.92	8.29	9.19	7.90
				Verbal ability					
PMA Verbal Meaning									
Men	54.14	55.85	55.29	53.03	53.28	48.83	43.04	38.51	32.61
Women	54.63	56.34	55.85	54.52	51.97	49.88	45.76	40.06	33.56
Total									
M	54.42	56.13	55.62	52.81	52.60	49.39	44.51	39.34	32.34
SD	7.73	6.52	7.88	7.42	8.18	8.77	8.73	8.69	8.60
ETS Vocabulary II									
Men	47.88	53.25	50.40	49.94	51.42	51.08	48.10	44.05	40.35
Women	48.97	50.45	52.23	51.75	50.01	51.52	50.41	49.19	49.70
Total									
M	48.38	51.65	51.51	50.91	50.70	51.30	49.37	46.87	45.58
SD	9.17	8.68	8.01	9.94	9.62	9.81	10.81	13.41	12.17
ETS Vocabulary IV									
Men	48.40	53.75	51.58	50.07	52.35	51.62	48.46	47.46	43.29
Women	46.82	50.55	51.17	50.69	48.58	51.46	49.71	48.80	48.30
Total									
M	47.63	51.92	51.23	50.41	50.44	51.44	49.14	48.19	46.61
SD	9.09	9.42	9.04	9.35	9.08	9.58	10.55	11.87	11.21
				Perceptual speed					
Identical Pictures									
Men	60.08	59.72	56.86	53.97	50.35	46.17	41.49	37.53	33.06
Women	60.99	55.89	57.59	54.22	50.92	47.66	43.89	39.19	34.48
Total									
M	60.60	59.24	57.29	54.10	50.64	46.99	42.79	38.43	33.42
SD	6.96	6.90	6.72	6.66	6.92	7.02	6.53	7.35	5.64
Number Comparison									
Men	54.87	54.19	53.26	50.51	49.99	46.54	43.51	37.66	35.24
Women	58.34	59.80	56.54	53.78	51.94	50.50	47.57	43.52	40.68
Total									
M	56.66	57.40	55.22	52.23	50.99	48.64	45.71	40.83	37.83
SD	9.24	8.86	9.74	8.15	8.81	8.43	8.34	8.56	7.35
Finding A's									
Men	53.78	52.27	51.98	49.04	48.37	48.22	45.74	41.54	39.88
Women	55.00	55.05	53.78	53.58	50.91	50.62	48.61	47.85	47.30
Total									
M	54.45	53.86	53.07	51.48	49.66	49.50	47.30	44.98	43.66
SD	11.30	9.04	10.47	9.71	10.00	9.71	8.33	8.71	7.46
				Verbal memory					
PMA Word Fluency									
Men	53.31	55.00	51.63	51.70	50.10	47.72	44.87	40.76	37.67
Women	54.81	54.76	54.68	53.26	50.27	49.39	48.04	45.75	43.88
Total									
M	55.02	54.86	53.57	52.52	50.19	48.65	46.58	43.69	40.48
SD	9.89	10.08	9.01	9.45	9.87	8.72	9.86	9.01	7.70
Immediate Recall									
Men	56.26	55.48	53.41	50.44	49.60	46.85	42.57	39.41	37.71
Women	59.56	58.67	57.05	53.63	51.44	50.78	47.08	44.54	40.91
Total									
M	57.87	57.87	55.65	52.15	50.54	48.85	45.03	43.69	39.51
SD	8.00	7.97	8.41	8.39	8.78	9.73	8.41	9.01	9.48
Delayed Recall									
Men	57.44	55.40	53.82	50.26	48.86	46.18	41.85	38.74	39.38
Women	61.09	59.78	56.87	54.36	51.47	51.20	46.12	43.87	39.96
Total									
M	59.22	57.90	55.67	52.46	50.19	48.79	44.18	41.56	39.36
SD	8.33	8.32	8.97	8.91	9.02	9.64	7.74	7.72	7.50

Note. PMA = Primary Mental Abilities; ADEPT = Adult Development and Enrichment Project; ETS = Educational Testing Service.

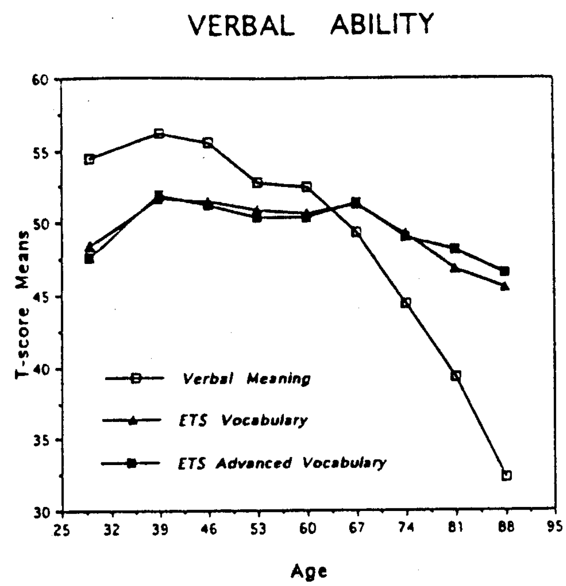

Figure 4. Age difference patterns for markers of verbal ability. (ETS = Educational Testing Service.)

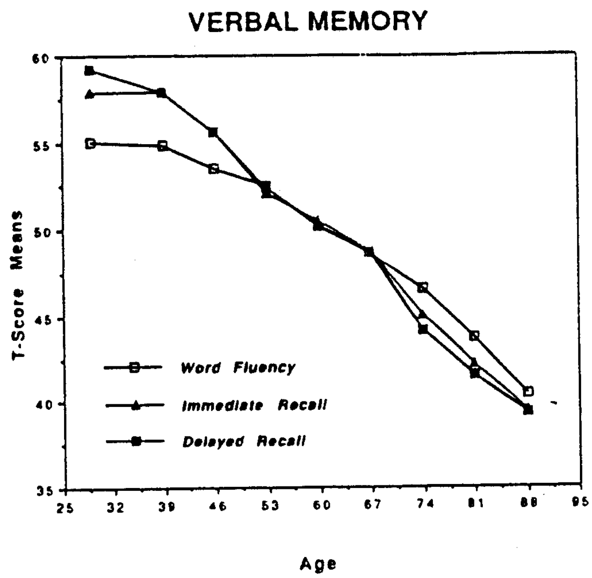

Figure 6. Age difference patterns for markers of verbal memory.

spatial orientation, perceptual speed, and verbal memory. By contrast, highest performance is shown at age 39 for verbal ability and at age 46 for numerical ability. Age differences again become statistically significant for the former abilities by the 50s, whereas the latter abilities show such significant differences only by the late 60s. Within age/cohorts there is substantial similarity of age difference patterns within the two ability groupings. In advanced age, however, verbal ability clearly remains the relatively best maintained ability, whereas perceptual speed appears most reduced (see Figure 7).

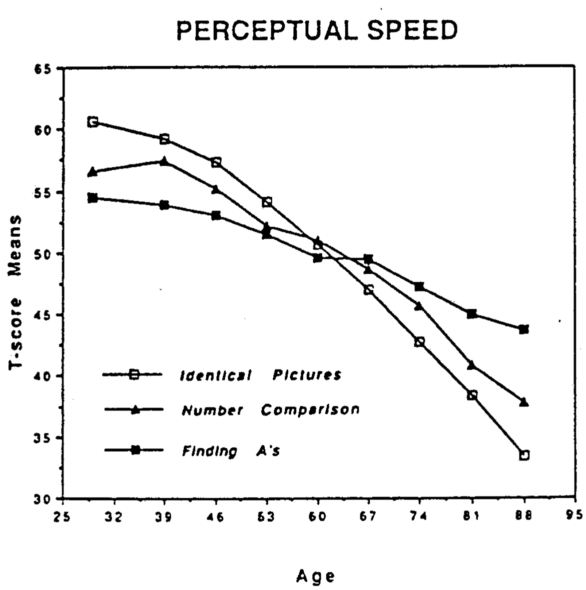

Figure 5. Age difference patterns for markers of perceptual speed.

At the ability level, significant overall gender effects ($p < .001$) were found favoring women for perceptual speed and verbal memory and favoring men for spatial orientation. As indicated earlier, there were no statistically significant Age/Cohort × Test × Gender interactions. However, we did find a significant Age/Cohort × Gender interaction for numeric ability. In this instance, the young adult men performed better, whereas in late midlife and advanced old age, women performed better than men.

Discussion and Conclusions

This study reports cross-sectional data from a multiply marked battery of psychometric abilities, the structure of which was established by a series of previous factor analyses. How are these data relevant to the issue of generalizing within and across domains of psychometric abilities? At the factor level, it is clear that age differences are not uniform across abilities. More adverse age profiles were found for constructs that involve fluid ability, mental rotation, memory, and speed than for constructs that are primarily crystallized in nature (cf. Horn, Donaldson, & Ekstrom, 1981).

We began this article by arguing that there are likely to be life stage differences in adulthood not only for different behavioral domains, but also in the degree of similarity that is to be expected for different markers of the same ability domain as well. Although we need to exercise caution in our inferences, because for once we rely entirely on cross-sectional data (Baltes, Cornelius, & Nesselroade, 1979; Schaie, 1977), we would argue,

Table 6
Means and Standard Deviations of Factor Scores for Six Psychometric Ability Domains in T-Score Units (M = 50, SD = 10)

Ability	Age 29	39	46	53	60	67	74	81	88
Inductive reasoning									
Men	59.37	58.26	56.63	52.92	52.02	47.25	43.44	37.52	36.24
Women	58.85	58.52	56.77	54.05	50.27	48.01	44.08	39.15	36.74
Total									
M	59.07	58.41	56.71	53.52	51.12	47.65	43.52	38.40	36.53
SD	8.02	7.05	6.94	7.51	7.99	8.16	7.44	6.34	5.12
Spatial ability									
Men	59.35	59.17	58.56	55.50	54.22	49.53	44.69	39.65	36.28
Women	55.43	54.48	55.49	52.52	49.89	46.74	42.81	39.03	33.70
Total									
M	57.11	56.48	56.73	53.93	51.99	48.06	43.68	39.31	34.83
SD	8.69	8.31	7.60	7.74	8.08	8.24	7.81	7.16	5.61
Numeric ability									
Men	52.49	51.28	53.83	50.43	53.53	49.72	49.38	43.12	38.33
Women	49.67	53.28	52.12	51.60	50.17	50.92	47.76	43.81	40.70
Total									
M	50.40	52.67	53.18	51.10	52.09	50.46	48.55	43.18	39.58
SD	9.42	8.69	10.04	9.75	10.06	9.88	8.80	9.02	8.27
Verbal ability									
Men	49.42	53.64	50.92	50.28	52.12	50.93	47.39	43.75	39.06
Women	51.20	51.32	52.25	51.40	49.27	51.16	49.21	47.10	46.13
Total									
M	50.44	52.32	51.71	50.87	50.65	51.05	48.37	45.54	43.02
SD	9.08	8.51	8.25	8.91	9.49	9.57	10.48	12.63	12.59
Perceptual speed									
Men	58.09	57.76	55.95	52.73	50.88	46.66	41.49	36.11	30.89
Women	59.40	59.46	57.58	54.88	51.55	49.04	44.95	39.64	33.56
Total									
M	58.84	58.73	56.92	53.86	51.23	47.92	43.35	38.02	32.39
SD	6.94	6.26	6.90	6.28	7.22	7.63	7.47	8.33	7.50
Verbal memory									
Men	57.46	55.68	52.89	50.54	49.24	56.50	42.21	38.13	36.61
Women	57.84	58.65	56.74	53.88	50.92	50.49	46.51	43.60	40.13
Total									
M	57.68	57.38	55.19	52.30	50.10	48.61	44.52	41.10	38.59
SD	8.16	7.47	8.38	8.18	8.71	9.11	7.61	8.41	7.92

nevertheless, that the data presented here provide at least some empirical evidence for our argument. On the one hand, these data reassure us of considerable similarity of age difference patterns (with the exception of verbal ability) both within and across domains during midlife. On the other hand, such agreement is not found across domains or within domains in young adulthood or in advanced old age.

Although significant Age/Cohort × Test interactions were found for all abilities, they account for relatively little within-subject variance (as compared with the substantial between-subjects cohort effects) for four of the six abilities studied. However, they do contribute substantial within-subject variance for the verbal ability and verbal memory factors. Similarly, we could demonstrate significant Test × Gender effects for five of the six abilities, but the within-subject variance accounted for (as has previously been observed for between-subjects variance on single markers; cf. Schaie & Hertzog, 1983) is fairly small.

Moreover, some technical cautions are in order: For lack of any independent comparison base and to obtain a comparable metric for all marker variables, we scaled the markers by using our total sample. Such scaling centers the data agewise at midlife; hence, it is possible that discrepancies might be unduly emphasized at the extreme ages. Because the scaling does represent a monotonic transformation, however, we would argue that the significance and direction of the effects are quite real, even though their magnitude might be slightly distorted by the scaling process.

The small but significant effects are certainly of theoretical interest because they would argue that different markers may be more or less efficient measures of their latent construct, depending on life stage and gender. In those instances where they account for substantial variance, there are also practical consequences to be discussed later on. First, we would consider what might account for the observed discrepancies in age difference patterns within abilities. We would at least speculate that some of our markers differ in qualitative attributes as well as the degree to which they may be confounded with variance on other constructs that themselves are subject to change across age.

Because of centralized and ability-specific behavioral slow-

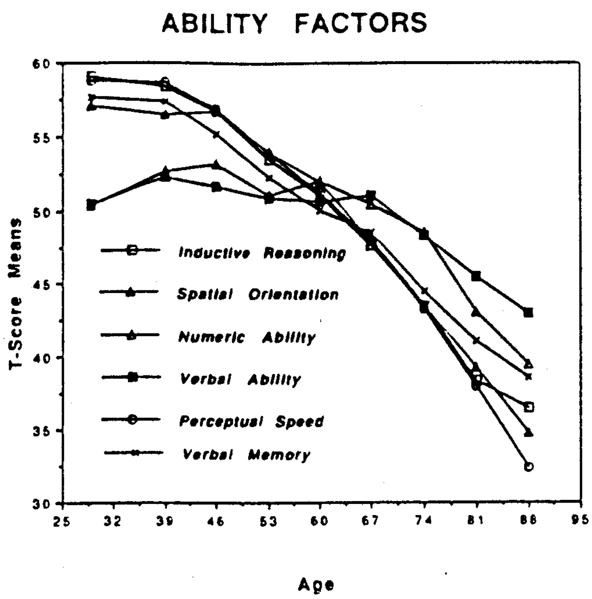

Figure 7. Age difference patterns for the intellectual ability constructs.

ing (cf. Salthouse, 1985) that affect most cognitive operations, markers that differ along the dimension from highly speeded to virtually unspeeded power test, also showed different age profiles. This is clearly seen in the differential patterns demonstrated for verbal ability, where one of the markers is highly speeded (cf. Hertzog, 1989). Likewise, age profiles for the factors showing relatively minor variation may do so because the marker variables varied in task meaningfulness (cf. Gonda, Quayhagen, & Schaie, 1981) or in familiarity and task complexity (Cornelius, 1984; Gardner & Monge, 1977; Salthouse, 1987).

The substantial discrepancy within measures of the verbal memory factor might possibly be explained by memory psychologists to be due to the fact that free recall of list learning might reflect episodic memory, whereas the Word Fluency test might more likely be a measure of semantic memory. However, within the ability framework these measures clearly marked a single factor (Schaie et al., 1991).

From a developmental perspective we conclude that alternate markers of abilities provide differentially effective measures of their underlying ability constructs. Given the fact that we found Age/Gender × Test interactions throughout, it might also be argued that using a single estimate of a particular construct may result in biased estimates of that construct for members of the adversely affected age group or gender.

One of the immediate consequences of the lack of congruency of age difference patterns among the markers of ability constructs is also a reinforcement of the argument that valid cross-age (and cross-gender) comparisons of psychometric abilities should be conducted at the construct level, that is, comparison of factor scores based on multiple markers (cf. Schaie et al., 1989). Such a procedure can accommodate application of differential weights for the observed variables in those instances where significant structural differences in age or gender are detected.

Finally, we again call attention to the lack of generalizability of age functions across different ability domains. Hence, broad theories of cognitive functioning must not only account for different aspects of intelligence but must offer hierarchical structures that accommodate differential relationships across life stages (cf. Schaie, 1977–1978; Willis, 1991).

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