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Comparable Consistency, Coherence, and Commonality of Measures of Cognitive Functioning Across Adulthood

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Abstract

Increased age is associated with lower scores in many cognitive tests, but interpretation of those results is based on the assumption that the measurement at different ages is equivalent, such that the differences reflect quantitative rather than qualitative changes. The assumption of measurement equivalence was investigated by comparing adult age differences in the relations among alternative versions of the same tests, among different tests of the same ability, and among different cognitive abilities. Results from three independent data sets revealed that only modest age differences were apparent at each level, which implies that cognitive abilities have similar measurement properties at different ages in adulthood.

Keywords

aging, cognition, measurement equivalence, hierarchical structure

Systematic relations between age and measures of the level of performance on cognitive tests are well documented (e.g., Salthouse, 2010). The primary question in the current study was whether adult age differences in the level of cognitive performance are associated with differences in the structural organization, or interrelations, among the measures. One reason for the interest in this question is that a recent study reported age-related declines in scores on several vocabulary tests at about the same age when weaker interrelations among the measures were first apparent (Salthouse, 2014c). The finding that changes in the structural organization of vocabulary measures occurred when mean cognitive functioning was declining raises the possibility that the two sets of results may be causally related, such that declines in level of performance may have been partially attributable to shifts in the meaning of the measures. However, only vocabulary measures were considered in the earlier study, and thus, little is known about possible relations between the level, and interrelations, of other types of cognitive measures.

The current project capitalized on the availability of a data set in which participants performed three versions of each of three tests representing four different cognitive abilities. Scores on the tests were used to specify the hierarchical structure portrayed in Figure 1, with relations among the measures at different levels in the structure assumed to reflect distinct structural properties. Specifically, interrelations of scores on alternate versions of the test at the bottom level of the hierarchy can be postulated to represent the *consistency* (or reliability) of measurement. Interrelations of scores on different tests of the same ability, portrayed in the middle of the hierarchy, can be postulated to indicate the *coherence* (or convergent validity) of the construct. Finally, interrelations of different abilities with one another, illustrated immediately below the top of the hierarchy, can be postulated to reflect *commonality* of influences.

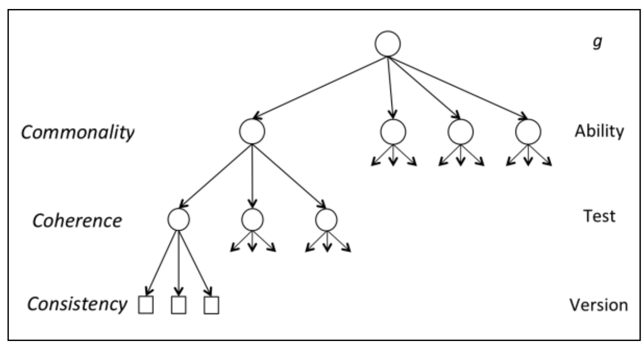

Figure 1. Illustration of hierarchical structure of cognitive abilities portraying relations among cognitive abilities (commonality), among different tests of the same ability (coherence), and among different versions of the same test (consistency).

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The most popular method of examining relations among multiple cognitive measures involves various types of factor analyses. Numerous factor analyses have been reported in adults of different ages (e.g., Hertzog & Bleckley, 2001; Nyberg et al., 2003; Schaie, Willis, Jay, & Chipuer, 1989; Sudarshan, Bowden, Saklofske, & Weiss, 2016; Taub, McGrew, & Witta, 2004; Tucker-Drob, 2009; Verhaeghen & Salthouse, 1997; Zelinski & Lewis, 2003), including several with data from subsets of the current sample of participants (e.g., Salthouse, 2004, 2012a, 2012b, 2014a, 2016; Salthouse & Ferrer-Caja, 2003; Soubelet & Salthouse, 2011; Tucker-Drob & Salthouse, 2008, 2009). In nearly every case, relatively small age differences were evident in loadings of the measures on the factors, which is consistent with the existence of qualitatively similar structures at different ages. Although clearly relevant, loadings of measures on a higher order variable only provide indirect information about the relations among the measures. The current study employed a more direct method of assessing relations among the measures, in the form of correlations among the measures at each level. That is, consistency, coherence, and commonality were each assessed by computing correlations among the measures at the relevant level in the structure portrayed in Figure 1.

Most of the earlier studies investigating relations of age on cognitive structures have focused only on relations among measures of different cognitive abilities at the highest level in the hierarchy, or what is referred to here as commonality. Results at this level have been mixed, with some reports of stronger relations at older ages (e.g., Cunningham, 1980; Hertzog & Bleckley, 2001; Schaie et al., 1989) and other reports of nearly constant relations (e.g., Nyberg et al., 2003; Tucker-Drob, 2009; Tucker-Drob & Salthouse, 2008; Verhaeghen & Salthouse, 1997; Whitley et al., 2016). Furthermore, Figure 1.17 in Salthouse (2010) indicated that small to nonexistent age relations were evident in correlations among scores on standardized tests administered to nationally representative samples.

One possible reason for the inconsistency in prior research is that commonality at the highest level is limited by coherence at the intermediate level, which in turn is limited by consistency at the lowest level. That is, the meaningfulness of an ability construct depends on the strength of the relations among the different tests of that ability, and the meaningfulness of a test construct depends on the strength of the relations among different versions of that test. Unfortunately, relatively little is known about possible age differences in the consistency or coherence of cognitive measures, and their role in any differences that might be found in commonality. A primary goal of the current project was to investigate relations of age on consistency and coherence in addition to commonality.

The relations among different versions of the same test could be weaker at older ages if there are age-related increases in the magnitude of across-time within-person variability. Furthermore, the relations among different tests of the same ability could be weaker at older ages if there are age-related increases in the magnitude of nonability, or test-specific, determinants of performance. And finally, the relations among abilities could be weaker at older ages if there are age-related increases in the distinctiveness or specificity of the abilities. Alternatively, the relations at each level could be stronger at older ages if increased age is associated with greater integration, or less segregation, of the elements.

Results from two studies are described in the current report; one based on data from an ongoing study of cognitive aging, and the other based on standardization data from the Wechsler Adult Intelligence Scale (WAIS IV; Wechsler, 2008) cognitive ability battery. Both projects are well-suited for analyses of consistency, coherence, and commonality because they involved moderately large numbers of participants from a wide range of ages who performed a battery of cognitive tests representing different cognitive abilities.

Study 1

The Virginia Cognitive Aging Project (VCAP; Salthouse, 2014a; Salthouse, Pink, & Tucker-Drob, 2008) is a cross-sectional and longitudinal study involving adults across a wide age range. All of the participants in the project performed 12 cognitive tests representing four different cognitive abilities. A unique feature of VCAP is a measurement burst design in which many of the participants performed alternate versions of the tests on three sessions within a period of about 2 weeks. The availability of scores on different versions of the same tests allows consistency to be examined in addition to coherence and commonality.

To investigate other issues, some VCAP participants performed different cognitive tests on the second and third sessions of the first occasion. The data from these participants with only one version of each test were used to replicate the analyses of coherence and commonality in data from a separate sample of participants. Many of the participants also returned for one or more subsequent occasions, and thus, analyses were also conducted to investigate possible age differences in the structure of change.

Method

Participants. Participants reported to the laboratory for three 2-hour sessions within a period of about 2 weeks. The primary analyses were based on data from 2,826 participants who performed alternate versions of the tests on Sessions 2 and 3 on the first occasion. Secondary analyses were based on data from an independent sample of 2,188 participants who performed the relevant tests only on the first session, and different cognitive tests on the other two sessions. A

Table 1. Demographic Characteristics of Participants in Cross-Sectional Virginia Cognitive Aging Project Samples With Three or One Test Versions on the First Occasion.

	M	*SD*	Age correlation
Primary sample: Three versions of each test			
N	2,826	NA	NA
Age	51.8	18.1	NA
Proportion female	0.65	0.48	−0.04
Self-rated health	2.3	0.91	0.10*
Years of education	15.6	2.7	0.16*
Estimated IQ	109.1	14.1	0.00
MMSE	28.3	2.0	−0.19*
Secondary sample: One version of each test			
N	2,188	NA	NA
Age	49.7	18.1	NA
Proportion female	0.65	0.48	0.01
Self-rated health	2.1	0.86	0.16*
Years of education	15.6	2.7	0.19*
Estimated IQ	109.6	14.5	0.03
MMSE	28.5	1.8	−0.11*
Longitudinal sample: Two occasions			
N	1,295	NA	NA
Age	54.6	16.5	NA
Proportion female	0.66	0.47	−0.05
Self-rated health	2.2	0.89	0.09*
Years of education	15.8	2.7	0.17*
Estimated IQ	110.7	13.8	0.06
MMSE	28.4	1.8	−0.08*

Note. Self-rated health was on a scale from 1 for *excellent* to 5 for *poor*. Estimated IQ was based on a regression equation predicting full-scale IQ from the cognitive tests (Salthouse, 2014b). MMSE is the Mini-Mental State Exam (Folstein et al., 1975). Approximately 79% of the participants classified themselves as White, 12% as African American, 5% as more than one ethnicity, and less than 2% each classified themselves as Asian or Native American.
*$p < .01$.

subset of the participants who performed alternate versions of the tests on the three sessions of the first occasion returned after an average interval of 3 years to repeat the three sessions. Data from these participants were used to investigate consistency, coherence, and commonality with longitudinal difference scores.

Descriptive characteristics of the participants are reported in Table 1. It can be seen that increased age was associated with lower levels of self-rated health, and lower scores on a dementia-screening test (i.e., Mini-Mental State Exam; Folstein, Folstein, & McHugh, 1975), but more years of education.

Measures. The 12 cognitive tests were selected to represent four cognitive abilities. The three reasoning ability tests were Matrix Reasoning, Shipley Abstraction, and Letter Sets. In the Matrix Reasoning test (Raven, 1962), the participant attempted to determine which pattern best completed the missing cell of a matrix. Three sample problems were followed by the 18 odd-numbered items from the Advanced Progressive Matrices. The participant was allowed 10 minutes to work on the 18 test problems. In the Shipley Abstraction test (Zachary, 1986), the participants were allowed 5 minutes to complete 20 series completion problems. The Letter Sets test (Ekstrom, French, Harman, & Dermen, 1976) involved participants selecting which of five groups of letters did not belong with the others. Ten minutes were allowed to work on 20 sets of letters.

Spatial visualization ability was assessed with the Spatial Relations, Paper Folding, and Form Boards tests. In the Spatial Relations test (Bennett, Seashore, & Wesman, 1997), the participant was to select which of four three-dimensional objects corresponded to an unfolded two-dimensional drawing. Ten minutes were allowed to solve 20 problems. In the Paper Folding test (Ekstrom et al., 1976), the participant attempted to determine which of five patterns of holes would result from the displayed sequence of folds and hole punches. There were 12 problems, and the time limit in the test was 10 minutes. In the Form Boards test (Ekstrom et al., 1976), 8 minutes were allowed to solve 24 problems consisting of determining which combination of 5 shapes was needed to create a complex figure.

Episodic memory ability was assessed with the Logical Memory, Word Recall, and Paired Associates tests. In the Logical Memory test (Wechsler, 1997b), the examiner read a story (of 65 words), and the participant attempted to recall as much of it as he or she could remember. A second story (of 86 words) followed immediately after the first, and then was repeated with another recall attempt. In the Word Recall test (Wechsler, 1997b), a list of 12 unrelated words was spoken four times, with the participant attempting to remember as many words as possible after each presentation. A different list of words (List B) was then presented and recalled, followed by an attempt to recall as many of the words from the original list. In the Paired Associates test (Salthouse, Fristoe & Rhee, 1996), participants listened to two trials of six word pairs each, with the participant instructed to recall the second member of the pair when presented with the first member.

Perceptual speed ability was assessed with the Digit Symbol, Pattern Comparison, and Letter Comparison tests. In the Digit Symbol test (Wechsler, 1997a), 2 minutes were allowed for the participant to write symbols below digits according to a code table displayed at the top of the page. In the Letter Comparison test (Salthouse & Babcock, 1991), 30 seconds were allowed on each of two pages for the participant to write the letter S for same or D for different between 21 pairs of 3, 6, or 9 letters. In the Pattern Comparison test (Salthouse & Babcock, 1991), 30 seconds were allowed on each of two pages for the participant to write the letter S for same or D for different between 30 pairs of patterns consisting of 3, 6, or 9 line segments.

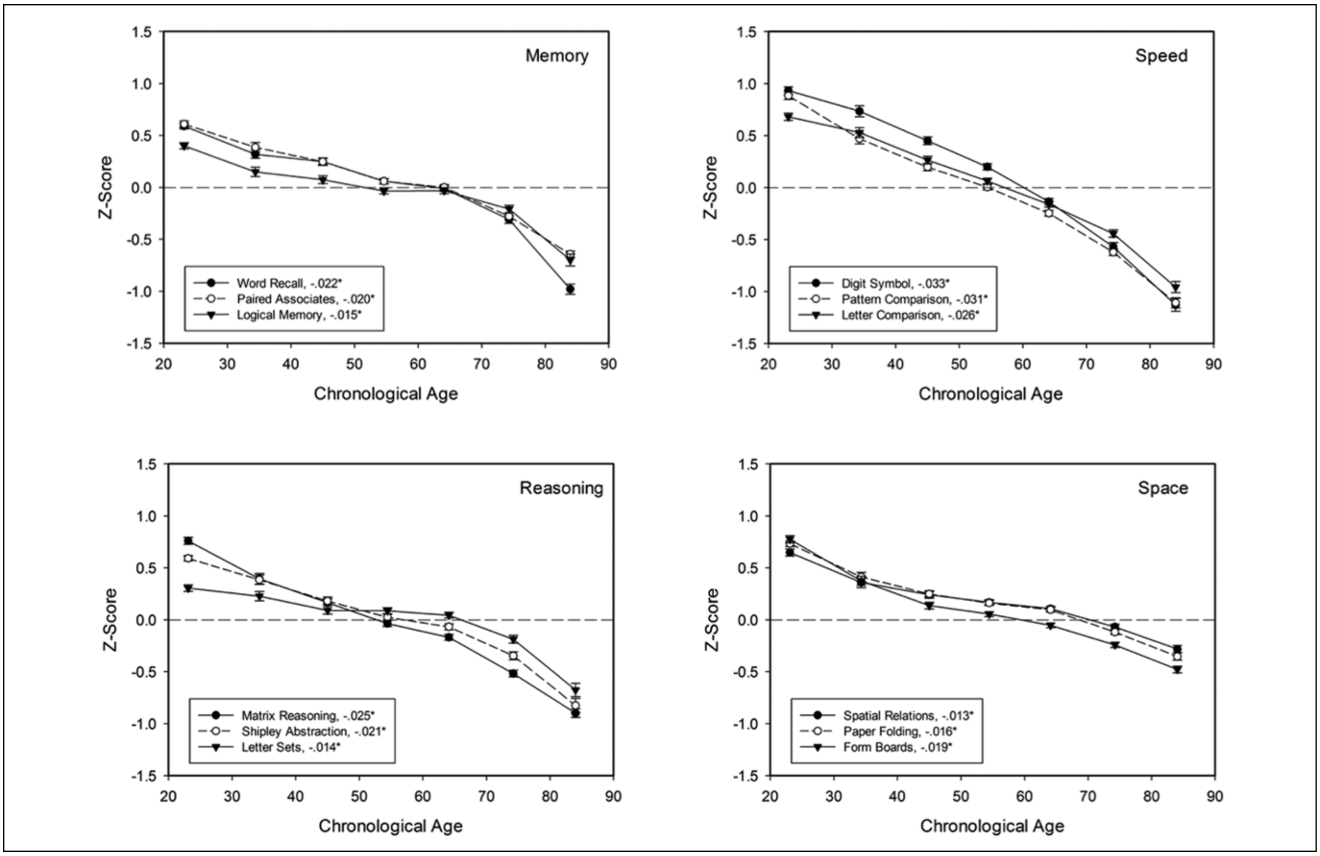

Figure 2. Means of scores on the three tests of each ability as a function of age in the primary Virginia Cognitive Aging Project sample, and slopes in z-score per year of age.
*p < .01.

Prior research has established that most of the internal consistency and test–retest reliabilities were above about .7, and validities, in the form of factor loadings, were .6 or higher (Salthouse, 2014a; Salthouse et al., 2008).

The alternate versions on Sessions 2 and 3 involved different items with the same format as the original tests. Scores on all versions were converted to the same scale as that on Session 1 by administering the test versions to a sample of participants in a counterbalanced order, and then using regression equations to statistically equate the mean scores across versions (for details, see Salthouse, 2007).

All scores were converted to z-scores based on the means and standard deviations of scores on the first session. In the primary sample, analyses of consistency were based on correlations among scores on different versions of the same tests, analyses of coherence were based on correlations among averages across the three versions of the three tests for each ability, and analyses of commonality were based on correlations of averages of the three tests of each ability across the four abilities. The analyses on data from participants with only one version of each test were based on correlations among the single scores on the three tests of each ability for coherence, and correlations among the composite scores representing each ability for commonality. The analyses in the longitudinal sample were based on the differences between the first and second occasion rather than scores only on the first occasion as in the analyses in the cross-sectional samples. In order to examine age relations, separate correlations were computed for participants in successive 10-year age ranges, and regression analyses were conducted on the correlations and mean ages in the seven age groups to determine the slope of correlation units per year of age.

Results

Mean levels of performance in the primary sample were computed across the three versions of each test, and are portrayed as a function of age in the four panels of Figure 2. All of the test scores had significant ($p < .01$) negative relations with mean age, with a range from −.013 to −.033 z-score units per year of age.

Correlations among the measures at the three levels of the hierarchical structure portrayed in Figure 1 are reported by age decade in Table 2. All of the correlations in the table were moderate in magnitude, and significantly ($p < .01$)

Table 2. Correlations at Different Levels of Analysis in Cross-Sectional Data With Three Test Versions.

	18-29	30-39	40-49	50-59	60-69	70-79	80-99	Slope
N	482	246	400	667	552	320	159	
Mean age	23.2	34.4	45.0	54.6	64.1	74.3	83.9	
Commonality								
Mem-Spd	.35*	.40*	.40*	.44*	.39*	.40*	.39*	.000
Mem-Reas	.56*	.65*	.65*	.62*	.54*	.54*	.45*	−.002
Mem-Space	.45*	.54*	.50*	.49*	.33*	.25*	.33*	−.004
Spd-Reas	.46*	.55*	.50*	.49*	.48*	.52*	.56*	.001
Spd-Space	.31*	.43*	.42*	.35*	.26*	.33*	.35*	−.001
Reas-Space	.71*	.72*	.70*	.72*	.65*	.57*	.60*	−.002
Coherence								
Memory								
Rec-PA	.65*	.73*	.75*	.71*	.67*	.63*	.61*	−.001
Rec-LM	.62*	.61*	.71*	.66*	.63*	.64*	.70*	.001
PA-LM	.55*	.53*	.65*	.62*	.58*	.53*	.53*	.000
Speed								
DS-PC	.44*	.64*	.57*	.59*	.55*	.66*	.72*	.003
DS-LC	.43*	.63*	.60*	.63*	.60*	.69*	.76*	.004
PC-LC	.57*	.69*	.65*	.70*	.65*	.68*	.77*	.002
Reasoning								
MR-Sh	.75*	.81*	.78*	.79*	.74*	.67*	.67*	−.002
MR-LS	.70*	.74*	.74*	.72*	.67*	.57*	.59*	−.003
Sh-LS	.74*	.76*	.80*	.79*	.78*	.71*	.77*	−.000
Space								
SR-PF	.77*	.83*	.75*	.70*	.67*	.52*	.43*	−.006*
SR-FB	.65*	.72*	.69*	.66*	.58*	.59*	.56*	−.002
PF-FB	.60*	.67*	.59*	.57*	.45*	.44*	.46*	−.004
Consistency								
Memory								
RecV1-V2	.66*	.66*	.70*	.72*	.65*	.70*	.63*	.000
RecV1-V3	.69*	.71*	.70*	.69*	.64*	.64*	.58*	−.002
RecV2-V3	.72*	.74*	.76*	.75*	.71*	.75*	.62*	−.001
PAV1-V2	.63*	.68*	.68*	.63*	.66*	.54*	.55*	−.002
PAV1-V3	.60*	.67*	.69*	.65*	.65*	.63*	.54*	−.001
PAV2-V3	.71*	.78*	.76*	.69*	.73*	.67*	.70*	−.001
LMV1-V2	.71*	.73*	.77*	.74*	.73*	.66*	.72*	−.001
LMV1-V3	.60*	.68*	.72*	.66*	.62*	.63*	.66*	−.000
LMV2-V3	.65*	.68*	.72*	.70*	.69*	.64*	.73*	.000
Speed								
DSV1-V2	.85*	.85*	.77*	.83*	.82*	.87*	.88*	.001
DSV1-V3	.82*	.84*	.78*	.81*	.82*	.84*	.85*	.000
DSV2-V3	.84*	.87*	.81*	.84*	.85*	.88*	.86*	.000
PCV1-V2	.68*	.70*	.66*	.69*	.66*	.67*	.66*	.000
PCV1-V3	.67*	.63*	.66*	.70*	.68*	.69*	.71*	.001
PCV2-V	.77*	.75*	.78*	.76*	.73*	.72*	.65*	−.002
LCV1-V2	.68*	.73*	.72*	.73*	.63*	.67*	.74*	−.000
LCV1-V3	.67*	.69*	.67*	.67*	.62*	.66*	.67*	.000
LCV2-V3	.76*	.78*	.71*	.75*	.65*	.71*	.72*	−.001
Reasoning								
MR V1-V2	.71*	.76*	.73*	.74*	.67*	.62*	.66*	−.002
MR V1-V3	.73*	.75*	.69*	.70*	.63*	.62*	.42*	−.004
MR V2-V3	.74*	.78*	.73*	.73*	.63*	.58*	.60*	−.003*
Sh V1-V2	.71*	.75*	.76*	.78*	.71*	.69*	.76*	−.000

(continued)

Table 2. (continued)

	18-29	30-39	40-49	50-59	60-69	70-79	80-99	Slope
Sh V1-V3	.73*	.80*	.82*	.80*	.71*	.74*	.77*	.000
Sh V2-V3	.72*	.75*	.78*	.76*	.68*	.71*	.74*	.000
LS V1-V2	.69*	.72*	.71*	.74*	.67*	.58*	.66*	−.001
LS V1-V3	.63*	.67*	.65*	.64*	.51*	.46*	.52*	−.003
LS V2-V3	.61*	.62*	.55*	.66*	.53*	.54*	.55*	−.001
Space								
SR V1-V2	.69*	.74*	.62*	.64*	.56*	.36*	.38*	−.006*
SR V1-V3	.70*	.73*	.65*	.66*	.59*	.52*	.39*	−.005*
SR V2-V3	.69*	.73*	.64*	.62*	.52*	.43*	.37*	−.006*
PF V1-V2	.70*	.71*	.66*	.65*	.56*	.46*	.48*	−.004*
PF V1-V3	.69*	.75*	.63*	.68*	.59*	.43*	.38*	−.006*
PF V2-V3	.69*	.77*	.69*	.66*	.64*	.45*	.33*	−.006*
FB V1-V2	.73*	.69*	.61*	.64*	.55*	.58*	.40*	−.005*
FB V1-V3	.49*	.50*	.48*	.47*	.43*	.37*	.32*	−.003*
FB V2-V3	.47*	.54*	.45*	.45*	.43*	.37*	.35*	−.003

Note. Mem = memory; Spd = speed; and Reas = reasoning; Rec = recall; PA = paired associates; LM = logical memory; DS = digit symbol; PC = pattern comparison; LC = letter comparison; MR = matrix reasoning; Sh = Shipley, LS = letter sets; SR = spatial relations; PF = paper folding; FB = form boards. Entries in the Slope column are slopes of regression equations relating correlation to mean age. V1, V2, and V3 refer to alternate versions of the tests administered on Sessions 1, 2, and 3, respectively.
*$p < .01$.

greater than zero. Several of the slopes for the consistency correlations involving the space measures were negative, indicating lower correlations at older ages. However, most of the age relations were weak, with slopes that were not significantly different from zero.

Means for the correlations at each age decade were computed by converting the correlations to *z*-scores, averaging the *z*-scores, and then converting the average *z*-scores back to correlations. The consistency mean was based on nine correlations corresponding to the three correlations among the alternate versions for each of three tests for a given ability. The coherence mean was based on the three correlations among the three tests of the same ability. Finally, the commonality mean was based on the three correlations between the target ability and the other three abilities.

The mean correlations at the three levels in the structure are plotted as a function of age decade in Figure 3, with slopes in correlation units per year of age reported in the legends. It can be seen that the age relations were fairly small, with the exception of lower consistency of space, and higher coherence of speed, at older ages.

Correlations at the coherence and commonality levels for participants with data on only one test version are reported by age decade in Table 3. Inspection of the entries reveals that the patterns were very similar to those in Table 2, with moderate correlations among the measures at each level, but relatively small age differences in the magnitude of the correlations.

To determine whether age differences might exist in the structure of cognitive change, parallel analyses were conducted on longitudinal difference (Time 2-Time 1) scores in 1,295 of the VCAP participants who returned for a second occasion after an average interval of 3 years. Most of the correlations among the differences in the measures were small, with means of .14 for consistency, .15 for coherence, and .13 for commonality, compared with .68, .64, and .50, respectively, with the cross-sectional data. Furthermore, only 29% of the longitudinal correlations were significantly ($p < .01$) different from zero, compared with 100% with the cross-sectional data. As might be expected given the weak correlations, none of the relations of age with the correlations was significant.

Discussion

Despite moderate negative relations of age with the mean scores (Figure 2), relations of age on the magnitude of interrelations among relevant measures at different levels were weak to nonexistent (cf. Tables 2 and 3, Figure 3). Small negative relations of age were evident in the consistency of the space measures, which are likely attributable to a measurement floor in the space measures at older ages. In addition, coherence of different types of speed measures was stronger at older ages, which may reflect greater influence of a general speed factor. However, most of the relations among measures at each level in the hierarchy were similar across the adult years in two independent samples involving the same cognitive tests.

The analyses of the longitudinal data revealed weak relations among the elements at each level, which may be attributable to the low consistency (reliability) of difference score measures of change. More reliable assessment of change can be obtained with latent change models based on

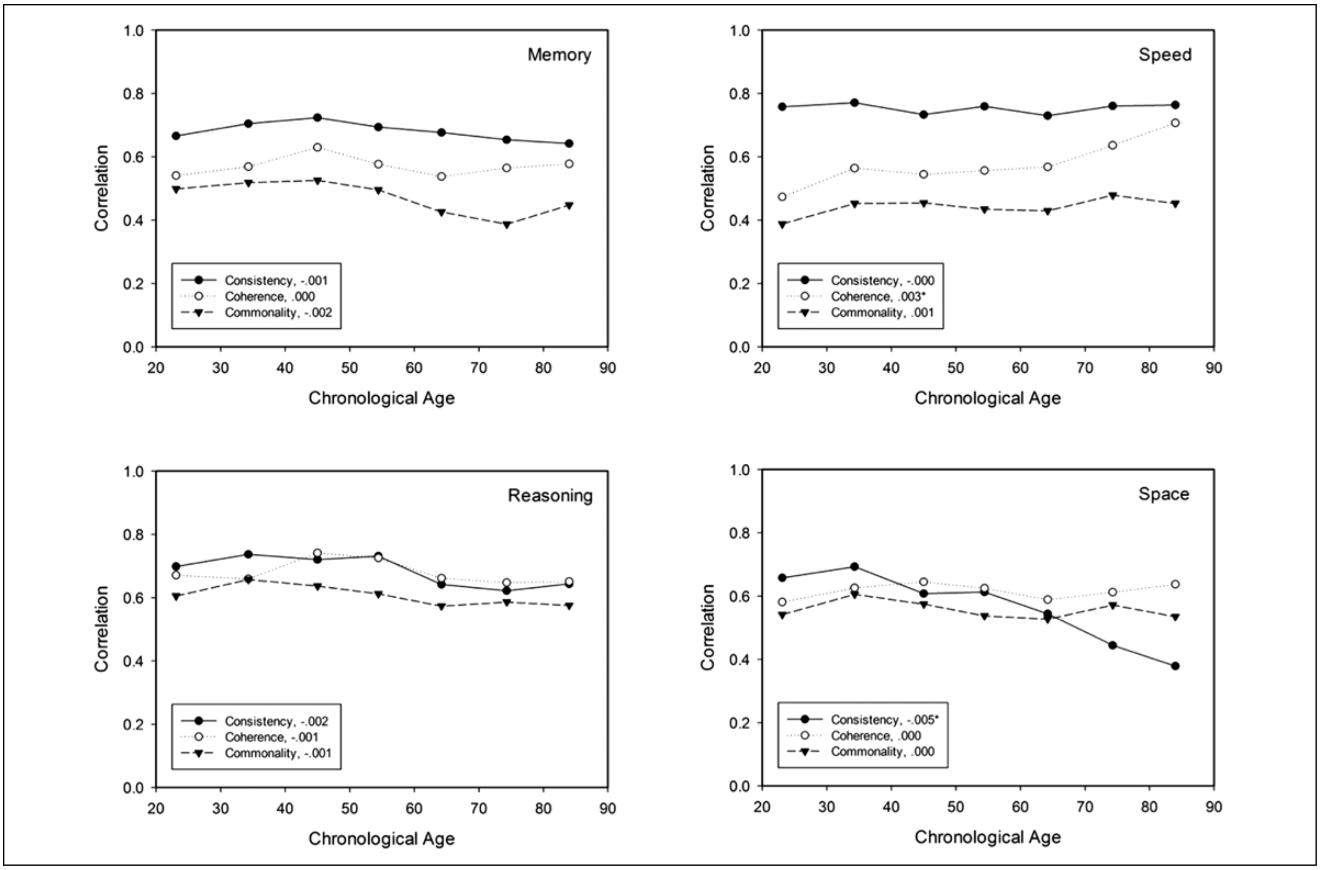

Figure 3. Means of correlations representing commonality, coherence, and consistency in four ability domains as a function of age in the primary Virginia Cognitive Aging Project sample, and slopes in correlation units per year of age.
*$p < .01$.

multiple indicators of latent variables at each longitudinal occasion. To illustrate, Salthouse (2016) recently reported latent change analyses of longitudinal change in memory and speed abilities in VCAP participants categorized into three age groups. Correlations of the latent changes across the first and second sessions, corresponding to test–retest reliability (consistency) ranged from .52 to .76 for memory, and from .60 to .82 for speed. No estimates of coherence were available, but correlations of memory change with speed change, corresponding to commonality, ranged from .35 to .52. As expected, the estimates of consistency and commonality with latent changes were much larger than those based on the Time 2 to Time 1 difference scores. Importantly, however, there were no age differences in reliabilities, or correlations of changes, with either method of examining change. These results suggest that cognitive measures have similar properties at different ages in both cross-sectional and longitudinal comparisons.

Study 2

To examine robustness of the results of Study 1 with different cognitive tests, the same types of analyses were carried out on data from a commercial test battery, the WAIS IV (Wechsler, 2008). In addition to including a variety of different cognitive tests, a valuable feature of the WAIS IV data set is that quota sampling was used to obtain a nationally representative sample of participants.

Method

Participants. The normative sample for the WAIS IV consisted of 2,200 individuals, with 200 adults in each age group, except for adults older than 70 years and over in which there were 100 adults per group. Details about the recruitment procedures, intended to obtain a sample that matched the population in terms of education, ethnicity, geographical region, and so forth, are contained in the technical manual (Wechsler, 2008).

Measures. Consistency, coherence, and commonality were examined with correlations among the WAIS IV core tests administered to participants of all ages. The tests consisted of Block Design, Matrix Reasoning, and Visual Puzzles as indicators of perceptual reasoning, Digit Span and Arithmetic as indicators of working memory, and Symbol Search

Table 3. Correlations at Different Levels of Analysis in Cross-Sectional Data With One Test Version.

	18-29	30-39	40-49	50-59	60-69	70-79	80-99	Slope
N	401	255	379	477	331	240	105	
Mean age	23.1	34.2	45.0	54.2	64.2	74.1	84.2	
Commonality								
Mem-Spd	.40*	.30*	.38*	.38*	.34*	.29*	.46*	.000
Mem-Reas	.58*	.60*	.59*	.55*	.43*	.40*	.52*	−.003
Mem-Space	.51*	.54*	.52*	.37*	.33*	.23*	.39*	−.004
Spd-Reas	.43*	.50*	.50*	.46*	.52*	.60*	.46*	.001
Spd-Space	.33*	.48*	.40*	.36*	.38*	.46*	.32*	.000
Reas-Space	.72*	.77*	.71*	.68*	.63*	.64*	.63*	−.002*
Coherence								
Memory								
Rec-PA	.51*	.59*	.58*	.53*	.51*	.60*	.55*	.000
Rec-LM	.52*	.50*	.60*	.49*	.45*	.50*	.59*	.000
PA-LM	.45*	.52*	.56*	.49*	.39*	.51*	.52*	.000
Speed								
DS-PC	.47*	.49*	.46*	.46*	.48*	.61*	.63*	.003
DS-LC	.49*	.48*	.50*	.52*	.54*	.55*	.69*	.003
PC-LC	.46*	.56*	.58*	.45*	.59*	.62*	.67*	.003
Reasoning								
MR-Sh	.67*	.69*	.70*	.71*	.60*	.66*	.66*	−.001
MR-LS	.55*	.60*	.68*	.61*	.52*	.51*	.51*	−.002
Sh-LS	.63*	.61*	.77*	.70*	.58*	.70*	.70*	.001
Space								
SR-PF	.74*	.77*	.70*	.67*	.62*	.56*	.62*	−.003*
SR-FB	.61*	.66*	.61*	.63*	.58*	.64*	.62*	.000
PF-FB	.55*	.59*	.51*	.48*	.46*	.48*	.45*	−.002

Note. Mem = memory; Spd = speed; Reas = reasoning; Rec = recall; PA = paired associates; LM = logical memory; DS = digit symbol; PC = pattern comparison; LC = letter comparison; MR = matrix reasoning; Sh = Shipley; LS = letter sets; SR = spatial relations; PF = paper folding; FB = form boards. Entries in the Slope column are slopes of regression equations relating correlation to mean age.
$^*p < .01$.

and Coding as indicators of perceptual speed. The technical manual (Wechsler, 2008) contains descriptions of the tests and scoring procedures.

Estimates of reliability, which were based on internal consistency except for the speed measures which were based on test–retest correlations, were obtained from Table 4.1 of Wechsler (2008). The coherence and commonality correlations were obtained from Table A of Wechsler (2008). Coherence correlations were based on correlations among the tests representing each ability domain, and the commonality correlations were based on correlations among the sums of age-corrected scaled scores for the relevant tests in each domain.

Results

Mean correlations and slopes, in correlation units per year of age, for the three abilities at each level are portrayed as a function of age in Figure 4. It can be seen that in each ability domain, there was very high consistency with slightly lower values of coherence and commonality. The mean correlations, computed with the same *r*-to-*z* transformation described above, were .88 for consistency, .61 for coherence, and .54 for commonality. Importantly, there was little evidence of a relation of age on the correlations at any level in any ability domain.

General Discussion

Strong negative relations were evident in Figure 2 between age and mean performance on each of the three cognitive tests in four ability domains. Despite the large effects on level of performance, however, the results in Figure 3 and in Tables 2 and 3 indicate that only small age differences were evident in the strength of the interrelations among the measures at three different levels of abstraction. The values of consistency, and to a lesser extent coherence and commonality, of space measures were weaker at older ages, and the values of coherence for speed measures were stronger at older ages. Nevertheless, most of the interrelations among the measures were similar at different ages, and the general lack of age relations at each level were replicated in analyses of the WAIS IV standardization data.

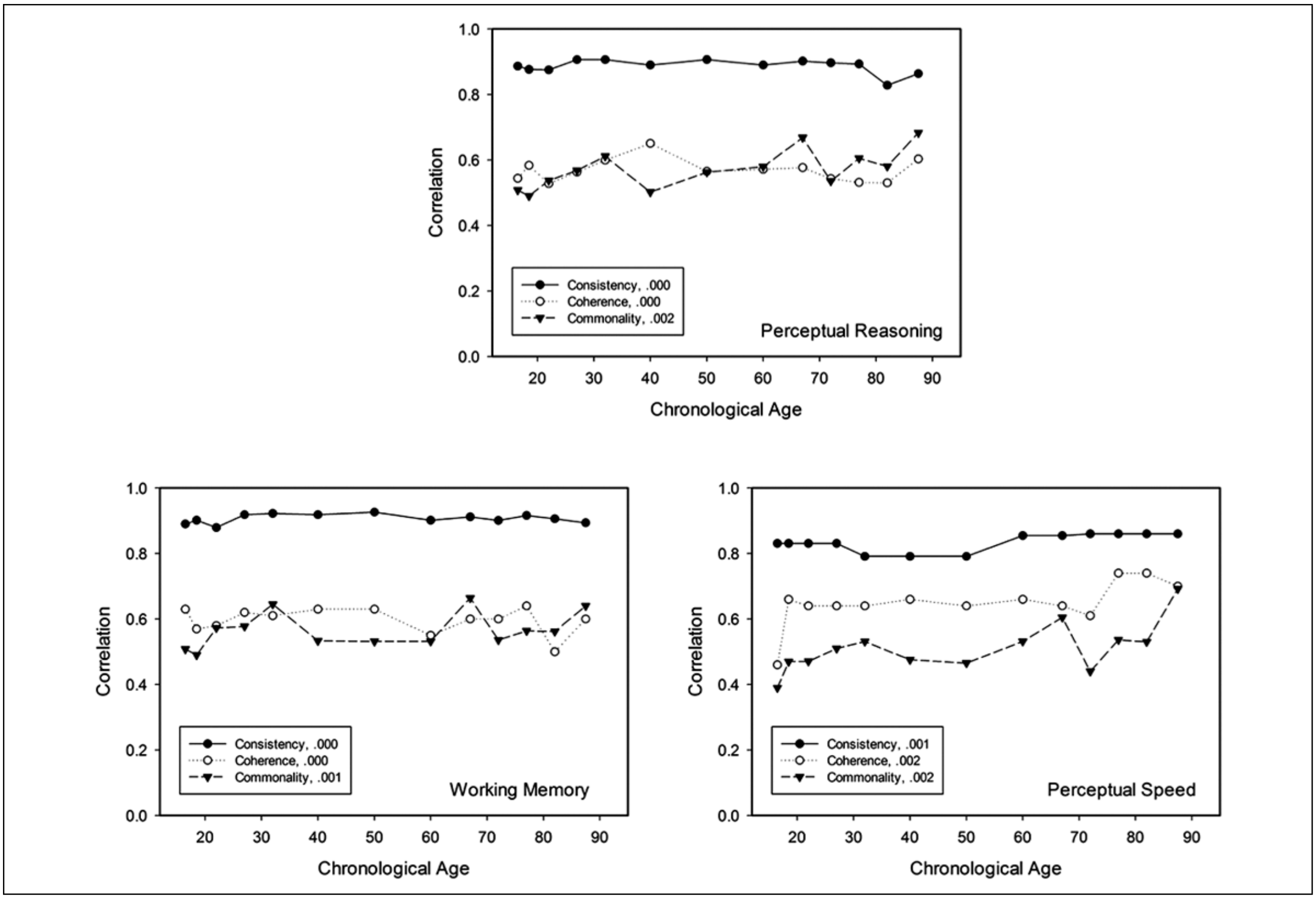

Figure 4. Means (and 95% confidence intervals) of correlations representing commonality, coherence, and consistency in three ability domains from the Wechsler Adult Intelligence Scale IV as a function of age, and slopes in correlation units per year of age.
$^*p < .01$.

The small to nonexistent age relations in Figures 3 and 4 suggest that the structure of cognitive measures at the levels of consistency (reliability), coherence (convergent validity), and commonality (correlations among abilities) is nearly comparable at different ages. These results, together with the generally small age differences found in many previous factor analyses (see earlier citations), suggest that cross-sectional age differences in the level of cognitive functioning are more quantitative than qualitative in that they reflect differences in how much, rather than what, the measures represent.

As noted in the introduction, Salthouse (2014c) reported that interrelations among vocabulary measures were weaker at around the same age when the levels of performance were lower, which was interpreted as implying the existence of both qualitative and quantitative shifts in vocabulary knowledge with increased age. In contrast, the analyses reported here indicate that the structure among measures of reasoning, spatial visualization, episodic memory, and perceptual speed was similar despite age-related declines in the means. These different patterns suggest that different mechanisms, and possibly neural substrates, are likely involved in the nearly continuous age-related declines from early adulthood in process measures of cognition, and in the late-life declines in product measures of cognition. That is, the shift in the relations among vocabulary measures suggests that age-related declines in products of processing carried out in the past at least partially reflect qualitative differences in the meaning of the measures. In contrast, the similar relations at different ages in the current study suggests that age differences in the efficiency of processing at the time of assessment, as reflected in tests of reasoning, spatial visualization, memory, and speed, reflect quantitative differences in measures that have nearly the same meaning at all ages.

Several limitations of this research should be acknowledged. For example, only healthy normal adults were considered, and stronger relations among measures might be evident in clinical groups, such as those with dementia or in individuals closer to death (e.g., Hulur, Ram, Willis, Schaie, & Gerstorf, 2015; Wilson, Segawa, Hizel, Boyle, & Bennett, 2012). Most of the participants were relatively high functioning, with an average estimated IQ of about 110, and it is possible that stronger relations among abilities might be evident among individuals with low average ability levels (e.g., Battersham, Christensen, & Mackinnon, 2011; Tucker-Drob, 2009). Some of the results may also be sample-specific, although the very similar patterns in the VCAP and WAIS IV data sets serve to mitigate this concern.

To summarize, the results of this study indicate that adult age differences in the structure of cognitive abilities are small relative to age differences in the level of performance. Moreover, the nearly comparable values of consistency, coherence, and commonality suggest that adult age differences in the level of cognitive functioning can occur with little or no qualitative shifts in the organizational structure, or measurement properties, of cognitive measures. At least among healthy adults between about 18 and 80 years of age, therefore, differences in cognitive functioning appear to be more quantitative (i.e., how much) than qualitative (i.e., what type).

Author's Note

The content is solely the responsibility of the author and does not necessarily represent the official views of the National Institute on Aging or the National Institutes of Health.

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