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Abstract:
Four measures of verbal ability derived from language sample analysis as well as 11 other measures of vocabulary, verbal fluency, and memory span were obtained from a sample of young adults and a sample of older adults. Factor analysis was used to analyze the structure of the 11 vocabulary, fluency, and span measures for each age group. Then an "extension" analysis was performed using structural modeling techniques to determine how the language samples measures were related to the other measures. One language sample measure of grammatical complexity was associated with measures of working memory including reading span and digit span; two measures, sentence length in words and a measure of lexical diversity, were associated with the vocabulary measures; the fourth measure, propositional density, was associated with the fluency measures as a measure of processing efficiency. The structure of verbal abilities in young and older adults is somewhat different, suggesting age differences in processing efficiency affecting sentence length, verbal fluency, and reading speed.

Text of paper:

The Structure of Verbal Abilities in Young and Older Adults

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The Structure of Verbal Abilities in Young and Older Adults

Verbal abilities in adulthood have been traditionally studied by testing older adults' abilities to produce definitions (Wechsler, 1981), select synonyms (Shipley, 1940), pronounce phonologically irregular words (Grober, Sliwinski, Schwartz, & Saffran, 1991), name pictures or drawings (Dunn, Dunn, & Dunn, 1997), and rapidly retrieve words (Borkowski, Benson, & Spreen, 1967). Across a wide range of tests both longitudinally and cross-sectionally, vocabulary has been shown to increase throughout the middle adult years but to decline in late adulthood (Albert, Heller, & Milberg, 1988; Botwinick & Siegler, 1980; Eisdorfer & Wilkie, 1973; Hultsch, Hertzog, Dixon, & Small, 1998; Schaie, 1983, 1996; Schaie & Willis, 1993).

Adopting a different approach, Kemper and her colleagues have traced age-related changes to verbal ability by analyzing spontaneous speech and writing samples. Language sample analysis has been traditionally used to assess children's mastery of vocabulary and grammar (Stromswold, 1996) although experimental techniques have been more recently developed to probe children's understanding of specific grammatical constructions (McKee, 1996) and maternal vocabulary inventories (Fenson, Dale, Reznick, Thal, Bates, Hartung, Pethick, & Reilly, 1991) have been developed to standardize the assessment of children's vocabulary. In a series of studies, Kemper and her colleagues investigated older adults' use of complex syntactic constructions in oral and written language samples (Kemper, 1992; Kemper, Kynette, Rash, Sprott, & O'Brien, 1989; Kemper, Rash, Kynette, & Norman, 1990; Kynette & Kemper, 1986). For example, Kemper (1987) analyzed the incidence of different types of embedded clauses in both a longitudinal sample and a cohort-sequential sample of adults' writings taken from diary entries. The longitudinal record spanned seven decades; the cohort-sequential sample contrasted adults born in the 1820s with those born in the 1860s for diary entries made when the adults were in their 40s versus in their 80s. The primary finding was the overall complexity of the adults' writing declined across the life-span; 70 and 80-year olds produced few sentences with embedded clauses, especially left-branching embeddings.

Kemper et al. (1989) reported that the mean number of clauses per utterance (MCU), a general measure of the complexity of adults language, is positively correlated with the adults backward digit span using the WAIS-R subtest (Wechsler, 1981). Further, Kemper and Rash (1988) calculated a measure of the working memory demands of sentence production, e.g., Yngve depth (Yngve, 1960), and found that it was positively correlated with WAIS-R digit span as well as with MCU.

In both speech and writing, older adults favor coordinate or right-branching constructions, e.g., She's awfully young to be running a nursery school for our church, over left-branching constructions, e.g., The gal who runs a nursery school for our church is awfully young. During the production of the left-branching constructions in which the embedded clause occurs to the left of the main clause, the form of the subject "the gal" must be retained and the grammatical form of the main clause verb "is" must be anticipated as the embedded clause "who runs a nursery school for our church" is being produced. Each clause is produced sequentially in the right-branching construction in which the embedded clause occurs to the right of the main clause. This asymmetry between left- and right-branching constructions has been assumed to reflect working memory limitations on the production of left-branching constructions (Gibson, 1988; Gibson, Schutze, & Salomon, 1996; Gibson, & Thomas, 1996).

The present study was designed to investigate the relationship between traditional measures of verbal abilities in adulthood and measures derived from language samples analysis. Language sample analysis relies on a variety of metrics to evaluate linguistic ability including measures of grammatical complexity, such as MCU and Yngve depth, and semantic content. In a previous study, Cheung and Kemper (1990) used structural modeling to investigate interrelationships among many language sample metrics including: Mean Length of Utterance (MLU) (Miller & Chapman, 1981); Developmental Sentence Scoring (DSS) (Lee, 1974); Developmental Level (D-Level) (Rosenberg & Abbeduto, 1987); four alternative ways of measuring syntactic complexity based on the Yngve (1960) and Frazier (1988) models of sentence production. In addition, Propositional Density (P-Density), based on Kintsch and Keenan's (1973) analyses of text difficulty, was used to assess the content of a language sample; it is computed by scoring the number of propositions or basic ideas occurring in a sample relative to the number of words in that sample.

Cheung and Kemper (1993) used EQS (Bentler, 1989) to model the relationships among these linguistic complexity metrics obtained from language samples produced by younger and older adults. The best-fitting model fit the data from both age groups with two correlated factors, verbal ability and working memory. The verbal ability factor was associated positively with WAIS-R vocabulary and with education; the working memory factor was associated positively with digit span. Age was negatively associated with working memory, reflecting a decline in digit span with advancing age, and somewhat positively associated with verbal ability, reflecting a slight vocabulary advantage for older adults. The working memory latent factor was related to three syntactic factors: length, reflecting MLU, the amount of embedding, linked to MCU, and the type of embedding, associated with DSS and D-Level as well as the syntactic complexity metrics derived from Yngve (1960) and Frazier (1988). Finally, the latent verbal factor ability predicted another linguistic factor, semantic content, defined by P-Density, which was not correlated with the syntactic factors. This analysis indicated that grammatical complexity can be assessed by a number of different metrics that are sensitive to the length of grammatical constituents, how many clauses are embedded within a sentence, and how those clauses are embedded. A key determinate of grammatical complexity, affecting the DSS, D-Level, Yngve, and Frazier metrics, is whether embeddings occur in the main clause subject, producing left-branching constructions such as Going to the St. Louis World Fair was a major undertaking, or in the main clause predicate, producing right-branching constructions such as I enjoyed going to the St. Louis World Fair. Left-branching constructions appear to be most vulnerable to age-related decline and to contribute highly to the D-Level, DSS, Yngve, and Frazier metrics.

One limitation of this analysis was that verbal ability was assessed by only a single measure of vocabulary, WAIS-R vocabulary, and verbal fluency was not assessed. Hence, the present project was undertaken to investigate how measures obtained from language sample analysis are related to a wider inventory of verbal ability measures, including diverse measures of vocabulary and verbal fluency. Four measures were selected from the language sample analysis; two traditionally used to assess child language development and two which have been used to assess age-group differences in language. Mean Length of Utterance (MLU) is traditionally used in child language research to assess language development (Miller & Chapman, 1981). MLU increases throughout early childhood, reflecting an increase in the use of sentence constituents such as subjects, adjectives, and prepositional phrases as well as increase in grammatical complexity through the use of relative clauses and infinitive complements. Type Token Ratios (TTRs) are also commonly used in the child language research to assess vocabulary development. It is a measure of the number of different words used in a language sample to the total number of words occurring in the sample. A TTR close to 1.0 indicates the use of a varied vocabulary; a TTR close to 0.0 indicates a limited, repetitive vocabulary.

Two additional measures were also obtained from the language samples. D-Level was selected as the sole measure of grammatical complexity used in the present analysis for a variety of reasons: it can be scored reliably, it is highly intercorrelated with the other measures of grammatical complexity such as MCU and Yngve depth, and it is sensitive to be the amount of embedding and the type of embedding used to create complex sentences. Finally, P-Density was selected as a measure of semantic content or how much information is packed into a sentence, relative to the number of words. It, too, can be reliably scored from language samples although extensive training and familiarization with this analysis technique is required to achieve acceptable reliability.

An additional reason for using D-Level and P-Density in the present analysis was that these measures have been used by Snowdon and his collaborators to investigate how linguistic ability affects risk for Alzheimer's disease and longevity. Snowdon, Kemper, Mortimer, Greiner, Wekstein, and Markesbery (1996) analyzed language samples from a group of nuns, members of the School Sisters of Notre Dame. The nuns produced autobiographical writing samples at the time they took their final religious vows, at 18 - 32 years of age. When the nuns were 75 to 93 years of age, they were given a battery of tests of cognition and memory designed to assess probably Alzheimer's dementia. Low linguistic ability in young adulthood, indicated by low D-Level (termed "grammatical complexity" by Snowdon et al.) and/or low P-Density (or "idea density") in these language samples, was associated with increased risk for poor performance on the cognitive and memory tests in late adulthood. Low P-Density in young adulthood was also associated with increased neuropathology characteristic of Alzheimer's disease for a small number of nuns who had died. In a follow-up study, Snowdon, Greiner, Kemper, Nanayakkara, & Mortimer (1999) linked low linguistic ability, measured by P-Density in young adulthood, to increased all-cause mortality among the nuns. Kemper, Greiner, Marquis, Prenovost, and Mitzner (in press) have traced these measures of linguistic ability over the life span, comparing the initial samples collected from from the nuns to those elicited when they were in their 40s, 70s, and 80s. Further, they investigated how education and adult experiences affected initial linguistic ability and its decline. P-Density appears to be a general measure of cognitive and neurological development that is not related to grades in high school English or mathematics nor is it affected by adult experiences including obtained advanced educational degress. Low P-Density in young adulthood may reflect suboptimal neurocognitive development which, in turn, may increase susceptibility to age-related decline due to Alzheimer's or other diseases.

A second goal of this project was to determine whether the organization of verbal abilities is stable across the adult years (Reinert, 1970). For example, age differences on verbal fluency tasks have not been found consistently; some researchers have observed better performance by young adults (Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992; Lindenberger, Mayr, & Kliegl, 1993;

McCrae, Arenberg, & Costa, 1987; Salthouse, 1993) whereas others report minimal differences across age groups (Davis, Cohen, Gandy, Colombo, VanDusseldorp, Simolke & Romano, 1990; Schaie, 1983). One reason for the conflicting findings regarding age differences may be that performance on verbal fluency tasks may be determined partially by the speed and efficiency with which words stored in memory can be searched and evaluated against the criteria and partially by the size of the mental lexicon and the availability of word candidates. Younger adults may perform better than older adults on word fluency tasks that emphasize demanding decision criteria whereas older adults may perform as well as younger adults on fluency tasks that emphasize retrieval of a large pool of candidate words (Bryan, Luszcz, & Crawford, 1997). Hence, verbal fluency may be limited by processing efficiency for older adults but by lexical knowledge for young adults, resulting in a different configuration of verbal abilities in young and older adults.

Method

Participants

One hundred young adults (18 to 28 years of age, M = 22.8, SD = 2.38) and 100 older adults (63 to 88 years of age, M = 76.4, SD = 6.21) participated in the study. The younger participants were undergraduate students recruited through both electronic mailings and posted announcements. The older participants were community-dwelling older adults recruited from a roster of previous research participants. All participants were native speakers of English. The groups did not differ in years of education (M_y = 15.8, SD_y = 1.5; M_o = 15.2, SD_o = 2.2), $t(198) < 1.0$, $p > .50$. Young adults received $20 for their participation; older adults received $40 including compensation for travel to the testing site.

Experimental Procedure

Participants were tested individually. Younger adults were tested in a laboratory setting. Older adults were tested either in the same laboratory setting or in their homes. The testing session lasted approximately one hour for younger adults and one hour and 10 minutes for older adults. During the first half of the testing session, background information was elicited from each participant and the Shipley Vocabulary, Reading Span, PPVT and Nelson-Denny tests were administered. Following a short break, the WAIS-R Vocabulary, Digits Forward and Digits Backward, AMNART and verbal fluency tests were administered, and a language sample was elicited. The second half of the session was audio recorded to permit accurate scoring of the verbal fluency tasks and transcription of the language sample.

Measures

All tests were administered in the same order for all participants. The experimenter administered each test using the instructions and procedures as described below.

Shipley Vocabulary Test. Participants first completed a paper-and-pencil version of the Shipley Vocabulary Test (Shipley, 1940). This measure comprises 40 stimulus words, presented in generally ascending order of difficulty. Participants selected the word that was the closest synonym to the stimulus word from among four presented options. Shipley (1940) reports a split-half reliability for this test as .87; the split-half reliability for the present sample of young adults was .84 and .92 for older adults.

Reading Span Test. Participants were next administered a paper version of the reading span task based on the original Daneman and Carpenter (1980) test. This test has been extensively used in

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studies of reading comprehension as well as studies of age differences in language processing (Daneman & Merikle, 1996; Kemtes & Kemper, 1997; van der Linden et al, 1999) although its reliability as a measure of working memory capacity has been questioned (Waters & Caplan, 1996). The reading span test requires the participant to read aloud progressively longer sets of sentences and then to recall the final word of each sentence within the set. Sentence sets varied in length from two to seven sentences, defining six reading span levels. Each level consisted of three sets of sentences of the defining length. The task began with administration of level two (sets of two sentences each requiring recall of two words). Testing was terminated when the participant failed to accurately recall all the final words from the sentences of two or three sets at a given level. The reading span score was defined as the highest set size (or level) at which the participant accurately recalled all the final words from at least two of three sets. A half-point was added if the participant was able to accurately recall all the final words from one of the three sets tested at the next level. Tirre and Pena (1992) report alternate-form reliability for Reading Span as .73. Test-retest reliability for alternate versions of the Reading Span test was computed for 50 young adults as .69 and as .84 for 50 older adults, each tested on two occasions approximately 1 week apart.

The Peabody Picture Vocabulary Test (PPVT). The Peabody Picture Vocabulary Test Third Edition (Dunn, Dunn & Dunn, 1997) was administered after the reading span test. The PPVT requires the participant to orally select, from among four numbered alternatives, the picture best representing the definition of a stimulus word given orally by the examiner. Stimulus items are numbered sequentially and presented in ascending difficulty in sets of 12. According to standard PPVT guidelines for assessing adults, testing began at item number 145. The task was terminated at the conclusion of a set in which the participant missed eight or more of the items in the set; the participant's score is defined as the difference between the highest-numbered item in the final set and the total number of items missed across all sets. Dunn and Dunn (1981) report split-half reliability for the PPVT = .83. Split-half reliabilities for the present sample were .87 for young adults and .85 for older adults.

Nelson-Denny Reading Test. Passage One from the paper-pencil version of the Nelson-Denny Reading Test, Form G (Brown, Fishco & Hanna, 1993) was administered after the PPVT. The participant is required, under a five-minute time constraint, to read a short passage and then to respond to a short set of multiple-choice questions about the passage. Reading rate is gauged by asking the participant, at an oral signal from the examiner one minute into the task, to indicate the line of text currently being read. To optimize measurement of first-pass reading comprehension, the procedure used in this study did not permit the reader to refer back to the passage to answer the questions. The comprehension score is defined as the number of correct responses to the questions. Brown et al. (1993) report alternate-form reliabilities for Rate = .68 and for Comprehension = .81. Test-retest reliability for alternate versions of the Reading Test was computed for 50 young adults as .63 and .78 for reading rate and reading comprehension, respectively, and .78 and .81 for reading rate and reading comprehension, respectively, for 50 older adults, each tested on two occasions approximately 1 week apart.

WAIS-R Vocabulary test. An oral response version of the vocabulary subtest of the WAIS-R (Wechsler, 1981) was administered after a five-minute intermission. This task required the participant to define a stimulus word presented orally by the examiner. Participants' definitions for each stimulus word were scored 0, 1 or 2. Responses scored as 0 represented wrong, vague or trivial answers.

Responses scored as 1 represented a vague or less pertinent synonym, a minor use, an attribute which is not definitive, an example that merely used the word or a concrete instance. Responses scored as 2 represented a good synonym, a major use, a definite or primary feature, a general classification, a correct figurative use or a good example of an action or causal relation. Stimulus words were presented in ascending order of difficulty; the task was terminated if a participant gave an "I don't know" response to five words in succession. The participant's total score was based on 32 stimulus words. Wechsler (1981) reports split-half reliability for vocabulary = .96. Split-half reliabilities for young adults in the present sample were .91 and .94 for older adults.

Digit span tests. The Digits Forward and Digits Backward span measures of the WAIS-R were administered following the WAIS-R Vocabulary test. These tasks have been previously shown to correlate with measures of grammatical complexity (Kemper et al, 1989; Kemper & rash, 1988) and to predict age-group and individual differences in text processing (Kwong See & Ryan, 1995; Stine & Hindman, 1994). In the forward span task, participants listened to a string of random single digits presented orally by the examiner, at the rate of approximately 1 per s. At the end of the string, participants were asked to repeat the string verbatim, i.e. same digits in the same order. Strings varied in length from three to nine digits, and were presented in pairs of equal length, i.e. a string was presented and scored, then a different string of equal length was presented and scored. Strings were scored as pass or fail; a string was passed only if all digits were repeated in correct order. The task began with the string of three digits and continued through strings of increasing length. Testing was terminated when both strings of a pair were failed. The participant's total score was based on the total number of strings passed, each passed string (regardless of length) was scored as 2 points; each failed string received 0 points. The backward span task was identical in procedure and scoring, except that in this task the participant was asked to repeat the presented string in reverse order, and strings varied in length from two to nine digits. Wechsler (1981) reports test-retest reliabilities for digits forward = .83 and digits backwards = .83. Test-retest reliability for alternate versions of the span tests was computed for 50 young adults as .72 and .76 for forward and backward span, respectively, and .88 and .85 for forward and backward span, respectively, for 50 older adults, each tested on two occasions approximately 1 week apart.

Pronunciation test. A paper version of the American Version of the National Adult Reading Test (AMNART) (Grober et al., 1991) was administered by the examiner following the digit span tasks. This task requires the participant to pronounce a stimulus word. Correct pronunciation cannot be derived from spelling-to-sound correspondence rules but must be retrieved from a memory representation; thus this task is designed as a measure of vocabulary knowledge. The task comprises 45 stimulus words; the participant's score was the number of correctly pronounced words. Keyser and Sweetland (1985) report test-retest reliability for the AMNART = .98. Test-retest reliability for alternate versions of the Reading Span test was computed for 50 young adults as .91 and as .89 for 50 older adults, each tested on two occasions approximately 1 week apart.

Verbal fluency. Two verbal fluency tasks were administered following the AMNART. In each, the participant was required to orally recall, within a 60-second time constraint, as many different words as possible that corresponded to a specified category. One stimulus category was the initial letter "f;" the other was "fruits and vegetables." The participant's score for each task was the total number of different words recalled within the time limit that met the criteria for each category. Repetitions and proper names were excluded. Bryan et al. (1997) report alternate-form reliability for initial letter fluency = .69; split-half reliability for category fluency was calculated as .73 for young adults and .75 for older adults.

Oral language sample measures.

An oral language sample was collected at the conclusion of the experiment. Approximately five minutes of discourse by the participant was elicited by asking the participant to relate or to describe an influential person or interesting experience that affected the participant's life. The sample was analyzed following the procedures described by Kemper et al., (1989). The samples were transcribed and coded by first segmenting each into utterances and then coding each utterance. Utterances were defined by discernable pauses in the participant's flow of speech; therefore, segments did not necessarily correspond to grammatically defined sentences but included interjections, fillers, and sentence fragments. "Fillers," defined as speech serving to fill gaps in the speech flow, included both lexical and non-lexical fillers. Non-lexical fillers, such as "uh," "umm," "duh," etc., were excluded from the transcript. Lexical fillers, such "and," "you know," "yeah," "well," etc. were retained in the transcript. Also excluded from the transcript were utterances that repeated or echoed those of the examiner. The final ten complete sentences from each transcript were analyzed.

Four measures (see Cheung & Kemper, 1992, for details) were then obtained from each language sample. Mean Length of Utterance (MLU) and Type-Token Ratio (TTR) were obtained automatically using the Systematic Analysis of Language Transcripts (SALT) software (Chapman & Miller, 1984). Developmental Level (D-Level) is an index of grammatical complexity based a scale originally developed by Rosenberg and Abbeduto (1987). Grammatical complexity ranges from simple one-clause sentences to complex sentences with multiple forms of embedding and subordination. Each complete sentence was scored and the average D-Level for each participant was then calculated. Propositional Density (P-Density) which was calculated according to the procedures described by Turner and Green (1977). Each utterance was decomposed into its constituent propositions, which represent semantic elements and relations between them. The P-Density for each speaker was defined as the average number of propositions per 100 words. Two trained coders independently scored 10% of the language samples to establish reliability. Reliability for D-Level was .94 and .91 for P-Density.

Results

Means and standard deviations for each age group on each of the fifteen measures are summarized in Table 1. As expected, older adults demonstrated better performance on the vocabulary measures including the Shipley vocabulary , the PPVT, the AMNART and the WAIS-R vocabulary (a minimum alpha level of .05 was used for all statistical tests). Also as expected, younger adults demonstrated better performance on the span measures and the category fluency and they scored higher on the reading comprehension test than the older adults.. In addition, younger adults had higher MLU, D-Level and P-Density scores, confirming previous findings (Kemper et al., 1989) whereas older adults had higher TTRs. Young and older adults performed similarly on initial letter fluency and reading rates.

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Intercorrelations among the measures for young and older adults are presented in Tables 2 and 3, respectively. For both groups, the different vocabulary measures were correlated with r's ranging from .61 to .84. The different span measures were also correlated, particularly for older adults with r's ranging from .53 to .67.

Scores for each age group were examined separately for skewness and kurtosis, using as a criteria values > ± 1.0 The PPVT, reading rate, reading span, and both fluency measures were nonnormally distributed. Accordingly, these scores were transformed to yield skewness and/or kurtosis measures closer to ±1.0 (see Table 4).

A structural model of the 11 traditional measures of verbal ability was first developed using the combined data from the young and older adults. Confirmatory factor analysis was used to test the equivalence of this model across groups. Subsequently, the 11 traditional measures of verbal ability were re-analyzed separately for each group. Finally, in order to determine the relationship between the traditional measures of verbal abilities and those derived from the language sample analysis, an "extension" analysis (Loehlin, 1998) was performed. In this procedure, the factor loadings and factor correlations obtained from the analysis of the traditional measures of verbal abilities were used to specify an initial structural model; the language sample measures were then added by fixing the factor loadings for the traditional measures at the previously estimated values and estimating the factor loadings for the language sample measures.

To test for the equivalency of factor structure across groups, an initial three-factor structural model was derived from a preliminary exploratory factor analysis of the combined data from the young and older adults. EQS (Bentler, 1989, 1990) was used to fit this model to separate covariance matrices for the young and older adults. In this model, three correlated factors were specified: the Shipley, PPVT, WAIS-R, and American NART vocabulary scores were loaded on a common factor with reading comprehension, the reading span and forward and backward span scores loaded on the second, correlated factor, and the reading rate, initial letter and category fluency tests loaded on the third, correlated factor. The first model specified equivalent factor loadings and factor variances and covariances across groups although factor residual variances and covariances and the error variances and covariances were permitted to vary across groups. This model did not fit the data: χ^2(93, N = 200) = 125.855, p = .01321, CFI = .885, SRMR = .229. The χ^2 statistic assesses deviations in fit reflecting the degree to which a model reproduces the input variance-covariance matrix (a smaller χ^2 indicates better fit). The CFI is a measure of the overall fit of the model that focuses on the fit of the hypothesized relations among constructs (a CFI closer to 1.0 indicates better fit). The SRMR indicates the average of the standardized unexplained residuals (an SRMR closer to 0 indicates a better fit). The second model tested released the constraints on the factor variances and covariances although factor loadings were still constrained across groups. This model also failed to fit the data: χ^2(90, N = 200) = 124.784, p = .00898, CFI = .878, SRMR = .214. Finally, a model was tested that released the constraints on the factor loadings but retained the same factor structure across groups. This model, too, failed to fit: χ^2(82, N = 200) = 116.681, p = .00714, CFI = .879, SRMR = .183. Consequently, separate models for young and older adults were developed.

Young adults. The initial model of the young adults' performance on the 11 traditional measures of verbal ability was obtained using exploratory factor analysis. The initial model is

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summarized in Table 5. The Shipley, PPVT, WAIS-R, and American NART tests loaded on a common vocabulary factor, accounting for 42% of the variance. The reading comprehension, reading span, and forward and backward digit span tests loaded on a second factor, working memory, accounting for 19% of the variance. Finally, reading rate as well as initial letter fluency and category fluency load on a third factor, processing speed or efficiency, accounting for 10% of the variance. These three factors are correlated; vocabulary-working memory, r = -.20; vocabulary-processing, r = .23; working memory-processing, r = -.30.

The factor loadings and factor correlations obtained from the initial exploratory analysis of the young adults' data were used to specify an initial structural model of the 11 traditional measures of verbal ability. Then, the loadings of the four language sample measures, MLU, TTR, D-Level, and P-Density, on each factor were estimated. The initial model for the young adults provided an excellent fit, χ^2(87, N = 100) = 55.872, p = .99618, CFI = 1.00, SRMR = .010. This model was simplified by dropping all nonsignificant factor loadings, both those specified for the traditional measures and those estimated for the language sample measures. The final model, shown in Figure 1, also provides an acceptable fit, χ^2(93, N = 100) = 82.046, p = .78455, CFI = 1.00, SRMR = .267).

Older Adults. The same procedure was followed to model the older adults' data. The exploratory factor analysis is summarized in Table 6. The Shipley, PPVT, WAIS-R, and American NART tests loaded on a common factor; in contrast to the young adults' model, reading comprehension also loaded on this vocabulary factor, accounting for 37% of the variance. Reading span, forward and backward digit spans loaded on a working memory factor, which accounted for 18% of the variance, and reading rate, initial letter fluency, and category fluency loaded on the third processing factor, which accounted for 16% of the variance. The three factors were less strongly correlated for the older adults than they were for the young adults, vocabulary-working memory, r = -.33; vocabulary-processing, r = .18; working memory-processing, r = .06

Again, the factor loadings and factor correlations obtained from the initial exploratory analysis of the older adults' data were specified in the initial structural model and factor loadings for the language sample measures were estimated. The initial model provided an excellent fit, χ^2(87, N = 100) = 87.401, p = .46773, CFI = .998, SRMR = .108). This model was then simplified by dropping all nonsignificant factor loadings, both those specified for the traditional measures and those estimated for the language sample measures. The resulting model also provided an good fit, χ^2(95, N = 100) = 108.373, p = .16456, CFI = .925, SRMR = .187). A third model was also fit; in this model, the nonsignificant covariance between the working memory factor and the processing factor was dropped. This model provides an excellent fit to the data, χ^2(96, N = 100) = 108.395, p = .18238, CFI = .95, SRMR = .118). This model is shown in Figure 2.

Discussion

One goal of the present analysis was to investigate the relationship of the language samples measures to other measures of verbal ability. A second goal was to compare the structure of verbal abilities for young and older adults. The analyses of the young and older adults' data indicates the structure of verbal abilities is somewhat different for the two groups although there is considerable similarity. Both analyses yielded three factors, a vocabulary factor, a working memory factor, and a processing factor. Both analyses indicate that TTR and D-Level covary with span measures of working memory whereas MLU and P-Density covary with measures of verbal fluency and reading rate.

Traditionally thought of as a measure of vocabulary, TTR measures lexical diversity; it loaded positively on the same factor as D-LEVEL and the span measures in both analyses, indicating that those individuals with higher span scores use a greater variety of words in their speech. D-Level is based on a seven-point rating system devised by Rosenberg and Abbeduto (1987) and modified by Cheung and Kemper (1990). Sentences are ordered in complexity roughly parallel to their order of appearance in children's speech; more complex sentences involve left-branching constructions such as relative clauses modifying the sentence subject and noun phrases or nominalizations used as the sentence subject as well as sentences involving multiple forms of embedding and subordination. Scores for individual sentences are averaged to compute the D-Level of a language sample; hence, scores close to 7 indicate the consistently with which complex sentences are produced. For both young and older adults, D-Level was related to the measures of working memory including digit span and reading span. Working memory imposes limits on how many digits may be retained (forward digit span), reordered (backward digit span), and how many words may be retained while other sentences are read (reading span). These analyses, like prior correlational findings (Kemper et al., 1989), indicate that working memory also imposes limits on how many sentence relations, particularly hierarchical relations, may be formulated at one time. Each embedded or subordinate clause increases the burden on working memory by imposing additional requirements for, e.g., subject-verb agreement, pronominal choice, linear ordering of adjectives, and other grammatical rules. Left-branching embeddings typically require that the grammatical form of the main clause be anticipated while the embedded clause is being produced, thus adding to the burden on working memory.

For both young and older adults, MLU and P-Density appear to be measures of processing efficiency. MLU measures utterance length in words. For both young and older adults, it loaded negatively on the same factor as the verbal fluency and reading rate measures. This suggests a relationship between processing efficiency and verbose speech -- individuals who perform poorly on the fluency measures use longer sentences than those who perform well on the fluency measures. P-Density also measures processing efficiency. As originally formulated by Kintsch and Keenan (1973), the propositional density of a text determined reading rate by affecting the amount of information which must be processed at one time. Propositions are linked together to form a text base, a representation of the meaning of a text. As a measure of production, P-Density appears to reflect how efficiently information can be concatenated into a single sentence. It is computed by identifying basic ideas or propositions, including concepts and the relations or connections among them. Each proposition may be a state or relation, an action or change of state, a modification of an action or state, or a connection between propositions. Since there is no one-to-one mapping between words and propositions, P-Density controls for word length reflecting whether ideas are expressed succinctly or verbosely. P-Density indicates how many basic ideas are expressed relative to the number of words required to express them. Averaged over a language sample, P-Density measures the consistently with which ideas are expressed succinctly or not. Individual differences in processing efficiency appear to affect reading rate, initial letter and category fluency, and P-Density by limiting how much information can be processed at one time. Processing efficiency appears to impose general limitations on task performance, affecting how efficiently the mental lexicon can be searched for words with the appropriate initial letter and how efficiently a text base can be searched for answers to comprehension questions. Those with higher P-Density scores read more rapidly (requiring fewer sec per word) and generated more items meeting the fluency criterion in the available time.

Arbuckle, Nohara-LeClair, & Pushkar (2000) have reported that speakers rated high in off-target verbosity also perform poorly on tests of inhibition, including initial letter fluency. They also report that speakers rated high in off-target verbosity use more words and hedges during a referential communication tasks and they refer to such speakers as "inefficient communicators." The present finding that MLU and P-Density load on the same factor as the verbal fluency tasks is consistent with this view. Both MLU and P-Density are affected by the use of fillers such as "you know" and "like." The use of such fillers increases MLU but decreases P-Density. Inefficient processors may use longer but less propositionally dense sentences because they use more fillers to hedge their meaning.

One difference between the models of young and older adults was the split loading for MLU for young adults but not for older adults. For young adults, MLU loaded negatively on the processing factor, in addition to loading on the working memory factor, suggesting that those young adults who use longer sentences were less efficient processors: they generated fewer items in the allocated time on the fluency tests, had lower propositional density, and read slowly. This increase in MLU may reflect their use of sentence fillers such as "you know," "like," and "I mean," which contribute little to grammatical complexity but lower propositional density while increasing MLU. The use of such fillers is rather common among young adults; all of the young adults who participated in this study used fillers and they used them in 10 - 18% of their utterances. In contrast, 82% of the older adults did not use fillers in their language samples and those who did so used them in 3 - 12% of their utterances.

In addition, for young adults, but not for older adults, P-Density also loaded on two factors, negatively on the processing efficiency factor and negatively on the vocabulary factor. This suggests that young adults with larger vocabularies tend to express themselves more succinctly, packing more information into their sentences, relative to the number of words. And young adults with lower propositional density also tended to perform poorly on the fluency measures, reflecting reducted processing efficiency.

The structure of verbal abilities in young and older adults also differs in two additional ways: First, reading comprehension scores for older adults loaded on the vocabulary factor whereas reading comprehension was loaded on the working memory factor for young adults. This finding suggests that older adults were able to answer the comprehension questions by drawing on their knowledge of vocabulary. Young adults' reading comprehension, in contrast, was limited by their ability to retain information in working memory in order to answer the comprehension questions. The design and construction of the Nelson Denny Test may contribute to this outcome; other reading tests, such as that from the Woodcock-Johnson (Woodcock & Johnson, 1989) test, might yield a different structure.

Second, the three factors are correlated for young adults whereas the working memory factor is not correlated with the processing factor for older adults. Among young adults, those with limited lexical knowledge tend to have smaller working memories and to be less efficient processors of information. In contrast, older adults with large vocabularies tend to be efficient processors and they tend to perform poorly on the span measures; however, among older adults, there is no relationship between performance on the span measures and the processing measures including verbal fluency and reading rate.

Performance on verbal fluency tasks has previously been shown to be correlated with performance on a variety of measures of processing speed, including digit-symbol substitution tests (Salthouse, 1993). In turn, processing speed has been linked to general measures of health (Salthouse, 1996; Hultsch, Hertzog, Dixon, & Small, 1998; Earles & Salthouse, 1995; Light, 1978; Earles, Connor, Smith, & Park, 1997). Thus, measures of processing efficiency, such as verbal fluency (Masur, Sliwinski, Lipton, Blau, & Crystal, 1994) and P-Density, may be a good candidates as measures of cognitive neurological development and as predictors of the onset and progression of Alzheimer's disease (Kemper et al., 1993; Lyons et al., 1994; Snowdon et al, 1996).

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Table 1

Means and Standard Deviations for Young and Older Adults on all Verbal Measures

	Young		Older		
Measure	M	SD	M	SD	*t*(df)
Age	22.8	2.3	76.4	6.2	
Years of education	15.8	1.5	15.2	2.4	.35
Shipley Vocabulary	32.4	3.6	35.2	3.7	-5.35**
PPVT	182.4	7.8	192.1	9.4	-7.94**
WAIS-R Vocabulary	43.4	8.7	47.2	7.2	-3.36**
AMNART	29.1	5.4	32.1	6.8	-3.45**
Reading Rate (words/min)	92.3	5.6	93.2	6.8	0.45
Reading Comprehension	5.8	1.8	4.2	2.5	5.19**
Reading Span	3.8	0.7	2.7	0.8	10.35**
Digits Forward	9.9	1.7	7.8	2.4	7.14**
Digits Backward	8.2	2.6	5.4	2.1	8.38**
Initial letter Fluency	14.9	4.7	14.6	5.2	0.43
Category Fluency	23.5	4.1	17.8	5.7	8.12**
D-Level	2.6	1.3	2.1	1.1	2.94*
P-Density	5.7	0.9	4.3	0.6	12.95**
MLU	12.1	3.6	9.2	4.2	5.23**
TTR	0.47	0.18	0.58	0.13	-5.76**

Note. n = 100 for each age group.
PPVT = Peabody Picture Vocabulary Test. AMNART = American National Adult Reading Test.
*p < .05, two-tailed. **p < .01, two-tailed.

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Table 2

Intercorrelations Among Verbal Measures for Young Adults

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Shipley Vocabulary	1.00	--	--	--	--	--	--	--	--	--	--	--	--	--	--
2. PPVT	.62	1.00	--	--	--	--	--	--	--	--	--	--	--	--	--
3. WAIS-R Vocabulary	.75	.61	1.00	--	--	--	--	--	--	--	--	--	--	--	--
4. AMNART	.62	.67	.66	1.00	--	--	--	--	--	--	--	--	--	--	--
5. Reading Rate	-.12	.02	.03	.03	1.00	--	--	--	--	--	--	--	--	--	--
6. Reading Comprehensi	.47	.46	.49	.43	.24	1.00	--	--	--	--	--	--	--	--	--
7. Reading Span	.11	.13	.18	.22	.20	.54	1.00	--	--	--	--	--	--	--	--
8. Digits Forward	.02	.05	.11	.25	.26	.48	.61	1.00	--	--	--	--	--	--	--
9. Digits Backward	.24	.23	.24	.26	.19	.55	.66	.53	1.00	--	--	--	--	--	--
10. Initial letter Fluency	. 50	.45	. 51	.43	.21	.43	.17	.11	.17	1.00	--	--	--	--	--
11. Category Fluency	.34	.35	.35	.49	.13	.57	.19	.15	.15	.68	1.00	--	--	--	--
12. D-Level	.19	.17	.08	.09	.05	.40	.55	. 50	.78	.17	.17	1.00	--	--	--
13. P-Density	-.10	-.14	-.09	-.12	-.49	.03	.04	.29	.25	-.02	.05	.14	1.00	--	--
14. MLU	.19	.23	.24	.26	.18	.34	.46	.42	.48	.21	.25	.17	.08	1.00	--
15. TTR	.32	.37	.21	.30	.11	.23	.18	.07	.11	.12	.21	.14	.11	.09	1.00

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Table 3

Intercorrelations Among Verbal Measures for Older Adults

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Shipley Vocabulary	--														
2. PPVT	.67	--													
3. WAIS-R Vocabulary	.84	.67	--												
4. AMNART	.70	.76	.71	--											
5. Reading Rate	-.14	-.04	-.07	-.12	--										
6. Reading Comprehension	.33	.42	.43	.30	.04	--									
7. Reading Span	.34	.27	.33	.28	.11	.35	--								
8. Digits Forward	.22	.11	.19	.26	.29	.22	.62	--							
9. Digits Backward	.22	.29	.17	.11	.19	.37	.63	.67	--						
10. Initial letter Fluency	.13	.14	.19	.15	.46	.11	.09	.12	.22	--					
11. Category Fluency	.23	.11	.14	.11	.43	.14	.14	.24	.21	.53	--				
12. D- Level	.26	.28	.27	.35	-.28	.22	.54	.65	.74	.29	.01	--			
13. P-Density	-.11	-.10	-.14	.13	.35	-.14	-.18	.11	.08	-.27	-.39	.00	--		
14. MLU	.03	.08	.11	.05	.24	.11	.32	.48	.33	.02	.27	.11	.21	--	
16. TTR	.32	.38	.44	.34	-.11	.43	-.04	.03	.11	.28	.23	.17	.28	.24	--

Kemper, S. & Sumner, A. (2001). The structure of verbal abilities in young and older adults. *Psychology and Aging, 16,* 312-322. Publisher's official version: http://psycnet.apa.org/doi/10.1037/0882-7974.16.2.312.
Open Access version: http://kuscholarworks.ku.edu/dspace/.

Table 4

Original and Transformed Verbal Measures for Young and Older Adults

		Original Measure				Transformed Measure			
		Younger Adults		Older Adults		Younger Adults		Older Adults	
Measure	Transformed	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
PPVT	$PPVT^2$	-1.10	1.84	-1.67	3.65	-.92	1.38	-1.32	2.65
Reading Rate (wpm)	θSec per word	2.34	7.28	1.63	-1.03	.11	.92	.13	-.71
Reading Span	Ln (Reading Span)	.54	.16	1.31	4.73	-.22	.10	.43	.67
Initial letter Fluency	Ln (Initial Letter Fluency)	-0.21	.08	1.21	3.16	-.92	1.27	.33	1.04
Category Fluency	Ln (Category Fluency)	-0.39	.10	.98	2.04	-.83	.48	.27	1.12
P-Density	Ln (P-Density)	2.15	5.77	1.55	4.32	1.02	1.82	.91	1.87

Note: Ln = Natural Log

Table 5

Results of the Exploratory Factor Analysis for Young Adults based on the Orthogonally Rotated Solution.

Measure	Factor 1	Factor 2	Factor 3
Shipley Vocabulary	.80	.06	.21
PPVT	.72	.08	.27
WAIS-R Vocabulary	.75	.12	.28
AMNART	.70	.18	.31
Reading Rate	-.30	.27	.51
Reading Comprehension	.39	.56	.44
Reading Span	.08	.79	.12
Digits Forward	-.02	.75	.13
Digits Backward	.20	.76	.06
Initial letter Fluency	.39	.04	.68
Category Fluency	.30	.09	.69

Table 6

Results of the Exploratory Factor Analysis for Older Adults based on the Orthogonally Rotated Solution.

Measure	Factor 1	Factor 2	Factor 3
Shipley Vocabulary	.81	.15	.14
PPVT	.80	.14	.06
WAIS-R Vocabulary	.83	.16	.04
AMNART	.81	.10	.09
Reading Rate	-.06	.31	-.70
Reading Comprehension	.42	.37	.04
Reading Span	.25	.72	.01
Digits Forward	.09	.80	.01
Digits Backward	.10	.80	.08
Initial letter Fluency	.09	.14	.73
Category Fluency	.07	.22	.72

Figure Caption

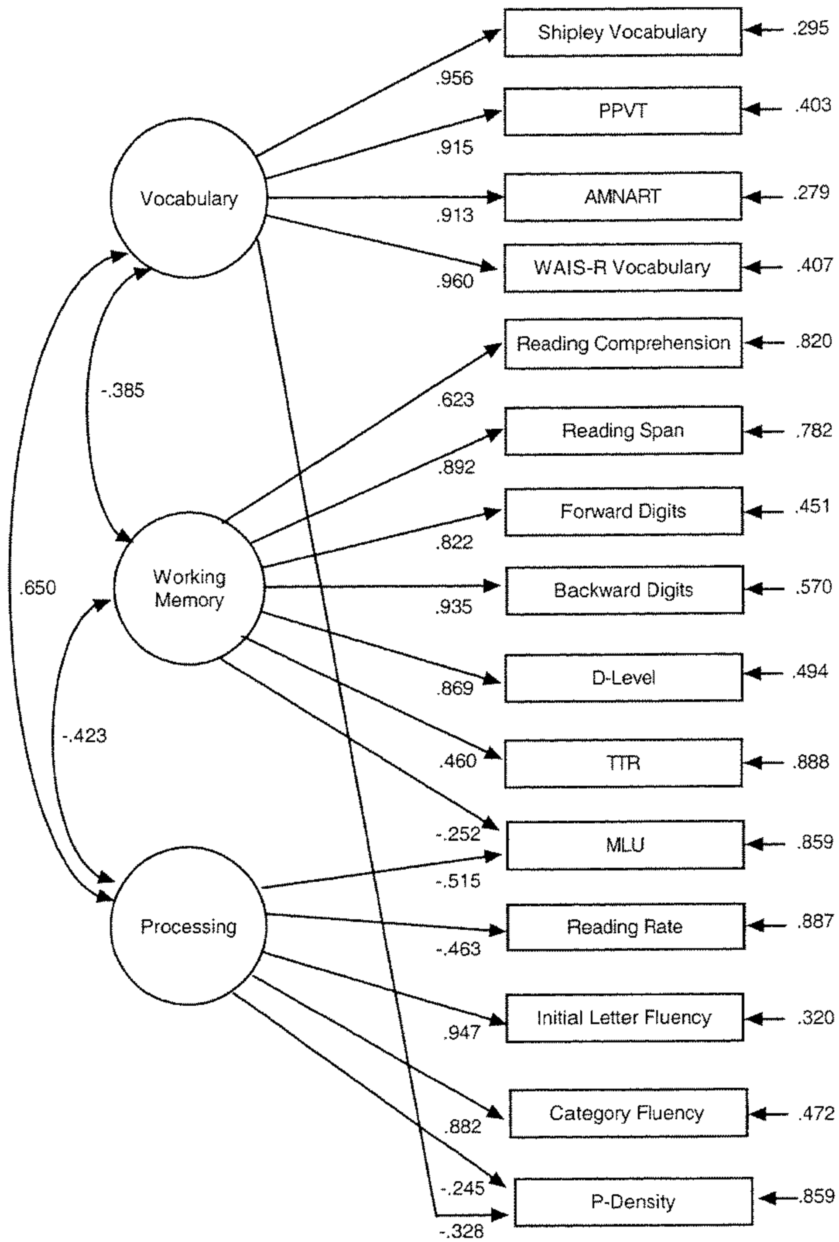

Figure 1. Final three-factor model for traditional and language sample measures of verbal ability for young adults. PPVT = Peabody Picture Vocabulary Test; AMNART = American National Adult Reading Test; WAIS-R = Wechsler Adult Intelligence Scale—Revised; D-Level = developmental level; TTR = type token ratio; MLU = mean length of utterance; P-Density = propositional density.

Figure 1. Final three-factor model for traditional and language sample measures of verbal ability for young adults.

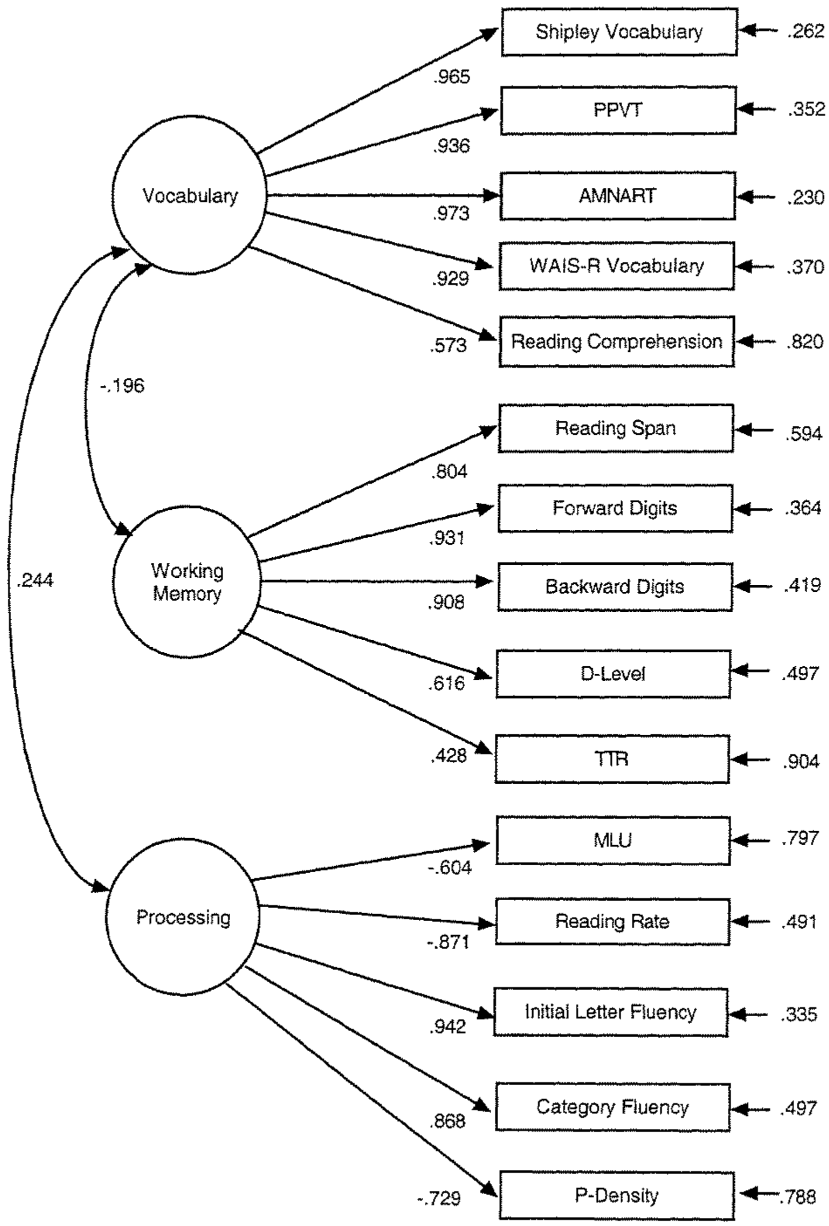

Figure 2. Final three-factor model for traditional and language sample measures of verbal ability for older adults. PPVT = Peabody Picture Vocabulary Test; AMNART = American National Adult Reading Test; WAIS–R = Wechsler Adult Intelligence Scale—Revised; D-Level = developmental level; TTR = type token ratio; MLU = mean length of utterance; P-Density = propositional density.

Figure 2. Final three-factor model for traditional and language sample measures of verbal ability for older adults.