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THE RELATIONSHIP BETWEEN THE WOODCOCK-JOHNSON PSYCHO-EDUCATIONAL BATTERY-REVISED *Gf-Gc* COGNITIVE CLUSTERS AND READING ACHIEVEMENT ACROSS THE LIFE-SPAN

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The relationships between the seven Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R) *Gf-Gc* cognitive clusters and measures of basic reading skills and reading comprehension were investigated in a large, nationally representative sample that covered most of the life span. Multiple regression analysis with the WJ-R cognitive clusters as predictors and the reading measures as criteria at 21 different age groups revealed significant relationships between six of the seven cognitive clusters and reading achievement at various ages. Analysis of the results as a function of age revealed differential developmental patterns in the degree of relationship between the cognitive clusters and reading achievement. The results have significant implications for the selection of intelligence batteries to use in psychoeducational assessment and also provide direction for new approaches to the investigation of aptitude-treatment interactions.

Recently, the *Journal of Psychoeducational Assessment (JPA)* published a special issue on *Intelligence: Theories and Practice* (Bracken & Fagan, 1990) that summarized a conference devoted to the exploration of the theoretical construct validity of six major intelligence batteries. Included in this special issue were three articles devoted to the Woodcock-Johnson Psycho-Educational Battery (WJ-R; Woodcock & Johnson, 1989). The WJ-R Battery includes a cognitive section designed to measure seven cognitive abilities based on the *Gf-Gc* theory of intelligence (McGrew, Werder, & Woodcock, 1991; Woodcock, 1990). The extensive technical information reported on the psychometric characteristics of the WJ-R (McGrew et al., 1991; Woodcock, 1990), and the subsequent independent reviews in the special *JPA* issue, support the conclusion that the cognitive section of the WJ-R is a "psychometrically sound, well-standardized measure of cognitive functioning" (Reschly, 1990, p. 260). Ysseldyke (1990, p. 274) concluded that "the WJ-R represents a significant milestone in the applied measurement of intellectual abilities. The manner in which theory and prior research were used in the development of the WJ-R . . . should serve as a model for future research and development in the fields of applied psychometrics and psychoeducational assessment." Although Reschly and Ysseldyke wrote positively about the theoretical and psychometric foundations of the WJ-R, both concluded that the ultimate utility of the WJ-R cognitive tests should rest in large part on treatment or intervention validity. Although the construct validity of the seven WJ-R

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cognitive clusters is acknowledged (Kaufman, 1990; Reschly, 1990; Ysseldyke, 1990), the burning question about the cognitive factors is, "What do they mean?" (Reschly, 1990, p. 265). Both Reschly and Ysseldyke suggest that in the final analysis the value of the WJ-R cognitive tests, as well as other cognitive tests, will be the degree to which they contribute to better aptitude-treatment-interaction research and findings.

The current study was designed to investigate a number of questions that need to be answered in order to judge whether the WJ-R cognitive tests have potential to facilitate ATI and other intervention-related research. Because ATIs rest on the assumption that the matching of different patterns of abilities with different interventions or treatments results in better outcomes, it is important to identify reliable and valid measures of aptitudes that show differential patterns of relationships with different achievement outcomes. The current study was designed to investigate whether the seven WJ-R cognitive clusters demonstrate differential patterns of validity with different reading outcomes across the life-span. In addition, the study was designed to demonstrate the unique potential the WJ-R battery has for conducting important theoretical research across the life-span.

METHOD

Subjects

The subjects were drawn from the WJ-R standardization sample of 6,359 individuals, who ranged in age from 24 months to 95 years. The WJ-R norm sample is a nationally representative sample that has been judged to be technically sound (Kaufman, 1990; Reschly, 1990; Ysseldyke, 1990). The characteristics of the standardization sample are described in detail in the *WJ-R Technical Manual* (McGrew et al., 1991). For the purpose of the current investigation, the sample was divided into 21 different age-based samples. The first 15 samples each represented one year of age starting at age 5 and continuing up through age 19. The remaining six samples each spanned 10 years of adulthood (i.e., 20-29; 30-39; 40-49; 50-59; 60-69; 70-79). Those norming subjects for whom complete information was available on the WJ-R measures described below were included in the investigation. Sample size and descriptive statistics for two WJ-R measures of reading (described below) for the 21 age groups are presented in Table 1.[1]

Instrumentation

The 35 WJ-R tests can be combined into various clusters according to the preferred level of interpretation for the WJ-R (McGrew, in press). Seven cognitive and two achievement clusters from the WJ-R battery were used in this investigation. Each of these nine clusters is comprised of two individual tests. The abilities measured by the seven WJ-R *Gf-Gc* cognitive and two reading achievement clusters from the battery are described in Table 2. The cluster scores used in this investigation were the *W* scores, a special transformation of the Rasch ability scale (Woodcock, 1978; Woodcock & Dahl, 1971). The *W* scale is an equal-interval scale centered on a

[1]Due to space limitations, descriptive statistics for all seven WJ-R cognitive clusters for all 21 age levels are not reported. This information can be obtained by contacting the author.

value of 500, which is the approximate average performance of a beginning fifth-grade student.

Table 1
Select Descriptive Statistics for 21 Samples Used in the WJ-R Gf-Gc/Reading Regression Models

Age group (years)	Basic reading skills *n*	*M*	*SD*	Rdg. comprehension *n*	*M*	*SD*
5	113	414.4	18.9	97	416.8	18.9
6	299	434.6	21.9	241	434.2	23.4
7	230	461.7	21.8	193	463.2	20.7
8	325	482.7	18.2	251	485.0	15.2
9	306	489.0	17.2	261	490.6	14.4
10	312	498.5	16.8	229	499.8	13.6
11	237	503.2	18.5	182	503.3	13.4
12	169	508.5	14.7	144	508.3	12.4
13	265	512.5	13.6	210	512.8	10.5
14	209	514.6	13.9	160	515.2	12.0
15	168	513.7	16.1	124	517.9	13.9
16	265	520.9	15.4	196	524.6	12.2
17	257	521.4	17.5	167	527.1	13.1
18	248	523.4	15.4	87	527.3	15.6
19	231	523.5	15.4	59	529.3	16.4
20-29	703	526.5	14.1	246	533.7	13.5
30-39	343	527.7	16.7	194	534.4	15.0
40-49	234	523.4	20.5	121	533.7	18.4
50-59	176	519.4	19.9	85	533.1	13.6
60-69	163	519.0	18.5	76	529.6	15.3
70-79	148	516.2	25.7	48	526.2	15.5

Note.—Due to different patterns of missing data, the sample sizes for the Basic Reading Skill and Reading Comprehension regressions differed.

Procedure

Gf-Gc/reading achievement regression analyses. To determine the relationship among the seven WJ-R cognitive clusters and two types of reading achievement (viz., basic skills and comprehension), two regression models were estimated in each of the 21 samples. In each model the predictor variables were the seven WJ-R cognitive clusters. In one of the models the criterion measure was the WJ-R Basic Reading Skills cluster, while in the other the criterion was the WJ-R Reading Comprehension cluster. The standardized regression coefficients were used as the primary unit of analysis. The standardized regression coefficients indicate the portion of standard deviation units that the criterion measure changes as a function of one standard deviation change in a predictor. For example, when a standardized regression coefficient of .25 is reported between the WJ-R Processing Speed cluster and the WJ-R Basic Reading Skills cluster, this means that for every standard deviation change observed in Processing Speed scores, there is an average .25 standard deviation change in Basic Reading Skills scores. Due to different patterns of missing data, the sample sizes at each age level differed for each of the regression models. Across

Table 2
Seven WJ-R Gf-Gc Cognitive (Predictors) and Two Reading Achievement (Criteria) Cluster Descriptions

Cluster name	Gf-Gc symbol	Cluster description
Fluid Reasoning	*Gf*	A combination of the Analysis-Synthesis and Concept Formation tests that measures the ability to reason, form concepts, problem solve, often with unfamiliar information or procedures
Comprehension-Knowledge	*Gc*	A combination of the Picture Vocabulary and Oral Vocabulary tests that measures breadth and depth of knowledge
Visual Processing	*Gv*	A combination of the Visual Closure and Picture Recognition tests that measures the ability to analyze and synthesize visual stimuli
Auditory Processing	*Ga*	A combination of the Incomplete Words and Sound Blending tests that measures the ability to analyze and synthesize auditory stimuli
Processing Speed	*Gs*	A combination of the Visual Matching and Cross Out tests that measures the ability to rapidly perform automatic cognitive tasks, especially when under pressure to maintain focused concentration
Short-Term Memory	*Gsm*	A combination of the Memory for Sentences and Memory for Words tests that measures the ability to temporarily store information and then use it within a few seconds
Long-Term Retrieval	*Glr*	A combination of the Memory for Names and Visual-Auditory Learning tests that measures the ability to store information and retrieve it later through association
Basic Reading Skills		A combination of the Letter-Word Identification and Word Attack tests that together measures word recognition skills that include sight word recognition and word analysis
Reading Comprehension		A combination of the Passage Comprehension and Reading Vocabulary tests that measures the comprehension of single words, sentences, and passages

the 21 age groups, a total of 5,401 subjects had complete data for the prediction of Basic Reading Skills, while 3,371 had complete data for the prediction of Reading Comprehension.

Age-related analyses. To investigate the possibility of age-related changes in the ability of the WJ-R cognitive clusters to predict the different reading criteria, the standardized regression coefficients for each cognitive predictor for each of the reading criteria were plotted by age. For example, in the prediction of Basic Reading Skills, there were 21 different Auditory Processing regression coefficients that corresponded to the 21 different age groups. Using the mean age for each age group as the x-axis, each of these 21 regression coefficients was plotted on a graph. Visual inspection of the graph allowed for a rough determination of any age-related changes in the predictive relationship between Auditory Processing and Basic Reading Skills. This was repeated for each WJ-R cognitive cluster for each of the two reading criteria measures.

Inspection of the graphs revealed apparent age-related changes that were examined for systematic trends through the use of the distance weighted least squares (DWLS) smoothing function (Wilkinson, 1990). The DWLS smoothing function produces a true, locally weighted curve that runs through points on the smoothed line, each of which is based on a weighted quadratic multiple regression on all the points (Wilkinson, 1990). Given the exploratory nature of this study, the DWLS function was selected over linear or low-order polynomial smoothing models that presuppose the shape of the function and curve. The resulting smoothed curves then were plotted together with the original regression coefficients to display visually the age-related changes in the relationship between a WJ-R cognitive cluster and each reading criterion. Because the original standardized regression coefficients contain sampling error, the smoothed values that utilize information from all the data points are probably better estimates of the population parameters (Zachary & Gorsuch, 1985).

RESULTS

Select statistics for the two regression models estimated at each of the 21 age levels are presented in Table 3.[2]

Gf-Gc/reading achievement regressions. Across both reading criteria and age groups, all regression models produced overall F-statistics that were significant beyond the .001 level. The multiple Rs ranged from .67 to .90 for the prediction of Basic Reading Skills and from .59 to .90 for Reading Comprehension. (See Table 3.) The magnitude of these multiple Rs indicates that the combined WJ-R cognitive clusters are highly related to both areas of reading achievement. For example, most of the multiple Rs are in the .70 to .80 range, values that indicate that the combined WJ-R cognitive clusters account for approximately 50% to 70% of reading achievement variance.

Inspection of the number of significant coefficients for the WJ-R cognitive clusters across age levels (Table 3) indicated that: (a) certain cognitive clusters are related significantly to both Basic Reading Skills and Reading Comprehension; (b) certain cognitive clusters demonstrate differential relationships with Basic Reading Skills and Reading Comprehension; and (c) one cognitive cluster appears to have little relationship to reading at any age. Based on a count of the number of significant regression coefficients, the Comprehension-Knowledge (18), Auditory Processing (18), Processing Speed (16), and Short-Term Memory (14) clusters displayed the most consistent relationship with Basic Reading Skills. Long-Term Retrieval also was related to Basic Reading Skills, although less consistently (8 significant coefficients). In contrast, Long-Term Retrieval had less association with Reading Comprehension (2). Similar to Basic Reading Skills, two of the top three cognitive clusters related to Reading Comprehension were Comprehension-Knowledge (19) and Short-Term Memory (12). In contrast to its weak association with Basic Reading Skills (only 3 significant coefficients), Fluid Reasoning was related to Reading Comprehension in more than half (11) of the samples. Two cognitive clusters (Processing Speed and Auditory Processing) that were related consistently to Basic Reading Skills (16 to 18 of their coefficients were significant, respectively) were found to be related to Reading Comprehension, although to a less noticeable degree (Processing Speed = 9; Auditory Processing = 8). Finally, the Visual Processing cluster was found to have little relationship with either Basic Reading Skills (1) or Reading Comprehension (2).

[2]Due to space limitations, all statistics for all regression models are not reported. This information can be obtained by contacting the author.

Table 3
Standardized Regression Coefficients and Multiple Rs for Regression Models with WJ-R Basic Reading Skills and Reading Comprehension Clusters as Criteria and WJ-R Gf-Gc Clusters as Predictors for 21 Age Groups

Age	Glr		Gsm		Gs		Ga		Gv		Gc		Gf		R	
group	BRS	RC	BRS	RC	BRS	RC	BRS	RC	BRS	RC	BRS	RC	BRS	RC	BRS	RC
5	.04	.07	.15	-.00	.36*	.24*	.31*	.18	-.06	-.01	-.01	.08	.14	.22*	.67	.59
6	.27*	.20*	.11*	.04	.28*	.26*	.27*	.25*	-.02	.00	-.02	.05	.05	.09	.72	.69
7	.08	.07	.08	.19*	.28*	.27*	.33*	.14*	-.07	.10	.13	.16*	.12	.15*	.77	.77
8	.14*	.04	.11*	.12*	.18*	.12*	.26*	.08	-.08	-.02	.25*	.48*	.09	.20*	.75	.83
9	.13*	.05	.08	.11*	.22*	.11*	.26*	.09*	-.08	-.06	.25*	.50*	.11*	.21*	.74	.81
10	.01	.02	.12*	.10	.19*	.20*	.20*	.16*	-.04	-.06	.38*	.52*	.08	.11	.71	.80
11	-.03	-.04	.22*	.11*	.11*	.20*	.22*	.04	-.05	-.11*	.27*	.58*	.14	.22*	.70	.83
12	.09	-.06	.18*	.17*	.12	.16*	.24*	.07	-.06	.03	.28*	.54*	.08	.11	.68	.79
13	.05	-.06	.17*	.08	.16*	.10	.24*	.03	-.04	.01	.37*	.57*	.06	.25*	.71	.77
14	.09	-.04	.27*	.17*	.12*	.11*	.16*	.03	-.04	.03	.32*	.56*	-.03	.20*	.68	.85
15	.17*	.08	.22*	.17*	.09	.05	.14*	.17*	.02	.03	.29*	.54*	.09	.07	.80	.89
16	-.01	.09	.16*	.08	.11*	.05	.26*	.11*	.05	.02	.36*	.54*	.09	.17*	.78	.84
17	.14*	.09	.10	.10	.23*	.09	.17*	.13*	-.05	.02	.39*	.60*	-.01	.05	.79	.87
18	.11*	.03	.22*	.25*	.14*	-.00	.14*	-.01	-.20*	.03	.47*	.54*	.05*	.28*	.78	.90
19	.05	.02	.17*	.13	.20*	-.15	.16*	.05	-.03	.15	.42*	.57*	.02	.21*	.77	.86
20-29	.10*	-.03	.13*	.22*	.09*	.22	.17*	-.15*	-.04	.20*	.47*	.63*	.01	.07	.74	.84
30-39	.07	.02	.15*	.13*	.12*	.04	.06	.03	-.02	.06	.56*	.72*	.01	.04	.78	.86
40-49	-.03	.01	.30*	.14*	.08	.04	-.01	-.00	-.04	.08	.52*	.62*	.15*	.14*	.85	.89
50-59	-.01	.19	.02	.07	.12	.10	.10	.09	.07	-.01	.70*	.55*	-.11	.01	.82	.82
60-69	.02	.05	.07	.04	.04	-.04	.21*	.04	-.11	-.09	.74*	.82*	-.09	.12	.83	.88
70-79	.12*	.31*	.04	.25*	.18*	-.01	.13*	-.06	-.04	-.04	.66*	.58*	-.06	-.02	.90	.85
# sign coefficients	8	2	14	12	16	9	18	8	1	2	18	19	3	11		

Note.—BRS = Basic Reading Skills; RC = Reading Comprehension; R = multiple R.
*Coefficients that were significant ($p < .05$) within each age group model.

Age-related analyses. The results of the age-related analyses are summarized by the 12 graphs presented in Figures 1 through 3.[3] For each WJ-R cognitive cluster, the plotting of the raw (connected by dotted line) and smoothed (connected by solid line) coefficients for each of the two reading criteria are presented side by side. Each graph's label lists the reading achievement cluster criterion and the respective *Gf-Gc* cognitive cluster abbreviations (*Glr* = Long-Term Retrieval; *Gsm* = Short-Term Memory; *Gs* = Processing Speed; *Ga* = Auditory Processing; *Gv* = Visual Processing; *Gc* = Comprehension-Knowledge; *Gf* = Fluid Intelligence).

Also included in each figure are two parallel dashed lines that correspond to standardized regression coefficients of .10 and .30. These lines are guides for interpreting the significance of the smoothed values in each figure. Based on a review of the significance tests for all standardized regression coefficients in this study, as well as two related studies in written language and mathematics that used the same methods (McGrew & Knopik, 1993; McGrew, 1993), it was determined that most coefficients at or above .10 were statistically significant ($p < .05$). Although there were exceptions to this rule, .10 also was judged to be a good practical significance criterion. Although some standardized coefficients in the .08s to .09s were significant, any change of less than one-tenth of a standard deviation in a reading criterion as a function of a full standard deviation change in a predictor is probably not practically meaningful. Thus, the .10 line was established as the minimal level of statistical and practical significance. Furthermore, it was decided that regression coefficients could be classified as either moderately or strongly related to the reading criteria. Moderate significance was defined arbitrarily as being from .10 to .29. Standardized coefficients at or above .30 (approximately one-third of a standard deviation) were considered to be strong.

A review of the smoothed lines in Figures 1 through 3 reveals a number of different relationships between the WJ-R cognitive clusters and the two reading criteria across the 21 age levels. The Long-Term Retrieval cluster (top half of Figure 1) appears unrelated to Basic Reading Skills in a meaningful sense throughout all ages. The fitted curve for Long-Term Retrieval and Reading Comprehension suggests that the abilities measured by this cognitive cluster are not associated highly with this aspect of reading until late adulthood (beyond approximately 55 years of age).

Although the strength of association between the Long-Term Retrieval cluster and both reading measures did not meet the criteria for meaningful significance, the relatively high and isolated regression coefficients for both Basic Reading Skills and Reading Comprehension at 6 years of age (see Table 3 and Figure 1) could be noteworthy and may demonstrate a potential limitation of the smoothing procedures. The two tests that comprise the WJ-R Long-Term Retrieval cluster are associational memory tests that require examinees to learn associations between visual and auditory stimuli, a task very similar to learning the relationship between the visual and auditory symbols for the alphabet. The relatively high coefficients at age 6 suggest that the fitted models may fail to capture accurately a potential critical time when Long-Term Retrieval abilities may be particularly important during the initial stages of learning to read.

[3]Graphs are not presented for Visual Processing because this cluster was not related significantly to either of the reading criteria except at three age levels.

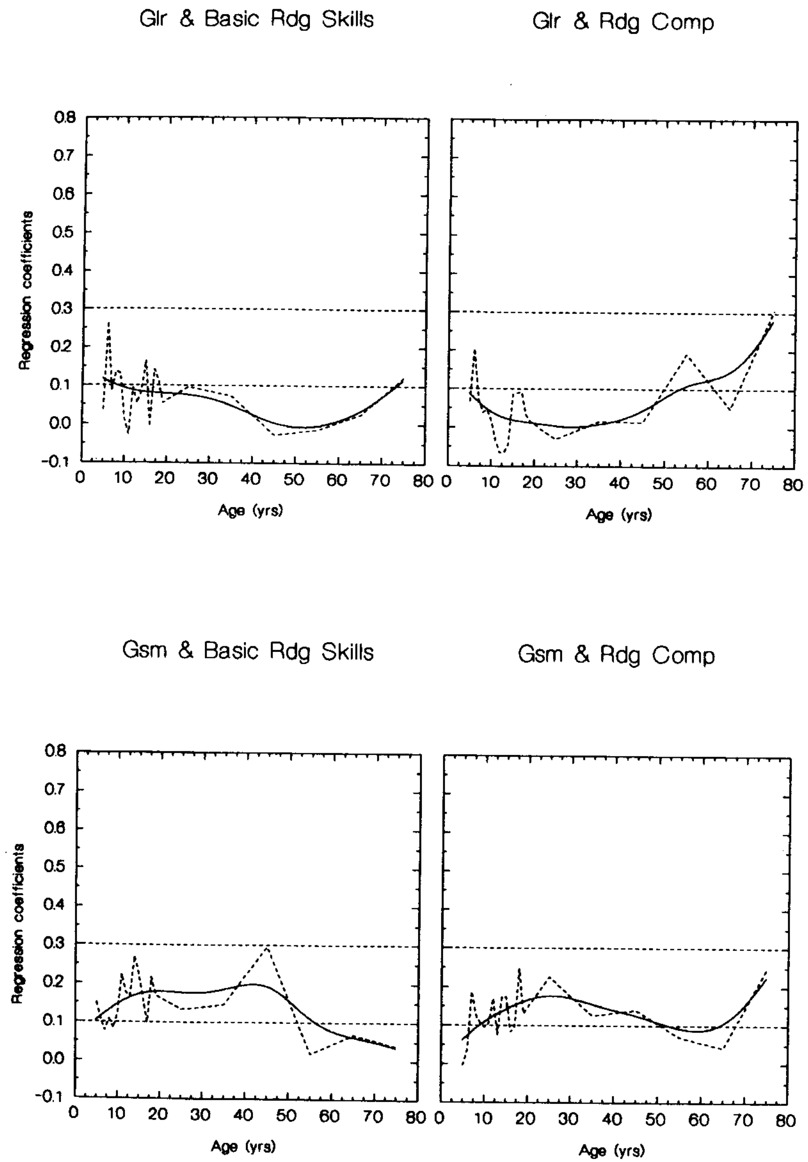

FIGURE 1. Raw and smoothed standardized regression coefficients for the WJ-R Long-Term Retrieval and Short-Term Memory cognitive clusters as predictors of WJ-R Basic Reading Skills and Reading Comprehension across 21 age groups.

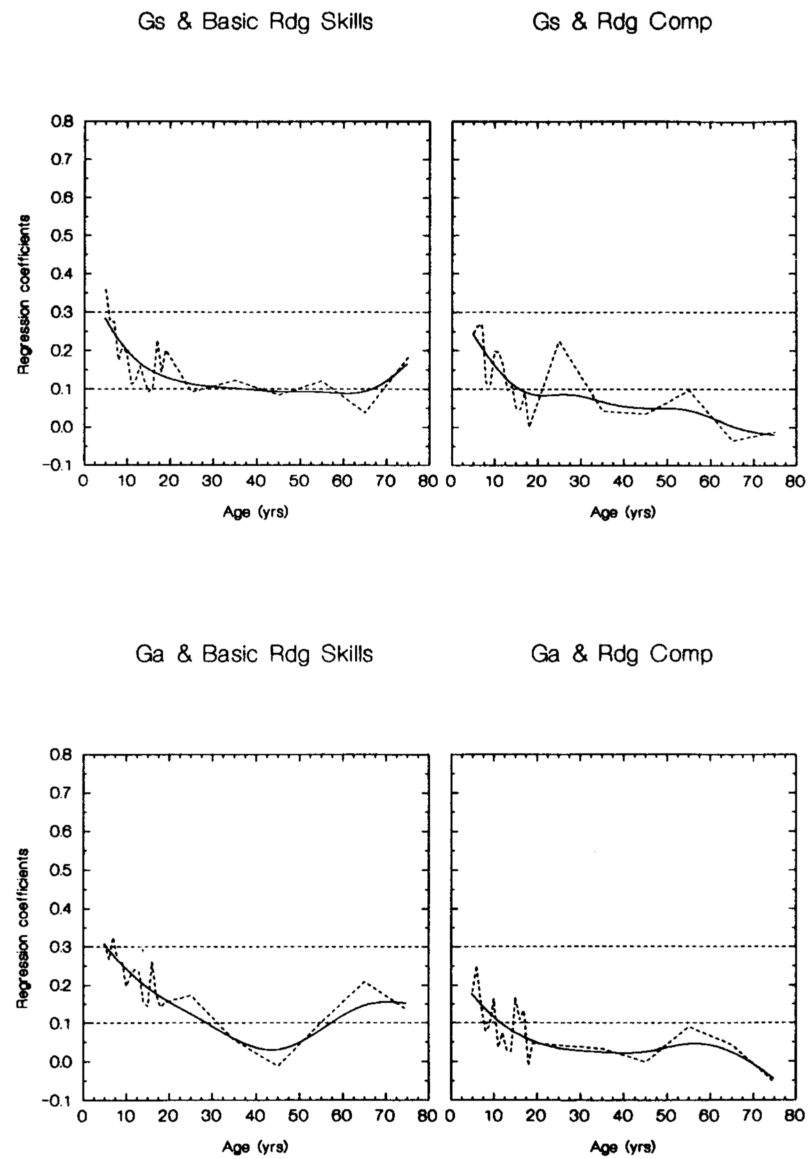

FIGURE 2. Raw and smoothed standardized regression coefficients for the WJ-R Processing Speed and Auditory Processing cognitive clusters as predictors of WJ-R Basic Reading Skills and Reading Comprehension across 21 age groups.

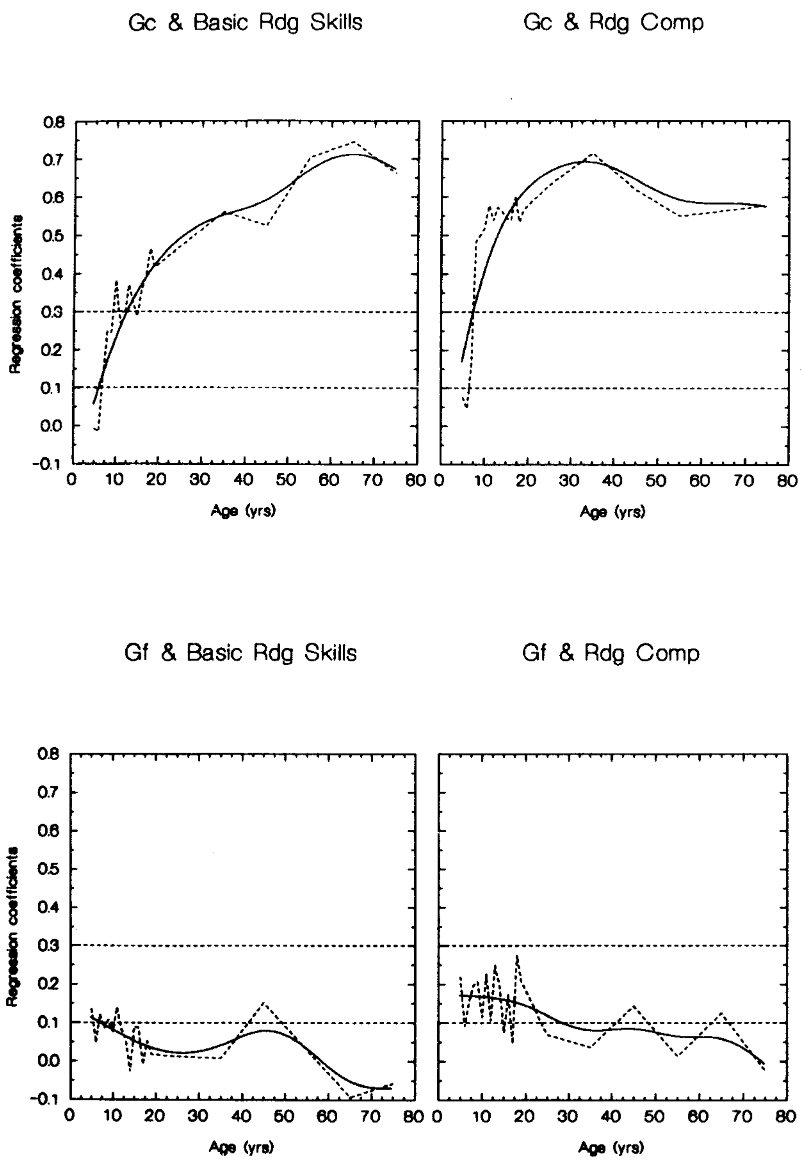

FIGURE 3. Raw and smoothed standardized regression coefficients for the WJ-R Comprehension-Knowledge and Fluid Reasoning cognitive clusters as predictors of WJ-R Basic Reading Skills and Reading Comprehension across 21 age groups.

In contrast to the curves for Long-Term Retrieval, the Short-Term Memory cluster (bottom half of Figure 1) demonstrates a significant relationship with both Basic Reading Skills and Reading Comprehension. In the case of Basic Reading Skills, a moderate association is suggested that increases slightly from approximately age 5 to approximately age 45, after which it systematically decreases in importance until it is no longer significant after approximately age 60. The strength of association appears slightly weaker for Reading Comprehension and varies differently as a function of age. In the case of Reading Comprehension, the Short-Term Memory cluster does not demonstrate a significant association until approximately 10 years of age, after which it is classified as moderate in strength. The association between Short-Term Memory and Reading Comprehension appears to increase systematically from age 10 to approximately age 25, after which there is a systematic decrease that is followed subsequently by a systematic increase into the moderate range after age 60.

Performance on the Processing Speed cluster (top half of Figure 2) appears to be related moderately to both reading areas, particularly before age 10. Processing Speed's relationship with both reading criteria demonstrates a systematically decreasing trend from the relatively high points at age 5. This decreasing trend ultimately reveals no meaningful association with Reading Comprehension after approximately age 15. The decreasing trend is less dramatic for Basic Reading Skills, where the smoothed curve does not pass below the .10 importance criterion until approximately 40 years of age. In addition, this is followed by an apparent increasing trend back into the moderate range in late adulthood. Visual inspection of both Processing Speed charts in Figure 2 and the respective regression coefficients in Table 3 suggests that Processing Speed abilities are associated more strongly with Basic Reading Skills than Reading Comprehension across a larger portion of the life-span.

Similar to Processing Speed, the Auditory Processing cluster shows moderate associations with both Basic Reading Skills and Reading Comprehension at the youngest ages. Both display their highest associations with Auditory Processing starting at age 5 and demonstrate decreasing systematic trends thereafter. Auditory Processing appears to be correlated more highly with Basic Reading skills than with Reading Comprehension. In the case of Basic Reading Skills, the association is in the moderate range from age 5 to approximately age 30. In contrast, in the area of Reading Comprehension the level of association is lower and drops below the .10 minimal significance level at approximately age 10. Similar to Processing Speed, there appears to be a possible increase in the relationship between Basic Reading Skills and Auditory Processing during late adulthood.

In contrast to all the other smoothed curves, those for Comprehension-Knowledge (top of Figure 3) consistently increase from the youngest to the oldest ages, with leveling off and possible slight decline starting after age 60 in the case of Basic Reading Skills and approximately age 30 for Reading Comprehension. The magnitude of the regression coefficients reflected in Table 3 and Figure 3 (most in the strong classification – at or above .30) suggests that comprehension-knowledge abilities are those that are associated most closely with both types of reading achievement, particulary beyond approximately age 10.

The results for the Fluid Reasoning cluster (bottom of Figure 3) suggest that the abilities measured by this cluster generally are uncorrelated with Basic Reading Skills across all ages. In contrast, Fluid Reasoning abilities appear to have a consistent and moderate relationship with Reading Comprehension that starts at the youngest ages and gradually decreases and becomes nonsignificant after approximately the age of 30.

DISCUSSION

This study was designed to investigate the relationship between the WJ-R *Gf-Gc* cognitive clusters and reading achievement in large, nationally representative samples across most of the life-span. The obtained results have significant implications for the use of the WJ-R cognitive tests in psychoeducational assessment, the field of psychoeducational assessment in general, and for intervention-related research.

The finding that the combined seven WJ-R cognitive clusters accounted for 50% to 70% of reading achievement variance across most of the life-span provides additional evidence for the validity of the WJ-R cognitive battery. These findings support the predictive validity of the WJ-R cognitive tests and their use in psychoeducational assessment. In addition, according to previous research results, the specialized WJ-R scholastic aptitude clusters (which are based on various combinations of the seven *Gf-Gc* areas) predict school achievement better than the Wechsler scales, the revised Stanford-Binet (SB:IV), and the Kaufman Assessment Battery for Children (K-ABC; McGrew, in press; McGrew et al., 1991). As a consequence, one reaches the conclusion that the WJ-R cognitive battery may be the best available instrument for assessing those cognitive abilities most strongly related to reading success.

Furthermore, it is important to note that this high predictive validity is not due to the fact that the WJ-R battery is excessively contaminated with achievement-like or crystallized tests, a criticism often made about the original WJ cognitive battery (Sattler, 1988; Shinn, Algozzine, Marston, & Ysseldyke, 1982; Thompson & Brassard, 1984a, 1984b) that subsequently was found to be based on inappropriate research methods and interpretation (McGrew, 1986, 1987; Woodcock, 1984). Joint confirmatory factor studies indicate that the WJ-R's content could be considered to be 14% achievement-like (viz., comprehension-knowledge and quantitative ability tests), while the SB:IV and Wechsler scales have more than 50% (Woodcock, 1990). Simply put, it appears that the WJ-R battery predicts school achievement better than most other instruments because it contains measures of cognitive abilities strongly related to school performance that are not included in other instruments (Woodcock, 1990).

This last point was made clear in the current investigation from a review of the smoothed curves that summarized the relationships between the various WJ-R cognitive clusters and reading achievement (Figures 1-3). For example, these results indicate that at different ages, performance on the WJ-R Long-Term Retrieval, Short-Term Memory, Processing Speed, Auditory Processing, Comprehension-Knowledge, and Fluid Reasoning clusters is related significantly to either basic reading skills or reading comprehension as assessed by the WJ-R reading clusters. These findings are important given the results of joint confirmatory factor analytic studies (Woodcock, 1990) that suggest that not all major intelligence batteries measure some of these critical abilities. According to Woodcock's (1990) empirical studies, the Wechsler scales do not include measures of long-term retrieval, auditory processing, and fluid reasoning. The SB:IV includes no apparent measures of long-term retrieval, processing speed, or auditory processing, while the K-ABC contains no apparent measures of long-term retrieval or auditory processing.[4] The combined results of the current investigation and Woodcock's (1990) joint confirmatory factor studies suggest that all three of these major intelligence batteries (K-ABC, SB:IV, Wechsler scales) do not include measures of cognitive abilities that appear related significantly to reading achievement. In contrast, large portions of the content of the K-ABC (44%), SB:IV (23%), and Wechsler scales (27-30%) are devoted to visual processing measures (Woodcock, 1990), measures similar to the WJ-R Visual Processing cluster that was found to be unrelated to reading achievement in the current study.

The finding that the seven WJ-R cognitive clusters demonstrate different age-related relationships with reading achievement, as well as different relationships for a single cognitive cluster across the two different reading domains, provides additional support for the construct validity of these clusters. These differential patterns suggest that the seven different WJ-R cognitive clusters are indeed measuring distinct and unique abilities. When combined with other evidence in the form of exploratory and confirmatory factor analysis of the WJ-R, inspection of differential growth curves for the cognitive clusters, and patterns of concurrent validity correlations with other measures (McGrew et al., 1991; Woodcock, 1990), one concludes that there is considerable empirical support for the position that the WJ-R cognitive battery is a measure of seven distinct *Gf-Gc* cognitive abilities (McGrew, in press; Reschly, 1990; Ysseldyke, 1990).

The current findings provide direction for future ATI and other intervention-related research. The results presented in Figures 1 through 3 suggest that past ATI research, particularly that based on the analysis of patterns of performance on tests such as the K-ABC, SB:IV, and Wechsler scales, may have been faulty from the start for a number of reasons. First, with the exception of visual processing abilities, six of the seven *Gf-Gc* abilities are related significantly to either basic reading skills or comprehension at some age level. Multiple abilities, and not a single ability, appear important to understanding the development of reading. Thus, past ATI research that was based on analysis of intelligence test profiles may have suffered from too limited coverage of important cognitive abilities and excessive coverage (e.g., visual processing) of relatively less important cognitive abilities, as they relate to possible targets of academic intervention. Second, there appear to be definite developmental trends whereby certain cognitive abilities may become more or less important at different ages. Thus, appropriately designed intervention research probably should reflect these developmental findings. For example, attempts to design instruction to teach basic reading skills during the primary and elementary school years appear to require the development of multivariate aptitude profiles that at a minimum include measures of short-term memory, processing speed, auditory processing, and comprehension-knowledge, with particular attention paid to processing speed and auditory processing. Different combinations of cognitive measures would be suggested for reading comprehension, as well as other achievement areas

[4]Technically, the K-ABC cognitive battery does not contain measures of comprehension-knowledge. However, the achievement portion of the K-ABC has been interpreted as measuring comprehension-knowledge or crystallized intelligence (Kaufman & Kaufman, 1983), and, thus, indicators of these abilities are covered in the complete battery.

(e.g., math, written language) at other ages (McGrew & Knopik, 1993; McGrew, 1993). These findings are consistent with the conclusions of Reschly (1990) and Ysseldyke (1990), both of whom suggested that a major benefit of the *Gf-Gc* theory based WJ-R battery may be the improvement of ATI research methods. Researchers and practitioners can consult the information presented in Figures 1 through 3 to guide their development of instructional or treatment hypotheses.

Although the results from the current study are positive and encouraging for the WJ-R and *Gf-Gc* theory as they relate to future ATI and other intervention-related research, a number of study limitations suggest caution and directions for additional investigation. First, some of the oldest adult samples were of very small size (e.g., less than 85 subjects for reading comprehension analyses at the three oldest age groups). Thus, the results at the oldest adult levels need additional investigation in larger samples. Second, the fitting of smoothed developmental curves to the regression coefficients across such a wide age range may mask some unique patterns at certain ages. The argument could be made that a more appropriate strategy would be to repeat the current procedures across a number of smaller age ranges and then combine the separate results into a total picture. Such fine-grain analyses may be more sensitive to specific age-related cognitive-achievement relationships. Third, the current study was based on a cross-sectional design. The next logical step would be to investigate the relationships between the WJ-R cognitive clusters and reading achievement in a longitudinal design. Fourth, the method used to generate this information was exploratory in nature, in that all seven WJTCA-R cognitive cluster scores were included in a full regression model that specified that each cognitive cluster had only one direct influence (i.e., a single direct path in path analysis terms) on the respective achievement criteria. The possibility exists that certain of the *Gf-Gc* abilities measured by the WJTCA-R cognitive clusters may have additional indirect paths of influence that are mediated through other *Gf-Gc* abilities. To capture the total direct and indirect influence of each *Gf-Gc* ability as measured by the WJ-R cognitive clusters on different achievement criteria, a researcher would need to specify a complex causal model that would estimate both direct and indirect influences. Currently, no one has conducted such research, primarily because no clearly articulated theoretical *Gf-Gc* and achievement explanatory model has been developed that would guide such efforts. Finally, it is important that the current findings not be overinterpreted. They only suggest that the WJ-R cognitive measures are promising measures that may help researchers to design studies that investigate the issue of treatment validity.

To summarize, the current study has a number of implications for psychoeducational research and practice. These findings suggest that psychoeducational assessment professionals should give serious consideration to using the WJ-R cognitive battery when they are evaluating individuals for academic problems. The WJ-R cognitive battery provides the broadest coverage of cognitive abilities that appear important in the development of reading skills. Practitioners who prefer to continue to use other intelligence batteries should consider augmenting their current instruments with parts of the WJ-R in order to measure all abilities related to reading achievement. In particular, Woodcock's (1990) empirical analysis suggests that the WJ-R Long-Term Retrieval, Auditory Processing, Processing Speed, and Fluid Reasoning cognitive clusters should be considered as supplements to the K-ABC, SB:IV, and Wechsler scales. The results of this investigation support Ysseldyke's

(1990) conclusion that the WJ-R cognitive test "represents a significant milestone in the applied measurement of intellectual abilities" (p. 274). It is hoped that the results of this investigation will encourage researchers and practitioners alike to employ the WJ-R in both clinical and research settings. Only through such careful and systematic study will the ultimate value of the WJ-R and *Gf-Gc* theory be fully understood.

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