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Examining Preschool Cognitive Abilities Using a CHC Framework

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Although there has been a substantial growth in the number of published studies examining tests of cognitive abilities and using contemporary theories of cognitive abilities, to date none have done so with preschool cognitive tests. In this study the relation between cognitive ability measures for young children and Cattell–Horn–Carroll (CHC) theory is examined. Tests and subtests from the Differential Ability Scales: Upper Preschool Level and the Woodcock–Johnson Tests of Cognitive Ability–Revised with a sample of 158 children between 4 and 5 years of age were used in a series of joint factor analyses. Although a series of models were explored, the model representative of the CHC theory of cognitive abilities was best supported by the data. This provides evidence for a greater differentiation of young children's cognitive abilities than are typically interpreted. Results are discussed with regard to understanding the link between contemporary theories of intelligence and young children's cognitive abilities, as well as implications for intellectual assessment practices with young children.

The past decade has witnessed a resurgence in research activity investigating the nature of intelligence and practices in intellectual assessment (Gustafsson & Undeim, 1996; Lohman, 1989). As a result, new and revised theories of intelligence continue to evolve and advances in intellectual assessment techniques and tools continue to be developed (Daniel, 1997; Das & Naglieri, 1997; Das, Naglieri, & Kirby, 1994a, 1994b; Flanagan & McGrew, 1997; Flanagan, McGrew, & Ortiz, 2000; McGrew &

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Flanagan, 1998; Naglieri & Das, 1990, 1997; Roid, 2003; Woodcock, McGrew, & Mather, 2001). Much emphasis has been placed on understanding and investigating the constructs of intellectual assessment tools regarding contemporary theories of cognitive ability (Flanagan & McGrew, 1998; Keith, 1997; Keith, Kranzler, & Flanagan, 2001; Kranzler, Keith, & Flanagan, 2000; McGhee, 1993; McGrew, 1997; McGrew & Flanagan, 1998; Naglieri & Das, 1997; Woodcock, 1990), with psychometric theories, including Carroll's (1993, 1994, 1997) three-stratum theory, Cattell–Horn's (e.g., Horn, 1994) contemporary Gf–Gc[1] theory, and McGrew and Flanagan's (McGrew, 1997; McGrew & Flanagan, 1998; Flanagan et al., 2000) integrated Cattell–Horn–Carroll Gf–Gc model of intelligence receiving the greatest amount of attention (Keith et al., 2001).

CONTEMPORARY INTELLECTUAL THEORY

Three-stratum theory and contemporary Gf–Gc theory were developed independently of each other. However, both are similar in that they represent hierarchical, multiple ability theories. That is, the theories espouse that intelligence is multidimensional in nature and that the relations among the various dimensions of ability are best accounted for by a smaller number of higher order factors, referred to as *broad abilities.* A brief review of each theory follows. The reader is referred to Horn (1985, 1988, 1994); Horn and Noll (1997); and Carroll (1993, 1994, 1997) for more detailed information.

Contemporary Gf–Gc Theory

Cattell (1941) first identified Gf–Gc theory as a dichotomous representation of cognitive abilities where the broad abilities of fluid (Gf) and crystallized intelligence (Gc) accounted for the relations among various primary mental abilities. Horn and Cattell (1966) expanded the model to include the broad abilities of visual processing (Gv), short-term apprehension and retrieval (Gsm), long-term storage and retrieval (Glr), and speed of processing (Gs). Auditory processing (Ga) was added in 1968 (Horn, 1968), and quantitative ability (Gq) and reading–writing ability (Grw) were added most recently (Horn, 1985; Woodcock, 1994). Thus, this theory identifies 10 different broad ability factors, each of which account for the intercorrelations among the primary mental abilities, or narrow abilities, subsumed under them. Support for the theory is derived from structural, developmental, achievement, heritability, and neurological data (Dean & Woodcock, 1999; Horn & Noll, 1997; McGrew & Woodcock, 2001).

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[1]The term *contemporary Gf–Gc theory* is used to distinguish this Gf–Gc theory from previous versions.

Three-Stratum Theory

Carroll's model is derived from the analysis of over 460 major sets of cognitive abilities data (Carroll, 1993, 1994, 1997), which resulted in the identification of eight broad cognitive abilities: Gf and Gc intelligence, general memory and learning (Gy), Gv and broad auditory perception (Gu), broad retrieval ability (Gr), Gs, and processing speed/decision speed (Gt). Unlike contemporary Gf–Gc theory, which does not identify a general intelligence (*g*) factor, Carroll argued that the evidence for *g* is overwhelming. Thus, three-stratum theory also includes a higher order *g* factor at the apex, or stratum III level, of the model (Carroll, 1997).

Integrating Gf–Gc Theory and Three-Stratum Theory

The most noted feature of contemporary Gf–Gc theory and three-stratum theory is the strong similarity across broad ability factors defined within each structure. These similarities have lead several to call for a convergence of the two models, as it is believed that they provide the best organizational framework currently available for understanding human cognitive abilities from a psychometric perspective (McGrew, 1997; McGrew & Woodcock, 2001). McGrew and Flanagan (Flanagan, Mascolo, & Genshaft, 2000; McGrew, 1997; McGrew & Flanagan, 1998) were the first to provide integrated models of the Cattell–Horn and Carroll theories, namely Cattell–Horn–Carroll Gf–Gc (CHC) theory. Most recently, the "amalgamation of [the] two similar theories" (Woodcock et al., 2001, p. 9) was endorsed by Carroll and Horn and provided the theoretical foundation for the third edition of the Woodcock–Johnson III Tests of Cognitive Ability (WJ–III; Woodcock et al., 2001).

LINKING THEORY TO ASSESSMENT

Researchers and practitioners alike have argued that current intellectual assessment techniques and tools should be better linked to contemporary theories of intelligence (Keith et al., 2001; Kranzler, 1997). Through confirmatory and joint confirmatory factor analyses of school- and adult-age intelligence tests, the relation between contemporary theories of intelligence and current cognitive assessment tools has been explored. Findings from such studies (Flanagan & McGrew, 1998; Kaufman & McClean, 1987; Keith et al., 2001; Keith & Novak, 1987; Kranzler & Keith, 1999; McGhee, 1993; McGrew, 1997; McGrew & Flanagan, 1998; Woodcock, 1990) indicated that whereas no test currently adequately assesses all broad cognitive ability factors, each is represented on at least one test battery.

As a result, Flanagan and McGrew (1997; Flanagan & Ortiz, 2001; McGrew & Flanagan, 1998; Ortiz, Flanagan, & McGrew, 1998) conceptualized the cross-battery approach to intelligence testing that allows practitioners to augment preferred batteries with subtests from other intelligence tests to complete more comprehensive and theoretically sound assessments. Further, efforts toward applying the integrated CHC theory to better understand the variability across tests at the narrow ability level and the relation between broad cognitive abilities and domains of academic achievement have also been made (Flanagan et al., 2000; McGrew & Hessler, 1995; McGrew, Keith, Flanagan, & Vanderwood, 1997).

Knowledge of the relation between contemporary theories of intelligence and intelligence tests promotes professional practice that is empirically validated as it provides a structural framework for the conceptualization and interpretation of cognitive ability profiles (Kamphaus, 1993). Further, it is useful for test developers as it promotes the development of more theoretically sound assessment tools (Daniel, 1997).

Despite progress toward understanding the relation between contemporary theories of intelligence and intellectual assessment tools and practice, few studies have been conducted that link commonly used measures of cognitive abilities in young children to contemporary theories. Flanagan et al., 2000; Flanagan and Ortiz, 2001; Ford & Dahinten, in press; McGrew and Flanagan, 1998; Tusing, Maricle, and Ford, 2003, provided several theoretically driven pieces that provide hypotheses regarding the relations between CHC theory and tests used with young children; however, the proposed relations have not been substantiated empirically. Thus, research efforts to link contemporary theories of cognitive ability to assessment tools used with young children are needed. The following section offers a brief history of the relation between intellectual theory and the psychometric study of young children's cognitive abilities as it provided the theoretical basis for this investigation.

COGNITIVE ABILITIES OF YOUNG CHILDREN: A PSYCHOMETRIC PERSPECTIVE

Any discussion of the nature of cognitive abilities, or intelligence, for young children generally takes a developmental perspective. That is, the usual interest is in determining what it is about intelligence that changes or develops over time (Siegler, 1986; Siegler & Richards, 1982). Piagetian theory and other information processing approaches have generally dominated research in this area (Flavell, Miller, & Miller, 1993; Siegler, 1986; Sternberg & Berg, 1992), whereas psychometric theories of the intellectual functioning of young children have been limited (Ford, in press; Gardner & Clark, 1992; Tusing et al., 2003). Likewise, most contemporary psychometric theories of intelligence were developed from research involving school-age children or adults (Ford & Dahinten, in press; Gardner

& Clark, 1992; Tusing et al., 2003), making generalization to younger age ranges difficult. As a result, relatively little is known about the early development of specific cognitive abilities from a psychometric perspective, or whether the structure of cognitive abilities as described by contemporary psychometric theories of intelligence even holds true for children younger than age 6.

Fortunately, atheoretical psychometric investigations of the cognitive abilities of infants and young children, coupled with research on the ability constructs measured by intelligence tests, do allow for a rudimentary psychometric perspective on the nature and development of young children's cognitive abilities (Gardner & Clark, 1992; Sternberg & Powell, 1983). This is evident in findings of age differences, or developmental changes, regarding the relative importance of different types of tasks in explaining individual differences across groups of children and the number of different domains of cognitive ability that can reliably differentiate children.

Changes in the Content of Discriminative Tasks

The types of tasks that discriminate between high- and low-functioning young children have been found to change noticeably in relation to increasing age. Sensorimotor tasks and tasks of fine motor coordination (e.g., block building, placing shapes into holes) best differentiate groups of very young children; however, the same tasks are found to have much less discriminative ability for children age 3 and older (Gardner & Clark, 1992; Siegler & Richards, 1982). Instead, as children age, tasks invoking verbal and symbolic abilities, including verbal communication skills and receptive language skills, become more effective in differentiating children (Gardner & Clark, 1992), a shift that appears to typically occur during the 3rd or 4th year of age. Similar results have been found in factor analytic investigations of intellectual assessment tools for young children, where the nature of the first unrotated factor, or *g,* is noticeably different for various age groups (Siegler & Richards, 1982).

For example, through principal components analyses of tests commonly used with young children during the time of their study, McCall, Eichorn, and Hogarty (1977) found significant differences in the nature of the general ability solution for children at 2, 8, 13, 21, and 36 months of age. In the group of children under 2 months of age, the general ability factor was described as responsiveness to the environment. From 2 to 7 months, it was described as active interaction with the environment. However, at 8 to 13 months, imitation of fine motor behaviors and elementary vocal behavior become the distinguishing feature of the general ability factor; and, between 1 and 2 years of age, labeling and verbal recognition were the most distinct features of the general factor solution. Finally, for children 2 to 3 years of age, verbal fluency and other symbolic abilities became most important, whereas motor skills were less related to the general factor.

Changes in the Number of Psychometric Factors

The concept of age-differentiation (Garrett, 1946) suggests that the development of intelligence involves a gradual differentiation of *g,* or general ability, into several distinct ability domains. In other words, intelligence is quantitatively different at various developmental periods in regard to the number of broad abilities present. Findings that both *g* variance and common variance associated with intelligence tests increase with age support this hypothesis (Roid & Gyurke, 1991), as does the consistent finding that intelligence tests for use across broad age ranges nearly always involve fewer factors at younger age levels than is evident for school-age levels (Blaha & Wallbrown, 1991; Keith, Cool, Novak, White, & Pottebaum, 1988; LoBello & Gulgoz, 1991; Stone, Gridley, & Gyurke, 1991; Thorndike, 1990).

Indeed, broad ability factors in addition to the traditional verbal–nonverbal dichotomy, although supported on school-age versions of intelligence tests, have been difficult to validate across most versions of the same tests for use with young children (Blaha & Wallbrown, 1991; Elliott, 1990b; Gyurke, Stone, & Beyer, 1990; Keith, 1990; Keith et al., 1988; Kline, 1989; Stone et al., 1991; Thorndike, 1990). For example, although present on the school-age version, a memory factor was not supported at younger age ranges on the Stanford–Binet Intelligence Scale: Fourth Edition (SB:IV). Instead, visual memory tasks contribute to the abstract–visual reasoning factor and verbal memory tasks contribute to the verbal reasoning factor (Keith et al., 1988; Thorndike, 1990). This was true for the Wechsler Preschool and Primary Scale of Intelligence–Revised (WPPSI–R) as well, as verbal memory tasks contribute to the verbal IQ factor (Gyurke et al., 1990) and continues with the Weschler Preschool and Primary Scale of Intelligence–III (WPPSI–III; Wechsler, 2002). Similar findings have also resulted when separate quantitative factors are examined across tests for young children (Blaha & Wallbrown, 1991; Elliott, 1990b; Gyurke et al., 1990; Thorndike, 1990).

However, studies outside the realm of intellectual assessment research have found support for a greater differentiation of cognitive abilities among young children than is indicated by most intelligence tests for young children. For example, Ellison, Horn, and Browning (1983) reported correlations among several Gf–Gc constructs for a group of preschool children that were comparable in strength to similar correlations observed in samples of older children. Furthermore, Horn (1985) was able to distinguish four Gf–Gc broad abilities, fluid reasoning, crystallized intelligence, short-term retrieval, and long-term retrieval, in samples of children as young as 4 years. And, both Horn (Horn & Noll, 1997) and Carroll (1992) theorized that a multidimensional framework for cognitive abilities should be able to be determined in early childhood.

THIS STUDY

In summary, psychometric findings regarding the nature of young children's cognitive abilities suggest that verbal and symbolic abilities (perhaps best represented as the traditional verbal–nonverbal dichotomy of most intelligence tests used with young children) are best at discriminating young children in regard to intellectual ability. However, evidence that additional cognitive abilities may be measurable at this age range exists. It is hypothesized that failure to support more than two ability factors across batteries used with young children may be more a function of the nature of cognitive tasks included in a battery than that of age differentiation.

Through joint confirmatory factor analyses of a combined group of subtests from two intelligence batteries for use with young children, we provide information regarding the validity of contemporary psychometric theories of intelligence in describing the structure of young children's cognitive abilities. Findings extend research linking intelligence theory and intellectual assessment tools to younger age ranges.

METHOD

Participants

Data collection occurred in three geographic locations: Texas, Wisconsin, and South Carolina, and included urban, suburban, and rural settings. One hundred fifty-eight children from 4:0 to 5:11 years of age participated in the study. The sample was evenly divided by gender (48% girls, 52% boys). Equal numbers of girls and boys were tested within each half-year interval in the age range (Table 1). Racial distribution of the sample was 88% White, 6% African American, 3% Hispanic, and 3% other. Maternal education levels are provided in Table 2. Half of the participants attended in-home child care (1%) or day care (49%). The remaining half (49%) participated in more educationally laden programs, namely, kindergarten (21%), preschool (21%), or Head Start (8%). None of the participants were receiving special education or related services.

Instruments

Woodcock–Johnson–Revised Tests of Cognitive Ability. The WJ–R was primarily developed for use with school-age populations; however, an intent

TABLE 1
Age of Participants

Years:Months	*Gender*	*n*	*%*
4:0–4:5	Male	19	12
	Female	18	11
4:6–4:11	Male	23	15
	Female	18	11
5:0–5:5	Male	21	13
	Female	23	15
5:6–5:11	Male	19	12
	Female	17	11

TABLE 2
Maternal Education

Education Level	*n*	*%*
Less than high school	2	1
High school graduate	22	14
1 to 3 years of college or technical school	64	41
4 or more years of college	69	44

of the 1989 revision was to extend the range of measurement downward to 2 years of age (McGrew, Werder, & Woodcock, 1991). As a result, nine tests from the battery demonstrate adequate psychometric properties for children 4 years of age and older (Flanagan & Alfonso, 1995; Tusing, 1998). The WJ–R was chosen because it was designed to be an operational representation of Horn and Cattell's Gf–Gc theory (Bickley, Keith, & Wolfle, 1995; Keith, 1997; McGrew & Flanagan, 1998; McGrew et al., 1991). Thus, each test is intended to represent a specific Gf–Gc broad ability (Table 3).

Differential Ability Scales: Upper Preschool Level. Psychometric integrity (Flanagan & Alfonso, 1995), increasing popularity, and cognitive abilities assessed by the Differential Ability Scales (DAS) provided the basis for its inclusion in this study. The DAS was developed within a traditional view of intelligence, emphasizing a hierarchical general ability factor, or *g,* with lower order ability factors, verbal ability and nonverbal ability (Elliott, 1990b; Keith, 1990). Similar to traditional tests, the verbal ability cluster measures acquired verbal concepts and knowledge. It is likened to the CHC Gc factor (Elliott, 1990c; McGrew & Flanagan, 1998). The nonverbal ability cluster is defined (Elliott, 1990b) as a measure of complex, nonverbal mental processing, including spatial-orientation and visual–motor abilities. Thus, it is described as a mix of Gv and Gf abilities

(McGrew & Flanagan, 1998). McGrew and Flanagan (1998) also hypothesized links between the remaining DAS diagnostic subtests and CHC theory (Table 4).

Procedure

Preschool versions of the DAS and WJ–R were administered to children following standardized procedures. Testing generally occurred across two sessions; however, some children were tested across three sessions. The average interval of time between sessions was 6.4 days (*SD* = 9.7; range 1–6 weeks). To control for potential practice effects, tests were administered in a counterbalanced fashion. Test admin-

TABLE 3
CHC Narrow Abilities Measured by DAS Subtests

Subtest	*Narrow Abilities*
Picture similarities	Induction
Matching letter-like forms	Visualization, spatial relations
Pattern construction	Spatial relations, visualization
Copying	Visualization
Recognition of pictures	Visualization, visual memory
Recall of objects	Free recall memory, visual memory
Recall of digits	Memory span
Verbal comprehension	Language development
Naming vocabulary	Lexical knowledge, general information, language development
Early number concepts	Math achievement, math knowledge, quantitative reasoning

Note. Narrow ability determinations were derived from McGrew and Flanagan (1998). CHC = Cattell–Horm–Carroll Gf–Gc Theory; DAS = Differential Ability Scales.

TABLE 4
CHC Narrow Abilities Measured by WJ–R Subtests

Subtest	*Narrow Abilities*
Visual closure	Closure speed
Picture recognition	Visualization, visual memory
Memory for words	Memory span, language development
Memory for sentences	Memory span, language development
Picture vocabulary	Lexical knowledge, general information, language development
Memory for names	Associative memory
Visual auditory learning	Associative memory, meaningful memory
Incomplete words	Phonic coding, res. auditory distraction
Sound blending	Phonic coding

Note. Narrow ability determinations were derived from McGrew and Flanagan (1998). CHC = Cattell–Horm–Carroll Gf–Gc Theory; WJ–R = Woodcock–Johnson–Revised Tests of Cognitive Ability.

istrators were advanced graduate students in school psychology, trained in the use of both tests with young children.

Model Estimation and Evaluation

To examine the relation between intellectual assessment tools for young children and contemporary theories of intelligence, a series of joint confirmatory factor analyses (CFAs) with subtests from the WJ–R and DAS were conducted. Subtest correlations and standard deviations for the sample were input for analyses using AMOS (Arbuckle, 1997; for a review, see Hox, 1995). AMOS provides maximum-likelihood estimations to calculate the relative fit of models examined. As is common practice, multiple-fit statistics were used in evaluating the models. These included the χ^2, ratio χ^2, root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), Akaike's Information Criterion (AIC), and change in χ^2 (χ^2_{diff}) (Loehlin, 1992). Given that the importance of the investigation was to compare alternative theoretical models rather than to test the validity of test structures, comparisons between the size of respective model fit statistics (particularly those that reward parsimony across models) and not the absolute value of the fit statistics were of greatest importance (Flanagan & McGrew, 1998; Tanaka, 1993).

The fit of seven alternative a priori models was compared. The models depicted an increasing number of broad ability factors and were reflective of various psychometric theories of intelligence. Models 1 and 2 reflect traditional conceptualizations of the structure of intelligence; whereas Models 3 through 7 reflect contemporary theories. The models also illustrate a gradual differentiation of broad abilities from unitary and dichotomous models to multifactor models of intelligence. This allowed for an examination of the degree to which multiple broad abilities can be determined from cognitive ability tests for young children.

Model 1: One-factor g model. Subtests from both batteries were forced to load on one factor. This model is most similar to Spearman's (1927) *g*-factor theory where performance on a specific cognitive measure (i.e., a subtest) can be accounted for by a single factor, or general intellectual ability.

Model 2: Two factor v:ed/k:m (verbal/nonverbal) model. Vernon (1950) provided a hierarchical theory of intelligence that differentiated verbal–educational (abilities representative of uniform educational experiences) and spatial–practical–mechanical (spatial, nonverbal skills) factors at a secondary level. The WPPSI–R and WPPSI–III (Wechsler, 1989, 2002) and the DAS (Elliott, 1990a) have been linked to this theory (Blaha & Wallbrown, 1991; Wallbrown, Blaha, & Wherry, 1973). Thus, it was included given that clinicians typically assume young children's cognitive abilities are dichotomous in nature.[2]

Model 3: Three-factor verbal–Gy–nonverbal model. Model 3 allowed for a differentiation of abilities into verbal, nonverbal, and memory domains. It was included to examine a multifactor representation of abilities measured by both batteries. The memory factor is similar to Carroll's Gy ability factor in that subtests identified with it are thought to measure the narrow abilities of associative memory, memory span, meaningful memory, free recall memory, and visual memory (Flanagan & McGrew, 1997; Flanagan & Ortiz, 2001).

Model 4: Four factor Gc–Ga–Gy–nonverbal model. This model differentiates Ga and Gc intelligence into separate broad ability factors. The Ga factor is similarly identified in both contemporary Gf–Gc and the CHC model. However, Carroll's three-stratum theory identifies the narrow ability of phonetic coding under Gc. Given that both WJ–R tests identified as measures of Ga are defined as specific measures of phonetic coding (Flanagan & McGrew, 1997; Flanagan & Oritz, 2001), a differentiation of the models of this type also provides information on this subtle difference between theories.

Models 5 and 6: Five-factor Gc–Ga–Gsm–Glr–nonverbal model. The next differentiation across models involved teasing apart the Gy into Gsm and Glr factors. This change accounts for the most distinct difference between Carroll's model versus the Cattell–Horn model and was represented in Model 5. It is also supported by developmental research on memory, which indicates that the distinction between memory capacity and association skills is evident even for young children (Siegler, 1986). The change involved allowing the two WJ–R tests identified as measures of associative memory to load on a separate Glr broad ability factor, although all other memory tasks continued to load on the Gsm factor.

Given a subtle difference in the placement of the narrow ability of visual memory in CHC theory (McGrew, 1997; McGrew & Flanagan, 1998), a second repre-

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[2]Determination of a two-factor verbal–nonverbal distinction of DAS core subtests was straightforward given the test's structure (Elliott, 1990b). Loadings for the remaining DAS subtests were determined based on factor analyses of all DAS subtests in an unpublished study with the same sample (Tusing, 1998). Determining dichotomous loadings for the WJ–R tests was more challenging given that the test was designed to represent a multifactor theory of intelligence. However, prior research suggests that subtests typically included in "nonverbal" test factors are actually influenced by visual processing (Flanagan et al., 2000; McGrew & Flanagan, 1998). Thus, tests from the WJ–R Visual Processing cluster were forced to load on the nonverbal factor and remaining subtests were forced to load on the verbal factor. Although this resulted in many WJ–R tests contributing to the verbal factor, the distinction has intuitive reason given that the tests forced to load on the latent verbal variable all have linguistic emphases either in the nature of the task presentation or response required (Flanagan et al., 2000).

sentation of memory abilities was accounted for in Model 6. For this model, subtests defining measures of visual memory were forced to load on the nonverbal factor instead of Gsm, as the nonverbal factor was most representative of visual processing abilities. This is consistent with previous factor analyses of school- and adult-age samples that identify visual memory as most strongly related to Gv (Lohman, 1989; McGrew, Werder, & Woodcock, 1991) and Carroll's (1993) comments about the indistinct nature of visual memory.

Model 7: Seven-factor Gc–Ga–Gsm–Glr–Gf–Gv–Gq model. The final model examined represents CHC theory in that it allows for three additional broad ability factors to be identified, Gq, Gf, and Gv. This allows two latent factors (Gf, Gq) to be identified by only one observed variable. However, by allowing early number concepts and picture similarities be lone indicators of Gq and Gf, respectively, the integrity of the Gv factor could be examined. This was believed to be a fairer treatment of the theoretical determinations of the CHC model. A common method of estimating models where latent variables with lone indicators are present was used. Subtest-factor paths and error variances were constrained to estimates based on the observed variance and reliability coefficients for the subtests (Picture Similarities $r = .72$; Early Number Concepts $r = .86$; Table 8.1 in Elliott, 1990b; cf. Keith et al., 1988).

Model 8: A posteriori model. AMOS provides a series of indexes helpful in determining whether additional constraints on a model will result in a better fit to the observed data. Based on these indexes and findings from the a priori model estimations, the fit of several a posteriori models was also investigated. A description of the models is provided later.

RESULTS

Means, standard deviations, kurtosis, and skewness values for DAS and WJ–R subtest scores are reported in Tables 5 and 6. Mean scores on all measures fell within the average range, with the exception of the WJ–R Picture Recognition test, which was in the above-average range. The mean DAS General Conceptual Ability score ($M = 105.13$, $SD = 13.15$) was 1.24 points higher than that of the WJ–R Early Development composite ($M = 103.89$, $SD = 12.25$); however, a pairwise t-test comparison indicated that the difference was not significant ($t = 1.43$, $p = .154$). The range of scores was not indicative of restriction of range difficulties. Correlations for the combined group of DAS and WJ–R subtests are in the Appendix.

Fit indexes presented in Table 7 for the joint CFA of the DAS and WJ–R preschool subtests indicate a clear difference between the fit of traditional factor analytic notions of intelligence (i.e., general ability or a v:ed/k:m dichotomy) and con-

TABLE 5
Means, Standard Deviations, Skewness, and Kurtosis for WJ–R Test Scores

Score	*M*	*SD*	*Skewness*	*Kurtosis*
Broad cognitive ability	108.5	12.7	–0.36	0.91
Sound blending	105.2	11.2	–0.09	0.05
Incomplete words	99.4	10.8	–0.04	1.61
Visual closure	107.3	12.7	–0.57	0.95
Picture recognition	110.9	16.1	0.02	–0.57
Memory for names	100.2	16.6	–0.50	–0.14
Visual–auditory learning	104.6	15.1	0.35	0.79
Memory for sentences	97.1	14.3	–0.01	–0.42
Memory for words	100.9	13.2	0.02	–0.08

Note. $M = 100$, $SD = 15$ for broad cognitive ability and subtests. WJ–R = Woodcock–Johnson–Revised Tests of Cognitive Ability.

TABLE 6
Means, Standard Deviations, Skewness, and Kurtosis for DAS Test Scores

Score	*M*	*SD*	*Skewness*	*Kurtosis*
General conceptual ability	105.0	13.2	–0.17	0.31
Early number concepts	51.9	8.7	–0.29	0.32
Verbal comprehension	50.7	7.8	–0.19	0.82
Naming vocabulary	54.6	8.7	–0.28	–0.54
Picture similarities	53.1	9.1	0.08	0.50
Pattern construction	54.5	8.5	–0.27	–0.08
Copying	50.6	9.1	0.16	0.43
Matching letter–like forms	52.5	10.2	0.27	–0.14
Recall of digits	51.1	8.8	–0.22	1.00
Recall of objects	49.6	10.5	–0.01	0.14
Recognition of pictures	54.9	9.3	0.06	–0.07

Note. $M = 100$, $SD = 15$ for general conceptual ability score; $M = 50$, $SD = 10$ for subtests. DAS = Differential Ability Scales.

temporary theories of intellectual functioning (i.e., CHC theory). Although the fit of Model 7, where seven broad ability factors were identified, did not significantly improve on that of previous models (the $\Delta\chi^2$ was not significant and parsimony fit indexes did not improve), findings clearly indicate multiple broad ability factors can be discerned from intelligence measures for young children. Specifically, these include Gc intelligence, Glr, Gsm, Ga, and a fifth factor that we refer to as nonverbal ability.

Models 5 and 6 were identified as the most appropriate fit to the observed data of the a prior models tested, as indicated by the increases in the size of fit indexes

TABLE 7
Fit Indexes for *A Priori* Models

Model	$\chi^2(df)$	*p*	χ^2/df	*GFI*	*AGFI*	*AIC*	*RMSEA*	χ^2_{diff}
1. *g*	391.8(152)	.00	2.58	.77	.71	467.9	.10	
2. Verbal–nonverbal	334.6(151)	.00	2.22	.81	.76	412.6	.09	57.2*
3. Verbal–*Gy*–nonverbal	318.3(149)	.00	2.14	.82	.77	400.3	.09	16.3*
4. *Gc–Ga–Gy*–nonverbal	284.2(146)	.00	1.95	.84	.79	372.2	.08	34.1*
5. *Gc–Ga–Gsm–Glr*–nonverbal (visual memory on *Gsm*)	256.3(142)	.00	1.81	.86	.81	352.3	.07	27.9*
6. *Gc–Ga–Gsm–Glr*–nonverbal (visual memory on nonverbal)	216.2(142)	.00	1.52	.87	.83	312.2	.06	68.0*
7. *Gc–Ga–Gsm–Glr–Gf–Gv–Gq*	204.4(133)	.00	1.54	.88	.82	332.8	.06	11.8

Note. GFI = goodness-of-fit index; AGFI = adjusted goodness-of-fit index; AIC = Akaike's Information Criterion; RMSEA = residual mean square error of approximation; Gy = general learning and memory; Gc = crystallized intelligence; Ga = auditory processing; Gsm = short-term memory; Glr = long-term memory; Gf = fluid intelligence; Gv = visual processing; Gq = quantitative ability.
*$p < .01$.

(i.e., χ^2 ratios less than 2.0, RMSEA's approaching the .05 criterion). Of the two five-factor models, Model 6 (Figure 1) provided the better representation of the data. The change in χ^2 for Model 6 relative to Model 4 was significant ($\chi^2_{\text{diff}} = 68$, $df = 4$, $p < .01$), and the fit indexes, particularly those awarding parsimony (AGFI = .83 and AIC = 312.2), were maximized. Thus, identifying the visual memory tasks as measures of Gv appears more appropriate than identifying them as being solely influenced by Gsm skills.

Although Model 6 represented the best fit among those structural models examined a priori, Bentler and Bonnet (1980) suggested that GFIs less than .90 generally can be improved on. Given the .87 GFI and .82 AGFI, Model 6 still appeared less than satisfactory. Inspection of modification indexes, the residual standardized covariance matrix, and interfactor correlations for Model 6 suggested several possible constraints that could improve on the fit of the five-factor model. Changes were only considered if they suggested significant improvements in the fit of the model and if they were theoretically logical. The first changes indicated involved allowing the error variance of three pairs of subtests to be correlated; specifically, the DAS Naming Vocabulary and WJ–R Picture Vocabulary tests, the WJ–R Visual Closure and Incomplete Words test, and the WJ–R Visual Closure and Picture Recognition subtests.

The first and second changes appeared logical in that they accounted for potential shared variance across subtests due to similarities in the tests' presentation and the response required from the child. The picture-naming subtests require verbally naming the pictures present, and some vocabulary items were actually identical across tests. The Visual Closure and Incomplete Words tests both involve closure

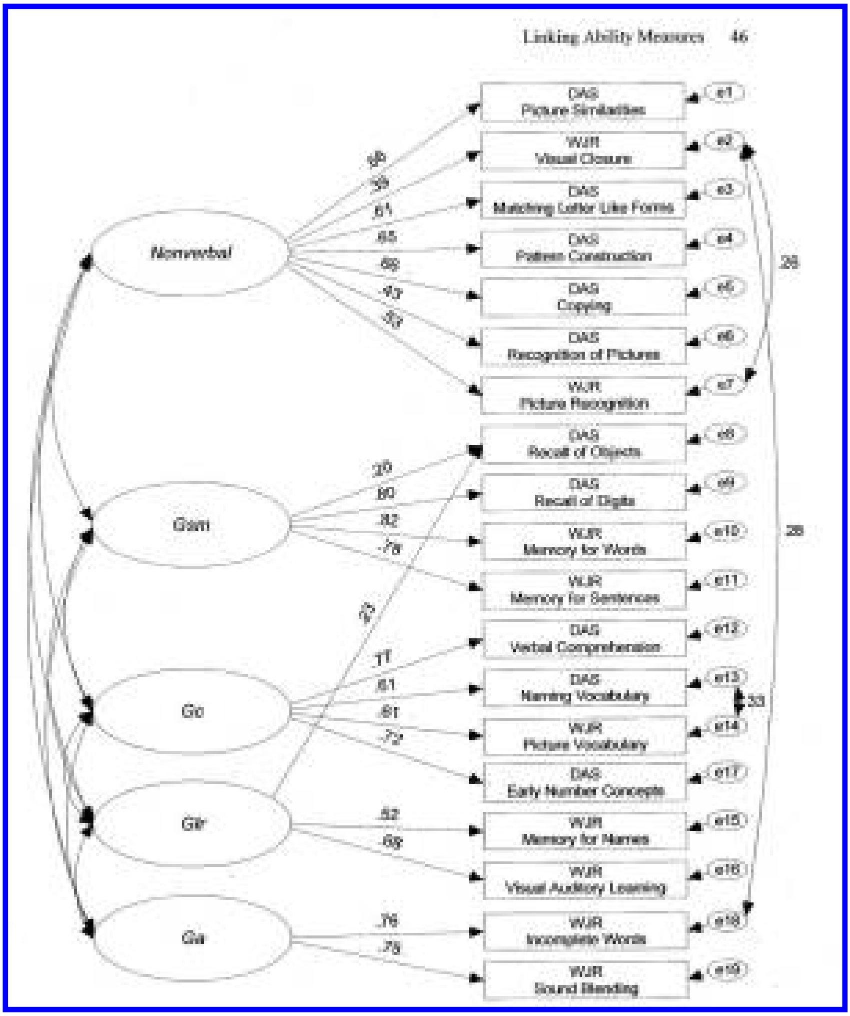

FIGURE 1 Model six: Five factor Gc–Ga–Gsm–Glr-nonverbal model.

skills in that the child must determine the entire word or picture represented by the incomplete stimulus presented. Finally, allowing errors to be correlated across the Picture Recognition and Visual Closure tests also accounted for potential shared variance due to similarities in the pictures (or incomplete pictures) presented in both for both tests. Following the changes, the resulting correlations between error variances ranged from $r = .26$ to .34.

The last change indicated involved allowing the DAS Recall of Objects subtest to be influenced by both Gsm and Glr, rather than the Gv factor. Although not originally hypothesized given the task demands (visual presentation of stimuli that the child must recall later), this change is partially grounded in theory. Flanagan and McGrew (1998; McGrew, 1997) categorized the Recall of Objects subtest as a mixed measure of the narrow abilities of Gv and Glr. Further, informal observations during data collection supports the notion that young children's attention skills may have impacted their ability to continue rehearsing the picture presented during the allotted practice time. Thus, the child's period of inattention may have intervened, causing the child to use retrieval skills to recall the picture names.

To provide a fair analysis of the link between theory and assessment tools, several a posteriori models were analyzed to compare to Model 6. The first allowed only for the identified error variances to be correlated. Then, various alternatives involving the relation between the Recall of Objects subtest and broad ability factors were examined (i.e., identification with Gv and Glr, with Gsm and Glr, with Gsm alone, and with Glr alone). Fit indexes are presented in Table 8. All representations significantly improved on Model 6, that is χ^2_{diff} values were all significant at the $p = .01$ level. Relative to the correlated errors-only model, the model, presented in Figure 2, which allowed the Recall of Objects subtest to be influenced by both the Glr and Gsm broad abilities was the only one to result in a significant improvement in fit. This was indicated by a significant χ^2_{diff} at the $p = .05$ level and equal or optimal fit indexes. Regression paths between broad factors and all subtests were also significant.

DISCUSSION

The findings reported previously are particularly meaningful given that this investigation is the first of its kind to empirically link preschool intellectual assessment tools to contemporary theories of cognitive ability. Although the intent of this

TABLE 8
Fit Indexes for *A Posteriori* Models

Model	$\chi^2(df)$	*p*	χ^2/df	*GFI*	*AGFI*	*AIC*	*RMSEA*	χ^2_{diff}
1. Correlated errors only	182.0(139)	.01	1.31	.90	.86	284.0	.04	
2. *Gv*/*Glr* → Recall of objects	178.5(138)	.01	1.29	.90	.86	282.5	.04	
3. *Gsm* → Recall of objects	179.3(139)	.01	1.29	.90	.86	281.3	.04	
4. *Glr* → Recall of objects	179.1(139)	.01	1.29	.90	.86	281.1	.04	
5. *Gsm*/*Glr* → Recall of objects	175.6(138)	.01	1.27	.90	.86	279.5	.04	40.6*

Note. GFI = goodness-of-fit index; AGFI = adjusted goodness-of-fit index; AIC = Akaike's Information Criterion; RMSEA = residual mean square error of approximation Gv = visual processing; Glr = long-range memory; Gsm = short-range memory.

*$p < .05$.

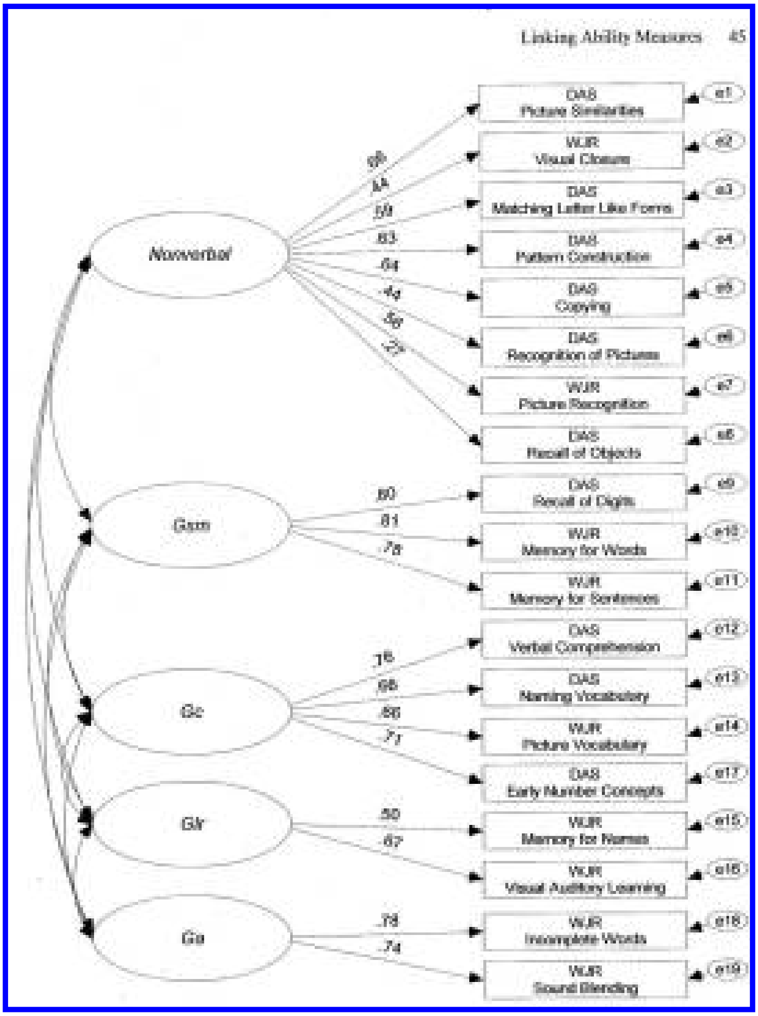

FIGURE 2 A posteriori model: Allows for correlated errors and DAS Recall of Objects subtest loading on Gsm and Glr.

study was to investigate the link between contemporary theories of intelligence and intellectual assessment tools used with young children, implications for assessment practice are also evident. Thus, the discussion that follows integrates implications for understanding the structure of intelligence for young children, for assessment practice, and for future research.

As expected, evidence for the traditional age-differentiation hypothesis was not established with this data. Instead, when a larger breadth of ability measures were assessed (i.e., the combination of subtests from both tests), support for a greater differentiation among the cognitive abilities of young children was determined. Thus, the notion that young children's cognitive abilities are best conceptualized as dichotomous is dismissed. In this study, five broad ability factors were reliably identified: Gc intelligence, Glr, Gsm, Ga, and a fifth factor that we originally referred to as nonverbal ability. This compliments previous psychometric research (Ellison et al., 1983; Horn, 1985) and substantiates the use of CHC theory in understanding the broad ability domains measured by preschool intelligence measures. Thus, it allows clinicians to work toward narrowing the "theory–practice gap" (Flanagan & McGrew, 1997) in cognitive assessment practices with young children by conceptualizing young children's cognitive abilities from a CHC framework.

The ability to isolate specific broad ability factors when assessment batteries for young children are combined adds to the clinical value of standardized assessment with young children. For example, it has long been acknowledged that phonological awareness skills, as indicated by the Ga factor in this study, are important predictors of early reading skills (Baker, Kameenui, Simmons, & Stahls, 1994; Chafouleaus, Lewandowski, Smith, & Blachman, 1997; Perfetti, Beck, Bell, & Hughes, 1987; Wagner, Torgesen, & Rashotte, 1994). Further, McGrew and Flanagan's (1998) review of the relations between broad cognitive abilities and academic achievement identify strong relations between Gc and Gs and early learning in both reading and mathematics. These relations are significant above and beyond the powerful effect of *g* (McGrew & Flanagan, 1998). Given that norm-referenced assessment with young children is frequently criticized (Bagnato & Neisworth, 1994; Bracken & Walker, 1997), advances in the level of sophistication and predictive value attainable when young children's cognitive abilities are assessed within a CHC framework are meaningful.

Evidence for the differentiation of the Gy factor represented in Carroll's three-stratum theory into two distinct broad abilities (Glr and Gsm) and the identification of visual-memory as a narrow ability under Gv provide further support for McGrew and Flanagan's (McGrew, 1997; McGrew & Flanagan, 1998) integration of three-stratum theory and Gf–Gc theory into CHC theory. The findings are also consistent with contemporary thought regarding young children's memory development, which suggests that children as young as 4 and 5 years can hold information in short-term memory, and even infants demonstrate aspects of long-term memory as they can form associations and recognize previously viewed objects as familiar (Siegler, 1986).

Determining that the distinction between short- and long-term memory abilities can be made with intellectual assessment tools for young children is important as both skills may be differentially related to separate aspects of learning and later academic achievement. Research with school-age samples has identified a link between naming fluency, a narrow ability subsumed under Glr that is measured by rapid automatized naming tasks, and early reading. Likewise, working memory, a narrow ability subsumed under Gsm, is significantly related to both reading and mathematics achievement (McGrew and Flanagan, 1998). Research in cognitive psychology has identified developmental differences across young children's capacity and speed of memory processes and working memory processes (Siegler, 1986). Thus, future research that combines knowledge of the link between cognitive assessment tools for young children and CHC theory with investigations of the developmental differences across these specific abilities may shed light on important preschool-age predictors of learning strengths and weaknesses.

Two broad ability factors thought to be represented by the subtests included in this study did not significantly distinguish themselves in this sample, namely, Gf and Gq. It is possible that these broad ability factors are not able to be distinguished from other broad abilities with samples of young children, as their loadings on the broad ability factor with which they were identified were significant. However, failure to identify the specific broad abilities of Gf and Gq is more likely due to a lack of additional tasks measuring the same abilities. Further, other broad ability factors were also missing with this data set (e.g., decision speed, processing speed) and thus did not allow for an investigation of the full CHC model. Future research that incorporates additional or different measures of cognitive ability will help clarify whether broad ability factors in addition to those identified in this study can be determined for young children.

The implications of this study for practice in education and psychology are great. As assessment tools for young children are better understood regarding their relation with broad and narrow ability factors, investigations examining the link between cognitive ability and later school achievement and development can be explored further. This could in turn result in the development of educational practices and interventions to address specific development and learning needs of young children.

Limitations

Although the implications for future research and practice from this study are rich, some limitations do exist. First, although CFA is a commonly accepted method for evaluating the link between contemporary theories of intelligence and intellectual assessment tools, it is not without limitations. CFA findings can be dependent on the methods used and interpretations made by the researcher (Keith, 1997; Loehlin, 1992). Further, factor analytic findings should not be accepted as evidence for a given structural model. Instead, hypothesized models are only supported by the data under investigation. It is always possible that some other model exists that could better represent the relations among sample data (Loehlin, 1992). Finally, the use of modification indexes to improve on the fit of the models investigated weakens the generalizability of this study, as they can be driven by chance associations among variables in this sample.

As a result, it is particularly critical that the results from this study be replicated and supported by other converging methods of research to ensure that they are not just an artifact of chance relations (Keith, 1997). Given the paucity of this type of research with young children, future research might also consider including different intellectual assessment tools. Although a challenging feat, joint CFA investigations that include measures of additional or different broad abilities (e.g., speed of information processing, quantitative ability, fluid reasoning) could improve on findings of this study, which was limited to the abilities measured by the DAS and WJ–R. It is quite plausible that these two batteries do not capture all potential broad abilities that can be differentiated for young children. In addition, inclusion of a broader age range of children would allow findings regarding the link between contemporary intellectual theory and the cognitive abilities of young children to be generalized beyond 4.0 to 5.11 years of age.

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REFERENCES

Arbuckle, J. L. (1997). *Amos user's guide 3.6.* Chicago: SmallWaters Corporation.

Bagnato, S. J., & Neisworth, J. T. (1994). A national study of the social and treatment "invalidity" of intelligence testing for early intervention. *School Psychology Quarterly, 9,* 81–102.

Baker, S. K., Kameenui, E. K., Simmons, D. C., & Stahls, S. (1994). Beginning reading: Educational tools for diverse learners. *School Psychology Review, 23,* 372–391.

Bentler, P. M., & Bonnet, D. G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. *Psychological Bulletin, 88,* 588–606.

Bickley, P. G., Keith, T. Z., & Wolfle, L. M. (1995). The three-stratum theory of cognitive abilities: Test of the structure of intelligence across the life span. *Intelligence, 20,* 309–328.

Blaha, J., & Wallbrown, F. H. (1991). Hierarchical factor structure of the Wechsler Preschool and Primary Scale of Intelligence–Revised. *Psychological Assessment, 3,* 455–463.

Bracken, B. A., & Walker, K. C. (1997). The utility of intelligence tests for preschool children. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 484–502). New York: Guilford.

Carroll, J. B. (1992). Cognitive abilities: The state of the art. *Psychological Science, 3,* 266–270.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies.* Cambridge, England: Cambridge University Press.

Carroll, J. B. (1994). Cognitive abilities: Constructing a theory from data. In D. K. Detterman (Ed.), *Current topics in human intelligence: Theories of intelligence* (Vol. 4, pp. 43–64). Norwood, NJ: Ablex.

Carroll, J. B. (1997). The three-stratum theory of cognitive abilities. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 122–130). New York: Guilford.

Cattell, R. B. (1941). Some theoretical issues in adult testing. *Psychological Bulletin, 38,* 592.

Chafouleaus, S. M., Lewandowski, L. J., Smith, C. R., & Blachman, B. A. (1997). Phonological awareness skills in children: Examining performance across tasks and ages. *Journal of Psychoeducational Assessment, 15,* 334–347.

Daniel, M. H. (1997). Intelligence testing: Status and trends. *American Psychologist, 52,* 1038–1045.

Das, J. P., & Naglieri, J. A. (1997). *Cognitive assessment system.* Itasca, IL: Riverside.

Das, J. P., Naglieri, J. A., & Kirby, J. R. (1994a). *Assessment of cognitive processes: The PASS theory of intelligence.* Needham Heights, MA: Allyn & Bacon.

Das, J. P., Naglieri, J. A., & Kirby, J. R. (1994b). Assessment of cognitive processes: The PASS theory of intelligence. *Journal of Psychoeducational Assessment, 13,* 397–409.

Dean, R. S., & Woodcock, R. W. (1999). *The WJ–R and Bateria–R in neuropsychological assessment.* Chicago: Riverside.

Elliott, C. D. (1990a). *Differential Ability Scales.* New York: Psychological Corporation.

Elliott, C. D. (1990b). *Differential Ability Scales: Introductory and technical handbook.* San Antonio, TX: Psychological Corporation.

Elliott, C. D. (1990c). The nature and structure of children's abilities: Evidence from the Differential Ability Scales. *Journal of Psychoeducational Assessment, 8,* 376–390.

Ellison, P. H., Horn, J. L., & Browning, C. (1983). A large-sample, many variable study of motor dysfunction of infancy. *Journal of Pediatric Psychology, 8,* 345–357.

Flanagan, D. P., & Alfonso, V. C. (1995). A critical review of the technical characteristics of new and recently revised intelligence tests for preschool children. *Journal of Psychoeducational Assessment, 13,* 66–90.

Flanagan, D. P., Mascolo, J., & Genshaft, J. L. (2000). A conceptual framework for interpreting preschool intelligence tests. In B. A. Bracken (Ed.), *The psychoeducational assessment of preschool children* (3rd ed.). Boston: Allyn & Bacon.

Flanagan, D. P., & McGrew, K. S. (1997). A cross-battery approach to assessing and interpreting cognitive abilities: Narrowing the gap between practice and cognitive science. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 314–325). New York: Guilford.

Flanagan, D. P., & McGrew, K. S. (1998). Interpreting intelligence tests from contemporary Gf–Gc theory: Joint confirmatory factor analysis of the WJ–R and KAIT in a non-White sample. *Journal of School Psychology, 36,* 151–182.

Flanagan, D. P., McGrew, K. S., & Ortiz, S. O. (2000). *The Wechsler Intelligence Scales and Gf–Gc theory: A contemporary approach to interpretation.* Boston: Allyn & Bacon.

Flanagan, D. P., & Ortiz, S. (2001). *Essentials of cross-battery assessment.* New York: Wiley.

Flavell, J. H., Miller, P. H., & Miller, S. A. (1993). *Cognitive development* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

Ford, L., & Dahinten, V. S. (in press). The use of intelligence tests in teh assessment of preschoolers. In D. Flanagan & P. Harrison (Eds.), *Contemporary intellectual assessment* (2nd ed.). New York: Guilford.

Gardner, M., & Clark, E. (1992). The psychometric perspective on intellectual development in childhood and adolescence. In R. J. Sternberg & C. A. Berg (Eds.), *Intellectual development* (pp. 16–43). New York: Cambridge University Press.

Garrett, H. E. (1946). A developmental theory of intelligence. *American Psychologist, 1,* 372–378.

Gustafsson, J. E., & Undheim, J. O. (1996). Individual differences in cognitive functions. In D. C. Berliner & R. C. Calfee (Eds.), *Handbook of educational psycholo*gy (pp. 186–242). New York: Macmillan.

Gyurke, J. S., Stone, B. J., & Beyer, M. (1990). A confirmatory factor analysis of the WPPSI–R. *Journal of Psychoeducational Assessment, 8,* 15–21.

Horn, J. L. (1968). Organization of abilities and the development of intelligence. *Psychological Review, 75,* 142–259.

Horn, J. L. (1985). Remodeling old models of intelligence. In B. B. Wolman (Ed.), *Handbook of intelligence: Theories, measurements, applications* (pp. 267–300). New York: Wiley.

Horn, J. L. (1988). Thinking about human abilities. In J. R. Nesselroade & R. B. Cattell (Eds.), *Handbook of multivariate psycholo*gy (2nd ed., pp. 645–865). New York: Wiley.

Horn, J. L. (1994). Theory of fluid and crystallized intelligence. In R. J. Sternberg (Ed.), *Encyclopedia of human intelligence* (pp. 443–451). New York: Macmillan.

Horn, J. L., & Cattell, R. B. (1966). Refinement and test of the theory of fluid and crystallized intelligence. *Journal of Educational Psychology, 57,* 253–270.

Horn, J. L., & Noll, J. (1997). Human cognitive abilities: Gf–Gc theory. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 53–91). New York: Guilford.

Hox, J. J. (1995). Amos, EQS, and LISREL for Windows: A comparative review. *Structural Equation Modeling, 2,* 79–91.

Kamphaus, R. W. (1993). *Clinical assessment of children's intelligence.* Boston: Allyn & Bacon.

Kaufman, A. S., & McClean, J. E. (1987). Joint factor analysis of the K–ABC and WISC–R with normal children. *Journal of School Psychology, 25,* 105–118.

Keith, T. Z. (1990). Confirmatory and hierarchical analysis of the Differential Ability Scales. *Journal of Psychoeducational Assessment, 8,* 376–390.

Keith, T. Z. (1997). Using confirmatory factor analysis to aid in understanding the constructs measured by intelligence tests. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 53–91). New York: Guilford.

Keith, T. Z., Cool, V. A., Novak, C. G., White, L. J., & Pottebaum, S. M. (1988). Confirmatory factor analysis of the Stanford-Binet Fourth Edition: Testing the theory-test match. *Journal of School Psychology, 26,* 253–274.

Keith, T. Z., Kranzler, J. H., & Flanagan, D. P. (2001). What does the Cognitive Assessment System (CAS) measure? Joint confirmatory factor analysis of the CAS and the Woodcock–Johnson Tests of Cognitive Ability (3rd edition). *School Psychology Review, 30,* 89–119.

Keith, T. Z., & Novak, C. G. (1987). Joint factor structure of the WISC–R and K–ABC for referred school children. *Journal of Psychoeducational Assessment, 4,* 370–386.

Kline, R. B. (1989). Is the Fourth Edition Stanford–Binet a four-factor test? Confirmatory factor analyses of alternative models for ages 2 through 23. *Journal of Psychoeductional Assessment, 7*(1), 4–13.

Kranzler, J. H. (1997). Educational and policy issues related to the use and interpretation of intelligence tests in the schools. *School Psychology Review, 26,* 150–162.

Kranzler, J. H., & Keith, T. Z. (1999). Independent confirmatory factor analysis of the Cognitive Assessment System (CAS): What does the CAS measure? *School Psychology Review, 28,* 117–144.

Kranzler, J. H., Keith, T. Z., & Flanagan, D. P. (2000). Independent examination of the factor structure of the cognitive assessment system (CAS): Further evidence challenging the construct validity of the CAS. *Journal of Psychoeducational Assessment, 18,* 143–159.

LoBello, S. G., & Gulgoz, S. (1991). Factor analysis of the Wechsler Preschool and Primary Scale of Intelligence–Revised. *Psychological Assessment, 3,* 130–132.

Loehlin, J. C. (1992). *Latent variable models: An introduction to factor, path, and structural analysis* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Lohman, D. F. (1989). Human intelligence: An introduction to advances in theory and research. *Review of Educational Research, 59,* 333–373.

McCall, R. B., Eichorn, D. H., & Hogarty, P. S. (1977). Transitions in early mental development. *Monographs of the Society for Research in Child Development, 42,* 108.

McGhee, R. L. (1993). Fluid and crystallized intelligence: Confirmatory factor analysis of the Differential Abilities Scale, Detroit Tests of Learning Aptitude–3, and Woodcock–Johnson Psycho-Educational Assessment Battery–Revised. *Journal of Psychoeducational Assessment, Monograph Series: Woodcock–Johnson Psycho-Educational Battery–Revised.* 20–38.

McGrew, K. S. (1997). Analysis of the major intelligence batteries according to a proposed comprehensive Gf–Gc framework. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment* (pp. 151–180). New York: Guilford.

McGrew, K. S., & Flanagan, D. P. (1998). *The intelligence test desk reference (ITDR): Gf–Gc cross-battery assessment.* Boston: Allyn & Bacon.

McGrew, K. S., & Hessler, G. L. (1995). The relationship between the WJR Gf–Gc cognitive clusters and mathematics across the lifespan. *Journal of Psychoeducational Assessment, 13,* 21–38.

McGrew, K. S., Keith, T. Z., Flanagan, D. P., & Vanderwood, M. (1997). Beyond *g:* The impact of Gf–Gc specific cognitive abilities research on the future use and interpretation of intelligence tests in the schools. *School Psychology Review, 26,* 189–210.

McGrew, K. S., Werder, J. K., & Woodcock, R. W. (1991). *WJ–R technical manual.* McAllen, TX: DLM.

McGrew, K. S., & Woodcock, R. W. (2001). *Technical manual for the Woodcock–Johnson Third Edition.* Itasca, IL: Riverside.

Naglieri, J. A., & Das, J. P. (1990). Planning, attention, simultaneous, and successive (PASS) cognitive processes as a model for intelligence. *Journal of Psychoeducational Assessment, 8,* 303–337.

Naglieri, J. A., & Das, J. P. (1997). Planning, attention, simultaneous, and successive theory and the cognitive assessment system: A new theory-based measure of intelligence. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 247–267). New York: Guilford.

Ortiz, S. O., Flanagan, D. P., & McGrew, K. S. (1998). Gf–Gc cross-battery interpretation and selective cross-battery assessment: Referral concerns and the needs of culturally and linguistically diverse populations. In K. S. McGrew and D. P. Flanagan, *The intelligence test desk reference (ITDR): Gf–Gc cross-battery assessment* (pp. 401–444). Boston: Allyn & Bacon.

Perfetti, C. A., Beck, I., Bell, L. C., & Hughes, C. (1987). Phonemic knowledge and learning to read are reciprocal: A longitudinal study of first grade children. *Merrill-Palmer Quarterly, 33,* 283–319.

Roid, G.H. (2003). *The Stanford–Binet Intelligence Scales–Fifth Edition.* Itasca, IL: Riverside.

Roid, G. H., & Gyurke, J. (1991). General-factor and specific variance in the WPPSI–R. *Journal of Psychoeducational Assessment, 9,* 209–223.

Roth, P. L. (1994). Missing data: A conceptual review or applied psychologists. *Personnel Psychology, 47,* 537–560.

Siegler, R. S. (1986). *Children's thinking.* Upper Saddle River, NJ: Prentice Hall.

Siegler, R. S., & Richards, D. D. (1982). The development of intelligence. In R. J. Sternberg (Ed.), *Handbook of human intelligence* (pp. 897–971). Cambridge, England: Cambridge University Press.

Spearman, C. E. (1927). *The abilities of man.* New York: Macmillan.

Sternberg, R. J., & Berg, C. A. (1992). *Intellectual development.* New York: Cambridge University Press.

Sternberg, R. J., & Powell, J. S. (1983). Comprehending verbal comprehension. *American Psychologist, 38,* 878–893.

Stone, B. J., Gridley, B. E., & Gyurke, J. S. (1991). Confirmatory factor analysis of the WPPSI–R at the extreme end of the age range. *Journal of Psychoeducational Assessment, 9,* 263–270.

Tanaka, J. S. (1993). Multifaceted conceptions of fit in structural equation modeling. In K. A. Bollen and J. S. Long (Eds.), *Testing structural equation models* (pp. 10–39). Newbury Park, CA: Sage.

Thorndike, R. M. (1990). Would the real factors of the Stanford–Binet Fourth Edition please come forward? *Journal of Psychoeducational Assessment, 8,* 412–435.

Tusing, M. E. (1998). *Validation studies with the Woodcock–Johnson Psycho-Educational Battery–Revised Tests of Cognitive Ability: Early Development Scale and the Differential Ability Scales: Preschool Level.* Unpublished doctoral dissertation, University of South Carolina, Columbia.

Tusing, M. E., Maricle, D. E., & Ford, L. (2003). Assessment with the Woodcock–Johnson III and young children. In F. A. Schrank & D. P. Flanagan (Eds.), *WJ III clinical use and interpretation: Scientist practitioner perspectives.* San Diego, CA: Academic.

Vernon, P. E. (1950). *The structure of human abilities.* New York: Wiley.

Wagner, R. K., Torgesen, J. K., & Rashotte, C. A. (1994). Development of reading related phonological processing abilities: New evidence of bi-directional causality from a latent variable longitudinal study. *Developmental Psychology, 30,* 73–87.

Wallbrown, F., Blaha, J., & Wherry, R. J. (1973). The hierarchical factor structure of the Wechsler Preschool and Primary Scale of Intelligence. *Journal of Consulting and Clinical Psychology, 41,* 356–362.

Wechsler, D. (1989). *Wechsler Preschool and Primary Scales of Intelligence–Revised.* San Antonio, TX: Psychological Corporation.

Wechsler, D. (2002). *Wechsler Preschool and Primary Scales of Intelligence–Third Edition.* San Antonio, TX: Psychological Corporation.

Woodcock, R. W. (1990). Theoretical foundations of the WJ–R measures of cognitive ability. *Journal of Psychoeducational Assessment, 8,* 231–258.

Woodcock, R. W. (1994). Measures of fluid and crystallized intelligence. In R. J. Sternberg (Ed.), *The encyclopedia of intelligence* (pp. 452–456). New York: Macmillan.

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock–Johnson III.* Itasca, IL: Riverside.