Psychological Assessment
2010, Vol. 22, No. 4, 827–836

© 2010 American Psychological Association
1040-3590/10/$12.00 DOI: 10.1037/a0020429

Investigation of the Factor Structure of the Wechsler Adult Intelligence Scale—Fourth Edition (WAIS–IV): Exploratory and Higher Order Factor Analyses

Gary L. Canivez
Eastern Illinois University

Marley W. Watkins
Arizona State University

The present study examined the factor structure of the Wechsler Adult Intelligence Scale—Fourth Edition (WAIS–IV; D. Wechsler, 2008a) standardization sample using exploratory factor analysis, multiple factor extraction criteria, and higher order exploratory factor analysis (J. Schmid & J. M. Leiman, 1957) not included in the WAIS–IV Technical and Interpretation Manual (D. Wechsler, 2008b). Results indicated that the WAIS–IV subtests were properly associated with the theoretically proposed first-order factors, but all but one factor-extraction criterion recommended extraction of one or two factors. Hierarchical exploratory analyses with the Schmid and Leiman procedure found that the second-order *g* factor accounted for large portions of total and common variance, whereas the four first-order factors accounted for small portions of total and common variance. It was concluded that the WAIS–IV provides strong measurement of general intelligence, and clinical interpretation should be primarily at that level.

Keywords: WAIS–IV, exploratory factor analysis, factor extraction criteria, Schmid-Leiman higher order analysis, structural validity

The Wechsler Adult Intelligence Scale—Fourth Edition (WAIS–IV; Wechsler, 2008a) is the latest version of the most frequently used intelligence test for adults and older adolescents. It includes 15 subtests (10 core and five supplemental), four first-order factor index scores (Verbal Comprehension [VC], Perceptual Reasoning [PR], Working Memory [WM], and Processing Speed [PS]), and the higher order Full Scale score (FSIQ). In addition to deleting the Object Assembly and Picture Arrangement subtests (reducing subtests with manipulative objects); creating and adding Visual Puzzles, Figure Weights, and Cancellation subtests; and increasing item coverage and range; the WAIS–IV theoretical foundation was updated. Like other recently published intelligence tests—such as the Wechsler Intelligence Scale for Children—Fourth Edition (WISC–IV; Wechsler, 2003a), the Stanford-Binet Intelligence Scales—Fifth Edition (SB–5; Roid, 2003a), Kaufman Assessment Battery for Children—Second Edition (KABC-II; Kaufman & Kaufman, 2004); Reynolds Intellectual Assessment Scales (RIAS; Reynolds & Kamphaus, 2003), and Wide Range Intelligence Test (WRIT; Glutting, Adams, & Sheslow, 2000a)—the WAIS–IV content and structure were modified in an attempt to reflect current conceptualizations of intellectual measurement articulated by Carroll, Cattell, and Horn (Carroll, 1993, 2003; Cattell & Horn, 1978; Horn, 1991; Horn & Cattell, 1966). With respect to the WAIS–IV factor index scores, it was noted in the Technical and Interpretive Manual that "analyses of these four index scores is recommended as the primary level of clinical interpretation, especially in cases with considerable variability across the index and or subtest scores" (Wechsler, 2008b, p. 127).

Confirmatory factor analytic (CFA) support for the WAIS–IV hierarchical structure was reported in the WAIS–IV Technical and Interpretive Manual (Wechsler, 2008b), and Figures 5.1, 5.2, and 5.3 in that manual illustrate the final standardized structural models for the 10 core subtests (ages 16–90 years), 15 core and supplementary subtests (ages 16–69 years), and 12 core and supplementary subtests (ages 70–90 years), respectively. These final models allowed the Arithmetic subtest to load on both the WM and VC factors although the standardized coefficients for the VC to Arithmetic paths appeared generally small. Also, although improvements were observed over the model with Arithmetic loading solely on WM, the improvements seemed modest. In general, CFA analyses supported the hierarchical model with general intelligence at the highest level and four first-order factors.

The WAIS–IV Technical and Interpretive Manual (Wechsler, 2008b) disappointingly presented only CFA results in support of the latent factor structure, albeit supportive of the hierarchical structure. Presenting only CFA, however, is becoming common among test authors and publishers (Elliott, 2007; McGrew & Woodcock, 2001; Roid, 2003b; Wechsler, 2008b) but is in contrast to previous (and some current) practice where exploratory factor analysis (EFA) and CFA results were both reported (Bracken & McCallum, 1998; Elliott, 1990; Glutting, Adams, & Sheslow, 2000b; Kaufman & Kaufman, 1993; Naglieri & Das, 1997; Wechsler, 1991, 2002a, 2002b, 2003b; Wechsler & Naglieri, 2006). EFA and CFA are considered by many to be complementary procedures that answer different yet important questions; and

This article was published Online First September 6, 2010.

Gary L. Canivez, Department of Psychology, Eastern Illinois University; Marley W. Watkins, School Psychology Program, Arizona State University.

This research was partially supported by a 2009 Summer Research Grant to Gary L. Canivez from the Council on Faculty Research, Eastern Illinois University. Preliminary results were presented at the 2010 Annual Convention of the American Psychological Association, San Diego, CA.

Correspondence concerning this article should be addressed to Gary L. Canivez, Department of Psychology, 600 Lincoln Avenue, Charleston, IL 61920-3099. E-mail: glcanivez@eiu.edu

when they are in agreement, there is greater confidence in the latent structure of the test (Gorsuch, 1983). Frazier and Youngstrom (2007) noted that there is cause for concern regarding the disagreement between the number of latent factors reported in contemporary intelligence tests based solely on CFA procedures (or on the most liberal EFA factor-extraction criteria) and the number of factors suggested by EFA procedures that included the most psychometrically sound methods for determining the correct number of factors to extract and retain. Without presentation of EFA procedures with standardization sample data, there is no way for clinicians to consider convergence or divergence of WAIS–IV CFA and EFA results. Such information is important in determining relative importance of various scores for interpretation, although it should be noted that EFA methods typically rely on principal factors extraction, whereas CFA methods typically rely on maximum likelihood extraction.

When independent investigations of intelligence test factor structures have been completed using EFA procedures, there have been serious and substantial challenges to the optimistic conclusions for the latent structures illustrated in test technical manuals. Both DiStefano and Dombrowski (2006) and Canivez (2008), using data from the SB–5 standardization sample, obtained markedly different results for the SB–5 than the CFA results presented in its technical manual (Roid, 2003b) and concluded that the SB–5 measured one fundamental dimension (*g*). No evidence for five factors in the SB–5 was found. Three investigations of the WISC–IV (Bodin, Pardini, Burns, & Stevens, 2009; Watkins, 2006; Watkins, Wilson, Kotz, Carbone, & Babula, 2006) indicated that most variance was associated with general intelligence (substantially lesser amounts at the factor level) and that interpretation of the WISC–IV should focus on the global FSIQ score because it accounts for most of the common variance and because of additional research showing FSIQ superiority in predictive validity (Glutting, Watkins, Konold, & McDermott, 2006; Glutting, Youngstrom, Ward, Ward, & Hale, 1997). In fact, the limited unique variance captured by the first-order factors may be responsible for the poor incremental predictive validity of the WISC–III and WISC–IV factor scores. Studies of the RIAS have also indicated that fundamental measurement is primarily that of general intelligence (Dombrowski, Watkins, & Brogan, 2009; Nelson, Canivez, Lindstrom, & Hatt, 2007), which was by design its primary goal (Reynolds & Kamphaus, 2003). A recent joint investigation of the WRIT and Wechsler Abbreviated Scale of Intelligence (WASI; Psychological Corporation, 1999) also found that most variability was associated with general intelligence, and smaller portions of variance were apportioned to the first-order factors; supporting primary interpretation of the FSIQ and GIQ (Canivez, Konold, Collins, & Wilson, 2009).

Also missing from the WAIS–IV Technical and Interpretive Manual were proportions of variance accounted for by the higher order *g* factor and the four first-order factors, subtest *g* loadings, subtest specificity estimates, and incremental predictive validity estimates of factors and subtests. Thus, clinicians do not have available the necessary information to judge the relative importance of the factor index scores and subtest scores relative to the Full Scale score. If the factor index scores and subtests do not capture meaningful portions of true score variance nor provide important amounts of incremental predictive validity, they will likely be of questionable clinical utility.

Major tests of intelligence, including the WAIS–IV, have applied Carroll's (1993) model of the structure of cognitive abilities to facilitate subtest and factor selection and to aid in interpretations of scores and performance. Carroll's (1993, 2003) three-stratum theory of cognitive abilities is hierarchical, proposing some 50–60 narrow abilities (Stratum I); 8–10 broad ability factors (Stratum II); and at the apex (Stratum III), the general ability factor (*g*; Spearman, 1904, 1927). Subtest performance on cognitive ability tests reflects combinations of both first-order (Stratum II) and second-order (Stratum III) factors, and because of this, Carroll argued that variance from the higher order factor must be extracted first to residualize the lower order factors, leaving them orthogonal to the higher order factor. Variability associated with a higher order factor is accounted for before interpreting variability associated with lower order factors. The Schmid and Leiman (1957) procedure is the statistical method to accomplish this, and was recommended by Carroll (1993, 1995, 1997, 2003); McClain (1996); Gustafsson and Snow (1997); Carretta and Ree (2001); Ree, Carretta, and Green (2003); and Thompson (2004). Carroll (1995) noted:

> I argue, as many have done, that from the standpoint of analysis and ready interpretation, results should be shown on the basis of orthogonal factors, rather than oblique, correlated factors. I insist, however, that the orthogonal factors should be those produced by the Schmid-Leiman (1957) orthogonalization procedure, and thus include second-stratum and possibly third-stratum factors. (p. 437)

The present study used data from the WAIS–IV standardization sample subtest correlation matrices published in the WAIS–IV Technical and Interpretive Manual (Wechsler, 2008b) to examine the factor structure using EFA procedures. Primary research questions included (a) Using multiple criteria, how many factors are recommended to be extracted and retained from the WAIS–IV standardization sample? and (b) When forcing extraction of four theoretical factors and applying the Schmid and Leiman (1957) procedure, what portions of variance are attributed to the general intelligence (Stratum III) dimension and the four broad ability factors (Stratum II)? Analyses were provided for the three principal test configurations that vary by age—10 core subtests (ages 16:0–90:11, $N = 2{,}200$), 10 core and five supplemental subtests (ages 16:0–69:11, $N = 1{,}800$), and 10 core and two supplemental subtests (ages 70:0–90:11, $N = 400$)—and which parallel the final CFA models presented in the Technical and Interpretive Manual. If multiple factors of the WAIS–IV are to be interpreted, particularly factor index scores, it is imperative that clinicians know how variability is apportioned across the first- and second-order dimensions.

Method

Participants

Participants were members of the WAIS–IV standardization sample and included a total of 2,200 individuals ranging in age from 16–90 years. Demographic characteristics are provided in detail in the WAIS–IV Technical and Interpretive Manual (Wechsler, 2008b). The standardization sample was obtained using stratified proportional sampling across variables of age, sex, race/ethnicity, education level (or parent education level for ages 16–19 years), and geographic region. Education level was a likely proxy for socioeconomic status where accurate information about income is difficult to obtain. Examination of tables in the Technical and Interpretive Manual revealed a close match to the October 2005 U.S. census across stratification variables.

Instrument

The WAIS–IV is an individual test of general intelligence for ages 16–90, and it originated with the 1939 Wechsler-Bellevue Intelligence Scale (Wechsler, 1939b). Consistent with Wechsler's definition of intelligence (i.e., "global capacity"; Wechsler, 1939a, p. 229) and all versions of his tests, the WAIS–IV measures general intelligence through the administration of numerous subtests, each of which is an indicator and estimate of intelligence. The WAIS–IV uses 10 core subtests to produce the FSIQ. The Verbal Comprehension Index (VCI) and Perceptual Reasoning Index (PRI) are each composed of three subtests, whereas the Working Memory Index (WMI) and Processing Speed Index (PSI) are each composed of two subtests. Supplemental subtests are provided to substitute for core subtests when necessary (one each for the VC, WM, and PS scales and two for the PR scale); however, three of the supplemental subtests (Figure Weights, Letter-Number Sequencing, and Cancellation) are not available for 70- to 90-year-olds.

Procedure

WAIS–IV subtest correlation matrices for the different age groups in the standardization sample were obtained from the Technical and Interpretive Manual (Wechsler, 2008b) and combined by averaging correlations through Fisher transformations. Three correlation matrices were created to represent the three WAIS–IV subtest configurations examined with CFA in the WAIS–IV Technical and Interpretive Manual: 10 core subtests for the total sample (ages 16–90; $N = 2{,}200$), 15 (core and supplementary) subtests for total sample (ages 16–69; $N = 1{,}800$), and 12 (core and supplementary) subtests for the total elderly sample (ages 70–90; $N = 400$). Specifically, for the WAIS–IV 10 core subtest EFA, the two correlation matrices for the 100 participants in each of the 70–74 and 75–79 age groups were first averaged, as were the two correlation matrices for the 100 participants in each of the 80–84 and 85–90 age groups, and then those two resulting correlation matrices ($n = 200$ each) were averaged with the correlation matrices of the 10 core subtests from the nine 200-participant age groups for the 16- to 69-year-olds. For the EFA of the 12 WAIS–IV core and supplemental subtests among the 70- to 90-year-olds, the four 100-participant age-group correlation matrices were averaged, and for the EFA of the 15 WAIS–IV core and supplemental subtests among the 16- to 69-year-olds, the nine 200-participant age-group correlation matrices were averaged.

Analyses

Principal axis EFAs (Cudeck, 2000; Fabrigar, Wegener, MacCallum, & Strahan, 1999; Tabachnick & Fidel, 2007) were used to analyze reliable common variance from each of the three WAIS–IV standardization sample correlation matrices representing the three primary configurations (10 subtests [ages 16–90], 15 subtests [ages 16–69], 12 subtests [ages 70–90]) using SPSS 17.0 for Macintosh OSX. Multiple criteria, as recommended by Gorsuch (1983), were used to determine the number of factors to retain and included eigenvalues > 1 (Guttman, 1954), the scree test (Cattell, 1966), standard error of scree (SE_{Scree}; Zoski & Jurs, 1996), Horn's parallel analysis (HPA; Horn, 1965), and minimum average partials (MAP; O'Connor, 2000; Velicer, 1976). The scree test was used to determine visually the optimum number of factors to retain but is a subjective criterion. The SE_{Scree} was used as programmed by Watkins (2007), as it was reported to be the most accurate objective scree method (Nasser, Benson, & Wisenbaker, 2002). HPA and MAP were included as they are typically more accurate and are helpful so as not to overfactor (Frazier & Youngstrom, 2007; Thompson & Daniel, 1996; Velicer, Eaton, & Fava, 2000; Zwick & Velicer, 1986). HPA indicated meaningful factors when eigenvalues from the WAIS–IV standardization sample data were larger than eigenvalues produced by random data containing the same number of participants and factors (Lautenschlager, 1989). Random data and resulting eigenvalues for HPA were produced using the Monte Carlo PCA for Parallel Analysis computer program (Watkins, 2000) with 100 replications to provide stable eigenvalue estimates.

For higher order exploratory analyses, the present study limited iterations in first-order principal axis factor extraction to two in estimating final communality estimates (Gorsuch, 2003), balancing sampling error and measurement error in estimating communality. Gorsuch noted that "Snook and Gorsuch (1989) found the resulting communalities to not differ significantly from the communalities designed into the study. This is a good procedure" (Gorsuch, 2003, p. 148). Each correlation matrix for the three WAIS–IV configurations was subjected to EFA (principal axis extraction of four factors), followed by promax (oblique) rotation ($k = 4$; Gorsuch, 2003). The resulting first-order factors were orthogonalized by removing all variance associated with the second-order dimension using the Schmid and Leiman (1957) procedure as programmed in the MacOrtho computer program (Watkins, 2004). This transforms "an oblique factor analysis solution containing a hierarchy of higher order factors into an orthogonal solution which not only preserves the desired interpretation characteristics of the oblique solution, but also discloses the hierarchical structuring of the variables" (Schmid & Leiman, 1957, p. 53).

Results

Factor-Extraction Criteria Comparisons

Figures 1, 2, and 3 illustrate scree plots from HPA for the three WAIS–IV configurations. Table 1 summarizes results from the multiple criteria (eigenvalues > 1, scree test, standard error of scree, HPA, and MAP) for determining the number of factors to extract and retain in each of the WAIS–IV configurations. As illustrated in Table 1, only the SE_{Scree} for the 15-subtest WAIS–IV configuration supported extraction of four factors. All other criteria across the three WAIS–IV configurations recommended extraction of only one or two factors.

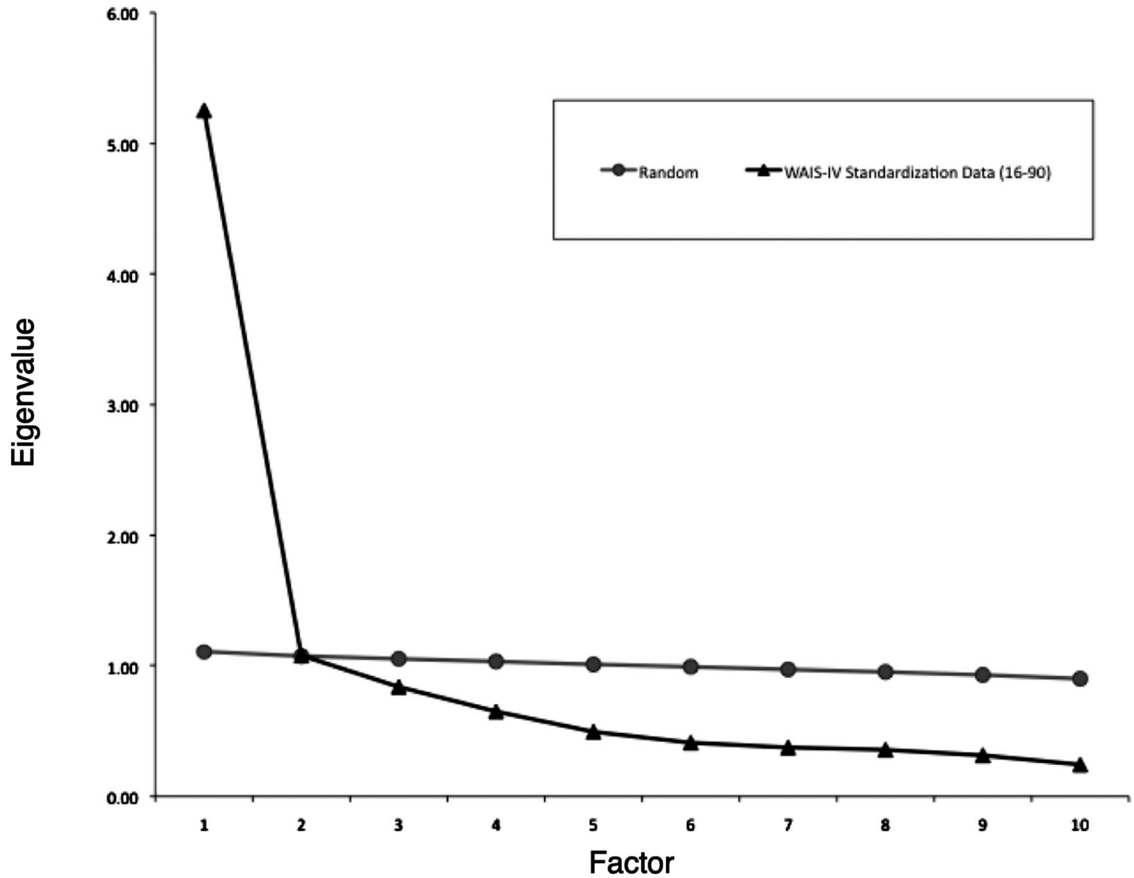

Figure 1. Scree plots for Horn's parallel analysis for the Wechsler Adult Intelligence Scale—Fourth Edition (WAIS–IV; Wechsler, 2008a) standardization sample ages 16–90 years and the 10 core subtests.

Higher Order Factor Analyses

WAIS–IV 10 core subtests (ages 16–90). Results for the 10 WAIS–IV core subtests with the total standardization sample ages 16–90 (N = 2,200) are presented in Table 2. All subtests were properly associated with their theoretically proposed factor. Correlations between the four first-order factors ranged from .54 to .76, based on the promax rotation (k = 4), and indicated the presence of a higher order factor. The second-order g factor accounted for 42.9% of the total variance and 67.0% of the common variance. The general factor also accounted for between 29% and 55% (Mdn = 44%) of individual subtest variability. At the first-order level, VC accounted for an additional 8.0% of the total variance and 12.4% of the common variance, PR accounted for an additional 4.3% of the total variance and 6.8% of the common variance, WM accounted for an additional 2.5% of the total variance and 3.9% of the common variance, and PS accounted for an additional 6.3% of the total variance and 9.9% of the common variance. The first- and second-order factors combined to measure 64.0% of the variance in WAIS–IV scores, resulting in 36.0% unique variance (combination of specific and error variance). Subtest specificity (variance unique to the subtest) estimates ranged from .11 to .37.

WAIS–IV 15 subtests (ages 16–69). Results for the 15 WAIS–IV core and supplemental subtests with the total standardization sample ages 16–69 (N = 1,800) are presented in Table 3, and all subtests were properly associated with the theoretically proposed factor. Correlations between the four first-order factors ranged from .49 to .71, based on the promax rotation (k = 4), indicating the presence of a higher order factor. The second-order g factor accounted for 40.6% of the total variance and 68.1% of the common variance. The general factor also accounted for between 18% and 52% (Mdn = 44%) of individual subtest variability. At the first-order level, VC accounted for an additional 7.1% of the total variance and 11.8% of the common variance, PR accounted for an additional 3.8% of the total variance and 6.3% of the common variance, WM accounted for an additional 2.8% of the total variance and 4.8% of the common variance, and PS accounted for an additional 5.3% of the total variance and 8.9% of the common variance. The first- and second-order factors combined to measure 59.6% of the variance in WAIS–IV scores, resulting in 40.4% unique variance (combination of specific and error variance). Subtest specificity (variance unique to the subtest) estimates ranged from .14 to .46.

WAIS–IV 12 subtests (ages 70–90). Results for the 12 WAIS–IV core and supplemental subtests with the total standardization sample ages 70–90 (N = 400) are presented in Table 4. As with the other analyses, all subtests were properly associated with their theoretically proposed factor. Correlations between the four

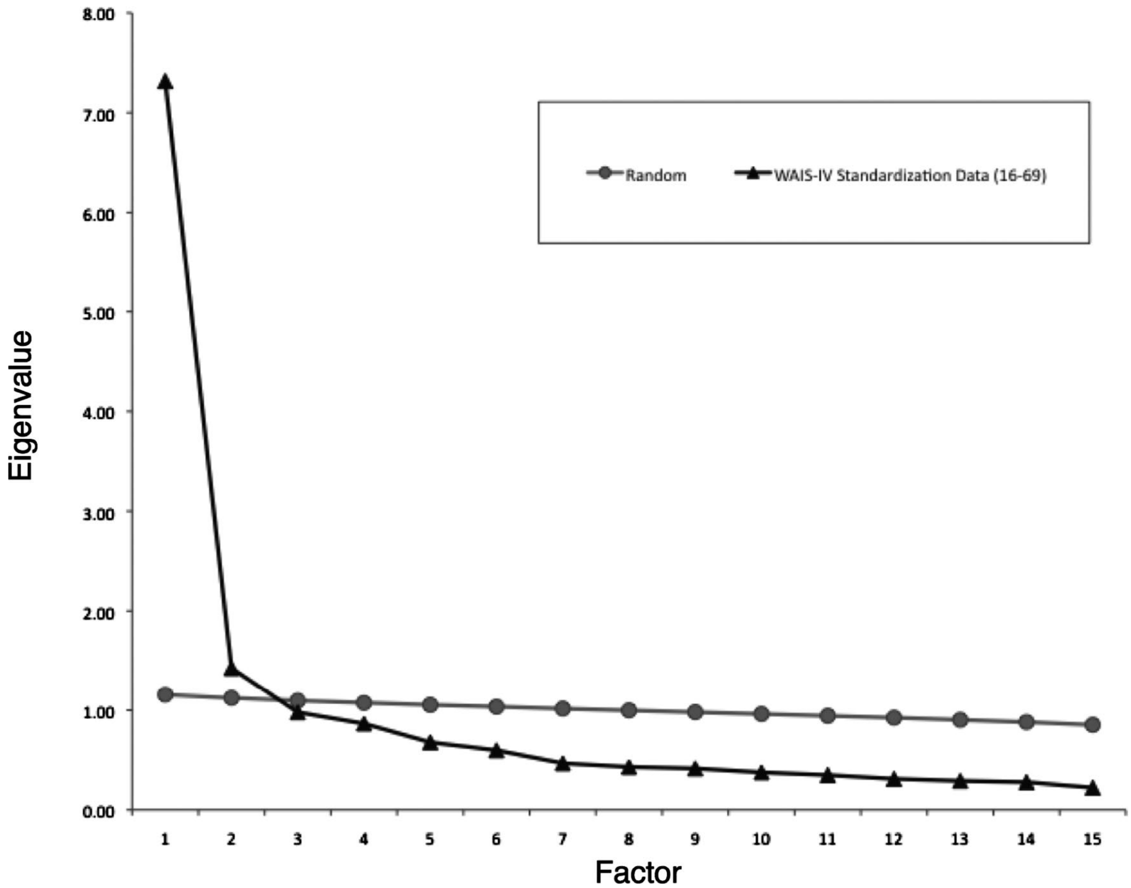

Figure 2. Scree plots for Horn's parallel analysis for the Wechsler Adult Intelligence Scale—Fourth Edition (WAIS–IV; Wechsler, 2008a) standardization sample ages 16–69 years and the 10 core and five supplemental subtests.

first-order factors ranged from .55 to .72, based on the promax rotation ($k = 4$), and indicated a higher order factor. The second-order *g* factor accounted for 44.7% of the total variance and 69.1% of the common variance. The general factor also accounted for between 35% and 53% (*Mdn* = 45.5%) of individual subtest variability. At the first-order level, VC accounted for an additional 7.8% of the total variance and 12.1% of the common variance, PR accounted for an additional 3.7% of the total variance and 5.7% of the common variance, WM accounted for an additional 3.0% of the total variance and 4.7% of the common variance, and PS accounted for an additional 5.4% of the total variance and 8.4% of the common variance. The first- and second-order factors combined to measure 61.7% of the variance in WAIS–IV scores resulting in 35.3% unique variance (combination of specific and error variance). Subtest specificity (variance unique to the subtest) estimates ranged from .07 to .42.

Discussion

Although the WAIS–IV Technical and Interpretive Manual presented CFA support of the hierarchical structure with *g* at the apex and four first-order factors, the absence of EFA procedures and results does not allow for consideration of convergence or divergence of CFA and EFA results. Frazier and Youngstrom (2007) illustrated the growing problem of CFA and EFA divergence when there is overreliance on CFA and/or not considering HPA and MAP procedures for recommending the number of latent factors to extract and retain. The present study examined the WAIS–IV factor structure using EFA methods to answer two main research questions: (a) How many factors should be extracted and retained using multiple criteria? and (b) When four factors are extracted and orthogonalized using the Schmid and Leiman (1957) procedure, how was variance apportioned to the first- and second-order dimensions? Multiple criteria for determining the number of factors to extract and retain included HPA and MAP because of superior accuracy (Thompson & Daniel, 1996; Velicer, Eaton, & Fava, 2000; Zwick & Velicer, 1986). The Schmid and Leiman procedure was used to examine the hierarchical structure and to apportion variance to the first- and second-order factors, as recommended by Carretta and Ree (2001); Carroll (1993, 1995, 1997, 2003); Gustafsson and Snow (1997); McClain (1996); Ree et al. (2003); and Thompson (2004). These analyses were necessary for test users to consider the adequacy of different available WAIS–IV scores as well as convergence or divergence of CFA and EFA results. These analyses were also necessary to help determine

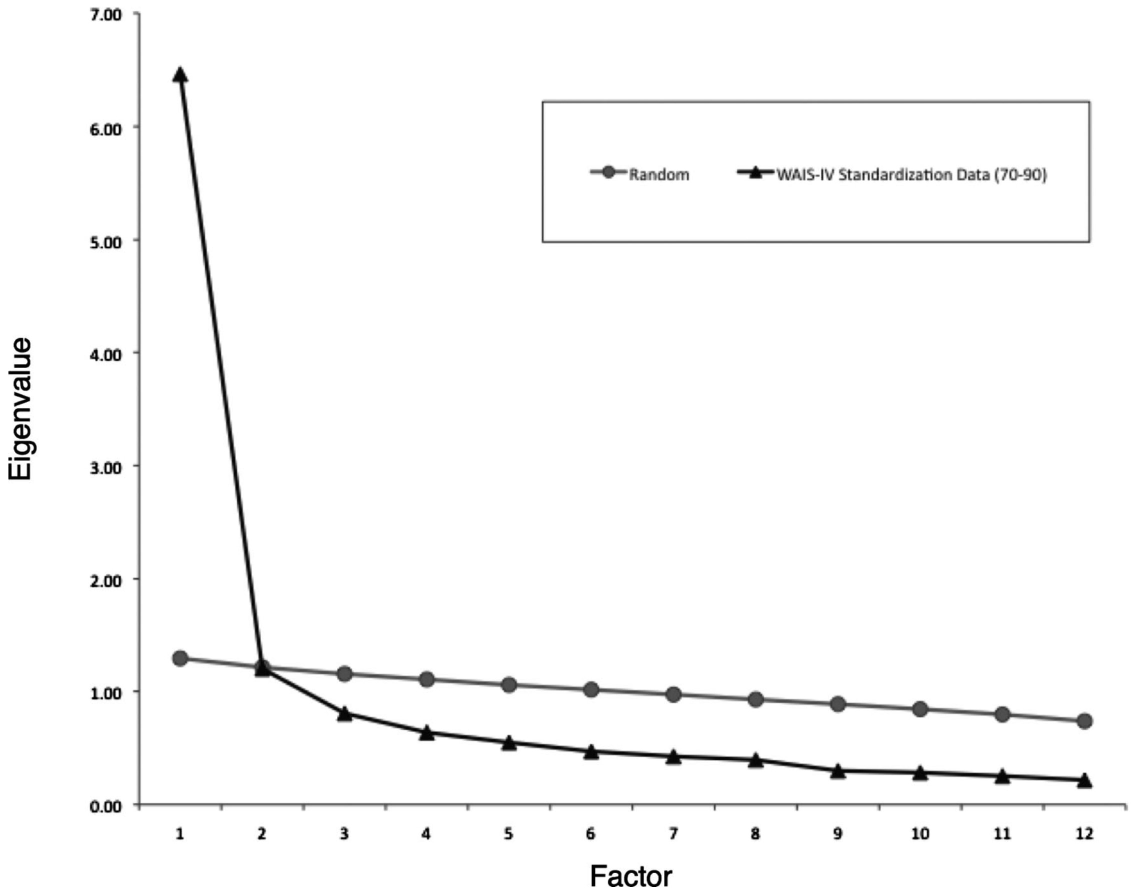

Figure 3. Scree plots for Horn's parallel analysis for the Wechsler Adult Intelligence Scale—Fourth Edition (WAIS–IV; Wechsler, 2008a) standardization sample ages 70–90 years and the 10 core and two supplemental subtests.

whether the factor index scores should be the primary level of clinical interpretation, as claimed in the WAIS–IV Technical and Interpretive Manual.

The present study found that when considering multiple factor-extraction criteria across the three principal WAIS–IV configurations (10, 12, and 15 subtests), only the SE_{Scree} for the 15-subtest configuration supported extraction of four factors. All other criteria and configurations suggested only one or two factors, which is consistent with results obtained by Frazier and Youngstrom (2007) and illustrated divergence from CFA results presented in the WAIS–IV Technical and Interpretive Manual. Consistent with studies of the WISC–IV (Bodin et al., 2009; Watkins, 2006; Watkins et al., 2006), RIAS (Dombrowski et al., 2009; Nelson et al., 2007), and WRIT and WASI (Canivez et al., 2009), the present study also found that although WAIS–IV subtests were properly aligned with the theoretically proposed factors, the second-order *g* factor accounted for the greatest portions of total and common variance. The modest portions of variance apportioned to the

Table 1
Number of Factors Suggested for Extraction Across Five Different Criteria

	Number of WAIS–IV factors suggested		
Extraction criterion	10 subtests ages 16–90	15 subtests ages 16–69	12 subtests ages 70–90
Eigenvalue > 1	2	2	2
Visual scree test	1	1–2	1–2
Standard error of scree (SE_{Scree})	2	4	2
Horn's parallel analysis (HPA)	1	2	1
Minimum average partials (MAP)	1	2	2

Note. WAIS–IV = Wechsler Adult Intelligence Scale—Fourth Edition (Wechsler, 2008a).

Table 2
Sources of Variance in the WAIS–IV Normative Sample (Ages 16:0–90:11; N = 2,200) 10 Core Subtests According to an Orthogonalized Higher Order Factor Model

WAIS–IV subtest	General		VC		PR		WM		PS			
	b	$\%S^2$	b	$\%S^2$	b	$\%S^2$	b	$\%S^2$	b	$\%S^2$	h^2	u^2
SI	0.67	45	**0.49**	**24**	0.02	0	−0.02	0	0.01	0	0.69	0.31
VO	0.70	49	**0.56**	**31**	−0.05	0	0.01	0	0.01	0	0.81	0.19
IN	0.65	42	**0.46**	**21**	0.05	0	−0.02	0	−0.02	0	0.63	0.37
BD	0.66	44	−0.01	0	**0.42**	**18**	−0.03	0	0.03	0	0.62	0.38
MR	0.66	44	0.08	1	**0.22**	**5**	0.08	1	0.04	0	0.50	0.50
VP	0.64	41	−0.01	0	**0.44**	**19**	−0.03	0	−0.02	0	0.61	0.39
DS	0.68	46	−0.02	0	−0.04	0	**0.43**	**18**	0.04	0	0.65	0.35
AR	0.74	55	0.14	2	0.07	0	**0.24**	**6**	0.00	0	0.63	0.37
SS	0.54	29	0.00	0	0.02	0	−0.02	0	**0.58**	**34**	0.63	0.37
CD	0.58	34	0.06	0	−0.05	0	0.03	0	**0.54**	**29**	0.64	0.36
% Total S^2		42.9		8.0		4.3		2.5		6.3	64.0	36.0
% Common S^2		67.0		12.4		6.8		3.9		9.9		

Note. WAIS–IV = Wechsler Adult Intelligence Scale—Fourth Edition (Wechsler, 2008a); b = loading of subtest on factor; S^2 = variance explained; h^2 = communality; u^2 = uniqueness; VC = Verbal Comprehension factor; PR = Perceptual Reasoning factor; WM = Working Memory factor; PS = Processing Speed factor; SI = Similarities; VO = Vocabulary; IN = Information; BD = Block Design; MR = Matrix Reasoning; VP = Visual Puzzles; DS = Digit Span; AR = Arithmetic; SS = Symbol Search; CD = Coding. Bold type indicates coefficients and variance estimates consistent with the theoretically proposed factor.

WAIS–IV first-order factors may be too small to be of clinical importance despite their CFA support.

Present results also closely parallel those of Watkins (2006) and Watkins et al. (2006) with the WISC–IV, where among the first-order factors, the VC factor accounted for the most additional variance followed by PS. The PR and WM factors accounted for smaller portions of common and total variance. In contrast to the WISC–IV (Watkins, 2006; Watkins et al., 2006), the WAIS–IV first-order factors capture somewhat greater portions of common and total variance. Whether the WAIS–IV factors capture enough variance to be of clinical importance remains to be seen and should be the focus of future research.

The WAIS–IV appears to be an excellent measure of general intelligence with exemplary norms, but divergence was observed in the present EFA results and CFA results reported in the Technical and Interpretive Manual. Canivez et al. (2009) noted that

Table 3
Sources of Variance in the WAIS–IV Normative Sample (Ages 16:0–69:11; N = 1,800) 10 Core and Five Supplemental Subtests According to an Orthogonalized Higher Order Factor Model

WAIS–IV subtest	General		VC		PR		WM		PS			
	b	$\%S^2$	b	$\%S^2$	b	$\%S^2$	b	$\%S^2$	b	$\%S^2$	h^2	u^2
SI	0.67	44	**0.49**	**24**	0.02	0	−0.02	0	0.01	0	0.68	0.32
VO	0.69	48	**0.56**	**32**	−0.05	0	0.01	0	0.01	0	0.80	0.20
IN	0.64	40	**0.46**	**21**	0.05	0	−0.02	0	−0.02	0	0.62	0.38
CO	0.67	44	**0.50**	**25**	0.01	0	0.00	0	−0.01	0	0.69	0.31
BD	0.68	46	−0.01	0	**0.42**	**18**	−0.03	0	0.03	0	0.63	0.37
MR	0.66	43	0.08	1	**0.22**	**5**	0.08	1	0.04	0	0.49	0.51
VP	0.66	44	−0.01	0	**0.44**	**19**	−0.03	0	−0.02	0	0.63	0.37
FW	0.71	50	0.09	1	**0.26**	**7**	0.12	1	−0.07	0	0.59	0.41
PCm	0.54	29	0.05	0	**0.25**	**6**	−0.04	0	0.13	2	0.38	0.62
DS	0.70	49	−0.02	0	−0.04	0	**0.43**	**19**	0.04	0	0.68	0.32
AR	0.72	52	0.14	2	0.07	1	**0.24**	**6**	0.00	0	0.60	0.40
LN	0.67	45	0.00	0	−0.01	0	**0.39**	**16**	0.00	0	0.60	0.40
SS	0.52	27	0.00	0	0.02	0	−0.02	0	**0.58**	**34**	0.61	0.39
CD	0.54	29	0.06	0	−0.05	0	0.03	0	**0.54**	**29**	0.59	0.41
CA	0.42	18	−0.08	1	0.08	1	0.03	0	**0.38**	**14**	0.33	0.67
% Total S^2		40.6		7.1		3.8		2.8		5.3	59.6	40.4
% Common S^2		68.1		11.8		6.3		4.8		8.9		

Note. WAIS–IV = Wechsler Adult Intelligence Scale—Fourth Edition (Wechsler, 2008a); b = loading of subtest on factor; S^2 = variance explained; h^2 = communality; u^2 = uniqueness; VC = Verbal Comprehension factor; PR = Perceptual Reasoning factor; WM = Working Memory factor; PS = Processing Speed factor; SI = Similarities; VO = Vocabulary; IN = Information; CO = Comprehension; BD = Block Design; MR = Matrix Reasoning; VP = Visual Puzzles; FW = Figure Weights; PCm = Picture Completion; DS = Digit Span; AR = Arithmetic; LN = Letter-Number Sequencing; SS = Symbol Search; CD = Coding; CA = Cancellation. Bold type indicates coefficients and variance estimates consistent with the theoretically proposed factor.

Table 4
Sources of Variance in the WAIS–IV Normative Sample (Ages 70:0–90:11; N = 400) 10 Core and Two Supplemental Subtests According to an Orthogonalized Higher Order Factor Model

WAIS–IV subtest	General		VC		PR		WM		PS			
	b	$\%S^2$	b	$\%S^2$	b	$\%S^2$	b	$\%S^2$	b	$\%S^2$	h^2	u^2
SI	0.73	53	**0.47**	**22**	0.08	1	−0.08	1	0.00	0	0.77	0.23
VO	0.70	49	**0.53**	**28**	−0.03	0	−0.02	0	0.00	0	0.77	0.23
IN	0.69	48	**0.42**	**18**	−0.02	0	0.09	1	−0.01	0	0.66	0.34
CO	0.68	46	**0.47**	**22**	−0.04	0	0.04	0	0.00	0	0.69	0.31
BD	0.67	45	0.02	0	**0.35**	**12**	0.02	0	0.01	0	0.57	0.43
MR	0.68	46	0.15	2	**0.24**	**6**	0.02	0	0.02	0	0.54	0.46
VP	0.63	40	−0.07	0	**0.46**	**21**	−0.01	0	−0.03	0	0.61	0.39
PCm	0.61	37	0.07	0	**0.20**	**4**	0.00	0	0.14	2	0.44	0.56
DS	0.65	42	0.07	0	0.05	0	**0.23**	**5**	0.15	2	0.51	0.49
AR	0.71	50	0.04	0	0.01	0	**0.54**	**29**	−0.04	0	0.80	0.20
SS	0.59	35	−0.04	0	0.01	0	0.00	0	**0.52**	**27**	0.62	0.38
CD	0.67	45	0.02	0	−0.01	0	−0.03	0	**0.58**	**34**	0.79	0.21
% Total S^2		44.7		7.8		3.7		3.0		5.4	64.7	35.3
% Common S^2		69.1		12.1		5.7		4.7		8.4		

Note. WAIS–IV = Wechsler Adult Intelligence Scale—Fourth Edition (Wechsler, 2008a); b = loading of subtest on factor; S^2 = variance explained; h^2 = communality; u^2 = uniqueness; VC = Verbal Comprehension factor; PR = Perceptual Reasoning factor; WM = Working Memory factor; PS = Processing Speed factor; SI = Similarities; VO = Vocabulary; IN = Information; CO = Comprehension; BD = Block Design; MR = Matrix Reasoning; VP = Visual Puzzles; PCm = Picture Completion; DS = Digit Span; AR = Arithmetic; SS = Symbol Search; CD = Coding. Bold type indicates coefficients and variance estimates consistent with the theoretically proposed factor.

factor analytic methods (CFA and EFA) cannot fully answer questions regarding validity, and because the latent constructs from CFA are not directly observable, *and* latent construct scores are difficult to calculate and not readily available, they offer no direct practical clinical application (Oh, Glutting, Watkins, Youngstrom, & McDermott, 2004). Additional methods are required to assess the relative importance of higher order versus lower order interpretation. For example, studies of WAIS–IV incremental predictive validity (Hunsley, 2003; Hunsley & Meyer, 2003) would be particularly informative and should be examined to determine if first-order factor scores provide important prediction of external criteria such as academic achievement, training success, and job performance beyond that predicted by the second-order Full Scale score. When academic achievement was the criterion, the incremental predictive validity of the WISC–III (Glutting et al., 1997) and WISC–IV (Glutting et al., 2006) were not favorable, but at present, no such incremental validity studies of the WAIS–IV are available. Another useful method of investigation would be to examine the diagnostic utility of factor index scores versus the second-order Full Scale score in correctly identifying individuals from different independently created diagnostic groups. If the small amounts of apportioned variance of WAIS–IV first-order factors observed in the present Schmid and Leiman (1957) analyses are able to account for meaningful portions of achievement variance beyond the second-order *g* factor or correctly differentiate individuals within different diagnostic groups beyond that provided by the Full Scale score, then the WAIS–IV factor scores may have clinical utility. Until then, interpretation of WAIS–IV scores should focus primarily on the Full Scale score, and extreme caution should be applied if moving to interpretations beyond the FSIQ.

One final comment regarding interpretation of WAIS–IV scores seems relevant in the present context and relates to the 15- and 12-subtest configurations. Although CFA (Wechsler, 2008b) and present EFA procedures examined these configurations, clinicians do not typically use 15- or 12-subtest WAIS–IV configurations. The five supplemental subtests for 16- to 69-year-olds and the two supplemental subtests for 70- to 90-year-olds are generally used only when replacing core subtests. Thus, although theoretical support is claimed for CFA results of the 15- and 12-subtest configurations, there is no provision for analysis and interpretation when all available subtests are administered (Wechsler, 2008b). Thus, results from the 10 core subtests seem most germane to clinical application and present results suggest interpretation focus on the FSIQ.

References

Bodin, D., Pardini, D. A., Burns, T. G., & Stevens, A. B. (2009). Higher order factor structure of the WISC–IV in a clinical neuropsychological sample. *Child Neuropsychology, 15,* 417–424.

Bracken, B. A., & McCallum, R. S. (1998). *Universal Nonverbal Intelligence Test: Examiners manual.* Itasca, IL: Riverside.

Canivez, G. L. (2008). Hierarchical factor structure of the Stanford-Binet Intelligence Scales—Fifth Edition. *School Psychology Quarterly, 23,* 533–541.

Canivez, G. L., Konold, T. R., Collins, J. M., & Wilson, G. (2009). Construct validity of the Wechsler Abbreviated Scale of Intelligence and Wide Range Intelligence Test: Convergent and structural validity. *School Psychology Quarterly, 24,* 252–265.

Carretta, T. R., & Ree, J. J. (2001). Pitfalls of ability research. *International Journal of Selection and Assessment, 9,* 325–335.

Carroll, J. B. (1993). *Human cognitive abilities.* Cambridge, England: Cambridge University Press.

Carroll, J. B. (1995). On methodology in the study of cognitive abilities. *Multivariate Behavioral Research, 30,* 429–452.

Carroll, J. B. (1997). Theoretical and technical issues in identifying a factor of general intelligence. In B. Devlin, S. E. Fienberg, D. P. Resnick, & K.

Roeder (Eds.), *Intelligence, genes, and success: Scientists respond to the bell curve* (pp. 125–156). New York, NY: Springer-Verlag.

Carroll, J. B. (2003). The higher-stratum structure of cognitive abilities: Current evidence supports *g* and about ten broad factors. In H. Nyborg (Ed.), *The scientific study of general intelligence: Tribute to Arthur R. Jensen* (pp. 5–21). New York, NY: Pergamon Press.

Cattell, R. B. (1966). The scree test for the number of factors. *Multivariate Behavioral Research, 1,* 245–276.

Cattell, R. B., & Horn, J. L. (1978). A check on the theory of fluid and crystallized intelligence with description of new subtest designs. *Journal of Educational Measurement, 15,* 139–164.

Cudeck, R. (2000). Exploratory factor analysis. In H. E. A. Tinsley & S. D. Brown (Eds.), *Handbook of multivariate statistics and mathematical modeling* (pp. 265–296). New York, NY: Academic Press.

DiStefano, C., & Dombrowski, S. C. (2006). Investigating the theoretical structure of the Stanford-Binet—Fifth Edition. *Journal of Psychoeducational Assessment, 24,* 123–136.

Dombrowski, S. C., Watkins, M. W., & Brogan, M. J. (2009). An exploratory investigation of the factor structure of the Reynolds Intellectual Assessment Scales (RIAS). *Journal of Psychoeducational Assessment, 27,* 494–507.

Elliott, C. D. (1990). *Differential Ability Scales.* San Antonio, TX: The Psychological Corporation.

Elliott, C. D. (2007). *Differential Ability Scales—Second Edition: Introductory and technical handbook.* San Antonio, TX: The Psychological Corporation.

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods, 4,* 272–299.

Frazier, T. W., & Youngstrom, E. A. (2007). Historical increase in the number of factors measured by commercial tests of cognitive ability: Are we overfactoring? *Intelligence, 35,* 169–182.

Glutting, J. J., Adams, W., & Sheslow, D. (2000a). *Wide Range Intelligence Test.* Wilmington, DE: Wide Range.

Glutting, J. J., Adams, W., & Sheslow, D. (2000b). *Wide Range Intelligence Test: Manual.* Wilmington, DE: Wide Range.

Glutting, J. J., Watkins, M. W., Konold, T. R., & McDermott, P. A. (2006). Distinctions without a difference: The utility of observed versus latent factors from the WISC–IV in estimating reading and math achievement on the WIAI–II. *Journal of Special Education, 40,* 103–114.

Glutting, J. J., Youngstrom, E. A., Ward, T., Ward, S., & Hale, R. (1997). Incremental efficacy of WISC–III factor scores in predicting achievement: What do they tell us? *Psychological Assessment, 9,* 295–301.

Gorsuch, R. L. (1983). *Factor analysis* (2nd ed.). Hillsdale, NJ: Erlbaum.

Gorsuch, R. L. (2003). Factor analysis. In J. A. Schinka & F. F. Velicer (Eds.), *Handbook of psychology: Vol. 2. Research methods in psychology* (pp. 143–164). Hoboken, NJ: Wiley.

Gustafsson, J.-E., & Snow, R. E. (1997). Ability profiles. In R. F. Dillon (Ed.), *Handbook on testing* (pp. 107–135). Westport, CT: Greenwood Press.

Guttman, L. (1954). Some necessary and sufficient conditions for common factor analysis. *Psychometrika, 19,* 149–161.

Horn, J. L. (1965). A rationale and test for the number of factors in factor analysis. *Psychometrika, 30,* 179–185.

Horn, J. L. (1991). Measurement of intellectual capabilities: A review of theory. In K. S. McGrew, J. K. Werder, & R. W. Woodcock (Eds.), *Woodcock-Johnson technical manual* (rev. ed., pp. 197–232). Itasca, IL: Riverside.

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

Hunsley, J. (2003). Introduction to the special section on incremental validity and utility in clinical assessment. *Psychological Assessment, 15,* 443–445.

Hunsley, J., & Meyer, G. J. (2003). The incremental validity of psychological testing and assessment: Conceptual, methodological, and statistical issues. *Psychological Assessment, 15,* 446–455.

Kaufman, A. S., & Kaufman, N. L. (1993). *Kaufman Adolescent and Adult Intelligence Test.* Circle Pines, MN: American Guidance Service.

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman Assessment Battery for Children—Second Edition.* Circle Pines, MN: American Guidance Service.

Lautenschlager, G. J. (1989). A comparison of alternatives to conducting Monte Carlo analyses for determining parallel analysis criteria. *Multivariate Behavioral Research, 24,* 365–395.

McClain, A. L. (1996). Hierarchical analytic methods that yield different perspectives on dynamics: Aids to interpretation. *Advances in Social Science Methodology, 4,* 229–240.

McGrew, K. S., & Woodcock, R. W. (2001). *Technical manual: Woodcock-Johnson III.* Itasca, IL: Riverside.

Naglieri, J. A., & Das, J. P. (1997). *Cognitive Assessment System: Interpretive handbook.* Itasca, IL: Riverside.

Nasser, F., Benson, J., & Wisenbaker, J. (2002). The performance of regression-based variations of the visual scree for determining the number of common factors. *Educational and Psychological Measurement, 62,* 397–419.

Nelson, J. M., Canivez, G. L., Lindstrom, W., & Hatt, C. (2007). Higher-order exploratory factor analysis of the Reynolds Intellectual Assessment Scales with a referred sample. *Journal of School Psychology, 45,* 439–456.

O'Connor, B. P. (2000). SPSS and SAS programs for determining the number of components using parallel analysis and Velicer's MAP test. *Behavior Research Methods, Instruments, & Computers, 32,* 396–402.

Oh, H. J., Glutting, J. J., Watkins, M. W., Youngstrom, E. A., & McDermott, P. A. (2004). Correct interpretation of latent versus observed abilities: Implications from structural equation modeling applied to the WISC–III and WIAT linking sample. *Journal of Special Education, 38,* 159–173.

Psychological Corporation. (1999). *Wechsler Abbreviated Scale of Intelligence.* San Antonio, TX: Author.

Ree, M. J., Carretta, T. R., & Green, M. T. (2003). The ubiquitous role of *g* in training. In H. Nyborg (Ed.), *The scientific study of general intelligence: Tribute to Arthur R. Jensen* (pp. 262–274). New York, NY: Pergamon Press.

Reynolds, C. R., & Kamphaus, R. W. (2003). *Reynolds Intellectual Assessment Scales.* Lutz, FL: Psychological Assessment Resources.

Roid, G. (2003a). *Stanford-Binet Intelligence Scales: Fifth Edition.* Itasca, IL: Riverside.

Roid, G. (2003b). *Stanford-Binet Intelligence Scales: Fifth Edition, Technical Manual.* Itasca, IL: Riverside.

Schmid, J., & Leiman, J. M. (1957). The development of hierarchical factor solutions. *Psychometrika, 22,* 53–61.

Snook, S. C., & Gorsuch, R. L. (1989). Component analysis vs. common factor analysis: A Monte Carlo study. *Psychological Bulletin, 106,* 148–154.

Spearman, C. (1904). "General intelligence": Objectively determined and measured. *American Journal of Psychology, 15,* 201–293.

Spearman, C. (1927). *The abilities of man.* New York, NY: Cambridge.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). Boston, MA: Pearson Education.

Thompson, B. (2004). *Exploratory and confirmatory factor analysis: Understanding concepts and applications.* Washington, DC: American Psychological Association.

Thompson, B., & Daniel, L. G. (1996). Factor analytic evidence for the construct validity of scores: A historical overview and some guidelines. *Educational and Psychological Measurement, 56,* 197–208.

Velicer, W. F. (1976). Determining the number of components from the matrix of partial correlations. *Psychometrika, 31,* 321–327.

Velicer, W. F., Eaton, C. A., & Fava, J. L. (2000). Construct explication through factor or component analysis: A view and evaluation of alternative procedures for determining the number of factors or components. In R. D. Goffin & E. Helmes (Eds.), *Problems and solutions in human assessment: A festschrift to Douglas Jackson at seventy* (pp. 41–71). Norwell, MA: Kluwer Academic.

Watkins, M. W. (2000). *Monte Carlo PCA for parallel analysis* [Computer Software]. State College, PA: Author.

Watkins, M. W. (2004). *MacOrtho.* [Computer Software]. State College, PA: Author.

Watkins, M. W. (2006). Orthogonal higher order structure of the Wechsler Intelligence Scale for Children—Fourth Edition. *Psychological Assessment, 18,* 123–125.

Watkins, M. W. (2007). *SEscree* [Computer software]. State College, PA: Ed & Psych Associates.

Watkins, M. W., Wilson, S. M., Kotz, K. M., Carbone, M. C., & Babula, T. (2006). Factor structure of the Wechsler Intelligence Scale for Children—Fourth Edition among referred students. *Educational and Psychological Measurement, 66,* 975–983.

Wechsler, D. (1939a). *The measurement of adult intelligence.* Baltimore, MD: Williams & Wilkins.

Wechsler, D. (1939b). *Wechsler Bellevue Intelligence Scale.* New York, NY: The Psychological Corporation.

Wechsler, D. (1991). *Manual for the Wechsler Intelligence Scale for Children—Third Edition*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2002a). *WAIS–III/WMS–III technical manual, updated.* San Antonio, TX: Psychological Corporation.

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

Wechsler, D. (2003a). *Wechsler Intelligence Scale for Children—Fourth Edition*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2003b). *Wechsler Intelligence Scale for Children—Fourth Edition: Technical and interpretive manual*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2008a). *Wechsler Adult Intelligence Scale—Fourth Edition.* San Antonio, TX: Pearson.

Wechsler, D. (2008b). *Wechsler Adult Intelligence Scale—Fourth Edition: Technical and interpretive manual.* San Antonio, TX: Pearson.

Wechsler, D., & Naglieri, J. A. (2006). *Wechsler Nonverbal Scale of Ability: Technical and interpretive manual.* San Antonio, TX: The Psychological Corporation.

Zoski, K. W., & Jurs, S. (1996). An objective counterpart to the visual scree test for factor analysis: The standard error scree. *Educational and Psychological Measurement, 56,* 443–451.

Zwick, W. R., & Velicer, W. F. (1986). Comparison of five rules for determining the number of components to retain. *Psychological Bulletin, 117,* 253–269.

Received February 3, 2010
Revision received April 29, 2010
Accepted May 18, 2010 ■

Online First Publication

APA-published journal articles are now available Online First in the PsycARTICLES database. Electronic versions of journal articles will be accessible prior to the print publication, expediting access to the latest peer-reviewed research.

All PsycARTICLES institutional customers, individual APA PsycNET® database package subscribers, and individual journal subscribers may now search these records as an added benefit. Online First Publication (OFP) records can be released within as little as 30 days of acceptance and transfer into production, and are marked to indicate the posting status, allowing researchers to quickly and easily discover the latest literature. OFP articles will be the version of record; the articles have gone through the full production cycle except for assignment to an issue and pagination. After a journal issue's print publication, OFP records will be replaced with the final published article to reflect the final status and bibliographic information.