

**Measurement Invariance of the Wechsler Intelligence Scale for Children, Fifth Edition 10
Subtest Primary Battery: Can index scores be compared cross age, sex and diagnostic
groups?**

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Abstract

Measurement invariance of the Wechsler Intelligence Scale for Children, Fifth Edition (WISC–V) ten subtest primary battery was evaluated across sex, age (6-8, 9-11, 12-14, 15-16 year-olds), and three diagnostic (ADHD, anxiety, encephalopathy) groups within a large clinical sample ($N = 5,359$) referred to a children’s specialty hospital. Competing models were tested using confirmatory factor analysis (CFA), and a five-factor oblique model corresponding to the publisher’s hypothesized first-order measurement model (e.g., Verbal Comprehension, Fluid Reasoning, Visual-Spatial, Working Memory, and Processing Speed) was found to have the best model fit. Multigroup CFA was subsequently used to evaluate progressively more restrictive constraints on the measurement model. Results indicated full metric invariance was attained across the three groups studied. Full scalar invariance was attained for sex and diagnostic groups. Partial scalar invariance was attained for age group. The results of this study provide support for the first-order scoring structure of the five WISC-V factors in the ten subtest primary battery with this large clinical sample.

Keywords: WISC–V, measurement invariance, multigroup confirmatory factor analysis

**Measurement Invariance of the Wechsler Intelligence Scale for Children, Fifth Edition 10-
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groups?**

Measurement invariance is an important but often underutilized aspect of construct validation for cognitive ability instruments. It assists in determining whether the measurement model holds across different groups nested within a broader target population being studied and, ultimately, whether resulting index/composite scores can be confidently interpreted across groups in the same way, if at all (Meredith, 1993). Measurement invariance may be conceptualized as a more technical extension of structural validity. Instead of focusing on a single group as occurs in traditional exploratory and confirmatory factor analysis (see Dombrowski et al., 2018a, 2018b for example), it works by constraining selected parameters to equality, permitting a ‘stress test’ on various elements of an instrument’s structure across the groups studied with the ultimate goal of determining whether an instrument’s scores may be compared among those groups. The most common way to assess measurement invariance is through multigroup confirmatory factor analysis (MGCFA; Davidov et al., 2014). In MGCFA, models are fitted to data using different sets of constraints corresponding to different levels or types of invariance. Researchers typically differentiate among three levels of measurement invariance that are sufficient for conducting most comparative data analyses: configural, metric, and scalar invariance (Vandenberg & Lance, 2000; see Meredith, 1993 for additional, more restrictive levels that are not commonly applied).

After a plausible baseline measurement model is identified, the first step in MGCFA is to determine whether the pattern of the loadings is the same across groups (configural invariance).

Once these constraints are applied and no meaningful attenuation in representative fit statistics is observed, it can be reasonably concluded that the test has equal form (or configuration) across groups. Once equal form is established, the equivalence of the magnitude of the loadings is evaluated (metric invariance). Within the assessment literature, metric invariance is frequently referred to as a form of *weak* invariance (Putnick & Bornstein, 2016). Finally, the latent intercepts are evaluated to determine whether they are equivalent across groups (scalar invariance). If so, then an instrument is thought to have attained *strong* invariance (Putnick & Bornstein, 2016) and the factor scores may be confidently interpreted across groups.

Invariance analyses have been conducted on the Wechsler Intelligence Scale for Children–Fifth Edition (WISC–V; Wechsler, 2014a) using the 16 primary and secondary subtests normative sample data to determine equivalence of age and sex (*sic.*, gender) in both US standardization samples (e.g., Reynolds & Keith, 2017; Scheiber, 2016a) and international samples (e.g., Chen et al., 2020; Pauls et al., 2019). However, only one invariance study has been conducted on the 10 primary subtest battery. Specifically, Graves et al. (2020) investigated invariance of the 10 primary subtest battery in a predominantly African-American sample and found that the structure failed to attain full metric invariance. The lack of analyses on the 10 primary subtest battery is noteworthy considering that it contains the most frequently administered group of subtests by practitioners (Benson et al., 2019). Additionally, analyses on referred clinical samples (e.g., ADHD, anxiety, brain injury) are important but rarely investigated (Chen et al., 2020). Children referred for evaluation of suspected disability are the ones most frequently administered tests of cognitive ability; and there are frequent calls for analyses with clinical samples (Chen et al., 2020; Graves et al., 2020). However, such analyses are less available in the literature. Accordingly, the purpose of this study was to investigate the

measurement invariance of the ten primary WISC–V subtests across sex (male/female), diagnostic group (ADHD, anxiety, and encephalopathy¹), and four age groups (6-8, 9-11, 12-14, 15-16 year-olds) with a large clinical sample.

Method and Data Analyses

A total of 5,359 children between the ages of 6 and 16 years were administered the 10 WISC–V primary subtests as part of clinical assessments completed at a large outpatient clinical psychology/neuropsychology clinic in a children’s specialty hospital. De-identified data from completed clinical evaluations were retrieved from the electronic medical record database following approval by the hospital’s Institutional Review Board as well as representative university equivalents. The sample was primarily composed of White/Caucasian and Black/African American youth (Table 1). Three diagnostic groups (ADHD, 47.6%; anxiety, 11.6%; and encephalopathy, e.g., non-traumatic diffuse brain dysfunction; 10.1%) comprised just over two-thirds of the sample (Table 2). The participants’ ages ranged from 6.0 to 16.93 years ($M = 10.69$, $SD = 2.74$). Compared with the U.S. standardization sample, this sample was slightly below average in subtest and composite scores, as is typical in clinical samples (Table 3). All subtest and composite scores showed univariate normal distributions with no appreciable skewness or kurtosis. However, Mardia’s (1970) multivariate estimates for the sample (Skewness = 1.344; Kurtosis = 125.128) indicated significant ($p < .0001$) multivariate nonnormality (Cain et al., 2017).

Mplus version 8.4 (Muthen & Muthen, 1998-2017) was used to estimate all baseline comparison and multiple group confirmatory factor analysis (CFA) models. The robust maximum likelihood estimator (i.e., Satorra & Bentler, 1988) that adjusts for non-normality was

¹ Encephalopathy is a generic category that includes brain injury of a diffuse but non-traumatic nature.

used to calculate estimates and corrected fit indices. The first-order five factor measurement model (nested within the higher order Model 5e, Fig. 5.2, Wechsler, 2014b, p. 84) for the WISC–V was tested against competing models (see Table 4). Once a baseline model was established, it was separately fit to each group to ensure model adequacy. Subsequently, a series of progressively restrictive constraints were applied on sets of model parameters to determine equivalence across sex (male/female), diagnostic group (ADHD, anxiety, and encephalopathy), and age group (6-8, 9-11, 12-14, 15-16 year-olds). Initially, the equivalence of the WISC–V across the instrument’s structure (configural invariance) was investigated. No between group parameter constraints were imposed other than those fixed to a value (i.e., setting the scale [1.0]) to adequately identify the model. Between group constraints were then imposed on all factor loadings except for the loadings on the referent indicator in each group (metric invariance), which were set to 1.0. In scalar specification, the intercepts were constrained to equality while the factor mean was fixed to zero in the first group but was allowed to be freely estimated in other groups. Differences to reject invariance across all specifications were $\Delta CFI \leq .01$, $\Delta RMSEA \leq .015$ for both factor loadings and intercepts, and $\Delta SRMR \leq .03$ for factor loadings and $\leq .01$ for intercepts (Chen, 2007; Cheung & Rensvold, 2002).

Results

Comparison of baseline models (Table 4) suggested that an oblique five-factor first-order model, corresponding to the first-order WISC–V measurement structure (see Figure 1), provided the best statistical fit ($S-B\chi^2(25) = 222.2, p < .05; CFI = 0.993$) to these data. In addition to having the best model fit among the competing models, the oblique five-factor model was selected on the basis that it is the model that guided how the test publisher recommends the instrument is scored and interpreted and subsequently how the majority of psychologists *actually*

interpret the test in practice (Benson et al., 2019). There is another essential point. Although the publisher preferred theoretical model is a conventional higher-order model where the influence of general intelligence on the measured variables is fully mediated through the first-order group factors, the scoring structure of the WISC-V primary subtests does not reflect this model: only 7 of 10 subtest load the general factor, while all 10 subtests contribute to their respective group factors. Since a general intelligence factor is fully mediated through group factors this model cannot be readily evaluated using higher-order factor analysis. Thus, the test publisher never fully examined its promoted scoring structure for the WISC-V 10 primary subtest battery, nor has it ever been evaluated in the extant literature until this study. A bifactor approach can model this structure albeit in a slightly different form than the bifactor models that have been previously investigated in the literature (see Table 4, “bifactor 5 score” for fit indices results).

The fit of the confirmatory factor analytic models for the sex, age, and diagnostic groups demonstrated that all single group models fit roughly equivalently to the total sample model (see Table 4). Model fit indices and statistics for progressively constrained models are presented in Table 5. The configural model fit these data well across sex, age, and diagnostic group with no appreciable loss in model fit. When the more restrictive metric constraints were applied, there was also no loss in discernable model fit across all three groups that were evaluated ([sex] Δ CFI = .000; Δ SRMR = .002; Δ RMSEA = .001; Δ AIC = 000; [age] Δ CFI = .005; Δ SRMR = .019; Δ RMSEA = .008; Δ AIC = -129; [diagnostic group] Δ CFI = .000; Δ SRMR = -.002; Δ RMSEA = .000; Δ AIC = 001). Constraining intercepts to equality indicated that the diagnostic group (Δ CFI = .005; Δ SRMR = .019; Δ RMSEA = .008) and the sex group (Δ CFI = .005; Δ SRMR = .019; Δ RMSEA = .008) met the threshold for scalar invariance. The age group (Δ CFI = .014; Δ SRMR = .024; Δ RMSEA = .020) did not. Inspection of modification indices suggested that the Fluid

Reasoning subtests intercepts were problematic causing the lack of full scalar invariance. This was similarly found in a study that investigated invariance of the WISC-V in referred black/white sample (Graves et al., 2020). Partial scalar invariance was subsequently achieved by freeing the Figure Weights intercept which significantly improved overall model fit (see Table 5).

Discussion

Investigation of measurement invariance requires consideration of whether an instrument's factor structure, factor loadings, and intercepts are equivalent across groups when subjected to increasingly restrictive parameter constraints. The evaluation of invariance provides an opportunity to impose a psychometric stress test on the structure of an instrument (thereby further substantiating its structural validity beyond single group analyses, if attained). With scalar invariance specification, where constraints are placed on intercepts, invariance determines whether an instrument's scores (in this case the WISC-V index scores) may be compared and whether resulting scores are not confounded by an artifact of the measurement structure.

The consideration of invariance is important to aid in better understanding the WISC-V 10 subtest primary battery. It has been argued that the WISC-V primary battery theoretical structure was essentially extrapolated from the 16 subtest battery (Dombrowski et al., 2017). Thus, important information regarding the structure of the ten subtest WISC-V is less available.

The present study evaluated numerous competing models and found that the five-factor oblique model, which also reflects the instrument's scoring structure, had the best model fit (see Table 4) with this clinical sample. Invariance testing proceeded using this model as baseline. The results suggested that the WISC-V evidenced weak (metric) invariance across all groups (sex [male/female], age [6-8, 9-11, 12-14, 15-16], and diagnostic group [ADHD, anxiety,

encephalopathy]) investigated. An evaluation of the strong (scalar) specification suggested that both sex and diagnostic groups attained full scalar invariance while age groups attained partial scalar invariance. The finding of full or partial scalar invariance was consistent with previous research findings with the extended WISC-V 16 primary and secondary subtest battery (e.g., Chen et al., 2020; Pauls et al., 2019; Reynolds & Keith, 2017; Scheiber, 2016) and other intelligence tests including the KABC-II (Reynolds et al., 2015; Scheiber, 2017), WJ (Edwards & Oakland, 2006; Keith, 1999), and DAS (Keith et al., 1999). However, this is the first study to investigate invariance of the WISC-V 10 primary subtest battery across several groups (e.g., sex, age, and clinical diagnosis) with a referred sample more than double the size of the normative sample. The present study's conclusions are limited by a lack of comparison to the standardization sample². This would have offered another vantage from which to assess invariance.

Conclusion and Implications for Practice

The present results have implications for interpretation of the broader measurement model in clinical practice and suggest that individuals from different sex, age, and clinical groups may have their index scores confidently compared to one another (Rudnev et al., 2018). This conclusion is particularly important for the clinical comparison group. There have been recent calls for structural validity and invariance analyses within clinical groups (Chen et al., 2020; Graves et al., 2020) but rarely are data sets such as the one in the present study available. In this case, although three distinctly different clinical groups were available-- an externalizing disorder (i.e., ADHD), an internalizing disorder (i.e., anxiety), and a neurologically-based disorder (i.e., encephalopathy)-- the scoring structure was either fully or partially invariant and functions the

² Our request for the standardization sample data was denied by NCS Pearson, Inc. Invariance analyses, like the present study, are not included in the WISC-V *Technical and Interpretive Manual*.

same way regardless of sex, age, or clinical group. Stated another way, users of the WISC-V ten primary subtest battery can be more confident that a score obtained on one of the WISC-V indices is a function of performance by a group member and unrelated to statistical distortions in the measurement instrument due to age, sex, or clinical condition. In sum, the attainment of configural, metric, and scalar invariance across three different groups with this clinical sample lends evidentiary support for the viability of the WISC-V first-order factors in clinical practice and suggests that the 10 WISC-V primary subtest battery measures intended first-order constructs with this sample in the way proposed by the publisher.

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Table 1
Demographic characteristics of the clinical sample

Race/Ethnicity	N	Percent	Sex		
			Female	Male	Unknown
White	2865	53.50%	885	1764	216
Black	1513	28.20%	443	940	130
Multi-racial	376	7.00%	117	257	2
Unknown/Other	209	3.90%	40	100	69
Asian	191	3.60%	54	108	29
Hispanic/Spanish origin	190	3.50%	57	132	1
American Indian/Alaskan native	12	0.20%	5	7	0
Native Hawaiian or Pacific Islander	3	0.10%	1	0	1
Total	5359		1602	3308	448
Percent		100.00%	29.90%	61.70%	8.40%

Table 2
 Diagnostic categories of the clinical sample

<u>ICD-10 Diagnosis</u>	<u>N</u>	<u>Percent</u>
ADHD/ADD	2552	47.6%
Encephalopathy	620	11.6%
Anxiety	539	10.1%
Adjustment disorder	213	4.0%
Behavior disorder	213	4.0%
Epilepsy	140	2.6%
Mood disorder	133	2.5%
Congenital anomaly	112	2.1%
Genetic condition	112	2.1%
Frontal lobe deficit	100	1.9%
Disorder of the nervous system	76	1.4%
Major depression	69	1.3%
Brain/spine injury	43	0.8%
Neoplasm/Tumor	40	0.7%
Hearing loss	38	0.7%
Leukemia	38	0.7%
Unknown	37	0.7%
Other depressive disorder	30	0.6%
Autism spectrum disorder	25	0.5%
Cancer (not brain/nervous system)	23	0.4%
Emotional disturbance	16	0.3%
Expressive/receptive language disorder	13	0.2%
Fetal alcohol syndrome	13	0.2%
Bipolar disorder	11	0.2%
Other mental/psychological disorder	11	0.2%
Reading/learning disability	11	0.2%
Tic/Tourette's disorder	11	0.2%
Misc Medical/Psychiatric Conditions	120	2.2%
Total	5359	100.0%

Note. ICD = international classification of diseases, tenth edition; ADD = attention deficit disorder; ADHD = attention deficit/hyperactivity disorder

Table 3

Descriptive Statistics for the WISC-V Clinical Sample.

Total Sample (N = 5,359)				
Subtest/Composite	<i>M</i>	<i>SD</i>	Skewness	Kurtosis
<u>Subtests</u>				
Block Design	8.69	3.33	0.12	-0.17
Similarities	9.14	3.30	-0.02	-0.07
Matrix Reasoning	9.02	3.38	0.08	-0.10
Digit Span	7.96	3.10	0.11	0.07
Coding	7.57	3.33	-0.03	-0.37
Vocabulary	8.99	3.56	0.06	-0.53
Figure Weights	9.52	3.12	-0.03	-0.28
Visual Puzzles	9.58	3.29	-0.04	-0.43
Picture Span	8.55	3.12	0.14	-0.16
Symbol Search	8.21	3.23	0.00	0.03
<u>Composites</u>				
VCI	94.96	17.41	-0.04	-0.18
VSI	95.15	17.23	0.08	-0.06
FRI	95.80	16.77	0.02	-0.37
WMI	89.94	15.82	0.14	-0.13
PSI	88.10	17.10	-0.15	0.03
FSIQ	91.03	17.27	-0.00	0.04

Note. VCI = Verbal Comprehension Index, VSI = Visual Spatial Index, FRI = Fluid Reasoning Index, WMI = Working Memory Index, PSI = Processing Speed Index.

Table 4
Model Fit of Competing Models and Separate Groups

Model	S-B χ^2	df	CFI	Δ CFI	TLI	Δ TLI	SRMR	Δ SRMR	RMSEA	90% CI RMSEA	Δ RMSEA	AIC	Δ AIC	BIC	Δ BIC
Total Sample (<i>N</i> = 5,359)															
Oblique 5 factor	222.2	25	.993	-	.987	-	.013	-	.038	.034-.043	-	250034	-	250298	-
Oblique 4 factor	405.4	29	.987	.006	.979	.008	.018	.005	.049	.045-.054	.011	250218	184	250455	157
Higher Order 5 factor	836.6	30	.972	.021	.957	.030	.033	.020	.071	.069-.077	.033	250668	634	250899	601
Higher Order 4 factor	570.8	31	.981	.012	.972	.015	.025	.012	.057	.053-.061	.019	250386	352	250610	312
Bifactor 4 factor	425.4	28	.986	.007	.977	.010	.022	.009	.052	.047-.056	.018	250240	206	250484	186
Bifactor 5 factor score	6773.2	31	.762	.231	.655	.332	.293	.28	.202	.198-.207	.164	256651	6617	256875	6577
Bifactor 4 factor score	6688.2	31	.765	.228	.659	.328	.291	.28	.200	.196-.204	.162	256566	6532	256790	6492
Baseline – Oblique 5 factor Male (<i>n</i> = 3,307) and Female (<i>n</i> = 1,606)															
Oblique 5 factor Male	143.2	25	.993		.988		.013		.038	.032-.044		155160		155404	
Oblique 5 factor Female	84.5	25	.994		.988		.015		.038	.030-.048		74128		74343	
Baseline –Oblique 5 factor Age 6 to 8 (<i>n</i> =1735); Age 9 to 11 (<i>n</i> =1818); Age 12 to 14 (<i>n</i> =1367); Age 15 + (<i>n</i> =405)															
Oblique 5 Age 6-8	97.7	25	.991		.983		.018		.041	.033-.050		81949		82167	
Oblique 5 Age 9-11	101.3	25	.993		.987		.014		.041	.033-.049		84684		84904	
Oblique 5 Age 12-14	90.6	25	.992		.985		.014		.044	.034-.054		62630		62839	
Oblique 5 Age 15-16	34.5	25	.996		.994		.017		.031	.000-.054		18740		18900	
Baseline Oblique 5 factor – ADHD (<i>n</i> = 2,277); Anxiety (<i>n</i> = 484); Encephalopathy (<i>n</i> =541)															
Oblique 5 factor ADHD	86.8	25	.994		.990		.013		.033	.026-.041		105987		106216	
Oblique 5 factor Anxiety	21.5	25	1.00		1.000		.011		.000	.000-.030		22451		22618	
Oblique 5 factor Enceph.	63.1	25	.988		.979		.020		.053	.037-.070		25826		25998	

Note. Best index fit in bold. Δ in comparison to best fit in total sample. Fit of Higher Order and bifactor five factor models identical due to constraints imposed to identify bifactor model. The small number of indicators per factor makes it necessary to constrain loadings which, in turn, makes invariance tests of bifactor models not of the actual data but of a constrained version of the data. Bifactor 5 factor Score=Actual implied scoring structure of WISC-V where 7 subtests load g and 10 load the respective 5 factors. Bifactor 4 score=Same as BF 5 score except fluid reasoning and visual-spatial subtests fused to form perceptual reasoning factor. Enceph. = encephalopathy; WISC-V =Wechsler intelligence scale for children, fifth edition. CFI = comparative fit index; TLI = Tucker–Lewis index; SRMR = standardized root mean square residual; RMSEA = root mean square error of approximation; AIC = Akaike information criterion; BIC = Bayesian information criterion.

Table 5

Invariance of the Five Oblique WISC-5 Measurement Model – Gender, Age and Diagnostic Group Samples

Model	S-B χ^2	df	CFI	Δ CFI	TLI	Δ TLI	SRMR	Δ SRMR	RMSEA	90% CI RMSEA	Δ RMSEA	AIC	Δ AIC	BIC	Δ BIC
Invariance - Male ($n = 3,307$) vs Female ($n = 1,606$)															
Configural	237.6	50	.993	-	.987	-	.014	-	.039	.034-.044	-	229287	0	229807	-
Metric	246.8	55	.993	.000	.988	.001	.016	.02	.038	.033-.043	.001	229287	0	229774	-33
Scalar*	345.9	60	.989	.004	.984	.004	.017	.03	.044	.040-.049	.006	229376	89	229831	24
Invariance – Age 6 to 8 ($n = 1742$); 9 to 11 ($n=1823$); 12 to 14 ($n=1378$); and 15 to 16 ($n = 405$)															
Configural	327.5	100	.992	-	.986	-	.016	-	.041	.036-.046	-	249081	-	250134	-
Metric	490.2	115	.987	.005	.980	.006	.035	.019	.049	.045-.054	.008	249210	-129	250165	34
Scalar**	768.4	180	.978	.014	.969	.017	.040	.024	.061	.056-.065	.020	249462	-381	250318	184
Part Scalar ^a	592.2	127	.984	-.003	.977	-.003	.036	.001	.052	.048-.057	.003	249290	80	250165	0
Invariance— ADHD ($n=2277$); Anxiety ($n=484$); Encephalopathy ($n=541$)															
Configural	170.9	75	.994	-	.990	-	.016	-	.034	.027-.041		154264	-	154996	-
Metric	194.9	85	.994	.000	.990	.000	.014	-.002	.034	.027-.041	.000	154265	1	154936	-60
Scalar***	271.9	95	.990	.004	.985	.005	.023	.009	.041	.035-.047	.007	154324	59	154934	-2

Note. * Scalar vs. metric S-B $\Delta\chi^2$ (5) = 99.1, $p < .0001$.

** Scalar vs. metric S-B $\Delta\chi^2$ (15) = 279.2, $p < .0001$.

***Scalar vs. metric S-B $\Delta\chi^2$ (10) = 78.42, $p < .0001$.

^aFigure weights intercept freely estimated.

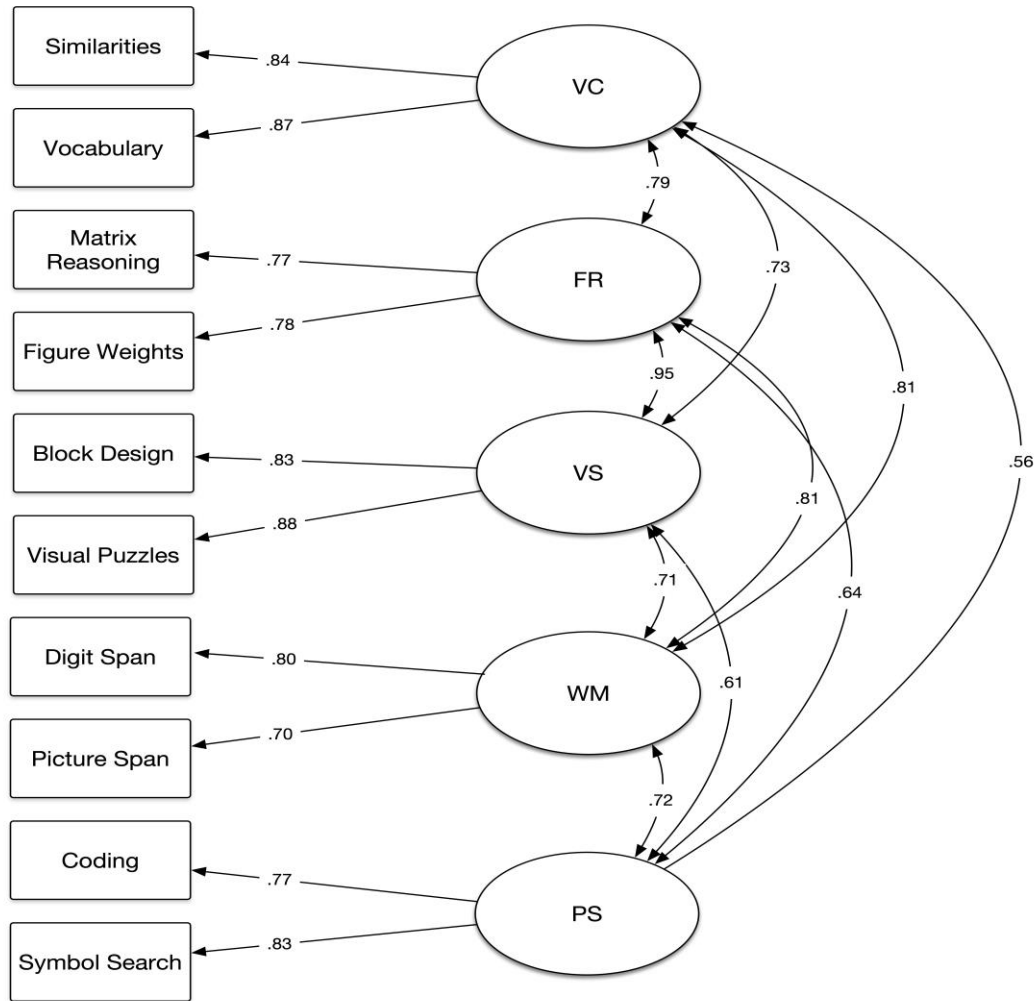


Figure 1. WISC-V Baseline Measurement Model Identified by the Present Clinical Sample.