Q-interactive® Special Group Studies: The WISC®–V and Children With Specific Learning Disorders in Reading or Mathematics

Q-interactive Technical Report 13

Susan Engi Raiford, PhD

Lisa Whipple Drozdick, PhD

Ou Zhang, PhD

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Introduction

This technical report describes the results of two special group studies tested using the *Wechsler Intelligence Scale for Children–Fifth Edition* (WISC–V; Wechsler, 2014) in digital format: Children with specific learning disorder in reading (i.e., SLD-R) and children with specific learning disorder in mathematics (i.e., SLD-M). In the initial phase of adapting tests to the Q-interactive platform, the goal was to maintain raw-score equivalence between standard (paper) and digital administration and scoring formats. This goal was facilitated to the extent that the effects of examinee–tablet interaction and assessment in the digital environment can be minimized, and that response capture and scoring remains accurate. If equivalence is demonstrated, then the norms, reliability, and validity information gathered for the paper format can be applied to results obtained on Q-interactive. To date, equivalence has been evaluated and demonstrated for the *Wechsler Intelligence Scale for Children–Fourth Edition* (WISC–IV; Wechsler, 2003) and the WISC–V (see Daniel, 2012, Daniel, Wahlstrom, & Zhang, 2014; Raiford et al., 2016).

The previous Q-interactive equivalence studies have used samples of nonclinical examinees to maintain focus on estimating the presence and size of any effects of the digital administration format. These studies were designed to show equivalence of the raw scores, and therefore focused on nonclinical cases to establish that the paper normative data apply equally well to the test when it is administered in a digital format. After normative equivalence was established, focus could shift to providing evidence of performance consistency in clinical conditions and special groups of interest who were administered the test in a digital format. Because the impact of computer-assisted administration with special populations (e.g., autism spectrum disorder, attention-deficit/hyperactivity disorder) and various clinical conditions was not known, further research was required to demonstrate whether similar results would be obtained when varying the administration format from paper to digital.

Understanding the interaction of administration format for examinees with clinical conditions or from other special populations is ultimately of importance for clinical applications of tests administered on Q-interactive. In the *Standards for Educational and Psychological Testing* (*Standards*; American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 2014), Standard 4.5 describes collecting and presenting evidence of how a target construct is or is not altered by allowable variations in administration conditions, such as paper and digital formats of the same test.

Multiple published investigations report results of special group studies of children that were tested on the WISC–V in digital format (Raiford, Drozdick, & Zhang, 2015; Raiford, Holdnack, Drozdick, & Zhang, 2014; Raiford et al., 2016). Those results indicated that the scores obtained by children in the special group studies were consistent with their previous group identifications. For example, Raiford et al. (2016) reported the results of seven special group studies (i.e., children identified as intellectually gifted, children with intellectual disability-mild severity, children with SLD-R, children with SLD-M, children with attention-deficit/hyperactivity disorder, children with autism spectrum disorder with language impairment, children with motor impairment) who were administered the 10 WISC–V primary subtests in digital format. These results indicated that administering the WISC–V in digital format produces scores that are useful in the assessment of these special conditions and are consistent with the paper format, and that the target constructs are not altered by varying the administration format. These results were consistent with those of the WISC–V format equivalence studies (Daniel et al., 2014) that found virtually no effect of format by ability level.

The studies described in this report differ from the Raiford et al. (2016) studies with children with specific learning disorders because the present studies included administration of the secondary and complementary subtests. The present studies therefore include the first reported results for children with specific learning disorders tested with the WISC–V secondary and complementary subtests in digital format. As noted, Raiford et al. (2016) demonstrated that children with SLD-R and children with SLD-M perform similarly on the WISC–V primary subtests, whether they are tested in digital or paper format.

Specific Learning Disorder-Reading

There is a large body of research evaluating the general and specific cognitive difficulties associated with SLD-R. Although a comprehensive review is beyond the scope of this technical report, some pertinent findings are highlighted here. In the verbal domain, studies show that vocabulary knowledge is associated with the development of reading skills (Ouellette, 2006). Children with SLD-R have difficulties with semantic search and retrieval (Booth, Bebko, Burman, & Bitan, 2007), and SLD-R is associated with lower performance on expressive, but not receptive, language measures (Cutting, Materek, Cole, Levine, & Mahone, 2009). Children with reading comprehension deficits show impairments in language functioning compared to controls and children with decoding-only deficits (Catts, Adlof, & Weismer, 2006).

Weaknesses in verbal comprehension, working memory, and processing speed are associated with both reading and math disorders. In a large sample of children diagnosed with ADHD and SLD, verbal comprehension and working memory were the best WISC–III/WISC–IV predictors of reading ability; however, working memory was among the best predictors of an SLD (Mayes & Calhoun, 2007). Children diagnosed with SLD-R also show reduced auditory working memory (Kibby & Cohen, 2008).

In relation to the new complementary subtests, rapid automatic naming measures that are similar to Naming Speed Literacy significantly predict reading ability in both younger and older children with reading disorder (Park & Lombardino, 2013). Moreover, a subset of children with reading disorder show deficits in naming speed (Adlof, Catts, & Lee, 2010; Georgiou, Parrila, Manolitsis, & Kirby, 2011; Mazzocco & Grimm, 2013) and have greater difficulty naming letters and digits than quantities (Pauly et al., 2011). Children with reading disorders have also been found to perform poorly on verbal learning measures (Kibby & Cohen, 2008) and on paired associate learning tasks that involve pairing a visual input (i.e., a symbol) with a verbal response (Litt & Nation, 2014; Messbauer & de Jong, 2003). In addition to these shared weaknesses, reading difficulties are uniquely associated with phoneme awareness and naming speed (Willcutt et al., 2013).

Specific Learning Disorder-Mathematics

Math disability and low math achievement are common problems in childhood (Geary, 2011b). As many as 7% of children have a math disorder, while another 10% have persistent low achievement in math (Geary, 2011b). Although the research base evaluating SLD-M is less extensive than for SLD-R, there is evidence for common cognitive difficulties between the two specific learning disorders, including difficulties in verbal comprehension, working memory, and processing speed (Willcutt et al., 2013). Geary (2011a) found that general cognitive functioning, processing speed, and components of working memory were longitudinal predictors of math achievement. Additionally, early number skills and conceptual reasoning skills predict math achievement (Fuchs, Geary, Compton, Fuchs, Hamlett, & Bryant, 2010); and language, nonverbal reasoning, and attention are significantly related to performance on math word problems (Fuchs, Geary, Compton, Fuchs, Hamlett, Seethaler, et al., 2010; Tolar et al., 2012). Although general cognitive functioning is a predictor for math achievement in typically developing children, it is not a primary cause of math disorder (Geary, 2011b). Difficulties with working memory (Geary, 2010), attention (Raghubar et al., 2009), and semantic-retrieval and visuospatial skills (Cirino, Morris, & Morris, 2007) are related to mathematics difficulties.

WISC–V Special Group Studies

Method

Measures

The WISC–V is an individually administered, comprehensive clinical instrument for assessing the intelligence of children ages 6 years 0 months through 16 years 11 months (6:0–16:11). The WISC–V provides primary index scores that represent intellectual functioning in specified cognitive areas (i.e., Verbal Comprehension Index [VCI], Visual Spatial Index [VSI], Fluid Reasoning Index [FRI], Working Memory Index [WMI], and Processing Speed Index [PSI]), a composite score that represents general intellectual ability (i.e., Full Scale IQ [FSIQ]), ancillary index scores that represent the cognitive abilities in different groupings based on clinical needs (i.e., Auditory Working Memory Index [AWMI], Quantitative Reasoning Index [QRI], Nonverbal Index [NVI], General Ability Index [GAI], and Cognitive Proficiency Index [CPI]), and complementary index scores that measure additional cognitive abilities related to academic achievement and learning-related issues and disorders (i.e., Naming Speed Index [NSI], Symbol Translation Index [STI], and Storage and Retrieval Index [SRI]).

All of the WISC–V subtests from the standardization edition were administered in digital format for the present studies. Pilot versions of the three Processing Speed subtests (i.e., Coding, Symbol Search, and Cancellation) in digital format, in which the child responded by touching or drawing on the tablet, were also administered. The results from that pilot indicated, however, that the correspondence between the paper and digital formats was not yet sufficient to support the use of these first versions of the Processing Speed subtests in digital format.

Further design and development work resulted in the publication of Coding and Symbol Search in digital format in April of 2016. Cancellation could not be adapted for a digital format that didn't involve a paper response booklet due to size restrictions of the iPad. However, because the present study data were collected using the Pilot 1 versions of the Processing Speed subtests in digital format (see Raiford et al., 2016, for explanation), the present special group study results do not include the Processing Speed subtests or any composite score that requires the Processing Speed subtests for the corresponding sum of scaled scores (i.e., the PSI, FSIQ, NVI, and CPI). However, results for all of the other subtests and composite scores are available and appear in this technical report. For special group study results relevant to Coding and Symbol Search as they are presently administered in digital format, see Raiford et al. (2016).

Participants

The special group samples consisted of children ages 6–16 with SLD-R or SLD-M. The matched control samples were drawn from the pool of nonclinical children ages 6–16 who were participating in the equivalence study of the WISC–V paper and digital formats. Pearson's Field Research staff recruited the participants and compensated all children (i.e., their parents/guardians) for their participation. Participants for the nonclinical samples were screened for general exclusion criteria listed in Appendix A of the WISC–V Technical and Interpretive Manual. Potential participants for the SLD-R and SLD-M groups were screened for general inclusion criteria and the corresponding specific special group criteria listed in Appendix B of the WISC–V Technical and Interpretive Manual.

Examiners participating in these studies were trained in WISC–V paper administration procedures. The examiners also received training in Q-interactive administration, conducted practice administrations, and were provided with feedback on any administration errors. Examiners were compensated for their participation.

Procedure

This study was carried out during the WISC–V standardization stage. All administrations occurred in April and May, 2014. Examiners captured response information in the standard manner used for norming and scored all items.

A team of several scorers at Pearson rescored all protocols. For each protocol, two independent scorers reevaluated all subjectively scored items using the final scoring rules, and an expert scorer or a member of the research team resolved any discrepancies between the two scorers as needed. All subtest raw scores were calculated by Pearson staff using the keyed item scores and the final scoring rules. The final subtest and composite norms were then applied.

Results

Specific Learning Disorder-Reading

The demographic data for the SLD-R group appear in Table 1.

Table 1. Demographic Data for the Specific Learning Disorder-Reading Group

N	24
Age	
Mean	12.2
SD	3.1
Range	6–16
Gender	
Female	37.5
Male	62.5
Parent Education	
0–12 years of school, no diploma	12.5
High school diploma or equivalent	12.5
Some college or technical school, associate's degree	33.3
Bachelor's degree	41.7
Race/Ethnicity	
African American	4.2
Hispanic	8.3
Other	–
White	87.5

Note. Except for sample size (*N*) and age, data are reported as percentages. Total percentage may not add up to 100 due to rounding.

The demographic characteristics of this sample are generally similar to those of the SLD-R special group study that was conducted with the WISC–V in paper format (Wechsler, 2014). However, the current sample has an older mean age and a larger proportion of children who are male. Compared with the analogous Raiford et al. (2016) WISC–V digital format special group sample, the present sample has a larger proportion of children with a parent education level of 16 years or more. Both the current sample and the Raiford et al. (2016) sample had larger proportions of children who are white. Table 2 presents the mean subtest and composite scores for the SLD-R and matched control groups.

Table 2. Specific Learning Disorder-Reading Compared to Matched Controls

	Specific Learning Disorder Reading		Matched Control					
Subtest/ Composite Score	Mean	*SD*	Mean	*SD*	Difference	*t* value	*p* value	Standard Difference[a]
SI	8.3	2.6	11.1	2.9	2.74	4.01	<.01	.99
VC	8.7	2.7	10.5	2.5	1.79	2.44	.02	.69
IN	8.3	2.3	11.0	3.0	2.75	3.64	<.01	1.03
CO	8.7	2.9	9.5	2.5	.87	1.62	.12	.32
BD	10.8	2.5	11.8	2.7	1.00	1.64	.11	.38
VP	8.7	2.3	10.6	3.1	1.92	2.49	.02	.70
MR	9.5	3.4	11.4	2.7	1.83	2.09	.05	.60
FW	9.7	2.9	10.6	2.2	.92	1.30	.21	.36
PC	8.8	2.7	11.6	2.5	2.79	3.98	<.01	1.07
AR	8.0	2.7	10.7	2.2	2.70	3.84	<.01	1.10
DS	8.4	2.8	11.3	2.3	2.83	4.22	<.01	1.10
PS	8.0	3.0	11.1	3.0	3.08	3.60	<.01	1.03
LN	8.4	2.4	11.3	1.5	2.88	5.87	<.01	1.44
VCI	91.4	12.0	104.1	13.2	12.74	4.02	<.01	1.01
VSI	98.4	10.7	106.6	15.4	8.21	2.49	.02	.62
FRI	97.6	15.2	105.7	11.6	8.08	2.31	.03	.60
WMI	89.8	13.7	106.6	13.4	16.79	4.89	<.01	1.24
QRI	93.3	14.0	103.3	9.5	9.96	3.09	<.01	.83
AWMI	91.3	12.8	106.8	8.8	15.46	6.02	<.01	1.41
GAI	95.1	11.5	107.2	12.5	12.04	4.73	<.01	1.00
NSL	80.0	13.6	103.8	13.1	23.87	6.13	<.01	1.79
NSQ	90.1	12.7	104.0	12.1	13.92	3.87	<.01	1.12
IST	93.4	10.9	105.1	14.3	11.75	3.44	<.01	.92
DST	94.4	8.9	107.5	17.0	13.05	2.79	.01	.96
RST	95.1	9.6	106.8	13.1	11.70	3.11	<.01	1.02
NSI	83.6	10.7	104.1	13.0	20.52	5.74	<.01	1.72
STI	93.4	9.4	107.3	17.1	13.95	3.07	<.01	1.01
SRI	86.5	8.8	106.8	15.2	20.32	5.36	<.01	1.64

[a] The Standard Difference is the difference of the two test means divided by the square root of the pooled variance, computed using Cohen's (1996) Formula 10.4.

WISC–V abbreviations are: SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, VP = Visual Puzzles, MR = Matrix Reasoning, FW = Figure Weights, PC = Picture Concepts, AR = Arithmetic, DS = Digit Span, PS = Picture Span, LN = Letter–Number Sequencing, VCI = Verbal Comprehension Index, VSI = Visual Spatial Index, FRI = Fluid Reasoning Index, WMI = Working Memory Index, QRI = Quantitative Reasoning Index, AWMI = Auditory Working Memory Index, GAI = General Ability Index, NSL = Naming Speed Literacy, NSQ = Naming Speed Quantity, IST = Immediate Symbol Translation, DST = Delayed Symbol Translation, RST = Recognition Symbol Translation, NSI = Naming Speed Index, STI = Symbol Translation Index, SRI = Storage and Retrieval Index.

When compared to a matched control group, children with SLD-R obtained significantly lower mean composite scores, with large effect sizes on most. The largest effect sizes among the primary index scores are observed for the WMI and the VCI, which is consistent with contemporary research that indicates a relationship between reading achievement and difficulties with multiple components of working memory (Wang & Gathercole, 2013) and with verbal ability (Reynolds & Turek, 2012). Large effect sizes are also present on the NSI, the STI, and the SRI, which measure aspects of learning and phonological processes shown to be areas of weakness in children with SLD-R (Litt & Nation, 2014).

Significantly lower performance is observed on all primary and secondary subtests with the exception of Comprehension, Block Design, and Figure Weights. Of the primary and secondary subtests, the lowest mean scores occur on Picture Span, Arithmetic, Information, Similarities, Digit Span, and Letter–Number Sequencing. The largest effect sizes are noted for Letter-Number Sequencing, Digit Span, Arithmetic, Picture Concepts, Information, Picture Span, and Similarities. All complementary subtests produce large effect sizes. The results indicate significant difficulties with immediate paired associate learning, rapid verbal naming, verbal comprehension, and working memory.

The consistency of the present findings with those obtained from a study of the WISC–V administered in paper format (Wechsler, 2014) replicate the results from Raiford et al. (2016) that indicate the WISC–V subtest and composite scores are measuring similar constructs in both formats. These results provide evidence that the WISC–V administered in digital format produces scores that are consistent with results obtained from administration of the paper format.

Specific Learning Disorder-Mathematics

The demographic data for the SLD-M group appear in Table 3.

Table 3. Demographic Data for the Specific Learning Disorder-Mathematics Group

N	23
Age	
Mean	12.3
SD	2.6
Range	8–16
Gender	
Female	56.5
Male	43.5
Parent Education	
0–12 years of school, no diploma	8.6
High school diploma or equivalent	26.1
Some college or technical school, associate's degree	30.4
Bachelor's degree	34.8
Race/Ethnicity	
African American	13.0
Hispanic	13.0
Other	13.0
White	60.9

Note. Except for sample size (*N*) and age, data are reported as percentages. Total percentage may not add up to 100 due to rounding.

The demographic characteristics of this sample are similar to those of the SLD-M special group study that was conducted with the WISC–V in paper format (Wechsler, 2014). However, the current sample has a lower mean age, a lower proportion of children who are Hispanic, and greater proportions of children who are White and children with a parent education level greater than a high school diploma. Compared with the analogous Raiford et al. (2016) WISC–V digital format special group sample, the present sample has a larger proportion of children with a parent education level of 16 years or more. Table 4 presents the mean subtest and composite scores for the SLD-M and matched control groups.

Table 4. Specific Learning Disorder-Math Compared to Matched Controls

Subtest/ Composite Score	Specific Learning Disorder Mathematics Mean	SD	Matched Control Mean	SD	Difference	t value	p value	Standard Difference[a]
SI	8.7	3.0	11.2	2.8	2.52	2.63	.02	.87
VC	8.3	2.1	10.5	2.9	2.13	3.20	<.01	.84
IN	8.7	2.3	10.6	2.9	1.96	2.29	.03	.75
CO	8.1	2.4	9.5	2.9	1.33	1.75	.10	.50
BD	8.0	2.8	11.1	2.9	3.13	3.54	<.01	1.10
VP	7.3	3.3	9.7	2.9	2.48	2.73	.01	.80
MR	8.4	3.0	10.5	3.2	2.09	2.32	.03	.67
FW	7.6	2.6	10.3	2.6	2.74	3.99	<.01	1.05
PC	9.1	3.5	10.3	2.7	1.22	1.30	.21	.39
AR	6.9	2.5	10.8	2.6	3.96	5.29	<.01	1.55
DS	7.7	2.4	11.1	2.3	3.43	4.95	<.01	1.46
PS	8.8	3.0	10.7	2.0	1.83	2.34	.03	.72
LN	8.0	2.7	10.2	2.2	2.13	2.92	<.01	.86
VCI	92.0	12.7	104.6	13.5	12.61	3.24	<.01	.96
VSI	86.9	15.4	102.4	14.0	15.57	3.49	<.01	1.06
FRI	88.3	13.9	102.3	14.0	13.96	3.46	<.01	1.00
WMI	89.9	14.0	105.2	9.3	15.26	4.04	<.01	1.28
QRI	84.0	13.1	103.2	12.5	19.26	5.58	<.01	1.50
AWMI	88.1	12.9	103.4	8.8	15.30	4.70	<.01	1.39
GAI	88.1	12.5	104.7	13.1	16.65	4.41	<.01	1.30
NSL	96.1	12.1	103.8	12.9	7.70	2.28	.03	.62
NSQ	91.0	11.4	104.0	11.7	13.04	4.03	<.01	1.13
IST	89.1	14.3	99.3	14.9	10.17	2.28	.03	.70
DST	91.9	14.0	100.7	16.0	8.78	1.65	.12	.58
RST	88.6	12.7	101.8	10.4	13.12	3.13	<.01	1.13
NSI	92.1	11.9	104.0	12.8	11.96	3.48	<.01	.97
STI	88.1	11.9	101.5	14.4	13.35	2.71	.02	1.01
SRI	87.6	12.1	103.9	12.7	16.35	4.34	<.01	1.32

[a] The Standard Difference is the difference of the two test means divided by the square root of the pooled variance, computed using Cohen's (1996) Formula 10.4.

WISC–V abbreviations are: SI = Similarities, VC = Vocabulary, IN = Information, CO = Comprehension, BD = Block Design, VP = Visual Puzzles, MR = Matrix Reasoning, FW = Figure Weights, PC = Picture Concepts, AR = Arithmetic, DS = Digit Span, PS = Picture Span, LN = Letter–Number Sequencing, VCI = Verbal Comprehension Index, VSI = Visual Spatial Index, FRI = Fluid Reasoning Index, WMI = Working Memory Index, QRI = Quantitative Reasoning Index, AWMI = Auditory Working Memory Index, GAI = General Ability Index, NSL = Naming Speed Literacy, NSQ = Naming Speed Quantity, IST = Immediate Symbol Translation, DST = Delayed Symbol Translation, RST = Recognition Symbol Translation, NSI = Naming Speed Index, STI = Symbol Translation Index, SRI = Storage and Retrieval Index.

All mean scores for the SLD-M group are significantly lower than mean scores for the matched control group, with the exception of Picture Concepts and Delayed Symbol Translation. The QRI has the largest effect size among all index scores, and the largest effect sizes for the primary index scores occur on the WMI and the VSI, which indicates difficulties with quantitative, working memory, and spatial reasoning abilities. The complementary index scores all have large effect sizes, suggesting impairment in rapid automatic naming and paired associate learning.

At the subtest level, the largest effect sizes for primary and secondary subtests are observed on Arithmetic, Digit Span, Block Design, and Figure Weights. On the complementary subtests, the largest effect sizes occur on Naming Speed Quantity and Recognition Symbol Translation. Overall, the results suggest that the most significant difficulties are with quantitative and spatial reasoning, auditory working memory, rapid automatic quantity naming tasks, and paired associate learning and recall.

The consistency of the present findings with those obtained from a study of the WISC–V administered in paper format (Wechsler, 2014) replicate the results from Raiford et al. (2016) that indicate the WISC–V subtest and composite scores are measuring similar constructs in both formats. These results provide evidence that the WISC–V administered in digital format produces scores that are consistent with results obtained from administration of the paper format.

Discussion

Results from these studies provide strong support for the validity and clinical utility of the WISC–V in digital format. Results are consistent with previous research and theoretical foundations. The scores obtained by children with specific learning disorders are consistent with their previous group identifications and consistent with patterns of results from previous comparison studies between children from these special group studies and matched controls, including those of the WISC–V in paper format (Wechsler, 2014). The consistency of results obtained across the WISC–V digital and paper formats suggests that the target constructs are not altered by varying the administration format.

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