Q-interactive

Q-interactive® Special Group Studies: The WISC®–V and Children with Autism Spectrum Disorder and Accompanying Language Impairment or Attention-Deficit/Hyperactivity Disorder

Q-interactive Technical Report 11

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Introduction

Q-interactive®, a Pearson digital system for individually administered tests, is designed to make assessment more convenient and accurate, provide practitioners with easy access to a large number of tests, and support new types of tests that cannot be administered or scored without computer assistance.

With Q-interactive, the examiner and examinee use wireless tablets that are synched with each other, enabling the examiner to read administration instructions, time and capture response information (including audio recording), and view and control the examinee's tablet. The examinee tablet displays visual stimuli and captures touch responses.

In the initial phase of adapting tests to the Q-interactive platform, the goal has been to maintain raw-score equivalence between standard (paper) and digital administration and scoring formats. This goal is 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 Q-interactive results. To date, equivalence has been evaluated and demonstrated for the *Wechsler Intelligence Scale for Children–Fourth Edition* (WISC–IV; Wechsler, 2003), *the Wechsler Intelligence Scale for Children–Fifth Edition* (WISC–V; Wechsler, 2014), the *Wechsler Adult Intelligence Scale–Fourth Edition* (WAIS–IV; Wechsler, 2008), and a number of other cognitive, achievement, and language tests (Daniel, 2012a, 2012b, 2012c, 2013a, 2013b, 2013c; Daniel, Wahlstrom, & Zhang, 2014; Daniel, Wahlstrom, & Zhou, 2014).

As stated in the WISC–V equivalence study technical report (Daniel, Wahlstrom, & Zhang, 2014), the 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 normative data, and therefore focused on non-clinical 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 on individuals with some clinical conditions is not known, further research was required to demonstrate whether similar results would be obtained when varying the administration format from paper to digital for special populations or with various clinical conditions.

Understanding the interaction of administration format for examinees with clinical conditions or from other special populations (e.g., autism spectrum disorder, attention-deficit/hyperactivity disorder) is ultimately of importance for clinical applications of 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.

Raiford, Holdnack, Drozdick, and Zhang (2014) previously reported on the results of two special group studies of children representing the extremes of ability levels (i.e., children identified as intellectually gifted and children with intellectual disability-mild severity) that were tested on the WISC–V digital version. Those results indicated that the scores obtained by children in the special group studies were consistent with their previous group identifications. Furthermore, other comparison studies between children from these special groups and matched controls using previous Wechsler intelligence scales and the WISC–V paper version (Rimm, Gilman, & Silverman, 2008; Rowe, Kingsley, & Thompson, 2010; Wechsler, 2002, 2003, 2008, 2012, 2014) indicated that the tests assess similar constructs, that the target construct is not altered by varying the administration format, and that the WISC–V digital version produces scores that are useful in the assessment of intellectual giftedness and intellectual disability. These results were consistent with those of the WISC–V equivalence study (Daniel, Wahlstrom, & Zhang, 2014) that found there was virtually no effect of format by ability level.

This technical report describes the results of two special group studies of children tested on the WISC–V digital version: Children with autism spectrum disorder with accompanying language impairment (ASD-L) and children with attention-deficit/hyperactivity disorder (ADHD). Additional special group study results are forthcoming in future reports.

Research indicates that assessments and interventions utilizing digital formats are equally or more effective relative to their paper counterparts when used with individuals with neurodevelopmental disorders (Bosseler & Massaro, 2003; Denaes, 2012; Fletcher-Flinn & Gravatt 1995; Hetzroni & Tannous, 2004). In addition, tablet technology has been used effectively with individuals with neurodevelopmental disorders for a variety of purposes related to learning and assessment (Bouck, Savage, Meyer, Tager-Doughty, & Hunley, 2014; Burton, Anderson, Prater, & Dyches, 2013; Kagohara et al., 2013; Murdock, Ganz, & Crittendon, 2013). The use of tablet technology is thought to increase motivation and attention for children in special education settings (Bruttin, 2011; Flewitt, Kucirkova, & Messer, 2014).

Children With Autism Spectrum Disorder With Accompanying Language Impairment

With the publication of *the Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM–5*; American Psychiatric Association, 2013), autistic disorder and Asperger’s disorder were reconceptualized within a single diagnosis, autism spectrum disorder. Children diagnosed with autism spectrum disorder are characterized by deficits in verbal and nonverbal communication and in social communication and interactions. They also exhibit restricted patterns of behavior, interests or activities. Specifiers can be used to more clearly describe a child’s symptomatology, including severity of symptoms; the presence of intellectual or language impairment; and the presence of other medical, genetic, or environmental factors, or comorbid neurodevelopmental, mental, or behavioral disorders.

Previous investigations have suggested that the general intellectual functioning of children with autism spectrum disorder is lower than that of matched controls; however, these studies suggest a pattern of strengths and weaknesses. Several studies demonstrate lower scores on measures of general intellectual functioning but relatively better performance on measures of fluid reasoning (Dawson, Soulieres, Gernsbacher, & Mottron, 2007; Mayes & Calhoun, 2008; Stevenson, 2011). Performance on verbal tasks is typically lower for most children with autism spectrum disorder with language impairment (ASD-L) than for typically developing children (Joseph, Tager-Flusberg, & Lord, 2002; Klinger, O’Kelley, Mussey, Goldstein, & DeVries, 2012; Mayes & Calhoun, 2008; Wechsler, 2003, 2012). A pattern of performance on the Verbal Comprehension subtests across various studies has emerged: the highest score is obtained on Similarities, which involves fluid reasoning, and the lowest score is obtained on Comprehension, which requires some knowledge of social judgment, a weakness in individuals with autism spectrum disorder (Mayes & Calhoun, 2008; Zayat, Kalb, & Wodka, 2011). In addition, some studies show relative strengths on visual spatial tasks for children with autism spectrum disorders (Mayes & Calhoun, 2008; Wechsler, 2003, 2012). Rapid naming tasks similar to Naming Speed Literacy have also been found to be impaired in ASD-L (Korkman, Kirk, & Kemp, 2007; Turner, 2010). Also, children with ASD-L demonstrate relatively intact immediate and delayed cued recall memory but impaired delayed recognition and free recall (Boucher, Mayes, & Bigham, 2012).

Children With ADHD

ADHD is a common neurodevelopmental disorder affecting roughly 5% of children (American Psychiatric Association, 2013; Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007). It is characterized by persistent behavioral difficulties with attention and/or hyperactivity-impulsivity. The general difficulties with attention and inhibition overlap considerably with the neuropsychological concepts of working memory and executive function (Barkley, 2007; Hale, Fiorello, & Brown, 2005; Hale et al., 2012; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005).

Traditional IQ scores generally have not been found useful in discriminating children or adults with ADHD from a nonclinical population; however, the global intellectual functioning of these individuals is mildly impaired in some studies (Hale et al., 2012). Children with ADHD demonstrate relatively preserved verbal comprehension and perceptual reasoning scores, with lower performance on auditory working memory and processing speed (Hale et al., 2012; Mayes, Calhoun, Chase, Mink, & Stagg, 2009; Mayes, Calhoun, Mayes, & Molitoris, 2012; Wakkinen, 2008; Wechsler, 2012; Zieman, 2010). These weaknesses are reflected in lower Cognitive Proficiency Index scores in relation to General Ability Index scores, although this discrepancy is also found in other clinical groups (Devena & Watkins, 2012).

Performance on measures of rapid verbal naming indicate somewhat slower response times and lower scores in children with ADHD (Elliott, 2007; Jacobson et al., 2011; Korkman et al., 2007). Multiple studies have found slower response times and increased response time variability in ADHD groups versus typically developing children (Chiang, Huang, Gau, & Shang, 2013; Crosbie et al., 2013; Lipszyc & Schachar, 2010; Rosch, Dirlikov, & Mostofsky, 2013). Moreover, Gau and Huang (2014) found that individuals with ADHD committed more omission and commission errors, in addition to longer latency times, on sustained attention and reaction time tasks than nonclinical controls.

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 [STI]).

All of the WISC–V subtests from the standardization edition on Q-interactive were administered for the ASD-L and ADHD special group studies. Digital versions of the three Processing Speed subtests (i.e., Coding, Symbol Search, and Cancellation), in which the child responded by touching or drawing on the tablet, were also administered. It was assumed that the paper and digital versions would not be raw-score equivalent because of the difference in response mode for the three Processing Speed subtests. The data from standardization indicated, however, that the correspondence between the paper and digital versions was not yet sufficient to support the use of these experimental digital versions of the Processing Speed subtests. Further design and development work on the Processing Speed subtests is underway. Therefore, the initial release of the published WISC–V digital version continues to use paper response booklets for the Processing Speed subtests (as did the WISC–IV), with a Q-interactive examiner interface for timing and recording that is similar to the one that was shown to be equivalent to the paper format in the WISC–IV equivalence study (Daniel, 2012a) and the WAIS–IV equivalence study (Daniel, 2012b). Because the study data were collected using the experimental digital versions of the Processing Speed subtests, however, no special group study results are available for the Processing Speed subtests, or for 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 the Processing Speed subtests as they are currently administered for Q-interactive (i.e., using paper response booklets), see the special group studies in Chapter 5 of the *WISC–V Technical and Interpretive Manual* (Wechsler, 2014).

Participants

The special group samples consisted of children ages 6–16 with ASD-L or with ADHD. 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 versions. Pearson's Field Research staff recruited the participants and compensated the children from all samples (i.e., their parents/guardians) for their participation. Participants for the samples of nonclinical children were screened for general exclusion criteria used for the WISC–V normative sample listed in Appendix A. Potential participants for the ASD-L and ADHD groups were screened for general inclusion criteria listed in Appendix B.

Children in the ASD-L group met *DSM–5* diagnostic criteria for autism spectrum disorder with accompanying language impairment. Additionally, these children had existing general cognitive ability scores that were no lower than 2.67 standard deviations below the mean (e.g., FSIQ < 60) and had adequate communication skills to complete testing. These criteria were the same as the analogous studies conducted with the WISC–V paper version.

Children in the ADHD group were identified as having ADHD according to *DSM–5* diagnostic criteria and clinically significant parent ratings on the Brown Attention-Deficit Disorder Scales for Children and Adolescents (Brown, 2001). All ADHD subtypes (i.e., inattentive, hyperactive, and combined) were included. Children in the ADHD group were required to undergo a minimum 24-hour period without psychostimulant medications prior to testing. They also had to produce an existing general cognitive ability score (e.g., FSIQ) of ≥80 on a standardized, individually administered measure of intellectual ability or documentation of an estimated general cognitive ability score of ≥80. These criteria were the same as the analogous studies conducted with the WISC–V paper version.

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 who were not Pearson employees were compensated for their participation.

Procedure

This study was carried out during the WISC–V standardization phase. All administrations occurred in April and May, 2014. Examiners captured response information in the standard manner used for norming, which includes writing the complete verbatim response to each Verbal Comprehension subtest item, and scored all items.

A team of several scorers at Pearson scored 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

Children With Autism Spectrum Disorder With Accompanying Language Impairment

The demographic data for the group of children diagnosed with ASD-L appear in Table 1.

Table 1. Demographic Data for the Autism Spectrum Disorder With Accompanying Language Impairment Group

N	30
Age	
Mean	11.6
SD	2.9
Sex	
Female	10.0
Male	90.0
Race/Ethnicity	
African American	13.3
Asian	6.7
Hispanic	26.7
White	53.3
Parent Education	
≤11 years	6.7
12 years	10.0
13–15 years	26.7
≥16 years	56.7

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 ASD-L special group study that was conducted with the WISC–V paper version (Wechsler, 2014). However, the current sample has slightly higher proportions of children with a parent education level of ≤12 years, children who are African American, and children who are male; and a lower proportion of children who are White. The overrepresentation of males in the sample reflects the combined effects of a higher prevalence rate for ASD-L in males than females and the greater prevalence of intellectual disability in females with autism spectrum disorder (American Psychiatric Association, 2013). Table 2 presents the mean subtest and composite scores for the ASD-L and matched control groups.

For the ASD-L group, all mean primary index scores are significantly lower than the corresponding means of the matched control group with large effect sizes. As with previous research, the FRI and VSI are relatively higher and produce smaller effect sizes than the VCI. The VCI has the second largest effect size of the primary index scores, behind the WMI. This is consistent with research demonstrating weaknesses in executive functioning and working memory and verbal comprehension in children with autism spectrum disorders (Boucher & Mayes, 2012; Corbett, Constantine, Hendren, Rocke, & Ozonoff, 2009; Englund, Decker, Allen, & Roberts, 2014; Mayes & Calhoun, 2007). These results are similar to those of the WISC–V paper version (Wechsler, 2014).

All mean primary and secondary scaled scores are significantly lower in the ASD-L group compared with the matched control group. Consistent with previous research, for the ASD-L group the highest mean Verbal Comprehension subtest score is Similarities, and the lowest is Comprehension. The largest effect size is observed on Comprehension, followed by Letter–Number Sequencing, Vocabulary, Picture Span, Arithmetic, and Digit Span. The smallest effect sizes are observed on Figure Weights, Matrix Reasoning, Visual Puzzles, and Block Design.

The ancillary and complementary index scores are all significantly lower than scores in the matched control groups, with large effect sizes. The lowest mean score and largest effect is observed on the AWMI. The complementary subtests are all significantly lower in the ASD-L group than in the matched controls. Both the composite and subtest-level results are very similar to those of the paper version.

These results replicate previous research indicating global cognitive deficits, relatively weaker verbal task performance, and relatively higher performance on visual spatial tasks (Barbeau, Soulieres, Dawson, Zeffiro, & Mottron, 2013; Klinger et al., 2012; Mayes & Calhoun, 2008; Soulieres, Dawson, Gernsbacher, & Mottron, 2011; Wechsler, 2003, 2012).

Table 2. Mean Performance of Autism Spectrum Disorder With Accompanying Language Impairment and Matched Control Groups

Subtest/ Composite Score	Autism Spectrum Disorder With Language Impairment Mean	*SD*	Matched Control Mean	*SD*	*n*	Difference	*t* value	*p* value	Standard Difference[a]
SI	7.0	3.3	10.7	2.8	30	3.73	4.64	<.01	1.22
VC	6.0	3.1	10.1	2.2	29	4.10	5.73	<.01	1.53
IN	6.2	4.2	11.0	3.2	30	4.87	5.00	<.01	1.30
CO	4.7	2.8	9.5	2.0	30	4.87	7.84	<.01	2.00
BD	8.7	2.6	11.7	2.3	30	2.97	5.34	<.01	1.21
VP	7.7	3.3	10.7	2.7	30	3.03	3.73	<.01	1.00
MR	8.4	3.1	11.2	2.8	30	2.80	3.99	<.01	.95
FW	8.6	2.8	11.0	3.1	30	2.40	3.32	<.01	.81
PC	6.9	3.0	11.0	3.0	30	4.07	7.38	<.01	1.36
AR	5.7	3.3	10.0	2.5	29	4.34	5.27	<.01	1.48
DS	6.3	3.7	10.9	2.4	30	4.63	5.82	<.01	1.48
PS	6.1	3.3	10.9	3.1	30	4.83	6.43	<.01	1.51
LN	5.7	3.2	11.0	2.4	30	5.30	7.24	<.01	1.87
VCI	81.5	16.5	102.4	12.8	29	20.90	5.20	<.01	1.42
VSI	90.0	15.1	106.7	12.8	30	16.70	4.78	<.01	1.19
FRI	91.3	15.8	106.4	14.1	30	15.10	4.28	<.01	1.01
WMI	78.1	18.3	105.1	13.5	30	26.93	6.81	<.01	1.67
QRI	83.5	15.3	102.4	13.7	29	18.93	5.14	<.01	1.30
AWMI	76.7	19.7	105.0	10.7	30	28.30	6.93	<.01	1.79
GAI	85.7	14.3	106.7	13.0	29	21.00	6.33	<.01	1.54
NSL	82.1	22.0	102.8	14.7	29	20.69	4.39	<.01	1.11
NSQ	78.9	20.4	103.7	10.6	30	24.83	6.64	<.01	1.53
IST	85.4	18.6	105.2	14.6	30	19.77	5.45	<.01	1.18
DST	86.2	19.2	105.2	15.0	26	18.92	5.15	<.01	1.10
RST	89.0	21.6	106.5	12.3	24	17.42	4.30	<.01	.99
NSI	81.7	18.4	103.4	13.4	29	21.72	5.54	<.01	1.35
STI	86.8	19.3	105.7	14.5	24	18.83	5.25	<.01	1.10
SRI	81.8	18.9	106.1	12.2	23	24.35	7.15	<.01	1.53

[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.

Children With Attention-Deficit/Hyperactivity Disorder

The demographic data for the ADHD group appear in Table 3.

Table 3. Demographic Data for the Attention-Deficit/Hyperactivity Disorder Group

N	25
Age	
Mean	10.5
SD	2.9
Sex	
Female	36.0
Male	64.0
Race/Ethnicity	
African American	16.0
Hispanic	16.0
White	64.0
Other	4.0
Parent Education	
12 years	12.0
13–15 years	40.0
≥16 years	48.0

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 ADHD special group study that was conducted with the WISC–V paper version. However, the current sample had a lower mean age, greater proportions of children with a parent education level of 16 years and higher and of children who are African American and Hispanic, and lower proportions of children who are White and children who have a parent education level of ≤12 years. Table 4 presents the mean subtest and composite scores for the ADHD and matched control groups.

Although the mean primary index scores for the ADHD group are in the average range, a significant difference is found between the ADHD and matched control groups on the FRI. The FRI has a moderate effect size; and the VCI, VSI, and WMI have small effect sizes. Of the ancillary index scores, the AWMI and the GAI are significantly lower in the ADHD group than in the matched control group and show moderate effect sizes. Small effect sizes are present on the STI and SRI complementary index scores.

The mean group differences for three subtests (i.e., Matrix Reasoning, Letter-Number Sequencing, and Delayed Symbol Translation) show statistically significant differences between the ADHD and matched control groups. A large effect is observed for Matrix Reasoning, and moderate effects are present for Block Design, Picture Concepts, Arithmetic, Letter-Number Sequencing, and Delayed Symbol Translation. These results indicate difficulties in visual spatial processing, fluid reasoning, auditory working memory, and visual-verbal associative memory.

Table 4. Mean Performance of Attention-Deficit/Hyperactivity Disorder and Matched Control Groups

Subtest/ Composite Score	Attention-Deficit Hyperactivity Disorder Mean	Attention-Deficit Hyperactivity Disorder *SD*	Matched Control Mean	Matched Control *SD*	*n*	Difference	*t* value	*p* value	Standard Difference[a]
SI	10.1	2.7	11.2	2.5	25	1.08	1.57	.13	.42
VC	9.4	2.6	10.5	2.7	25	1.04	1.58	.13	.39
IN	9.7	2.6	10.9	2.6	25	1.20	1.69	.10	.46
CO	9.1	2.5	9.7	2.7	23	.61	.77	.45	.23
BD	10.2	2.5	11.6	2.5	25	1.40	1.75	.09	.56
VP	10.0	3.5	10.2	2.4	25	.24	.27	.79	.08
MR	8.9	2.1	11.5	2.5	25	2.56	3.89	<.01	1.11
FW	10.4	2.2	10.9	3.1	25	.48	.65	.52	.18
PC	9.0	3.2	10.9	3.3	25	1.92	1.93	.07	.59
AR	8.3	3.1	10.0	2.8	24	1.71	1.97	.06	.58
DS	9.8	2.8	11.2	3.3	24	1.42	1.64	.12	.46
PS	9.6	2.4	10.5	3.5	25	.88	1.22	.24	.29
LN	9.1	3.0	11.5	2.6	25	2.40	3.14	<.01	.85
VCI	98.8	12.5	104.7	13.0	25	5.88	1.85	.08	.46
VSI	100.2	15.4	104.8	12.0	25	4.60	1.10	.28	.33
FRI	98.0	11.3	107.0	13.6	25	9.04	2.63	.01	.72
WMI	98.8	12.4	104.6	17.3	24	5.83	1.45	.16	.39
QRI	96.3	13.8	102.0	14.7	24	5.79	1.34	.19	.41
AWMI	96.8	14.4	107.4	14.8	24	10.58	2.67	.01	.72
GAI	98.8	11.8	107.4	11.9	25	8.64	2.61	.02	.73
NSL	102.9	17.3	104.5	17.7	24	1.63	.33	.74	.09
NSQ	99.8	14.6	100.3	11.9	25	.56	.14	.89	.04
IST	99.8	12.6	103.6	14.6	25	3.84	.90	.38	.28
DST	95.4	14.6	104.8	17.3	23	9.43	2.06	.05	.59
RST	100.4	10.8	103.2	13.8	20	2.80	.67	.51	.23
NSI	102.2	14.2	102.6	15.5	24	.42	.10	.92	.03
STI	98.0	9.7	104.4	15.7	20	6.35	1.28	.22	.49
SRI	99.5	12.1	104.5	15.1	20	5.05	1.10	.29	.37

[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.

The group of children with ADHD tested on the WISC–V digital version had a younger mean age, a generally higher parent education level, and greater proportions of children who are African American or Hispanic than the analogous group that was tested on the WISC–V paper version (Wechsler, 2014). In addition, there was no cogent way to control for symptom severity across the two groups. Not surprisingly, those two samples produced slightly different results; however, the direction of the differences are the same, and the subtest- and composite-level means and effect sizes are generally similar. The same slight differences are observed if the matched-control (nonclinical) groups drawn for the WISC–V digital version study and the WISC–V paper version study are compared, yet the equivalence of the paper and digital versions in nonclinical samples has been established previously (Daniel, 2012b, Daniel, Wahlstrom, & Zhang, 2014). Taken together, these patterns of results imply that differences in demographic characteristics (e.g., parent education) or symptom severity are likely responsible for the slight differences across the WISC–V digital and paper ADHD group studies. Comparisons of the WISC–IV paper version's ADHD special group study results (Wechsler, 2003) with analogous published studies on the WISC–IV using groups of children with different demographic characteristics (e.g., Mayes et al., 2009; Zieman, 2010) similarly show sample-related fluctuations .

Discussion

The scores obtained by children in the special group studies 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 paper version (Wechsler, 2014). For the ADHD group, comparing studies across digital and paper formats is difficult because there is no good way to control for severity across the ADHD groups being compared. If one ADHD sample consists largely of more severe cases than the other ADHD sample, then different effect sizes are expected, although the same patterns should emerge, as was the case with the current ADHD study.

The similarities in results observed across the WISC–V digital version and previous Wechsler intelligence scales indicates that the tests are assessing similar constructs. The consistency of results obtained across the WISC–V digital and paper versions suggests that the target construct is not altered by varying the administration format. Taken together, these results provide evidence that the WISC–V digital version produces scores that are useful in the assessment of children with ASD-L and ADHD.

Appendix A. Exclusion Criteria for the Nonclinical Sample

Children were excluded from participation if any of the below criteria were met:

- primary language is not English;
- primarily nonverbal or uncommunicative;
- disruptive behavior or insufficient compliance with testing to ensure a valid assessment;
- tested on any intelligence measure in the previous 6 months;
- close friend, relative, or ward of the examiner, or a child with whom the examiner lives;
- identical sibling of another child in the sample;
- uncorrected visual impairment;
- uncorrected hearing loss;
- upper extremity disability that would affect motor performance;
- currently admitted to hospital or psychiatric facility;
- currently taking medication that might impact cognitive test performance (e.g., anticonvulsants, antipsychotics, some antidepressants and anxiolytics);
- history of electroconvulsive therapy or radiation treatment of the central nervous system;
- period of unconsciousness not related to surgery or greater than 20 minutes related to a medical condition; or
- previously or currently diagnosed with any physical condition, neurological condition, psychological condition, or illness that might depress test performance, such as epilepsy, traumatic brain injury, or mood disorder.

Appendix B. Inclusion Criteria for Special Groups

General Inclusion Criteria

Children were eligible for inclusion if they met all of the following criteria:

- age 6–16;
- primary language is English;
- able to communicate at a level commensurate with age and diagnosis, and not completely uncommunicative;
- normal hearing and vision (with aid);
- normal fine and gross motor ability;
- no physical conditions, illnesses, or impairments that could impact cognitive functioning or test performance;
- no diagnosis of a neurological condition (e.g., seizure disorder, epilepsy, encephalitis, brain surgery, brain tumor);
- no period of unconsciousness not related to surgery or greater than 20 minutes related to a medical condition;
- no diagnosis of a pervasive developmental disorder;
- no diagnosis of a psychiatric disorder (e.g., psychotic disorders, mood disorders) other than the condition of interest (i.e., ASD-L or ADHD);
- not currently admitted to a hospital, inpatient treatment, or psychiatric facility;
- not currently taking medication that might impact test performance; and
- has not completed the WISC–IV or any other measure of cognitive ability in the 6 months prior to the testing date.

Specific Inclusion Criteria

Autism Spectrum Disorder With Accompanying Language Impairment

Participation criteria included:

- has a full scale score ≥60 on a standardized, individually administered measure of cognitive ability or documentation that a psychologist has estimated IQ as ≥60;
- meets *DSM–5* criteria for a current diagnosis of autism spectrum disorder with accompanying language impairment; and
- has adequate communication skills to complete testing.

Attention-Deficit/Hyperactivity Disorder

Participation criteria included:

- has a full scale score ≥80 on a standardized, individually administered measure of cognitive ability or documentation that a psychologist has estimated IQ as ≥80;
- meets *DSM–5* criteria for a current diagnosis of ADHD; and
- has not taken ADHD medication for at least 24 hours prior to testing.

References

American Educational Research Association, American Psychological Association, & National Council on Measurement in Education. (2014). *Standards for educational and psychological testing.* Washington, DC: Author.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Association.

Barbeau, E. B., Soulieres, I., Dawson, M., Zeffiro, T. A., & Mottron, L. (2013). The level and nature of autistic intelligence III: Inspection time. *Journal of Abnormal Psychology, 122*(1), 295–301. doi:10.1037/a0029984

Barkley, R. A. (2007). School interventions for attention deficit hyperactivity disorder: Where to from here? *School Psychology Review, 36*(2), 279–286.

Bosseler, A., & Massaro, D. W. (2003). Development and evaluation of a computer-animated tutor for vocabulary and language learning in children with autism. *Journal of Autism and Developmental Disorders, 33*(6),653–672.

Boucher, J., & Mayes, A. (2012). Memory in ASD: Have we been barking up the wrong tree? *Autism, 16*(6), 603–611. doi:10.1177/1362361311417738

Boucher, J., Mayes, A., & Bigham, S. (2012). Memory in autistic spectrum disorder. *Psychological Bulletin, 138*(3), 458–496. doi:10.1037/a0026869

Bouck, E. C., Savage, M., Meyer, N. K., Taber-Doughty, T., & Hunley, M. (2014). High-tech or low-tech? Comparing self-monitoring systems to increase task independence for students with autism. *Focus on Autism and Other Developmental Disabilities, 29*(3), 156–167.

Brown, T. E. (2001). *Brown attention-deficit disorder scales for children and adolescents*. San Antonio, TX: The Psychological Corporation.

Bruttin, C. D. (2011). Computerised assessment of an analogical reasoning test: Effects of external memory strategies and their positive outcomes in young children and adolescents with intellectual disability. *Educational & Child Psychology, 28*(2), 18–32.

Burton, C. E., Anderson, D. H., Prater, M. A., & Dyches, T. T. (2013). Video self-modeling on an iPad to teach functional math skills to adolescents with autism and intellectual disability. *Focus on Autism and Other Developmental Disabilities 28*(2), 67–77.

Chiang, H. -L., Huang, L. -W., Gau, S. S. -F., & Shang, C. -Y. (2013). Associations of symptoms and subtypes of attention-deficit hyperactivity disorder with visuospatial planning ability in youth. *Research in Developmental Disabilities, 34*(9), 2986–2995. doi:10.1016/j.ridd.2013.06.020

Cohen, B. H. (1996). *Explaining psychological statistics.* Pacific Grove, CA: Brooks & Cole.

Crosbie, J., Arnold, P., Paterson, A., Swanson, J., Dupuis, A., Li, X., . . . Schachar, R. J. (2013). Response inhibition and ADHD traits: Correlates and heritability in a community sample. *Journal of Abnormal Child Psychology, 41*, 497–507. doi:10.1007/s10802-012-9693-9

Corbett, B. A., Constantine, L. J., Hendren, R., Rocke, D., & Ozonoff, S. (2009). Examining executive functioning in children with autism spectrum disorder, attention deficit hyperactivity disorder and typical development. *Psychiatry Research, 166*(2‐3), 210–222. doi:10.1016/j.psychres.2008.02.005

Daniel, M. H. (2012a). Equivalence of Q-interactive administered cognitive tasks: WAIS–IV (Q-interactive Technical Report 1). Bloomington, MN: Pearson. Retrieved from http://www.helloq.com/content/dam/ped/ani/us/helloq/media/ QinteractiveTechnical%20Report%201_WAIS-IV.pdf

Daniel, M. H. (2012b). Equivalence of Q-interactive administered cognitive tasks: WISC–IV (Q-interactive Technical Report 2). Bloomington, MN: Pearson. Retrieved from http://www.helloq.com/content/dam/ped/ani/us/helloq/media/ Technical%20Report%202_WISC-IV_Final.pdf

Daniel, M. H. (2012c). Equivalence of Q-interactive administered cognitive tasks: CVLT–II and selected D-KEFS subtests (Q-interactive Technical Report 3). Bloomington, MN: Pearson. Retrieved from http://www.helloq.com/content/dam/ped/ani/us/helloq/media/ Technical%20Report%203_CVLT_DKEFS_final_rev.pdf

Daniel, M. H. (2013a). Equivalence of Q-interactive and paper administrations of cognitive tasks: Selected NEPSY–II and CMS subtests (Q-interactive Technical Report 4). Bloomington, MN: Pearson. Retrieved from http://www.helloq.com//content/dam/ped/ani/us/helloq/media/ Technical%20Report%204_NEPSY-II_CMS.pdf

Daniel, M. H. (2013b). Equivalence of Q-interactive and paper scoring of academic tasks: Selected WIAT–III subtests (Q-interactive Technical Report 5). Bloomington, MN: Pearson. Retrieved from http://www.helloq.com/content/dam/ped/ani/us/helloq/media/ Technical-Report-5-WIAT-III.pdf

Daniel, M. H. (2013c). Equivalence of Q-interactive and paper administration of WMS–IV cognitive tasks (Q-interactive Technical Report 6). Bloomington, MN: Pearson. Retrieved from http://www.helloq.com/content/dam/ped/ani/us/helloq/media/ Technical_Report_6_WMS-IV.pdf

Daniel, M. H., Wahlstrom, D., & Zhang, O. (2014). Equivalence of Q-interactive and paper administrations of cognitive tasks: WISC–V (Q-interactive Technical Report 8). Bloomington, MN: Pearson. Retrieved from http://www.helloq.com/content/dam/ped/ani/us/ helloq/media/Technical-Report_WISC-V_092514.pdf

Daniel, M. H., Wahlstrom, D., & Zhou, X. (2014). Equivalence of Q-interactive and paper administrations of language tasks: Selected CELF–5 tests (Q-interactive Technical Report 7). Bloomington, MN: Pearson. Retrieved from http://www.helloq.com/content/dam/ped/ani/ us/helloq/media/Technical%20Report%207_CELF-5_Final.pdf

Dawson, M., Soulieres, I., Gernsbacher, M. A., & Mottron, L. (2007). The level and nature of autistic intelligence. *Psychological Science, 18*(8), 657–662. doi:10.1111/j.1467-9280.2007.01954.x

Denaes, C. (2012). Analogical matrices in young children and students with intellectual disability: Reasoning by analogy or reasoning by association? *Journal of Applied Research in Intellectual Disabilities, 25*, 271–281.

Devena, S. E., & Watkins, M. W. (2012). Diagnostic utility of WISC–IV general abilities index and cognitive proficiency index difference scores among children with ADHD. *Journal of Applied School Psychology, 28*(2), 133–154. doi:10.1080/15377903.2012.669743

Elliott, C. D. (2007). *Differential ability scales* (2nd ed.). Bloomington, MN: Pearson.

Englund, J. A., Decker, S. L., Allen, R. A., & Roberts, A. M. (2014). Common cognitive deficits in children with attention-deficit/hyperactivity disorder and autism: Working memory and visual-motor integration. *Journal of Psychoeducational Assessment, 32*(2), 95–106. doi:10.1177/0734282913505074

Fletcher-Flinn, C. M., & Gravatt, B. (1995). The efficacy of computer assisted instruction (CAI): A meta-analysis. *Journal of Educational Computing Research, 12*(3), 219–241.

Flewitt, R., Kucirkova, N., & Messer, D. (2014). Touching the virtual, touching the real: iPads and enabling literacy for students experiencing disability. *Australian Journal of Language and Literacy, 37*(2), 107–116.

Gau, S. S.-F., & Huang, W.-L. (2014). Rapid visual information processing as a cognitive endophenotype of attention deficit hyperactivity disorder. *Psychological Medicine, 44*, 435–446. doi:10.1017/ S0033291713000640

Hale, J. B., Fiorello, C. A., & Brown, L. L. (2005). Determining medication treatment effects using teacher ratings and classroom observations of children with ADHD: Does neuropsychological impairment matter? *Educational & Child Psychology, 22*(2), 39–61.

Hale, J. B., Yim, M., Schneider, A. N., Wilcox, G., Henzel, J. N., & Dixon, S. G. (2012). Cognitive and neuropsychological assessment of attention-deficit/hyperactivity disorder: Redefining a disruptive behavior disorder. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (3rd ed., pp. 687–707). New York, NY: Guilford Press.

Hetzroni, O. E., & Tannous, J. (2004). Effects of a computer-based intervention program on the communicative functions of children with autism. *Journal of Autism and Developmental Disorders, 34*(2), 95–113.

Jacobson, L. A., Ryan, M., Martin, R. B., Ewen, J., Mostofsky, S. H., Denckla, M. B., & Mahone, E. M. (2011). Working memory influences processing speed and reading fluency in ADHD. *Child Neuropsychology, 17*(3), 209–224. doi:10.1080/09297049.2010.532204.

Joseph, R. M., Tager-Flusberg, H., & Lord, C. (2002). Cognitive profiles and social-communicative functioning in children with autism spectrum disorder. *Journal of Child Psychology and Psychiatry, 43*(6), 807–821. doi:10.1111/1469-7610.00092

Kagohara, D. M., van der Meer, L., Ramdoss, S., O'Reilly, M. F., Lancioni, G. E., Davis, T. N., . . . Sigafoos, J. (2013). Using iPods and iPads in teaching programs for individuals with developmental disabilities: A systematic review. *Research in Developmental Disabilities, 34*, 147–156.

Klinger, L. G., O'Kelley, S. E., Mussey, J. L., Goldstein, S., & DeVries, M. (2012). Assessment of intellectual functioning in autism spectrum disorder. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (3rd ed., pp. 670–686). New York, NY: Guilford Press.

Korkman, M., Kirk, U., & Kemp, S. (2007). *NEPSY–II*. Bloomington, MN: Pearson.

Lipszyc, J., & Schachar, R. (2010). Inhibitory control and psychopathology: A meta-analysis of studies using the stop signal task. *Journal of the International Neuropsychological Society, 16*(6), 1064–1076. doi:10.1017/S1355617710000895

Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with attention deficit/hyperactivity disorder. *Journal of the American Academy of Child & Adolescent Psychiatry, 44*(4), 377–384.

Mayes, S. D., & Calhoun, S. L. (2007). Learning, attention, writing, and processing speed in typical children and children with ADHD, autism, anxiety, depression, and oppositional-defiant disorder. *Child Neuropsychology, 13,* 469‑493. doi:10.1080/09297040601112773

Mayes, S. D., & Calhoun, S. L. (2008). WISC–IV and WIAT–II profiles in children with high-functioning autism. *Journal of Autism and Developmental Disorders, 38,* 429–439. doi:10.1007/s10803-007-0410-4

Mayes, S. D., Calhoun, S. L., Chase, G. A., Mink, D. M., & Stagg, R. E. (2009). ADHD subtypes and co-occurring anxiety, depression, and oppositional defiant disorder: Differences in Gordon diagnostic system and Wechsler working memory and processing speed index scores. *Journal of Attention Disorders, 12*(6), 540–550. doi:10.1177/1087054708320402

Mayes, S. D., Calhoun, S. L., Mayes, R. D., & Molitoris, S. (2012). Autism and ADHD: Overlapping and discriminating symptoms. *Research in Autism Spectrum Disorders, 6,* 277–285. doi:10.1016/j.rasd.2011.05.009

Murdock, L. C., Ganz, J., & Crittendon, J. (2013). Use of an iPad play story to increase play dialogue of preschoolers with autism spectrum disorders. *Journal of Autism & Developmental Disorders, 43*, 2174–2189. doi:10.1007/s10803-013-1770-6

Polanczyk, G., de Lima, M. S., Horta, B. L., Biederman, J., & Rohde, L. A. (2007). The worldwide prevalence of ADHD: A systematic review and metaregression analysis. *American Journal of Psychiatry, 164*(6), 942–948.

Raiford, S. E., Holdnack, J. A., Drozdick, L. W., & Zhang, O. (2014). Q-interactive special group studies: The WISC–V and children with intellectual giftedness and intellectual disability (Q-interactive Technical Report 9). Bloomington, MN: Pearson. Retrieved from http://www.helloq.com/content/dam/ped/ani/us/helloq/media/Technical_Report_9_WISC-V_Children_with_Intellectual_Giftedness_and_Intellectual_Disability.pdf

Rimm, S., Gilman, B., & Silverman, L. (2008).Nontraditional applications of traditional testing. In J. L. VanTassel-Baska (Ed.), *Alternative assessments with gifted and talented students* (pp. 175–202). Waco, TX: Prufrock Press.

Rosch, K. S., Dirlikov, B., & Mostofsky, S. H. (2013). Increased intrasubject variability in boys with ADHD across tests of motor and cognitive control. *Journal of Abnormal Child Psychology, 41*(3), 485–495.

Rowe, E. W., Kingsley, J. M., & Thompson, D. F. (2010). Predictive ability of the general ability index (GAI) versus the full scale IQ among gifted referrals. *School Psychology Quarterly, 25*(2), 119–128. doi:10.1037/a0020148

Soulieres, I., Dawson, M., Gernsbacher, M. A., & Mottron, L. (2011). The level and nature of autistic intelligence II: What about Asperger syndrome? PloS ONE, 6(9), e25372. doi:10.1371/journal.pone.0025372

Stevenson, J. L. (2011). Autistic cognition: Effects of test domain and reasoning level (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses. (UMI No. 3486771)

Turner, V. (2010). *Performance of children with autism on selected measures of reading achievement and cognitive linguistic ability*. (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses. (UMI No. 3434388)

Wakkinen, H. B. (2008). *Maximizing resources to gain information about clients: Profile analysis, configural frequency analysis, and the WISC–IV* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses. (UMI No. 3322469)

Wechsler, D. (2002). *Wechsler preschool and primary scale of intelligence* (3rd ed.). Bloomington, MN: Pearson.

Wechsler, D. (2003). *Wechsler intelligence scale for children* (4th ed.). Bloomington, MN: Pearson.

Wechsler, D. (2008). *Wechsler adult intelligence scale* (4th ed.). Bloomington, MN: Pearson.

Wechsler, D. (2012). *Wechsler preschool and primary scale of intelligence* (4th ed.). Bloomington, MN: Pearson.

Wechsler, D. (2014). *Wechsler intelligence scale for children* (5th ed.). Bloomington, MN: Pearson.

Zayat, M., Kalb, L., & Wodka, E. L. (2011). Brief report: Performance pattern differences between children with autism spectrum disorders and attention deficit-hyperactivity disorder on measures of verbal intelligence. *Journal of Autism and Developmental Disorders, 41*(12), 1743–1747. doi:10.1007/s10803- 011-1207-z

Zieman, S. F. X., Jr. (2010). *Performance analysis on the WISC–IV working memory and processing speed index among ADHD subtypes*. (Doctoral dissertation). Retrieved from WorldCat. (Accession No. 526695555)