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NONVERBAL ASSESSMENT OF IQ, ATTENTION, AND MEMORY ABILITIES IN CHILDREN WITH FRAGILE-X SYNDROME USING THE LEITER-R

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This study examined the clinical utility of the recently revised Leiter International Performance Scale (Leiter-R) with a sample of children with fragile-X syndrome. The sample included 25 male children ranging in age from 4.0 to 12.8 years and was 92% European American. All subjects were administered the entire Attention and Memory Battery, and the four subtests from the Visualization and Reasoning Battery that comprise the Brief IQ composite. These tasks were selected to address specific concerns pertaining to memory and attention in individuals with fragile-X. Initial examination of the data revealed that all of the children completed the subtests comprising the Brief IQ and, outside of the Attention Divided subtest, over 80% of the children completed most of the subtests on the Attention and Memory Battery. Findings from the Leiter-R were generally consistent with previously reported assessment results with this population. Overall, the sample fell within the mild to moderate range of mental retardation, with over 80% of the group at or below this range of functioning. As a group, relative difficulty was noted on tasks tapping selective attention and working memory. Ipsatively, a relative strength was apparent across cases on the Associated Pairs subtest. Chronological age had a significant moderate positive correlation with the Leiter-R growth score for the composite scales and a significant strong negative correlation with the age-based standard score for Brief IQ. These findings are discussed with respect to the clinical and research applications of the Leiter-R for children with fragile-X as well as for children with other developmental disabilities.

Nonverbal assessment strategies have been defined as any procedures that reduce demands for language by the examiner or examinee (Anastasi, 1988). Such assessment strategies have typically been used to gain a more accurate estimate of some function or set of abilities in populations in which language demands create bias and reduce the accuracy of the assessment (Harris, Reynolds, & Koegel, 1996). For example, one of the primary uses of nonverbal strategies has been to assess minority and/or culturally diverse populations. Harris et al. (1996) suggested that many culturally based language differences

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could be eliminated, or at least minimized, by using nonverbal assessmentstrategies. Nonverbal assessment methods have also been used for individuals with a variety of acquired and developmental disabilities, particularly when language abilities are suspect or impaired. Here, the primary rationale for their use rests on the idea that language-based assessment focuses on areas of relative weakness and may reduce the accuracy of a cognitive appraisal. For these individuals, not only is the nonverbal nature of the testing procedure important, but other test variables become critical to the assessment and tracking processes as well (e.g., sufficient floors/ceilings). To date, however, few instruments are readily available that can address this range of needs.

The Leiter International Performance Scale, and its adaptation (Arthur, 1949), is a nonverbal tool with a 60-year history of application to individuals with developmental disabilities and disorders. The current revision of this tool, the Leiter-R (Roid & Miller, 1997), was developed for use with individuals ranging in age from 2 through 20 years. In comparison to the original version of the Leiter, the Leiter-R incorporates many of the advances made in test development over the years. In addition to a national standardization of over 2,000 children and adolescents, the use of item-response theory and Rasch scaling for item selection/placement, and the employment of factor analyses to produce summary domains, the newly revised Leiter was designed to tap a wider range of functions than the original version.

The current version is comprised of 20 subtests organized into two major sections: Reasoning and Visualization (10 subtests) and Memory and Attention (10 subtests). Standard scores ($M = 100$, $SD = 15$) are generated for each of the factor-based composites on the Visualization and Reasoning Battery (i.e., Fluid Reasoning, Brief IQ, Fundamental Visualization, Spatial Visualization, and Full IQ) and the Attention and Memory Battery (i.e., Memory Screen, Associative Memory, Memory Span, Memory Process, and Recognition Memory), and for each of the subtests comprising these respective domains ($M = 10$, $SD = 3$). As such, this tool not only appears to hold great promise for assessment in culturally sensitive cases, but it also should continue to prove useful for assessing individuals with developmental disabilities. Indeed, the previous versions of the Leiter enjoyed much use with these populations (Crowe & Hay, 1990), and the technological advances embedded in the current version should make the revised Leiter even more useful.

One population in which contemporary nonverbal assessment procedures, such as the Leiter-R, might prove useful is individuals with fragile-X syndrome. Fragile-X syndrome is an X-linked genetic disorder that contributes to a wide-ranging spectrum of developmental disabilities. This spectrum of problems can range from mild learning and attention problems to severe mental retardation, with fragile-X being the leading inherited cause of mental retardation. Additional characteristics that have been associated with individuals with fragile-X include attention deficits, sensory processing impediments, speech and language difficulties, sequential processing problems, high anxiety levels, and a number of physical stigmata (e.g., large or protruding ears, long thin face, flat feet, hyperextensible joints, hypotonia). Bailey, Mesibov, Hatton, Clark, Roberts, and Mayhew (1998) also noted that as many as 25% of males with fragile-X syndrome may meet criteria for autism. In general, males tend to be more affected and, consequently, more impaired than females (Freund, 1994), with prevalence rates ranging from 1:4000 for affected males and 1:8000 for affected females (Warren & Sherman, in press). The cognitive impairment, physical features, and behavioral characteristics of fragile-X syndrome result from the lack of FMR1 protein (Tassone et al., in press), and a definitive diagnosis can be made only by genetic testing. Although a large number of interventions have been used to work with children with fragile-X, there are few data available that document the safety or efficacy of these interventions (McCabe, de la Cruz, & Clapp, 1999).

One of the key questions that has been debated with respect to individuals with fragile-X is whether their intellectual abilities decline over time. Hay (1994) noted a number of significant methodological problems that clouded a definitive response to this concern (e.g., pooling data from different tests; application of intelligence tests to lower functioning individuals), particularly with individuals with fragile-X (e.g., the wide array of specific difficulties, such as language, that can be presented). In their review of the literature, Bennetto and Pennington (1996) noted that this IQ decline appears to be a real phenomenon for males, but not necessarily for females, although the etiology and timing for this decline remain elusive at present. More recently, Bailey, Hatton, and Skinner (1998) reported positive developmental trajectories of most developmental functions in their preschool sample of male children with fragile-X syndrome, although the gains were only about one half those of typically developing children. Although somewhat in contrast to the findings related to IQ decline, these latter findings are important in that in addition to issues related to measurement, issues pertinent to specific age of decline might be critical to understanding the cognitive functioning of this population. In their review, Bennetto and Pennington (1996) also reported that, given the genetic impact on the development of selected neuroanatomical regions in the brain (e.g., hippocampus, frontal regions), attention, memory, and executive functions might be differentially impaired in individuals with fragile-X syndrome. Obviously, the lack of good cognitive measurement with satisfactory technical qualities and the capacity to facilitate longitudinal tracking has contributed to the IQ debate. Further, most of the available cognitive tools (e.g., WISC-III, K-ABC)—even nonverbal tools (e.g., C-TONI)—provide little in the way of description of selected areas of functioning.

In this regard, it would seem that the Leiter-R might be a nonverbal assessment tool that could be used productively with individuals with fragile-X. Indeed, the original Leiter has been used with this population (Crowe & Hay, 1990), and the Leiter-R should prove to be useful as well. For individuals with fragile-X syndrome, a nonverbal tool such as the Leiter-R will not only minimize the impact of documented speech and language difficulties during a cognitive appraisal, but it could also lessen the hyperarousal and social anxiety that can be manifested by many of these individuals; that is, eliminating the requirement for verbal responding might reduce anxiety and, thus, enhance performance (Hatton, Bailey, Hargett-Beck, Skinner, & Clark, in press). In addition to its ability to provide an estimate of overall intellectual functioning, the Leiter-R should serve to provide a vehicle for examining selected attention and memory abilities in this population and subsequently permit follow-up of the speculations offered by Bennetto and Pennington (1996) regarding the integrity of these functions in individuals with fragile-X syndrome.

The primary purpose of this study is to examine the utility of the Leiter-R in a sample of children with fragile-X syndrome. Given the social-behavioral presentation of many of these children, we initially examined how many of the Leiter-R subtests the children in the sample were able to complete in a standardized fashion. Given the propensity of many of these children to become anxious and/or overactive in new settings, a nonverbal testing strategy may actually facilitate their performance. It was suspected that, given the nonverbal nature of the Leiter-R, most if not all of the children would be able to perform some aspect of this test. The sample was also described in terms of their IQ, attention, and memory functioning. In this regard, both normative and ipsative types of analyses were examined. It was expected that intra-individual weaknesses would be seen in selected attention and memory tasks. Finally, in addition to detailing these functions, as defined by the Leiter-R, an effort is made to estimate the general developmental trend of IQ and memory abilities in this sample. Specifically, although a positive association was expected between chronological age and the growth scores for the Leiter-R composites, a negative association was expected between chronological age and the age-based standard scores. This would suggest that children with fragile-X are making gains, but at a much slower rate (Bailey et al., 1998).

METHOD

Subjects

The sample included 25 children ranging in age from 4.0 years to 12.8 years ($M = 7.9$ years, $SD = 2.0$), with all but 1 child aged 10 or younger. All of the subjects were males with the full mutation fragile-X syndrome. The sample included 23 children of European American descent and 2 African American children. The socioeconomic status of the sample was estimated according to whether families were receiving public assistance at the time of testing, with approximately 28% ($n = 7$) receiving this type of financial assistance. Two of the children had symptoms consistent with Autistic Disorder as determined by the Childhood Autism Rating Scale. All of the children and families were participating in a larger longitudinal study of the early development of children with fragile-X syndrome, and subject ascertainment was determined by which subjects were being scheduled for their longitudinal examination in the larger study.

Instruments and Procedures

The principal measure used for this study was the Leiter-R (Roid & Miller, 1997). All subjects were administered the 10 subtests from the Leiter-R Attention and Memory Battery and the 4 subtests from the Visualization and Reasoning Battery that comprise the Brief IQ composite. Although there was an attempt to counterbalance these two major portions of the Leiter-R, this could not be conducted consistently across cases given the typical behavioral challenges and general level of cognitive functioning evidenced by this sample. Further, given the suspected level of functioning of this sample, suggested starting points were abandoned in favor of beginning each subtest with the first item. All of the testing was completed at a child development center, in the child's school, or in the child's home setting, with the Leiter-R being administered by a trained psychologist.

Initially, the number of children who completed the requisite subtests was tabulated. Descriptive results were profiled in accordance with scoring criteria for the Leiter-R and discussed from a normative perspective. Test scatter was also examined for each individual via (a) scale score differences between Leiter-R subtests, (b) scale score differences between Leiter-R subtests and the individual mean score for the Brief IQ and Attention and Memory batteries, and (c) standard score differences between the Leiter-R composite scores as per guidelines proposed in the Leiter-R manual (Roid & Miller, 1997). In addition, although these data did not permit longitudinal comparisons, chronological age was correlated with Leiter-R growth scores, and with age-based standard scores for six of the seven composites, in order to examine the general developmental trend of IQ and memory abilities in this sample of children. Growth scores were not developed for the Attention subtests given their multipoint scoring format (Roid & Miller, 1997) and consequently were not included in this comparison.

RESULTS

Subtest Completion

It was suspected that, given the nonverbal nature of the Leiter-R, most if not all of the children would be able to perform some aspect of this test. This was critical to the clinical use of this test with difficult populations, but it was also necessary for examiners to begin to examine profile patterns. Examination of Table 1 shows that this was generally true for this sample. For the Brief IQ, all of the children were able to complete the four required subtests. Further,

Table 1
Percent of Cases Completing Required Subtests on the Brief IQ and Attention and Memory Batteries

Leiter-R Subtests	% Completing Subtests
Brief IQ Subtests	
Figure Ground	100.0
Form Completion	100.0
Sequential Order	100.0
Repeated Patterns	100.0
Attention/Memory Subtests	
Associated Pairs	84.0
Immediate Recognition	83.3
Forward Memory	84.0
Attention Sustained	80.0
Reversed Memory	95.2
Visual Coding	95.2
Spatial Memory	95.2
Delayed Pairs	95.2
Delayed Recognition	81.0
Attention Divided	66.7

although it was not clear if the children in this sample performed at a maximal level, it was clear that the overall results from the Brief IQ were consistent with the level of functioning typically reported for children with fragile-X syndrome.

For the Attention and Memory Battery, 56% of the sample completed all of the tasks required, and an additional 28% completed all but one of the tasks. Most of the subtests not completed were by subjects who were younger (i.e., ages 4 and 5), but not necessarily the lowest functioning. Subtest completion rates ranged from about 67% for the Attention Divided subtest, with most of the children having the greatest difficulty on this task, to about 95% for the Reversed Memory, Visual Coding, Spatial Memory, and Delayed Pairs subtests.

Profile Analyses

Standard score and growth score means with their respective standard deviations across all of the Leiter-R subtests and associated composite scores are presented in Table 2. As can be seen, this sample of individuals with fragile-X syndrome had a mean Brief IQ score of 58.24, which fell at the lower end of the mild range of mental retardation; however, there was considerable variability around this score. Specifically, 12% ($n = 3$) of the children were at least 4 standard deviations below the normative mean of 100; 40% ($n = 10$) were 3 to 4 standard deviations below the mean; 28% ($n = 7$) were 2 to 3 standard deviations below the mean; and 16% ($n = 4$) were 1 to 2 standard deviations below the mean. Only 4% ($n = 1$) of the children fell within the average range of functioning. As a group, the four subtests from the Visualization and Reasoning Battery comprising the Brief IQ reflected little variation, with scaled scores about 2 standard deviations below the normative mean for all four subtests. On the Attention and Memory Battery, all of the scores fell below the normative mean. Qualitatively, as a group, when the Attention and Memory Battery composite scores were compared to each other, a relative strength was suggested on the Associative Memory Composite and relative weaknesses were suggested on the Memory Span, Memory Process, and Attention composite scores. This group profile is illustrated in Figure 1.

Individual profiles were also examined using several strategies: intersubtest scatter, subtest-to-test mean comparisons, and composite-to-composite comparisons, with a particular focus on the presence of statistically and clinically significant differences. With respect to intersubtest scatter for a particular subject on the Brief IQ subtests, the difference between the highest and lowest subtest score needed to be approximately 5 scaled score points for statistical significance at the $p < .05$ level and at least 8 scaled score points for clinical significance. This latter difference was the magnitude of range evidenced by less than 15% of the standardization sample, and it reflected a significantly rare difference. On the Brief IQ subtests, none of the children in this sample manifested a subtest difference that even met the statistical difference criterion.

On the Attention and Memory Battery subtests, the difference between the highest and lowest subtests needed to be about 3 to 4 scaled score points (depending on the specific comparison) to be statistically significant and about 8 to 10 points (depending on the age level and number of subtests administered) to be clinically significant. In this regard, over 95% of the children

Table 2
Standard Score and Growth Score Means and Standard Deviations for the Fragile-X Group (N = 25)

Leiter-R Tasks	Standard Score Mean (*SD*)	Growth Score Mean (*SD*)
Visualization and Reasoning Battery		
Brief IQ	58.24 (15.02)	455.56 (9.54)
Figure Ground	3.48 (2.62)	460.16 (10.95)
Form Completion	4.56 (2.04)	455.20 (12.68)
Sequential Order	4.00 (2.52)	451.12 (11.94)
Repeated Patterns	3.72 (2.56)	454.56 (18.17)
Attention and Memory Composites		
Memory Screen	63.19 (6.30)	470.19 (9.22)
Associative Memory	75.10 (6.84)	473.50 (8.32)
Memory Span	51.60 (6.01)	456.20 (15.17)
Attention	52.21 (12.75)	–
Memory Process	53.20 (7.77)	459.20 (14.06)
Recognition Memory	69.30 (14.68)	474.20 (15.19)
Attention and Memory Subtests		
Associated Pairs	6.52 (1.44)	476.10 (9.68)
Immediate Recognition	4.65 (2.39)	475.50 (15.04)
Forward Memory	1.86 (1.06)	458.86 (15.41)
Attention Sustained	2.70 (2.32)	–
Reverse Memory	2.25 (1.33)	448.90 (4.88)
Visual Coding	4.90 (1.80)	457.05 (17.78)
Spatial Memory	3.80 (1.88)	456.20 (20.17)
Delayed Pairs	4.30 (1.75)	469.70 (10.34)
Delayed Recognition	4.55 (3.14)	473.00 (15.44)
Attention Divided	2.29 (2.34)	–

Note.–The Brief IQ and Composite scores from the Attention and Memory Battery have a mean of 100 and a standard deviation of 15. All of the subtests have a mean of 10 and a standard deviation of 3. Growth scores can range from approximately 380 to 560, with scores centered at the 10 year 4 month level.

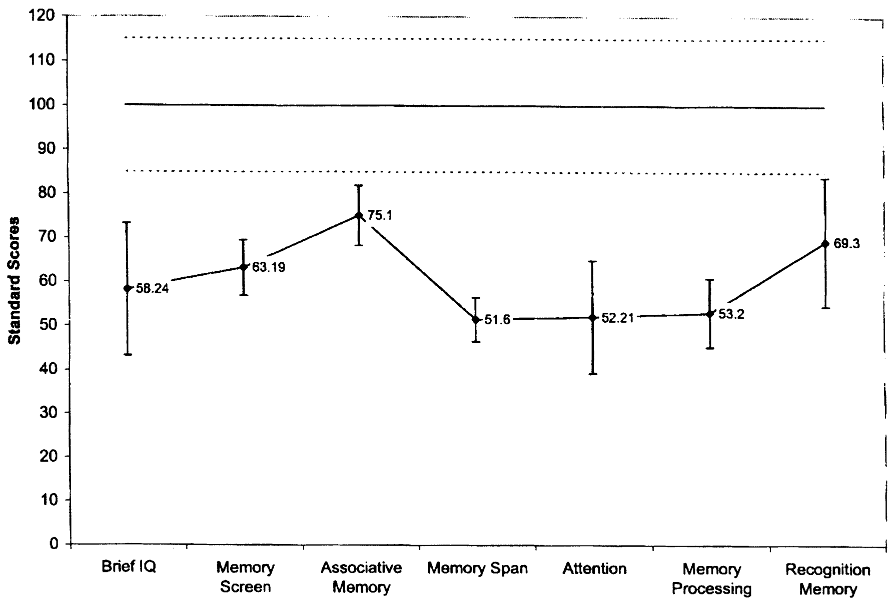

FIGURE 1. Mean Leiter-R composite scores for children with fragile-X syndrome (*N* = 25).

demonstrated subtest scatter that was statistically significant, but only about 24% of these cases evidenced clinically significant, or rare, subtest scatter.

Another strategy for examining test scatter on the Leiter-R is to compare a specific subtest score to the child's overall mean across all of the administered Brief IQ subtests or the Attention and Memory subtests. For most of the Brief IQ subtests, a difference of about 4 scaled score points was needed for statistical significance and a difference of about 5 points was needed on the Attention and Memory Battery. Using this strategy, a profile of strengths and weaknesses could begin to be charted for a particular child. As can be seen in Table 3, very few strengths or weaknesses were apparent on the Brief IQ Battery, with only the Figure Ground subtest reflecting minor variability. On the Attention and Memory Battery, however, slightly more variability was evident for this sample. Although few relative weaknesses were noted—likely secondary to the lower overall performance of this sample (i.e., the average score for nearly all of the cases was less than a scaled score of 5, thus making the ability to detect a relative weakness impossible with this strategy)—several strengths were apparent across the subjects in this sample. In particular, nearly 20% of the sample showed a significant relative strength on the Associated Pairs subtest. Selected cases also demonstrated relative strengths on Immediate Recognition, Attention Sustained, Delayed Pairs, and Delayed Recognition.

A final strategy for examining test scatter on the Leiter-R was to compare the various composite scores. The Leiter-R manual provides for 13 possible com-

Table 3

Percent of Cases Showing Significant Differences between Subtest Scores and Their Overall Mean Score for the Brief IQ and Attention/Memory Batteries

Subtests	Strengths	Weaknesses
Brief IQ Subtests		
Figure Ground	4.0	4.0
Form Completion	0.0	0.0
Sequential Order	0.0	0.0
Repeated Patterns	0.0	0.0
Attention/Memory Subtests		
Associated Pairs	19.1	0.0
Immediate Recognition	5.0	0.0
Forward Memory	0.0	0.0
Attention Sustained	5.0	0.0
Reverse Memory	0.0	5.0
Visual Coding	0.0	0.0
Spatial Memory	0.0	0.0
Delayed Pairs	5.0	0.0
Delayed Recognition	5.0	0.0
Attention Divided	0.0	0.0

Note.–Subtest strengths and weaknesses were calculated by first obtaining an average score for all of the scaled scores on the Brief IQ battery and the Attention/Memory battery, respectively, and then comparing each specific subtest to the respective mean score. A difference of about ± 4 scaled score points was needed for a strength or weakness to be identified on the Brief IQ subtests, and a difference of about ± 5 points was needed on the Attention and Memory subtests.

posite comparisons across the Brief IQ and Attention/Memory batteries. These comparisons are listed in Table 4. As can be seen in Table 4, many of the subjects in this sample demonstrated statistically significant differences between the various composite comparisons, ranging from about 7% on the Memory Span versus Attention and Memory Process versus Attention comparisons to 90% on the Associated Memory versus Memory Span composite comparisons. The size of the differences for many of the cases also reflected clinical significance, wherein less than 15% of the standardization group obtained differences of such magnitude. The observations noted in Table 4 provide the direction of the difference for all of these comparisons.

Table 4

Percent of Cases Showing Statistically Significant and Clinically Significant Score Differences between Selected Composite Scores

Composite Comparison	% Statistically Significant	% Clinically Significant	Observations
BIQ vs. MS	28.6	-	BIQ >MS in 17% of cases
BIQ vs. MP	30.0	-	BIQ > MP in 50% of cases
RM vs. MS	23.8	80.0	RM > MS in 20% of cases
AM vs. MSp	90.0	61.1	AM > MSp in all cases
AM vs. MP	80.0	68.8	AM > MP in all cases
AM vs. ATT	78.6	90.9	AM > ATT in all cases
AM vs. MS	28.6	100.0	AM > MS in all cases
MS vs. MP	10.0	50.0	MS < MP in all cases
MSp vs. ATT	7.1	100.0	MSp < ATT in all cases
MSp vs. MS	30.0	100.0	MSp < MS in all cases
MP vs. ATT	7.1	0.0	MP < ATT in all cases
MP vs. MS	10.0	50.0	MP < MS in all cases
ATT vs. MS	46.2	0.0	ATT < MS in all cases

Note.—BIQ = Brief IQ, MS = Memory Screen, AM = Associative Memory, MSp = Memory Span, ATT = Attention, MP = Memory Process, and RM = Recognition Memory. All possible comparisons were extracted from the Leiter-R manual. The statistical difference was set at the $p < .05$ level as determined by chronological age as illustrated in the Leiter-R manual. Clinically significant differences were determined by the magnitude of the difference not being evidenced by more than 15% of the standardization population as noted in the Leiter-R manual. The percent was calculated based on the number of children showing statistically significant differences.

Developmental Trends

Given the small sample size and cross-sectional restrictions of this study, the data do not lend themselves to uncovering clear developmental findings in this sample of children; however, the data do allow for examination of possible developmental trends from which additional hypotheses could be established regarding children with fragile-X syndrome. To examine the general developmental trend of IQ and memory abilities in this sample of children, chronological age was correlated with (a) the Leiter-R growth scores for the six composite indices and (b) the Leiter-R age-based standard scores for the six composite indices. Specifically, chronological age correlated with Brief IQ, $r = .45$,

$p < .02$; Memory Screen, $r = .66$, $p < .001$; Associative Memory, $r = .50$, $p < .02$; Memory Span, $r = .58$, $p < .007$; and Memory Process, $r = .66$, $p < .001$. The correlation of chronological age with the Recognition Memory composite approached significance, $r = .42$, $p < .06$. As can be seen, nearly all of the correlations were significant, moderate to strong, and positive. These findings suggest that absolute gains were evidenced for this sample with increasing age.

When chronological age was correlated with the age-based standard scores, few significant associations emerged. Chronological age did correlate significantly and strongly with Brief IQ in a negative fashion, $r = -.70$, $p < .001$, suggesting that as age increased the Brief IQ score declined. In contrast, chronological age did not correlate with any of the memory composites.

Table 5
Correlations between Chronological Age and Growth Scores, and Chronological Age and Standard Scores for the Leiter-R Composite Scores

Leiter-R Composites	Correlation of CA and Growth Scores	Correlation of CA and Standard Scores
Brief IQ	.45*	-.70***
Memory Screen	.66***	-.10
Associative Memory	.50*	.05
Memory Span	.58**	-.28
Memory Process	.66***	.04
Recognition Memory	.42+	-.09

Note.—Growth scores were not developed for the Attention subtests given their multipoint scoring format.
+$p < .06$; *$p < .05$; **$p < .01$; ***$p < .001$.

DISCUSSION

One of the primary purposes of this study was to examine the IQ, attention, and memory functioning of children with fragile-X syndrome using the Leiter-R and to begin to determine the clinical utility of this test with such populations. Although the rapport established by the examiner and the behavior management strategies that may need to be employed should not be underestimated when working with individuals with severe developmental impairments, the nonverbal format of the Leiter-R for the examiner and examinee appears to provide both clinicians and researchers working with such populations a valuable assessment tool.

In this sample, all 25 of the children were able to complete the four subtests contained within the Brief IQ Battery, and over 80% of the children completed most of the subtests within the Attention and Memory Battery. These findings were generally true for the most impaired individuals, although there was a sense that the younger the child, the greater the difficulty gaining a performance that could be scored. The Leiter-R Brief IQ faired particularly well in this sample, and this array of tasks should prove useful to clinicians and researchers considering this battery with difficult and/or complex populations. The Attention Divided and Attention Sustained subtests from the Attention and Memory Battery seemed to present the most difficulty for this sample, which may be qualitatively related to the types of problems that children with fragile-X can manifest. In general, the nonverbal nature of the Leiter-R may create a less threatening testing situation for highly reactive children and thus allow for more tasks to be attempted and more cognitive abilities to be estimated.

When compared to previous descriptions of males with fragile-X (see Bennetto & Pennington, 1996), the results from the Leiter-R appear to be highly consistent with these findings, with the overall sample falling within the mild-to-moderate range of mental retardation. In addition, composite scores on the Attention and Memory Battery that tap specific functions related to selective attention (Attention composite) and working memory (Memory Span composite) may be disproportionately lower than other abilities in this sample. In contrast, the sample presented relatively higher Associative Memory and Recognition Memory capabilities. These findings would be consistent with recent assertions concerning these cognitive functions in males with fragile-X syndrome (e.g., Bennetto & Pennington, 1996) and would question the functional integrity of specific neuroanatomical regions where the FMR1 protein tends to be expressed in individuals with fragile-X (i.e., frontal regions, hippocampal regions). More generally, the Leiter-R might prove useful in addressing the pursuit of a neurocognitive phenotype in this population, particularly if included as part of a more carefully constructed assessment battery addressing information-processing issues specific to individuals with fragile-X.

Not only did the Leiter-R generate an overall level of functioning that was consistent with much of the literature describing children with fragile-X syndrome, but it also has some capacity to describe intra-individual differences. In particular, using the various methods to detect test scatter, there was some indication that the Associated Pairs subtest represented a relative strength in the overall profiles of many of the children. Although selected weaknesses may have been more difficult to detect in this group given the relatively lower overall level of functioning of the sample, the finding of a possible relative strength across cases in this sample does lend itself to possible intervention strategies using paired associate learning paradigms.

In addition to the apparent utility of the Leiter-R in describing the level and pattern of abilities in this population, this test battery appears uniquely suited to addressing the question of declining IQ. For example, the wide normative age range of this revision of the Leiter (i.e., ages 2-0 to 20-11) would permit its use in longitudinal designs. It also appears to have ample floor (i.e., raw scores that extend at least 2 standard deviations below the mean) across the age ranges represented, which should permit most individuals to "get on the board" on most of the subtests. Indeed, this seemed true of the present sample as a whole (although the younger children seemed to experience more difficulty). Further, it is difficult to track change over time with tools that adjust for chronological age, with most tests not being equipped to address change over time via growth-curve methodology. The Leiter-R can address this problem with its use of the growth score. The growth score is a standard score that is intimately linked to the raw score of specific tasks via item response theory. It is a special transformation of the Rasch ability scale. Key features of the growth score are its equal-interval measurement properties and its sensitivity to change over time (Woodcock & Dahl, 1971). The growth scores for each task of the Leiter-R were developed using growth-curve trajectories, and their range of application extends from toddlerhood through young adulthood. The use of the growth score should facilitate addressing the question as to whether children with fragile-X show declines in their IQ and/or manifest true neurocognitive deterioration. Although longitudinal comparisons were not possible with the current data, this sample of children did evidence moderate to strong positive correlations of chronological age with the growth scores for the Brief IQ and nearly all of.the Attention and Memory Battery composites. A strong negative correlation of chronological age with Brief IQ was also noted. These findings suggest that this sample did continue to make absolute gains over time, although their overall Brief IQ score was declining with increasing age. The growth score should also facilitate examination of treatment effects for any given child (e.g., task-related versus age-related declines).

There have been vast improvements in this tool, and these improvements should provide additional contributions to the understanding of disorders such as fragile-X syndrome. The Leiter-R provides an overall estimate of intellectual functioning, utilizing nonverbal testing strategies on the part of the examiner and examinee, and it provides estimates of specific cognitive functions such as visual processing, attention, memory, and selected executive functions. For children with fragile-X syndrome, as well as other disorders in which the use of a nonverbal tool may be necessary, the Leiter-R should be considered in the clinical evaluation, tracking, and research efforts. Future research should examine how females with fragile-X perform on this battery of tasks and how the fragile-X population in general compares to other populations with developmental disabilities (e.g., Autism, Down Syndrome). Although the levels of overall function might be similar, will the patterns of nonverbal cognitive abilities differ across samples? How will intra-individual patterns of performance vary across the various Leiter-R subtests? It would also be important to determine how the Leiter-R and/or specific subtests from this battery might work in tandem with other measurement strategies to obtain a detailed, yet efficient measure of a wide range of neurocognitive abilities (e.g., what other attentional tasks might be necessary?). In general, continued efforts to examine the utility of this tool in the cognitive assessment of cases where culture- and/or language-based problems are manifest would appear to hold great promise.

REFERENCES

Anastasi, A. (1988). *Psychological testing* (6th ed.). New York: Macmillan.

Arthur, G. (1949). The Arthur adaptation of the Leiter International Performance Scale. *Journal of Clinical Psychology, 5*, 345–349.

Bailey, D. B., Hatton, D. D., & Skinner, M. (1998). Early developmental trajectories of males with Fragile-X Syndrome. *American Journal on Mental Retardation, 103*, 29–39.

Bailey, D., Mesibov, G., Hatton, D., Clark, R., Roberts, J., & Mayhew, I. (1998). Autistic behavior in young boys with fragile-X syndrome. *Journal of Autism and Developmental Disorders, 28,* 499–507.

Bennetto, L., & Pennington, B. F. (1996). The neuropsychology of Fragile-X Syndrome. In R. J. Hagerman & A. Cronister (Eds.), *Fragile-X Syndrome: Diagnosis, treatment, and research* (2nd ed., pp. 210–248). Baltimore: Johns Hopkins University Press.

Crowe, S. F., & Hay, D. A. (1990). Neuropsychological dimensions of the Fragile-X Syndrome: Support for a non-dominant hemisphere dysfunction hypothesis. *Neuropsychologia, 28,* 9–16.

Freund, L. S. (1994). Diagnosis and developmental issues for young children with Fragile-X Syndrome. *Infants and Young Children, 6,* 34–45.

Harris, A. M., Reynolds, M. A., & Koegel, H. M. (1996). Nonverbal assessment: Multicultural perspectives. In L. A. Suzuki, P. J. Meller, & J. G. Ponterotto (Eds.), *Handbook of multicultural assessment: Clinical, psychological, and educational applications* (pp. 223–252). San Francisco: Jossey-Bass.

Hatton, D. D., Bailey, D. B., Hargett-Beck, M. Q., Skinner, M., & Clark, R. D. (in press). Behavioral style of young boys with fragile-X syndrome. *Developmental Medicine and Child Neurology.*

Hay, D. A. (1994). Does IQ decline with age in Fragile-X? A methodological critique. *American Journal of Medical Genetics, 51,* 358–363.

McCabe, R. B., de la Cruz, F., & Clapp, K. (1999). Workshop on Fragile-X: Future research directions. *American Journal of Medical Genetics, 85,* 317–322.

Roid, G. H., & Miller, L. J. (1997). *Leiter International Performance Scale-Revised.* Wood Dale, IL: Stoelting.

Tassone, F., Hagerman, R. J., Ikle, D. N., et al. (in press). FMRP expression as a potential indicator in fragile-X syndrome. *American Journal of Medical Genetics.*

Warren, S. T., & Sherman, S. L. (in press). The fragile-X syndrome. In C. R. Scriver, S. L. Beaudet, W. S. Sly, & D. Valle (Eds.), *Metabolic basis of inherited disease.* Philadelphia: Williams & Wilkins.

Woodcock, R. W., & Dahl, M. N. (1971). A common scale for the measurement of person ability and test-item difficulty. *AGS Paper Number 10,* Circle Pines, MN: American Guidance Service.