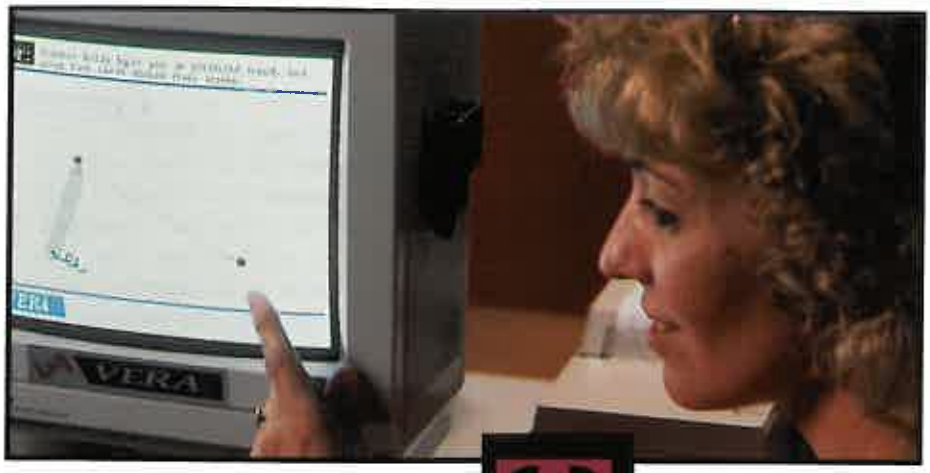
COMPUTERIZED VISION SCREENING: VALIDITY AND REALIABILITY OF THE



VTA/VERA VISION SCREENER

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Abstract

School vision screening is an important part of health assessment for school-age children because vision disorders are common in this population and they affect learning efficiency. A new computerized vision screening device, the VTA\VERA, was studied for validity and reliability. Thirty-six school children's VERA scores were compared to results from comprehensive optometric eye examinations. VERA vision tests were also compared to manifest symptoms of documented vision disorders. Analysis showed the VERA to be highly specific (93% accurate non-referral) and reasonably sensitive (75% of subjects with vision problems detected). Statistical analysis revealed significant relationships to exist between VERA tests and vision symptoms in a sample of 214 school children. The study suggests that the VTA\VERA, when compared to a specific optometric exam battery, is an acceptable alternative to professional vision screenings and can be easily administered by non-professional personnel. Validity and reliability were analyzed by several methods and are discussed in relation to clinical applicability.

Key Words

vision screening, computerized vision screening, VTA\VERA

The purpose of school vision screening is to detect and refer children who may require professional eye examinations. Vision screening is appropriate at any age, but logistically, school vision screenings survey a high percent of the school-age population because most of the children are accessible. While many doctors feel that all children deserve comprehensive routine eye care, all children and their guardians may not desire or may not have reasonable access to receive comprehensive eye care. Screenings are not a substitute for professional eye examinations. The public often misunderstand this and believe that children who receive screenings have had complete eye care. Despite these concerns, school vision screening represents the only chance to detect and refer many children who would otherwise go without care. Thus, most educators and health professionals agree that school screening is important. Many states mandate vision screening, and federal law requires vision assessment for special education and early intervention.

What constitutes an appropriate vision screening is controversial.[1] The National Society to Prevent Blindness recommendations are listed in Table 1. In contrast, the American Academy of Ophthalmology recommends Snellen acuity and ocular alignment testing only. The American Optometric Association endorses the Modified Clinic Technique (MCT) listed in Table 2. In yet another example, the New York State Optometric Association developed its own screening battery shown in Table 3. There are also commercial vision screening devices available, such as the Massachusetts Vision Kit[a] and the Keystone Visual Skills.[b] Some states set guidelines for vision screening, but few have the resources to implement or enforce complete compliance. Thus, adoption of a particular screening program is usually left to individual schools or districts. The above cited discrepancies between organization recommendations has led to problems. In the mid-1980s, New York State, in conjunction with the New York State Optometric Association, decided to implement the NYSOA screening battery. The state did not solicit ophthalmological input, and a group of New York ophthalmologists successfully lobbied against its implementation, citing that most of the tests had no proven value in assessing vision disorders.[2] Such controversy indicates that adoption of consistent vision screening programs may be difficult in the near future.

Table 1.
National Society for the Prevention of Blindness Vision Screening Recommendations[1]

Eye Alignment Measure
Gross External Examination
Case History for Asthenopia
Snellen Acuity

Table 2.
Modified Clinic Technique[3]

Snellen Acuity
Retinoscopy
Cover Test
Color Vision
Gross External Examination
Ophthalmoscopy

Table 3.
New York State Optometric Association Vision Screening[1]

Snellen Acuity distance and near
Plus 1.50 D lens test
Accommodative facility
Nearpoint of Convergence
Stereopsis
King-Devick Saccade Test
Phorias at distance and near
Color vision
Winter Haven Copy Form Test

The MCT is the most effective and cost efficient screening program.[1,3] It was developed in the late 1950s as a "bipartisan" project between optometry and ophthalmology. Input for this screening battery was obtained from university medical and optometric faculty as well as optometrists and ophthalmologists from across the country. Peters et al., in the Orinda study,[3] established the validity, reliability, and cost effectiveness with over 3,000 cumulative screenings and comprehensive eye exams. The final sensitivity, specificity, and phi coefficient was found to be 97%, 98% and +0.95 respectively. In a recent review, Schmidt[1] concluded that the MCT was more effective than the Massachusetts Vision Kit, the Keystone Visual Skills and other less commonly used programs.

Despite the proven effectiveness of the MCT, few schools use it. Waigandt et al.[4] surveyed 127 schools in Missouri in the late 1980s and found little use of effective screening batteries. In their study, only 3% of schools screened for ocular pathology, which shows at least 97% of schools did not use the MCT. Several reasons might explain this. The MCT requires participation by an optometrist or ophthalmologist for retinoscopy and ophthalmoscopy. Doctor availability, schedule adjustments and potential cost make school personnel leery of implementation. School districts may have legal restrictions on allowing outside medical personnel into the school. Educators may be unaware of differences between vision screening programs. Thus, commercially available screeners such as the Massachusetts Vision Kit and the Keystone Visual Skills continue to be used by many schools. The advantages of these tests are that school nurses, teachers, or volunteers can administer them and they test functions such as hyperopia, stereopsis and phorias. As indicated above, the effectivity of these screening tests are significantly lower than the MCT. Further, two studies have found that screening with the Random Dot E stereogram is more accurate than the commercial tests.[5,6] These results are not uniform,[7] but they do point to the relative inaccuracy of the available commercial tests.

It seems, therefore, that there is a reluctance of schools to use the best screening techniques, and instead use commercial instruments where administration is controlled "in house." In response to this trend, Vision Technology Applications, Inc. (VTA) has introduced a new vision screening device which uses computer technology. The VTA\VERA[c] (Visual Efficiency Rating Apparatus) is an attempt to provide schools with "in house" vision screening that concentrates on functional vision skills. The device includes tests called Visual Acuity, Plus Lens Test, Saccades A, Saccades B, Accommoflex, Fusion and Phorias (see Table 4).

Table 4.
VTA\VERA Subtests and Scoring

Visual acuity right eye at 3 meters (10 feet)
Visual acuity left eye at 3 meters (10 feet)
Visual acuity both eyes at 3 meters (10 feet)
Plus 1.50 D lens test both eyes at 3 meters (10 feet) with acuity line one above best acuity both eyes
Saccadics A: timed hand-eye coordination
Total responses
Subtotal score consisting of responses and accuracy
Saccadics B: reading eye movement
Accommoflex: biocular accommodative facility with ±1.50 diopter lenses. Scored in cycles per minute
Accommoflex right eye stimulate, left eye relax
Accommoflex left eye stimulate, right eye relax
Subtotal score for right and left eye combined
Phorias: dissociated horizontal phorias
Composite score derived from scaled formula for entire screening. Failure of any visual acuity or plus lens test resulted in automatic referral.

The VERA is a hardware and software package. The hardware is similar to an IBM personal computer with a high resolution color monitor (see Figure 1). The software instructs an examiner or patient to administer and input responses to vision tests provided on the computer screen. The first test is visual acuity at a 3-meter (10 feet) test distance. The software instructs the examiner to have the patient wear any distance correction, occlude one eye at a time, and have the patient indicate which direction each E in a set of "Tumbling E's" is pointed. The software randomizes the E's, so memorization of the chart does not result in false negatives. The software changes the next presentation, higher or lower acuity level, depending on the accuracy of the previous response, until a maximum acuity is obtained.

Figure 1. The VTA\VERA (Visual Efficiency Rating Apparatus)

The second test is a plus lens test for hyperopia. The software programs a line of "Tumbling E's" at the maximum acuity level. The patient wears +1.50 lenses over his/her correction and is asked to identify the direction of the E's. If the patient correctly identifies 50% of the E's, then hyperopia is assumed to be significant. A third test is a timed visual motor integration test called Saccades A. While seated 40 cm (16") from the screen, the patient is given a light pen and instructed to touch the pen to a green box on the screen (see Figure 2). The software programs the green box to move around the screen and the patient is to touch the pen to the green box as quickly and as accurately as possible. The software records the number of responses and the accuracy of each response. The test lasts one minute. The next test is called Saccades B. In this test, the software programs a random set of numbers to flash across the screen similar to reading eye movements. The patient is instructed to identify the last number seen. The computer numbers are flashed faster and faster until the patient can no longer respond accurately. The Accommoflex test is a biocular accommodative facility

test. The patient wears red/green glasses with +1.50 lens over one eye and -2.00 lens over the other eye. Three numbers appear in either red or green with the appropriate background for cancelation. The patient identifies as many numbers as possible in one minute. The computer alternates the numbers red or green to either stimulate or relax accommodation. The patient switches to a second pair of red/green glasses that reverse the plus and minus lenses to opposite eyes. The test is then repeated. The computer records cycles per minute and accuracy of responses.

The last two tests evaluate binocular vision. The Fusion Test is a Random Dot Stereo-Vergence Test. Again, red/green glasses are worn over the patient's correction. If stereopsis is present, a number (either 1,2,3 or 4) will be seen in pattern on the screen. The subject identifies the number seen and if recorded correctly, the software increases disparity between the red and green targets. The disparity continues to increase until the numbers are not seen correctly. This represents the vergence break point. The disparity then decreases until a recovery is recorded. Base-out is done first, followed by base-in. The final test is Phorias, shown in Figure 3. A red diamond is displayed in the middle of the screen and a vertical blue line is on the left edge. The subject wears red/green glasses. When the examiner presses the space bar, the blue line moves toward the center. The patient tells the examiner "Now" when the line appears directly in the center of the diamond and the examiner presses the space bar again. The software then does a vertical phoria by using a horizontal blue line descending from the top of the screen. Both horizontal and vertical phorias are repeated.

In a previous study,[8] a VERA prototype did not correlate with the MCT. Comparing one screening technique to another, however, is not as valid as comparing a screening program to comprehensive eye examinations and behavioral measures. At the request of VTA Inc., a more comprehensive study was designed to evaluate the VERA's validity and reliability. The VERA's relationship to manifest symptoms was also investigated.

In this report, data are presented on the VERA's validity, reliability, and relationship to manifest symptoms. The purpose, here, is to make these comparisons based on the specific tests the VERA performs and their comparative optometric examination tests. The purpose is not to debate whether these tests are the most appropriate for school vision screening or what the relationship between certain vision disorders and learning may be.

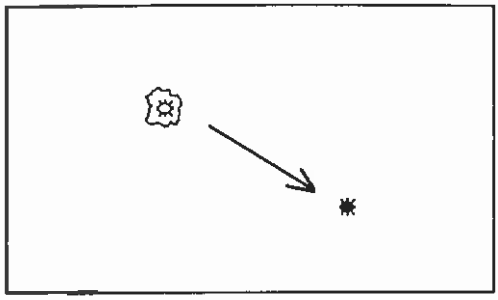

Figure 2. Illustration of Saccades A exercise on the VERA computer screen.

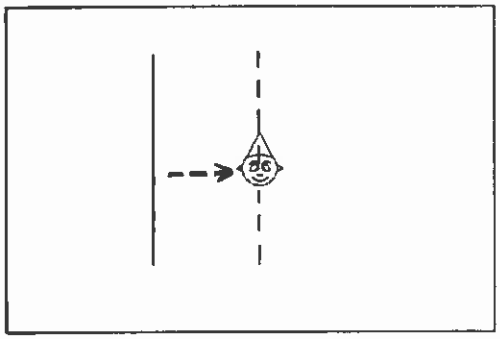

Figure 3. Illustration of the Phorias exercise on the VERA computer screen.

Table 5.
Demographics of subjects in the sample.

Age	Public School	Parochial School	Retest
6-7	67	127	20
8	47	72	10
9	45	54	8
10	37	63	12
11	30	35	9
12-13	21	4	1
TOTALS	247	355	60

Methods

In a previous study,[8] standard scores, normative data and referral criteria were developed for the VTA/VERA. Individual VERA tests, subtotal scores, and an overall composite were available. Table 4 lists the individual tests and subtotal scores. Scores for visual acuity were recorded in Snellen equivalent. Plus 1.50 diopter lens test was recorded as pass or fail. Total responses for Saccades A were the number of boxes attempted during a one-minute period. The subtotal score was a weighted formula combining number of responses and the accuracy of response. This formula and others were derived from the sample and were based on variation of performance and correlation of symptoms. Accommoflex scores were reported in cycles per minute with a subtotal score equal to the sum of each eye. The composite score was also a weighted formula. It consisted of scores from each test multiplied by coefficients to appropriately weigh each variable. For example, coefficients for visual acuity were weighted so high that poor visual acuity automatically led to referral. Coefficients on saccades, however, were weighted lower because a saccadic problem may not be worthy of immediate referral.

For the present study, 602 subjects, age 6 to 13, were recruited from two schools. Demographic data is presented in Table 5. After obtaining informed parent consent, these 602 subjects were surveyed with the VERA's standard school vision screening. The screening was administered by parent volunteers trained by VTA, Inc. Subjects who had corrective distance lenses wore them for the screening. From this survey, an overall percentage of referrals was calculated. In addition, a sample of 214 (35.6%) of the subjects' parents responded to a questionnaire designed to probe signs and symptoms of vision disorders. The questionnaire is presented in Appendix A. It used a 5-point ordinal scale that could be easily understood and provide a quantitative measure of visually-related discomfort. The signs and symptoms described were developed from those documented in the literature for conditions such as hyperopia,[9-12] strabismus,[12-14] convergence insufficiency,[12,15-18] convergence excess,[12,18,19] accommodative dysfunctions,[17,20-23] and eye movement disorders.[12,24-26]

Data was all double entered and key verified, using a custom data entry program. All data was stored using dBase IV. Statistical analysis was performed on all

data, using SPSS/PC+[d] (Version 4.0) on an MSDOS computer. Pearson r correlation coefficients were computed among questions on the parent questionnaire and the VERA results for each test listed in Table 4. A summary score from the questionnaire, consisting of the total of all ordinal responses, was also correlated with the VERA scores. One-way analysis of variance (ANOVA) with and without adjustments for age were also used to compare VERA scores for each of the five score groups (1- 5) on the parent questionnaire. A test for linearity was performed to examine if a dose-response relationship existed within the five groups. From the above analysis, referral criteria from the previous study[8] was further refined. After this refinement (see Results section), a pass or fail was determined for a subset of 36 subjects used for the validity study. VERA pass/fail was determined prior to in-office optometric examination.

Validity was determined from data of the 36 subject samples who also received comprehensive in-office eye examinations in addition to screenings. The 36 exams were performed by the same licensed optometrist. This examiner did not have knowledge of VERA results. The in-office examination rated pass, fail, and borderline, based on the criteria listed in Table 6. A chi squared test was performed, based on the two-by-three matrix in Table 7. For the purpose of further analysis, borderline cases were then categorized by the optometrist as pass or fail, based on his/her experience, and was made without knowledge of VERA scores. This categorization was based on whether treatment would or would not be recommended for the subject. Further analysis then consisted of calculated sensitivity, specificity and phi coefficient.

Reliability was determined by test-retest Pearson r correlation's for 60 subjects. Student t tests were also computed for differences in paired means between test and retest sessions.

Results

Refinement of the VERA referral criteria led to the removal of Saccades B (reading eye movements) and Fusion (Random Dot stereo vergence) because these tests had no influence on outcome. The data was analyzed based on this refined criteria.

From the survey of 602 subjects, 15% would be referred by the VERA. Correlations between vision screening tests and parent questionnaire summary scores are presented in Table 8. Accommoflex, Phorias and overall composite scores were weakly but significantly correlated with questionnaire responses (Table 8). Individual variables correlated to each question did not reveal any higher correlations and are therefore not reported. However, a statistically significant dose-response

Table 6.
Comprehensive Optometric Eye Examination: Protocol and Criteria.

Tests Performed	Pass	Borderline	Fail
Snellen Acuity -each eye	20/30	N/A	20/30
Ophthalmscopy disease	Normal	N/A	any
Keratometry	Clear mires	N/A	Irregular mires
Cover Test	Phoria	N/A	Strabismus
Pursuits/Saccades-modified Marcus system[13]	Smooth/ accurate	Intermediate	Jerky/ inaccurate
Nearpoint of convergence	<3"	3-6"	>6"
Randot stereopsis	<40"	N/A	>40"
Accommodative facility- +/-2.00 D flippers in cycles per minute (cpm)	>6 cpm	4-6 cpm	<4cpm
Retinoscopy and subjective refraction	<-0.75D <+1.50 D <1.00 D	myopia hyperopia cylinder	any > refractive error
Distance & Near phorias	4 eso to 6 exo	NA	>6 exo >4 eso
Distance vergence	>9 BI >16 BO	6-9 BI 10-16 BO	<6BI <10BO
Near vergence	>14 BI >16 BO	8-10 BI 10-16 BO	<8BI <10BO
Vectogram Quoits	SILO	Flat	Suppress
10 Base-out jump vergence	Fusion in <4"	Fusion after 4"	No fusion

Overall failure was given if subjects failed on any one test. Subjects were classified as borderline overall if they were borderline on two or more tests. Results of one borderline or no borderline and pass on all other tests were classified as pass overall.

Table 7.
Comparison of Comprehensive Optometric Eye Examination with VTA/VERA Composite Score.*

Optometric Exam	Mean VERA composite score +/-SD
Fail—6 Subjects	50.5 +/-29.2
Borderline—11 Subjects	75.8 +/- 9.1
Pass —19 Subjects	74.8 +/-10.6

	Optometric Exam		
VERA	Fail	Borderline	Pass
Above 60.00	2	11	17
Below 60.00	4	0	2
Totals	6	11	19

chi squared = 13.5, df = 2, p = 0.001

*Composite score < was considered failure on the VERA.

Table 8.
Correlations (Pearson r) among VERA variables and Parent Questionnaire Responses

	Saccade	Accommoflex	Phorias	Composite
Questionnaire	-0.05	-0.25**	0.20*	0.27**

* p<0.01
**p<0.001

Table 9.
Pass/Fail Cross Tabulation

Correct non-referrals	28
Correct referrals	6
Under referrals	2
Over referrals	2
Total sample	36

Sensitivity = 75%. Seventy-five percent of all vision disorders detected in the comprehensive eye exams were correctly referred by the VERA.

Specificity = 93%. Ninety-three percent of subjects referred by the VERA had vision disorders.

Phi coefficient = +0.69. Phi coefficients can range from -1.00 to +1.00. The closer to +1.00, the more accurate the referral rate.

Table 10.
Correlation of VERA Subtests with Retest.

	Pearson r	p-value	Test (Means ±SD) Retest
Acuity Right Eye	0.55	<0.001	24.08 +/-4.09 25.25 +/-5.9
Acuity Left Eye	0.44	<0.001	24.58 +/-5.1 33.00 +/-4.9
Acuity Both Eyes	0.26	<0.004	21.42 +/-2.6 22.67 +/-6.1
Saccade	0.58	<0.001	0.78 +/-0.23 0.80 +/-0.24
Accommoflex	0.56	<0.001	122.9 +/-46.8 139.4 +/-54.7
Phorias	0.47	<0.001	1.62 +/-3.0 1.26 +/-1.3
Composite	0.47	<0.001	68.3 +/-19.4 74.2 +/-16.9

for linearity was found between the VERA variables and questionnaire responses. This means that within the five score groups symptoms significantly increased as performance diminished. The symptoms most highly correlated were: headaches associated with near work, double vision, cover one eye during reading, and discomfort associated with near work.

Data from comprehensive in-office eye examinations of 36 subjects was cross tabulated with overall VERA composite scores and is presented in Table 7. Chi squared analysis showed the VERA to be valid for these 36 subjects (chi square = 13.5, df = 2, p = 0.01). Sensitivity, specificity, and phi coefficient were found to be 75%, 93%, and +0.69 respectively (see Table 9).

Reliability results of individual screener tests and composite scores are listed in Table 10. Retest scores reflect approximately a 5% increase or learning curve.

Discussion

The VTA\VERA is a reasonably valid device for detecting vision disorders that would be diagnosed in a comprehensive eye exam with criteria like the one in Table 6. Our results do not suggest the VERA to be as effective as the MCT. However, since few schools use the MCT for reasons described previously, the VERA may be a better alternative than other commercially available screening devices.

Weak but statistically significant correlations were found between the extensive symptom questionnaire and the VERA tests of accommodative facility, phorias, and overall composite score (r =0.25, 0.20, 0.27 respectively, p<0.01 for all three). The symptoms most highly correlated were previously given in Results. These data indicate a relationship between the types of binocular, accommodative, and eye movement vision symptoms reported in the literature and the performance of subjects on the screener. The test for linearity shows that the severity of symptoms, as reported by parents, is related to visual performance on the screener. It must be pointed out, however, that the ability of the screener to predict symptomatic versus asymptomatic patients is low (composite score r = 0.27).

Test-retest or reliability of a sample of 60 subjects revealed variations between VERA tests. Visual acuity was more reliable for the right eye (r = 0.55) than the left eye (r = 0.44), and binocular acuity was less reliable than either eye (r = 0.26). Patient attention and fatigue probably explains this because the program tests right eye, left eye, and both eyes in that order. Saccades A, Accommoflex, and Phorias all had a similar degree of reliability (Pearson's r values of 0.58, 0.56, and 0.47 respectively). Statistically, the sample size and the expected learning curve reflect a reasonable reliability.

Conclusions

The VTA\VERA was studied for validity compared to comprehensive eye examinations and manifest symptoms. In a sample of 36 school children, VERA scores were compared to results from comprehensive optometric eye examinations. In a sample of 214 school children, tests performed by the VERA were compared to symptom severity as reported by subjects' parents on a questionnaire. The VERA was also investigated for reliability by test-retest with 60 school children. A chi square for validity of the 36 examined subjects showed statistical significance (p = 0.01). Further analysis showed the VERA to be highly specific (93% accurate non-referral) and reasonably sensitive (75% of subjects with vision problems detected). Phi coefficient for overall screener validity was +0.69. Reliability results were good (Pearson r correlation coefficient = 0.47, p = 0.009) for VERA composite test scores. One way ANOVA revealed statistically significant (p) relationships between symptoms of headache, double vision, covering one eye during reading, and discomfort during near work, when compared to VERA composite scores, accommodative facility, and dissociated phoria. A test for linearity revealed that a dose response relationship existed. This indicates that the frequency or severity of symptoms increased with concurrent subject score performance on the three VERA tests. However, the VERA's scores were not highly predictive in discriminating symptomatic versus asymptomatic patients (r value ranges 0.20 to 0.31). The study suggests that the VTA\VERA, when compared to a specific optometric exam battery, is an acceptable alternative to professional vision screenings and can be easily administered by non-professional personnel.

Appendix A
VTA Vision Screener Parent Questionnaire

	Frequency of Occurrence 1 = never 5 = often				
VISUAL					
Avoidance of near tasks such as models, puzzles, reading for pleasure	1	2	3	4	5
Headache associated with near work	1	2	3	4	5
Double vision	1	2	3	4	5
Occasional blurry vision far or near	1	2	3	4	5
Cover or closes one eye when reading or doing near tasks	1	2	3	4	5
Complains of discomfort or inability to learn in tasks demanding consistent attention to fine detail	1	2	3	4	5
Tilts head extremely or works to one side of desk	1	2	3	4	5
Either eye turns in or out occasionally	1	2	3	4	5
Rubs eyes or forehead a lot	1	2	3	4	5
VISUAL-MOTOR					
Frequent errors in copying	1	2	3	4	5
Word or letters seem to jump around	1	2	3	4	5
Loses place easily while reading	1	2	3	4	5
Uses finger to keep place	1	2	3	4	5
Handwriting is sloppy	1	2	3	4	5
Easily frustrated trying to draw figures	1	2	3	4	5
Reaches too far or too short for things	1	2	3	4	5
Reaches too quickly or slowly	1	2	3	4	5
Switches hands while printing	1	2	3	4	5
Holds reading material very close	1	2	3	4	5
Writes in small, cramped style	1	2	3	4	5
READING/LANGUAGE					
Reverses letters or words	1	2	3	4	5
Omits words/letters when writing	1	2	3	4	5
Spells poorly	1	2	3	4	5
Has trouble sounding out words	1	2	3	4	5
Confusion of left vs. right	1	2	3	4	5
Gets tired easily when reading	1	2	3	4	5
ATTENTION					
Trouble sitting still	1	2	3	4	5
Fidgets	1	2	3	4	5
Poor attention to reading	1	2	3	4	5
Understands directions poorly	1	2	3	4	5

HEALTH

Any family history of reading problems or learning disability?

Birth weight: _____

Any health conditions (e.g., asthma, allergies, development delay)? Please list:

Any history of ear infections?
Currently taking any medications? Please list:

Any other comments you would like to make regarding your child's learning or approach to learning, school, or reading?

Number of months since child's last eye examination: _____
Last examination results (check only those which apply):
Glasses prescribed for:____full time wear, ____far vision only,____close vision only
Any history of medical/surgical treatment for eye problems?____
If yes, please describe:

Thank you for your time.

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Footnotes

a. Massachusetts Vision Kit
Mast/Keystone
4673 Air Center Circle
Reno, NV 89502

b. Keystone Visual Skills Screening
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4673 Air Center Circle
Reno, NV 90502

c. Visual Technology Applications, Inc.
3600 Market St.
Philadelphia, PA 19104
(215) 387-3600

d. SPSS
444 N. Michigan Ave.
Chicago, IL 60611
(312) 329-3500

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