ISSN: (Online) 2410-1516, (Print) 2413-3183

A review of vision screening methods for children

Authors:
Ingrid T. Metsing[1]
Wanda Jacobs[2]
Rekha Hansraj[3]

Affiliations:
[1]Department of Optometry, University of Johannesburg, South Africa

[2]Department of Nursing, University of Johannesburg, South Africa

[3]Discipline of Optometry, University of KwaZulu-Natal, South Africa

Corresponding author:
Ingrid Metsing,
ingridm@uj.ac.za

Dates:
Received: 12 Mar. 2018
Accepted: 26 July 2018
Published: 21 Nov. 2018

How to cite this article:
Metsing IT, Jacobs W, Hansraj R. A review of vision screening methods for children. Afr Vision Eye Health. 2018;77(1), a446. https://doi.org/10.4102/aveh.v77i1.446

Background: What constitutes an appropriate vision screening protocol is controversial, because the tests or methods are expected to be cost-effective, expedient and easy but efficient in detecting visual anomalies among children.

Aim: This review intends to compare the different vision screening tests for children and methods in the interest of identifying the most effective screening method from the standpoint of validity, public acceptance, expediency and cost.

Method: The literature search was performed for this review using the Medline, Science Direct and EBSCOhost databases. The search terms used were *vision screening methods or tests*, *children's vision screenings*, *computer software programs* and *vision screening instruments*. The inclusion criteria for the articles reviewed were all types of articles related to vision screening methods. The exclusion criteria were all articles for which full text was not available and those not available in English. Eighty articles were analysed, of which 33 were found to have complied with the inclusion criteria and were selected. From the first round of articles retrieved, additional references were identified by a manual search among the cited references.

Results: Evidence from the literature reviewed demonstrated that the conventional vision screening method (isolated and combination tests) is the method commonly used to detect a range of relevant visual anomalies among the schoolgoing age group (≥ 6 years) and drew attention to the need for training of vision screening personnel. However, in addition to the conventional method, other vision screening methods include instruments as an adjunct for screening preschoolers and those difficult to screen (≤ 6 years).

Conclusion: Inconsistencies in what constitutes an appropriate vision screening method still exist, especially with the booming market of using computer software programs, which still needs to be validated.

Definition of vision screening

Friis and Sellers[1] defined 'screening' as a presumptive method used to identify unrecognised disease or defects by applying rapid tests or procedures. The screening tests are not diagnostic and thus individuals with a positive test are usually referred for a diagnostic evaluation to confirm the presence or absence of disease. Vision screenings are meant to identify children for whom reduced vision is a significant problem and not to detect all cases with subnormal function to avoid unnecessary referrals of 'normal' children.[2]

In a position statement by the Australian Optometrists Association on vision screenings, it is stated that the screenings must involve testing for a particular condition in a population not defined by symptomatology.[3] In reviewing the vision screening programme on children aged 4–5 years old for the United Kingdom National Screening Committee, it was agreed that although screening is a process of identifying apparently healthy people at risk of a disease, those identified with defects or diseases should be offered information for further comprehensive diagnostic tests to be undertaken in order to reduce the risk of complications that may later arise.[4] School vision screening is further defined by its principal objective, which is to detect children with vision problems, or potential vision problems likely to affect physiological or perceptual processes of vision, and to find those who have vision problems that might interfere with performance in school.[5,6]

Purpose of vision screening

The focus of most vision screening protocols is to detect amblyopia, strabismus and refractive errors (especially myopia and anisometropia). However, the risk factors for the development of

amblyopia and strabismus, such as uncorrected hyperopia, convergence and accommodative dysfunctions, are largely overlooked when vision screening methods are considered in most vision screening programmes.[7] The purpose of conducting vision screenings in children is twofold. The first objective for conducting the vision screenings in young children (≤ 6 years) is to detect visual impairments, namely amblyopia, strabismus and ocular pathology, detected by conducting the objective tests. Early identification of these visual or ocular anomalies is reported to lead to successful treatment because of the plasticity of the visual system at that age. The second objective is related to academic performance of children, and this requires both objective and subjective tests to detect the visual anomalies related to learning.

Vision anomalies among children of schoolgoing age such as visual efficiency and motor processing skills limit learning performance and career opportunities available to them. The screening programmes measuring distance visual acuity (VA) only were criticised for not measuring visual function at near, arguably the visual skills related to reading and writing.[8] Therefore, the evaluation of VA only among children of schoolgoing age was found to likely lead to the non-detection of other visual deficiencies such as refractive errors (latent hyperopia and astigmatism), poor ocular motilities, accommodative and convergence dysfunctions that can contribute towards poor academic performance.

Vision screening tests and methods

The screening tests are expected to be simple, rapid, inexpensive, safe and acceptable.[1] The utilisation of valid and reliable test batteries is fundamental to successful implementation of the screening programme. Therefore, the tests to be included in the screening programme should be appropriate for the age of the children in order to be able to detect the target condition based on the epidemiological data.[9] Several recommendations have been made regarding the constitution of appropriate vision screenings by the National Society for the Prevention of Blindness. This includes observation (appearance, behaviour and complaint signs), stereopsis testing and distance vision measurements.[10] The validity of including tests investigating binocular vision disorders, accommodative dysfunctions and poor ocular motilities when vision screenings in children are conducted is questioned. This is because only professionally trained eye-care providers such as optometrists can accurately conduct the tests investigating the aforementioned visual anomalies.

There are numerous conventional vision screening methods, which include measurements of VA, combination tests including evaluations of VA combined with stereopsis, Hirschberg, cover test and nearpoint of convergence (NPC); modified clinical techniques (MCT) and the New York State Optometric Association (NYSOA) battery of tests. There are also other methods of vision screening available on the market such as optical instruments (Keystone Telebinocular, Titmus, Optec series, auto-refractors), computer software (Vision Efficiency Rating [VERA], Spectrum Eyecare Software) and photoscreeners.

A joint policy statement titled 'Instrument-Based Paediatric Vision Screening Policy Statement' was issued by the American Academy of Paediatrics, the American Academy of Ophthalmology, the American Association for Paediatric Ophthalmology and Strabismus and the American Association of Certified Orthoptists. In this joint policy statement, reference was made to the fact that instrument-based vison screenings are quick and child cooperation required is minimal, which can be beneficial in preverbal, preliterate or developmentally delayed children.[11] In addition, the evolution of modern technology has led to the development of numerous mobile computing applications that demonstrate efficacy in screening visual skills. Demand and interest in the usage of modern technology (e.g. EyeSpy and Spectrum) is growing because the methods are easy to use and expedient.[12,13,14]

Conventional vision screening methods

Conventional methods consist of measurement of distance and near VA, plus the lens test for hyperopia screening, cover test, NPC, stereoacuity measurements and combination tests.

Visual acuity measurements are the primary tests used to describe visual function.[15] Different methods of evaluating VA in the paediatric population and their developmental processes are considered in this literature review. The optotypes used in VA evaluation are letters or numbers (Snellen chart, Sloan charts, HOTV or tumbling E chart) or symbols (e.g. LEA symbols).

Snellen acuity charts

Most vision screening programmes rely on the assessment of VA using the Snellen chart to evaluate or screen for visual impairments. The Snellen acuity test is a standardised test chart introduced in 1862 by the Dutch ophthalmologist Hermann Snellen. The chart is used in conventional testing of VA.[16] The chart consists of a series of symbols (e.g. block letters, numbers and pictures) in gradually decreasing sizes corresponding to the distance at which that line of letters subtends 5 minutes of arc at the nodal point of the eye. However, the Snellen chart is a universally accepted test for VA testing.[17] In addition, the difficulty in reading the Snellen chart is compounded by the 'contour interaction' or 'visual crowding' phenomenon, making legibility of the optotypes less clear when presented with other optotypes in close proximity.[18,19]

Fundamental design flaws in the Snellen chart, including non-geometric progression of letter sizes, variable number of letters per line and lack of a standardised scoring system, are likely to cause gross overestimation and underestimation of changes in VA, as a result compromising the clinical sensitivity of the test.[20] Nonetheless, the Snellen acuity charts

are the preferred method for vision screening because they are less expensive and are suitable where time and resources are limited.[21] However, the well-documented limitations of the Snellen chart have led to the development of alternative charts, as discussed next.

Sloan/Logarithmic Minimum Angle of Resolution charts

The Sloan chart was developed in 1951 in order to circumvent the problems encountered with the Snellen acuity charts. The Sloan chart has individual letters with different degrees of difficulty, and the overall shape of these letters provides clues to identify them; thus the psychic task of recognition enhances VA beyond the level of pure recognition. Each letter is assigned a difficulty score based on how often that letter is read correctly, considered as the VA threshold.[22] The Sloan chart is therefore a VA chart recommended for the purposes of vision screening.[23]

The Sloan chart using Logarithmic Minimum Angle of Resolution (LogMAR) grading has gained acceptance in clinical and research settings for its high accuracy in VA testing.[24] The development of these charts incorporated the recommendation by the Committee on Vision of the National Academy of Sciences – National Research Council in 1980 for VA charts to use logarithmic scaling of the distance between letters on successive lines, with the same number of letters on each line of the chart. These charts were used for VA evaluation in the Early Treatment of Diabetes Retinopathy Study.[25] The LogMAR charts maintain a consistent ratio between optotypes and spacings no matter what the angular subtense of the optotype is, unlike the Snellen charts with each individual letter assigned an individual score.[24,26,27] LogMAR chart configurations are used with LEA symbols, HOTV or other letters, numbers, illiterate E's and Landolt C's, including in illuminated-panel formats, charts and flip books, and are now available for evaluating the VA of adults and children.[24,27]

Computer LogMAR charts have recently emerged in the marketplace to assist in the acquisition of VA information in younger and older patients.[12] The single presentations, with or without crowding, whole line or whole charts, are also now available. Although LogMAR charts are superior in their scientific principles, clinical accuracy and reproducibility, practical difficulties with incorporating them into clinical practice are encountered. These difficulties relate to the fact that most examination rooms are designed for Snellen charts at 6 metres, although this problem can be solved by a simple conversion factor.[24] Furthermore, the LogMAR chart is not as commonly used as the Snellen acuity charts because of arguments that it is more time-consuming and less easy to understand. However, with experience the potential difficulty in its use could be easily overcome.[26]

Stereotests

Tests investigating stereopsis are widely used to provide overall assessments of the presence of amblyopia and its associated conditions of strabismus and refractive error as well as binocularity.[28] It may therefore be useful in screening batteries that include other tests to assess binocular vision status. The main types of stereotests used in the paediatric population fall in two categories, namely line and global targets. These include the Titmus Stereo Fly, random dot, Frisby and Lang stereotests.[29] Fricke and Siderov,[30] in their literature review, concluded that choosing an appropriate stereotest for a particular task is critically dependent on the perceptual age of the patient evaluated and the type of information the clinician wants to gather from the test. The Titmus Stereo Fly test uses line stereograms and requires the use of polarisers. This test requires a reasonable level of cognitive development, because the task of getting a child to locate a target in depth (e.g. the fly wings) can be challenging.[30]

The test can be used on 3–5-year-olds, but its disadvantage is the presence of monocular cues. The random dot stereotest performed on schoolgoing children is the preferred optional test compared to the Lang and Frisby tests. However, the use of polarisers in this test may be cumbersome for young children and may be more difficult to use in preschoolers. However, its sensitivity to refractive blur is found to be slightly better than in the aforementioned two tests.[28,29] In a study by Reinecke and Simons,[31] the random dot stereograms were effective in screening for strabismus and amblyopia where a 250 seconds of arc disparity is used.

The effectiveness of the random dot stereotest as a screening instrument was demonstrated in a study conducted by Rosner.[32] Ten children with binocular visual anomalies were evaluated using the stereotest. These children failed to correctly identify the position of the stereoscopic target of 168 sec arc disparity, and the same children failed a screening test using the modified clinical technique (MCT), therefore indicating that the findings of the randot stereotest as a screening method are similar to the MCT screening battery in detecting poor VA, binocular anomalies and amblyopia. Consistent with these findings in another study investigating the accuracy of the random dot stereotest, a double masked investigation was conducted on 483 schoolchildren with a mean age of 7.23 years.[33] Children were tested with both the random dot stereotest and MCT. Each technique's validity was determined using the phi coefficient (Ø) and was compared with similar reports in the literature for MCT, Snellen acuity and vision screening kits. The effectivity of the random dot stereotest was reported as +0.52 more than all the other procedures except for the MCT. In the study, the sensitivity and specificity of the random dot E stereogram test were found to be 64% and 90%, respectively.

The Lang stereotest is considered to be the best test in a vision screening situation, because it does not require the use of polarisers and because it is easy to administer and sensitive to the detection of constant strabismus. However, it has not been shown to be sensitive to refractive blur and hence is not recommended as an isolated test in paediatric vision screening. This test has been found to be useful in children

from six months to four years. The Frisby stereotest, using global stereograms and not requiring the use of polarisers, was found to be successfully administered in children under the age of three years. However, it has also been shown not to be sensitive to refractive blur.[30] The advantages of using stereotests as the screening tool include the test being fast, providing accurate results in general and that it can detect amblyopia, strabismus and refractive errors. Furthermore, the specificity and sensitivity, including positive predictive values, were found to have improved with the combination of VA assessments.[29]

Plus lens test

The plus lens test was recommended 60 years ago by the Massachusetts Department of Public Health, which reported that 7% of all schoolchildren tested with a positive lens (1.50 D or 1.75 D) were apparently found to have hyperopia.[34] According to Johnson (1953), the report did not state how the scientific evidence of that claim was accomplished. Subsequent to that, various studies were conducted that found the percentage of children tested with plus lenses having hyperopia to be far less than those mentioned in the Massachusetts Department of Public Health report (Johnson 1953). Consistent with the findings of the studies included in Johnson's (1953) report, a study by Shaffer[35] on 127 children to evaluate several widely known vision screening methods such as the Snellen test for VA at 6 m, the Massachusetts Vision Test and the Keystone Telebinocular including the plus lens test.

The plus lens test was found to have a high number of false positive referrals compared to the findings of the 'gold standard' in a comprehensive diagnostic visual examination conducted subsequent to the vision screenings. Those who failed (n = 6) the +1.50 plus lens test used to screen for hyperopia were found to have low (normal) degrees of hyperopia. The limitation for generalisation of the findings of this study was the small number (n = 6) of participants with sufficient degrees of simple hyperopia who had 6/6 vision through +1.50 lenses. Nonetheless, the plus lens test is based on sound physiological principles and is found to be less prone to failing to detect a legitimate refractive error.[36] There appears to be a lot of support for the inclusion of the plus lens test in most vision screening protocols. However, not much recent research has been conducted to test its validity among children of schoolgoing age.[10]

Feldman et al.[37] in their recent study compared the sensitivity and specificity of the plus lens test to that of the Spot Vision Screener (Welch-Allyn) in detecting high hyperopia > 3.50 D, and cycloplegic refraction was used as the 'gold standard'. The study was conducted on children between the ages of 2 and 12 years, referred to their clinic for a comprehensive diagnostic visual examination. They found the plus lens test sensitivity for 3.50 D hyperopia to be 43.75%, and the specificity was 89.25%. These findings were compared to those of a Spot Vision Screener, which was found to have a sensitivity of 31.25% and specificity of 100.00%. In addition, the sensitivity was found to increase with high degrees of hyperopia, thus indicating that both methods demonstrated good specificity and overall moderate sensitivity in detecting hyperopia, with the plus lens test slightly more sensitive than the Spot Vision Screener.

The amount of plus-sphere appropriate for detecting hyperopia (especially latent hyperopia) in different age groups necessitates further research. The 4 D lens used in other studies is regarded as being very high.[38] Hyperopia of less than 1.50 D may be considered normal in very young children. However, among older children, lesser degrees of hyperopia are significant for reading. Therefore positive lenses of lower strength such as 0.75 D or 1.00 D can be used in this test.[35] The length of time an individual should wear the plus-sphere before VA is determined in this test is also very important, and this is another matter needing further research. However, the inclusion of the plus lens test in vision screening programmes to investigate the presence of hyperopia has proven to be appropriate, because the test is simple and quick and can be used in conventional and software vision screening protocols.

Combination vision screening tests

There is a variety of combination vision screening tests used for children of schoolgoing age. The combination tests consider the detection of a wide spectrum of visual anomalies such as reduced vision at far and near, vergence and accommodative dysfunctions including strabismus and refractive errors.

The modified clinical technique

The MCT was developed in a United States-based study conducted at Orinda Elementary School in California. Conducted in 1954, the Orinda Study pioneered inclusion of specific vision parameters for effective school vision screenings. A number of specific visual and ocular problems that should be prioritised for screening were identified by optometrists and ophthalmologists in this study. These included reduced VA, a range of refractive errors (hyperopia, myopia, astigmatism and anisometropia), binocular coordination disorders at distance and near (strabismus and significant heterophoria) and ocular pathology (see Table 1). The aim of the study was 'to design the least expensive, least technical and most effective screening programme for essentially detecting all elementary school children with vision anomalies'.[39] The MCT was the first vision screening protocol to be validated, and it is often considered to be the gold standard paediatric screening protocol, because it had the least number of under-referrals. The clinical criteria defined for the MCT by the Orinda Study remain the foundation of vision screening programmes today and are presented in Table 1.

The screening methods included in the Orinda Study were parent questionnaires, teacher observation forms, nurse observation forms, VA measurements, retinoscopy, cover test, ophthalmoscopy and magnifier (investigating ocular

TABLE 1: Clinical procedures and referral criteria for the modified clinical techniques.

Testing procedure	Characteristic measured	Referral criteria
Snellen distance	Visual acuity	Visual acuity 20/40 or less, either eye
Retinoscopy with lens rack neutralisation	Refractive error Hyperopia Myopia Astigmatism Anisometropia	1.50 D or more −0.50 D or more ±1 D or more ±1 D or more
Distance cover test	Coordination at distance Tropia Esophoria Exophoria Hyperphoria	Any 5 pd or more 5 pd or more 2 pd or more
Nearpoint cover test	Coordination at near Tropia Esophoria Exophoria Hyperphoria	Any 6 pd or more 10 pd or more 2 pd or more
Observation and direct ophthalmoscopy	Organic	Any verified pathology or medical anomaly of the eye and/or adnexa

Source: Adapted from Blum et al. 1959[39] and Mozlin 2002[40].
D, dioptre; pd, prism diopters.

pathology internally and externally). The mean referral rate of MCT was reported to be high at 11.5%, compared with 5.8% based on measurements of VA alone. Almost all children were classified with extremely high sensitivity (98%), specificity (99%) and predictive values (positive predictive value of 0.90 and negative predictive value of 0.99). Measurements of distance VA alone demonstrated poor sensitivity (27%) but relatively good specificity (99%).[39]

The sensitivity of the MCT was markedly improved by including a test of the refractive error (such as retinoscopy) rather than depending only on the measurement of distance VA.

Concerns about the MCT's gold standard status relate to the requirement of professionally trained eye-care practitioners (e.g. optometrists and/or ophthalmologists) as being the only personnel to administer the vision screening tests. This is because the use of retinoscopy and ophthalmoscopy in detecting visual anomalies were found to be difficult to be administered by non-trained vision screeners. This raised questions about the suitability of the Orinda MCT as a screening tool.[41] Additional concerns raised were related to failure of the replication of remarkably high sensitivity and specificity reported by the Orinda Study and by subsequent studies that also used the battery of tests included in the screening protocol. In subsequent studies, positive predictive values were found to be lower (0.69 and 0.52).[42,43,44] In explaining the reasons for the extremely high sensitivity and specificity of the MCT in the Orinda Study and problems with replication of the findings, absence of a definitive pass–fail criterion was suspected to be the cause.[7] Further limitations identified on the suitability of MCT were related to the fact that it does not assess non-strabismic dysfunctions such as convergence insufficiency.[44,45]

In considering the disadvantages inherent in the Orinda MCT, between 1980 and 1983 a modified form of the vision screening protocol, namely the Portsea MCT, was considered as an important public health initiative at Portsea in Victoria, Australia. Tests added to the Orinda MCT screening protocol included the evaluation of fusional vergence, accommodative facility, ocular motility, stereopsis and colour vision tests. These tests were added on the basis that they were more comprehensive in their measurement of visual parameters, presumably associated with reduced school performance.[46] Although the number of tests was increased in the Portsea MCT, vision screening could be performed quickly, within 5–6 min, and the referral rates were 17.7% (classified as 'unsatisfactory') and 10.4% (classified as 'borderline'), comparable to those of the Orinda MCT.[47] However, the disadvantages of both the Portsea and Orinda MCT screening protocols appear to be similar, because both require professionally trained eye-care practitioners such as optometrists or ophthalmologists to administer them and present expediency problems because numerous tests are included in this screening method.

The New York State Optometric Association screening battery

The NYSOA screening battery was developed in 1985 with the aim to identify a wider range of visual problems in the paediatric population related to learning.[48] The sensitivity and specificity of the NYSOA battery were 72% and 65%, respectively.[49] Compared to the MCT, the NYSOA targeted reduced distance and near VA. It further targeted hyperopia greater than two dioptres, as well as non-strabismic dysfunctions including accommodative infacility, convergence insufficiency, reduced fusional reserves, colour vision defects, poor stereopsis, poor saccadic eye movements and poor visual motor integration. In addition, it included a selection of tests in the NYSOA battery, allowing administration by non-ophthalmological trained screeners, even though the test battery was designed to be used by optometrist-trained parent volunteers. The battery of tests included the use of the Keystone Telebinocular to evaluate convergence, fusion, stereopsis, saccadic eye movements, visual motor integration and colour vision (see Table 2). The overall referral rate of the NYSOA battery is reported to be high, at 53%, when compared to the 19% using the MCT in the Orinda Study.[50] Table 2 sets out the clinical procedures and referral criteria of the NYSOA screening battery.

The NYSOA screening battery was reported to be more time-consuming than the MCT because of its additional tests.[48] The Orinda MCT can be administered quickly, between 5 min and 6 min per child, compared with 15 min using the NYSOA battery.[34,49] Rapidity is the essence of any screening programme. The amount of time required to conduct a screening is directly related to its perceived value.[1] Therefore, a screening procedure that requires only 5 min is more likely to be perceived as valuable compared to the one requiring more time to administer. However, by including fewer tests, for example, by measuring only VA, there is the possibility that up to 40% of children with potentially important visual problems such as hyperopia, binocular disorders or ocular disease could be missed. However, increasing the number of

tests in a vision screening battery has time consequences.[51] Since its initial validation in 1985, there have been relatively few studies using the NYSOA screening battery, because the battery of recommended tests is not widely used. Another drawback preventing the widespread use of the NYSOA battery of tests appears to be related to the inclusion of the Keystone Telebinocular for evaluating convergence and fusion. The disadvantage of using instruments for binocular function is their inability to evaluate performance over time, accommodation and ocular motilities including affordability.

Computerised vision screening programmes

A broad range of visual functions in children can be investigated using computerised screening programmes. This wide range includes the measurement of VA, refractive errors and visual efficiency skills. Visual Efficiency Rating (VERA)[52] is an example of computer software created for school nurses to screen for visual problems that can interfere with reading and school performance.

The screening programme takes approximately 12–15 min for each child and was designed to maximise specificity. VERA was developed with a focus on a better functional screening protocol to detect a wider range of learning-related vision problems using tests that can be easily administered by school personnel not requiring professional supervision. The VERA visual skills test evaluates VAs at 3 m, visual motor integration, accommodation flexibility and phorias at distance and near.[52]

TABLE 2: Clinical procedures and referral criteria for the New York State Optometric Association screening battery.

Testing procedures	Characteristic measured	Criteria of referral
Snellen acuity at 6 m	• myopia • high astigmatism • amblyopia • high hyperopia	20/40 or worse in either eye or more than two-line difference between the eyes
Reduced Snellen chart – 33 cm	• reduced Snellen Chart-at 33 cm • high refractive error • focus • dysfunction	20/40 or worse in either eye or more than two-line difference between the eyes
1.50 sphere VA test – at 6 m	mild hyperopia	Less than two-line blur of the best distance acuity
±2.00 flippers – 33 cm	• accommodative facility • focus ability	Fewer than three cycles in 30 s
Bell push	• convergence ability	Not greater than 10 cm
Keystone skills • vertical imbalance • four ball fusion – distance • four ball fusion – near	• suppression • fusion ability • muscle balance	Line through any figure other than ball two or four two or four
Titmus stereotests	• stereopsis perception • binocularity	Seven or fewer
NYSOA K-D	• eye track skills	Greater than 1 standard deviation above age norms in the NYSOA manual
Winterhaven copy forms	• eye–hand coordination, visual • motor coordination • visual organisation • form • reproduction	Less than age norms in the NYSOA manual
Keystone colour card	• colour deficiency	Failure to read numbers

Source: Adapted from Cohen AH, Lieberman S, Stolzberg M, Ritty JM. The NYSOA vision screening battery – A total approach. J Am Optom Assoc. 1983;54(11):979–984.[49]

NYSOA, New York State Optometric Association; K-D, King-Devick Saccadic Eye movement test; VA, visual acuity; cm, centimetre; m, metre.

The screening procedure using VERA is two-tiered: children are required to first pass VA and hyperopia screening tests, followed by a basic binocular vision screening consisting of suppression, stereopsis and alignment. Passing the first level of evaluation is followed by the administering of a visual skills battery, including tests of vergence facility, accommodative facility and saccadic tracking scored in combination. Scores for each test are compared to an age-normed database of 1500 children. The results are displayed as percentile scores for each test and cumulative percentile scores with categories of pass, fail and borderline.

In investigating the validity of the VERA protocol, 154 children in Grades 3–6 from six different elementary schools were evaluated. Results of VERA visual skills screening were compared to clinical optometric testing including step vergences at near, accommodative amplitude and facility, vergence facility, NPC and the Developmental Eye Movement Test. In addition to vision testing, the children were administered the Convergence Insufficiency Symptom Survey (Convergence Insufficiency Treatment Trial Investigator group 2008) and the Word Recognition and Fluency subtests from the Woodcock–Johnson III Tests of Achievement. Each child's teacher filled out the VERA classroom behaviour survey. The sensitivity of VERA in detecting visual skills problems was found to be relatively low at 45% (i.e. it failed to detect 55% of children who had visual problems), while the specificity was 83%, less compared to the MCT and the NYSOA screening protocols.[52]

The sensitivity of the VERA screening results increased to 64% and specificity to 100% when done in conjunction with the classroom behaviour survey, particularly in children showing unexplained reduced academic performance.[47] However, the study conducted by Hatch[48] showed VERA to have 75% sensitivity and 93% specificity in detecting a range of visual anomalies including VA, refractive errors and visual skills problems, compared to eye examination results in 36 subjects. Nevertheless, the sensitivity and specificity of VERA improved when combined with a symptom survey (Convergence Insufficiency Symptom Survey), reading level and classroom behaviour survey (completed by a teacher). It was therefore concluded that VERA is more accurate as a screening tool when specifically targeting underachieving children, as determined by the classroom behaviour survey and a test of the child's reading level.

VERA screening protocol is regarded as one of the efficient tools to identify learning-related visual problems among schoolchildren. This is remarkable, given the estimated prevalence of undetected visual skills problems of 15% – 20% in the school-age population. The validity of using VERA has led to the identification of children with learning problems caused by visual anomalies. Although VERA is reported to have low specificity and was found not to be expedient, its administration was found to be easy. The validity of the other computer software programs such as Spectrum, iPads and tablets still has to be determined through research.

Instrument screeners

Auto-refractors

Instrument-based screening determines the refractive error of the eye without the need for subjective responses by the patient. The use of auto-refractors was found to be beneficial in children aged between 3 and 5 years. The refractive error is determined objectively by monitoring the retinal image of the eye, measuring the vergence of ray bundles emerging from the eye or via the wavefront analysis. The principles of retinoscopy are used by instruments measuring the vergence of light. Measurement of refractive error using these instruments typically takes less than a second and can be performed by lay personnel. Various types of auto-refractors have been developed since they were first introduced in the 1970s. The auto-refractors come in different types, in the form of table-tops or handheld. The table-top auto-refractors are beneficial in 3-year-olds and older children when fixation and accommodation are more easily controlled. The advantage of using handheld auto-refractors is that alignment is easier because they do not have a chin rest and are easily portable. These are important features, especially for younger children with special needs. Commercially available handheld auto-refractors are the Retinomax, SureSight and Palm AR.[53]

The Retinomax autorefractor was the first available and was widely used in paediatric studies. Retinomax has also been used in younger children and its reliability and ease of use were found to be high, with more than 99% of children found to complete the procedure. The sensitivity and specificity were reported in recent studies to be 63% – 78% and 90%, respectively. Measurements with Retinomax show excellent discrimination for hyperopia and acceptable discrimination for cylinder.[54] The SureSight auto-refractor uses wavefront technology to measure the refractive error. Its accuracy to determine spherical refractive error differs in the literature, with studies finding overestimation of hyperopia or myopia.[55] The sensitivity and specificity using the SureSight auto-refractor were reported to be 85% and 62%, respectively. Both the SureSight and Retinomax were found to be the same in the Vision in Preschoolers Study conducted in a large high-risk Head Start population. Another new handheld autorefractor is the Marco Palm AR. Its testability was found to be greater than 99%. It is lightweight and small compared to all the other auto-refractors. Its specificity and sensitivity are reported at 90% and 74%, respectively.[56]

The reliability of using non-cycloplegic auto-refraction compared to non-cycloplegic retinoscopy has been questioned over the years. Non-cycloplegic auto-refraction was found to have low sensitivity and high false positives and negatives.[57] In addition, the disadvantage of using the autorefractor as a screening tool is that it determines only the refractive status and not the other visual anomalies such as poor ocular motilities, convergence and accommodation dysfunction that can impact negatively on the learning capacity of children. Auto-refractors cannot always be used for massive national vision screening programmes because of their high costs. However, they are easy to use in paediatric populations.

Stereoscopic vision screeners

There are numerous types of commercially available stereoscopes for vision screening using a set of cards, including the Keystone Telebinocular, Titmus and Optec instruments. These instruments screen for the presence of reduced acuity, stereopsis defects, colour vision defects and lateral phoria imbalance at near and distance. Stereoscopes such as the Visiotest, Optec and Ergovision are recommended vision screeners regarded as fast with low maintenance costs; they are used in most European countries such as France and England.[58]

In their study, Horberry et al.[59] found the Titmus 2, Keystone VS-II and Optec 2500 results for vision screening to be close to those found in the gold standard visual examinations performed by optometrists. The use of stereoscopes as a vision screening method for children of schoolgoing age is still a subject of debate. Consequently, instruments appear to have few advantages over the Snellen acuity chart because they provide constant illumination, constant object distance and additional visual tests (lateral phorias, stereopsis and colour vision) besides distance VA. However, they have their disadvantages including higher costs, a high number of false referrals, moderate amount of training time and failure to detect eye health disorders.[60] Notably, stereoscopes are included as additional tests in the vision screening protocols of Kansas and Tennessee for special populations requiring non-verbal responses but not for children 5 years and younger.[61,62]

Conversely, vision screening policies, programmes and protocols in other countries, and stereoscope machines (such as Titmus Vision Tester, Stereo Optical's Optec and Keystone's Telebinocular) are cited as having increased the incidence of false positive results, and thus the use of these machines is not recommended for school vision screenings. However, if a stereoscope machine is utilised, it is recommended that students not meeting the pass criteria should be rescreened using a wall chart.[36]

Conclusion

Evidence revealed three methods of vision screenings (i.e. conventional, instruments and computer software) among children of schoolgoing age, which are subjective, objective or both. The objective methods such as the instruments and computer software used to detect visual anomalies among children younger than six years appear to be relatively expensive. However, some instruments such as the auto-refractors and photoscreeners have been found to be efficient in objectively determining the refractive status only. Meanwhile, other instruments such as the Titmus, Optec or Keystone Telebinocular were found to be subjective tests

TABLE 3: Vision screening techniques: A summary of the advantages and disadvantages.

Vision screening tests	Advantages	Disadvantages
Snellen charts – Snellen 1968	• fast • inexpensive • operated by laymen	• poor reproducibility and reliability • non-geometric progression of letter sizes • progressively harder from 6/6 to 6/60 • crowding phenomenon
LogMar – Bailey and Lovie 1976	• consistent ratio between optotypes and spacings • LEA symbols, HOTV, letters, numbers, illiterate E's, and Landlot C's • scientifically accurate and reproducible	• not used clinically, difficult to understand • laymen need to be trained to use it
Random dot stereotest	• easy to use • inexpensive • fast • evaluates optical, motor or neural components	• not sensitive to refractive blur • dependent on the perceptual age of the child • not easily understood by children
Modified Clinical Technique – Blum et al.[39]	• evaluates VAs, refractive errors, strabismus and significant heterophoria and ocular pathology • fast	• requires an eye professional to administer • no replication of findings • poor positive predictive value • absence of a definitive pass–fail criterion • non-strabismic binocular dysfunctions not identified • expensive
New York State Optometric Association screening battery	• more tests included to evaluate the visual status • hyperopia ≥ 2.00 D • accommodation facility • nearpoint of convergence • fusional reserves • colour vision • stereopsis • saccadic eye movements • visual motor integration • high referral rate, 53%	• inclusion of instruments, for example, Telebinocular • time-consuming • not widely used • expensive
Computer software Visual Efficiency Rating EyeSpy 20/20 Spectrum Eyecare software	• detects learning-related visual anomalies • visual efficiency skills evaluated • easy to administer • fast • targets academically under-performing children	• expensive • low sensitivity and specificity • requires classroom behaviour survey
Auto-refractors†	• fast • easy	• detects only the refractive status • does not detect VES deficiencies • expensive
Retinomax†	• excellent discrimination for hyperopia and astigmatism	• detects only the refractive status • does not detect VES deficiencies • expensive
Suresight†	• uses wavefront technology	• overestimation of hyperopia and myopia • does not detect VES deficiencies • expensive
Marco Palm AR†	• handheld and lightweight • testability > 99%	• expensive • investigates only the refractive errors • does not detect VES deficiencies • expensive
Keystone Telebinocular†	• evaluates functional skills such as lateral phorias • easy to use, lay personnel can be trained to use it	• expensive • performance of sustained accommodation or ocular motilities are not evaluated • induces esophoria at near
Titmus or Optec†	• evaluates all the learning-related visual skills • easy to use, lay personnel can be trained to use it	• very expensive • few studies related to its sensitivity and specificity • performance for sustained accommodation or ocular motilities are not evaluated

VES, visual efficiency skills; VA, visual acuity.

†, instruments.

with the advantage of investigating other visual anomalies besides amblyopia, such as binocular vision anomalies. These instruments, in addition to being expensive, were found to have low sensitivity and specificity because of induced phorias caused by the artificially simulated infinity and near working distance using prisms and lenses (see Table 3). Nonetheless, the conventional method with the combination tests were found to be expedient, inexpensive and to have high sensitivity and specificity, but they required professionally trained vision screening personnel. Other combination tests such as the MCT and NYSOA were not always expedient because of the numerous tests included in the protocols, and they further required professionally trained vision screeners such as ophthalmologists, optometrists or optical dispensers.

Despite the large number of screening tests available, not much appears to be known about the effectiveness of these tests, especially those that are computer-based. In order for tests included in vision screening programmes to be effective, they must identify both a high proportion of children with the target condition (high sensitivity) and without specific visual disorders (high specificity). The screening tests were largely found to show an increase of sensitivity with age, while specificity remained unchanged. However, it is important to note that the specificity and sensitivity of different vision screening methods cannot be directly compared, because of the differences in age, ethnicity, screening personnel and socio-economic characteristics of the samples between the studies.

Acknowledgements

Dr E.W. Nel was a co-supervisor of I.T.M.'s DPhil studies.

Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

I.T.M. was the primary author. W.J. supervised I.T.M.'s DPhil studies, which led to the drafting of this manuscript. R.H. was co-supervisor of I.T.M.'s DPhil studies and contributed immensely to the editing of this manuscript.

References

1. Friis RH, Sellers TA. Epidemiology for health care practice. Gaithersburg, MD: Aspen Publishers, 1999; p. 206.
2. Wilson JMG, Junger G. Principles and practice of screening for disease [homepage on the Internet]. Geneva, Switzerland: World Health Organization; 1968. [cited 25 Feb 2017]. Available from: www.who.int/iris/handle/10665/208882
3. Optometrists Association Australia. Position statement: Vision screenings [homepage on the Internet]. 2009. [cited 24 June 2015]. Available from: http://www.optometry.org.au/media/278175/position_statement_vision_screenings.pdf
4. Solebo AL, Rahi JS. Vision screening in children aged 4–5 years. External review against programme appraisal criteria for the United Kingdom National Screening Committee [homepage on the Internet]. 2013. [cited 18 May 2015]. Available from: https://legacyscreening.phe.org.uk/policydb_download.php?doc=36
5. Schmidt P. Vision screening. in principles and practices of pediatric optometry. In: Rosembloom A, Morgan M, editors. Philadelphia, PA: Lippincott-Raven, 1990; p. 467.
6. Health Professions Council of South Africa (HPCSA). Professional board for optometrists and dispensing opticians. Guidelines to vision screening, itinerant practices and mobile clinics [homepage on the Internet]. 2007; p. 1–9. [cited 13 Aug 2016]. Available from: http://www.hpcsa.co.za/Uploads/editor/UserFiles/downloads/optometry/vision_screening_12_09.pdf
7. Hopkins S, Sampson GP, Hendicott P, Wood JM. Review of guidelines for children's vision screenings. Clin Exp Optom. 2013;96(5):443–449. https://doi.org/10.1111/cxo.12029
8. Ethan D, Basch CE. Promoting healthy vision in students: Progress and challenges in policy, programs, and research. J Sch Health. 2008;78(8):411–416. https://doi.org/10.1111/j.1746-1561.2008.00323.x
9. Hatch SW. Optometric care within the public health community. Cadyville, NY; Vision Screening. Old Post Publishing, 2009; p. 1–22.
10. Prevent Blindness. Model state school–entry vision screening legislation [homepage on the Internet]. National Center for Children's Vision & Eye Health; 2017. [cited 03 Feb 2018]. Available from: https://www.preventblindness.org/model-state-school-entry-vision-screening
11. American Academy of Paediatrics. Instrument-based paediatric vision screening policy statement [homepage on the Internet]. 2012. [cited 03 Feb 2015]. Available from: www.pediatrics.org/cgi/doi/10.1542/peds.2012-2548
12. Perera C, Chakrabarti R, Isla FMA, Crowston J. The eye phone study: Reliability and accuracy of assessing Snellen visual acuity using smartphone technology. Eye. 2015;29(7):888–894. https://doi.org/10.1038/eye.2015.60
13. Trivedi RH, Wilson ME, Petersei MM, Cole KB, Teed RGW. A pilot study evaluating the use of EyeSpy video game software to perform vision screening in school-aged children. J AAPOS. 2010;14(4):311–316. https://doi.org/10.1016/j.jaapos.2010.03.008
14. Sun JK, Aiello LP, Cavallerano JD, et al. Visual acuity testing using autorefraction or pinhole occluder compared with a manual protocol refraction in individuals with diabetes. Ophthalmol. 2011;118(3):537–542. https://doi.org/10.1016/j.ophtha.2010.07.022
15. Rosenbloom AA, Morgan MW. Principles and practice of pediatric optometry. Philadelphia, PA: J.B. Lippincott Co, 1990; p. 478.
16. Benjamin WJ. Borish's clinical refraction. 2nd ed. St. Louis, MO: Butterworth Heinemann Elsevier, 2006; p. 223.
17. Gibson RA, Sanderson HF. Observer variation in ophthalmology. Br J Ophthalmol. 1980;64(6):457–460. https://doi.org/10.1136/bjo.64.6.457
18. Flom MC, Weymouth FW, Kahneman D. Visual resolution and contour interaction. JOSA. 1963;53(9):1026–1032. https://doi.org/10.1364/JOSA.53.001026
19. Simmers AJ, Gray LS, McGraw PV, Winn B. Contour interaction for high and low contrast optotypes in normal and amblyopic observers. Ophthalmic Physiol Opt. 1999;19(3):253–260. https://doi.org/10.1016/S0275-5408(98)00056-8
20. Bailey IL, Lovie JE. New design principles for visual acuity letter charts. Am J Optom Physiol Optics. 1976;53(11):740–745. https://doi.org/10.1097/00006324-197611000-00006
21. Rathinam SR. Customised LogMAR charts for mass vision-screening. J Postgrad Med. 2005;51(2):115.
22. Sloan L. Measurement of visual acuity. Arch Ophthalmol. 1951;45:704. https://doi.org/10.1001/archopht.1951.01700010719013
23. Wong D, Kaye SB. Chart for visual acuity screening. Br J Ophthalmol. 1989;73(6):457–460. https://doi.org/10.1136/bjo.73.6.457
24. Bailey IL, Lovie-Kitchin JE. Visual acuity testing. From the laboratory to the clinic. Vision Res. 2013;90:2–9. https://doi.org/10.1016/j.visres.2013.05.004
25. Cummings GE. Vision screening in junior schools. Public Health. 1996;110(6):369–372. https://doi.org/10.1016/S0033-3506(96)80010-2
26. Hussain B, George M, Saleh GM, Sivaprasad S, Hammond CJ. Clinical controversy: Changing from Snellen to LogMAR: Debate or delay? Clin Exp Ophthalmol. 2006;34:6–8. https://doi.org/10.1111/j.1442-9071.2006.01135.x
27. Plainis S, Tzatzala P, Orphanos Y, Tsilimbaris MK. A modified ETDRS visual acuity chart for European-wide use. Optom Vis Sci. 2007;84(7):647–653. https://doi.org/10.1097/OPX.0b013e3180dc9a60
28. Griffin JR, Grisham JD. Binocular anomalies. Diagnosis and vision therapy. 4th ed. New York: Elsevier, Butterworth-Heinemann, 2002; p. 59.
29. Duckman RH. Visual development diagnosis, and treatment of the pediatric patient. 1st ed. New York: Lippincott Williams & Wilkins, 2006; p. 292–294.
30. Fricke TR, Siderov J. Stereopsis, stereotests, and their relation to vision screening and clinical practice. Clin Exp Optom. 1997;80(5):165–172. https://doi.org/10.1111/j.1444-0938.1997.tb04876.x
31. Reinecke RD, Simons K. A new stereoscopic test for amblyopia screening. Am J Ophthalmol. 1974;78(4):714–721. https://doi.org/10.1016/S0002-9394(14)76311-1
32. Rosner J. The effectiveness of the random dot E stereotest as a preschool vision screening instrument. J Am Optom Assoc. 1978;49(10):1121–1124.
33. Hammond RS, Schmidt PP. A random dot E stereogram for the vision screening of children. Arch Ophthalmol (Chicago, IL: 1960). 1986;104(1):54–60. https://doi.org/10.1001/archopht.1986.01050130064021
34. Johnson L. Hyperopia in school children: It's detection with a plus sphere lens and its significance in reading. J Sch Health. 1953;23(9):268–271. https://doi.org/10.1111/j.1746-1561.1953.tb07544.x
35. Shaffer TE. Study of vision testing procedures. Am J of Public Health. 1948;38(8):1141–1146. https://doi.org/10.2105/AJPH.38.8.1141
36. Proctor SE. To see or not to see: Screening the vision of children in school. In: Department of Education (Colorado), editor. Guidelines for school vision screening programs: Kindergarten through to Grade 12. 2006. [cited 27 June 2016]. Available from: https://www.cde.state.co.us/sites/default/files/documents/healthandwellness/download/nurvisionguidelines.pdf
37. Feldman S, Peterseim MMW, Trivedi RH, Edward Wilson M, Cheeseman EW, Papa CE. Detecting high hyperopia: The plus lens test and the spot vision screener. J Pediatr Ophthalmol Strabismus. 2017;54(3):163–167. https://doi.org/10.3928/01913913-20161013-05
38. Williams WR, Latif AHA, Hannington L, Watkins DR. Hyperopia and educational attainment in a primary school cohort. Arch Dis Child. 2005;90(2):150–153. https://doi.org/10.1136/adc.2003.046755
39. Blum HL, Peters HB, Bettman JW. Vision screening for elementary schools: The Orinda study. Berkeley and Los Angeles, CA: University of California Press, 1959; p. 1–43.
40. Mozlin R. The epidemiology of school vision screenings. J Behav Optom. 2002;13(30);59–65.
41. Marsh-Tootle W, Corliss DA, Alvarez SL, et al. A statistical analysis of modified clinical technique vision screening of preschoolers by optometry students. Optom Vis Sci. 1994;71(10):593–603. https://doi.org/10.1097/00006324-199410000-00001
42. Bailey RN. Assessing the predictive ability of the test – positive findings of an elementary school vision screening. Optom Vis Sci. 1998;75(9):682–691. https://doi.org/10.1097/00006324-199809000-00024
43. Paech M. The Orinda Study: Should the 'modified clinical technique' retain its 'gold standard' status as a vision screening tool? Clin Exp Optom. 2010;93(1):31–36. https://doi.org/10.1111/j.1444-0938.2009.00439.x
44. Hayes GJ, Cohen BE, Rouse MW, De Land PN. Normative values for the nearpoint of convergence of elementary schoolchildren. Optom Vis Sci. 1998;75(7):506–512. https://doi.org/10.1097/00006324-199807000-00019
45. Junghans B, Kiely PM, Crewther DP, Crewther SG. Referral rates for a functional vision screening among a large cosmopolitan sample of Australian children. Ophthalmic Physiol Opt. 2002;22(1):10–25. https://doi.org/10.1046/j.1475-1313.2002.00010.x
46. Dwyer PS. The Portsea Lord Mayor's Children's Camp vision screening: A rationale and protocol for Op to metric Screening. Aust J Optom. 1983;66(5):178–185. https://doi.org/10.1111/j.1444-0938.1983.tb03711.x
47. Walters J. Portsea modified clinical technique: Results from an expanded optometric screening protocol for children. Aust J Optom. 1984;67(5):176–186. https://doi.org/10.1111/j.1444-0938.1984.tb03729.x
48. Bodack MI, Chung I, Krumholtz I. An analysis of vision screening data from New York City public schools. Optometry. 2010;81(9):476–484. https://doi.org/10.1016/j.optm.2010.05.006
49. Cohen AH, Lieberman S, Stolzberg M, Ritty JM. The NYSOA vision screening battery – A total approach. J Am Optom Assoc. 1983;54(11):979–984.
50. Reynolds DC. The validity of a screening test. Am J Optom Physiol Opt. 1982;59:67–71. https://doi.org/10.1097/00006324-198201000-00010
51. Werner DL, Field S. A mammoth vision screening – public relations and public service. J Am Optom Assoc. 1982;53(9):731–737.
52. Gallaway M. The need for better school vision screening: The use of VERA vision screening in a community setting. OVD. 2010;41(4):232.

53. Hatch SW. Computerized vision screening: Validity and reliability of the VTA/VERA Vision Screener. JBO. 1993;4(6):143–149.

54. El-Defrawy S, Clarke WN, Belec F, et al. Evaluation of a hand-held autorefractor in children younger than six. In: Duckman RH, editor. Visual development, diagnosis and treatment of the pediatric patient. New York: Lippincott Williams & Wilkins, 2006; p. 253–254.

55. Buchner TF, Schnorbus U, Grenzebasch UH, et al. Examination of preschool children for refractive errors. First experience using a hand held autorefractor. In: Duckman RH, editor. Visual development, diagnosis and treatment of the pediatric patient. New York: Lippincott Williams & Wilkins; 2006; p. 252.

56. Carter A, Ciner E. A comparison of two autorefractors in the vision in preschoolers study. In: Duckman RH, editor. Visual development, diagnosis and treatment of the pediatric patient. Philadelphia, PA: Lippincott Williams & Wilkins, 2006; p. 253.

57. Grosvenor T. Primary care optometry. 5th ed. MO: Butterworth & Heineman, Elsevier, Missouri, 2006; p. 222.

58. Molina-Torres M, Crespo MS, Frances AT, Lacarra BL, Ronda-Perez E. Diagnosis accuracy of two vision screeners for visual health surveillance of workers who use video display terminals. J Occup Health. 2016;58:444–451. https://doi.org/10.1539/joh.15-0247-OA

59. Horberry TJ, Gale AG, Taylor SP. Vision screeners for display screen equipment users: An experimental. Displays. 1997;17(2):111–117. https://doi.org/10.1016/S0141-9382(97)00002-4

60. Harley RK, Lawrence GA, Sanford L, Burnett R. Visual impairment in the schools. 3rd ed. IL: Springfield: Charles C Thomas, Illinois, 2000; p. 111.

61. Kansas Department of Health and Environment Bureau for Children. Youth and families vision screening guidelines for infants, toddlers, children and youth [homepage on the Internet]. 5th ed. 2004; p. 1–65. [cited 16 Mar 2015]. Available from: http://www.kdheks.gov/bfh/download/VisionGuidelines2004.pdf

62. Tennessee Department of Education. Tennessee School Health Screenings Guidelines [homepage on the Internet]; 2008. [cited 27 Feb 2015]. Available from: https://www.tn.gov/assets/entities/education/attachments/