• Review Article •

A review of paediatric vision screening protocols and guidelines

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Abstract

● Vision screening plays an important role in the early detection of children who have or probably are predisposed to have specific visual problems. The validity and reliability of the screening batteries in relation to the age group to be screened, and the person administering the test as well as the referral and follow-up criteria contribute to the overall outcome of the vision screening. Despite the long history of vision screening and significant improvement in the development of screening protocols, no agreement exists concerning the age at which children should be screened, the exact test batteries that should be included and who should conduct the screening. This review highlights some important aspects of the history of paediatric vision screening and available evidence in support of their use to detect visual conditions in children. It also examines some of the barriers against the development of paediatric vision screening models especially in low and medium income countries.

● **KEYWORDS:** vision screening; children; visual problems; screening batteries

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INTRODUCTION

The primary goal of pediatric vision screening is to detect children with unsuspected remediable visual conditions, to implement early treatment and reduce the impact that any untreated condition may have on their educational and social progress[1-2]. Starting with the first approved vision screening program in Connecticut in 1899[3] that utilized the traditional visual acuity (VA; Snellen) chart, screening programs and test batteries have evolved over the years. Despite the significant improvements, the value of paediatric vision screening programs and the ideal protocol to be adopted has continued to dominate scientific and health policy discussions. While it is generally accepted that the detection of vision anomalies in children depends on the availability of valid and reliable test batteries, no agreement exists concerning the age at which children should be screened, the exact test batteries that should be included and who should conduct the screening. This review highlights some important aspects of the history of paediatric vision screening and available evidence in support of their use to detect visual conditions in children. It also evaluates some of the more contentious issues against the development of paediatric vision screening guidelines.

THE NEED FOR VISION SCREENING

According to the recommendations of the World Health Organisation, effective screening programs should include tests to detect conditions that are common and can present serious health problems. Such conditions can easily be detected through cheap and reliable screening tests that are available. It should also be economically amenable to treatment[4].

Significant refractive error (RE) is a leading cause of visual impairment in childhood and its detection is the main target of vision screening programs[5]. A series of Refractive Error Study in Children (RESC) surveys, conducted in several countries on children of comparable age group and by utilizing common diagnostic criteria and measurement methods observed that uncorrected RE was responsible for about 56%-94% of cases of reduced vision in children[6]. The studies suggest that the vision of those children would have been effectively treated with early detection and spectacle correction. There are over 19 million children less than 15 years of age with visual impairment worldwide with 12.8 million of them due to uncorrected RE[6].

Amblyopia is also a common cause of vision loss in children. It is mostly cause by strabismus, RE and congenital cataract[7-8]. Testing for amblyopia is one of the focus areas of many screening programs because of its prevalence, its effect on children and society, and the effectiveness of amblyopia treatment. It is estimated that 2%-4% of people in developed nations are affected by amblyopia depending on the population and study[9-10]. Individuals with amblyopia are more likely to have bilateral vision impairment compared to non-amblyopic persons which exacts a significant burden on the individual and society[11-12]. Amblyopia can be easily treated by cost effective means including optical correction of any significant RE, patching of the non-amblyopic eye, or use of atropine in the non-amblyopic eye[8,13]. Available studies indicate that amblyopia can be treated later in life but is most effectively treated, and can only be prevented, in early childhood[7-8,13].

The condition of strabismus or misalignment of the eyes is related to amblyopia and therefore, there may also be a "critical period" after which permanent vision loss may occur without early intervention. For instance, to avoid confusion of receiving two disparate retinal images, the brain can ignore or suppress the image from one eye which could remotely lead to amblyopia. Once the visual system in the brain is fully developed, however, such adaptations are not possible[7].

Colour vision deficiency (CVD) is rarely included in screening protocols considering that congenital CVD are untreatable and not always considered as a disease. However, some people argue that CVD testing should be included as part of screening batteries as CVD can affect the development of a child. As such early identification will help to counsel the affected child of possible career choices thereby reducing the psychological effect this may have in the future[14]. Screening for accommodative and binocular dysfunction is preferable, as there is some evidence in support of an association with impaired school performance. Other conditions targeted in paediatric vision screening programs include ocular pathology such as trachoma, vitamin A deficiency, cataract, glaucoma and retinoblastoma[5].

HISTORICAL DEVELOPMENT OF VISION SCREENING PROTOCOLS

Traditional Methods The first state approved school vision screening program that included only a Snellen chart was established in Connecticut in 1899. However, this achievement was marred by poor test results owing to the under-standardization of the testing conditions. In 1934, a series of slides that were used in the assessment of VA, fusion and stereopsis was developed[3]. The development marked an important point in the history of vision screening, as it became the first commercially available stereoscope, after incorporating it into the Keystone Ophthalmic Telebinocular Vision Testing instruments. Similarly, the tests results were considered unacceptable by the American Medical Association in 1939 due to its high failure rates of 85%[3].

The idea of incorporating ocular examination into screening programs, as well as ensuring a wider coverage through rapid and precise methods led to the development of the Massachusetts Vision Test in 1938, which included tests for VA using the Snellen chart, hyperopia using +1.00 D lenses, and heterophoria using the Maddox rod. Teachers were entrusted with the responsibility of identifying children in need of vision correction and promptly referring them to the ophthalmologist. The screening maintained good correlation with ophthalmologists producing agreements of 86% of those who passed and 93% of those who failed. The main challenge for this screening test was the inability to develop consistent and reliable passing criteria[15].

Contemporary Methods Using the concept of the Massachusetts Vision Test, optical companies started producing commercially available vision screening instruments that included the Massachusetts School Vision Screening Test, the modified Keystone Telebinocular, the modified Bausch and Lomb School Ortho-Rater, and the Titmus Optical School Vision Tester in 1955. Although these instruments provided a cost-effective and rapid testing approach, the issue of who should administer the test, how often it should be performed, and the referral and follow-up criteria were still controversial[3].

The first comprehensive and systematically validated children's vision screening tool known as the Modified Clinical Technique (MCT) was developed from a three-year study period in the Orinda School District in California, USA. Starting from 1954, parents, teachers, nurses and optometrists utilized a combination of assessment procedures to re-examine a single cohort of primary school children seven or eight times in every subsequent year of the study. The Orinda study identified reduced VA, RE, binocular vision dysfunction (strabismus) and ocular pathology as specific problems that should be prioritised for screening by either optometrists or ophthalmologists[16-17]. Interestingly, the test protocol can be completed in about 5 to 6min per child[14]. The remarkably high sensitivity (98%), specificity (99%) and good predictive value (positive predictive value of 0.90 and negative predictive value of 0.99) of the Orinda Study and its MCT has gained wide acceptance as it is considered as the "gold standard" vision screening procedure for school-aged children[14,18].

However, tests for non-strabismic binocular dysfunction were not part of the MCT and ophthalmic-trained personnel (ophthalmologists and optometrists) are required to perform RE assessment with a retinoscope and to screen for ocular disorders[19]. With the exception of distance and near cover test, no other functional and performance-oriented testing was included in the MCT battery[19]. In addition, the high sensitivity and specificity reported for the Orinda MCT has not been replicated in subsequent studies that applied the MCT battery[14,18]. This may be due to the lack of a definitive pass/fail criterion for the MCT in the Orinda study. A child is considered to have passed or failed the test based on the decision of two independent optometrists after reviewing the results of the series of tests. In case of any disagreement between the optometrists, four additional vision care experts are consulted[14]. Given that the MCT cannot be administered by non-ophthalmic trained vision screeners including the non-replication of its sensitivity and specificity values, the status of a "gold standard" vision screening protocol has been questionable[18].

A modified version of the Orinda MCT (Portsea MCT) was introduced in vision screening programs between 1980 and 1983 as part of a larger public health initiative at Portsea in Victoria, Australia[14]. In the Portsea MCT fusional vergence ranges, accommodative facility, ocular motility, stereopsis and colour vision tests were added to the Orinda battery to provide a comprehensive assessment of visual parameters associated with reduced school performance[20]. However, the added test protocols did not increase the time efficiency of the Portsea MCT when compared to the Orinda MCT[20-21]. Similarly, when compared to other screening programs that utilized the Orinda MCT the referral rate from the Portsea study of 17.7% and 10.4% was classified as unsatisfactory and borderline, respectively[16-17,22].

In 1985 a screening battery that uses a functional vision screening approach to detect learning related vision problems was developed by the New York State Optometric Association (NYSOA)[23]. The test battery included distance and near VA, as well as screening tests for hyperopia, convergence, fusion (with the Keystone Telebinocular), stereopsis, saccadic skills, visual motor integration, and colour vision and was designed to be administered by parent volunteers trained by an optometrist. A validation study for the screening protocol observed a sensitivity of 72% and specificity of 65% when compared to professional eye examination, and that the Snellen test missed 75% of the visual problems that were detected in the full examinations. Concerns about the practical applicability of this screening protocol apparently contributed to its lack of acceptance by schools. The test battery is long and involves both optometrists and trained parent volunteers, as school nurses cannot alone administer the screening and schools may not be able to provide enough of their own personnel for the screening[14,23].

Computerized Methods The development of computerised screening protocols helped to tackle some of the issues which has been a major drawback for screening programs. For instance, a computer software known as Visual Efficiency Rating (VERA) was developed to address some of the concerns of NYOSA test batteries, so that school nurses could screen for binocular, accommodative, and ocular motor disorders in addition to hyperopia and VA. The protocol involves a 2-level testing approach in which children must pass VA, hyperopia, and stereopsis screening tests before the performance of a visual skills battery. The visual skills screened are vergence facility, accommodative facility and saccadic tracking. VERA screening batteries were designed to increase specificity and can be completed in about 12 to 15min per a child. A study was conducted by Gallaway and Mitchell[24] to validate the VERA visual skill test. Initially, the sensitivity of VERA in detecting visual skills problems was 45%, and the specificity was 83%. The sensitivity increased to 64% and specificity to 100% in professional eye examination data in 28 subjects when the symptom survey (Convergence Insufficiency Symptom Survey), reading level and a classroom behaviour survey (completed by the teacher) were included. The analysis was not limited to visual skills data but also comprised of acuity and refractive data. It was noted that VERA was an acceptable alternative to other protocols for screening visual skills and could be efficiently administered by a school nurse.

Although several vision screening protocols that can detect broad range of paediatric vision problems have been developed, there sensitivity/specificity, time efficiency and level of expertise required for their administration differs[14,16,23]. For instance, MCT which takes only about 5 to 6min per child requires some qualified ophthalmic personnel to administer, whereas the NYOSA test batteries which can be administer by a train non-ophthalmic personnel takes about 12 to 15min to complete per child[23]. Therefore, in developing optimum screening guideline, it is important to strike a balance between sensitivity/specificity and time efficiency[14].

VISION SCREENING MODEL IN SELECETED COUNTRIES AND REGIONS

Vision screening programs are in existence in most developed countries across the world[8,14,25-27]. However, the debate on the fundamental components and nature of the screening programs has not been resolved. Even within a country, there has not been any agreement about when children should be screened, which conditions should be targeted, which protocols should be used, and which screening personnel are best equipped to provide services. In addition, traditional VA test protocol has continued to be the fundamental of test batteries for these screening programs, despite significant improvement in the screening protocols. The implication is that the screening programs that mainly assess distance VA are likely to miss other basic visual skills necessary for optimum school performance[14]. A summary of screening programs from selected countries are presented in Table 1[1,8,14,25-28].

Non-governmental organisations working in eye health have also recommended screening guidelines to be adopted by specific countries in their regions of operation. In Eastern Mediterranean region[29] and India[30], the recommended guidelines for school vision screening prioritised the detection and correction of significant RE to reduce the prevalence of preventable blindness and low vision due to uncorrected RE

Table 1 Summary of paediatric vision screening guidelines from selected countries

Country	Age screened	Screening test	Screening personnel
British Columbia, Canada[8]	3y	Amblyopia, strabimus (eye check HOTV), Randot preschool stereo test, sure sight vision screener; reduced VA	Public health staff
Manitoba, Canada[25]	Kindergarten to Grade 1	Stereoacuity, vertical or lateral heterophoria, reduced VA	School health nurse
	Grade 3 and above	Vertical or lateral heterophoria, reduced VA, plus lens test (+2.25 D)	School health nurse
Kansas, USA[26]	Birth to 6mo	Eyelid reflex, fixation, tracking, pupil response, corneal reflex test	School health nurse, volunteers
	6-18mo	Tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity	School health nurse, volunteers
	18mo-3y	Fixating, tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity, fusion (Worth-4-dot), stereopsis, HOTV	School health nurse, volunteers
	3-5y	Fixating, tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity, fusion (Worth-4-dot), stereopsis, HOTV, colour vision test	School health nurse, volunteers
	5-8y	Fixating, tracking pupil response, corneal reflex test, cover test, NPC, Teller card acuity, fusion (Worth-4-dot), stereopsis, distance VA, colour vision test, plus lens test, near VA	School health nurse
	8-12y	Pupil response cover test, NPC, stereopsis, distance VA, colour vision, plus lens, near VA	School health nurse
Alaska, USA[27]	Distance VA: preschool, kindergarten, Grade 1 to 12	Sloan, LEA or HOTV, occluder	
	Binocular vision: Preschool, kindergarten, Grade 1	Stereofly or butterfly test, random dot 'E' Cover test or Hirschberg, paddle ocluder and fixation target	
	Photoscreen: preschool or kindergarten, special needs population	Valid photoscreen instrument	
Queensland, Australia[14]	0-18mo	Visual behaviour, Hirschberg test (6-18mo)	Well child visit, health nurse
	2.5-3.5y	Hirschberg test, vision, near cover test	School entry screening; child health nurse
	4-5y	Hirschberg test, vision, near cover test, distance and near cover test, vision: LEA/HOTV/STYCAR	Child health nurse
	6-12y	Vision-Snellen chart	Referred by parents; child health nurse
United Kingdom[1]	Pre-kindergarten, kindergarten	logMAR crowded test	Orthoptics
Spain[28]	4-5y	LEA charts, ocular alignment test, ocular motility test, Random dot stereo test	Qualified healthcare professional

VA: Visual acuity; LEA and HOTV: VA chart for children; STYCAR: Screening test for young children and retardates; NPC: Near point of convergence.

in the region. However, the guidelines fail to specify the age of children to be screen, the screening tools to use and who should administer the screen.

Recently a standard guideline for comprehensive school eye health programs in low and medium income countries was developed by International Agency for Prevention of Blindness (IAPB)[5]. The guideline was a revised version of an earlier document develop by a coalition of non-governmental organisations working in the field of eye health. The guideline was designed to provide direction in planning and implementation of efficient and sustainable school eye health programs through step by step approach that will be implemented base on the availability of resources and the nature of existing child eye health service in any given system. The guideline recommends that health care professionals and trained non-health professionals such as school teachers should be involved in the provision of school health programs and that schools should be visited every 1-2y[5]. Although common childhood eye conditions including eye infections, lid infections and allergies were recommended to be screened, the focus of the screening strategy is on visual conditions that can cause reduced VA and loss of vision in children (Recommendation of the IAPB for school eye health program)[5]. Visual problems such as accommodative and vergence disorders which can reduce functional performance and overall quality of life of a child are not among the conditions to be screened.

VISION SCREENING PROGRAMS AND CHILD EYE HEALTH IN NIGERIA

Early detection and treatment of potential visual impairment and blinding diseases is a key factor in the actualization of children rights, particularly the right to the highest attainable health and ensuring their protection against preventable diseases[31]. While the expanded program on immunization against measles and vitamin A supplementation have impacted positively on child eye health, the realization of efficient and a sustainable child eye health program in Nigeria has not been achieved.

Eye care services in Nigeria are delivered in public and private hospitals, however, reports indicate that eyecare services are mainly provided by private health institutions[32-33]. A situational review of paediatric eye care in Nigeria report that there were only 400 ophthalmologists in Nigeria (including those in training) with only 12 of them specializing in paediatric ophthalmology[32]. Similarly, a situational analysis of optometry in Africa, indicates that there are approximately 4000 optometrists in Nigeria[34]. The reviews[32,34] also emphasized on the uneven distribution of eye health facilities and eyecare practitioners. Among the ophthalmologists in Nigeria, 95%-99%[32] were practising in urban areas and state capitals and according IAPB[34] 60% of optometrists in Africa are working in their various country capitals with only 40% practising mainly in urban areas of the constituent states or provinces.

Although, eye health is included as one of the components of primary health care (PHC) in Nigeria, eyecare services are only provided in few PHC centres across the country. In some states secondary eye care services are non-existent and where it is provided, it is grossly under-resourced and limited by inadequate human resource capacity, equipment and referral opportunities to tertiary level services. The few tertiary centres are not adequately prepared to support the child eye health in Nigeria. The two most active and equipped tertiary paediatric centres are privately owned and are in the north central and south west geopolitical zones. In addition, only a few states have functioning blindness prevention programs and school eye health is not a priority of all the three tiers of government in Nigeria[32-33]. Thus, the provision of eyecare services including school eye health programs is mainly by private eyecare facilities. Vision screenings delivered in school settings, as well as religious centres by local eye care practitioners, are often driven by commercial interest and availability of time of the individuals involved. There is no strategic coordination between eyecare practitioners and no screening guidelines on how and when children should be screened, the screening batteries that should be included and the appropriate referral criteria. Furthermore, some prevailing eye disorders including accommodation and vergence anomalies, low amount of hyperopia and astigmatism are not necessarily included by individual eyecare practitioners. Altogether, the screening programs administered by private individuals in Nigerian are unmethodical and irregular.

MAJOR CHALLENGES TO THE DEVELOPMENT OF A VISION SCREENING MODEL

Evidence for Childhood Vision Screening One of the major challenges facing vision screening programs of school children is the lack of direct evidence demonstrating the effectiveness of childhood vision screening in reducing the prevalence of ocular disorders or in improving visual outcomes. For instance, a Cochrane review of literature from 1966 to 2004 on screening for correctable VA impairment in school-aged children and adolescents concluded that there were no available robust trials that can be used in evaluating the advantages of school vision screening. The harmful effect of reduced VA on schooling needs to be quantified. The authors suggest that in assessing the impact of a screening program, consideration will be given to the geographical and the socio-economic environment in which it is administered[35]. This however does not imply that there is no benefit derived from screening programs, rather the impact has not been systematically tested in randomized controlled trial[36]. In contrast, a convincing series of indirect evidence supports the early detection of sight threatening visual condition[36-37]. In addition, the American Academy of Ophthalmology and the American Academy of Paediatrics recommend visual assessment from birth and at all routine health visits[38].

Components of Vision Screening Protocol Even though computerized methods of vision screening are now available, the VA chart has continued to be one of the basic tools of a vision screening protocol especially in the developing countries where the acquisition of computerized instruments is not always easy. While children with uncorrected myopia can easily be detected through measures of unaided distance VA, it is not always same for those with near vision anomalies such as hyperopia, astigmatism, accommodative and binocular vision dysfunction[39-40]. A validation study[40] for VA protocol and RE detection recorded a high sensitivity and specificity for myopia detection in 12-year-old children but was not effective in detecting hyperopia or astigmatism. Children with good accommodative ability were still able to read a 6/6 (20/20) letters on the VA chart, despite having high amount of hyperopia and astigmatism. However, with increasing age and excessive near work activities, these children may experience some visual discomforts[38-39]. In another study involving high school children with poor reading ability in California, only 17% had reduced VA of less than 20/40 or worse in at least one eye, whereas 80% had deficiency in at least one of the clinical measures of accommodative and vergence functions including, near fusional amplitude, accommodative facility and near point of convergence[41]. Likewise, a significant increase in the prevalence of binocular vision problems was found among public school children in New York City[42]. The implication of these findings is that with traditional VA measurement which is mostly used in school vision screening programs, many children with impaired reading ability would be missed. Consequently, Bodack *et al*[42] had reiterated the importance of periodic screening and rescreening for hyperopia and binocular vision anomalies in addition to distance visual acuities.

Provision of Vision Screening Vision screening conducted by adequately trained health professionals is vital for the detection of vision problems in children[5,43]. An assessment of screening programs in Sweden[44] and Vietnam[45] revealed that adequately trained non-ophthalmic personnel can competently screen 4-year-old children, while children who fail screening tests should be referred to an ophthalmologist[44]. A study on the SureSight vision screener found an inverse relationship between the experience of the screeners and the referral rate. In this case, the referral rate decreased as the volunteers gained more experience. At the beginning, the average referral rates for the screeners were 10.6% which overtime decreased markedly to 7%[46]. Although, the study did not assess the sensitivity, specificity, or positive predictive values of the screeners, it revealed that vision screenings are mostly subjective, and the accuracy of screening results will depend greatly on the experience of the screener. Overall, these studies revealed that the sensitivity of the test administered by different people varied depending on the protocol adopted and the age of the children being screened. However, adequate training is necessary to achieve a reliable result.

The Vision in Preschoolers Study compared the performance of vision screening tests in 3- to 5-year old by trained nurses and lay screeners, using the results of examination administered by an ophthalmologist or optometrist as the gold standard. The screening tests performed included SureSight, Retinomax, crowded linear LEA Symbols, single LEA Symbols (administered by lay screeners only) and stereo smile II test[47]. Except for linear LEA symbols which were significantly higher, the sensitivities of all other tests were not statistically significant, even though the sensitivities were marginally higher when administered by nurse screeners than lay screeners. In contrast, lay screeners achieved a considerably higher sensitivity with the Single LEA Symbols VA test than did nurses or lay screeners using the Linear LEA Symbols VA test. These findings indicate that similar results can be achieved by adequately trained nurses and lay screeners in preschool vision screening[47].

The Age to Administer Vision Screening There is no consensus on the ideal age at which screening should be administered in children. In Australia, vision screening is mostly conducted at school entry which for most children is about 5 to 6 years of age. This guarantees a wider coverage and early detection of amblyopia, as children are readily available[11,39]. Sjöstrand and Abrahamsson[48] recommend vision screening for amblyopia at 5 years of age because at that age children can be properly screened with a linear acuity chart and adequately treated, with less psychosocial burden for the child and the family. Besides, treatment at this age can result in a better visual outcome as children are still in the critical period of visual development[11,39]. According to Hartmann *et al*[46] the chance of achieving a better test result is higher in older children, as screening in younger children is more difficult. Due to the subjective nature of most screening protocols, screening younger children may be difficult and lengthy especially for the inexperienced screener.

Preschool vision screening has also received some support, as it allows for timely detection and treatment of amblyopia before schooling begins[49-50]. Screening for amblyogenic factors in school-aged children is also warranted because amblyopia can be effectively treated into the teenage years and beyond[51]. While there may be some disadvantage in delaying the detection of amblyopia until school entry, the reliability of the screening is higher and the costs significantly less. It is more difficult for a preschool age group to follow test procedures and instructions. Thus, there is more likelihood of having a higher false positive rate from preschool vision screening than for that performed at school entry[43]. However, some others have recommended the performance of vision screening at regular intervals. For example, the American Academy of Ophthalmology and the American Academy of Paediatrics recommend eye health screening from birth and at all routine health visits[40]. The guidelines on school eye health recently developed by IAPB recommend that schools be visited at least once in every two years to screen new intake and to rescreen those given spectacle the previous year[5]. Similarly, Bodack *et al*[42] have stressed the relevance of periodic screening and rescreening for various ocular defects.

CONCLUSION

Vision screening of children is a valuable approach for the detection of potential visual disorders that may impact negatively on the overall development of a child. The specific test batteries, the age group to be screen, and the personnel administering the test all contribute to the overall outcome of the vision screening. While the VA chart is a traditional screening tool, it may not be effective in the detection of some visual disorders like, hyperopia, astigmatism and anomalies of binocular function. Since children of different age groups present with varying degrees of visual problems, it may be necessary to use age appropriate test batteries to assess vision in the different age group of children. There seems to be no agreement as to who should be administering the children's vision screening programs and the age at which it should be administered. Perhaps, a collaborative effort of eye care professionals, nurses and lay screeners (while keeping the cost very low) may be ideal. This will require the development of test protocols for each of the group of screeners base on their expertise and knowledge. As indicated in the reports, eye care professionals are better equipped to provide complex screening procedures. Overall, the studies reviewed emphasized on adequate training of the vision screener as being essential in achieving a reliable screening result. In addition, screening of all children at school entry age may offer a wider coverage, as the children can reliably cooperate with vision screening tests and are readily accessible. Subsequent periodic screening as recommended by the American Academy of Ophthalmology and the American Academy of Paediatrics will be essential. The lack of randomized controlled data has not helped the evaluation of the effectiveness of vision screening. However, no studies have observed any risk associated with screening: the tests can detect the defects they are meant to detect, and there are effective treatments for these vision defects.

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