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Findings From The Vision In Preschoolers (VIP) Study

Vision In Preschoolers (VIP) Study Group

Abstract

The Vision in Preschoolers (VIP) Study Group conducted a multi-center, multi-disciplinary, two phase study to evaluate the performance of vision screening tests for identifying preschool children with amblyopia, strabismus, significant refractive error, or unexplained reduced visual acuity (VA). The results of the Vision in Preschoolers (VIP) Study provide evidence-based guidelines for preschool vision screening. The best screening tests administered by eye care professionals were noncycloplegic retinoscopy, Retinomax Autorefractor, SureSight Vision Screener, and linear, crowded Lea Symbols® visual acuity (VA) at 10 feet. The best screening tests administered by trained nurses and/or lay screeners were Retinomax, SureSight, and VIP single, crowded Lea Symbols® VA screening test system at 5 feet. Eye care professionals can improve detection of strabismus by combining unilateral cover test with a refraction test and trained lay screeners can improve detection of strabismus by combining Stereo Smile II with SureSight. The best performing tests had high testability whether performed by trained eye care professionals, nurses or lay screeners (≥98%). Although very few children were unable to complete these tests, a child who was 'unable' was much more likely to have a vision problem than a child who passed; therefore children who are unable to complete one of these tests should be referred for further evaluation. When screening using the Retinomax, repeated testing to achieve the manufacturer's suggested confidence number is valuable and improves specificity. Federal initiatives to increase the number of preschool children receiving vision screening or examination will increase the number of preschool children identified with amblyopia, strabismus and/or significant refractive error. Although there is general agreement regarding the importance of early detection of amblyopia, controversy exists regarding the importance of early detection of refractive error. Because of the high prevalence of significant refractive errors and lack of evidenced-based guidelines for correction of refractive error in preschool children, future research is needed to evaluate the value of correcting refractive errors in preschoolers who do not have amblyopia and/or strabismus.

Keywords

vision screening; preschool children; visual acuity; autorefraction; photoscreening; amblyopia; strabismus; refractive error

Amblyopia, strabismus, and significant refractive error are the most prevalent preschool vision disorders.[1, 2] Preschool vision screenings have been recommended as a cost-effective way to identify children with vision disorders who may benefit from early detection to allow treatment or follow-up eye care.[1, 3, 4] The Vision in Preschoolers (VIP) Study group conducted a multi-center, multi-disciplinary, two phase study to evaluate the performance of vision screening

Corresponding author: Marjean Taylor Kulp, The Ohio State University College of Optometry, 338 West 10th Avenue, Columbus, Ohio 43210, kulp.6@osu.edu.

The Vision in Preschoolers Study Group: Executive Committee: Paulette Schmidt, OD, MS (Chair); Agnieshka Baumritter, MA; Elise Ciner, OD; Lynn Cyert, PhD, OD; Velma Dobson, PhD; Beth Haas; Marjean Taylor Kulp, OD, MS; Maureen Maguire, PhD; Bruce Moore, OD; Deborah Orel-Bixler, PhD, OD; Ellen Peskin, MA; Graham Quinn, MD, MSCE; Maryann Redford, DDS, MPH; Janet Schultz, RN, MA, CPNP; Gui-shuang Ying, PhD.

tests for identifying preschool children with amblyopia, strabismus, significant refractive error, or unexplained reduced visual acuity (VA)(Table 1).[5,6] Phase 1 of the study evaluated the performance of eleven screening tests when administered by licensed eye care professionals. Because screening tests are typically administered in the school by school nurses and lay volunteers, Phase 2 evaluated the performance of selected screening tests from Phase I as administered by nurse and lay screeners.

Best Preschool Vision Screening Tests in the Hands of Licensed Eye Care Professionals

In Phase I of the study, 11 preschool vision screening tests were administered by licensed eye care professionals to 2,588 three- to five-year-old children enrolled in Head Start over a two-year study period. Head Start is a national, comprehensive child development program that serves preschool children and their families in the United States. The goal of Head Start is to increase the school readiness of children from low income families. All licensed eye care professionals who performed screening tests were trained and certified on the screening and examination procedures. Screening tests evaluated included noncycloplegic retinoscopy, Retinomax Autorefractor (Retinomax) (RIGHTmedical Products, Virginia Beach, VA), SureSight Vision Screener (SureSight) (Welch Allyn, Inc., Skaneateles Falls, NY), Lea Symbols® VA (crowded, linear optotypes at 10 feet) (Good-Lite Co., Elgin, IL), HOTV VA (crowded, linear optotypes at 10 feet)(Precision Vision, La Salle, IL), Power Refractor II (Plusoptix, Nuremburg, Germany), iScreen Photoscreener (iScreen, Inc., Memphis, TN), MTI Photoscreener (Photoscreener, Inc. West Palm Beach, FL), cover-uncover test (unilateral cover test), Random Dot “E” stereoacuity (StereoOptical Co., Chicago, IL), and Stereo Smile II (StereoOptical Co., Chicago, IL) stereoacuity. For autorefractors and photorefractors, the screeners were instructed to test up to three times (as needed) to meet the manufacturers' recommended guidelines (e.g., for confidence number). A lap card was used for VA testing to increase testability by allowing children to identify the letter/symbol seen by either naming or pointing (matching). Details of these procedures have been published previously.[5] After screening, children underwent a comprehensive vision examination by a trained, masked examiner that included VA, cover testing and cycloplegic retinoscopy.5 Screening tests and vision examinations were performed in a mobile unit designed for the study.7

Sensitivities for detection of ≥1 targeted conditions (amblyopia, strabismus, significant refractive error or unexplained reduced VA) were compared at set specificities of 90% and 94%. Sensitivity refers to the percentage of children with the targeted vision disorder who are correctly identified (referred) and specificity refers to the percentage of children with no vision disorders who are correctly identified (passed) as normal. For example, if the sensitivity and specificity of a screening test were 70% and 90% respectively, the screening correctly identified/referred 70/100 children with the disorder; failed to identify (incorrectly passed) 30/100 children with the disorder; correctly identified/passed 90/100 of the normal children and incorrectly over-referred 10/100 children with normal vision. It is important to compare sensitivities at a set specificity because a change in one value can impact the other. For example, an increase in sensitivity is often accompanied by a decrease in specificity. Therefore, the set specificity allows comparison across tests. A specificity of 90% was selected as being within the scope of interest for mass screening. A specificity of 94% was selected because 2 tests with established failure criteria achieved a specificity of 94%.[5]

When performed by eye care professionals and when overall specificity was set to either 90% or 94%, noncycloplegic retinoscopy, Retinomax, SureSight, and Lea Symbols® VA performed best in detecting children with ≥1 targeted conditions, amblyopia and children with the most important/severe conditions.[5, 8] Sensitivity for detection of ≥1 targeted conditions was somewhat lower for HOTV VA than for Lea Symbols® VA, but the differences were not

statistically significant. Noncycloplegic retinoscopy, Retinomax, and SureSight performed significantly better than the static photorefractors (iScreen Photoscreener and MTI Photoscreener). Associated referral criteria for the best tests are shown in Tables 2 and 3.[5, 8] Over 99% of children were testable on the tests of refraction (noncycloplegic retinoscopy, Retinomax, SureSight) and VA (Lea Symbols® and HOTV).[5, 9] At 90% specificity, the best tests detected approximately two-thirds of children with ≥1 targeted conditions and nearly 90% of children with the most important/severe levels of each condition.[5]

Best Preschool Vision Screening Tests in the Hands of Trained Nurse and Lay Screeners

Because vision screenings are often performed by nurse or lay screeners, Phase II of the VIP study compared the performance of trained nurse and lay screeners in administering some of the best preschool vision screening tests from Phase I. Three of the four best-performing tests in phase I (Retinomax Autorefractor, SureSight Vision Screener, and crowded Linear Lea Symbols VA test) were included in phase II. The fourth test, NCR, was not included because its use requires a high degree of training, skill, and clinical knowledge. A test of stereoacuity, the Stereo Smile II test, was also included because it was one of the most effective tests for detection of strabismus in phase I and, therefore, was of interest for potential use in combination with another screening test. Phase II testing was conducted in a more typical school screening environment inside the schools.[6] Trained nurse and lay screeners administered the Retinomax, SureSight, Lea Symbols® VA test (linear, crowded optotypes at 10 feet), and Stereo Smile II test to 1,452 three-to five-year-old Head Start preschoolers. Lay screeners also administered a single, crowded Lea Symbols® VA screening test (Good-Lite Co., Elgin, IL) which was developed by the VIP group in response to the poor performance of lay screener–administered crowded Lea Symbols® VA test at 10 feet in initial testing during Phase I. To facilitate the screeners' ability to engage the child during VA testing, the test was designed to use presentation of single, crowded Lea symbols® (Good-Lite, Inc.) on a light stand (Richmond Products, Inc., Albuquerque, NM) at a distance of 5 feet. Similar to Phase I, autorefraction was performed up to three times (as needed) to meet the manufacturers' recommended guidelines for confidence number and a lap card was used for VA testing to allow the child to identify symbols by naming or pointing. Details of these procedures have been published previously.[6] Study-certified eye care professionals (masked to the screening results) then performed a comprehensive eye examination on each child that included VA, cover testing and cycloplegic retinoscopy. As in Phase I, screening tests' sensitivities for detection of children with ≥1 targeted conditions were compared at 90% specificity.[6]

High testability was found for each screening test (≥98%) when performed by trained nurse and lay screeners, similar to that achieved by licensed eye care professionals in Phase I. Testing times were similar for nurse and lay screeners. Screeners' median testing times were two minutes for autorefraction (both eyes), four minutes for monocular VAs (both eyes), and three minutes for stereoacuity testing. Screeners required an average of 1.20 to 1.28 attempts to achieve a satisfactory reading on the autorefractors.

Using Retinomax and SureSight, with specificity set at 90%, trained nurse and lay screeners achieved similar sensitivities for detecting preschool children with ≥1 targeted conditions. Nurse screeners achieved lower sensitivity than licensed eye care professionals using the Lea Symbols® VA tests (crowded linear optotypes at 10 feet) and lay screeners achieved significantly lower sensitivity for detection of ≥1 targeted conditions than nurse screeners for this test. However, lay screeners achieved significantly higher sensitivity for detection of ≥1 targeted conditions when they tested with the VIP single, crowded Lea Symbols® VA screening test system at 5 feet than did nurse or lay screeners using the linear, crowded Lea Symbols® VA test at 10 feet (and similar to that of licensed eye care professionals using the

linear, crowded Lea Symbols® VA test at 10 feet). The improved sensitivity with the VIP single, crowded Lea Symbols® VA screening test system at 5 feet may be due to greater ease in engaging the child at the closer test distance, the newness of symbols presented in the test wheel's window, the lower complexity of single versus linear presentation of optotypes, and the use of an improved scoring template.[6] Associated referral criteria for Retinomax, SureSight, and Lea Symbols® VA test performed by trained nurse and lay screeners are shown in Tables 2 and 3.[6] Similar sensitivities were achieved with the Retinomax, SureSight, and VIP single, crowded Lea Symbols® VA screening test system at 5 feet for detection of ≥1 targeted conditions. Advantages of autorefraction include shorter testing time while advantages of VA testing include lower equipment costs.

Test Combinations

Phase II showed that combining the Stereo Smile II Stereoacuity test with one of the tests of autorefraction or VA did not result in improved sensitivities for detecting ≥1 targeted conditions.6 However, a test of alignment is often included in preschool vision screenings to detect strabismus because of its potential visual, psychosocial, developmental, and psychological effects.10¯13 Therefore, analysis was performed to determine whether detection of strabismus would be significantly improved by pairing one of the best screening tests for eye alignment (unilateral cover test, Random Dot “E”, Stereo Smile Test II, and MTI PhotoScreener) with one of the best tests for identifying children with ≥1 targeted conditions (non-cycloplegic retinoscopy, Retinomax, SureSight, and Lea Symbols® and HOTV VA tests).14 Strabismus was found in 157 of the 4,040 children tested. Detection of strabismus by licensed eye care professionals was significantly improved (by 15%-25%) by pairing a test of refraction with unilateral cover test (with a referral criterion of any movement on the cover/uncover test at distance or near5). Trained lay screeners' sensitivity for detection of strabismus was significantly increased (by 21%) by combining SureSight with Stereo Smile II (using a referral criterion of 480 arc sec for three-year-olds and 240 arc sec for four- or five-year-olds). Testing of eye alignment can be included in a screening program to increase detection of strabismus if this meets the screening program's goals (e.g., targeted visual conditions) and resources.14

Children Unable to Perform Preschool Vision Screening Tests

Because there is often uncertainty regarding whether to retest (pass) or refer children who are unable to perform a preschool vision screening test, the VIP Study Group investigated the relative prevalence of targeted conditions among children who were unable to perform preschool vision screening tests when administered by trained nurse or lay screeners. The impact of classifying these ‘unables’ as either screening failures or passers on measures of screening test performance (sensitivity, specificity, and positive and negative predictive values) was also examined.[15] The analyses showed that preschool children who were unable to perform Retinomax, SureSight, or Lea Symbols® VA test (linear, crowded at 10 feet for nurse screeners; single, crowded system at 5 feet for lay screeners), were more than two times more likely to have vision disorders than were children who passed the tests. Because ≤2% of children were unable to do each test, referring these children for an eye examination had little impact on measures of screening test performance.15 Therefore, children who are unable to complete these preschool vision tests should be referred for further evaluation.

Effect of Retinomax Autorefractor Confidence Number on Screening Accuracy

Because Retinomax was one of the best preschool vision screening tests in the hands of trained licensed eye care professionals, nurse or lay screeners, it is important to determine whether

repeated testing to achieve a higher confidence number improves screening accuracy in preschool children. Sensitivity and specificity for detecting VIP-targeted conditions for trained nurse and lay screeners using Retinomax (N=1452 children) was compared among groups of children who had confidence numbers below, at, or above the manufacturer's suggested minimum confidence number of 8.[16] Screeners were instructed to test up to three times (as needed) to meet the manufacturer's recommended guidelines for confidence number; results were compared between initial reading and repeated test reading with the highest confidence number in the same child for 771 (53.1%) children who had repeated testing either by lay or nurse screeners because of a low confidence number (<8) for one or both eyes on the initial test. Repeated testing resulted in a confidence number of 8 or above in 87% of cases, and the increased confidence number that resulted from repeated testing was associated with significantly higher specificity (0.81 vs. 0.86, p=0.002) and a nonsignificant change in sensitivities.16 Therefore, the higher confidence number is associated with better screening accuracy and repeated testing to reach the manufacturer's recommended minimum value is valuable in preschool vision screening using Retinomax. Further, children with a targeted vision condition were more likely to have a low confidence number. This suggests that an inability to attain the manufacturer's recommended minimum confidence number through repeated testing may be an indication for referral for a comprehensive eye examination.16

Future Research

Federal initiatives are in progress to increase the number of preschool children receiving vision screening or examination.[17, 18] Results from the VIP study provide important information to guide the development and implementation of more effective screening protocols. There is consensus that amblyopia is valuable to detect early, because it can lead to loss of vision unless detected and treated during childhood.[1] Because the best tests for detection of amblyopia or ≥ 1 targeted condition are also the best tests for detection of significant refractive error, increased vision screening will result in an increased number of preschool children identified as having significant refractive error. Although significant refractive error is often associated with amblyopia and strabismus[5, 8 and is the most prevalent and easily corrected vision disorder, 1, 19 consensus has not been reached on the value of detecting refractive errors in preschool children.[20] The decision of whether to prescribe refractive correction for preschool children who do not have amblyopia and/or strabismus (particularly for those with hyperopia) can be challenging because evidence-based guidelines are not available and most young children have some degree of hyperopia. In addition, children with vision problems generally do not complain because they do not understand their symptoms are abnormal and/or cannot communicate their symptoms. Studies have shown that hyperopia may interfere with learning and development, [21-27] which may indicate that correction may be of value. Because of the high prevalence of significant refractive errors in preschool children, future research is needed to determine whether correction of refractive errors is beneficial in preschoolers who do not have amblyopia and/or strabismus.

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Table 1

Definition of VIP Targeted Disorders by Hierarchy.

Group 1: Very important to detect and treat early
Amblyopia
Presumed Unilateral: ≥ 3 line interocular difference, a unilateral amblyogenic factor, and worse eye VA ≤ 20/64
Suspected Bilateral: a bilateral amblyogenic factor, worse eye VA < 20/50 for 3-year-olds or < 20/40 for 4-year-olds, contralateral eye VA worse than 20/40 for 3-year-olds or 20/30 for 4-year-olds
Strabismus: Constant in primary gaze
Refractive Error
Hyperopia ≥ 5.0 D
Astigmatism ≥ 2.5 D
Myopia ≥ 6.0 D
Group 2: Important to detect early
Amblyopia
Suspected Unilateral: 2-line interocular difference and a unilateral amblyogenic factor
Presumed Unilateral: ≥ 3 line interocular difference, a unilateral amblyogenic factor, and worse eye VA > 20/64
Strabismus: Intermittent in primary gaze
Refractive Error
Anisometropia, (Interocular difference > 1D hyperopia, > 1.5D astigmatism, or > 3D myopia)
Hyperopia > 3.25 D and < 5.0 D AND interocular difference in SE ≥ 0.5 D
Astigmatism > 1.5 D and < 2.5 D
Myopia ≥ 4.0 D and < 6.0 D
Group 3: Detection clinically useful
Unexplained Reduced VA
Bilateral: no bilateral amblyogenic factor, worse eye VA < 20/50 for 3-year-olds or < 20/40 for 4-year-olds, contralateral eye VA worse than 20/40 for 3-year-olds or 20/30 for 4-year-olds
Unilateral: no unilateral amblyogenic factor, worse eye VA < 20/50 for 3-year-olds or < 20/40 for 4-year-olds or ≥ 2 line difference between eyes (except 20/16 and 20/25)
Refractive Error
Hyperopia > 3.25 D and < 5.0 D AND interocular difference in SE < 0.5 D
Myopia > 2.0 D and < 4.0 D

* Modified from Table 1 of VIP Study Group. Does Assessing Eye Alignment along with Refractive Error or Visual Acuity Increase Sensitivity for Detection of Strabismus in Preschool Vision Screening?, Invest Ophthalmol Vis Sci. 2007;48:3115–3125.

Table 2

Failure Criteria (Inability to Pass) for Lea Symbols® Visual Acuity to Maximize Sensitivity for Detecting ≥ 1 Targeted Conditions.

Screener		Sensitivity for ≥ 1 Targeted Conditions (%)	Sensitivity for Most Severe Conditions (%)	3-year-olds	4-year-olds	5-year-olds
Licensed Eye Care Professionals*[5, 8]	at 90% specificity	61	77	10/32 line	10/20 line	10/20 line
	at 94% specificity	49	65	10/32 line	10/25 line	10/20 line
Nurse Screeners*[6]	at 90% specificity	49	60	10/32 line	10/25 line	10/20 line
Lay Screeners**[6]	at 90% specificity	61	78	5/12.5 line	5/10 line	5/10 line

* Linear, crowded Lea Symbols® VA test at 10 feet

** VIP single, crowded Lea Symbols® VA screening test system at 5 feet

Table 3

Failure Criteria for Retinoscopy and Autorefractor Screening Tests to Maximize Sensitivity when Specificity was Set at 90% and/or 94%.

Instrument	Specificity	Screener	Sensitivity for ≥ 1 Targeted Condition (%)	Sensitivity for Most Severe Conditions (%)	Hyperopia	Myopia	Astigmatism	Anisometropia*
Non-Cycloplegic Retinoscopy	at 90%	LEP[5]	64	90	≥2.75 D	≥2.75 D	≥1.25 D	≥1.50 D
	at 94%	LEP[5, 8]	57	87	≥2.50 D	≥2.75 D	≥2.00 D	≥1.50 D
Retinomax Autorefractor	at 90%	LEP[5]						
	Year 1		63	87	≥1.50 D	≥2.75 D	≥1.50 D	≥2.00 D
	Year 2		64	88	≥1.50 D	≥2.75 D	≥1.50 D	≥1.75 D
	at 94%	LEP[5, 8]						
	Year 1		52	81	≥1.75 D	≥2.75 D	≥2.00 D	≥2.75 D
	Year 2		52	81	≥2.50 D	≥2.75 D	≥1.75 D	≥2.50 D
	at 90%	Nurse[6]	68	88	≥1.75 D	≥3.25 D	≥1.50 D	≥2.75 D
	at 90%	Lay[6]	62	85	≥1.50 D	≥3.00 D	≥1.75 D	≥2.00 D
SureSight Vision Screener**	at 90%	LEP[5]	63	81	≥4.00 D	≥1.00 D	≥1.50 D	≥3.00 D
	at 94%	LEP[5, 8]	51	75	≥4.25 D	≥1.00 D	≥1.75 D	≥3.50 D
	at 90%	Nurse[6]	64	83	≥4.00 D	≥1.00 D	≥1.75 D	≥2.75 D
	at 90%	Lay[6]	61	82	≥4.50 D	≥1.00 D	≥1.75 D	≥2.25 D

Abbreviations: LEP, Licensed eye care professional; D, diopter

*The maximum of inter-eye differences in the power of the most positive meridian, the most negative meridian, and the magnitude of cylinder was used to determine presence of anisometropia for all tests.

**Used in child mode, which adds a correction for accommodation. The VIP criteria may be programmed into the SureSight by School Health, Corp (Hanover Park, IL) such that an asterisk appears when one of the VIP criteria have been met.