Preschool Vision Screening Tests Administered by Nurse Screeners Compared with Lay Screeners in the Vision in Preschoolers Study

The Vision in Preschoolers Study Group

Purpose. To compare the performance of nurse screeners with that of lay screeners in administering preschool vision screening tests.

Methods. Trained nurse and lay screeners administered the Retinomax Autorefractor (Right Manufacturing, Virginia Beach, VA), SureSight Vision Screener (Welch Allyn, Inc., Skaneateles Falls, NY), crowded Linear Lea Symbols visual acuity (VA) test at 10 ft (Precision Vision, Inc., La Salle, IL), and Stereo Smile II test (Stereo Optical, Inc., Chicago, IL) to 3- to 5-year-old Head Start participants. Lay screeners also administered a crowded Single Lea Symbols VA test at 5 ft (Good-Lite, Inc.). Screening results were compared with the classification of the children according to the presence of one or more of four conditions (amblyopia, strabismus, significant refractive error, and unexplained reduced VA) based on the results of a gold standard eye examination by study-certified optometrists and ophthalmologists. The primary outcome measure was sensitivity for detecting children with one or more targeted conditions at 0.90 specificity.

Results. Nurse screeners achieved slightly higher sensitivities with the Retinomax, SureSight, and Stereo Smile II tests than did lay screeners; however, most differences were small and not statistically significant. Nurse screeners achieved significantly higher sensitivity with the Linear Lea Symbols VA test than did lay screeners. Lay screeners achieved strikingly higher sensitivity with the Single Lea Symbols VA test than did nurse or lay screeners using the Linear Lea Symbols VA test. Combining the Stereo Smile II test with each of the other tests did not result in improved sensitivities for detecting one or more targeted conditions.

Conclusions. Nurse and lay screeners can achieve similar sensitivity, when specificity is set at 0.90, for detecting preschool children in need of a comprehensive eye examination. (*Invest Ophthalmol Vis Sci.* 2005;46:2639–2648) DOI:10.1167/iovs.05-0141

The Vision in Preschoolers (VIP) Study is a multicenter, multidisciplinary, phased study to evaluate vision screening tests for identifying preschool children who would benefit from a comprehensive eye examination. Conditions targeted for identification are amblyopia, strabismus, significant refractive error, and reduced visual acuity (VA) in the absence of amblyogenic conditions.

Phase I of the VIP Study provided a comparison of 11 screening tests administered by optometrists and ophthalmologists experienced in assessment of preschool-aged children.[1] The 11 screening tests included VA tests (crowded Linear Lea Symbols VA test [Precision Vision, Inc., La Salle, IL, or Good-Lite, Inc., Steamwood, IL], crowded Linear HOTV VA test [Precision Vision, Inc.]), stereoacuity tests (Random Dot E and Stereo Smile II [Stereo Optical, Inc., Chicago, IL]), autorefractors (Retinomax Autorefractor [Right Manufacturing, Virginia Beach, VA], SureSight Vision Screener [Welch Allyn, Inc., Skaneateles Falls, NY]), instruments based on photorefractive technology (iScreen Photoscreener, MTI Photoscreener, Power Refractor II), and two procedures frequently used by eye care professionals (noncycloplegic retinoscopy [NCR] and the cover–uncover test). Tests were conducted in specially equipped VIP vans that provided a standard environment with minimal distractions.

The performance of the screening tests varied widely in phase I. At high levels of specificity (0.90 and 0.94; i.e., over-referral rates for normal children of 10% and 6%, respectively), the sensitivity of the best four tests (NCR, Retinomax Autorefractor, SureSight Vision Screener, and crowded Linear Lea Symbols VA) for detecting children with one or more targeted conditions was similar. For example, for specificity of 0.90, sensitivities were 0.64 for NCR, 0.63 for Retinomax Autorefractor, 0.63 for SureSight Vision Screener, and 0.61 for Lea Symbols VA. Sensitivities for the Power Refractor II and the HOTV VA test were somewhat lower (0.54), and the remaining tests (Random Dot E, Stereo Smile II, MTI Photoscreener, iScreen Photoscreener, and cover–uncover) showed even lower sensitivities. When sensitivity was examined for conditions judged to be most important to detect and treat (group-1 conditions[1]), the same four tests (NCR, Retinomax Autorefractor, SureSight Vision Screener, and crowded Linear Lea Symbols VA) showed the highest sensitivity, ranging from 0.90 for NCR to 0.77 for the Lea Symbols VA test, at 0.90 specificity.

In the United States, pediatric vision screening is usually conducted by nurses and lay people, rather than by the li-

From The Vision in Preschoolers Study Group.

The members of the Vision in Preschoolers Study Group are listed in the Appendix.

Supported by National Eye Institute Grants U10EY12534, U10EY12545, U10EY12547, U10EY12550, U10EY12644, U10EY12647, and U10EY12648. PS was principal investigator for a grant (<$20,000) issued to The Ohio State University Research Foundation from Welch Allyn, Inc. for testing a prototype of the SureSight Autorefractor. The Pennsylvania College of Optometry receives royalties of <$10,000 annually on sales of the Stereo Smile test.

Submitted for publication February 2, 2005; revised March 30, 2005; accepted March 31, 2005.

Disclosure: **P. Schmidt**, Welch Allyn, Inc. (F); **E. Ciner**, Stereo Optical, Inc. (F); all others in **The Vision in Preschoolers Study Group**, None

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censed eye care professionals (LEPs) who served as screeners for phase I.[2,3] Phase II of the VIP Study was designed to compare nurse and lay screeners' performances in administering selected 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 selected for phase II. The fourth test, NCR, was not selected because its use necessitates a high degree of training, skill, and clinical knowledge. A test of stereoacuity, the Stereo Smile II test, was selected because it was one of the most effective tests for detection of strabismus in phase I and may, when used in combination with another screening test, provide better screening results than a single test.

Screening programs are usually conducted in environments with more distractions and less optimal physical conditions than the controlled environment of the VIP van used in phase I. Therefore, most of the phase II screenings were conducted in more typical screening environments within Head Start centers.

Materials and Methods

As shown in Table 1, data for phase II were collected during two academic years: 2002 (2002–03) and 2003 (2003–04). Although nearly all of the phase II data were collected during the 2003 academic year at Head Start centers by nurse and lay screeners, initial data were collected in the VIP vans by lay screeners during the 2002 academic year.[1] The method for recruiting children for participation in VIP was the same in both academic years.

Participants

Participating children were ≥3 and <5 years of age at the beginning of the academic year (September 1) and were enrolled in Head Start programs[4] near a VIP clinical center (Berkeley, CA; Boston, MA; Columbus, OH; Philadelphia, PA; and Tahlequah, OK). To obtain a sample that was overweighted with children who had vision problems, recruitment of children was based on the results of the local Head Start vision screening. All eligible children who had failed the local Head Start vision screening and a randomly selected subset of children who had passed the screening were asked to participate. As in phase I, children with special needs were excluded. Children were eligible to participate in only 1 year of the study. The research adhered to the tenets of the Declaration of Helsinki and was approved by the appropriate local institutional review board(s). Parents or legal guardians of children provided written informed consent.

Screeners

All screeners completed VIP Study-specific training and certification. Nurse screeners either were pediatric nurses or had ≥3 years of experience in a pediatric setting. Lay screeners were individuals with at least a high school degree; four had a bachelor's degree (not in a medical field). All had ≥2 years of experience working with young children. Fifteen nurse screeners conducted testing in the 2003 academic year only. Fifteen lay screeners conducted the initial testing in the 2002 academic year, and 16 conducted testing in the 2003 academic year.

Training of Screeners

At the beginning of each academic year, a team of VIP Study personnel conducted a day-long, local training program for screeners. The program included instruction and practice with each screening test, an overview of the VIP Study, and instruction in matters of confidentiality, cultural sensitivity, health and safety, data collection procedures, and research ethics. After several practice screening sessions, nurse and lay screeners were observed by the local principal investigator or coinvestigator while testing at least two children 3 to 5 years of age. Screeners completed human subjects training and certification and written knowledge assessments.

Screening Procedures

Detailed descriptions of the standard procedure for administration of several of the screening tests have been published previously.[1] These procedures will be described briefly.

Retinomax Autorefractor and SureSight Vision Screener. Two hand-held autorefractors, the Retinomax Autorefractor (Right Manufacturing) and the SureSight Vision Screener (software version 2.12; Welch Allyn, Inc.), were used to measure refractive error monocularly. If the reliability rating for the summary reading of an eye was less than the manufacturer's recommended minimum value,[1] the process was repeated. A maximum of three readings per eye were taken. Results for both eyes were transmitted to a printer by an infrared signal.

Linear Lea Symbols VA Test at 10 ft. A modification of the MassVAT[5] form of the Lea Symbols test[6] was used to screen monocular VA (Precision Vision, Inc., and Good-Lite, Inc.).[7] The test consisted of cards with linear arrays of either four (10/100 size) or five (age-specific acuity levels) picture optotypes (heart, house, circle, and square), with the array surrounded by a crowding bar (rectangular box). Screening began with a binocular pretest, in which the child identified verbally or by matching, each optotype presented singly at 3 ft. If the child

Table 1. Summary of Screening Tests by Year and Type of Screener

Academic Year and Setting	VIP Phase	Screener		
		LEP	Nurse	Lay Screener
2001–02 van	I	Retinomax Autorefractor Linear Lea Symbols VA (10 ft) HOTV VA Random Dot E Cover–uncover Noncycloplegic retinoscopy	None	None
2002–03 van	I, II	Retinomax Autorefractor SureSight Vision Screener Stereo Smile II Power Refractor II iScreen Photoscreener MTI Photoscreener	None	Linear Lea Symbols VA (10 ft) Stereo Smile II
2003–04 Head Start Center	II	None	Retinomax Autorefractor SureSight Vision Screener Linear Lea Symbols VA (10 ft) Stereo Smile II	Retinomax Autorefractor SureSight Vision Screener Single Lea Symbols VA (5 ft) Stereo Smile II

successfully completed the pretest, screening of the right eye began. The tester first presented the 10/100 card at 10 ft, followed by age-specific cards (10/32 and 10/25 for 3-year-olds; 10/25 and 10/20 for 4-year-olds). The screener recorded the size of the smallest optotype for which the child correctly identified three of three or three of four optotypes. The same procedure was repeated for the left eye.

Single Lea Symbols VA Test at 5 ft. This test was developed by the VIP Study group in response to the poor performance of lay screener–administered Linear Lea Symbols VA testing during the initial (2002) data-collection period. To increase the ability of the screener to engage the child in the task, the test was designed to use presentation of single, crowded Lea symbols[6] at a distance of 5 ft (Good-Lite, Inc.). Symbols were surrounded on all four sides by a crowding bar at 0.5-optotype width and printed on a disk that had an overlay mask with a window, allowing presentation of single crowded symbols (Fig. 1). Two disks were used for each age: one disk for the right eye and one for the left eye. Disks for 3-year-olds contained four 5/16 and four 5/12.5 optotypes. Disks for 4-year-olds contained four 5/12.5 and four 5/10 optotypes.

Screening began with a binocular pretest at 3 ft, identical with that used with the Linear Lea Symbols VA test at 10 ft. If the child successfully completed the pretest, the tester conducted screening of the right eye. The tester first presented the 5/50 card at 5 ft, followed by testing with the appropriate age-specific disk for the right eye. The 5/50 card and the age-specific disks were presented on a lighted stand (True Daylight Illuminator with Easel; Richmond Products, Inc, Boca Raton, FL) that provided standardized illumination and positioning. Luminance was measured at each test session by using a light meter (cal-LIGHT, model 400F; The Cooke Corp., Auburn Hills, MI) and was at least 85 cd/m^2. The screener recorded the child's responses on a disk-specific score sheet that listed all the symbols in the order presented to the child. When the child incorrectly identified two symbols on a line (or optotype size on the disk) or provided responses for all symbols at the smallest optotype level, screening was complete for that eye. The same procedure was repeated for the left eye.

FIGURE 1. Crowded Single Symbols Visual Acuity Test. A single symbol surrounded by four crowding bars at 0.5 optotype width is presented in a window in the mask covering the disk. A second, small window indicates the specific test age (4 years) and eye (left) being tested, and the place in the sequence of four optotypes (no. 1) of the symbol that is shown in the window. Four disks were used: one for each eye in 3-year-old children, each containing four 5/16 and four 5/12.5 optotypes, and one for each eye in 4- and 5-year-old children, each containing four 5/12.5 and four 5/10 optotypes. Test distance was 5 ft.

Stereo Smile II Stereoacuity Test. The Stereo Smile II test (Stereo Optical, Inc.) consisted of a "blank" plate (a random dot pattern), a demonstration plate (a nonstereo "smile face" on a background of random dots), and three plates each displaying a random-dot stereo smile face of successively finer levels of stereopsis (480, 240, and 120 arc sec disparity). Testing was conducted at 40 cm, with the child wearing Polaroid glasses (Polaroid Corp., Cambridge, MA). If, during the pretest, the child correctly identified the demonstration plate on four of four or four of five presentations of the demonstration plate paired with the "blank" plate, testing of stereoacuity began. The screener presented the blank plate paired with each stereo plate for up to five presentations, proceeding to finer disparities as long as the child correctly identified the stereo plate on four of four or four of five presentations. The screener varied the left–right position of the plate in a nonsystematic manner. In the 2003 academic year, the testing plates were presented on the same lighted stand as described for the Single Lea Symbols VA test.

Screening Environment and Procedures

In the 2002 academic year (initial testing period), lay screeners administered the Linear Lea Symbols VA test at 10 ft and the Stereo Smile II stereoacuity test in one of the rooms of the VIP van.[1,8] In the 2003 academic year, all screenings were performed in local Head Start centers, in locations such as hallways, cafeterias, and classrooms. VA test luminance was measured in each setting and was ≥85 cd/m^2. Each child was tested by a nurse screener and a lay screener, each of whom conducted four screening tests: Retinomax Autorefractor, SureSight Vision Screener, Lea Symbols VA test (with the nurse screener using the linear array test at 10 ft and the lay screener using the single symbol test at 5 ft), and the Stereo Smile II stereoacuity test. Children were assigned randomly to either the nurse or lay screener first. Each screener conducted the subjective tests (VA and stereoacuity) first, with test order assigned randomly. The Retinomax Autorefractor and SureSight Vision Screener were administered after the subjective tests, with test order assigned randomly. Time stamps were used to indicate the beginning of each screening test and the completion of the final screening test.

During both years of phase II testing, children wearing spectacles removed them before screening. VIP screeners were masked to the Head Start screening results.

Gold Standard Examiners

As in phase I, comprehensive (gold standard [GS]) eye examinations were conducted in the VIP van by optometrists and ophthalmologists who were experienced in providing care to children. All 46 examiners in the 2002 academic year and all 47 examiners in the 2003 academic year had undergone VIP Study–specific training and certification.

Training of GS Examiners

As in phase I, all GS examiners were trained by the VIP training team during a day-long program at the local clinical center. Of the 47 examiners in phase II, 43 had participated in phase I. All examiners completed human subjects certification and written knowledge assessments. New examiners were observed performing GS examination (GSE) procedures on two or more preschool children.

GSE Procedures

As described previously,[1] monocular distance VA assessment, cover testing at distance and near, and cycloplegic retinoscopy, conducted as part of a comprehensive eye examination, were used to determine the presence of amblyopia, strabismus, significant refractive error, and/or unexplained reduced VA. Anterior segment evaluation and dilated fundus examination were also performed to detect other possible causes of reduced VA. The GSEs were conducted in the VIP van.[1,8]

Examiners were masked to the Head Start and VIP screening results, but did know whether a child wore spectacles.

Monocular Distance VA Testing. Monocular, distance threshold VA testing was conducted with crowded, single H, O, T, and V optotypes using the Electronic Vision Assessment (EVA) system at 10 ft,[9] according to the protocol used in the Amblyopia Treatment Study.[1,10,11] Children who wore spectacles were tested while wearing their spectacles. Children were retested with their full cycloplegic refractive correction if their initial VA score for either eye was worse than 10/25 (for 3-year-olds) or 10/20 (4- and 5-year-olds) or if they had an interocular difference of ≥2 lines with VA in the worse eye 10/16 or worse.

Cover Testing. Ocular alignment was evaluated using a cover–uncover test and an alternating cover test performed at distance (10 ft) and near (16 in.).[1]

Cycloplegic Retinoscopy. Retinoscopy was performed 30 to 40 minutes after instillation of cycloplegic drops. In the 2002 academic year, the first instillation consisted of 1 drop of 0.5% proparacaine, followed by 1 drop each of 1% cyclopentolate and 0.5% tropicamide. A second instillation of the cycloplegic agents was performed approximately 1 minute later at the discretion of the examiner. In the 2003 academic year, the first instillation consisted of 1 drop of a combination of 0.5% proparacaine, 1% cyclopentolate, and 1% tropicamide. A second instillation of the combination agents was performed approximately 1 minute later. At the discretion of the examiner, combination drops were preceded by an anesthetic drop. Retinoscopy was performed with the child wearing spectacles corresponding to the examiner's working distance, while the child watched a children's video presented at 10 ft.[1]

Classification of Children

Detailed definitions of targeted conditions have been published previously.[1] In brief, children were classified as having unilateral amblyopia if they had a 3-line (presumed amblyopia) or 2-line (suspected amblyopia) interocular acuity difference accompanied by strabismus and/or anisometropia. VA was considered reduced if it was worse than 20/50 in 3-year-olds and worse than 20/40 in 4-year-olds. Children classified as having bilateral amblyopia had reduced VA and an amblyogenic factor in each eye (i.e., astigmatism >2.5 D, hyperopia >5.0 D, or myopia >8.0 D). Targeted disorders were also categorized into three groups, based on severity of the ocular condition (Table 2).

TABLE 2. Frequency of the Hierarchy of VIP Targeted Disorders in Academic Year 2003–04

Group: Condition	*n**	Percent
1: Very important to detect and treat early	**210**	**14.5**
Amblyopia	63	4.3
Presumed unilateral and worse eye VA ≤20/64	26	1.8
Bilateral	37	2.5
Strabismus, constant	31	2.1
Refractive error	198	13.6
Severe anisometropia (Interocular difference >2D hyperopia, >3D astigmatism, or >6D myopia)	27	1.9
Hyperopia ≥5.0 D	80	5.5
Astigmatism ≥2.5 D	114	7.9
Myopia ≥6.0 D	9	0.6
2: Important to detect early	**144**	**9.9**
Amblyopia	14	1.0
Suspected unilateral	11	0.8
Presumed unilateral and worse eye VA >20/64	3	0.2
Strabismus, intermittent	9	0.6
Refractive error	136	9.4
Anisometropia, but not severe	47	3.2
Hyperopia >3.25 D and <5.0 D and interocular difference in SE ≥0.5 D	29	2.0
Astigmatism >1.5 D and <2.5 D	84	5.8
Myopia ≥4.0 D and <6.0 D	1	0.1
3: Detection clinically useful	**108**	**7.4**
Reduced VA	74	5.1
Bilateral	22	1.5
Unilateral	52	3.6
Refractive Error	41	2.8
Hyperopia >3.25 D and <5.0 D and interocular difference in SE <0.5 D	32	2.2
Myopia >2.0 D and <4.0 D	9	0.6
Normal	**990**	**68.2**
Total number of children	**1452**	**100.0**

Details of classification of targeted disorders have been published.[1]

* Each child is represented in *only one* of the four groups, corresponding to the child's most severe condition. Within each group, a child may be represented *more than once* if the child had more than one condition within the group.

Data Analysis

Only data from children who were both screened and examined are included in this report. Children who did not have a complete VA test, cover test, or cycloplegic refraction on the GSE are excluded from the analysis of sensitivity and specificity. When multiple readings were obtained with the Retinomax Autorefractor or the SureSight Vision Screener, the first reading with a reliability score considered acceptable by the manufacturer was used in the analysis. If no acceptable readings were obtained, the reading with the highest reliability score was used.

For tests of VA or stereoacuity, children were considered testable if they were able to complete the pretest successfully. For the Retinomax Autorefractor and SureSight Vision Screener, children were considered testable if they provided a measurement for each eye. Data from children who had no targeted conditions were used to estimate specificity (defined as the proportion of children who passed a screening test among those children who did *not* have one or more targeted conditions). Because children who failed the Head Start screening were overrepresented, the estimate of specificity was weighted based on the proportion of children who failed (1/6) or passed (5/6) the Head Start screening. Sensitivity was defined as the proportion of children who failed a screening test among those children who had one or more targeted conditions. Additional estimates of sensitivity were calculated for groups 1, 2, and 3, as defined in Table 2 and for each of the four targeted conditions.

Children failed a screening test if they met the failure criteria in one or both eyes. For each screening test, failure criteria were chosen to maximize the overall sensitivity for detecting one or more targeted conditions with specificity set to 0.90. When more than one set of failure criteria for the autorefractors provided the same level of overall sensitivity, the set with the highest sensitivity for detecting group-1 conditions was chosen. Failure criteria for the VA and stereoacuity tests were age specific.

Comparisons of sensitivity between nurse and lay screeners for the same screening test performed in the same year were made using the McNemar χ^2 test for correlated data. When screening for a child was completed by only one of the screeners in the 2003 academic year, a modification of the Mantel-Haenszel procedure was used to compare the sensitivities.[12] Comparisons between nurse and lay screeners of sensitivity of tests performed in different years were made with the χ^2 test for independent data. Confidence intervals (CIs) for differences in independent and correlated proportions were calculated (Confidence Interval Analysis [CIA] 2.1.1 software; Trevor Bryant, University of Southampton, UK); all other calculations were performed with commercial software (SAS/STAT ver. 8.0 software; SAS Institute, Inc., Cary, NC).

RESULTS

Study Population

In the 2003 academic year, 1987 potential subjects, comprising 1004 children who had failed the Head Start vision screening and 983 children who had not failed the screening, were selected for enrollment. Eligibility criteria were fulfilled, and consent was obtained for 1629 (82.0%) of the 1987 children, of whom 844 had failed the Head Start vision screening. VIP screening was conducted in 1541 (94.6%) of the enrollees, and GSEs were performed on 1475 (95.7%) of children who were screened. Subjects in the present report are the 1452 (98.4%) of these 1475 children who had complete information for classification. Demographic characteristics for the 1452 children from the 2003 academic year were very similar to those of the children reported for phase I.[1] The children were racially diverse, and approximately 95% were between 42 and 65 months of age.

Table 2 provides the classification of children participating in the 2003 academic year according to the hierarchy of ocular disorders used in the VIP Study. Overall, 462 (31.8%) of the 1452 children who were screened and examined had one or more of the targeted disorders; the 990 (68.2%) who did not have one of the targeted disorders were classified as normal. Children with multiple conditions are included in the group corresponding to their most severe disorder(s). For example, a child with constant strabismus (a group 1 disorder), hyperopia ≥5.00 D (a group 1 disorder), and suspected unilateral amblyopia (a group 2 disorder) would appear in Table 2 in group 1 only. However, the child would be listed twice in group 1, once for constant strabismus and once for high hyperopia. The child's group-2 disorder would not be listed in Table 2.

Testability, Number of Repeated Procedures, and Test Times

Nearly all children (≥98%) were testable on each screening test, regardless of type of screener. Testability was nearly identical (99.4%) for the Linear and Single Lea Symbols VA tests. Testability differed between nurse and lay screeners for only the SureSight Vision Screener: 1419 (97.9%) of 1449 children were testable by nurse screeners versus 1436 (99.0%) of 1450 by lay screeners ($P = 0.005$).

The mean number of attempts to achieve a satisfactory reading with the Retinomax Autorefractor was 1.28 for nurse screeners and 1.25 for lay screeners ($P = 0.09$). A satisfactory reading was obtained on the first attempt using the Retinomax Autorefractor on 2253 (77.7%) of 2898 eyes (1449 children) by nurse screeners and on 2317 (79.9%) of 2900 eyes (1450 children) by lay screeners. The mean number of attempts to achieve a satisfactory reading with the SureSight Vision Screener was 1.20 for nurse screeners and 1.23 for lay screeners ($P = 0.02$). Nurse screeners obtained a satisfactory reading on the first attempt on 2359 (81.4%) of 2898 eyes versus 2234 (77.0%) of 2900 eyes tested by lay screeners.

Comparison of the distributions of testing times showed that there were only very small differences in the time necessary for nurse and lay screeners to administer each test. For both types of screeners, the median was 2 minutes for readings of two eyes with the autorefractors, 4 minutes for monocular VA testing of two eyes, and 3 minutes for binocular stereo acuity testing.

Sensitivity of Screening Tests

The failure criteria that maximize sensitivity when specificity is set to 0.90 for the autorefractors are listed in Table 3. For both autorefractors, the criteria for nurse and lay screeners were within 0.5 D for the spherical and cylindrical components of refractive error. For anisometropia, the failure criteria differed by 0.75 D in spherical equivalent for the Retinomax Autorefractor. Failure criteria for the tests of VA and stereoacuity are provided in Table 4. In general, criteria depended on the age of the child.

Table 5 displays the sensitivity of the tests for detection of children who have any targeted condition and for detection of children with group 1, 2, or 3 conditions when specificity is set at 0.90. The overall sensitivity for detecting children with one or more conditions with the Retinomax Autorefractor was 0.06 higher for nurse screeners than for lay screeners (0.68 vs. 0.62; $P = 0.004$). For the SureSight Vision Screener, the overall sensitivity for nurse and lay screeners did not differ significantly (0.64 vs. 0.61; $P = 0.16$). The overall sensitivity with the Linear Lea Symbols VA test was higher for nurse screeners than for lay screeners (0.49 vs. 0.37; $P = 0.0004$) even though lay screeners administered the test in the relatively distraction-free VIP van during the 2002 academic year. In the 2003 academic year, when lay screeners in Head Start centers used the Single Lea Symbols VA test, overall sensitivity was substantially higher than for lay screeners in the VIP van using the Linear Lea Symbols VA test (0.61 vs. 0.37; $P < 0.001$) and for nurse screeners in the Head Start centers using the Linear Lea Symbols VA test (0.61 vs. 0.49, $P < 0.0001$). Overall sensitivity of the Stereo Smile II test was higher with nurse screeners than with lay screeners, but the difference was not statistically significant (0.45 vs. 0.40; $P = 0.06$). When lay screeners administered the Stereo Smile II in the VIP van, overall sensitivity (0.47) was not significantly different from the results obtained in Head Start centers.

Sensitivity for detecting children with group-1 conditions (very important to detect and treat early) did not differ significantly between nurse and lay screeners for assessments conducted using the Retinomax Autorefractor, SureSight Vision Screener, Linear Lea Symbols VA test, or Stereo Smile II (Table 5). In the 2003 academic year, sensitivity for group-1 conditions was significantly higher (0.78) when lay screeners administered the *Single* Lea Symbols VA test in Head

TABLE 3. Failure Criteria for Autorefractor Screening Tests to Maximize Sensitivity

Instrument	Hyperopia	Myopia	Astigmatism	Anisometropia
Retinomax Autorefractor				
Nurse screener	≥1.75	≥3.25	≥1.50	≥2.75
Lay screener	≥1.50	≥3.00	≥1.75	≥2.00
SureSight Vision Screener*				
Nurse screener	≥4.00	≥1.00	≥1.75	≥2.75
Lay screener	≥4.50	≥1.00	≥1.75	≥2.25

Failure criteria were chosen to maximize overall sensitivity for detecting any targeted condition when specificity was set to 0.90. Data are expressed in diopters.

* Used in child mode, which adds a correction for accommodation.

TABLE 4. Failure Criteria for Visual Acuity and Stereoacuity Tests to Maximize Sensitivity when Specificity Was Set at 0.90

		Failure Criterion* (Inability to pass)	
	Age (y)	Nurse screeners	Lay screeners
Linear Lea Symbols VA†	3	10/32	10/25
	4	10/25	10/25
	5	10/20	10/25
Single Lea Symbols VA	3	—	5/12.5
	4	—	5/10
	5	—	5/10
Stereo Smile II (2003 academic year)	3	480 arc sec card	240 arc sec card
	4	120 arc sec card	120 arc sec card
	5	120 arc sec card	120 arc sec card
Stereo Smile II (2002 academic year)†	3	—	240 arc sec card
	4	—	120 arc sec card
	5	—	120 arc sec card

* Failure criteria for each year of testing were chosen to maximize overall sensitivity for detecting any targeted condition when specificity was set to 0.90.

† Lay screeners conducted testing in a VIP van in the 2002 academic year.

Start centers than when lay screeners used the *Linear* Lea Symbols VA test in the VIP van (0.50; $P < 0.0001$) or when nurse screeners used the *Linear* Lea Symbols VA test in Head Start centers (0.60; $P < 0.001$). Lay screeners administering the Stereo Smile II test in the VIP van achieved significantly higher sensitivity for detecting children with group-1 conditions than lay screeners administering the test in the Head Start centers (0.70 vs. 0.56; $P = 0.004$).

Table 6 provides the sensitivity of the tests for detection of children with each of the targeted conditions when overall specificity is set at 0.90. For amblyopia, reduced VA, and strabismus, the differences in sensitivity between nurse and lay screeners generally favored nurse screeners; however, the differences were small and not statistically significant. For detection of children with refractive error, nurse screeners achieved significantly higher sensitivity than lay screeners with the Retinomax Autorefractor (0.78 vs. 0.71; $P < 0.001$) and the Linear Lea Symbols VA test (0.51 vs. 0.37; $P < 0.001$). When lay screeners administered the *Single* Lea Symbols VA test in Head Start centers, sensitivity for each condition was 0.13 to 0.40 higher than when lay screeners administered the *Linear* Lea Symbols VA test in the VIP van ($P = 0.06$ to <0.0001) and 0.08 to 0.26 higher than when nurse screeners administered the *Linear* Lea Symbols VA

TABLE 5. Sensitivity by VIP Hierarchy of Conditions with Specificity Set to 0.90 for Screening Tests

	Sensitivity				
Screening Test	Any Condition* ($n = 462$)	Group 1 ($n = 210$)	Group 2 ($n = 144$)	Group 3 ($n = 108$)	Specificity ($n = 990$)
Retinomax Autorefractor					
Nurse screener	0.68	0.88	0.59	0.39	0.90
Lay screener	0.62	0.85	0.49	0.36	0.90
Difference	0.06	0.03	0.10	0.03	
95% CI	(0.02–0.09)	(−0.01–0.07)	(0.04–0.17)	(−0.06–0.12)	
SureSight Vision Screener					
Nurse screener	0.64	0.83	0.57	0.34	0.90
Lay screener	0.61	0.82	0.51	0.34	0.90
Difference	0.03	0.01	0.06	0.00	
95% CI	(−0.01–0.06)	(−0.02–0.05)	(0.00–0.12)	(−0.10–0.10)	
Linear Lea Symbols Visual Acuity (10 ft)					
Nurse screener	0.49	0.60	0.38	0.42	0.90
Lay screener†	0.37	0.50	0.19	0.35	0.90
Difference	0.12	0.10	0.19	0.07	
95% CI	(0.05–0.19)	(−0.01–0.19)	(0.08–0.29)	(−0.06–0.20)	
Single Lea Symbols Visual Acuity (5 ft)					
Lay screener	0.61	0.78	0.51	0.40	0.91
Stereo Smile II					
Nurse screener	0.45	0.58	0.37	0.30	0.90
Lay screener	0.40	0.56	0.31	0.23	0.90
Difference	0.05	0.02	0.06	0.07	
95% CI	(0.00–0.09)	(−0.05–0.09)	(−0.02–0.14)	(−0.04–0.15)	
Lay screener†	0.47	0.70	0.31	0.26	0.90

* Includes all children who had one or more VIP targeted conditions (amblyopia, strabismus, significant refractive error, reduced VA), regardless of whether the condition was subclassified into group 1, 2, or 3.

† Lay Screeners conducted testing in a VIP van in the 2002 academic year. In the 2002 academic year, 391 children had one or more GSE conditions, 172 had group 1 conditions, 121 had group 2 conditions, 98 had group 3 conditions, and 1055 children had no GSE conditions.

TABLE 6. Sensitivity by Condition Type with Specificity Set to 0.90 for Screening* Tests

Screening Test	Sensitivity				Specificity
	Amblyopia (n = 101)	Reduced VA (n = 117)	Strabismus (n = 47)	Refractive Error (n = 387)	(n = 990)
Retinomax Autorefractor					
Nurse screener	0.87	0.48	0.62	0.78	0.90
Lay screener	0.81	0.46	0.60	0.71	0.90
Difference	0.06	0.02	0.02	0.06	
95% CI	(0.00–0.12)	(−0.06–0.09)	(−0.10–0.15)	(0.03–0.10)	
SureSight Vision Screener					
Nurse screener	0.82	0.52	0.53	0.70	0.90
Lay screener	0.79	0.53	0.49	0.69	0.90
Difference	0.03	−0.01	0.04	0.01	
95% CI	(−0.03–0.09)	(−0.08–0.08)	(−0.06–0.14)	(−0.02–0.05)	
Linear Lea Symbols Visual Acuity (10 ft)					
Nurse screener	0.69	0.53	0.53	0.51	0.90
Lay screener†	0.56	0.48	0.39	0.37	0.90
Difference	0.13	0.05	0.14	0.14	
95% CI	(0.00–0.27)	(−0.08–0.18)	(−0.05–0.31)	(0.07–0.22)	
Single Lea Symbols Visual Acuity (5 ft)					
Lay screener	0.87	0.61	0.79	0.64	0.91
Stereo Smile II					
Nurse screener	0.64	0.43	0.64	0.47	0.90
Lay screener	0.61	0.37	0.72	0.42	0.90
Difference	0.03	0.06	−0.08	0.05	
95% CI	(−0.07–0.13)	(−0.04–0.14)	(−0.21–0.04)	(0.00–0.10)	
Lay screener†	0.74	0.31	0.79	0.49	0.90

* Children may have more than one condition.

† Lay screeners conducted testing in a VIP van in the 2002 academic year. In the 2002 academic year, 81 children had amblyopia, 96 children had decreased VA, 62 children had strabismus, 299 had significant refraction error, and 1055 children had no GSE conditions.

test in the Head Start centers (P = 0.08 to <0.0001). Lay screeners administering the Stereo Smile II test in the VIP van achieved higher sensitivity than lay screeners administering the test in Head Start Centers, for detecting amblyopia and strabismus, but the differences were not statistically significant ($P > 0.10$).

Sensitivity and Specificity for Combined Results of the Stereo Smile II with Other Screening Tests

Failure criteria for the autorefractors and visual acuity tests were reset to provide 0.90 specificity when the test results were combined with the Stereo Smile II test results. As shown in Table 7, the sensitivity for detecting children with one or more condition or with group-1 conditions using the combined results did not increase, relative to using the test alone, for most of the screening tests administered by nurse and lay screeners. However, for lay screeners, incorporating the results of the Stereo Smile II test increased the sensitivity for detecting children with group-1 conditions for both the Retinomax Autorefractor (0.91 vs. 0.85; P = 0.003) and the SureSight Vision Screener (0.89 vs. 0.82; $P < 0.001$).

The sensitivity for detecting children with strabismus using the combined results increased between 0.10 and 0.21, relative to using the test alone, for all the screening tests administered by nurse and lay screeners (Table 7). The increase in sensitivity was statistically significant for all the tests administered by lay screeners and for the Retinomax Autorefractor and the SureSight Vision Screener administered by nurse screeners. These increases in sensitivity for detecting strabismus by nurse screeners were accompanied by statistically significant de-

TABLE 7. Change in Sensitivity for Selected Outcomes for Tests in Combination with Stereo Smile II with Specificity Set to 0.90 in the 2003 Academic Year

Stereo Smile II Test Combined with	Any Condition (n = 462)	Group I (n = 210)	Strabismus (n = 47)	Specificity (n = 990)
Retinomax Autorefractor				
Nurse screener	−0.05*	0.01	0.19*	0.90
Lay screener	0.03	0.06*	0.14*	0.90
SureSight Vision Screener				
Nurse screener	−0.06*	−0.02	0.11*	0.90
Lay screener	0.02	0.07*	0.21*	0.90
Linear Lea Symbols Visual Acuity (10 ft)				
Nurse screener	−0.02	0.00	0.11	0.90
Single Lea Symbols Visual Acuity (5 ft)				
Lay screener	0.00	0.00	0.10*	0.90

Negative changes indicate that sensitivity of the combined test results was lower than that for the results of the test alone (not in combination with the results of the Stereo Smile II).

* Denotes statistically significant change in sensitivity of the combined tests ($P < 0.05$).

creases in the sensitivity for detecting children with one or more targeted conditions.

Discussion

Phase II of the VIP Study was a continuation of a comprehensive investigation of preschool vision screening. In phase I, results were compared of 11 preschool vision screening tests administered by LEPs (optometrists and ophthalmologists experienced in working with children).[1] Phase II was designed to compare pediatric nurses and lay people as screeners administering the three best-performing tests from phase I that could be performed by nurse and lay screeners (Retinomax Autorefractor, SureSight Vision Screener, and Lea Symbols Visual Acuity test) and a test (Stereo Smile II test) that was one of the most effective in detecting children with strabismus in phase I.

Testability and Time Needed for Testing

As shown for optometrist and ophthalmologist screeners in phase I, nurse and lay screeners were each able to achieve high testability (≥98%) on all tests. Furthermore, the amount of time needed to administer the tests was nearly identical for the two types of screeners. Thus, these four screening tests are age-appropriate for 3- to 5-year-old children, regardless of whether the tests are administered by eye care professionals, by trained nurses, or by lay screeners.

Detection of Children with One or More Targeted Conditions

As shown in Table 5, the results of phase II indicated that, when failure criteria were chosen to provide specificity of 0.90, sensitivity of the Retinomax Autorefractor for detection of children with one or more condition was modestly higher when the test was administered by nurses than by lay screeners (0.68 vs. 0.62; 95% CI for the difference = 0.02–0.09), and similar to that found in phase I for LEPs (0.63–0.64).[1] Overall sensitivity of the SureSight Vision Screener was comparable when administered by nurses and lay screeners (0.64 and 0.61, respectively) and similar to that found in phase I for LEPs (0.63).[1] It is also noteworthy that the two autorefractors were similarly effective, whether testing was conducted in the controlled environment of phase I or in the preschool setting of phase II.

The sensitivity of the Lea Symbols VA test varied with the screener and with test format (crowded Linear Symbols at 10 ft versus crowded Single Symbols at 5 ft). When failure criteria were selected to provide specificity of 0.90, the sensitivity of the Linear Lea Symbols VA test was higher when administered by nurse screeners (0.49) than by lay screeners (0.37). Unlike with the autorefractors, sensitivities for the Linear Lea Symbols VA test administered by nurse and lay screeners were markedly lower than those obtained in phase I by LEPs (0.61).[1] To see whether sensitivity of the test administered by lay screeners could be improved, the test was modified to use single, crowded symbols (rather than linear symbols) and a test distance of 5 ft (rather than 10 ft). This resulted in sensitivity (0.61) equivalent to that of LEPs in phase I.

When the Stereo Smile II test was performed by LEPs in phase I, sensitivity for detection of one or more targeted conditions (0.44) was lower than the best four tests (sensitivity ≥0.60). Not surprisingly, results of phase II show that the Stereo Smile II test, at 0.90 specificity, was no more effective for detection of one or more targeted conditions when conducted by nurses or by lay screeners than when conducted by LEPs.[1] However, as in phase I, the Stereo Smile II test was one of the most effective screening tests for detection of children with strabismus (Table 6).

Detection of Children by Severity of Condition

Although all VIP targeted conditions merit evaluation by an eye care professional, severity varies within each condition. For group-1 conditions (very important to detect and treat early), sensitivity at 0.90 specificity (Table 6) was 0.88 to 0.82 for the autorefractors, whether administered by nurse or by lay screeners, and comparable to the values of 0.81 to 0.88 obtained by LEPS in phase I.[1] Lay screeners administering the Single Lea Symbols VA test also achieved sensitivity (0.78) comparable to that achieved by LEPS administering the Linear Lea Symbols test (0.77).

Visual Acuity Testing

VA testing is the most widely used method for screening vision in preschool children.[2,3,13–20] Also VA charts are far less expensive than autorefractors and require less maintenance. However, results of phases I and II of the VIP Study indicate that the performance of VA testing varies widely with the format of the test, the screening environment, and the personnel administering the test. The sensitivity of the Linear Lea Symbols test at 10 ft was highest when administered by LEPs in the VIP van, lower when administered by nurses in preschool settings, and lowest when administered by lay screeners in the VIP van (Tables 5, 6). However, when the format of the test was changed to single, crowded symbols presented at 5 ft, sensitivity of the test administered by lay screeners in Head Start centers equaled that of the Linear Lea Symbols test administered by LEPs. The improved sensitivity when the lay screeners performed the Single Lea Symbols test at 5 ft may be attributable to the screener's increased ability to engage the child's attention due to the closer test distance, novelty of each optotype appearing in the window, and decreased complexity of presentation of single symbols rather than a linear array of symbols.

Combining Results of Screening Tests and the Stereo Smile II Test

Preschool vision screening guidelines often recommend the combined use of VA testing (for detection of reduced VA due to amblyopia, significant refractive error, or other causes) and stereoacuity testing (for detection of strabismus).[2,3,13,14,16,17,19,20] However, at 0.90 specificity, the overall sensitivity for detection of one or more conditions of the Lea Symbols test and the Stereo Smile II test combined was not improved from the sensitivity of the Lea Symbols tests alone for either nurse or lay screeners (Table 7). Similarly, when this combination of tests was evaluated for detection of group-1 conditions, the sensitivity of the combined tests was unchanged from the sensitivity of the Lea Symbols test alone. In this study population, combining results from both tests increased the sensitivity by 0.10 for detection of strabismus, for both nurse and lay screeners. However, the improvement was statistically significant for lay screeners only.

Combining the results of the Stereo Smile II test with those of the autorefractors did not result in large gains in overall sensitivity when specificity was 0.90. However, sensitivity for detecting children with strabismus increased significantly for each autorefractor administered by each type of screener. The increased sensitivity of combining results of an autorefractor and the Stereo Smile II test for detecting children with strabismus must be weighed against increasing the screening time from 2 to 5 minutes per child, and the additional expense (approximately $1000) of the Stereo Smile II test.

Limitations of Phase I and II VIP Study Results

The results from phases I and II of the VIP Study provide insight into which vision screening tests are most accurate in detecting the most prevalent vision disorders in preschool-aged children, and indicate that nurse and lay screeners can achieve results that are comparable to those of LEP screeners. However, generalizability of the results may be limited by several factors. First, in phase I, all testing was conducted by highly skilled personnel in a controlled environment (VIP van), whereas typical screenings are conducted by less-skilled personnel in a less-ideal environment. Second, in both phases I and II, children underwent screening that involved six to eight procedures, substantially more than the one to two tests typically used during routine screenings. It is reasonable to suspect that preschool children required to perform so many tests would occasionally fail because of fatigue rather than because of a vision problem. We cannot judge the impact of fatigue on our results. Third, in both phases I and II, all children were enrolled in Head Start programs and therefore may not have been representative of all young children in the general population. Finally, the sample of children was selected to overrepresent children with vision disorders, which necessitated the use of a weighting factor in calculation of specificity (see the Data Analysis section in the Methods section). This approach was chosen for VIP since it allows a direct comparison of performance of the screening tests head to head, but sensitivity and specificity of an individual test may be different when used in a general population.

CONCLUSIONS

The results of phase II of the VIP Study indicate that two of the best-performing tools for vision screening of preschool children (Retinomax Autorefractor and SureSight Vision Screener) are as effective when used by nurse screeners and by lay screeners as they are when used by optometrists and ophthalmologists. A third tool (Linear Lea Symbols VA screening) that was one of the most effective screening tools when used by optometrists and ophthalmologists was much less effective when used by nurse screeners and lay screeners. However, there was a marked improvement in the performance of lay screeners when the test distance was reduced from 10 to 5 ft and the test format was modified from linear presentation to single, crowded symbols. Although these results are promising and support the use of autorefraction and some types of VA testing as screening tools for preschool children, a broad recommendation cannot be made, because the data were collected within the context of a research protocol specifically designed to compare tests and screening personnel in a selected group of children. The next phase of the VIP Study is being designed to address additional questions related to how screening of preschool children should be accomplished.

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APPENDIX

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