Vision and Eye Health

Moving Into the Digital Age With Instrument-Based Vision Screening

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Significant advancements in vision screening research are leading to improved design, functionality, and reliability of screening tools. Presently, two vision screening approaches are available to school nurses for children ages 3 years and older: optotype-based screening and instrument-based screening. Optotype-based screening pertains to tests of visual acuity using optotypes (e.g., pictures, letters, and numbers), which children identify to determine visual acuity. Instrument-based screening pertains to automated devices that measure amblyogenic risk factors, such as refractive error, media opacities, and eye misalignment. Differences between the two approaches; best and acceptable practice recommendations for both approaches; unacceptable tests of visual acuity; and best, acceptable, and unacceptable occluders are described.

Keywords: optotype-based screening; instrument-based screening; occluders; preschool vision screening; school-age vision screening; LEA symbols; HOTV; Sloan letters

Screeners used a Snellen chart in 1899 when the first school vision screening program started in Connecticut (Appelboom, 1985). Fast forward more than 115 years. Significant advancements have occurred in vision screening research, leading to improved design, functionality, and reliability of screening tools. Presently, two vision screening approaches are available to school nurses for children ages 3 years and older: optotype-based screening and instrument-based screening. Optotype-based screening pertains to tests of visual acuity using *optotypes* (e.g., pictures, letters, and numbers), which children identify to determine visual acuity. Instrument-based screening pertains to automated devices that measure amblyogenic risk factors, such as refractive error, media opacities, and eye misalignment.

This article describes tools and techniques for school nurses to screen the vision of children in the school environment. However, some children, according to the National Expert Panel to the National Center for Children's Vision and Eye Health at Prevent Blindness (NCCVEH), should bypass vision screening and receive a referral for a comprehensive eye examination by an optometrist or ophthalmologist (Cotter, Cyert, Miller, & Quinn, 2015; Marsh-Tootle, Russ, & Repka, 2015). Examples of children who are at an increased risk for vision abnormalities are identified in Table 1. A referral for an eye examination is recommended for these children; however, school nurses can attempt screening if classmates may consider these children as "outcasts" because they are not included in screening activities.

Instrument-Based Screening

Often referred to as devices, automated screening instruments, or automated vision screening devices, instrument-based screening uses automated technology to provide an estimation of refractive error and information about the presence and magnitude of abnormalities of the eyes (Miller & Lessin, 2012). Most instruments can be placed in two categories: photorefraction/photoscreening devices and handheld, portable autorefractors.

Photoscreeners use optical images of the eye's red reflex to provide an estimate of refractive error; some devices also provide information about eye alignment and media opacities, such as cataract (Miller & Lessin, 2012). Photoscreeners have similarities and differences. For example, some immediately provide a printable report on both eyes simultaneously. Some provide the additional ability to screen one eye at a time. Some require trained technicians at a site, away from the screening venue, to review the results.

Handheld, portable autorefractors analyze light reflected from the retina to

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Table 1. Examples of Children Who Should Bypass Vision Screening and Receive a Referral for an Eye Examination by an Optometrist or Ophthalmologist

Children with:
• Readily observable ocular abnormalities
• Neurodevelopmental disorders
• Systemic conditions that have associated ocular abnormalities
• First-degree relatives with strabismus or amblyopia
• A history of prematurity (< 32 completed weeks)
• Parents who believe their child has a vision problem
• Hearing impairments
• Motor abnormalities, such as cerebral palsy
• Down syndrome
• Cognitive impairment
• Speech/language delays
• Autism spectrum disorders

Source: Cotter, Cyert, Miller, and Quinn (2015); Marsh-Tootle, Russ, and Repka (2015).

provide an estimate of refractive error. Whether a child passes the vision screening depends on pass/fail settings in the device. Autorefractors, such as the Welch Allyn SureSight® Vision Screener, usually screen one eye at a time and provide an estimate of refractive error but do not provide a report with words stating that a child passed the screening or should have an eye exam.

During instrument-based screening for many devices, the school nurse points the device toward the child's eyes, at the prescribed distance for the device, in a dimly lit room. The child is required only to look at the device while lights or sounds at the front of the instrument engage the child's attention as the instrument captures the measurement.

Instruments differ in screening distance and data collection. For example, some instruments:

- Are used at 14 inches from the child's eyes; others are used at around 3 feet.
- Permit preloading a spreadsheet of child demographics and selecting a specific child's file prior to screening; results will automatically load into the child's file on the device.
- Permit screening of children within a specific age range, without demographic data, and entering data only on children who do not pass vision screening.
- Permit exporting results to paper printers or electronic medical records to share with parents or eye care providers.
- Permit creating reports to determine, for example, which children at which age did not pass vision screening at which school on which date.
- Permit the screener to customize referral criteria. For those devices, the school nurse is encouraged to consult local eye care providers for preferred referral criteria settings.

Instrument-based screening results can have three outcomes:

1. The child passed the screening,
2. The child should be referred for an eye exam, or
3. A reading could not be achieved.

Pupil size, pupil color, environmental lighting, and a child's ability to fixate on the device's target can influence whether or not a reading can be achieved. Depending on the instrument used, results are determined by the device's automated image analysis system or interpreted by a trained technician at a central reading center. Table 2 illustrates examples of commercially available instruments. Vision screening machines that use cards or slides with optotypes and require a subjective response from the child are not included among the instrument examples.

Optotype-Based Screening

Optotype-based screening refers to using tests that directly measure visual acuity with pictures, letters, or numbers. Optotype-based screening provides information about visual acuity, or the clarity of vision when identifying pictures, letters, or numbers at a prescribed distance. Visual acuity provides information about the presence, or absence, of refractive error and pathology within the visual pathway (Anstice & Thompson, 2014).

Children ages 3 through 5 years may identify optotypes verbally or by matching optotypes on a response card. Visual acuity is measured as the last line where the child correctly identified the majority of optotypes. The NCCVEH recommends that children age 3 years identify the majority of optotypes on the 20/50 line and children ages 4 and 5 years should identify the majority of optotypes on the 20/40 line (Cotter et al., 2015). Using these recommendations, children ages 6 years and older must identify the majority of optotypes on the 20/32 line to pass. Guidelines from the American Association for Pediatric Ophthalmology and Strabismus (AAPOS, 2014) recommend lines 20/50 for 3-year-old children, 20/40 for 4-year-old children, and 20/32 for children ages 5 years and older.

Tests of visual acuity are calibrated for various distances. The NCCVEH

Table 2. Examples of Commercially Available Instruments

						
Welch Allyn Spot™ Vision Screener	Welch Allyn SureSight® Vision Screener	Plusoptix S12C	Righton Retinomax 3	2WIN for Vision	iScreen Vision	GoCheck Kids

Table 3. Examples of Tests of Visual Acuity

					
Flipbooks or disk cards with single, surrounded optotypes	Charts with full lines for threshold screening[a]	Charts for critical line screening[b]	Flipbooks with full lines of optotypes for threshold[a] and critical line[b] screening	Software for matching optotypes with single, surrounded optotypes	iPad apps with threshold and critical line formats
Vision in Preschoolers (VIP) screening test with Illuminator Cabinet at 5 feet or Massachusetts Visual Acuity Test format	Sloan letters wall chart	VIC LEA symbols & Sloan letters wall chart	AAPOS Basic Kit	EyeSpy 20/20™	AAPOS Screening App for the iPad

a. Threshold screening = Moving down the chart until the child can no longer correctly identify the majority of optotypes on a line.
b. Critical line screening = Child identifies the majority of optotypes on the critical line of visual acuity for the child's age.

recommends a 5-foot testing distance for children ages 3 through 5 years. A 10-foot distance remains an acceptable practice. A 20-foot distance is unacceptable (Cotter et al., 2015). Tests of visual acuity should adhere to national and international guidelines for standardized eye chart design and illumination, which can impact visual acuity results (Nottingham Chaplin & Bradford, 2011). For illumination, the NCCVEH (Cotter et al., 2015) recommends a minimum luminance of 80 cd/m^2. Illumination best practices include a light box, a lighted stand to hold and evenly light the test, or a computer screen display (Cotter et al., 2015). Competing light sources that create glare or uneven lighting on the test, such as screening near a window, can negatively affect visual acuity screening. Table 3 illustrates examples of tests of visual acuity for optotype-based screening.

Differences Between the Two Screening Approaches

Optotype-based screening provides a subjective measure of recognition visual acuity or the child's ability to recognize black pictures, numbers, or letters on a white background at a prescribed distance. Instruments do not measure visual acuity and do not provide reports with visual acuity values. Instrument-based screening provides objective

information about the presence of risk factors in the eyes that could lead to problems with visual acuity and, potentially, cause amblyopia. Common amblyogenic risk factors detected by vision screening devices include (Neely, 2013):

- significant refractive errors (hyperopia, myopia, and astigmatism),
- asymmetry of the refractive error from one eye to the other (anisometropia),
- misalignment of the eyes, and
- presence of media opacities (cataract).

Some devices also provide information about pupil size.

Approved Instruments and Optotype-Based Tools

The American Academy of Pediatrics Section on Ophthalmology and Committee on Practice and Ambulatory Medicine, the American Academy of Ophthalmology, the AAPOS, the American Association of Certified Orthoptists, and the NCCVEH support the use of both instrument- and optotype-based screening.

The American Academy of Pediatrics (AAP) and co-sponsors published a policy statement in October 2012 supporting instrument-based pediatric vision screening, but not specific instrument recommendations (Miller & Lessin, 2012). This group is currently revising national recommendations for optotype-based vision screening. The AAPOS (2014) issued a statement in May 2014 on pediatric vision screening techniques, which includes information on optotype- and instrument-based screening. In January 2015, the National Expert Panel to the NCCVEH published recommendations for screening the vision of children ages 36 to < 72 months, which include suggestions for instrument- and optotype-based screening tools, as well as appropriate and inappropriate examples of tests of visual acuity (Cotter et al., 2015).

Refractive error cutoffs for referral criteria are age dependent and should be reflected in the instrument settings or manually selected by the screener. Currently, no national guidelines are available for instrument referral criteria settings. School nurses should check their state referral guidelines or state school nurse consultants for appropriate instrument referral criteria settings. If no instrument referral criteria guidelines exist, school nurses should work with a trusted local eye care professional group. The AAPOS (2014) recommends that eye care professionals be familiar with an instrument's sensitivity and specificity to detect amblyogenic risk factors when advising school nurses and others about referral criteria options for a particular device.

Referral criteria settings determine whether to err on the side of under- or over-referral of children for eye examinations (Nottingham Chaplin, Marsh-Tootle, & Bradford, 2015). Altering referral criteria often results in a trade-off between sensitivity and specificity. High sensitivity (high detection of at-risk children) risks excessive over-referrals and high specificity (minimization of over-referrals) risks under-referring children with vision disorders (AAPOS, 2014; Miller & Lessin, 2012).

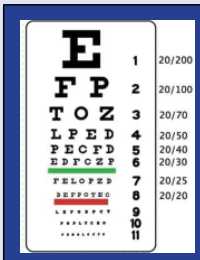
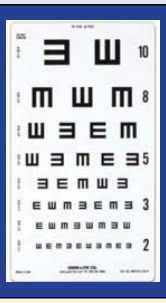
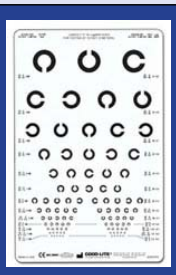
Sensitivity refers to the percentage of children with a vision disorder who were correctly identified by the screening; specificity is the percentage of children without a vision disorder who appropriately passed the screening. If sensitivity is 80%, the screening test correctly identified and referred 80 of 100 children *with* a vision disorder and failed to identify and refer 20 of 100 children with a vision disorder. The 20 children passed vision screening, although they had a vision disorder. This is an example of under-referring. If specificity is 80%, the screening test correctly passed 80% of children *without* a vision disorder and incorrectly referred 20 of 100 children without a vision disorder for further evaluation by an eye care professional. The 20 children failed the vision screening even though they did not have a vision disorder. This is an example of over-referring (Nottingham Chaplin et al., 2015). Currently, no national guideline exists for a specific sensitivity and specificity setting for vision screening instruments.

For optotype-based screening, the AAPOS (2014) recommends using matching picture optotypes, such as LEA symbols or HOTV letters, presented as either a line of optotypes surrounded by a box or single optotypes surrounded by four lines (crowding bars) for preschool-age children. When children know their letters, the AAPOS (2014) recommends using charts with Sloan letters. The AAPOS (2014) vision screening techniques document states that "Sloan Letters charts match national and international guidelines for standardized eye charts and replace traditional Snellen charts, which do not adhere to guidelines" (p. 1) (Committee on Vision, 1980; Nottingham Chaplin & Bradford, 2011).

The National Expert Panel to the NCCVEH (Cotter et al., 2015) provides recommendations for optotype- and instrument-based screening for children ages 3 through 5 years in three categories based on high-quality, published, peer-reviewed data: best practice, acceptable practice, and unacceptable. A designation of *best practice* indicates that the instrument has high-quality published performance data for the targeted age group and is commercially available with appropriate U.S. Food and Drug Administration status. *Acceptable practice* indicates that the instrument has fewer high-quality, published performance articles for the targeted age group than best practice instruments, but the available data suggest that the instrument will perform well and might even outperform best practice instruments. A systematic process is available at the NCCVEH for instrument manufacturers to apply for a classification. This process can be viewed at http://nationalcenter.preventblindness.org/vision-screening-device-review.

For instrument-based screening for children ages 3 through 5 years, the National Expert Panel to the NCCVEH (Cotter et al., 2015) classifies the Retinomax and Welch Allyn SureSight® Vision Screener Versions 2.24 or 2.25 as best practice and the Plusoptix S12C as an acceptable practice. The National Expert Panel designated the Welch Allyn Spot™ Vision Screener as an acceptable

Table 4. Examples of Unacceptable Tests of Visual Acuity for Children Ages 36 to < 72 Months

					
Snellen	Allen pictures	Tumbling E	Landolt C	Lighthouse (house, apple, umbrella)	Kindergarten "Sailboat"

Source: Cotter, Cyert, Miller, and Quinn (2015).

practice after the recommendations article was accepted for publication. The NCCVEH website provides updated information on instrument recommendations (http://visionsystems.preventblindness.org/screening/instrument-based-vision-screening.html).

For optotype-based screening of children ages 3 through 5 years, the National Expert Panel to the NCCVEH (Cotter et al., 2015) recommends monocular visual acuity screening using single HOTV letters or LEA symbols surrounded by four crowding bars at a test distance of 5 feet as best practice. Children may respond by naming the optotypes or matching the optotypes on a response card. Acceptable practice tools are tests of visual acuity with a single line of HOTV letters or LEA symbols surrounded by a rectangular crowding box at 10 feet. Table 4 illustrates six tests of visual acuity deemed unacceptable for children ages 36 to < 72 months (Cotter et al., 2015).

The six tests of visual acuity included in Table 4 are considered unacceptable because children ages 3 through 5 years typically do not know their letters; some charts require discrimination of left-right directionality, which is not fully developed in preschool-age children; and they do not meet national and international recommendations for standardized eye chart design (Cotter et al., 2015; Nottingham Chaplin & Bradford, 2011). Prevent Blindness has convened a work group to update its national position statement for school-age vision screening, which will be available on the Prevent Blindness website (http://www.preventblindness.org/).

Six additional unacceptable practices from the National Expert Panel to the NCCVEH (Cotter et al., 2015) for screening children ages 36 to < 72 months include:

1. A 20-foot testing distance because a shorter test distance (a) improves the school nurse's ability to maintain the child's attention and (b) permits a smaller screening area to avoid distractions commonly found in a crowded hallway or large screening room.
2. Near cards because even 3 diopters of myopia (nearsightedness) may be undetected at a test distance of 14 inches.
3. Binocular screening because "unilateral amblyopia is masked by the better-seeing eye when amblyopic children are tested binocularly" (p. 9).
4. Using a hand, tissue, paper cup, or cover paddle as an occluder because children ages 36 to < 72 months often attempt to peek around these occluders to use their better eye. Preferred occluders are adhesive eye patches and 2-inch-wide hypoallergenic surgical tape. Specially constructed, commercially available occluder glasses are considered acceptable.
5. Vision testing machines that optically simulate distance vision, such as those used at motor vehicle testing facilities. While developing recommendations, the National Expert Panel concluded that machines optically simulating distance vision have potential and actual methodological problems that preclude their effective use today.
6. Red reflex and cover testing. When used as part of a vision screening protocol, red reflex testing for media opacity detection and cover testing for eye misalignment should be conducted only by health care personnel who are professionally trained to perform and interpret the tests.

Guidelines for Using Instruments and Optotype-Based Tools

The 2012 policy statement from the AAP and co-sponsors (Miller & Lessin, 2012) provides recommendations for primary care practices. These recommendations are not targeted to mass screening activities that school nurses would encounter in a school-based setting. Five recommendations include the following:

1. Photoscreeners and handheld autorefractors may be electively performed with children ages 6 months to 3 years to permit earlier detection of disorders that could lead to amblyopia. (Studies are under way to confirm the efficacy of using devices for this younger age group.)

2. Photoscreeners and handheld autorefractors may be electively performed with older children who are unable or unwilling to participate in optotype-based screening.
3. Photoscreeners and handheld autorefractors are an alternative to tests of visual acuity for children ages 3 through 5 years.
4. Tests of visual acuity to assess amblyopia in children ages 3 to 5 years remain a viable practice.
5. Tests of visual acuity are more efficient and less expensive for children ages 6 years and older.

Four AAPOS (2014) recommendations are:

1. Measuring visual acuity with standardized eye charts remains the preferred method for vision screening, unless the child cannot participate in optotype-based screening.
2. Instrument-based screening is recommended for children ages 1 to 3 years because children this age cannot participate in optotype-based vision screening.
3. Although screening children with optotype-based screening can be accomplished as young as age 3 years, instrument-based vision screening remains an acceptable alternative for children ages 3 to 5 years.
4. Most children are able to participate in optotype-based screening "with a high degree of success and reliability by age 5 years" (p. 1).

Primary Vision Screening Approach Selection

Although vision screening instruments are useful tools, not all children can be screened with a device. However, often children who cannot be screened with a device can still be screened with a test of visual acuity and vice versa. The Vision in Preschoolers Study (Vision in Preschoolers Study Group, 2007) found that children who were unable to participate in vision screening with a handheld autorefractor were nearly always able to participate in vision screening with a test of visual acuity. Children who were unable to participate in a test of visual acuity were nearly always able to participate in vision screening with a handheld autorefractor.

Choosing whether to use optotype- or instrument-based screening, or a mixture of both, depends on at least six factors (Cotter et al., 2015; Nottingham Chaplin et al., 2015).

1. screener preference,
2. number of children to screen,
3. screening environment,
4. time allotted for screening,
5. reporting requirements, and
6. funding resources.

Vision Screening as Part of a 12-Component Vision and Eye Health System of Care

Regardless of the selected tools, vision screening is only one part of a 12-Component Vision and Eye Health System of Care as defined by the Year of Children's Vision, a project of various organizations including the National Head Start Association, the NCCVEH, the AAPOS, Good-Lite, School Health Corporation, and the American Academy of Optometry's Binocular Vision, Perception & Pediatric Optometry Section (Nottingham Chaplin, Ramsey, & Baldonado, 2014). The following is a sample of the comprehensive components:

1. Ensuring that all parents/caregivers receive vision and eye health educational material that respects cultural and literacy needs.
2. Providing parents/caregivers of children who do not pass vision screening with written *and* verbal vision screening results in easy-to-understand language that respects cultural and literacy needs and provides steps to take for prompt follow-up with an eye care provider.
3. Including formal training for staff that leads to certification in evidence-based vision screening procedures. The World Health Organization (2003) recommends training because "the skill of the tester affects very significantly the validity and variability of the outcome" (p. 6).
4. Creating direct referral policies for children with increased risk factors for vision problems, including children identified in Table 1 (Cotter et al., 2015; Marsh-Tootle et al., 2015).
5. Considering ways to engage parents/caregivers in peer-to-peer conversations to encourage follow-up for eye care and adherence to prescribed treatments.

School nurses wanting to create a vision and eye health system of care can visit this link for a comprehensive overview of all 12 recommended components: http://nationalcenter.preventblindness.org/sites/default/files/national/documents/12_component_vision_health_system_of_care%20%282%29.pdf. School nurses wanting to evaluate their current vision and eye health system of care can visit this link: http://nationalcenter.preventblindness.org/sites/default/files/national/documents/VSProgramEvaluationNHSAVersion.pdf.

Conclusion

An eye chart was used to screen children's vision in Connecticut in 1899 (Appelboom, 1985). Since that time, many school nurses have been tasked to conduct vision screening in the school environment. As a consequence of ongoing research and the creation of new and standardized tools, school nurses today have multiple choices for screening vision, including tests of visual acuity for optotype-based screening and devices for instrument-based screening. Children may receive their first vision screening when they begin school; thus, it is important that school nurses are equipped with the knowledge and tools to do the best screening possible, helping to ensure children succeed in an academic environment. The key to successful vision screening in the digital age is to use evidence-based and age-appropriate tools and techniques as one of the 12 components of a strong vision and eye health system of care. ■

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