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ORIGINAL ARTICLE

Preschool Visual Acuity Screening with HOTV and Lea Symbols: Testability and Between-Test Agreement

VISION IN PRESCHOOLERS STUDY GROUP

ABSTRACT: *Purpose.* To compare the performance of 3- to 5-year-old children on visual acuity screening with HOTV letters vs. Lea symbols as optotypes. *Methods.* Subjects included 1253 Head Start children who were aged either 3 or 4 years on September 1 of the school year of testing. The sample over-represented children who had not passed a Head Start screening. Binocular pretesting at 1 m demonstrated the child's ability to identify the optotypes verbally or by matching optotypes on a lap card. Acuity was tested monocularly at 3 m using crowded single lines of optotypes. Lines tested were based on age at the beginning of the school year (September 1) with 3-year-old children tested with lines 10/100, 10/32, 10/25, and 10/20 and 4-year-old children tested with 10/100, 10/25, 10/20, and 10/16. *Results.* Overall, 99% of children were able to complete the binocular pretest for each test successfully, and there was no difference between the tests ($p = 0.83$). Children's ability to complete the pretest increased slightly with age. HOTV test scores were slightly worse than Lea symbols test scores ($p = 0.047$), primarily because more children were unable to pass the monocular 10/100 card for the HOTV test than for the Lea symbols test (2.6% vs. 1.3%). The percentage of identical results on HOTV vs. Lea overall was 67.3% and increased significantly with age. When the results were different, 3-year-old children, but not 4- and 5-year-old children, tended to have worse results on the HOTV letter test. *Conclusions.* The vision of nearly all 3- to 5-year-old children can be screened using either HOTV letters or Lea symbols. HOTV letters may be slightly more difficult than Lea symbols for 3- to 5-year-old children, with the largest difference between acuity results on the two tests occurring in 3-year-old children. (Optom Vis Sci 2004;81:678–683)

Key Words: visual acuity, HOTV letter optotypes, Lea symbols, preschool vision screening, children's vision

Preschool visual acuity screening tests to detect amblyopia, strabismus, high refractive error, and other vision disorders have been incorporated into state guidelines and requirements for health-related evaluation of preschool children. The intention of these guidelines and requirements is to identify children with vision problems when they are most amenable to treatment and before the child's entry into elementary school. However, there is no consensus regarding which of the many available screening tests is best. In a 1999 summary of vision screening guidelines for preschool children in the 50 United States and the District of Columbia, Ciner et al.[1] reported that recommended tests included Snellen letters, illiterate or tumbling E, Michigan Preschool Slides containing E symbols pointing toward one of four pictures, HOTV letter charts, Allen picture cards, blackbird vision screening test, modified Sjögren hand test, picture acuity charts, Blackhurst picture test, Faye symbols chart, Lea single symbol book, and the Lea symbols chart.

When considering the many tests available for screening visual acuity, how should health care providers (e.g., nurses, optometrists, ophthalmologists, and pediatricians) decide which test to choose for screening preschool children? Guidelines for construction of visual acuity charts for adults, established by the Committee on Vision,[2] recommend that all the optotypes (letters or symbols) presented at a given acuity level should be equally detectable. Spacing between adjacent optotypes also should not be less than the overall size of the optotype, and single, isolated optotypes should not be used.[3, 4] Use of "crowded" optotypes is especially important in detection of amblyopia because the visual acuity measured in people with amblyopia is overestimated if isolated optotypes are used.[5–7]

Unfortunately, the optotypes and optotype layouts used in preschool vision-screening tests rarely conform to the aforementioned guidelines. Many preschool tests are constructed of picture optotypes that vary in the ease with which they may be distinguished when they subtend the same visual angle. Many preschool tests also vary in the spacing between optotype sizes, in the spacing between optotypes of the same size, and in the number of optotypes presented at different sizes. In addition, a format in which optotypes

are presented as single, isolated letters or pictures is often used. As indicated previously, this format is less sensitive than crowded optotypes to the detection of amblyopia, a condition that is targeted by most preschool vision-screening programs.

In addition to consideration of optotypes and optotype presentation, health care professionals selecting a vision-screening test for preschool children must consider the cognitive level of young children. Tests that permit the child to match test optotypes to similar forms on a lap card, rather than asking a child to respond verbally, increase the testability of preschool children. Because young children often have difficulty when asked to identify rightward- vs. leftward-pointing optotypes (e.g., in the tumbling E chart),[8–11] Sheridan, one of the early developers of preschool visual acuity tests, also recommended the use of optotypes with left-right symmetry.[12]

A report published in 2000 by the Task Force on Preschool Vision Screening assembled by the Maternal and Child Health Bureau of the Health Resources and Services Administration of the Department of Health and Human Services and the National Eye Institute of the National Institutes of Health of the Department of Health and Human Services recommended assessing visual acuity in young children with the letters H, O, T, and V or with Lea symbols (apple, house, circle, square).[13, 14] The letters H, O, T, and V have left-right symmetry. Three of the letters (H, O, and V) are Sloan letters and are considered to be equal in difficulty to the Landolt ring.[2] Sheridan also recommended the use of H, O, T, and V because 3-year-old children (and some 2-year-old children) can successfully identify these letters in a matching task.[12] The Lea symbols have left-right symmetry and are about equally discriminable.[14] The Task Force also recommended the use of crowding bars surrounding the optotype(s) or line presentation of optotypes to avoid the underestimation of the acuity deficit in amblyopia.[13]

Although HOTV and Lea symbols optotypes have been recommended for use with preschool children, only one study has compared visual acuity screening testability of 3- to 5-year-old children with the two optotypes.[15] In this study, optotypes were arranged in isolated lines (personal communication) that were presented using translucent charts placed on a chart illuminator. Trained testers from Prevent Blindness Florida conducted the testing in school settings. Children were judged testable if they were cooperative and gave appropriate responses during monocular testing at 10 feet. Overall testability did not differ between the two tests and was higher in older children than in younger children.

The purpose of the present study was to provide a direct comparison of the ability of a large cohort of 3- to 5-year-old preschool children to complete visual acuity screening with the letters H, O, T, and V vs. with Lea symbols optotypes. In contrast to the Hered[15] study, in which optotypes were presented on an illuminated light box, optotypes in the present study were presented in the MassVAT (Precision Vision, LaSalle, IL) screening test format.[16] The MassVAT is a set of handheld test cards each containing a single line of Lea symbols. A crowding bar surrounds the line on all four sides. A second purpose of the present study was to examine the level of agreement between acuity results obtained with H, O, T, and V letter optotypes vs. Lea symbols optotypes.

METHODS

Subjects

Subjects were 1257 three- to five-year-old children who were participants in Head Start in one of the five cities in which a Vision in Preschoolers (VIP) Clinical Center was located (Berkeley, CA, Boston, MA, Columbus, OH, Philadelphia, PA, and Tahlequah, OK). All the children were either 3 or 4 years of age on September 1, 2001 and underwent VIP screening during the academic year 2001 to 2002. The average age on the day of screening was 45 months (range, 40 to 47 months) for 3-year-old children, 54 months (range, 48 to 59 months) for 4-year-old children, and 63 months (range, 60 to 68 months) for 5-year-old children.

To obtain a sample of children with a high proportion of vision problems, and therefore a wide range of visual acuities, an effort was made to recruit all the children who had failed the local annual Head Start vision screening, along with a random sample of those who had not failed. Children who had not failed were those children who had passed, who had missed the screening, or whose test results were not available. The tests included in the annual Head Start vision screening are determined by each local agency and therefore vary widely. As a result of this selective recruitment, the study included 735 (58.5%) children who had failed and 522 (41.5%) who had not failed the local Head Start vision screening. Children designated "special needs" by Head Start were excluded from the data analysis because this designation indicates they have sensory, cognitive, and/or motor impairments that may impair their ability to perform vision-screening tests. Therefore, the children tested in this study were not a representative sample of children enrolled in Head Start.

The institutional review boards of each of the participating academic institutions and the Cherokee Nation approved this research. A parent or guardian of each child provided written informed consent.

Visual Acuity Screening Tests

The commercially available MassVAT test uses Lea symbols optotypes. To allow direct comparison of screening results with HOTV and Lea symbols optotypes, we asked the manufacturer of the MassVAT cards (Precision Vision, La Salle, IL) to provide us with two versions of the test: one using the letters H, O, T, and V (Fig. 1A), and the second using the Lea symbols apple, house, circle, and square (Fig. 1B). Optotype size and stroke width for the HOTV letters conformed to the standard definitions for visual acuity, in which 20/20 Snellen acuity optotypes subtend a visual angle of 5 min in height and a visual angle of 1 min in critical details.[2] Optotype size and stroke width for the Lea symbols was based on the test developer's empirical determination of overall optotype size and stroke width necessary to produce equal acuity thresholds in response to blur.[14]

We also requested the addition of a card containing a line of four 10/100 optotypes for each test, and we requested that cards for each test be assembled into spiral-bound booklets, one containing 10/32, 10/25, and 10/20 optotypes to be used for testing children aged 3 years on September 1, 2001, and one containing 10/25, 10/20, and 10/16 optotypes to be used for testing children aged 4 years on September 1, 2001. The purpose of adding the 10/100

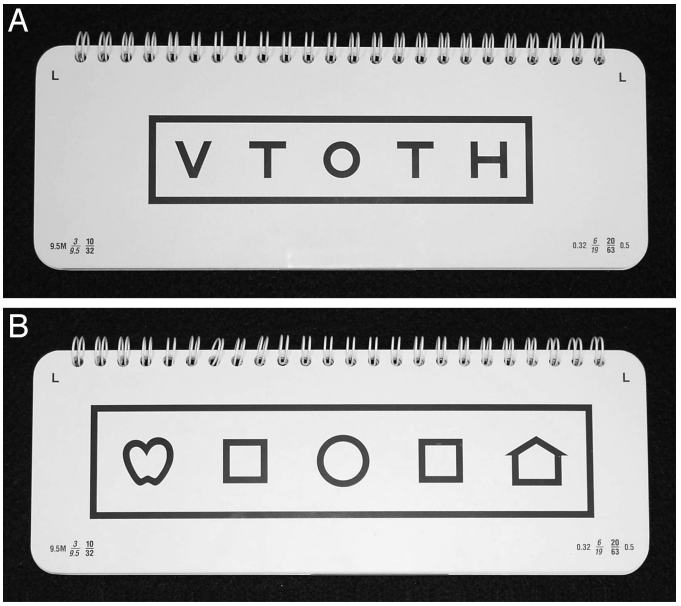

FIGURE 1.
Photograph of 10/32 line from one page of one flipbook from the HOTV letter test (A) and the Lea symbols test (B).

card to the commercially available test was to increase the chance of the child successfully making the transition from binocular pretesting at near to monocular testing at 3 m. The purpose of using age-specific test booklets was to decrease tester error. For each age group, the three optotype sizes selected included the optotype size recommended as the visual acuity screening passing criterion by the Task Force on Preschool Vision Screening,[13] as well as two additional lines, larger than the criterion line by 1 and 2 logarithm of the minimum angle of resolution units, respectively. Testing with three optotype sizes in addition to the 10/100 size allowed between-optotype agreement for HOTV and Lea symbols to be compared at several acuity levels.

Physically, each test consisted of (1) a 18 cm × 18 cm lap card on which the four optotypes were printed; (2) four 9 cm × 9 cm cards containing single optotypes used during pretesting; (3) a 49 cm × 17.3 cm card on which was printed a line of the four 10/100 optotypes surrounded by a crowding bar; and (4) two books, one for 3-year-olds and one for 4-year-olds, each containing three 8.4 cm × 23 cm pages on which were printed single lines of five optotypes. For each book, opening the book from one side allowed sequential presentation of pages for testing the right eye. Opening the book from the other side allowed sequential presentation of pages for testing the left eye.

Each line of optotypes was surrounded on all sides by a bar (crowding contour). The bars were extended to touch, thereby forming a crowding rectangle around each line of optotypes. The average distance between the optotypes and the crowding rectangle was 0.5-optotype width. Interoptotype distance averaged 1-optotype width.

Procedure

The HOTV and the Lea symbols tests were part of the battery of Phase I VIP screening tests performed by optometrists or ophthalmologists experienced in working with children and who were trained and certified in the VIP Study testing protocols. Before the screening day, teachers were provided with copies of the screening optotypes for both tests and were asked to familiarize the children with the optotypes. The VIP Study staff did not monitor compliance with this request. All the children were tested in a mobile vision van that traveled to the Head Start center each screening day. The van was divided into separate screening rooms. The HOTV and Lea symbols tests were conducted in different rooms by different VIP screeners who were masked to the child's Head Start screening results and the results of the other acuity test. Screeners were also masked as to which children wore spectacles because spectacles were removed at screening check-in. To minimize bias caused by fatigue or learning, the order in which children visited the screening stations was randomly assigned.

For the HOTV and Lea symbols tests, pretesting at near under binocular conditions was used to ensure that the child was able to identify the four optotypes. The examiner showed cards containing single, large optotypes to the child at a distance of about 1 m. The child's task was to match each optotype to the correct one on a lap card or to identify the optotype verbally. The child was allowed two attempts to identify each optotype. If the child could not identify the four optotypes, the child was classified as "unable," and the testing procedure ended.

If the child successfully completed pretesting, the examiner began monocular testing of the right eye. Test distance was 3 m. The left eye was occluded with an adhesive eye patch. If the child refused the patch even after coaxing, the child was permitted to occlude the eye with the palm (but not the fingers) of his or her hand. The examiner began monocular testing with the 10/100 card, followed by the optotypes in the age-specific book. Three of three or three of four optotypes had to be identified correctly for testing to progress to the next smallest optotype size. If the child responded verbally with a symbol that was not one of the four on the test, the child was asked to respond by matching using the lap card. If the examiner noticed that a child gave a response while not paying attention to the visual acuity task, that response was ignored. The examiner refocused the child's attention on the task and continued testing. The testing procedure was repeated for the left eye with the right eye occluded.

The screening visual acuity was recorded as the smallest optotype size for which the child was able to identify three of three or three of four optotypes. Testing was scored as "incomplete" if the child became uncooperative at any point during monocular testing or if the child had to leave the screening because of scheduling constraints.

Data Analysis

Confidence intervals (CIs) for proportions were calculated using the Wilson method.[17] Comparisons between the two visual acuity tests of the proportions of children unable to successfully complete the pretest and of children who did not complete the entire testing procedure were performed using the McNemar exact test for paired proportions. The association of age with visual acuity test results was assessed with the exact Cochran-Mantel-Haenszel test for linear trend. The distributions of results from the two visual acuity tests were compared using the Cochran Q test for marginal

homogeneity[18] and with the Wilcoxon signed rank test to detect a shift (overall higher or lower scores on the HOTV test). A generalized weighted least squares model was used to assess whether results from the right eye were different from results with the left eye. Calculations were performed using Confidence Interval Analysis CIA 2.1.0 software (University of Southampton, Southampton, Hampshire, UK) and SAS/STAT 8.0 software (SAS Institute, Cary, NC).

RESULTS

Binocular Pretest

The binocular pretest for both tests was presented to 1253 children. Because the primary purpose of this article is to compare the two visual acuity screening tests, data from four children who left the screening van before one of the pretests could be initiated were excluded from the analysis. Among the 1253 children, the binocular pretest was successfully completed by 1236 (98.6%; 95% CI, 97.8%, 99.2%) children for the HOTV letter test and by 1238 (98.8%; 95% CI, 98.0%, 99.3%) children for the Lea symbols test. The proportion of children who could complete the binocular pretest did not differ for the two tests ($p = 0.83$). For the HOTV test, the percentage able to complete the pretest successfully increased slightly with the child's age on the day of screening (Fig. 2; $p = 0.01$), although there was a slight decrease between ages 4 and 5 years. An increase in success rate with age was also observed for the Lea symbols test ($p = 0.02$). Overall, >95% of each age group was able to perform the pretest for the HOTV test and the Lea symbols test.

Visual Acuity Test Results

In addition to the 34 eyes of 17 children who were unable to pass the HOTV pretest, there were 20 eyes of 12 children (1.0%) with an incomplete HOTV test. In addition to the 30 eyes of 15 children who were unable to pass the Lea symbols pretest, there were 15 eyes of 11 children (0.9% of 1253) with an incomplete Lea symbols test. There was no difference in the rate of incomplete test results for the two tests ($p = 1.0$). The proportion of children with incomplete testing was similar across age groups for the HOTV test ($p = 0.29$) and the Lea symbols test ($p = 0.82$). Data collection errors after the pretest were responsible for an additional 2 eyes not having a Lea symbols test result and an additional 13 eyes not having an HOTV test result. After accounting for these exclusions, there were 2456 eyes of 1237 children having results from the HOTV test and the Lea symbols test available for comparison.

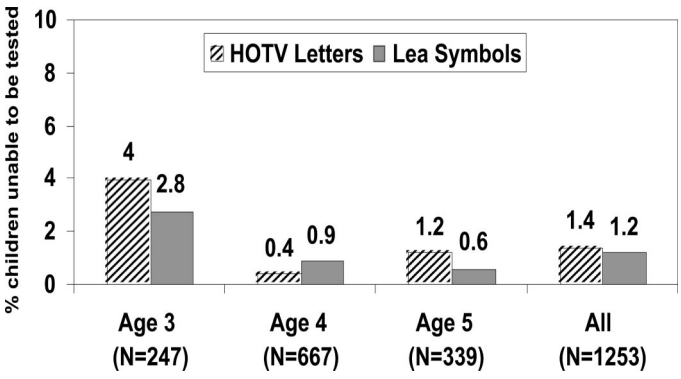

FIGURE 2.

Percentage of children who were unable to complete the binocular pretest for the HOTV letter and Lea symbols tests by age of the child at screening. Number above each bar shows the percent value for that bar.

In the primary analyses presented below, only results from right eyes (1236 children) are reported. This decision was made because of the high correlation between right and left eyes in results from the HOTV test (Spearman $r = 0.78$; $p < 0.001$) and the Lea symbols test (Spearman $r = 0.78$; $p < 0.001$). The difference between HOTV and Lea symbols acuity results for right eyes also was significantly correlated with the difference between the HOTV and Lea symbols acuity results for left eyes (Spearman $r = 0.41$; $p < 0.001$).

Table 1 compares the HOTV test result with the Lea symbols test result for the right eyes of the 1236 children. The overall distribution of the percentage of children in each category for the HOTV vs. Lea symbols tests appears similar. For example, 65.5% of the children passed the card with the smallest age-specific HOTV optotypes, and 66.7% of the children passed the smallest age-specific Lea symbols card. However, closer inspection reveals some evidence of higher testability on the Lea symbols ($p = 0.047$). Modeling of the distributions of test results identified the difference between the HOTV and the Lea symbols test results as primarily attributable to the difference in the percentage of children able to successfully complete the binocular pretest but unable to pass the monocular 10/100 card. Overall, 2.6% of children were unable to pass the monocular 10/100 card for the HOTV test, whereas 1.3% were unable to pass the monocular 10/100 card for the Lea symbols test. The higher failure rate for the HOTV 10/100 card than for the Lea symbols 10/100 card was present for 3-year-olds (4.2% vs. 2.3%), 4-year-olds (2.2% vs. 1.4%), and 5-year-olds (2.2% vs. 0.9%). Examination of Table 1 shows that there were identical results on the two tests in 832 of 1236 eyes (67.3%). The simple κ statistic and 95% CI for agreement was 0.38 (0.34, 0.42). This level of agreement is considered to be fair.[19]

The pattern of agreement between the HOTV test and the Lea symbols test varied with the age of the child at the time of screening (Fig. 3). Exact agreement between test results was observed in 142 of 242 (58.7%) 3-year-olds, 456 of 659 (69.2%) 4-year-olds, and 234 of 335 (69.9%) 5-year-olds ($p = 0.009$). When the test results were not identical, 3-year-old children tended to have worse results on the HOTV letter test, but there was no tendency for 4- and 5-year-old children to have worse visual acuity on either test.

All the aforementioned analyses were repeated for the results of left eyes and for the results of the child's worse eye for each test. Patterns of agreement were similar to those for the right eye (data not shown). There also were no systematic differences between the results of right eyes (always tested first) and left eyes on the data from either the Lea symbols test or the HOTV test ($p > 0.40$).

DISCUSSION

The present study provides a comparison of vision screening results obtained from 1253 three- to five-year-old children, each of whom was tested with two sets of optotypes—the letters H, O, T, and V vs. the four Lea symbols (apple, house, circle, and square). The optotypes were presented using identical testing procedures in

TABLE 1.
Comparison of the results of testing with HOTV and Lea symbols optotypes[a]

	HOTV CARDS [N (%)]						
	3 Age-specific Cards	2 Age-specific Cards	1 Age-specific Card	10/100	Missed 10/100	Unable	Total
LEA CARDS [N (%)]							
3 Age-specific cards	700 (56.6)	63 (5.1)	30 (2.4)	19 (1.5)	10 (0.8)	2 (0.2)	824 (66.7)
2 Age-specific cards	79 (6.4)	40 (3.2)	23 (1.9)	15 (1.2)	4 (0.3)	2 (0.2)	163 (13.2)
1 Age-specific card	20 (1.6)	28 (2.3)	41 (3.3)	22 (1.8)	4 (0.3)	2 (0.2)	117 (9.5)
10/100	8 (0.6)	22 (1.8)	26 (2.1)	39 (3.2)	5 (0.4)	4 (0.3)	104 (8.4)
Missed 10/100	1 (0.1)	0 (0.0)	1 (0.1)	6 (0.5)	7 (0.6)	1 (0.1)	16 (1.3)
Unable	2 (0.2)	2 (0.2)	0 (0.0)	1 (0.1)	2 (0.2)	5 (0.4)	12 (1.0)
Total	810 (65.5)	155 (12.5)	121 (9.8)	102 (8.3)	32 (2.6)	16 (1.3)	1236 (100.0)

[a] Each cell shows number of right eyes and in parentheses the percent of total number of right eyes.

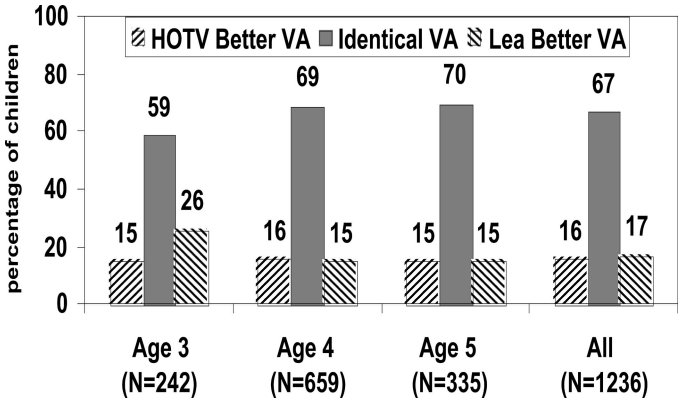

FIGURE 3.
Percentage of children who showed better HOTV than Lea symbols visual acuity (bars with right diagonal lines), equal HOTV and Lea symbols visual acuity (gray bars), and better Lea symbols than HOTV letter visual acuity (bars with left diagonal lines), plotted by age at screening (right eye only). Number above each bar shows the percent value for that bar.

identical formats designed to overcome the limitations found in many preschool visual acuity tests. Overall, testability was high for both tests (98.6% for HOTV letters and 98.8% for Lea symbols; Fig. 2), even among the 3-year-olds. The testability reported here for 3-year-olds would probably be lower if the sample included young 3-year-old children (36 to 40 months of age).[20, 21]

Examination of Table 1 shows that the smallest age-specific line (10/20 for 3-year-olds and 10/16 for 4- and 5-year-olds) was passed by 65.5% of children when tested with HOTV letters and by 66.7% of children when tested with Lea symbols. These data cannot be interpreted as representative of visual acuity in the general population of preschoolers because the study population was enriched with children suspected of having vision problems.

The only previous study comparing testability of 3- to 5-year-old children for HOTV letters and Lea symbols optotypes was conducted by Hered et al.[15] Overall testability was high in the Hered et al. study and in the present study but was significantly higher in the present study than in the Hered et al. study for HOTV letters (98.6% vs. 93%; $p < 0.001$) and Lea symbols (98.8% vs. 95%; $p < 0.001$). The higher testability in the current study may be attributed to (1) a lower percentage of 3-year-olds in the current study (20% vs. 41%); (2) differences in personnel (study certified optometrists and pediatric ophthalmologists in the current study vs. trained testers from Prevent Blindness Florida in the Hered et al. study; (3) differences in the level of distractions present in the screening environment (a mobile medical unit in the current study vs. schools in the Hered et al. study); and (4) differences in the criteria used to define whether a child was testable (the child's ability to identify the isolated optotypes binocularly at 1 m in the current study vs. the screener's judgment that the child was cooperative and gave appropriate responses on monocular testing at 10 feet in the Hered et al. study).

Comparison of screening visual acuity results between the two tests using the simple κ statistic showed fair overall agreement ($\kappa = 0.38$), with an age-related increase in the proportion of children who had identical screening acuity results. There is some evidence in the present study that the HOTV test may have been slightly more difficult for the children than the Lea symbols test. Although the percentage of children who were classified as untestable was similar for both tests, there was a difference in the percentage of children who were able to pass the binocular pretest at 1 m but were unable to pass the 10/100 line at 3 m when tested monocularly (right eye). For HOTV 2.6% of children were unable to pass the 10/100 line, whereas for Lea symbols 1.3% of children were unable to pass the 10/100 line, a twofold difference. This difference was found for each of the three age groups. Although it is likely that a small number of children were unable to pass the 10/100 line because they could not see it, vision deficits alone should not have caused a difference in the failure rate between the two tests.

There is also an age effect in the visual acuity results found for the two tests. When screening acuity results on the two tests were not identical, 3-year-olds more frequently showed poorer acuity for HOTV letters than for Lea symbols. Four- and 5-year-olds did not show this bias. Hered et al.[20] also found poorer visual acuity with the HOTV test than with Lea symbols for 3-year-olds but not for 4- and 5-year-olds.

In conclusion, the results of this study show that the vision of nearly all 3- to 5-year-old children can be screened using either HOTV letters or Lea symbols when these optotypes are arranged as isolated 5-optotype lines surrounded by crowding bars and presented at a test distance of 3 m while using a lap card. Comparison of visual acuity screening results between the two tests indicated

that HOTV letters may be slightly more difficult than Lea symbols for 3- to 5-year-old children, with the largest difference between acuity results on the two tests occurring in 3-year-olds.

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APPENDIX
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