1040-5488/03/8011-0753/0 VOL. 80, NO. 11, PP. 753–757
OPTOMETRY AND VISION SCIENCE

ORIGINAL ARTICLE

Testability of Preschoolers on Stereotests Used to Screen Vision Disorders

THE VISION IN PRESCHOOLERS STUDY GROUP

ABSTRACT: *Objective.* The purpose was to determine whether preschool children aged 3 years 0 months through 3 years 6 months could be tested with the Random Dot E, Stereo Smile, and Randot Preschool stereoacuity tests, which are random dot stereotests marketed for use with preschoolers. *Methods.* A total of 118 children from five Vision In Preschoolers Study Clinical Centers participated. Strabismic children, as determined by the cover test at distance and near, were excluded from this study. Stereopsis was tested on each child using each of the three tests in a variable, balanced order. A child's testability for each test was determined by the ability to complete the nonstereo task (pretest) and the gross stereo task for each stereotest. Proportions of children able to perform each test were compared using statistical methods accommodating multiple measurements per child. *Results.* Testability of children on the pretest was greater for the Stereo Smile test (91%) than for the Random Dot E test (81%; p = 0.007) or the Randot Preschool test (71%; p < 0.0001) and greater for the Random Dot E test than for the Randot Preschool test (p = 0.02). For all children, testability on the gross stereo task was greater for the Stereo Smile (77%; p < 0.0001) and Random Dot E (74%; p = 0.005) tests than for the Randot Preschool test (56%) but did not differ significantly between the Stereo Smile and Random Dot E tests (p = 0.19). There were no significant differences among the proportion of children able to complete the gross stereo task among those who were testable on the pretest (p > 0.12, all comparisons). *Conclusions.* Among preschoolers aged 3 years 0 months through 3 years 6 months, testability differs significantly across the three commercially available random dot stereotests evaluated. The results suggest that two-choice procedures increase testability of young preschoolers. (Optom Vis Sci 2003;80:753–757)

Key Words: stereoacuity, stereopsis, early intervention, preschool children

Amblyopia, strabismus, and significant refractive error are important causes of visual impairment in childhood. These disorders and their estimated prevalence in children include amblyopia (2% to 5%), strabismus (3% to 4%), and significant refractive errors (15% to 30% depending on the threshold definition for significant refractive error).[1–5]

Stereoacuity is a measure of the quality of depth perception, and reduced stereoacuity can be a sign of amblyopia, strabismus, and/or amblyogenic refractive error. Accordingly, stereotesting is included in the recommendations for preschool vision screening issued by the Preschool Vision Screening Task Force.[6]

Theoretically, screening with visual acuity and stereoacuity tests may be useful because together the two tests cover the primary disorders targeted for detection in preschoolers. Specifically, visual acuity tests may detect decreased acuity often associated with amblyopia and uncorrected refractive error, whereas stereoacuity tests may detect reduced depth perception frequently associated with amblyopia, strabismus, and anisometropia (unequal refractive error between the two eyes).[1, 2]

Stereotesting has been evaluated in 10 vision-screening studies including preschool-age children, seven that include quantitative results.[7–16] Some studies have demonstrated the usefulness of stereoacuity alone; others report the results when stereotesting is used in combination with visual acuity or retinoscopy in screening preschool children. When preschool children are pretrained, testability is higher than when pretraining is not performed. Studies that provide quantitative results include the testability of children on nonrandom-dot stereotests. Such tests are compromised by monocular depth cues. Furthermore, all studies report testability for a wide range of ages and do not provide specific information about the testability of only the youngest preschool children.

Therefore, although screening guidelines recommend stereotesting, previous studies have not compared the testability of young preschool children on random dot stereotests marketed for use in 3- to 5-year-old children (the Random Dot E test, the Stereo Smile test, and the Randot Preschool test). When pretraining is used for each of the three tests, comparing the testability of the youngest preschool children on each of the tests could provide the following useful information:

1. Choosing a test to evaluate stereopsis as part of a comprehensive vision examination or to monitor the effect of treatment for refractive, strabismic, or amblyopic disorders.
2. Determining testability for the youngest preschool children using the Random Dot E Stereotest, currently included in many preschool vision screening guidelines.
3. Comparing testability of young preschool children on the RDE Stereotest with testability on two other commercially available random dot stereotests especially targeted for use with young children.
4. Providing guidance as to which commercially available stereotests are usable with the youngest preschoolers. Such tests would then be suitable for evaluation of their effectiveness (sensitivity and specificity) as screening tests to detect amblyopia, strabismus and significant refractive error in 3- and 4-year-old preschool children.

Therefore, the primary purpose of this study was to compare the percentage of young preschool children, aged 3 years 0 months through 3 years 6 months, who (1) were able to complete the nonstereo pretest as pretraining and (2) demonstrated large-disparity random dot stereopsis on each random dot stereo test.

METHODS

Stereotest Selection

Based on a review of the literature,[7–16] the following stereotests were selected for this study: (1) the Random Dot E test (Stereo Optical, Chicago, IL), (2) the Stereo Smile test (Stereo Optical), and (3) the Randot Preschool test (Stereo Optical). These tests have some or all of the following desirable attributes: (1) random dot stereoacuity targets, (2) can be completed by either pointing to or matching the stimulus, (3) targets are designed to be identifiable by most preschool children, and (4) targets are designed to be of interest to preschool children.

Subjects

To participate in the study, children had to be between 3 years 0 months and 3 years 6 months of age, inclusive. Strabismic children, as determined by near and distance cover testing, were excluded from the study. We wanted to limit participation to children who could be expected to do the gross stereo task. No children were excluded based on their refractive error.

A total of 118 preschool children, predominantly Head Start participants, from Vision In Preschoolers (VIP) Study Clinical Centers in Berkeley, California; Boston, Massachusetts; Columbus, Ohio; Philadelphia, Pennsylvania; and Tahlequah, Oklahoma participated. Head Start is a federally-funded early-childhood development program that provides comprehensive developmental service to preschoolers aged 3 to 5 years who come from low-income American families.[17] Head Start children were the focus of this investigation because children enrolled in Head Start are at higher risk for developmental delays than their counterparts in the general population.[17]

Requirements for the participation of human subjects were met at each of the five VIP Study Clinical Center affiliated institutions. Written, informed consent was obtained from each child's parent or legal guardian before testing.

Testing Procedures

Each child was tested using each of the three tests (Random Dot E, Stereo Smile, and Randot Preschool) in a predetermined, variable, balanced order prescribed for each VIP Study Clinical Center. For each test, a nonstereo task (pretest) was conducted first. A nonstereo pretest was established for each of the three stereotests. In order for the child to proceed to the stereo task, the nonstereo pretest had to be successfully completed. The pretest was performed using the nonstereo images unique to each test to demonstrate the child's ability to understand the task and to identify, match, or point to the test symbol required for completion of each stereotest. Children who were able to complete the pretest were then immediately presented a gross stereo task for each test (Random Dot E, Stereosmile, andRandot Preschool). The gross disparities (504, 480, and 800 sec arc, respectively) were the largest disparities associated with the viewing distance (50, 55, and 40 cm, respectively) for each test. Children were classified as testable or untestable for both the pretest and the gross stereo task. Polarizing glasses were worn for both the pretest and the stereotest. Standardized lighting ($>$85cd/m^2) was used at each VIP Study Clinical Center for all tests.

Random Dot E Test. For pretesting, the model E card was placed at a 50-cm viewing distance, and the child was directed to point to the E (Fig. 1A). Next, the model E card and a blank test card were shuffled behind the tester's back and presented at 50 cm. The child was again directed to point to the card with the E on it. Thus, the child's response was a two-choice task. This procedure was repeated up to four more times, varying the position (left, right, up, and down) of the E. For each presentation during testing, the proper orientation of the E was maintained. If the child missed more than one of the five presentations, the test was stopped, and the child was classified as untestable. If the child correctly identified 4 of 4 or 4 of 5 presentations, the child was classified as testable on the Random Dot E pretest. Children had an 18.75% chance of passing this phase of testing by guessing at random.

Children who were testable on the pretest with the model E were then presented a stereo E vs. the blank test card up to five times at a distance of 50 cm (504 sec arc of disparity), with the position (left, right, up, and down) of the stereo E varied from presentation to presentation. If the child missed more than one of the five presentations, the test was stopped, and the child was classified as unable to do the gross stereo task. If the child correctly identified the position of the stereo E on 4 of 4 or 4 of 5 presentations, the child was classified as able to do the gross stereo task.

Stereo Smile Test. For the pretest, the training card was placed at a 55-cm viewing distance, and the child was directed to point to the model smile face (Fig. 1B). Next, the training card was flipped so that the smile face appeared on the opposite (right-left) side and the child was again directed to point to the smile face. This procedure was repeated up to four times, varying the position (left-right) of the smile face. The child's response was a two-choice task. If the child missed $>$1 of the 5 presentations, the test was stopped, and the child was classified as untestable. If the child correctly identified 4 of 4 or 4 of 5 presentations, the child was classified as testable on the Stereo Smile pretest. After pretesting the child with the model smile face, the tester presented the stereo smile stereo test card at a distance of 55 cm (480 sec arc of disparity) up to five times, with the left-right position of the smile face varied from presentation to presentation. If the child missed >1 of the 5 presentations, the test was stopped, and the child was classified as unable to do the gross stereo task. If the child correctly identified the position of the stereo smile on 4 of 4 or 4 of 5 presentations, the child was classified as able to do the gross stereo task at 480 sec arc. Children had an 18.75% chance of passing this phase of testing by guessing at random.

Randot Preschool Test. For pretesting, Book #3 was opened and placed at a 40-cm viewing distance (Fig. 1C). The bottom set of pictures was covered to focus the child's attention. The child was directed to identify or point to each of the four nonstereo, two-dimensional shapes on the top left-hand page of the book (elephant, heart, square, and duck). If the child identified 0, 1, or 2 shapes, the test was stopped, and the child was classified as untestable. If the child identified 3 or 4 shapes correctly, the child was classified as testable on the Randot Preschool pretest. Children had a 5.08% chance of passing this phase of testing by guessing at random.

After pretesting the child with the two-dimensional shapes, the tester showed the child the top set of stereo plates in Book #3 at 40 cm (800 sec arc of disparity). The bottom sets of pictures and stereo plates were covered to focus the child's attention. The child was directed to identify the shapes seen in the stereo plates on the top right-hand page of the book (heart, square, and duck) or to match them to the identical nonstereo shapes on the top left-hand page of the book. If the child identified 0 or 1 shape, the test was stopped, and the child was classified as unable to do the gross stereo task. If the child identified at least 2 of 3 shapes, the child was classified as able to do the gross stereo task.

FIGURE 1.
A: Random Dot E Stereotest; B: Randot Stereo Smile Test; C: Randot Preschool Stereoacuity Test. Color version of this figure is available at www.optvissci.com.

Methods of Analysis

Proportions of children testable with each test were compared using the generalized estimating equations approach to logistic regression that accommodates multiple, possibly unequal in number, tests per child. Calculations were performed using SAS/STAT 8.0 software (SAS Institute, Cary, NC).

RESULTS

A total of 117 children were tested on the Random Dot E and Randot Preschool tests; 118 children were tested on the Stereo Smile test. Two children did not complete all three tests because of scheduling problems; one child did not complete the Random Dot E test, and the other child did not complete the Randot Preschool test.

Pretesting

As shown in Table 1, testability on the pretest was significantly greater for the Stereo Smile test (91%) than for the Random Dot E test (81%; $p = 0.007$) or the Randot Preschool test (71%; $p < 0.0001$) and greater for the Random Dot E test than for the Randot Preschool test ($p = 0.02$)

Stereotesting

As shown in Table 2, the percentage of all children able to complete the gross stereo task was statistically significantly higher for the Stereo Smile (77%) and the Random Dot E (74%) tests, than for the Randot Preschool test (56%; $p < 0.0001$ and 0.005, respectively). The difference between the Stereo Smile and Ran-

TABLE 1.
Testability of young preschool children on nonstereo test-related tasks.[a]

Stereotest	N	Testable
Random Dot E	95/117	81%
Preschool Randot	83/117	71%
Stereo Smile	107/118	91%

[a] p Values for comparisons: 0.02 for Random Dot E vs. Preschool Randot; 0.007 for Random Dot E vs. Stereo Smile; $<$ 0.0001 for Preschool Randot vs. Stereo Smile.

TABLE 2.
Ability of young preschool children to complete gross disparity random dot stereo tasks.[a]

Stereotest (Criterion in sec arc, testing distance)	Among All Children		Among Children Testable On Nonstereo Task	
	N	%	N	%
Random Dot E (504 sec arc, 50 cm)	87/117	74	87/95	90
Preschool Randot (800 sec arc, 40 cm)	66/117	56	66/83	80
Stereo Smile (480 sec arc, 55 cm)	91/118	77	91/107	85

[a] p Values for comparisons: For all children, testability on the gross-stereo task was greater for the Stereo Smile (77%; $p < 0.0001$) and Random Dot E (74%; $p = 0.005$) tests than for the Randot Preschool test (56%) but did not differ significantly between the Stereo Smile and Random Dot E tests ($p = 0.19$). There were no significant differences among the proportion of children able to complete the gross-stereo task among those testable for each test ($p > 0.12$, all comparisons).

dom Dot E tests was not significant ($p = 0.19$). Among children testable on the nonstereo task, the percentage of children able to complete the gross stereo task was similar for the Random Dot E (90%), Stereo Smile (85%), and Randot Preschool (80%) tests. There were no significant differences among the proportion of children able to complete the gross stereo task among children testable on the corresponding nonstereo task ($p > 0.12$, all comparisons).

DISCUSSION

Pretesting

Among children aged 3 years 0 months through 3 years 6 months, 71% to 91% were able to perform the nonstereo tasks required to complete subsequent stereopsis testing on three commercially available random dot stereotests marketed for use with young children. For the nonstereo tasks, more children were able to carry out the two-choice pointing task required for the Stereo Smile (91%) and Random Dot E tests (81%) than the task of verbally identifying or pointing to shapes used in the Randot Preschool test (71%). These response rates differ significantly from one another. At age 3 years 0 months to 3 years 6 months, children are just beginning preschool and identifying or pointing to multiple shapes may be too difficult. In addition, using the scoring criteria specified in the instructions provided with each test, children could pass the two-alternative-choice tests by guessing at random with a probability of 18.75%. However, the Randot Preschool test scoring criterion allowed passing by guessing at random with a probability of 5.08%. Furthermore, significantly more children were able to point to the "smile face" stimulus than the more abstract E stimulus, supporting the saliency of the face stimulus in testing young children, as has been previously reported.[18]

Stereotesting

Of the children testable on the nonstereo task, a high percentage of young preschoolers (85% to 90%) were able to perform the gross random dot stereoacuity. Because no child was strabismic on cover testing and the disparity of the stereo targets for all three tests were above age-specific norms for stereoacuity,[19–27] we expected that the great majority of children would be able to detect the gross disparity target. Inability to perform the stereo task among children who had been able to perform the nonstereo task may be attributable to increased complexity of identifying a shape from a dot image rather than a solid image. Normal binocularity requires a short period of time for perception of a stereo image to form. Some young 3-year olds may not be able to sustain attention on the stereo stimulus long enough for the perception of the stereo image to develop. Children were not excluded from the study based on refractive error, so some of the children with no measurable stereopsis may have lacked gross stereopsis due to anisometropia or high refractive error. The percentages of children able to complete gross random dot stereoacuity testing drop to 56% to 77% when all children, testable and untestable on the nonstereo task, were included in the analysis.

CONCLUSIONS

Among preschoolers aged 3 years 0 months through 3 years 6 months, the testability, as determined by a nonstereo task, differs significantly across the three commercially available random dot stereotests evaluated. Approximately 75% of the children were able to perform the nonstereo task and the gross disparity stereo test for both the Stereo Smile test and the Random Dot E test. The testability for the Stereo Smile test was greater than for the Random Dot E test, and the testability for the Random Dot E test was greater than for the Randot Preschool test. The results suggest that stereotests that employ two-choice procedures increase testability of young preschoolers.

Writing Committee

Paulette P. Schmidt, OD, MS (Chair); Maureen G. Maguire, PhD; Bruce Moore, OD; and Lynn Cyert, PhD, OD.

Vision in Preschoolers Study Group Executive Committee

Elise Ciner, OD, FAAO, Pennsylvania College of Optometry, Philadelphia, Pennsylvania; Lynn Cyert, PhD, OD, FAAO, Northeastern State University, College of Optometry, Tahlequah, Oklahoma; Velma Dobson, PhD, FAAO, Department of Ophthalmology, University of Arizona, Tucson, Arizona; Beth Haas, The Ohio State University, College of Optometry, Columbus, Ohio; Marjean Taylor Kulp, OD, MS, FAAO, The Ohio State University, College of Optometry, Columbus, Ohio; Maureen Maguire, PhD, FAAO, Department of Ophthalmology, University of Pennsylvania, Philadelphia, Pennsylvania; Bruce Moore, OD, FAAO, The New England College of Optometry, Boston, Massachusetts; Deborah Orel-Bixler, PhD, OD, FAAO, University of California Berkeley, School of Optometry, Berkeley, California; Ellen Peskin, MA, Department of Ophthalmology, University of Pennsylvania, Philadelphia, Pennsylvania; Graham Quinn, MD, MSCE, FACS, FAAP, Division of Pediatric Ophthalmology, The Children's Hospital of Philadelphia, Philadelphia, Pennsylvania; Maryann Redford, DDS, MPH, National Eye Institute, Bethesda, Maryland; Paulette P. Schmidt, OD, MS, FAAO, The Ohio State University, College of Optometry, Columbus, Ohio (Chair); and Janet Schultz, RN, MA, CPNP, University of Maryland University College, Early Head Start, Adelphi, Maryland.

ACKNOWLEDGMENTS

Supported, in part, by funds from the institution of each VIP Study Group member; affiliated Head Start and Preschool Programs in Berkeley, Boston, Columbus, Philadelphia, and Tahlequah; and Precision Vision and Amblyopia Treatment Trials. Further support was provided by the Cherokee Nation Head Start to Dr. Cyert; National Eye Institute, National Institutes of Health grant EY05804 to Dr. Dobson; an unrestricted gift to the University of Pennsylvania from Research to Prevent Blindness to Dr. Maguire; unrestricted funds to The Ohio State University College of Optometry and the Morris Funds to Dr. Schmidt; and National Eye Institute, National Institutes of Health grant T35 EY07151 to The Ohio State University (Dr. Mark Bullimore).

Received January 16, 2003; revision received August 23, 2003.

REFERENCES

1. Ciner EB, Schmidt PP, Orel-Bixler D, Dobson V, Maguire M, Cyert L, Moore B, Schultz J. Vision screening of preschool children: evaluating the past, looking toward the future. Optom Vis Sci 1998;75: 571–84.
2. Schmidt PP. Screening for the vision problems of young children. In: Moore BD, ed. Eye Care for Infants and Young Children. Boston, MA: Butterworth-Heinemann; 1997;175–89.
3. Gerali P, Flom M, Raab E. Report of the Children's Vision Screening Task Force. Schaumburg, IL: National Society to Prevent Blindness, 1990.
4. von Noorden GK. New clinical aspects of stimulus deprivation amblyopia. Am J Ophthalmol 1981;92:416–21.
5. Ciuffreda KJ, Levi DM, Selenow A. Amblyopia: Basic and Clinical Aspects. Boston: Butterworth-Heinemann; 1991;10–4.
6. Hartmann EE, Dobson V, Hainline L, Marsh-Tootle W, Quinn GE, Ruttum MS, Schmidt PP, Simons K. Preschool vision screening: summary of a Task Force report on behalf of the Maternal and Child Health Bureau and the National Eye Institute Task Force on Vision Screening in the Preschool Child. Pediatrics 2000;106:1105–16.
7. Fern K. A comparison of vision screening techniques in preschool children. Invest Ophthalmol Vis Sci. 1991;32(Suppl):962.
8. Birch E, Williams C, Hunter J, Lapa MC, the ALSPAC "Children in Focus" Study Team. Random dot stereoacuity of preschool children. J Pediatr Ophthalmol Strabismus 1997;34:217–22; quiz 47–8.
9. Rosner J. The effectiveness of the random dot E stereotest as a preschool vision screening instrument. J Am Optom Assoc 1978;49: 1121–4.
10. Ruttum MS, Nelson DB. Stereopsis testing to reduce overreferral in preschool vision screening. J Pediatr Ophthalmol Strabismus 1991; 28:131–3.
11. Schmidt PP. Vision screening with the RDE stereotest in pediatric populations. Optom Vis Sci 1994;71:273–81.
12. Hammond RS, Schmidt PP. A Random Dot E stereogram for the vision screening of children. Arch Ophthalmol 1986;104:54–60.
13. Peduti-Cuhna L, Caldeira J. Stereopsis and visual acuity: their combined importance in eye screening preschool children. Binocular Vis Q 1990;5:65–70.
14. Williams C, Birch EE, Emmett PM, Northstone K. Stereoacuity at age 3.5 y in children born full-term is associated with prenatal and postnatal dietary factors: a report from a population-based cohort study. Am J Clin Nutr 2001;73:316–22.
15. Ruttum M. Visual screening with random dot stereograms. Semin Ophthalmol 1988;3:175–80.
16. Marsh-Tootle WL, Corliss DA, Alvarez SL, Clore KA, Daum KM, Gordon A, Houston G, Perry FF, Swanson MW. A statistical analysis of Modified Clinical Technique vision screening of preschoolers by optometry students. Optom Vis Sci 1994;71:593–603.
17. U.S. Department of Health and Human Services. Head start: promoting early childhood development. Available at: http://www.hhs.gov/news/press/2002pres/headstart.html. Accessed August 19, 2002.
18. Fantz RL. Pattern vision in young infants. Psychol Rec 1958;8:43–7.
19. Romano PE, Romano JA, Puklin JE. Stereoacuity development in children with normal binocular single vision. Am J Ophthalmol 1975;79:966–71.
20. Cooper J, Feldman J. Random-dot-stereogram performance by strabismic, amblyopic, and ocular-pathology patients in an operant-discrimination task. Am J Optom Physiol Opt 1978;55:599–609.
21. Simons K. Stereoacuity norms in young children. Arch Ophthalmol 1981;99:439–45.
22. Heron G, Dholakia S, Collins DE, McLaughlan H. Stereoscopic threshold in children and adults. Am J Optom Physiol Opt 1985;62: 505–15.
23. Birch E, Hale L. Operant assessment of stereoacuity. Clin Vision Sci 1989;4:295–300.
24. Ciner EB, Schanel-Klitsch E, Scheiman M. Stereoacuity development in young children. Optom Vis Sci 1991;68:533–6.
25. Birch EE, Salomao S. Infant random dot stereoacuity cards. J Pediatr Ophthalmol Strabismus 1998;35:86–90.
26. Orel-Bixler D, Brodie A. Vision screening of infants and toddlers: photorefraction and stereoacuity. Invest Ophthalmol Vis Sci 1995; 36:S868.
27. Ciner EB, Schanel-Klitsch E, Herzberg C. Stereoacuity development 6 months to 5 years: a new tool for testing and screening. Optom Vis Sci 1996;73:43–8.

The Vision in Preschoolers Study Center
The Ohio State University
College of Optometry
320 West Tenth Avenue
PO Box 182342
Columbus, OH 43218-2342