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Stereoacuity of Preschool Children with and without Vision Disorders

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Abstract

Purpose—To evaluate associations between stereoacuity and presence, type, and severity of vision disorders in Head Start preschool children and determine testability and levels of stereoacuity by age in children without vision disorders.

Methods—Stereoacuity of children aged 3 to 5 years (n = 2898) participating in the Vision in Preschoolers (VIP) Study was evaluated using the Stereo Smile II test during a comprehensive vision examination. This test uses a two-alternative forced-choice paradigm with four stereoacuity levels (480 to 60 seconds of arc). Children were classified by the presence (n = 871) or absence (n = 2027) of VIP Study–targeted vision disorders (amblyopia, strabismus, significant refractive error, or unexplained reduced visual acuity), including type and severity. Median stereoacuity between groups and among severity levels of vision disorders was compared using Wilcoxon rank sum and Kruskal-Wallis tests. Testability and stereoacuity levels were determined for children without VIP Study–targeted disorders overall and by age.

Results—Children with VIP Study–targeted vision disorders had significantly worse median stereoacuity than that of children without vision disorders (120 vs. 60 seconds of arc, $p < 0.001$). Children with the most severe vision disorders had worse stereoacuity than that of children with milder disorders (median 480 vs. 120 seconds of arc, $p < 0.001$). Among children without vision

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disorders, testability was 99.6% overall, increasing with age to 100% for 5-year-olds ($p = 0.002$). Most of the children without vision disorders (88%) had stereoacuity at the two best disparities (60 or 120 seconds of arc); the percentage increasing with age (82% for 3-, 89% for 4-, and 92% for 5-year-olds; $p < 0.001$).

Conclusions—The presence of any VIP Study–targeted vision disorder was associated with significantly worse stereoacuity in preschool children. Severe vision disorders were more likely associated with poorer stereopsis than milder or no vision disorders. Testability was excellent at all ages. These results support the validity of the Stereo Smile II for assessing random-dot stereoacuity in preschool children.

Keywords

preschool; stereoacuity; stereopsis; children; vision disorders

Stereopsis, or depth perception, is based on the horizontal retinal image disparity between the two eyes. Stereoacuity, which is a threshold measure of the acuteness of this depth perception, provides an indication of the level of sensory binocularity an individual has. Reduced stereoacuity can be associated with vision disorders, including strabismus, amblyopia, or significant refractive error.[1–10] Stereopsis testing is, therefore, often used clinically for detecting vision disorders and monitoring sensory binocularity. Random-dot (global) stereotesting is more effective than contour or line (local) stereotesting for detecting vision anomalies. There are fewer monocular cues for target detection, and perception of the target in depth requires binocular sensory input.[1,9] There are several stereopsis tests that have been designed for younger children and are useful in pre-school settings for both screening and/or examination.[10–16] Two-alternative forced-choice paradigms using random-dot stimuli have been found to have a high testability among younger pre-school children.[17–19] The Stereo Smile II is a portable handheld random-dot stereogram (adapted from an earlier prototype called the Stereo Smile I) using a familiar “smiley face” as the stimulus against a random-dot background.

The Vision in Preschoolers (VIP) Study is a multicenter, multidisciplinary, cross-sectional, two-phased study designed to evaluate the performance of vision screening tests for identifying preschool children with amblyopia, strabismus, significant refractive error, or unexplained reduced visual acuity (VA) who would benefit from a comprehensive vision examination. The results of the VIP Study provide evidence-based guidelines for preschool vision screening.[20–23]

Previous VIP Study results evaluated testability[18,20,22,24] for several measures of stereoacuity in a screening setting including the Random Dot E, Randot Preschool Stereoacuity Test (RPST), and the Stereo Smile II. These studies demonstrated higher testability for the Stereo Smile II screening protocol, along with a higher sensitivity in detecting strabismus amonga preschool population.[18,20,22]

The purpose of this study is to evaluate the association between stereoacuity and the presence, type, and severity of vision disorders in Head Start preschool children and to

determine testability and expected levels of stereoacuity in an examination setting to establish normative data for preschool children without vision disorders.

METHODS

The present study is a secondary analysis of the VIP Study data. The purpose and methods of each of the phases (I and II) of the VIP Study, including exclusion and inclusion criteria, have been previously described.[20,22]

Included in this analysis are the data from the Stereo Smile II conducted in an examination setting where the testing sequence is slightly longer and in which additional trials are required to obtain a threshold of stereoacuity. The VIP Study provided a large cohort of preschool children with and without vision disorders. This allows an assessment of the association between stereoacuity and the presence, type, and severity of vision disorders in Head Start preschool children. It also provides data on the levels of stereoacuity expected in preschool children without vision disorders.

Subjects

A total of 2898 three- to five-year-old children attending preschool Head Start and enrolled in the VIP Study through one of five clinical sites (Berkeley, California; Boston, Massachusetts; Columbus, Ohio; Philadelphia, Pennsylvania; Tahlequah, Oklahoma) during a 2-year period (2002 to 2003) were included in this study. Participants included all children who failed and a random sample (~20%) of children of the same age and from the same school who had passed a standard vision screening. This provided a racially and ethnically diverse population from across the country that was enriched with children who had vision disorders. All children were aged 3 to 5 years based on their age as of September 1 of the academic year they were enrolled in the study.

The VIP Study adhered to the tenets of the Declaration of Helsinki and was approved by the appropriate local institutional review boards associated with each VIP center. Parents or legal guardians of participating children provided written informed consent after explanation of the nature and possible consequences of the study and before testing.

Comprehensive Vision Examinations

All children underwent a comprehensive vision examination that included VA, cover testing, and cycloplegic retinoscopy, as previously described.[20,22] All examinations were completed by licensed eye care professionals; optometrists and ophthalmologists (examiners) who had experience in the examination of young children and who had completed VIP Study–specific training and certification on all examination procedures including stereopsis.[20,22] Comprehensive vision examinations were conducted in one of five identical mobile vision units specifically designed for the VIP Study and outfitted with the same testing conditions (e.g., seating, lighting, and testing equipment) across all five study centers.[25] In addition to providing uniformity in testing conditions, the mobile vision units traveled to the Head Start Centers to enable increased accessibility for participating children and their parents.

Results from the comprehensive vision examinations were used to classify children with respect to the presence of any of the four VIP Study–targeted eye disorders: amblyopia, strabismus, significant refractive error, and unexplained reduced VA. These vision disorders were further classified into three hierarchical severity groups: Group 1 (most severe), Group 2 (moderate), and Group 3 (mild), as previously reported[20,22] (Table 1).

Stereoacuity Testing

Stereoacuity testing was administered as part of the comprehensive vision examination and was assessed with the Stereo Smile II, a two-alternative forced-choice test consisting of the following six cards. A Demonstration or Pretest Card A (non–stereo smile face on a background of a random-dot pattern seen without stereoacuity), a Blank card (random-dot pattern only), and four Test cards, each displaying a random-dot stereo smile face of successively finer levels of disparity in one-octave steps when viewed through polarized glasses at a test distance of 40 cm. These four cards are labeled Card B, 480 seconds of arc; Card C, 240 seconds of arc; Card D, 120 seconds of arc; Card E, 60 seconds of arc (best stereoacuity). The child wears colorful pediatric-sized polarized glasses throughout the testing (Fig. 1).

The examiner conducted a pretest by presenting the Demonstration Card A and asking the child to point to the “Smile” or “Happy Face.” Card A was then paired next to the Blank card at the 40-cm test distance from the child’s eyes. The tops of the cards were tilted slightly back (5 to 10 degrees) toward the examiner to maximize illumination and minimize glare on the cards. If the child passed the demonstration card by correctly pointing to the “Smile” on four of four or four of five presentations, the examiner then presented the Blank card paired with Card B (480 seconds of arc) and repeated the procedure. The order of testing then proceeded from Card B (480 seconds of arc) to Card D (120 seconds of arc), initially skipping Card C (240 seconds of arc). If the child was unable to pass Card D (120 seconds of arc), the examiner next administered Card C (240 seconds of arc), after which the testing stopped. If the child was able to pass Card D (120 seconds of arc), the examiner next administered Card E (60 seconds of arc), after which the testing stopped. This procedure allowed the test to be shortened by one stereoacuity card level (with four to five presentations), thereby reducing test time and fatigue in these young children (Fig. 2).

The examiner randomly varied the left-right position of the cards by shuffling them in a manner that did not allow the child to follow the position of the card or to see the back of the card with identifying information (e.g., stereoacuity level or identification of card as Blank).

The child’s stereoacuity level was the best disparity for which the child was able to obtain four correct responses out of a maximum of five presentations at each disparity level (the child was allowed up to one error at each level). Children who could not complete the Pretest Card A were classified as “unable.” Children who were only able to complete Card A were scored as being testable but having “no measurable stereopsis.”

Statistical Analysis

The distribution of stereoacuity was examined by the proportion of each stereoacuity level (60, 120, 240, 480 seconds of arc, “no measurable stereopsis” or “unable”) and summarized

by the median and the first and third quartiles (without considering “unables” because their stereoacuity was unknown). The comparison of the stereoacuity between children with versus without any VIP Study–targeted vision disorder was performed using the Fisher exact test for comparing proportions (including “unables”) and the Wilcoxon rank sum test for comparison of median (excluding “unables”). Similar comparisons were made for the types of vision disorders (amblyopia, strabismus, significant refractive error, and unexplained reduced VA) and by severity (Groups 1, 2, 3) of vision disorders. The comparison of stereoacuity among severity groups of vision disorders was performed by the Kruskal-Wallis test. The comparison of proportion of “unable” with increasing age groups (3-, 4-, or 5-year-olds) was performed using the Cochran-Armitage Trend Test. All the statistical analyses were performed in SAS version 9.3 (SAS Institute Inc., Cary, NC), and two-sided $p < 0.05$ is considered to be statistically significant.

RESULTS

Of the 2898 participating children, 871 children had one or more VIP Study–targeted vision disorders and 2027 did not have any VIP Study–targeted vision disorder. When stratified by age, 628 (21.7%) of the children were aged 3 years, 1553 (53.6%) were aged 4 years, and 717 (24.7%) were aged 5 years. Consistent with the overall participants, about 30% of the children in each age group were classified as having one or more vision disorders.

In the study, 29 children were unable to complete Card A (termed “unable”). Although the percentage of “unable” was low in both groups of children, the percentage of “unable” was higher in children with vision disorders than in children without vision disorders (2.3 vs. 0.4%, $p < 0.001$; Table 2). Within each group, the percentage of “unable” decreased with age ($p < 0.01$ for test of trend).

Overall, 242 children were able to complete the pretest (Card A) only and were classified as having “no measurable stereopsis.” A significantly higher percentage of children with vision disorders than without vision disorders had “no measurable stereopsis” (212 [24.3%] of 871 vs. 30 [1.5%] of 2027, respectively, $p < 0.001$; Table 2). The percentage of “no measurable stereopsis” tended to decrease with age for children with vision disorders (25.9% in 3-year-olds, 26.2% in 4-year-olds, 18.8% in 5-year-olds, $p = 0.08$ for test of trend) and for children without vision disorders (2.7% in 3-year-olds, 1.2% in 4-year-olds, 1% in 5-year-olds, $p = 0.03$ for test of trend).

The distribution of stereoacuity levels by presence or absence of any vision disorder overall and by age is provided in Table 2. Children with VIP Study–targeted vision disorders had a median stereoacuity of 120 seconds of arc, which is significantly poorer than in those without vision disorders (60 seconds of arc, $p < 0.001$). A similar pattern of differences was seen at each age group (all $p < 0.001$; Table 2).

The distribution of stereoacuity levels by each type of VIP Study–targeted vision disorder is shown in Table 3. Stereoacuity was poorer in children with each type of vision disorder compared with that in children without any of the vision disorders (all $p < 0.001$). Median stereoacuity was “no measurable stereopsis” for children with strabismus, 480 seconds of

arc for children with amblyopia, 240 seconds of arc for children with significant refractive error, and 120 seconds of arc for children with unexplained reduced VA, whereas median stereoacuity was 60 seconds of arc in children without any vision disorder. Furthermore, children with severe (Group 1) vision disorders also had worse stereoacuity than that of children with moderate or mild vision disorders (median stereoacuity of 480, 120, and 120 seconds of arc, respectively, for severe, moderate, and mild vision disorders, $p < 0.001$; Table 4). Compared with children without any vision disorder, children with severe (Group 1) vision disorders were much less likely to achieve the best level (i.e., 60 seconds of arc) of stereopsis (9.2 vs. 64%, $p < 0.001$) and much more likely to demonstrate "no measurable stereopsis" (41.6 vs. 1.5%, $p < 0.001$).

For preschool children without any VIP Study–targeted vision disorder, 88% were able to pass one of the two best levels of stereoacuity (60 or 120 seconds of arc) and ranged from 81.6% in 3-year-olds to 91.6% in 5-year-olds (Table 2). Increasing age was also associated with an increasing percentage of preschool children able to obtain the best level of stereoacuity of 60 seconds of arc (52.2% of 3-year-olds, 64.9% of 4-year-olds, and 71.4% of 5-year-olds, $p < 0.001$ for test of trend).

DISCUSSION

The VIP Study tested a geographically, racially, and ethnically diverse population of Head Start preschool children whose sample population was enriched with vision disorders.[26] Although the study participants may not necessarily be representative of a general population, the higher prevalence of vision disorders in this study population allows assessment of the comparative relationship between stereoacuity levels of preschool children with and without these vision disorders. This association can reasonably be extended to the general population of preschool children. Therefore, this study provides useful clinical information for the testing of stereopsis in preschool children with and without vision disorders.

This study demonstrated a higher testability (>99%) of the Stereo Smile II on 3- to 5-year-old preschool children when compared with other studies that used random-dot tests of stereopsis, with the greatest difference in the cohort of 3-year-old children.[10,11,15,16,27,28] Although the Sydney Paediatric Eye Disease (SPED) Study[27] showed an overall higher testability for the Lang-Stereotest II, only children younger than 30 months were administered the Stereo Smile II, whereas children of all ages (aged 6 to 72 months) were administered the Lang-Stereotest II. It is also not clear whether the actual SPED test procedure used for the Stereo Smile II included the use of the Demonstration Card (A) or a shortened format. Furthermore, the lower testability reported in the SPED Study could be attributable to the fact that testability was defined as an attempt to "match all corresponding figures and completion...of the tests" rather than by an ability for the child to understand the task and complete the demonstration card or monocularly viewed items only. The Stereo Smile II test is an inherently more difficult task because it assesses more and finer (60 seconds of arc) levels of stereoacuity compared with the Lang II (Lang II: 600, 400, 200 seconds of arc; Stereo Smile II: 480, 240, 120, 60 seconds of arc).

Overall, the VIP Study shows that preschool children who were "unable" to complete stereoacuity testing were 5.75 times more likely to have a vision disorder. These findings support an earlier analysis from the VIP Study that showed that children who were tested as "unable" on screening tests including autorefraction and VA were two times more likely to have a vision disorder than children who were testable.[29] This suggests that, in a screening setting, preschool children who test "unable" should be referred for a vision examination. In an examination setting, these results also can be helpful to suggest the presence of a vision disorder. Children who were only able to complete the Demonstration Card A and therefore had "no measurable stereopsis" were 16.2 times more likely to have a vision disorder.

Each vision disorder was also associated with a reduced median level of stereoacuity, which was always worse than that in the population of children without vision disorders and could indicate poor sensory binocularity. Although the presence of strabismus is often accompanied by a severe reduction or absence of stereopsis, the relatively poorer levels of median stereoacuity for each VIP Study–targeted vision disorder provide support that stereoacuity can be an indicator of the level of binocular vision a child has in the presence of any of these disorders. In addition, the inverse relationship between the severity of vision disorders (Groups 1, 2, and 3) and levels of stereopsis (better levels of stereopsis in less severe vision disorders) can be a further indicator of visual function and binocularity and supports the validity of the Stereo Smile II for assessment of stereopsis in preschool children. Thus, there is a significantly decreased likelihood that a child with a severe vision disorder would demonstrate 60 seconds of arc stereopsis. Children with a severe vision disorder have a poorer median level of stereoacuity and are at a relatively high risk of having either poor or "no measurable stereopsis."

The SPED Study compared the diagnostic reliability and normative values of three tests of stereopsis for the detection of amblyopia, strabismus, and anisometropia in children aged 24 to 72 months. The authors concluded that the RPST "was found to be most reliable in detecting ocular conditions" but only performed the Stereo Smile II on a smaller subset of less testable children (younger than 30 months or those unable to complete the RPST) with a very low prevalence of vision disorders, whereas the RPST was only performed on older, more cooperative children (aged 30 to 72 months).[27] In contrast, the VIP Study included a very large cohort of preschool children with vision disorders over a smaller age range (aged 36 to 59 months) that also included children with a significant refractive error.

Future investigations can determine whether stereopsis could be used to monitor and help identify the type of intervention that might be most effective in improving binocularity and evaluating treatment efficacy (e.g., lenses, patching, vision therapy, or surgery) once it is provided.

This study also provides normative data on the expected levels of stereoacuity in preschool children without any VIP Study–targeted vision disorder that are similar to levels found in other studies with random-dot tests designed for preschoolers.[6,15] Most children without VIP Study–targeted vision disorders were able to obtain one of the two best levels of stereoacuity, whereas only a small percentage had either "no measurable stereopsis" or the poorest level. The reduced stereoacuity in a small percentage of children without any VIP

Study–targeted vision disorder may be attributable to other unidentified factors, such as poor visual attention, large accommodative lags, or mild undiagnosed cognitive, visual motor, or visual perceptual deficits, which were beyond the scope of this study. Although the median stereoacuity was the same for all three age groups, the percentage attaining the best levels of stereoacuity (60 or 120 seconds of arc) increased with age (81.6% in 3-year-olds, 89.2% in 4-year-olds, and 91.6% in 5-year-olds, $p < 0.001$), indicating that stereoacuity either may not be fully developed or some children's ability to complete all disparity levels is still improving as they enter the preschool years. When applied in a clinical setting, preschool children with poorer levels of stereoacuity on the Stereo Smile II (e.g., "unable," "no measurable stereopsis," 480 or 240 seconds of arc) should be considered to be at an elevated risk for a vision disorder compared with children with a stereoacuity of 120 seconds of arc or better. Future investigations that include younger and older children, along with finer disparity levels, may provide further stratification of stereoacuity.

CONCLUSIONS

The VIP Study provided a large sample population of preschool children with and without VIP Study–targeted vision disorders. The testability of the Stereo Smile II was 99%, allowing for measurement of stereoacuity at all ages in this cohort. This secondary analysis of the VIP Study data provides evidence that the presence, type, and increasing severity of any VIP Study–targeted vision disorder are all highly associated with worse stereoacuity in preschool children. In contrast, most preschool children without vision disorders are able to obtain stereoacuity of 120 seconds of arc or better, with younger preschool children without vision disorders slightly less likely to achieve stereoacuity of 60 seconds of arc compared with older preschool children.

This study provides a framework and normative values that may be applicable to clinical testing and management of vision disorders, including strabismus, amblyopia, and significant refractive error, which are prevalent in a preschool population.

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The Stereo Smile II is currently available as the Preschool Assessment of Stereopsis with a Smile (PASS) Test through Vision Assessment Corporation, Chicago, IL. The Pennsylvania College of Optometry at Salus University receives a small amount of royalties from the PASS Test that is earmarked for a research fund at the university. The authors have no commercial interest.

References

1. Schmidt PP. Sensitivity of random dot stereoacuity and Snellen acuity to optical blur. Optom Vis Sci. 1994; 71:466–71. [PubMed: 7970562]
2. Greenwood JA, Tailor VK, Sloper JJ, Simmers AJ, Bex PJ, Dakin SC. Visual acuity, crowding, and stereo-vision are linked in children with and without amblyopia. Invest Ophthalmol Vis Sci. 2012; 53:7655–65. [PubMed: 23074213]

3. Ip JM, Robaei D, Kifley A, Wang JJ, Rose KA, Mitchell P. Prevalence of hyperopia and associations with eye findings in 6- and 12-year-olds. Ophthalmology. 2008; 115:678–85. [PubMed: 17664011]
4. Richardson SR, Wright CM, Hrisos S, Buck D, Clarke MP. Stereoacuity in unilateral visual impairment detected at preschool screening: outcomes from a randomized controlled trial. Invest Ophthalmol Vis Sci. 2005; 46:150–4. [PubMed: 15623768]
5. Subramanian V, Jost RM, Birch EE. A quantitative study of fixation stability in amblyopia. Invest Ophthalmol Vis Sci. 2013; 54:1998–2003. [PubMed: 23372053]
6. Afsari S, Rose KA, Pai AS, Gole GA, Leone JF, Burlutsky G, Mitchell P. Diagnostic reliability and normative values of stereoacuity tests in preschool-aged children. Br J Ophthalmol. 2013; 97:308–13. [PubMed: 23292927]
7. Ying GS, Huang J, Maguire MG, Quinn G, Kulp MT, Ciner E, Cyert L, Orel-Bixler D. The Vision in Preschoolers (VIP) Study Group. Associations of anisometropia with unilateral amblyopia, interocular acuity difference, and stereoacuity in preschoolers. Ophthalmology. 2013; 120:495–503. [PubMed: 23174398]
8. Pascual M, Huang J, Maguire MG, Kulp MT, Quinn GE, Ciner E, Cyert LA, Orel-Bixler D, Moore B, Ying GS. Vision in Preschoolers (VIP) Study Group. Risk factors for amblyopia in the Vision in Preschoolers Study. Ophthalmology 2013. Oct 18.2013 epub ahead of print. 10.1016/j.ophtha.2013.08.040
9. Griffin, JR.; Grisham, JD. Binocular Anomalies: Diagnosis and Vision Therapy. 4. Boston, MA: Butterworth Heinemann; 2002.
10. Tomac S, Altay Y. Near stereoacuity: development in preschool children; normative values and screening for binocular vision abnormalities—a study of 115 children. Binocul Vis Strabismus Q. 2000; 15:221–8. [PubMed: 10960225]
11. Tarczy-Hornoch K, Lin J, Deneen J, Cotter SA, Azen SP, Borchert MS, Wang Y, Varma R. Multi-ethnic Pediatric Eye Disease Study Group. Stereoacuity testability in African-American and Hispanic preschool children. Optom Vis Sci. 2008; 85:158–63. [PubMed: 18317330]
12. Kulp MT, Mitchell GL. Randot stereoacuity testing in young children. J Pediatr Ophthalmol Strabismus. 2005; 42:360–4. [PubMed: 16382561]
13. Ohlsson J, Villarreal G, Abrahamsson M, Cavazos H, Sjostrom A, Sjostrand J. Screening merits of the Lang II, Frisby, Randot, Titmus, and TNO stereo tests. J AAPOS. 2001; 5:316–22. [PubMed: 11641643]
14. Birch E, Williams C, Hunter J, Lapa MC. ALSPAC “Children in Focus” Study Team. Random dot stereoacuity of preschool children. J Pediatr Ophthalmol Strabismus. 1997; 34:217–22. [PubMed: 9253735]
15. Birch E, Williams C, Drover J, Fu V, Cheng C, Northstone K, Courage M, Adams R. Randot Preschool Stereoacuity Test: normative data and validity. J AAPOS. 2008; 12:23–6. [PubMed: 17720573]
16. Trager MJ, Dirani M, Fan Q, Gazzard G, Selvaraj P, Chia A, Wong TY, Young TL, Varma R, Saw SM. Testability of vision and refraction in preschoolers: the strabismus, amblyopia, and refractive error study in Singaporean children. Am J Ophthalmol. 2009; 148:235–41. [PubMed: 19426960]
17. Cooper J, Feldman J. Operant conditioning and assessment of stereopsis in young children. Am J Optom Physiol Opt. 1978; 55:532–42. [PubMed: 742643]
18. Schmidt PP, Maguire MG, Moore B, Cyert L. The Vision in Preschoolers (VIP) Study Group. Testability of preschoolers on stereotests used to screen vision disorders. Optom Vis Sci. 2003; 80:753–7. [PubMed: 14627942]
19. Ciner EB, Scheiman MM, Schanel-Klitsch E, Weil L. Stereopsis testing in 18- to 35-month-old children using operant preferential looking. Optom Vis Sci. 1989; 66:782–7. [PubMed: 2616139]
20. Schmidt P, Maguire M, Dobson V, Quinn G, Ciner E, Cyert L, Kulp MT, Moore B, Orel-Bixler D, Redford M, Ying GS. Vision in Preschoolers (VIP) Study Group. Comparison of preschool vision screening tests as administered by licensed eye care professionals in the Vision in Preschoolers Study. Ophthalmology. 2004; 111:637–50. [PubMed: 15051194]

21. Vision In Preschoolers (VIP) Study Group. Sensitivity of screening test performance for detecting VIP-targeted vision disorders and associated risk factors when specificity is set at 94%. Optom Vis Sci. 2005; 82:432–8. [PubMed: 15894920]

22. Vision in Preschoolers (VIP) Study Group. Preschool vision screening tests administered by nurse screeners compared with lay screeners in the Vision in Preschoolers Study. Invest Ophthalmol Vis Sci. 2005; 46:2639–48. [PubMed: 16043831]

23. Kulp MT. Vision in Preschoolers Study Group. Findings from the Vision in Preschoolers (VIP) Study. Optom Vis Sci. 2009; 86:619–23. [PubMed: 19417714]

24. Schmidt P, Maguire M, Kulp MT, Dobson V, Quinn G. The Vision in Preschoolers (VIP) Study Group. Random Dot E stereotest: testability and reliability in 3- to 5-year-old children. J AAPOS. 2006; 10:507–14. [PubMed: 17189143]

25. Vision in Preschoolers (VIP) Study Group. Implementation of a preschool vision screening program in a mobile setting. NHSA Dialog. 2005; 8:16–24.

26. Ying GS, Maguire M, Cyert LA, Ciner E, Quinn GE, Kulp MT, Orel-Bixler D, Moore B. The Vision in Preschoolers (VIP) Study Group. Prevalence of vision disorders by racial and ethnic group among children participating in Head Start. Ophthalmology 2013. Oct 31.2013 epub ahead of print. 10.1016/j.ophtha.2013.09.036

27. Pai AS, Rose KA, Samarawickrama C, Fotedar R, Burlutsky G, Varma R, Mitchell P. Testability of refraction, stereopsis, and other ocular measures in preschool children: the Sydney Paediatric Eye Disease Study. J AAPOS. 2012; 16:185–92. [PubMed: 22525178]

28. Shallo-Hoffmann J, Coulter R, Oliver P, Hardigan P, Blavo C. A study of preschool vision screening tests' testability, validity and duration: do group differences matter? Strabismus. 2004; 12:65–73. [PubMed: 15672929]

29. Maguire MG. Vision in Preschoolers (VIP) Study Group. Children unable to perform screening tests in Vision in Preschoolers Study: proportion with ocular conditions and impact on measures of test accuracy. Invest Ophthalmol Vis Sci. 2007; 48:83–7. [PubMed: 17197520]

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Study Center

Columbus, OH: The Ohio State University College of Optometry

Paulette Schmidt, OD, MS (PI); Beth Haas (Study Coordinator).

Coordinating Center

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National Eye Institute

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FIGURE 1.
Photo of Stereo Smile II Test.

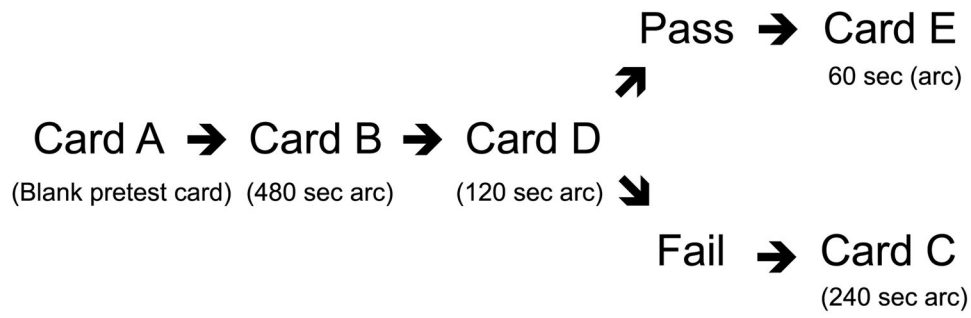

FIGURE 2.
A flowchart of the order of testing.

TABLE 1

Definition of VIP-targeted disorders by hierarchy

Group 1: Very important to detect and treat early
Amblyopia
Presumed unilateral: ≥3-line interocular difference, a unilateral amblyogenic factor, and worse eye VA ≤20/64
Suspected bilateral: a bilateral amblyogenic factor, worse eye VA <20/50 for 3-year-olds or <20/40 for 4-year-olds, contralateral eyeVAworsethan20/40for3-year-oldsor20/30for4-year-olds
Strabismus: constant in primary gaze
Refractive error
Severe anisometropia (interocular difference >2 D hyperopia, >3 D astigmatism, or >6 D myopia)
Hyperopia ≥5.0 D
Astigmatism ≥2.5 D
Myopia ≥6.0 D
Group 2: Important to detect early
Amblyopia
Suspected unilateral: 2-line interocular difference and a unilateral amblyogenic factor
Presumed unilateral: ≥3-line interocular difference, a unilateral amblyogenic factor, and worse eye VA >20/64
Strabismus: intermittent in primary gaze
Refractive error
Anisometropia (interocular difference >1 D hyperopia, >1.5 D astigmatism, or >3 D myopia)
Hyperopia >3.25 D and <5.0 D and interocular difference in SE ≥0.5 D
Astigmatism >1.5 D and <2.5 D
Myopia ≥4.0 D and <6.0 D
Group 3: Detection clinically useful
Unexplained reduced VA
Bilateral: no bilateral amblyogenic factor, worse eye VA <20/50 for 3-year-olds or <20/40 for 4-year-olds, contralateral eye VA worse than 20/40 for 3-year-olds or 20/30 for 4-year-olds
Unilateral: no unilateral amblyogenic factor, worse eye VA <20/50 for 3-year-olds or <20/40 for 4-year-olds or ≥2-line difference between eyes (except 20/16 and 20/25)
Refractive error
Hyperopia >3.25 D and <5.0 D and interocular difference in SE <0.5 D
Myopia >2.0 D and <4.0 D

Modified from Tables 2 and 3 of VIP Study Group. Comparison of preschool vision screening tests as administered by licensed eye care professionals in the Vision in Preschoolers Study.[20]

TABLE 2

Comparison of stereoacuity between preschoolers with and without VIP Study–targeted vision disorders

		With vision disorders	Without vision disorders	p
Overall (N = 2898)	Stereoacuity levels (seconds of arc)	(n = 871)	(n = 2027)	<0.001*
	Unable	20 (2.3%)	9 (0.4%)	
	No measurable stereopsis	212 (24.3%)	30 (1.5%)	
	480	86 (9.9%)	62 (3.1%)	
	240	116 (13.3%)	139 (6.9%)	
	120	220 (25.3%)	494 (24.4%)	
	60	217 (24.9%)	1293 (63.8%)	
	Median (Q1, Q3)	120 (60, 480)	60 (60, 120)	<0.001†
Aged 3 years (n = 628)	Stereoacuity levels (seconds of arc)	(n = 189)	(n = 439)	<0.001*
	Unable	8 (4.2%)	6 (1.4%)	
	No measurable stereopsis	49 (25.9%)	12 (2.7%)	
	480	24 (12.7%)	19 (4.3%)	
	240	24 (12.7%)	44 (10.0%)	
	120	45 (23.8%)	129 (29.4%)	
	60	39 (20.6%)	229 (52.2%)	
	Median (Q1, Q3)	240 (120, no measureable stereopsis)	60 (60, 120)	<0.001†
Aged 4 years (n = 1553)	Stereoacuity levels (seconds of arc)	(n = 469)	(n = 1084)	<0.001*
	Unable	11 (2.4%)	3 (0.3%)	
	No measurable stereopsis	123 (26.2%)	13 (1.2%)	
	480	40 (8.5%)	35 (3.2%)	
	240	59 (12.6%)	66 (6.1%)	
	120	121 (25.8%)	263 (24.3%)	
	60	115 (24.5%)	704 (64.9%)	
	Median (Q1, Q3)	120 (60, no measureable stereopsis)	60 (60, 120)	<0.001†
Aged 5 years (n = 717)	Stereoacuity levels (seconds of arc)	(n = 213)	(n = 504)	<0.001*
	Unable	1 (0.5%)	0 (0.0%)	
	No measurable stereopsis	40 (18.8%)	5 (1.0%)	
	480	22 (10.3%)	8 (1.6%)	
	240	33 (15.5%)	29 (5.8%)	
	120	54 (25.4%)	102 (20.2%)	
	60	63 (29.6%)	360 (71.4%)	
	Median (Q1, Q3)	120 (60, 480)	60 (60, 120)	<0.001†

*Value of p is from Fisher exact test.

†Value of p is from Wilcoxon rank sum test.

Q1, first quartile; Q3, third quartile.

TABLE 3

Stereoacuity by the type of VIP Study–targeted vision disorders

	Amblyopia (n = 189)	Strabismus (n = 109)	Significant refractive error (n = 679)	Reduced VA (n = 231)	Without any VIP Study–targeted vision disorders (n = 2027)
Stereoacuity levels (seconds of arc)					
Unable	2 (1.1%)	6 (5.5%)	16 (2.4%)	6 (2.6%)	9 (0.4%)
No measurable stereopsis	92 (48.7%)	71 (65.1%)	181 (26.7%)	31 (13.4%)	30 (1.5%)
480	28 (14.8%)	8 (7.3%)	72 (10.6%)	26 (11.3%)	62 (3.1%)
240	23 (12.2%)	8 (7.3%)	92 (13.6%)	31 (13.4%)	139 (6.9%)
120	28 (14.8%)	5 (4.6%)	168 (24.7%)	67 (29.0%)	494 (24.4%)
60	16 (8.5%)	11 (10.1%)	150 (22.1%)	70 (30.3%)	1293 (63.8%)
p	<0.001*	<0.001*	<0.001*	<0.001*	
Median (Q1, Q3)	480 (240, no measureable stereopsis)	No measureable stereopsis (240, no measureable stereopsis)	240 (120, no measureable stereopsis)	120 (60, 480)	60 (60, 120)
p	<0.001†	<0.001†	<0.001†	<0.001†	

*For comparison with children without any VIP Study–targeted vision disorder using the Fisher exact test.

†For comparison with children without any VIP Study–targeted vision disorder using the Wilcoxon rank sum test.

Q1, first quartile; Q3, third quartile.

TABLE 4

Stereoacuity by the severity of VIP Study–targeted vision disorders

Stereoacuity levels, seconds of arc	Group 1 (severe) (n = 382)	Group 2 (moderate) (n = 265)	Group 3 (mild) (n = 224)	Without any VIP Study–targeted vision disorders (n = 2027)	p for comparison among the four groups
Unable	11 (2.9%)	3 (1.1%)	6 (2.7%)	9 (0.4%)	
No measurable stereopsis	159 (41.6%)	34 (12.8%)	19 (8.5%)	30 (1.5%)	
480	52 (13.6%)	21 (7.9%)	13 (5.8%)	62 (3.1%)	
240	55 (14.4%)	34 (12.8%)	27 (12.1%)	139 (6.9%)	
120	70 (18.3%)	84 (31.7%)	66 (29.5%)	494 (24.4%)	
60	35 (9.2%)	89 (33.6%)	93 (41.5%)	1293 (63.8%)	
p	<0.001*	<0.001*	<0.001*		<0.001†
Median (Q1, Q3)	480 (120, no measurable stereopsis)	120 (60, 240)	120 (60, 240)	60 (60, 120)	
p	<0.001‡	<0.001‡	<0.001‡		<0.001§

*For comparison with children without any VIP Study–targeted vision disorder using the Fisher exact test.

†For comparisonof anydifference amongthefourgroupsof children(i.e., Group 1, Group 2, Group3, andnormals) usingtheFisher exact test.

‡For comparison with children without any VIP Study–targeted vision disorder using the Wilcoxon rank sum test.

§For comparison of any difference among the four groups of children (i.e., Group 1, Group 2, Group 3, and normals) using the Kruskal-Wallis test for comparison of medians.

Q1, first quartile; Q3, third quartile.