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FEATURE ARTICLE ON LINE

Stereoacuity Testability in African-American and Hispanic Pre-School Children

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ABSTRACT

Purpose. To determine testability using the Randot Pre-school Stereoacuity Test in black and Hispanic children 30 to 72 months of age.

Methods. A population-based cohort of children 30 to 72 months of age was administered the Randot Pre-school Stereoacuity Test, with presenting refractive correction, and before cover testing, visual acuity testing, or refraction. Children who could not point to specified two-dimensional demonstration pictures, and children who would not try to name or match random dot figures to the corresponding two-dimensional pictures, were classified as unable to perform the test. Children who were able to perform the task but could not correctly identify at least two 800-arcsecond random dot figures were classified as having no stereopsis, and were retested by another examiner.

Results. Stereoacuity testing was attempted in 1662 Hispanic and 1470 black children. Overall, 80% of children were able to be tested; 33% of children 30 to 36 months of age, 73% of children 37 to 48 months of age, 96% of children 49 to 60 months of age, and 98% of children 61 to 72 months of age were testable. Older children were significantly more likely to complete testing successfully than younger children ($p < 0.0001$). After adjusting for age, there was no significant ethnicity-related difference in testability ($p = 0.19$); however, there was a small but significant gender-related difference ($p = 0.0002$) with more girls (82%) than boys (77%) able to complete testing.

Conclusions. Eighty percent of children aged 30 to 72 months can be tested using the Randot Pre-school Stereoacuity test. Testability increases steadily with age, and 97% of children over 48 months of age can complete the test. Testability does not differ between children of Hispanic and black ethnicity.
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Key Words: stereoacuity, Randot, preschool, testability, African-American, Hispanic

The Randot Pre-school Stereoacuity Test[1] was developed to provide an age-appropriate quantitative tool for measuring global stereopsis in young children using random-dot stereograms. Birch et al.[1] reported testability in research, clinical, daycare, and screening settings of 60 to 70% in 2 years olds, 80 to 90% in 3 years olds, and nearly 100% in 4 years olds. The Vision in Pre-Schoolers (VIP) study[2] has reported the demonstration of gross stereopsis using this test in 56% of 3 years olds. The Randot Pre-school Stereoacuity test has never been studied in population-based samples of preschoolers of varying ethnicities. The purpose of this study is to evaluate the age-specific testability rates for the Randot Pre-school Stereoacuity test in a multiethnic population-based sample of children between 30 and 72 months of age. This study is conducted in the context of the ongoing Multi-Ethnic Pediatric Eye Disease Study (MEPEDS), a cross-sectional study of the prevalence of eye disease in children[3]; two ethnic groups, black and Hispanic, have been studied to date. Because comparison of results of eye examinations between different populations presupposes that the testing methods are applicable to all populations, a secondary aim of this study is to confirm that stereopsis testability is similar in black and Hispanic children.

METHODS

The MEPEDS is a population-based cross-sectional study in which comprehensive eye examinations are performed on children aged 6 to 72 months of age.[3] All examinations are performed by MEPEDS optometrists or ophthalmologists who specialize in pediatric eye care and are trained and certified using standardized protocols. This research follows the tenets of the Declaration of Helsinki regarding research involving human subjects. Institutional Review Board/Ethics Committee approval was obtained from the Los Angeles County/University of Southern California Medical Center Institutional Review Board. Following explanation of the nature and possible consequences of the study, written informed consent was obtained from the parent or legal guardian of each participant.

Stereopsis testing using the Randot Pre-school Stereoacuity test (Stereo Optical, Inc., Chicago, IL) was performed according to the following standardized protocol for all the participants included in the present analysis. All children aged at least 30 months of age or older were tested. Children who habitually wore glasses and brought them to the examination wore their glasses for stereoacuity testing. Testing was performed before any assessment of ocular alignment, visual acuity, or refraction, and before lensometry if the child came with glasses; this ensured that examiners were as unbiased as possible with regard to expected stereoacuity, and also ensured that stereopsis was tested before any dissociating procedures such as cover testing or monocular occlusion. Polarized spectacles were placed on the child and a measuring string attached to the test booklet was used to maintain a testing distance of 40 cm. Standardized auxiliary lighting was used. Hispanic children who were not bilingual were addressed and instructed in Spanish.

Testing began with the 800- and 400-arcsecond stereogram booklet, and proceeded in order of decreasing stereodisparity (increasing difficulty of detection). Attention was directed first to the high contrast, black and white two-dimensional figures on the left-hand side of the booklet. The child was asked to identify a specified two-dimensional figure to confirm figure-recognition capabilities. The child was then asked to identify one of the three 800-arcsecond random-dot figures, either by naming, or by pointing to the corresponding two-dimensional figure. This was repeated for different figures until the child had either given two correct answers, in which case testing proceeded to next stereoacuity level, or two incorrect answers, in which case testing was considered complete.

A child was considered unable to perform the test if he or she refused to wear polarized filter glasses, refused to look at the test booklet while wearing the polarized glasses, refused to attempt to identify figures either by naming or pointing, or could not correctly identify the two-dimensional figures. In some cases of children who would not name figures and were therefore asked to match to two-dimensional figures, the child persevered in pointing to the location (upper left, upper right, lower left, or lower right) on the left side of the booklet corresponding to the location of the random-dot figure in question. Children, who misconstrued the task to be one of matching of location rather than matching of the content of the boxes, even though the examiner explained that the matching picture could be found in any of the four boxes, were also recorded as being unable to perform the test.

Children who were cooperative and capable of figure recognition and of grasping the task but could not correctly identify the 800-arcsecond random dot figures were recorded as having "no stereopsis." Children scored as having no stereopsis and subsequently found not to have strabismus on clinical examination underwent retesting on the same day by a different examiner, if available. Although the primary purpose of retesting was to repeat cover testing to increase the chances of identifying a subtle microstrabismus that might have been missed by the first examiner, stereopsis was also retested by the second examiner. The primary analysis of testability takes into consideration only the results of the initial test, not the results of retesting by a different examiner.

In a subset of consecutive children who were either unable to perform stereoacuity testing as described above, or who were scored as having no stereopsis, we conducted an ancillary study in which the test was repeated by the original examiner with the following difference: rather than asking the child to name or match a specified random-dot figure, the examiner asked the child to find a specified two-dimensional figure among the random-dot figures. If the child successfully located two figures at a particular stereoacuity level, the examiner proceeded to the next level, in a manner analogous to that described above. This method is hereafter referred to as the "find" method. The primary analysis of testability takes into consideration only the results of the initial test, not the results of testing with the "find" method.

After stereoacuity testing, all children underwent a comprehensive eye examination that included visual acuity testing using the Amblyopia Treatment Study HOTV visual acuity testing protocol[4] on the Electronic Visual Acuity tester,[5] cover testing for strabismus at distance and near (with Hirschberg testing if cover testing could not be performed), and cycloplegic refraction using the Retinomax autorefractor (Right Manufacturing, Virginia Beach, VA). Children with decreased visual acuity were retested with correction after refraction. For children who could not complete HOTV visual acuity testing (16% of children),[6] fixation preference testing was substituted. Strabismus was defined as any constant or intermittent tropia. Unilateral amblyopia was defined as a two-line interocular best-corrected visual acuity difference with visual acuity of 20/32 or worse in the worse eye, or, in the absence of optotype acuity, as no ability to hold fixation with the non-preferred eye, associated with one of the following: strabismus, anisohyperopia of $\geq$1 diopter (D), anisomyopia of $\geq$3 D, anisoastigmatism of $\geq$1.5 D, or visual axis occlusion. Bilateral amblyopia was defined as visual acuity worse than 20/50 in both eyes, or worse than 20/40 in both eyes for children $\geq$48 months of age, associated with one of the following bilateral amblyopic risk factors: bilateral spherical hyperopia of $\geq$4 D, bilateral spherical myopia of $\geq$6 D, bilateral astigmatism of $\geq$2.5 D, or bilateral visual axis occlusion.

Age-, gender-, and ethnicity-specific stereopsis testability rates were calculated. Comparisons of testability among different groups were performed using χ^2 analyses, Fisher's exact test where indicated, and the trend test (SAS software 9.1, SAS institute, Inc., Cary, NC). Testability was plotted against age by gender and ethnic groups with locally weighted regression lines using STATA software (StataCorp, College Station, TX).

RESULTS

Testing was performed in 3132 black and Hispanic participants aged 30 to 72 months residing in 37 census tracts in Los Angeles County, CA. Among eligible children, the participation rate in this population-based study was 77%. The demographic characteristics of the participants are summarized in Table 1. There were 1470 black children and 1662 Hispanic children, with 1575 female and 1557 male children.

Overall, 80% of all participants could be tested and scored as having either a particular level of stereoacuity or as having no stereopsis (81% black, 79% Hispanic; 82% female, 77% male). Table 2 summarizes the results for testability stratified by age, gender, and ethnicity. Age-specific testability was 33, 73, 96, and 98% in children aged 30 to 36 months, 37 to 48 months, 49 to 60 months, and 61 to 72 months, respectively. Older children were significantly more likely to successfully complete testing than younger children ($p < 0.0001$, trend test). Testability increased steadily with age up to the age of about 4 years, by which time it was uniformly high in all subgroups, as shown in Fig. 1. Ninety-seven percent of all children over 48 months of age were testable.

Adjusting for age, there was no significant difference in testability between black and Hispanic children ($p = 0.19$). There was a small but significant gender-related difference in testability after adjusting for age ($p = 0.0002$); girls were more often able to complete the test (82%) than boys (77%). After stratifying by ethnicity, this difference remained significant in black children, with 84% of black females and 78% of males testable ($p = 0.0007$, adjusting for age). Among Hispanic children, similarly, 81% of females and 76% of males were testable, but the difference did not reach statistical significance ($p = 0.06$, adjusting for age). Gender differences were most apparent among younger children (Table 2).

There was a significant association between testability for visual acuity and testability for stereopsis ($p < 0.0001$); 91% of the children who successfully completed visual acuity testing were able to perform stereopsis testing, compared with only 21% of the children who were unable to complete visual acuity testing. Conversely, 96% of children able to complete stereopsis testing were also able to perform visual acuity testing, compared with only 39% of children who could not complete the stereoacuity test.

In the younger age groups, environmental factors appeared to be associated with stereopsis testability. For children 48 months of age and younger, testability rates were higher in children who attended school or daycare (Table 3). Similarly, in the 30- to 36-month-old age group, children in families with self-reported household incomes over $20,000 had higher stereopsis testability (44%) than children from households with income under $20,000 (32%) ($p = 0.007$). There was no significant association between testability and income in any other age group.

Of all children able to complete the test, 94% had demonstrable stereopsis, as opposed to a score of "no stereopsis." The predictive value of a score of "no stereopsis" with respect to a subsequent diagnosis of amblyopia or strabismus increased with age; of children scoring "no stereopsis," 0, 11, 22, and 32% of those aged 30 to 36 months, 37 to 48 months, 49 to 60 months, and 61 to 72 months, respectively turned out to have strabismus or amblyopia. After excluding children with amblyopia or strabismus, only 4% of children were classified as having no stereopsis. The frequency of scoring "no stereopsis" among children without a condition such as strabismus or amblyopia, i.e., among children who would be expected to have at least gross stereopsis, varied from 2 to 7%, depending on age; the highest frequency of "no stereopsis" scores in children who would not be expected to lack binocularity occurred among 3 years olds (Table 4).

TABLE 1.
Demographic characteristics of participants

	N (%)
Age (months)	
30–36	549 (18)
37–48	853 (27)
49–60	899 (29)
61–72	831 (27)
Gender	
Female	1575 (50)
Male	1557 (50)
Ethnicity	
Black	1470 (47)
Hispanic	1662 (53)
Total	3132 (100)

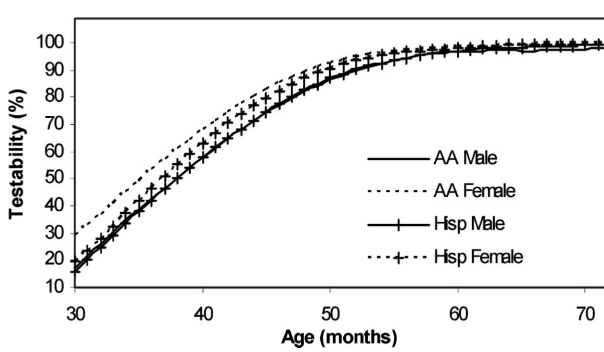

FIGURE 1.
Locally weighted regression lines for Randot Pre-school Stereoacuity testability by month of age in all participants, separated by gender and ethnicity (Hisp indicates Hispanic; AA, African-American).

TABLE 2.
Randot Preschool Stereoacuity testability stratified by age and gender

	Number testable/total (%)			
	30–36 Months	37–48 Months	49–60 Months	61–72 Months
Hispanic male	47/162 (29)	157/225 (70)	224/236 (95)	207/211 (98)
Black male	39/121 (32)	140/204 (69)	194/201 (97)	189/197 (96)
Hispanic female	41/132 (31)	181/239 (76)	226/233 (97)	223/224 (>99)
Black female	55/134 (41)	148/185 (80)	222/229 (97)	199/199 (100)
Total	182/549 (33)	626/853 (73)	866/899 (96)	818/831 (98)

TABLE 3.
Randot Preschool Stereoacuity testability stratified by age and daycare/school attendance

	Testable/total (%)			
	30–36 Months	37–48 Months	49–60 Months	61–72 Months
Attending daycare or school[a]	67/148 (45)	279/339 (82)	634/656 (97)	742/754 (98)
Not attending daycare or school[a]	113/391 (29)	332/496 (67)	226/237 (95)	65/66 (98)
p value	0.0003	<0.0001	0.37	1.0

[a]Answer refused, unknown or missing for 10 children aged 30–36 months, 18 aged 37–48 months, 6 aged 49–60 months, and 11 aged 61–72 months.

TABLE 4.
Randot Preschool Stereoacuity Test results in non-amblyopic, non-strabismic children

	N (%)			
Stereopsis test result	30–36 Months (n = 521)	37–48 Months (n = 806)	49–60 Months (n = 851)	61–72 Months (n = 785)
Unable	344 (66)	202 (25)	28 (3)	7 (1)
Able, but with “no stereopsis”	14 (3)	54 (7)	32 (4)	16 (2)
Able, with stereopsis	163 (31)	550 (68)	791 (93)	762 (97)

TABLE 5.
Randot Preschool Stereoacuity retest results in non-amblyopic, non-strabismic children scoring “no stereopsis” initially

	N (%)			
Retest result	30–36 Months (n = 12)	37–48 Months (n = 35)	49–60 Months (n = 23)	61–72 Months (n = 12)
Unable or “no stereopsis”	8 (67)	20 (57)	12 (52)	6 (50)
200–800 arcseconds	2 (17)	7 (20)	9 (39)	5 (42)
40–100 arcseconds	2 (17)	8 (23)	2 (9)	1 (8)

Children who appeared to have no stereopsis, yet did not have strabismus, underwent retesting of stereopsis by a different examiner. Of those children who were initially felt to have no stereopsis and who did not have any strabismus or amblyopia, 44% (36 of 82) demonstrated at least 800 arcseconds of stereopsis on retesting. Demonstrable stereopsis on retesting of children initially classified as having no stereopsis was observed in every age group, with proportions showing stereopsis ranging from 33 to 50% (Table 5). Among children aged 48 months and younger, the degree of stereopsis shown on retesting by children who initially showed no stereopsis was not different from that shown by children who demonstrated stereopsis on the initial test: 53% of those showing stereopsis on the second test had stereoacuity of 100 arcseconds or better, compared with 52% with scores of 100 arcseconds or better among children showing stereopsis the first time. Among older children, however, those who showed stereopsis on retesting after initially scoring “no stereopsis” appeared to have worse stereoacuity than those who showed stereopsis initially, with only 18% scoring 100 arcseconds or better, compared with 79% of the older children who showed stereopsis on the initial test ($p < 0.0001$).

A subgroup of children initially unable to complete testing or scoring “no stereopsis” were tested again by the same examiner using the “find” method, in which children were asked to find a particular figure among the random-dot figures, rather than to name or match a particular random-dot figure. Excluding children with strabismus or amblyopia, we found that of children initially scored as unable, 10 of 150 (6%) had demonstrable stereopsis using the “find” method. Of those initially scored as “no stereopsis,” 10 of 71 (14%) had demonstrable stereopsis using the “find” method.

DISCUSSION

Using the Randot Pre-school Stereoacuity Test, we have found high overall rates of testability in a population-based sample of minority pre-school children, with four of five pre-school children aged 30 to 72 months able to perform the test, with no ethnicity-related differences in testability.

The percentage of children able to complete the test is highly age dependent, with fewer than half of children 30 to 36 months of age able to perform the test, but 97% of children over 48 months of age able to do so. This is consistent with the observations of Birch et al.[1] using the same test. This pattern is most likely related to maturation of the attentional and cognitive abilities required to grasp and perform the tasks associated with the test. As has been pointed out by other authors,[2] perception of a random dot stereo figure is not immediate, but requires a brief period of attention to the figures, and some young pre-school children may not attend to a stimulus that does not immediately appear to contain anything of interest. An alternative but very unlikely explanation for our findings would be that many of our youngest participants were misclassified as being unable to do the test, when in fact they were able, but lacked stereopsis of at least 800 arcseconds because of age-related maturation of the visual function itself. Some investigators have indeed proposed, on the basis of pre-school stereopsis testing, that development of binocularity might be incomplete even at 5 years of age.[7] However, the evidence from normative data using forced-choice preferential looking techniques to measure random dot stereoacuity[8,9] makes it very unlikely that a substantial proportion of 36-month-old children would still have worse than 800 arcseconds of stereopsis.

The small but significant difference in testability between boys and girls, especially apparent at younger ages, may similarly be related to the cooperation and sustained attention required to complete the task, reflecting slight behavioral differences, on average, between younger male and female children in our study population. Indeed, differences in overall psychomotor and mental development between boys and girls can be identified as early as 1 year of age, and persist at 4 years of age.[10]

The age dependence of stereopsis testability appears to reflect a more general phenomenon of increased testability with increasing age, with the age-related trends closely resembling those seen for optotype visual acuity testing in the same population[6]; indeed, a child able to perform one of the tests is highly likely to be able to perform the other. Among younger children, daycare or school attendance appears to increase the likelihood that the child is able to complete stereoacuity testing, possibly because children attending such settings have more experience with following instructions and responding to questions. However, we can not rule out the possibility that children who are more mature may simply be placed in school or daycare earlier (resulting in a spurious association of school attendance with testability), rather than acquiring their test-taking skills as a result of early socialization or education.

When assessing stereoacuity in young pre-school children, it can be extremely difficult to distinguish between lack of understanding of the task (inability to do the test) and actual lack of stereopsis. High rates of "no stereopsis" scores among children who ought to have normal binocularity based on clinical examination would raise a concern of misclassification of children who in fact did not understand the test and would more accurately have been classified as "unable" rather than as able to do the test and truly lacking stereopsis; such misclassification could result in artificially inflated testability rates. In our study, because only 4% of non-strabismic, non-amblyopic children received a score of "no stereopsis," we are confident that we did not overestimate testability by a large amount.

Although we believe we have not overestimated testability by mislabeling children as having "no stereopsis" when in fact they have not understood the test, our data provide evidence that such misclassification does occur; over 40% of the non-amblyopic, non-strabismic children in our study who scored "no stereopsis" subsequently demonstrated stereopsis when retested by a different examiner. Undoubtedly, some non-amblyopic, non-strabismic children scoring "no stereopsis" do in fact have absent or reduced stereopsis because of factors such as uncorrected refractive error, anisometropia, or for unknown reasons, as observed in a recent study of 12-year-old children by Robaei et al.[11] Indeed, among the older children in our study, an initial score of "no stereopsis" seemed to be indicative of poorer levels of stereoacuity even when some stereoacuity was observed on retesting. Among children 48 months of age and younger, however, non-strabismic, non-amblyopic children who initially scored "no stereopsis" and then showed stereoacuity on retesting appeared to be no different from those who showed stereoacuity the first time, in terms of the distribution of level of stereoacuity; this finding underscores the potential for misclassification in young pre-school children. Retesting can reduce the likelihood of mislabeling a young child without visual deficits as having "no stereopsis."

We have also found that some young children who do not demonstrate stereopsis on initial testing may have an easier time understanding the test if they are asked to find a particular figure among the random-dot figures, rather than being asked to name or identify a particular random-dot figure. Although the test is not designed to be administered this way, we believe that this method, like retesting, may help to distinguish between children with truly absent stereopsis and those who simply do not understand the test.

Comparing our results with those of other investigators, we found lower testability in younger age groups than Birch et al.,[1] who reported testability of 60 to 70% in 2 years olds, 80 to 90% in 3 years olds, and nearly 100% in 4 years olds. We considered whether the differences could reflect differences in the rate of misclassification of normal children as being testable with absent stereopsis. In a screening setting, Birch et al. found that only 9% of "testable" 3-year-old participants who would be expected to have normal binocularity based on clinical examination scored 200 arcseconds or worse (including absent stereopsis) on stereoacuity testing; therefore, the higher testability rates compared with the present study are unlikely to be simply an artifact of misclassification.

The lower testability rates in our study may instead reflect socioeconomic or environmental differences between our populations and the children studied by Birch et al.,[1] who tested children at a vision research laboratory and a children's medical center in Texas, a daycare center in Brazil, and a screening program in the United Kingdom. Our study, by contrast, focused on minority children, over 86% of whom had families with self-reported household incomes below the median household income for Los Angeles County. Within this population, among younger children, we observed an association between testability and household income, and between testability and daycare or pre-school attendance, which may be related to income. Among children attending school or daycare, our testability rates for 30 to 36 months olds and 37 to 48 months olds, respectively, were 45 and 82%, closer to the levels reported by Birch et al. for similar ages. Differences in age distribution within age categories, may also contribute to differences in testability, because testability is highly sensitive to age, as shown in Fig. 1. For example, if the 3-year-old children studied by Birch et al. were nearer to 47 months of age on average than to 36 months of age, then we would anticipate higher testability than in our 37- to 48-month-old age group, which is evenly distributed with regard to months of age.

Although our overall testability rate of 73% in 37 to 48 months olds is lower than that reported by Birch et al. for 3-year-old children, it is higher than that reported by the VIP study for 36 to 42 months olds.[2] The VIP study examined children without strabismus, who were therefore expected to have at least some stereopsis on clinical grounds. Seventy-one percent of their participants were able to identify two-dimensional figures by naming or pointing, but this figure would represent an overestimate of true testability, because of these, 20% did not demonstrate at least 800 arcseconds of stereopsis, suggesting lack of comprehension. Overall, 56% of VIP participants demonstrated at least 800 arcseconds of stereopsis. By contrast, in our study, 66% of all 37- to 48-month-old children, and 68% of those without strabismus or amblyopia, demonstrated at least 800 arcseconds of stereopsis. Given the steep dependence of testability on age for children under 48 months of age, the testability difference found in between the MEPEDS and VIP studies in this age bracket is easily attributable to MEPEDS including children up to 48 months of age, whereas VIP included children only up to 42 months of age.

Overall, we conclude from our findings that the Randot preschool Stereoacuity Test is a simple and easy to use test of stereopsis that may be used successfully in children even as young as 2½ years old, as demonstrated in a population-based sample of minority children aged 30 to 72 months. Eighty percent of pre-school children are testable. There are no ethnicity-related differences in testability, but girls are somewhat more likely to be testable than boys, and testability is strongly dependent on age. It remains difficult to discriminate between lack of comprehension and true lack of stereopsis in pre-school children when stereopsis is not demonstrable, and this poses a distinct challenge to the use of such a test as a single-modality screening tool, especially for the youngest age groups, where stereopsis is frequently not demonstrable even when presumed to be present on clinical grounds. Referral of all 3 years olds without demonstrable stereopsis would refer over a quarter of normal children, whereas referring only those with a score of no stereopsis would miss children with true deficiencies of stereopsis among the more than 25% of children in this age range who are not testable. Despite these limitations, however, it is clear that the Randot Pre-school Stereoacuity Test is a highly usable and valuable tool for the evaluation of the presence of global stereopsis in the general pre-school population, particularly in children 4 years of age and older.

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