The dynamic optotype (Dyop): a novel visual acuity test for use in children

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PURPOSE To evaluate the "dynamic optotype" (Dyop), a simple visual acuity test based on a dynamic target that requires minimal knowledge of symbols and letters.

METHODS A total of 160 consecutive, systemically healthy children, 4-17 years of age were prospectively recruited from the Pediatric Ophthalmology Unit of Meir Medical Center. Children were tested with the Dyop visual acuity test and the Early Treatment Diabetic Retinopathy Study (ETDRS) Lea numbers chart. The results of both tests were compared. The eye with the poorest acuity was tested with the new Dyop eye chart and the Lea numbers chart. The order of the testing was reversed between children. The logMAR visual acuity scores for each eye chart were compared.

RESULTS We found a strong linear correlation ($r = 0.88$) between visual acuity measures. The mean difference in visual acuity was −0.01 (95% CI, −0.02 to 0.01). The 95% limits of agreement were ±1.2 lines. The logMAR equivalent mean difference was about less than 1 letter. The Dyop test underestimated visual acuity relative to the Lea numbers chart.

CONCLUSIONS The results of this study support the Dyop eye chart as a valid measure of visual acuity in children 4-17 years of age, with visual acuity ranging from 20/16 to 20/200. (J AAPOS 2021;■:1.e1-5)

Visual acuity tests are considered one of the most important measures of general visual function.[1] Although it can be challenging to assess visual acuity in individuals who are nonverbal or developmentally challenged, this is a fundamental part of the ophthalmologic examination.[2] Several tools can be used to obtain a general sense of a child's visual function.[3] Although new, digital approaches and platforms to measure visual acuity have been developed in the computer age, they are mainly digital adaptations of Snellen or similar charts and do not represent a genuinely novel approach to visual acuity testing.

Recently, a new testing modality has been developed that uses a dynamic target visual assessment tool. This tool, called the dynamic optotype (Dyop; Shemesh Health Solutions, Johannesburg, South Africa) uses a segmented, circular figure composed of equally spaced gaps/segments that spin at a constant velocity (Figure 1), unlike static image vision tests, such as a logMAR chart (Harris PA, Keim E. IOVS 2015;56:ARVO E-Abstract 3888).

The Dyop test measures resolution visual acuity, based on the patient's ability to perceive the apparent motion resulting from the Dyop strobic effect, which is diminished at lower visual acuity levels.

A patient is presented with two Dyops, side by side, one spinning and one static and is asked to indicate the direction and/or location of the spinning Dyop.[4] At a 20-feet viewing distance, the 20/20 Dyop is 13.5 mm in diameter (7.6 arcmin) on a typical monitor that is 580 mm wide (880 arcmin or ~15 arcdeg). At 3.33 feet viewing distance, the 20/20 Dyop is 2 mm in diameter on the same 880 arcmin display.

The Dyop can be varied by diameter (angular arc width or arc areas), contrast or color, at constant or reversed rotational velocities, to assess visual acuity thresholds in terms of minimum perceptible resolution. In addition, unlike static image tests, which may depend on cognition as much as visual acuity, the Dyop test retains a high level of accuracy, as visual acuity decreases with increased blur (ARVO E-Abstract 3888). Dyop visual acuity test is intended to be a more precise and faster replacement for the Snellen, Sloan, and Landolt visual acuity or refraction tests.[4] The objective of this validation study was to compare visual acuities obtained with the new Dyop chart with those obtained from the standard Lea numbers chart.[5]

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Materials and Methods

The study was approved by the Institutional Review Board of Meir Medical Center and conformed to the Declaration of Helsinki. Patients or their guardians provided informed consent before participating. Inclued patients were 4-17 years of age, with visual acuity ranging from 20/16 to 20/200 in at least 1 eye, who were considered able to undergo visual acuity evaluation using the Lea numbers chart with crowded figures. Consecutive patients were recruited from among those undergoing routine eye examination at the Pediatric Ophthalmology Unit of Meir Medical Center.

The basic Dyop test screen displays a pair of identical, segmented Dyop rings, of which one is spinning. The objective of the test is to determine the visual acuity endpoint based on the size of the smallest diameter Dyop pair in which the spinning Dyop is identified. The spinning Dyop equivalent to 0 logMAR visual acuity (20/20) has an optimum 10% stroke width, rotates at 40 revolutions per minute, and has an angular arc width diameter of 7.6 arcmin. These attributes create a Dyop gap/segment visual stimulus area of 0.54 arcmin^2 (Figure 1).

Monocular distance visual acuity was evaluated using Dyop visual acuity testing and the Lea numbers chart. The order of the tests was switched among patients. The eye with the poorest visual acuity was tested to enable us to accumulate a broad range of visual acuities. The same examiner conducted both tests on each child and was not masked to the results of either test. The chart was placed 3 m from the examination chair. The participant's other eye was covered with an adhesive opaque patch during testing. Standard lighting was used to illuminate the chart, and all tests were conducted in the same room. In order to indicate which Dyop was rotating, the patient was instructed to raise his or her corresponding hand (right or left). The patient was also given a plastic round device (similar to the Dyop shape) and was instructed to rotate it according to the perceived Dyop rotation.

Visual Acuity Scoring

Best-corrected visual acuity was used because uncorrected refractive error has a different effect on visual acuity than conditions that cause reduced best-corrected visual acuity. For the Lea numbers chart, optotypes on a single crowded line of 5 optotypes, two lines bigger than the previously recorded visual acuity, from left to right, were used. The visual acuity score was determined by the total number of optotypes correctly identified. The following formula was used to transform scores to logMAR values: logMAR visual acuity score = $1.10 - 0.02T_c$. A value of 0.02 log units was assigned to each optotype identified, and T_c was the total number of optotypes correctly identified. This method of determining visual acuity is based on a previous study that compared the Lea symbols, a different set of 4 optotypes, to the Bailey-Lovie chart.[5]

For the Dyop visual acuity test, the tester asked the subject to identify which of the two figures presented was rotating and in which direction. The visual acuity corresponding to the last 3 of 3 Dyop figures that were recognized correctly, that is, correct recognition of both rotation and direction, was recorded. Dyop visual acuity values were collected in logMAR for purposes of this evaluation, which were according to the visual angle of the outer diameter of the circular optotype. These were presented to the participants on a Chart2020 system (Shemesh Health Solutions, Johannesburg, South Africa). Patients' ocular diagnoses, ages, and the order in which the charts were tested were recorded as well.

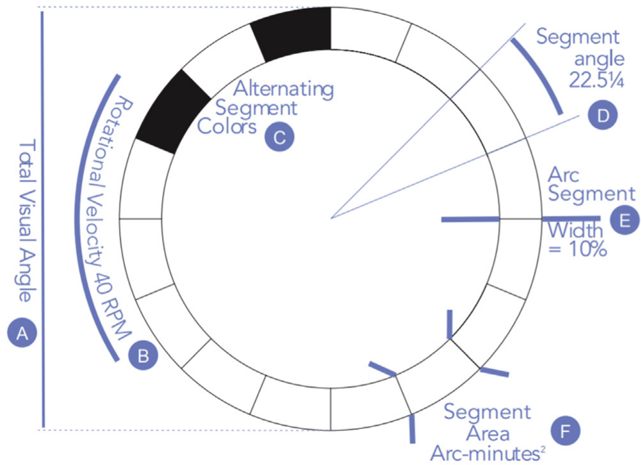

FIG 1. Fundamental geometry of the dynamic optotype (Dyop): total circular diameter or visual angle (A), speed of rotation (B), color contrast (in this study black and white) (C), segment angle (D), segment arc width (E), and area of each segment in arcmin^2 (F).

In the current study, a high contrast, black-and-white Dyop target was used, with the rotating figure appearing on a 50% gray background. Contrast and color can also be varied for other visual function assessments, but they were not varied in the current study.

Statistical Analysis

MATLAB version R2016b (MathWorks, Natick, MA) was used to analyze the data. Paired *t* tests, limits of agreement, and linear regression were used to assess agreement between the Dyop and Lea numbers visual acuity tests. *P* values of <0.05 were considered significant.

Results

A total of 160 children were enrolled in the study. Three were not able to complete the Dyop visual acuity test (age <5 years), because they did not understand the rotation concept. Therefore, results from 76 boys and 81 girls (N = 157) were analyzed. The mean patient age was 8.4 ± 2.9 years (standard deviation; range, 4-17). Table 1 provides the diagnoses, which include apparently typical development as well as several pathologies. Only 4 subjects appeared normal.

Figure 2 presents the raw visual acuity data. Using the scoring method described above, the best-corrected logMAR visual acuity ranged from −0.04 to 0.602 for the Lea numbers chart and from −0.038 to 0.653 for the Dyop. The mean logMAR visual acuity obtained with the Dyop test was 0.16 (20/29) ± 0.13 and 0.15 (20/

Table 1. Participant diagnoses (N = 157)[a]

Diagnosis	No. (%)
Amblyopia	49 (30)
Anisometropia	35 (22)
Anterior segment opacity	4 (0.25)
Normal	4 (0.25)
Optic nerve pathology	4 (0.25)
Other	68 (42)
Retinal pathology	3 (0.18)
Strabismus	62 (39)

[a]Some participants had more than one diagnosis.

28) ± 0.11 for the Lea numbers chart ($t = -1.96$; $P = 0.052$).

The differences between the test outcomes (Lea value minus the Dyop value) are shown in Figure 3. The difference in the mean visual acuity was −0.01 ± 0.06 logMAR (range, −0.12 to 0.12). The 95% confidence interval for the mean difference was −0.02 to 0.001, which indicates that the patients scored up to1 letter better with the Lea chart than with the Dyop visual acuity test, on average.

Figure 4 presents a Bland-Altman plot of the difference between the visual acuities obtained using both tests plotted as a function of the mean of the two approaches. The plot demonstrates the limits of agreement of the tests (mean ±2 standard deviations), which were −0.13 to 0.11 logMAR. Defining one line as equivalent to 0.1 logMAR, the width of the interval defined by the limits of agreement was 0.24 logMAR, equivalent to ±1.2 lines.

Figure 5 represents the regression analysis of the Dyop visual acuities compared with the Lea numbers tests. The 0.88 correlation coefficient indicates that the visual acuities measured with the two charts have a strong linear association.

Discussion

The findings presented here for children 4-17 years of age with a broad range of visual acuities (20/16 to 20/100) confirm the validity of Dyop testing. A strong, positive linear correlation of 0.88 and a mean difference between tests of 0.03 ± 0.08 logMAR (equivalent to approximately 1 letter of visual acuity difference) was found, indicating that over the range of visual acuities tested, the participants scored an average of 1 letter better on the Dyop visual acuity test than on the Lea numbers chart. Based on individual assessments, the 95% limits of agreement were ±1.2 lines. This indicates that the difference between the two tests would be ±1.2 lines in 95% of patients. Although there is a recognized difference in mean visual acuity by different optotypes and different presentations, such as the 0.42-line difference between PEDIG's EVA and E-ETDRS,[6] the difference of less than 1 in 5 letters found in this study is similar to the Handy Eye Chart study.[2] This validation study of the Dyop visual acuity test chart was patterned after the study used to validate the Lea symbol chart, which has been used and assessed in several studies.[7-11]

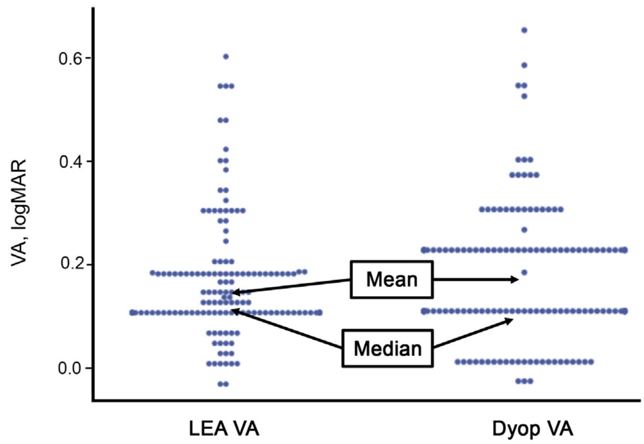

FIG 2. Raw visual acuity (VA) data from the Lea numbers chart and the Dyop visual acuity test for each patient: mean and median values (logMAR) for each test.

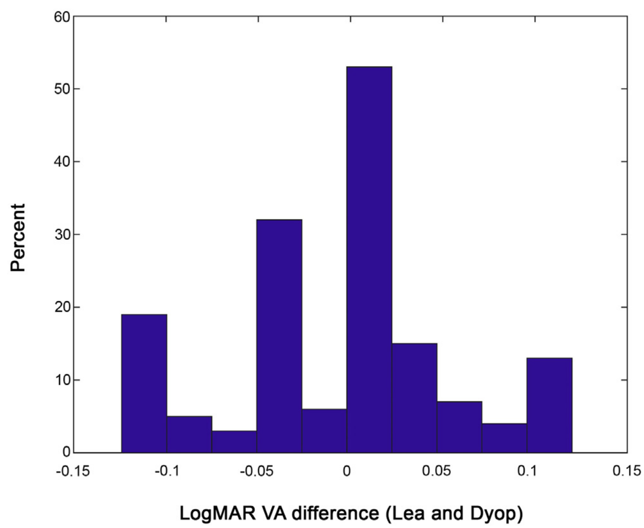

FIG 3. Histogram of the acuity difference between the Dyop visual acuity test and the Lea numbers chart for each participant. The mean difference in acuity was −0.01 ± 0.06 logMAR (95% CI, −0.02 to 0.001), or approximately 1 letter. The range of visual acuity differences was −0.12 to 0.12 logMAR.

Although conventional visual acuity testing relies on central fixation on a steady small optotype projected on the foveola in the macula, with other testing methods, other visual signals are conveyed from extramacular representation and also movement. This is one reason the Teller method for children may correlate with but not be exactly the same as visual acuity.[12] Unlike other nonconventional visual acuity methods (Teller, Catford drum, etc), Dyop perception is foveal and uses apparent motion detection from the strobic stimulus.

The Dyop visual acuity test is a new way of testing visual acuity in children. One method of testing visual acuity

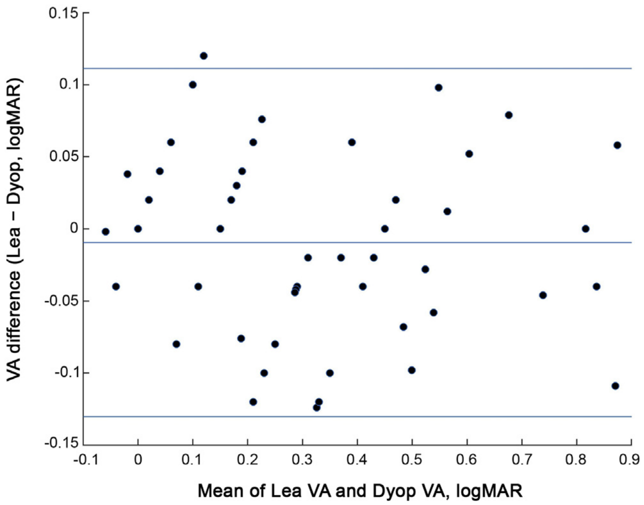

FIG 4. Bland-Altman style plot showing monocular acuity difference as a function of the mean acuity for each participant. The horizontal lines are drawn at the mean (−0.01) and ±2 standard deviations. The difference in acuity between the 2 tests appears uniform across the range of visual acuity (VA) tested. The 95% limits of agreement between the two tests were −0.13 to 0.11 logMAR.

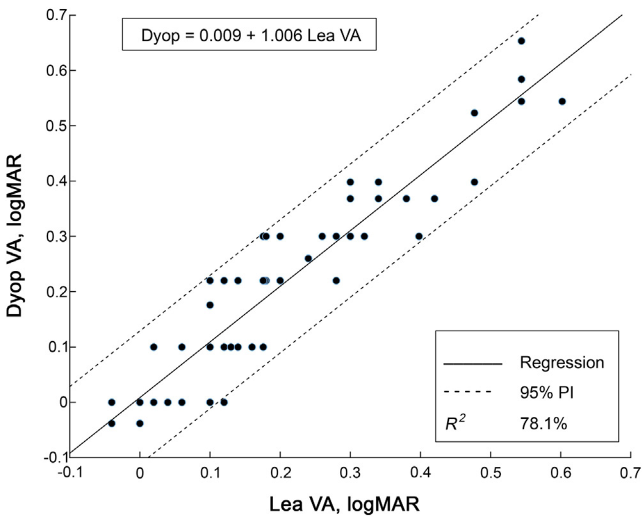

FIG 5. Linear regression of the Dyop visual acuity test against Lea numbers chart showing a strong linear correlation of 0.88. The regression equation is Dyop visual acuity test = 0.009 + 1.006 (Lea numbers chart). *PI*, prediction interval.

among nonverbal children is matching. But when a child looks away from the phoropter to choose the matching optotype, the continuity of the examination is disrupted.[13] The Dyop lets children use one hand to indicate what they see, without looking away from the chart. This may be useful when checking visual acuity in children with language delays or difficulties and children who do not speak the common language. The Dyop method has additional advantages, such as shorter time and ease of administration both for the examiner and the patient (unpublished results). In addition, the Dyop method can be used on a forced choice preferential looking platform in the Dyop infant version.

Commonly used pediatric visual acuity tests result in varying estimates of visual acuity in adults, suggesting that pediatric visual acuity tests are not all equally well designed.[14] The Dyop may have advantages for assessing visual acuity compared to routine methods. In addition to a strong correlation with traditional methods, advantages of the Dyop include rapid identification of the threshold endpoint, finer visual acuity granularity compared to typically used "line" steps, and ease of use.[4]

Future research may compare the Dyop method with other dynamic tests, such as Smith's method,[15] and in patients with learning disabilities, trouble with visuospatial skills, or dyslexia.

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