Validation of the Dyop® Acuity Test

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PURPOSE

A Dutch Ophthalmologist, Herman Snellen, developed a standardized vision-testing chart more than 150 years ago that has been adopted worldwide with minor changes in concept and form. The computer age has opened many doors to new ways to measure visual acuity and visual performance but they are generally only computerized graphic images or portions of standard charts.

Inventor Allan Hytowitz designed a new dynamic target called the "Dyop" (short for Dynamic Optotype), which is a rotating, segmented optotype. The Dyop may be varied by diameter (angular arc width or arc areas), contrast, or color at constant or reversed rotational velocities to assess acuity threshold as a functional measure of minimum perceptible resolution. Results of this study could alter and improve how visual acuity is measured.

METHODS

162 subjects were seated in a standard examination chair and were assessed for visual acuity thresholds by viewing, on a fully randomized basis, two different acuity charts with a series of test conditions. Testing was done at a full 20 foot testing distance with the only room lighting generated from the LCD monitors used by the computerized testing systems. Threshold acuities were assessed for each of the following test conditions for all subjects:

- *Sloan Letters*
  - Refraction uncorrected
  - Refraction corrected
  - Refraction corrected with: +2.00 lens; +3.00 lens; +4.00 lens
- *Dyop Optotype*
  - Refraction uncorrected
  - Refraction corrected
  - Refraction corrected with: +2.00 lens; +3.00 lens; +4.00 lens

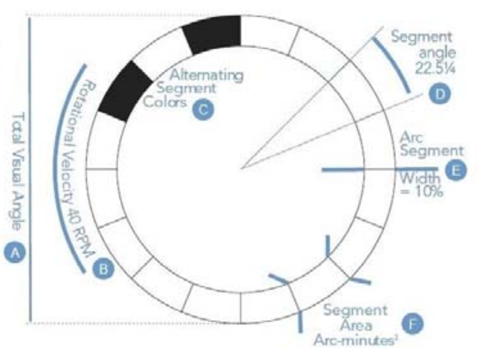
Dyop acuity values were collected in arc minutes for purposes of this testing that were equal to the visual angle of the outer diameter of the circular optotype. These were presented to the subjects on a Chart2020® system (Shemesh Medical, Johannesburg, SA). Sloan letter acuity was measured on a Smart System® (M&S Technologies, Niles IL) using a new stair-step methodology, the Harris Visual Acuity Protocol, that features much finer graded steps than standard acuity lines.

WHAT IS A DYOP?

A Dyop is a segmented, circular figure composed of equally spaced segments that rotates at constant velocity. The Dyop is smoothly scaled from large to small until a novel endpoint, not experienced with historical acuity assessments, is reported. The rotation appears to stop when the acuity threshold is reached. The continuous battle (and associated frustrations) to push a patient to the point of confusion necessary with standard threshold determinations is replaced with this almost binary event in which the optotype fades into the gray background.

In this study, a high contrast black and white Dyop target was used with the rotating figure appearing on 50% grey background. While contrast and color can also be varied for other visual function assessments, it was not a variable in this study. The structure of the zooming Dyop allows very rapid closure to and bracketing of the threshold size. Dyops may be a universal measure as they are cultural, literacy, and language independent.

Figure 1. Illustrates the fundmental geometry of the Dyop - dynamic optotype. The total circular diameter or visual angle (A), speed of rotation (B), contrasting colors, in this study black and white (C), segment angle (D), segment arc width (E), and area of each segment in arc minutes 2 (F).



The calibrated Dyop image uses a combination of image diameter (angular arc width), segment/gap stroke width, percentage of total width (angular arc area), rotation speed (RPM), contrast, color, and the pixelized strobic photoreceptor refresh rate to create an acuity threshold as an indicator for the measurement of visual acuity. As photoreceptors require change in stimulus to evoke an excitatory response from the photoreceptors, a kinetic optotype may more favorably match the nature of the visual response mechanism than a static optotype in which small eye motions help tease out the visual response. Additionally, unlike static images, which get increasingly blurry as they get smaller or further away, the rotation of Dyop images stops being detectable at a discrete point as the acuity threshold is reached. The precise Dyop diameter serves as an indicator of acuity based upon the angular arc width and viewing distance.

Figure 2 shows three Dyop optotypes on the screen with the largest on the left and the smallest on the right. Each would be turning in a random direction. In this configuration the subject reports which direction the middle Dyop is turning. As threshold is reached, in the largest Dyop (left), motion is seen, the yellow highlighted middle sized Dyop appears to stop moving or "twinkles", and the right smallest Dyop clearly no motion is reported. In typical acuity threshold ranges, the left could be 20/14, the middle 20/13, and right 20/12.

RESULTS

There was a strong linear relationship between Sloan and Dyop acuity measures (Pearson r=.94; p<001). In a single predictor model, the Dyop measure explained 89% of the variance in Sloan acuity. An interaction model relaxing the assumption of common slopes by testing condition indicated a significant measure X condition interaction (p=.004), and explained over 91% of the variance in Sloan acuity. Optimal conversion algorithms between Dyop and Sloan measures were developed via regression models.

Figure 3 is a plot of the log of the Sloan VA/20 against the log of the Dyop size in arc minutes. The linear Pearson correlation is very strong (r= .95; p< .001). This includes all conditions for all 162 subjects. Figure 4 shows the breakout for each condition.

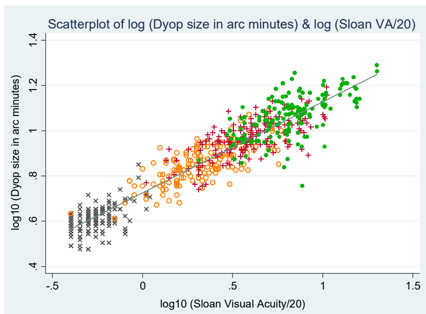


Figure 3 *shows the plot of the log of the Dyop size in arc minutes against the log of the Sloan VA/20.*
Rx Corrected = Dark Gray (x) +2.00 blur = Orange (o) +3.00 blur = Red (+) +4.00 blur = Green (•)

The best fit for this in a simple linear form is:

log(Snellen LogMAR) = -1.557 + 2.204(log(Dyop))

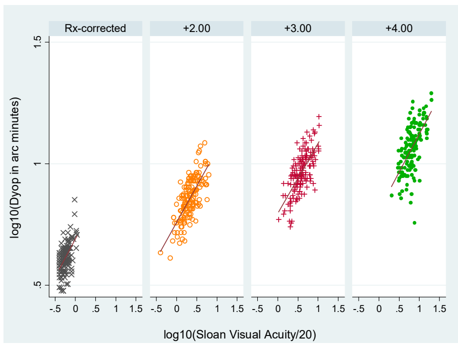


Figure 4 *show the scatter plots for each of the separate conditions. Correlations were significant to the p <.001 level in all conditions. Pearson correlations for each condition were: Rx Corrected r=.54, +2 blur r=.72, +3 blur r=.72, +4 blur r=.63, overall pooled r=.94.*

VARIABILITY, EFFICIENCY, EASE OF USE

We noticed that with the Dyop we were able to get to endpoints very quickly, and when plotted, the data showed a marked reduction in variability with far more linearity. At times, when looking at averaged data the richness of clinical observations made gets obfuscated. Figures 4 and 5 show the Log plots for all of the individual subjects by test condition.

Figure 5 *shows each individual subject and their raw data from the Dyop with blur; Mean = 0.873 Variance = 0.035.*

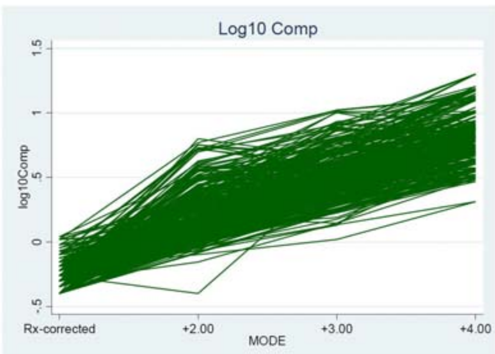


Figure 5 *shows each individual subject and their raw data from the Sloan VA with blur; Mean = 0.368 Variance = 0.193.*

We noticed in Figure 5 some outlier lines which seemed to indicate that going from one level of blur to another, where we expected a decrease in visual acuity, that we actually got an increase. At the lowest part of the graph, a green line can be seen shifting downward (better visual acuity) towards +2.00 on the X-axis. Based on this finding we looked at individual sets of data to determine how often this occurred.

In the Sloan VA testing, 31 of the 162 subjects had these anomalies. 15 of them had a recording of a better level of visual acuity at the +4.00 level of blur than at +3.00. 12 of them had a recording of a better level of visual acuity at +3.00 blur over the +2.00 blur. Four subjects had the same exact level of visual acuity recorded at two different levels of blur, either at both the +2.00 and +3.00 or the +3.00 and +4.00 level of blur.

With the Dyop there were only three of 162 such instances. With one subject the visual acuity recorded was the same with the +3.00 and +4.00 blur. With one subject it was better with the +4.00 vs. the +3.00 blur and with one other subject it was better at the +3.00 than at the +2.00 level.

Study Condition	Variance
Sloan letters (2013)	0.233
Sloan letters, Harris Method (2014)	0.193
Dyop – Triplet (2013)	0.060
Dyop – Doublet (2014)	0.035

Table 1 *summarizes the variance in the test conditions over the two years of the study.*

DISCUSSION

In preliminary work with the Dyop we liked the speed with which we could hone in on the acuity threshold. We appreciated the granularity of the measures and the apparent repeatability of the findings with the Dyop. The difficulties and frustration (with both subject and examiner) common in taking visual acuity measures are many and need not be summarized here. For the promise of the Dyop to be realized, it was important that not only should the measurements at threshold match from method to method, but that they should do so over a wide range of blur conditions.

One year prior, a similar set of data was obtained, but instead, we used a standard Sloan logMAR type visual acuity test with the standard line to line step sizes, which made very large jumps at the lower levels of visual acuity. For example the higher levels went from 20/80 to 20/100 to 20/125 to 20/200 to 20/400. This led to data that can be seen in Figure 6.

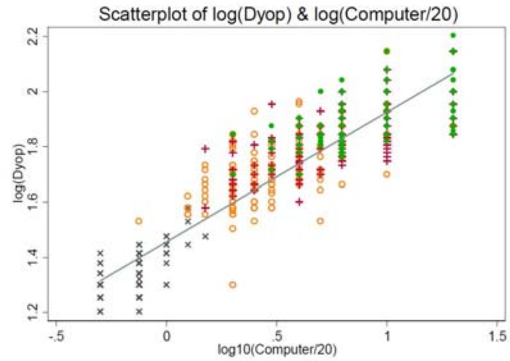


Figure 6 *shows data from 150 subjects taken in the summer of 2013 using computer based M&S Technology visual acuity plotted vs. the Dyop.*

This led to our interest in improving the measure of visual acuity with finer gradations in letter size. This uses a standard Sloan letter optotype that begins at 20/8 visual acuity. A stair-step design is used, at first with coarse and then with finer and finer steps to hone in on a more precise threshold quickly. Visual acuities of 20/37 or 20/84 could be obtained and this can been seen in Figure 1. At this level of visual acuity measure gradation, the robustness of the relationship between the Dyop and visual acuity became evident that is not apparently with large pooling of acuity ranges.

Our results clearly suggest and support our clinical experiences and with our 312 subjects over a 2-year period that the Dyop measurement is easier to obtain and the data is robust. The only difficulty we had with getting the Dyop results was confusion in some subjects. Keep in mind that most subjects were second and third year optometry school students who understand the concept of clockwise vs. counter-clockwise spin movements. We had to keep on the wall near the Chart2020 display a sign to help our subjects respond. Between years we asked for the inclusion of a silent way to stop all rotation of the Dyops being shown, which led to the paradigm of asking which one of the pair of optotypes was rotating rather than which direction the optotype was rotating. This turned out to be a far superior way to identify the endpoint of the Dyop testing.

Figure 7 *shows the signs placed above the Dyop Chart2020 system showing two Dyop optotypes on the screen. The direction/motion of each optotype is randomized with each step, i.e. one optotype is randomly selected to rotate and the direction of the rotating optotype is randomized. The subject is required to identify the rotating Dyop and the rotation direction.*

CONCLUSIONS

The Dyop is a novel method of measuring visual acuity that is strongly associated with, and may offer an improvement in assessment of visual acuity compared to historical methods. In additional to a strong correlation with traditional methods, the Dyop was reported to be advantageous due to the speed at which the threshold endpoint is defined, finer acuity granularity compared to the typically used acuity "line" steps, and ease of endpoint identification by subjects.

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