Initial Validation of the Dyop® Infant Acuity Test

Proof-of-Concept Test

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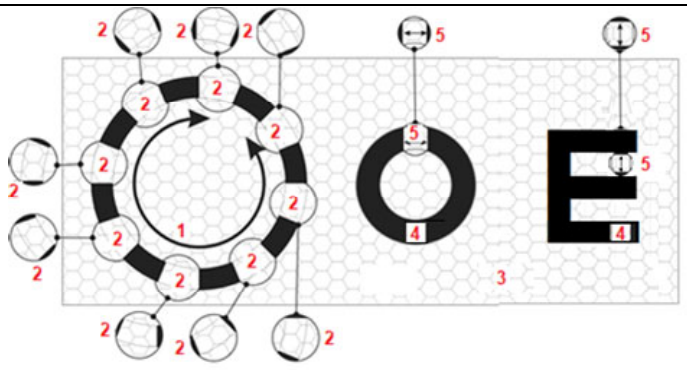
Test Results:

The **Dyop Infant Acuity Test** was used to determine visual acuity of an infant 3.5 months-old (14-weeks). The infant acuity values are based on the documented Dyop acuity values for adults. (A larger Dyop arc width diameter indicates less visual clarity.) The **infant's basic acuity (Black/White on Gray) was in the range of 44 arc minutes (20/440 or 6/135) to 40 arc minutes (20/375 or 6/115).** While that arc width acuity value is MUCH higher than a typical adult or child's vision, this prototype test was with an infant who at the time was only 3.5 months old with a typically under-developed infant visual system. The variables available with a Dyop were also used for testing with colored Dyop segments. The acuity endpoint for **Red/Gray was 70 arc minutes (20/1000 or 6/300)**, **Green/White was 64 arc minutes (20/950 or 6/300)**, and **Blue/Black was 104 arc minutes (20/2000 or 6/600)**. The infant's color preference of **being able to see a smaller spinning Green/White Dyop versus a spinning Blue/Black Dyop** is indicative of the infant **NOT** having a disposition for symptoms of dyslexia, migraines, or epilepsy. A reversal of that relative relationship between the acuity endpoint sizes those two color/contrast Dyops (i.e., being better able to see a smaller arc width spinning **Blue/Black Dyop** versus a spinning **Green/White Dyop**) would be indicative of those symptoms. Each of the specific Dyop tests was binocular and took about 20 seconds for each color/contrast permutation.

Explanation of the tests:

Visual acuity is the term used to describe visual clarity, which is the lowest threshold where you **can** clearly determine the identity of a visual target. **Sub-acuity** is the perception status where the identity of the visual target **cannot** be detected, as in static letter tests where you cannot identify the letters. Visual targets typically use **Recognition Acuity** as static letters or shapes as an optotype, which is both literacy and culture dependent, or they use **Resolution Acuity**, which is the ability to detect the gap between two points or lines. A **Dyop®** (short for "dynamic optotype") uses a **spinning segmented ring Resonance Acuity** as a visual target (Figure 1)[1] s a used. The term Dyop is short for "dynamic optotype" with "**optotype**" as the formal name for a visual target. However, a typical "dynamic optotype" refers to a visual target moving (horizontally) across the visual field. A Dyop is best categorized with its location as stationary but its gaps/segments visual components are in motion. A Dyop also uses **Resonance Acuity** where the physiological response to the perception of the optotype in motion is because it is resonating with the vibratory motion of the visual saccades. As a result, a Dyop is independent of literacy, culture, and possibly species[2]. Dyop sub-acuity is where Dyop diameter ring gets sufficiently small, and the size of the spinning gaps gets small enough, that the subject cannot differentiate the gaps from the segments, and thereby cannot detect the motion direction of spin of the segmented ring. Instead of a spinning ring (the direction of spin being irrelevant), with Dyop sub-acuity you see a blurred and almost solid ring.



Item 1 – the visual angular movement/velocity for the strobic contrast response (**40 RPM** optimum) with **a 0.33 arc minute squared per second** refresh rate.
Item 2 – the moving segmented **0.54 arc minute squared** Minimum **Area of Resolution (MAR)** for dynamically stimulating a **20 photoreceptor cluster.**
Item 3 – retinal photoreceptor cell clusters
Item 4 – examples of a historic static **Recognition** or **Resolution** acuity optotype
Item 5 – the static **1.0 arc minute squared** Minimum **Area (MAR)** of a **40 retina photoreceptor cluster** for a historic static optotype

Figure 1 – Dyop components

The "**basic Dyop Test**" has alternating **8 Black segments and 8 White gaps** to provide maximum contrast on a "neutral" Gray background and central Gray core. The primary optional color contrast permutations for a Dyop are Red, Yellow, Green, and Blue segments with Gray gaps and a Gray background and Gray core, or Green segments with a White gap on a White background, or Blue segments with a Black gap on a Black background. The changes in the angular width diameter are typically in 1-arc minute increments for lower values below 25 arc minutes, 5 arc minute increments for values below 60 arc minutes and 15 arc minutes for values below 102 arc minutes. Values above 120 arc minutes are categorized as Low Vision.

The "**Adult Dyop Acuity Test**" includes two Dyops near the center of a computer or electronic display. One Dyop of the duo is static and the other is spinning. The static Dyop serves as a comparison to the pinning Dyop in that when you cannot detect the motion of the spinning Dyop you can use the static Dyop as a comparison in that you "know" (perceive) that one of the Dyops is NOT spinning (sub-acuity). One of those Dyops IS spinning; you just cannot detect which one. The threshold of making that spinning Dyop incrementally larger determines the acuity endpoint where spinning of one of the Dyops is distinctively detected (Figure 2). The program setup allows for calibration of the subjects' test monitor size and viewing distance (Figure 3).

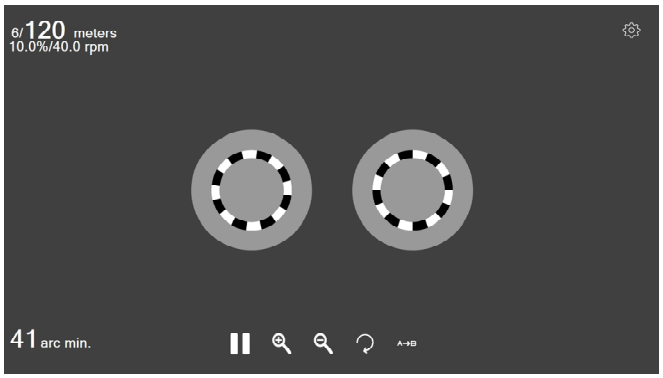


Figure 2 –Dyop Adult Test

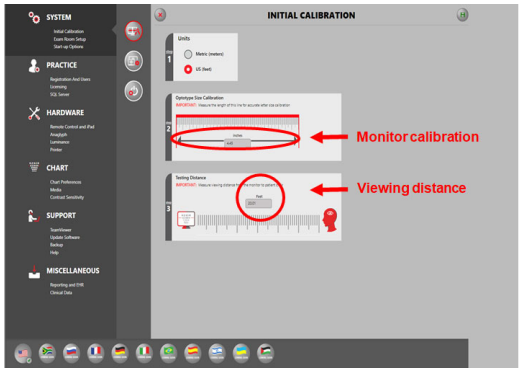


Figure 3 – Dyop test calibration setup

A second Dyop Test variant is the "**Children's Acuity Test**" which has two Dyops each on the periphery of the screen. The advantage of the "Children's Test" is that in addition to asking which of the two Dyops is detected as spinning (Left or Right) the subject has the potential for a more distinctive response. Because of preferential looking the subject will look at the side of the monitor display which has the spinning Dyop and/or distinctively pointing to the Left or the Right side of the screen at the spinning Dyop. This becomes even more useful for semi-literate individuals or young children who lack the verbal skills to identify "left or right" (Figure 4).

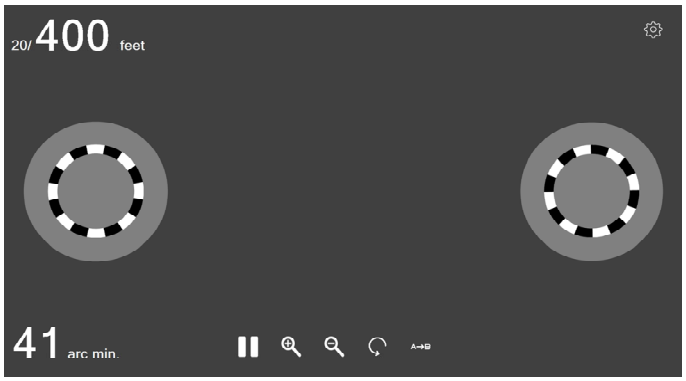


Figure 4 – Dyop Children's Test

The Dyop "**Children's Test**" was inspired by the Teller Visual Acuity Cards, which use preferential viewing by a child viewing a series of white cards with an area of vertical stripes on one peripheral side of the card. The Cards are traditionally three feet by two feet in size with an area of vertical stripes, which are about one foot square and located six inches from the top, bottom, and side of the card. To determine the left or right visual preference of the subject (infant) the card is reversed 180 degrees in its orientation. The twelve-inch high stripes are about 1 inch wide in the initial card. Subsequent cards have the stripe width reduced from to a half-inch down to about one-sixteenth of an inch in width. Acuity is measured by the size of the stripes (in cycles) where the subject has preferential viewing for the location of the striped area as displayed on the left or the right side of the card. As the stripes get thinner, the lines become a (almost) gray blur and lose the attention of the (infant) subject. The test normally takes about 10 minutes in a distraction-free environment. The full 16 card series of the test retails for about $2500. The Dyop equivalent is included free as part of the Chart2020/Dyop platform and takes about 10 to 20 seconds per eye (or binocular) to determine the child's acuity endpoint as previously validated by children as young as one year of age (Figure 5).

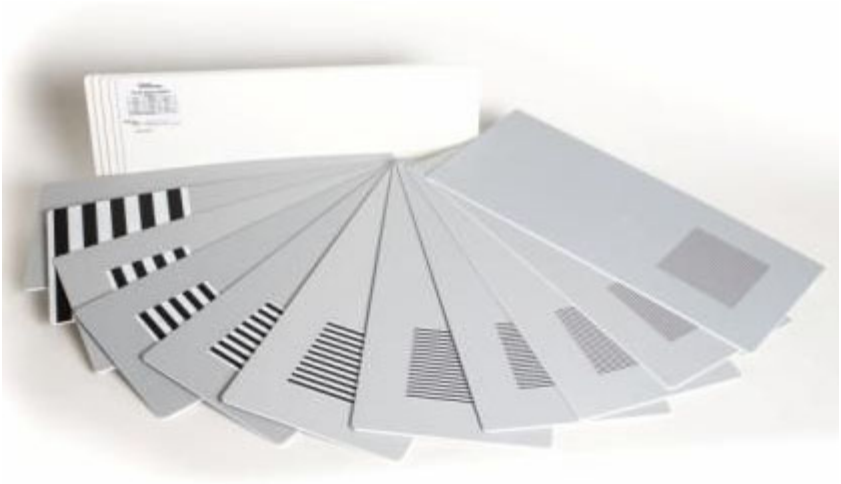


Figure 5 – Teller Infant Acuity Cards

A third variant is the **NEW** "**Infant Acuity Test**" which has only **ONE** Black Dyop (Figure 6), which is spinning on a white background and whose location alternates from one side of the screen to the other as its diameter changes. The test objective is to have the subject (Figure 7) notice the spinning Dyop due to the innate preference for motion detection with the result that the subject's (infant's) eyes and possibly their head switches its gaze to the other side of the screen when the location of the spinning Black Dyop moves to that side.

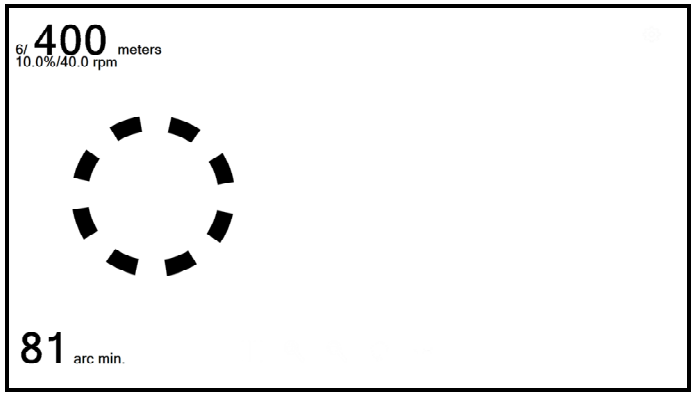


Figure 6 – Dyop Infant Acuity Test

Figure 7 – Infant Test Subject

Additional test variants include a "**Single Dyop**" test, a high "**Precision Dyop**" duo (pair), and a "**Color/Contrast Dyop.**" The "**Precision Dyop" has** diameter size changes in approximately 0.3 arc

minute increments versus the 1 arc minute increment changes of the first three variants. The "**Color/Contrast Dyop**" duo allows the color/contrast of the gaps/segments to be finely adjusted as well as the ability to customize the Dyop ring stroke width and Dyop rotation speed (Figure 8).

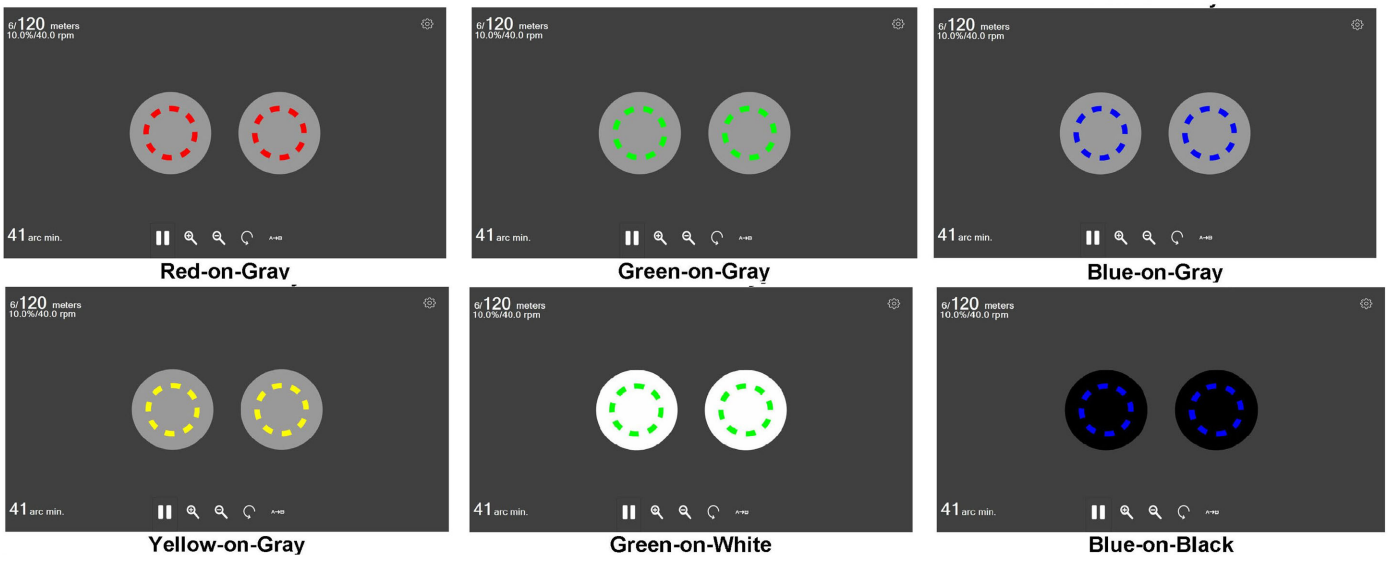


Figure 8 – Dyop Basic Color/Contrast Permutations

However, the common variant of all of the Dyop tests is that the **Dyop acuity endpoint is directly related to the angular arc width of the smallest Dyop detected as spinning**. That Dyop acuity endpoint size also has a linear relationship to the viewing distance, unlike Snellen-based measurements, which have a logarithmic relationship. The crucial discovery of the Dyop concept is not the use of a dynamic optotype to measure acuity but rather that the discovery that the traditional Snellen visual stimulus gap of 1.0 arc minute squared is actually twice the size area of the actual typical human stimulus area. The classic Snellen logarithmic increase in size curve is actually also a measure of the inherent imprecision and inconsistency of Snellen acuity testing (Figure 9).

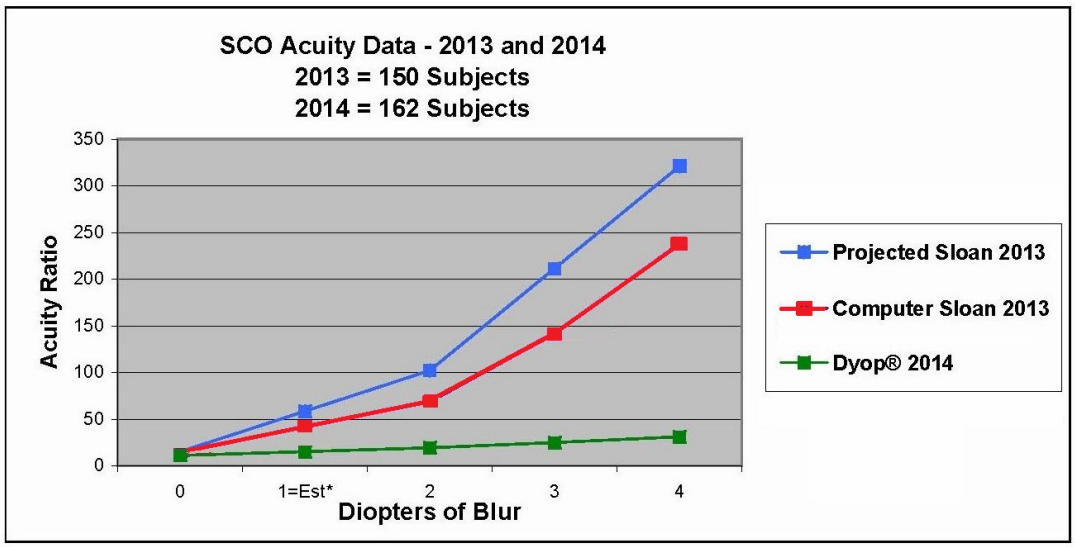


Figure 9 – Ratio of size to diopters of blur of Snellen versus Dyop testing.

Table 1 is the **Dyop arc widths versus Snellen values and the Dyop screen diameters at key viewing distances.** Arc widths cited in **Yellow** and **Orange** **ARE INCLUDED** in the standard Dyop test. Arc widths cited in **Yellow** are the standard values for the **Teller Infant Acuity Cards**.

Table 1 - Dyop arc width versus Snellen values and Dyop screen diameters

Dyop Arc Min	Snellen Acuity Standard Values		Viewing Distance 6 meters	Viewing Distance 3 meters	Viewing Distance 2 meters	Viewing Distance 1 meter
	20 / Feet	6 / Meters	Dyop = mm	Dyop = mm	Dyop = mm	Dyop = mm
104	2000	600	185	92.5	62	31
81	1300	400	144	72	48	24
70	1000	300	124	62	41	21
62	**800**	**240**	110	55	37	18
57	650	200	101	50.5	34	17
52	590	180	92	46	31	15
46	475	145	82	41	27	14
41	400	120	73	36.5	24	12
39	350	100	69	34.5	23	12
35	300	90	62	31	21	10
32	**250**	**80**	57	28.5	19	10
30	220	70	53	26.5	18	9
28	200	60	50	25	17	8
25	165	50	44	22	15	8
24	150	45	43	21.5	14	7
22	130	40	39	19.5	13	7
21	120	35	37	18.5	12	6
20	**110**	**33**	36	18	12	6
19	100	30	34	17	11	6
18	90	25	32	16	11	5
17	82	25	30	15	10	5
16	70	21	28	14	9	5
15	66	20	27	13.5	9	5
14	**58**	**18**	25	12.5	8	4
13	50	15	23	11.5	8	4
12	45	14	21	10.5	7	4
11	38	12	20	10	7	3
10	32	10	18	9	6	3
9	27	8	16	8	5	3
8	**22**	**7**	14	7	5	2
7	18	5	12	6	4	2
6	13	4.5	11	5.5	4	2
5	10	4	9	4.5	3	2
4	6	2	7	3.5	2	1

Infant Acuity Test Results:

The initial intent was to display the Dyop images on an iPad, but having the test displayed on a MacBook allows a larger screen and a wider peripheral separation of the Dyop locations. It also permits the remote examiner to track the motion of the test subject eyes with Facetime using the MacBook top center camera. The Dyop Setup screen Calibration Line separation (Figure 2) **as viewed on the subject's MacBook** was determined as 50 mm**.** The adjusted Dyop diameters when viewed on the MacBook conformed to the "standard" diameters for the Adult Dyop test (per Table 1).

Table 2 displays the Dyop arc width increments for a test at a 3-foot (1 meter) viewing distance per the Adult and Children's Dyop Test calibration. The **maximum standard Dyop acuity measurement is 104 arc minutes (20/2000 or 6/600).** Acuity above that level is regarded as being functionally blind. The size of the spinning Dyop at **185 mm (104 arc minutes)** is also almost the maximum size which will fit on a computer monitor when viewed at 20 feet. The larger arc widths as displayed in **Blue** in the table below **are NOT** included in the standard Dyop test. Arc width values in **Yellow** and **Orange** **ARE INCLUDED** in the standard Dyop test. Arc width values in **Yellow** are the standard values for the **Teller Infant Acuity Cards**.

The **Dyop Infant Test** calibration conforms to the "standards" of Teller Card increments, which has a lower maximum value of **81 arc minutes (20/1300 or 6/400)** for the acuity endpoint. The Teller Cards are intended for use at a **3-foot (1 meter) viewing distance**.

When the Infant Test examination had the subject 3 feet from the MacBook screen, the subject only noticed the location of the largest spinning Dyop at **81 arc minutes** (20/1300 or 6/400 acuity). The infant was easily distracted when smaller Dyop diameters were displayed.

Table 2 - Dyops viewed at 3 feet (1 meter)

Dyop	Snellen Acuity Standard Values		Viewing Distance @ 3 ft (1 meter)
Arc Min	20 / Feet	6 / Meters	Diameter = mm
104	2000	600	31
81	1300	400	24
70	1000	300	21
62	**800**	**240**	18
57	650	200	17
52	590	180	15
46	475	145	14
41	400	120	13
39	350	100	12
35	300	90	11
32	**250**	**80**	10
30	220	70	9
28	200	60	8.5
25	165	50	8
24	150	45	7.5
22	130	40	7
18	90	25	5

In the Setup screen (Figure 3), when you double the Dyop physical diameter and double the Dyop viewing distance, the arc width remains the same (Table 3 and Table 4). The "makeshift solution" for a wider range

of larger diameters was to use the linear relationship of the Dyop diameters to the acuity endpoints and **double the Dyop diameter** by changing the Setup viewing distance to **six feet** while actually maintaining the 3-foot (1 meter) actual viewing distance.

Table 3 - Dyops viewed at 3 feet (1 meter)

	Snellen Values		Screen
Arc Min	Feet	Feet	Diameter = mm
81	**1300**	**400**	**24**
70	1000	300	**21**
52	590	180	**15**
46	475	145	**13**
35	300	180	**11**
32	**250**	**80**	**9**
25	165	50	**8**
22	130	40	**7**
18	**90**	**25**	**5**

Table 4 - Dyops viewed at 6 feet (2 meters)

	Snellen Values		Screen
Arc Min	Feet	Feet	Diameter = mm
81	1300	400	**48**
70	1000	300	**41**
52	590	180	**31**
46	475	145	**27**
35	300	180	**21**
32	**250**	**80**	**19**
25	165	50	**15**
22	130	40	**13**
18	**90**	**25**	**11**

The result of the recalibrated arc width scale was that the infant subject was readily and distinctively able to track the location of the now larger single spinning Dyop as it switched from the left to the right side and back of the MacBook screen. The revised ratio of the Dyop arc width to screen diameter and Snellen acuity is in **Table 5** below.

Table 5 - Dyops Scaled to 6 feet (2 meters) but Viewed at 3 feet (1 meter)

Color Acuity Endpoint	Displayed 6 ft - Dyop Value Arc Min	Actual 3 ft - Dyop Value Arc Min	Actual Snellen Acuity Standard Values		Displayed Diameter Viewed 1 meter
			20 / Feet	6 / Meters	Diameter = mm
	81	**162**	**4400**	**1300**	**96**
	70	**140**	**3400**	**1000**	**82**
Blue/Black	**52**	**104**	**2000**	**600**	**62**
	46	**92**	**1600**	**500**	**48**
Red/Gray	**35**	**70**	**1000**	**300**	**41**
Green/White	**32**	**64**	**950**	**300**	**37**
	25	**50**	**550**	**170**	**30**
B/W-Gray	**22**	**44**	**440**	**135**	**27**
	18	**36**	**310**	**95**	**22**

The adjustment of the setup calibration facilitated the determination that the **infant's basic acuity (Black/White on Gray) was 44 arc minutes (20/440 or 6/135)** (Table 5). However, more precise scaling of the Dyop diameters would likely have produced a more precise result closer to a value of **40 arc minutes (20/375 or 6/115**) **with a 24 mm diameter**. Note that the infant's acuity is MUCH lower than a typical adult or child's vision, but an infant who is only 3.5 months old has an under-developed visual system.

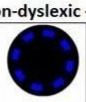
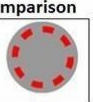
The scale adjustment also allowed additional color acuity testing because of the availability of the larger diameter optotype Dyops. The acuity endpoint for **Red/Gray was 70 arc minutes (20/1000 or 6/300)**, **Green/White was 64 arc minutes (20/950 or 6/300)**, and **Blue/Black was 104 arc minutes (20/2000 or 6/600)**. However, the preferential relationship of being able to see a smaller Green/White Dyop versus the Blue/Black Dyop is indicative of **NOT** having a disposition for symptoms of dyslexia[3], migraines[4], or epilepsy

(per Table 6). A reversal of the relationship between those two color/contrast Dyops (being better able to see the Blue/Black versus the Green/White) would be indicative of those symptoms[5].

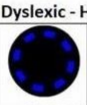
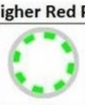
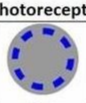
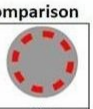
Table 6 - Relative Dyop color/contrast acuity endpoints

Note: smaller arc width indicates better acuity

Myope - 6 Subjects - Non-dyslexic - Balanced Red Photoreceptors Color Acuity Comparison

Dyop							
Color	Basic Acuity	Chromatic	Screening	Blue	Green	Amber	Red
Arc Width	8	13	11	12	12	11	15
Snellen-Feet	20/20	20/50	20/40	20/45	20/40	20/40	20/65
Snellen-Meters	6/6	6/15	6/12	6/14	6/12	6/12	6/20

Myope - 3 Subjects - Dyslexic - Higher Red Photoreceptor Ratio Color Acuity Comparison

Dyop							
Color	Basic Acuity	Chromatic	Screening	Blue	Green	Amber	Red
Arc Width	8	10	15	17	13	11	14
Snellen-Feet	20/20	20/32	20/65	20/ 75	20/50	20/40	20/60
Snellen-Meters	6/6	6/9.5	6/20	6/23	6/15	6/12	6/18

Color-Blind Hyperope - 3 Subjects - Higher Red Photoreceptor Ratio Color Acuity Comparison

Dyop Feet							
Color	Basic Acuity	Chromatic	Screening	Blue	Green	Amber	Red
Arc Width	8	14	12	10	22	14	10
Snellen-Feet	20/20	20/60	20/45	20/32	20/130	20/60	20/32
Snellen-Meters	6/6	6/18	6/14	6/9.5	6/40	6/18	6/9.5

Recommendations:

This proof-of-concept test is of only a prototype with a single subject and needs to have more extensive testing and validation. The algorithm for varying the optotype size also needs to be modified to allow for larger optotypes on smaller display monitors using the standard Dyop algorithm rather than the less precise Teller format.

Conclusion:

The Dyop test has previously proven to be a more precise and efficient method of measuring visual acuity in Adults and Children versus the Snellen test. Due to the not yet fully developed nature of the infant visual system, the significantly more subtle methodology for Adult and Children's testing is not simple enough. By implementing a simpler single Dyop with a basic Black/White strobic acuity dynamic stimulus, the Dyop Infant acuity test should prove to be a precise and efficient methodology of measuring infant vision using the same metrics and parameters as adult vision and based on identical technology. When used with color/contrast permutations, the Dyop Infant Acuity Test might also be a diagnostic for potential symptoms of dyslexia, migraines, and epilepsy. It should also prove to be a far more precise, more efficient, more convenient, and less expensive method of measuring infant acuity than use of the Teller Acuity Cards for infant acuity testing.

References:

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5. Drew S, Borsting E, Stark L, Chase C. **Chromatic Aberration, Accommodation, and Color Preference in Asthenopia**. Optometry and Vision Science: July 2012 - Volume 89 - Issue 7; p 1059–1067.