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Case Report

Dyop Color Perception as a Potential Diagnostic

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Abstract: Due to the ease of use and simplicity of the concept, when Dutch Ophthalmologist Herman Snellen created a scaled series of optotypes in 1862, it quickly became the global standard of vision measurement. What was missing from his innovation was the realization that the mechanics of vision is not limited to humans, and that individuals who did not have cultural familiarity with letter-based words, or could not read were severely impeded in being able to use Snellen's methodology. Snellen also ignored the reality of most applications of vision in that it is a dynamic and automatic process rather than a static process per his optotype. He also ignored the inherent inconsistency of his optotype formats and that, for most individuals, vision is a color perception process as well as modulated by the shape of the visual target. This paper reports four cases and/or elucidates the functionality of a new optotype called a Dyop (pronounced "di-op") which uses the motion of a segmented ring to create a strobic stimulus of the fovea. That strobic stimulus can have the gaps and segments modulated as to color and shade to precisely measure contrast and acuity in color, with a precision up to six times that of Snellen-type testing and a consistency of up to eight times that of Snellen-type testing. The disparity of the color acuity endpoints, despite black/white acuity endpoints being identical, can be associated with diagnosed symptoms of dyslexia (and possibly migraines and epilepsy), ADHD behavior, and early onset glaucoma. That disparity may also solve one of vision science's long-standing dilemmas as to what is the regulatory mechanism for acuity and accommodation.

Keywords: new color optotype, Dyop color test, stable near image, near vision stress

1. Introduction:

The basic functioning of the human eye developed about 300,000 years ago [1]. One of the illusions of "modern" vision science [2-4] is that the concept of measuring acuity and refractions using calibrated sizes of European letters actually reflects human visual processes. Because of the survival pressures, vision is a dynamic process utilizing a specific spectrum of visible light.[5-7] The function of vision in most animals is not to be able to read text, but rather to identify objects and other animals by their size and appearance so that the observer can eat rather than be eaten.

In this short case report, the color/contrast perception of four patients will be explicitly analyzed to revolutionize our understanding of the assessment of color acuity endpoints as a potential diagnostic tool for eye defects or diseases

Background:

The recently developed form of a dynamic optotype called a Dyop (pronounced "di-op") combines the inherent preference for motion detection as well as the advantages of seeing our environment in color. [8]

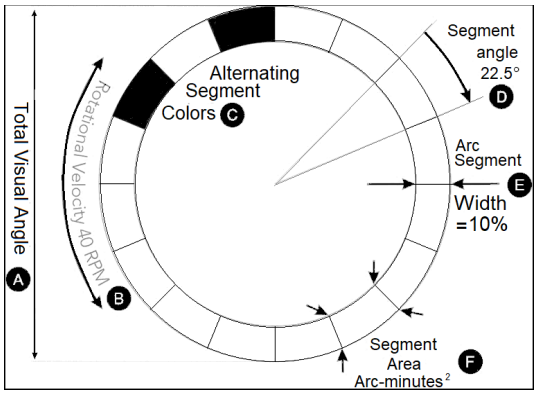


Figure 1

A Dyop provides a strobic stimulus to the photoreceptors, primarily in the fovea, rather than the "traditional" concept of a dynamic optotype, a visual target moving across the horizontal plain.

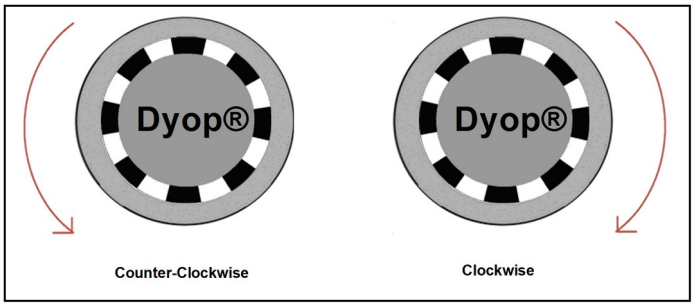


Figure 2

While the 1862 developed Snellen test, using static European letters as visual targets (optotypes), provided a much more precise easier-to-use array of visual targets than being able to see specific combinations of stars, or counting the number of fingers extended from a hand at a specific distance, it is inadequate as to its precision and consistency per the technology of the 21st century.

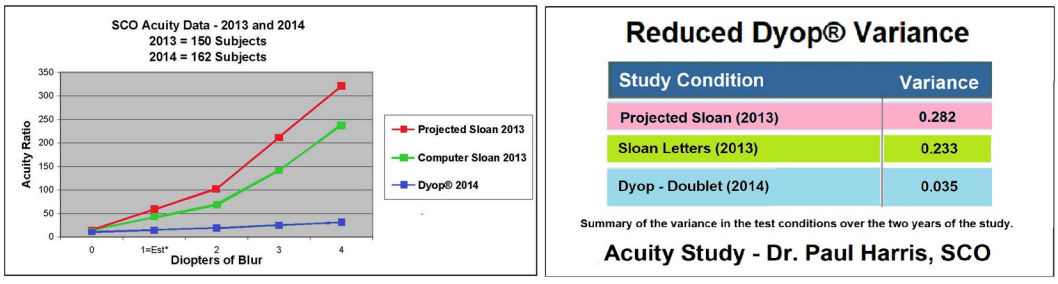


Figure 3

Using a Dyop is significantly more precise (6x) than Snellen/Sloan optotypes, significantly more consistent (8x), and the innovation of using a bracketing algorithm for the Dyop sequence sizes now has it twice as efficient as Snellen/Sloan acuity/refraction. [8-10] Dyop measurements are typically calculated in arcminutes to take advantage of the concept of vision not being dependent upon culture, literacy, race, age, or possibly species. [11-13]

However, a novel area of Dyop functionality in color is just now being explored as a potential diagnostic tool.

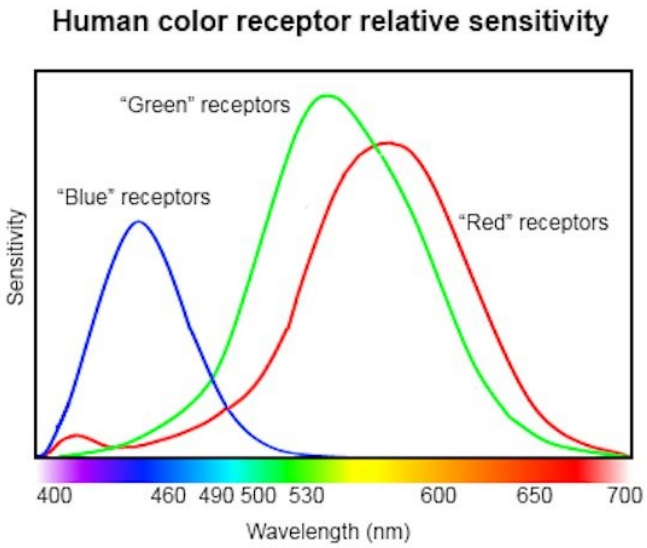


Figure 4

The perception of color by the cone-shaped photoreceptors has specific peaks at (what we now label) blue (464 nm), green (549 nm), and red (612 nm). [14]

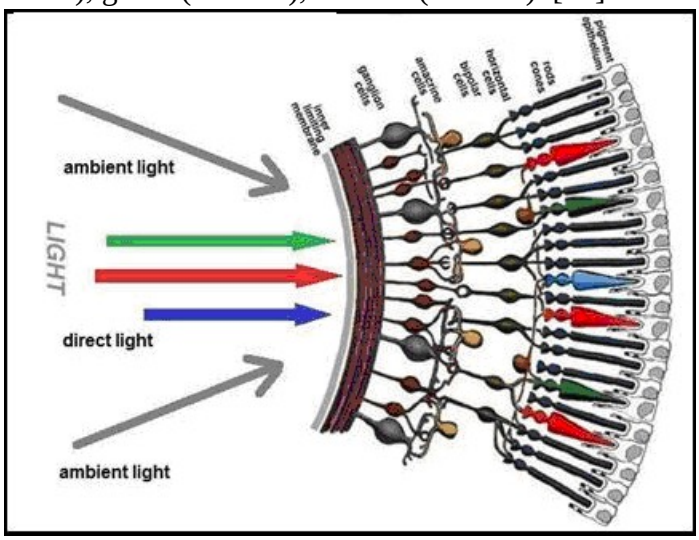


Figure 5

Those color-sensitive cone-photoreceptors are also located in the rear center of the retina called the fovea, with the color sensitive cone areas at the rear of the photoreceptor, facilitating a directional sensitivity to the source of light. Those cone receptors, however, are sensitive to a range of colors with Green being the most sensitive

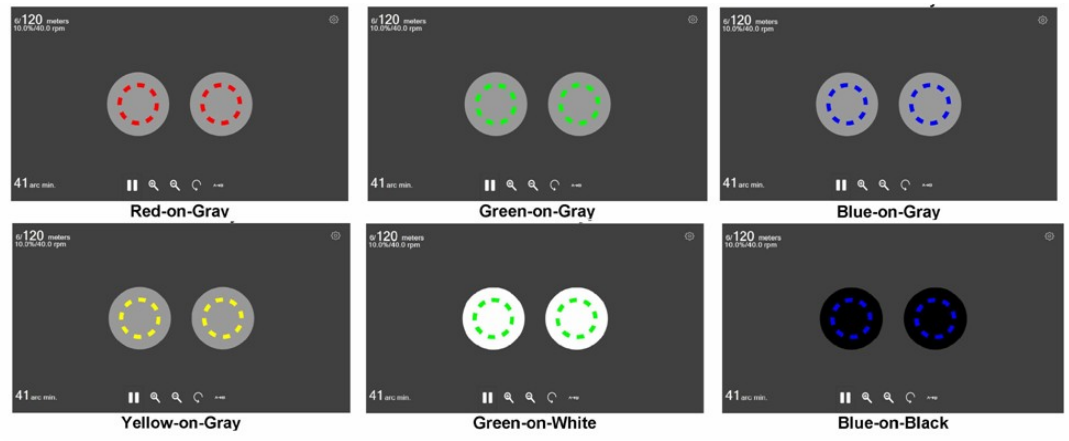


Figure 6

The gaps and segments of a Dyop may also be modified to whatever hexadecimal combination desired, although the principal permutations are Red/Gray, Yellow/Gray, Green/Gray, Blue/Gray to coordinate with the Gray background of the primary Black/White Dyop used in basic acuity determination. The added permutations of Green/White and Blue/Black are also useful as a screening tool for potential symptoms of dyslexia, migraines, and epilepsy. [15]

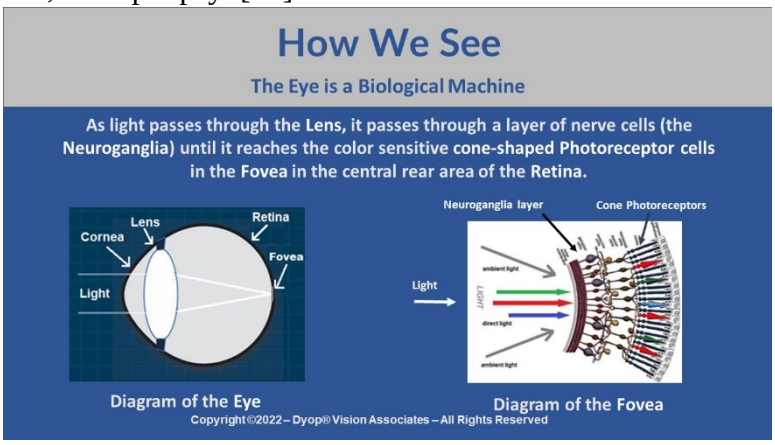


Figure 7

As light passes through the lens it is focused on the central (foveal) area at the rear of the retina.

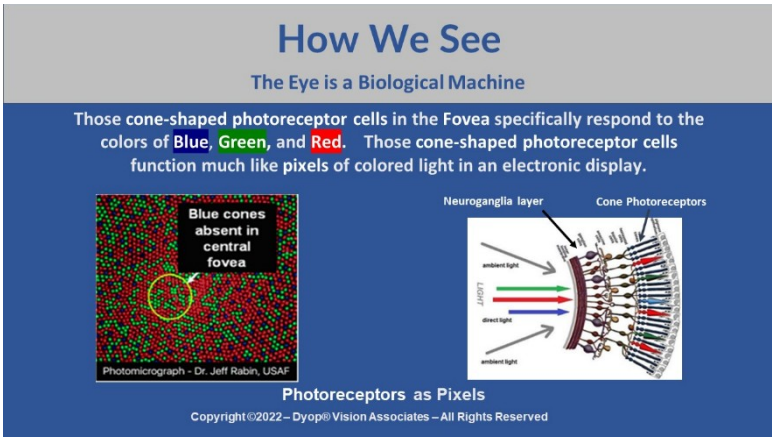


Figure 8

Those cone shaped photoreceptor cells in the Fovea respond to the colors of red, green, and blue, and function much like pixels of colored light in an electronic display.

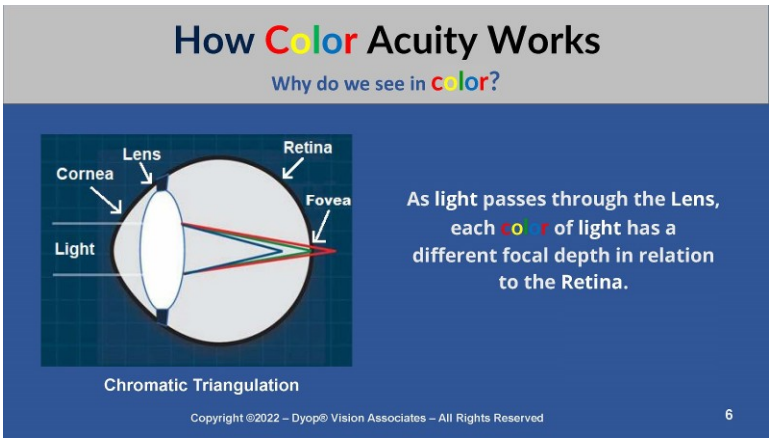


Figure 9

The significance of those colors is that they are refracted (bent) and focused at different depths in relation to the retina.

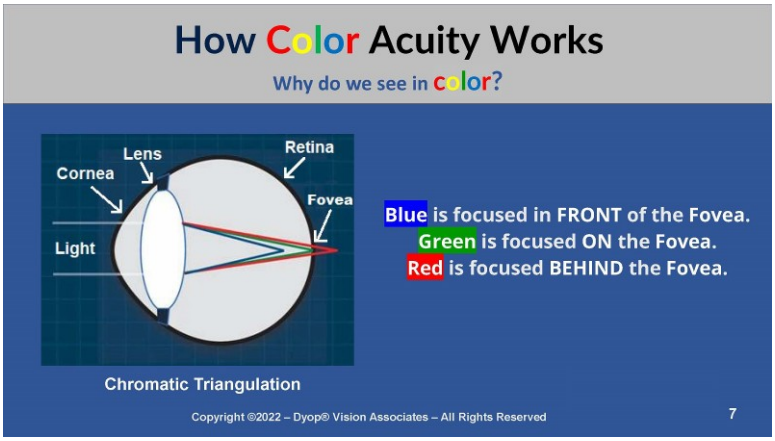


Figure 10

At an optimal focus, Blue is focused in **FRONT** of the retina, Green is focused **ON** the retina, and Red is focused **BEHIND** the retina

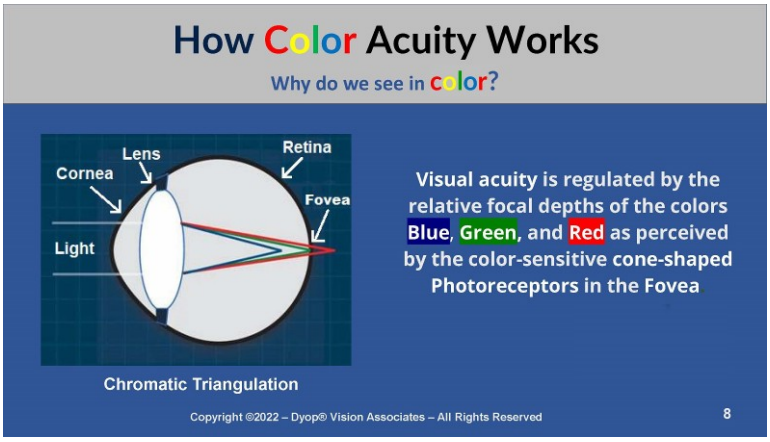


Figure 11

Visual acuity is regulated by the relative focal depths of the colors of Blue, Green, and Red as perceived by the color-sensitive, cone-shaped photoreceptors in the fovea.

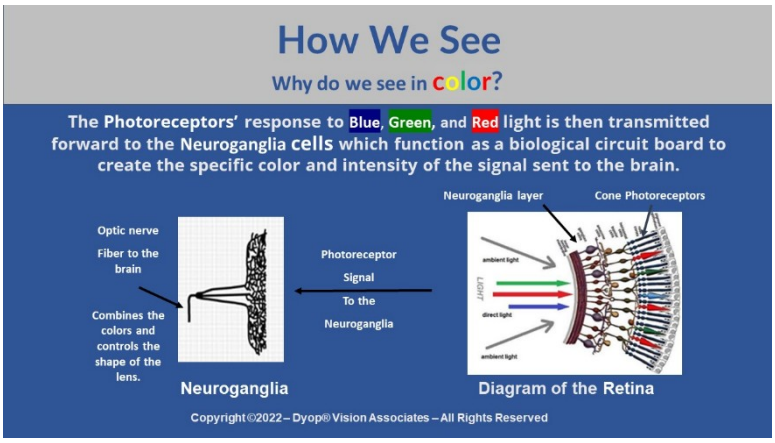


Figure 12

The intensity of the Blue, Green, and Red color response by their respective cone-photoreceptors is then transmitted to the layer of Neuroganglia cells which function as the equivalent of a biological circuit board. The Neuroganglia cells combine the responses of 100 photoreceptor cells per each Optic Nerve Fiber. The Neuroganglia cells also transmit their combined response to the intensity of the colors and focal depths of Blue, Green, and Red to the ciliary muscles around the lens.

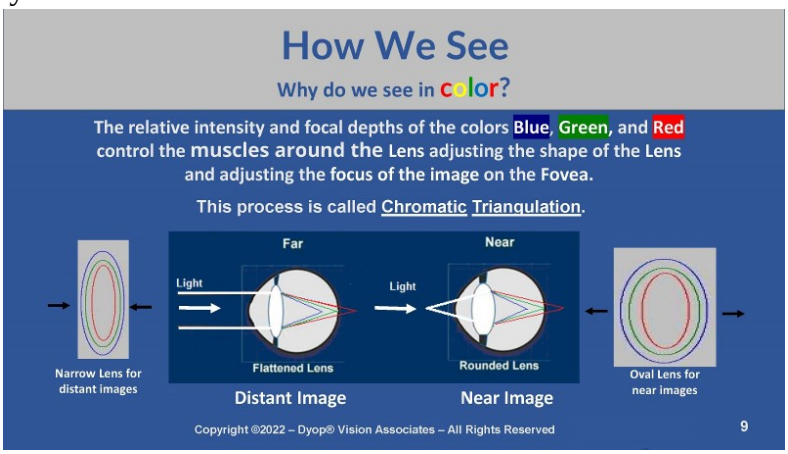


Figure 13

The response of the ciliary muscles around the lens to the color and focal depths of Blue, Green, and Red is to adjust the shape of the lens which then adjusts the focus of the image on the fovea to maximize visual clarity. That process is called **Chromatic Triangulation**.

Color Acuity Response Normative Values:

Because acuity is determined as a matrix response to the perception components of Red, Green, and Blue, discrepancies in the percent components of those cone-photoreceptors will have an effect on image perception.

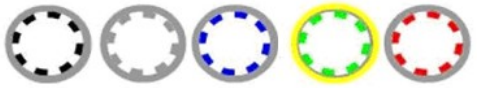
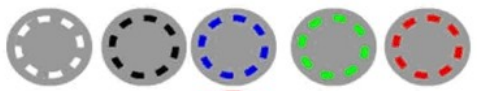
	Foreground Background	Black White	Gray White	Blue White	Green White	Red White
	Dyop® image					
Arc Width Endpoint	Normal	8.7	10.2	9.6	12.7	10.2
	Dyslexic	9.1	10.2	10.7	15.2	11.3
	Difference	-0.4	0.0	-1.1	-3.5	-1.1
Foreground Background	Black/White Gray	White Gray	Black Gray	Blue Gray	Green Gray	Red Gray
Dyop® image						
Normal	7.6	10.4	10.2	11.0	11.6	14.4
Dyslexic	8.2	9.0	8.2	17.2	13.0	15.2
Difference	-0.6	1.4	2.0	-6.2	-1.4	-0.8
	Foreground Background	White Black	Gray Black	Blue Black	Green Black	Red Black
	Dyop® image					
Arc Width Endpoint	Normal	7.9	9.0	18.0	8.5	8.7
	Dyslexic	8.2	9.6	10.2	8.2	9.0
	Difference	-0.3	-0.6	7.8	0.3	-0.3

Figure 14

While the Basic Acuity endpoint for 6/6 (20/20) acuity may be nearly identical for "Normal Vision" (7.6 arcminutes) and "Dyslexic Vision" (*8.2 arcminutes) color perception for Blue, Green, and Red are significantly different. (Note that **better acuity** is associated with a smaller arc width acuity endpoint.)

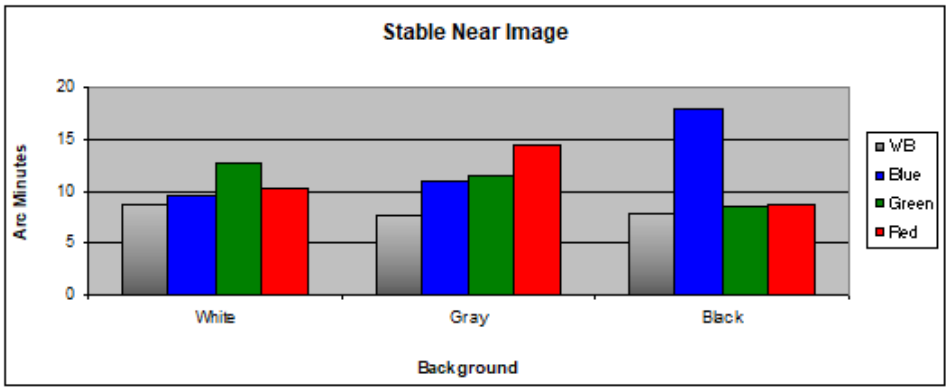


Figure 15

The ability to see Green-on-White (GOW) is significantly better than the ability to see Blue-on-Black (BOB).

SNI	WB	Blue	Green	Red
White	**8.7**	**9.6**	**12.7**	**10.2**
Gray	**7.6**	**11.0**	**11.6**	**14.4**
Black	**7.9**	**18.0**	**8.5**	**8.7**

Table 1

A **Stable Near Image** (**SNI) is associated with** "**Normal Vision"** [15] and the ability to perceive a spinning Green-on-White Dyop (12.7 arcminutes) more easily than a spinning Blue-on-Black Dyop (18.0 arcminutes).

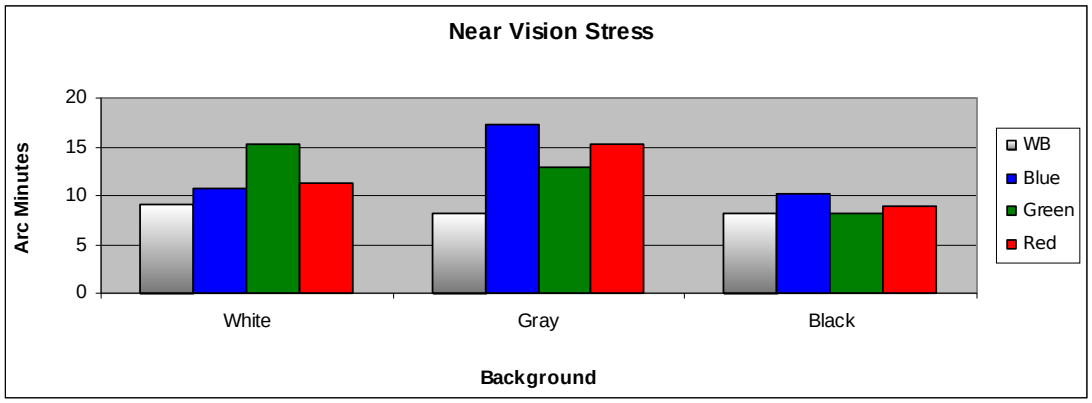


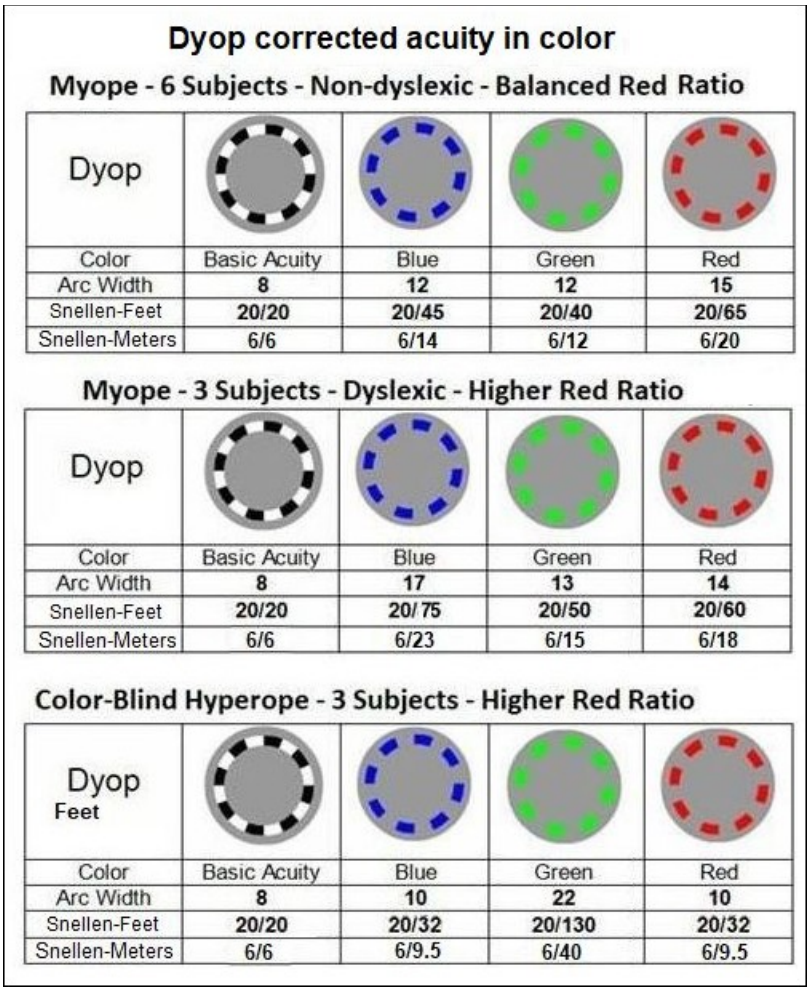
Figure 16

The ability to see Blue-on-Black (BOB) is significantly better than the ability to see Green-on-White (GOW).

NVS	WB	Blue	Green	Red
White	9.1	10.7	15.2	11.3
Gray	8.2	17.2	13	15.2
Black	8.2	10.2	8.2	9

Table 2

Near Vision Stress (NVS) (typified by symptoms of dyslexia, migraines, and epilepsy) typically is indicated by the ability to perceive a spinning Blue-on-Black Dyop (10.2 arcminutes) more easily than a spinning Green-on-White Dyop (15.2 arcminutes).



Dyop corrected acuity in color

Myope - 6 Subjects - Non-dyslexic - Balanced Red Ratio

Dyop				
Color	Basic Acuity	Blue	Green	Red
Arc Width	8	12	12	15
Snellen-Feet	20/20	20/45	20/40	20/65
Snellen-Meters	6/6	6/14	6/12	6/20

Myope - 3 Subjects - Dyslexic - Higher Red Ratio

Dyop				
Color	Basic Acuity	Blue	Green	Red
Arc Width	8	17	13	14
Snellen-Feet	20/20	20/75	20/50	20/60
Snellen-Meters	6/6	6/23	6/15	6/18

Color-Blind Hyperope - 3 Subjects - Higher Red Ratio

Dyop Feet				
Color	Basic Acuity	Blue	Green	Red
Arc Width	8	10	22	10
Snellen-Feet	20/20	20/32	20/130	20/32
Snellen-Meters	6/6	6/9.5	6/40	6/9.5

Figure 17

Based on color acuity benchmarks, it is possible to predict vision diagnostics based on the relative color acuity values (in arcminutes).

An individual with a **Stable Near Image** will have similar values for Blue-on-Gray and Green-on-Gray.

An individual with a **Near Vision Stress** will have higher diminished acuity for Blue-on-Gray versus Green-on-Gray.

An individual with a **Hyperopia** (far-sighted) will have a diminished Green-on-Gray versus Blue-on-Gray or Red-on-Gray.

Dyop Rotation Speed Comparison **5/3/2019**

Dyop acuity endpoint is the smallest arc width where spinning can clearly be detected.

Color	Black/White	Red	Yellow	Green	Blue	Blue/Black	Green/White
RPM	Arc Min	Arc Min	Arc Min	Arc Min	Arc Min	Arc Min	Arc Min
20	8.1	9.9	10.9	11.1	9.5	15.4	13.6
40	7.6	9.1	10.5	11.6	9.1	13.9	13.1
60	8.7	12.1	13.1	17.0	11.1	20.0	15.7
80	9.5	12.6	14.2	18.4	11.6	24.5	18.1
100	10.9	16.3	17.4	25.0	15.1	28.8	20.8
120	12.6	16.7	18.8	30.0	16.7	36.7	24.0

Table 3

A Black/White Dyop has an optimum rotation rate of 40 rpm, as indicated by the lowest acuity endpoint. However, modulation of the rate of strobic stimulus of the photoreceptors seems to be optimized at 40 rpm rotation rate regardless of the stimulus color indicating that the refresh rate of the cone-photoreceptors is not a factor in acuity regulation. [13]

3. Results

Four patients were examined to determine their acuity in color using the primary Dyop gaps/segments for Red, Yellow, Green, and Blue.

By having the data/graphs in arcminutes, and arranging the color permutations by their relative wave length of light, it is easier to create the graphs and the data looks more coherent as to changes in color perception and differences as to patients.

Case A – Subject has a <u>Stable Near Vision</u>.

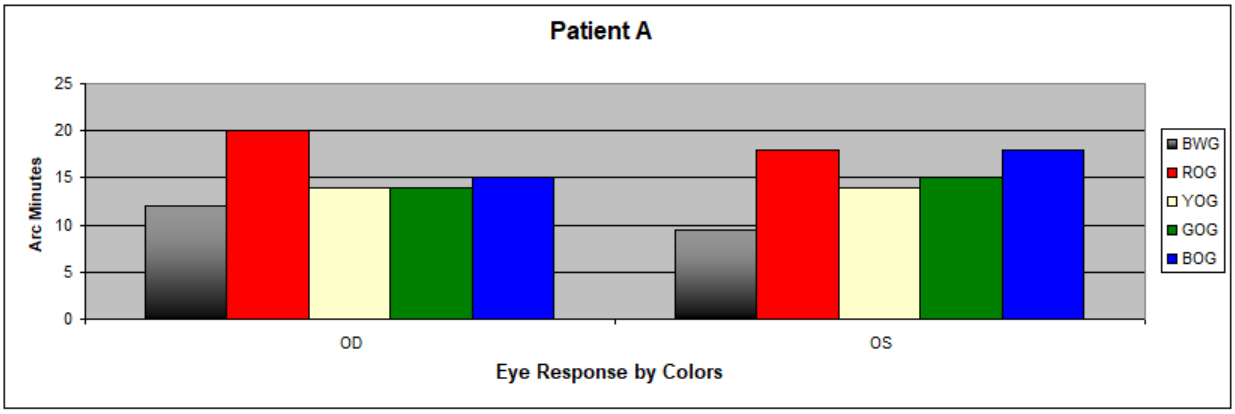


Figure 18

The ability to see Green-on-Gray (GOG) is better than the ability to see Blue-on- Gray (BOG).

Patient E	OD	OS
BWG	12	9.5
BOG	15	18
GOG	14	15
YOG	14	14
ROG	20	18

Table 4

Patient A (female) is aged 26 years with a family history of glaucoma, and a history of ocular hypertension and is currently on Misopt and Xalatan to manage raised intraocular pressure (IOP). Her Basic Dyop acuity (BDA) assessment was 12 and 9.5 arcminutes at distance as well as near (at 40 cm) in her right and left eye respectively. Vertical C/D ratio was 0.47 and 0.50 (symmetric) and average RNFL thickness was 99um and 101um in right and left eye respectively.

Case B- Subject has <u>Near Vision Stress</u>

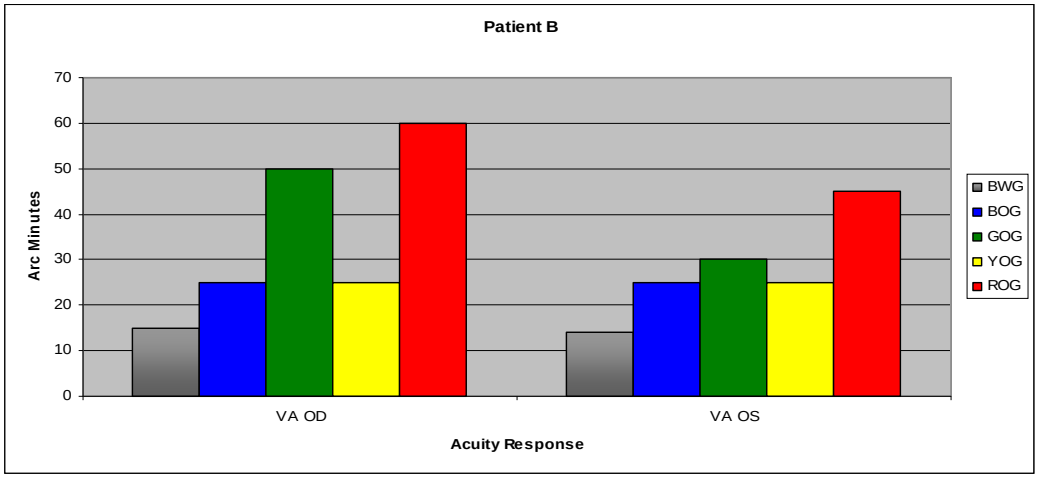


Figure 19

The ability to see Blue-on- Gray (BOG) is better than the ability to see Green-on-Gray (GOG).

Patient B	VA OD	VA OS
BWG	15	14
ROG	60	45
YOG	25	25
GOG	50	30
BOG	25	25

Table 5

Patient B (female) is aged 20 years with a history of retrobulbar optic neuritis which eventually claimed her left eye. The BWG assessment of her right eye is 16 arcminutes at distance and 16 arcminutes at 25cm with relative distance magnification to compensate for acquired near vision stress. Her intraocular pressure was 17 mmhg but the vertical C/D ratio was 0.8 with temporal disc pallor.

Case C – Subject has a significantly better Red acuity and is a far-sighted (hyperope).

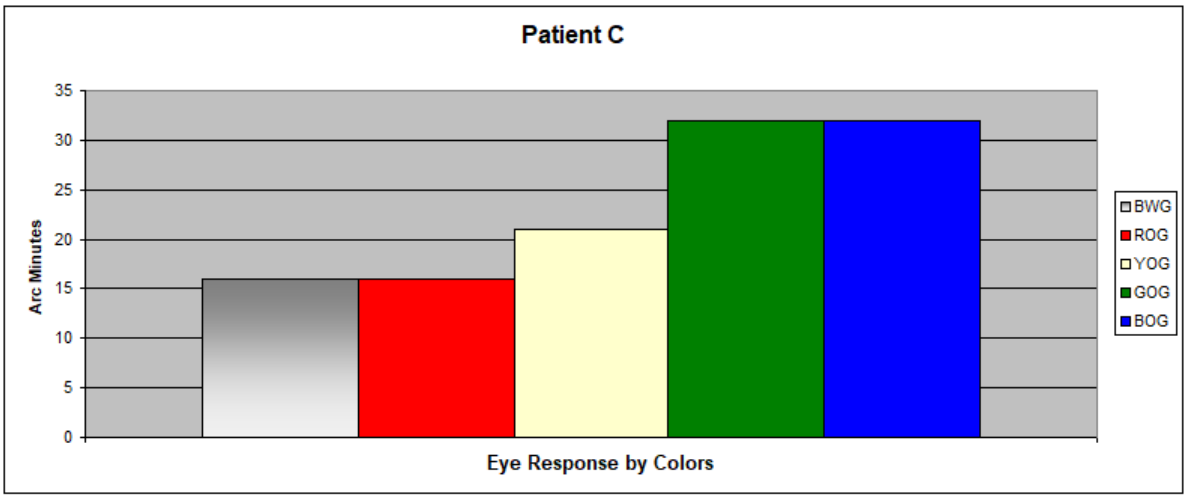


Figure 20

The ability to see Blue-on-Gray (BOG) is similar the ability to see Green-on-Gray (GOG), but the ability to see Red-on-Gray (ROG) is significantly better.

Patient C	VA-OD-1
BWG	16
BOG	32
GOG	32
YOG	21
ROG	16

Table 6

Patient C (male) is aged 45 years with a family history of glaucoma, and a history of ocular hypertension and is currently on Xalatan to manage his raised IOP. His aided (with +1.50 diopters) BDA/BWG was 15 and 14 arcminutes at distance as well as near (at 40 cm) in her right and left eye respectively. Vertical C/D ratio was 0.52 and 0.44 and average RNFL thickness was 91um and 106um in right and left eye respectively.

Case D - Treatment revealed significantly improved acuity in blue and green.

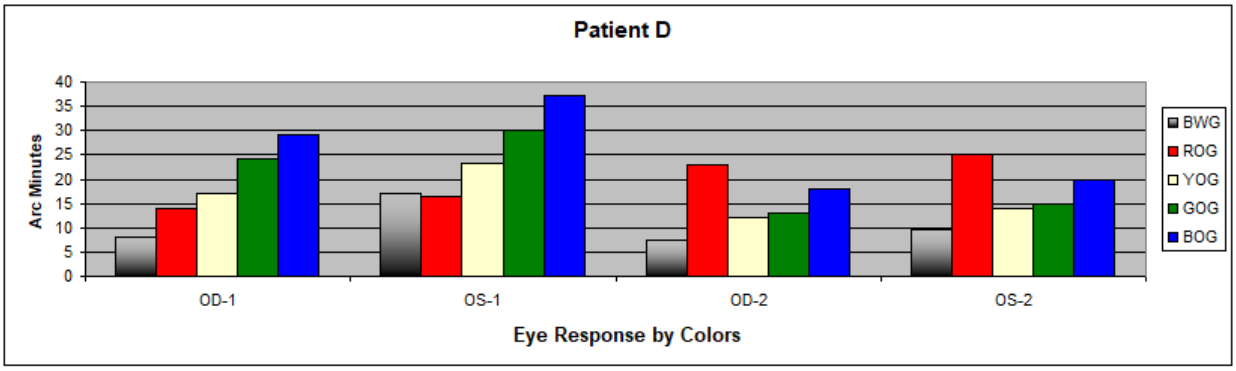


Figure 21

The ability to see Blue-on-Gray (BOG) and Green-on-Gray (GOG) improved in both eyes, especially in the Left eye (OS-2).

	BEFORE		AFTER	
Patient D	OD-1	OS-1	OD-2	OS-2
BWG	8	17	7.5	9.5
ROG	14	16.4	23	25
YOG	17	23.4	12	14
GOG	24.3	30.1	13	15
BOG	29	37.2	18	20

Table 7

Patient D (female) is aged 50 years with no family history of glaucoma, a history of bilateral ocular hypertension with higher pressure in the left eye. She did not yet to ant glaucoma drugs management of her raised IOP. Her BWG assessment with the raised IOP was 8 and 17 arcminutes at distance in her right and left eye respectively. GOG color acuity

assessment was 24.3 and 30.1 arcminutes as well as BOG was 29 and 37.2 in her right and left eye respectively.

However, bilateral trabeculectomy was recommended as a remedy to cushion the high IOP and she consented. The surgical procedure was done and the pressure dropped to 10mmhg in both eyes. The OCT result revealed that her vertical C/D ratio is 0.48 and 0.05 and her average RNFL thickness was 91um and 103um in right and left eye respectively.

Dyop colors test was repeated after the eyes were stable post-operation, and there was huge improvement in acuity as compared to the initial acuity before surgery. Acuity was especially improved from for GOG 13 arcminutes (OD2) and 15 arcminutes (OS2) and BOG 18 arcminutes (OS2) and 20 arcminutes (OS2) respectively.

4. Discussion

Rather than having color acuity be regarded as a novelty or a subjective metric such as with Ishihara, Farnsworth, or the HRR test, a Dyop color acuity test gives a precise value as to color perception based on the physiology of the eye and its objective response to color.

Previous Dyop testing has demonstrated a 90% correlation to diagnosed symptoms of dyslexia. [15]

Other color perception studies have indicated a therapeutic response to color for treating migraines. That study also discovered that therapeutic modulation was provided by tinting the entire visual field rather than just using glasses or colored overlays. [12]

What is implied from these observations is that not only does color let us discern visual attributes of the objects of an individual’s focus, but the pattern of the quantified acuity endpoints for the cone-photoreceptors respond to symptomatic vision attributes. The ONLY possible explanation for these correlations is that the dynamic variations in the chromatic focal depths of Blue, Green, and Red versus the benchmark distance of the fovea from the lens creates Chromatic Triangulation. The intensity of the Blue, Green, and Red color response of the respective cone-photoreceptors is then transmitted to the ciliary muscles which control the shape and focal depth of the lens using the layer of Neuroganglia cells which function as the equivalent to a biological circuit board

5. Conclusions

Note that it is also possible to adjust the Dyop gaps and segments to various hexadecimal shades of gray to evaluate contrast sensitivity. However, the interest in contrast sensitivity is primarily from the lack of understanding as to why Black and White optotypes are so relatively inaccurate and inconsistent. **Eye care practitioners fail to utilize the fact that acuity is a foveal color perception process**. Color contrast sensitivity by a Dyop is far more precise and informative as to how we see. Using the built-in Dyop contrast sensitivity

matrix will entice Eye Care Professionals and Vision Scientists to study Dyop contrast and realize that it is best done in color.

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Conflicts of Interest:

There is no conflict of interest.

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