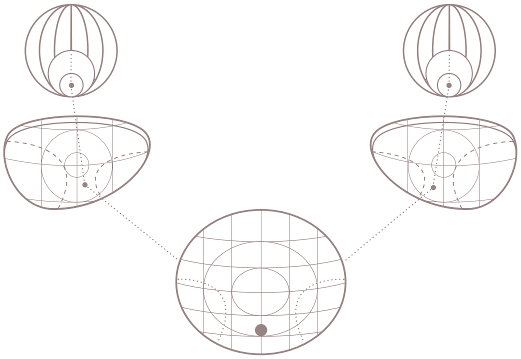
Understanding three Binocular Vision Technologies that drive clear, comfortable vision for PAL wearers

Authors

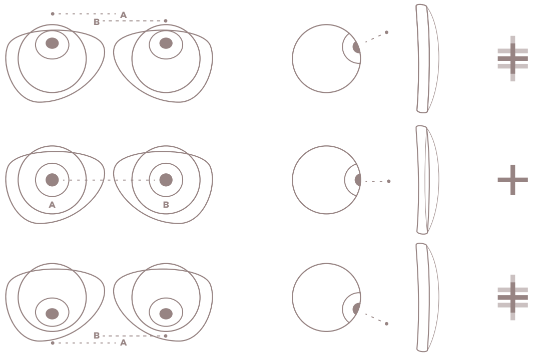
Dr. Thomas Gosling
Optometrist and Consulting Lens Specialist,
Illinois College of Optometry,
Littleton, Colorado, United States

Warren Modlin
VP Technical Marketing,
HOYA Vision Care

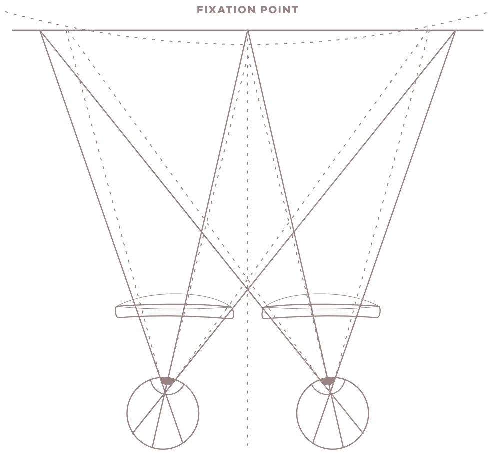
Binocular Eye Model



Binocular Harmonization Technology



3D Binocular Vision



HOYA
FOR THE VISIONARIES

Table of Contents

Overview

Binocular optimization of PAL design – for easy adaptation and enhanced vision performance.

Progressive addition lens (PAL) adaptation remains a concern for both patients and eyecare professionals. In a consumer survey of PAL wearers, most unsatisfied respondents report problems when learning how to focus with progressive lenses, followed by lack of clear vision and problems when reading because of the limited field of vision.

HOYA Vision Care adopts a lens design philosophy that addresses adaptation challenges by incorporating advanced binocular vision technologies into their premium lenses. This approach not only supports patient acceptance but also offers the advantages of binocular balance, an optimized reading zone, and minimal peripheral distortions, all of which contribute to enhanced visual comfort.

> **HOYA's 3D Binocular Vision reduces the occurrence of unwanted prismatic effects for near lateral vision, leading to improvements in stable and comfortable vision.**

In this review of HOYA Vision Care Binocular Vision Technologies, the authors explore the unique lens design features used to achieve a high level of patient satisfaction and adaptation acceptance through three patented technologies:

1. **HOYA's Binocular Eye Model**
2. **HOYA's Binocular Harmonization Technology**
3. **HOYA's 3D Binocular Vision**

HOYA's 3D Binocular Vision is the latest technology introduced in their PALs, and it reduces the occurrence of unwanted prismatic effects for near lateral vision, leading to improvements in comfortable, stable vision.

Introduction

As presbyopia sets in, wearing progressive addition lenses (PALs) can help patients see clearly and comfortably. However, some presbyopes have difficulty when wearing PALs and may experience moderate to severe visual symptoms such as blurred vision, headaches, perceived movement of the peripheral visual field or "swim", balance issues, and nausea.[1,2] Having balanced binocular vision is essential for performance benefits with PALs including improved visual clarity, depth perception, peripheral awareness and reduced cognitive load compared to those without balanced binocular vision.[3]

To achieve the best binocular vision performance, algorithms should be adjusted to account for right and left spectacle lens designs. This can help alleviate asthenopia, commonly known as eye strain, which is often not directly attributed to the spectacle lenses themselves. Unless the binocular eye model calculations are considered, even the smallest prescription difference between the eyes will refract light differently when passing through the lenses. This means that it is difficult to truly deliver the same perceived visual quality that is obtained during the refraction.

Here, we present how HOYA Vision Care PAL's binocular vision technologies including the Binocular Eye Model, Binocular Harmonization Technology, and 3D Binocular Vision work together to help improve focus, depth of vision, stability, and comfort in patients with binocular disharmony due to the difference in prescription between eyes. The Binocular Eye Model provides evaluation indices, Binocular Harmonization Technology enhances both spectacle lenses to improve binocular indices, and 3D Binocular Vision enhances not only the horizontal and vertical fields, but also improves performance of depth perception.

Monocular and Binocular Evaluation Methods

Design validation methods are essential to evaluate the performance of progressive addition lens design lenses. Monocular evaluation indexes, including Astigmatic Error, Mean Addition Power, Clearness Index, Deformation Index, Skew Deformation Index, and Dynamic Deformation Index, are insufficient for evaluating advanced progressive addition lens design lenses. Here, we discuss the reasons behind and the details of the Binocular Evaluation Methods developed by HOYA.

Monocular Eye Model

Design validation methods that use conventional monocular maps are no longer adequate to evaluate the performance of advanced progressive addition lens designs lenses. Monocular evaluation methods (Appendix 1) do not consider the effect of the right and left eye looking through different parts of the complex PAL design creating mismatched images for the brain to process. When viewing an image binocularly through a progressive design, it is necessary to consider magnification imbalance, imbalance of the impact of binocular accommodation and convergence differences, unwanted vertical prism effects and unmatched clearness zones between the eyes. While this is not a major problem when wearing single vision lenses, it does become more serious when progressive lenses are used.

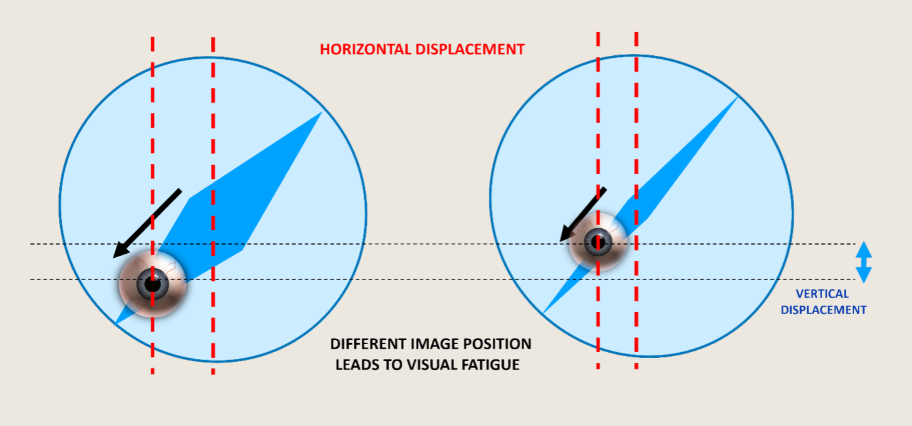
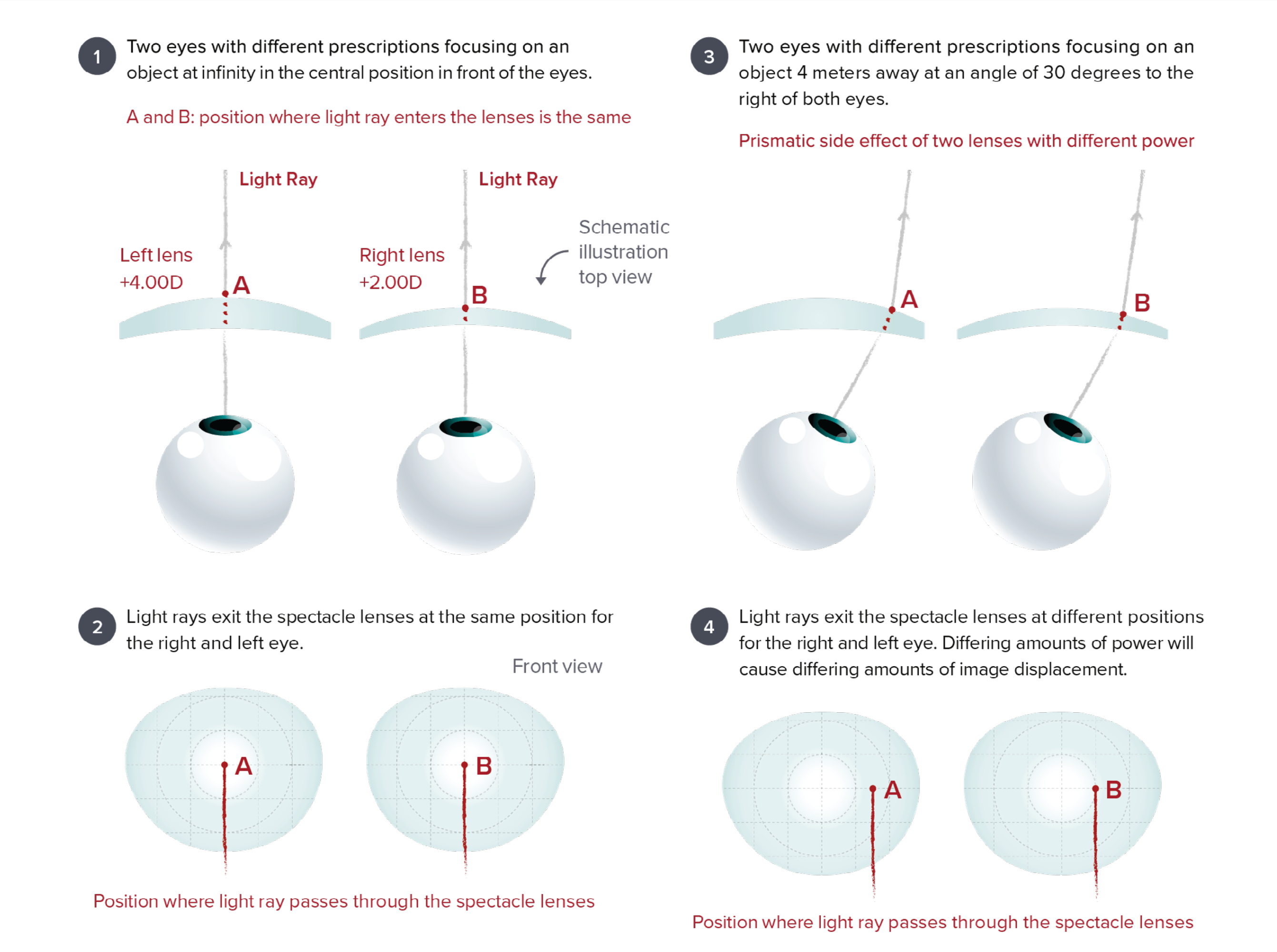


Fig 1 – Horizontal and vertical displacement created by a difference in powers between eyes (Anisometropia). When there is no compensation for horizontal or vertical displacement in the periphery under binocular vision conditions, the images seen by the two eyes will not be aligned. This can lead to a number of problems, including double vision, reduced depth perception and eye strain.



1 Two eyes with different prescriptions focusing on an object at infinity in the central position in front of the eyes.

A and B: position where light ray enters the lenses is the same

2 Light rays exit the spectacle lenses at the same position for the right and left eye.

Position where light ray passes through the spectacle lenses

3 Two eyes with different prescriptions focusing on an object 4 meters away at an angle of 30 degrees to the right of both eyes.

Prismatic side effect of two lenses with different power

4 Light rays exit the spectacle lenses at different positions for the right and left eye. Differing amounts of power will cause differing amounts of image displacement.

Position where light ray passes through the spectacle lenses

Fig 2 – The impact of different prescriptions in the case of anisometropia on the prismatic effect in binocular vision.

The problem is caused by the prismatic side effect of a spectacle lens and cannot be compensated by the PAL wearer. As a result, each eye will use a different area of the spectacle lens when viewing near objects. While single-vision lens wearers can compensate for this by changing the position of their reading material or tilting their head to look through the optical center of the spectacle lenses. When they read, progressive lens wearers must lower their eyes to get into the near vision area. As a result, the eyes will experience different amounts of prism and different powers of accommodative support. This difference in accommodative support leads to a situation where the image clarity is different for each eye. Consequently, the brain will try to equalize the image clarity for both eyes, leading to rivalry between the eyes. Because compensation for one eye causes extra blur for the other, all efforts to compensate for this retinal rivalry can lead to asthenopic complaints such as tired and burning eyes and headaches.

Binocular Eye Model and Evaluation Methods

Binocular lens properties can only be evaluated properly by using a system of coordinates that is not related to the surface of individual lenses. Consequently, a system has been developed that defines the binocular lens properties by considering angles in object space.

HOYA has developed five patented binocular evaluation methods, which are summarized in the Binocular Eye Model. These evaluation methods focus on assessing the binocular performance of the different design variations. The maps presented in this paper are based on ray tracing technology. This technology makes it possible to trace the path of a very small bundle of light rays through the lens. This tiny bundle of light rays can be seen as a circle in object space and changes in shape and size depending on aberrations in the lens.

> **These unique evaluation methods guarantee that each design is verified under real-life circumstances before it goes into production.**

Binocular Eye Model

The Binocular Eye Model considers all elements that are important for enhanced binocular performance of progressive lenses, and includes the patented Binocular Clearness Index, Binocular Accommodation Demand Difference, Binocular Vertical Prismatic Difference, Binocular Convergence, and the Binocular Magnification Difference. These unique evaluation methods guarantee that each design is verified under real-life circumstances before it goes into production, and ensure unprecedented binocular performance of the lenses, regardless the prescription difference of both eyes.

Clearness Index (binocular). The Binocular Clearness Index describes how clearly the wearer sees an image through both spectacle lenses. It is derived by combining both the right and left monocular clearness index when both eyes are focused on the same point in object space with the same accommodation state. With both eyes, a person usually sees with a higher level of clarity as compared with only one eye.

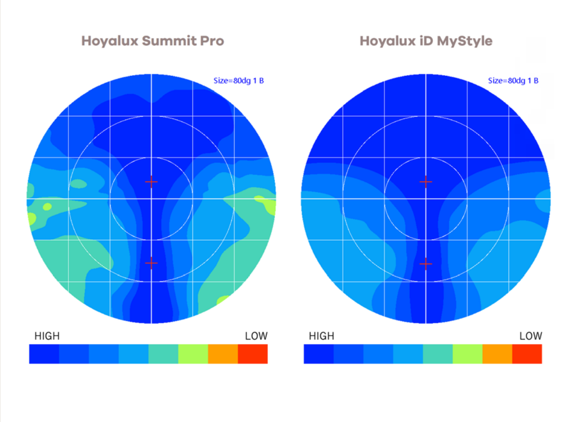


Fig 3 – Binocular Clearness Index Mapping
Blue – High Clarity Red – Low Clarity

If a pair of spectacle lenses is designed so that both eyes have a similar monocular clearness index across the visual field, the binocular clearness index should be better than a design that each spectacle lens is designed separately. An example is illustrated in Figure 3. In this case, the right eye and the left eye have different prescriptions (anisometropia). Left side map is the binocular clearness index map of traditional design PAL design (Summit Pro), right side map is the binocular clearness index map of newest individual design Hoyalux iD MyStyle which shows better clearness.

Convergence Distance (binocular). Convergence Distance is defined as the distance between point O and the intersection point of both visual lines (Figure 4) OAB. Convergence Distance is the same as real object distance in the case of no prescription. When the patient wears spectacle lenses, the convergence situation will change not only depending on the real distance of the object but also on the prism of each spectacle lens at the position the ray passes through.

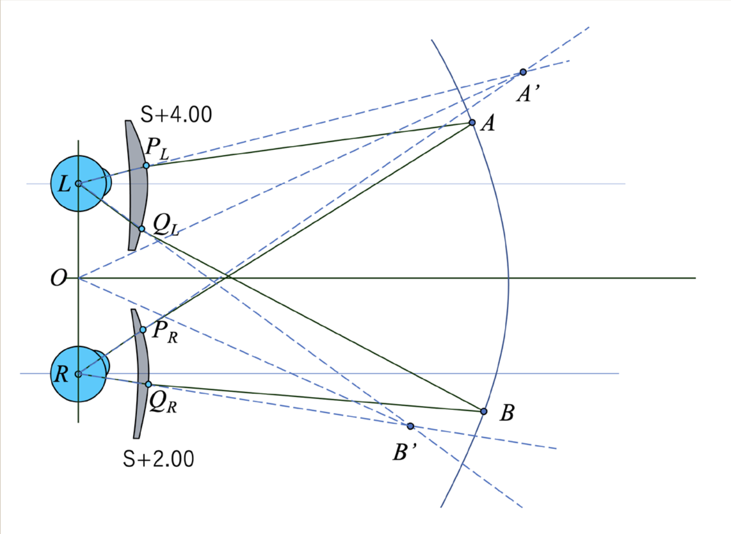
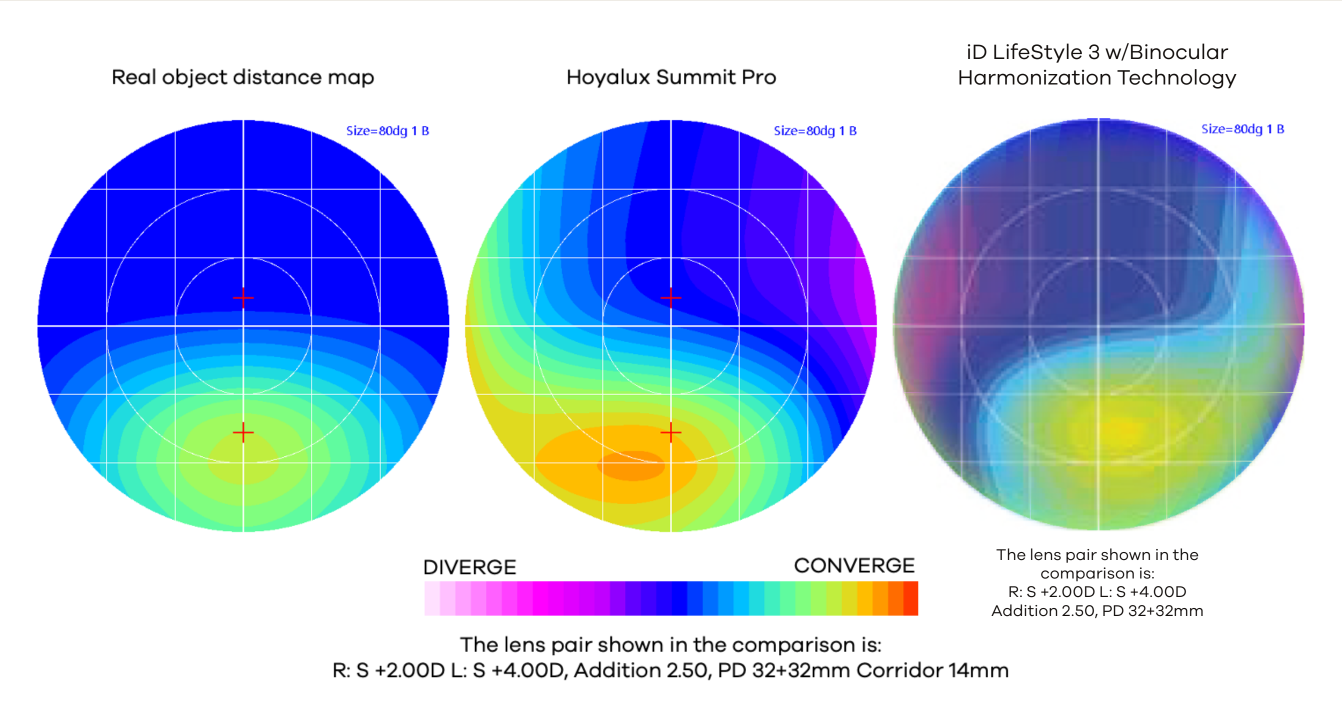


Fig 4 – Shows a case that two points A and B of the same real distance have different convergence distance OA' and OB' because of the different positions on lens to see them with spectacles in which right and left power is different.

Figure 5 shows the Convergence Distance maps of two different lens designs. The target real object distance map is represented by the left map. Dark blue on the map indicates areas where no convergence or divergence is necessary. Cyan and yellow areas indicate where convergence is necessary. With Hoyalux iD LifeStyle 3 lenses, the power difference between the right and left eye and individual wearing parameters are considered during lens optimization, thereby significantly reducing the vergence requirements in the binocular state. Note, however, that controlling the prismatic side effects that unavoidably arise in anisometropic prescriptions is not the goal of iD LifeStyle 3 lenses.



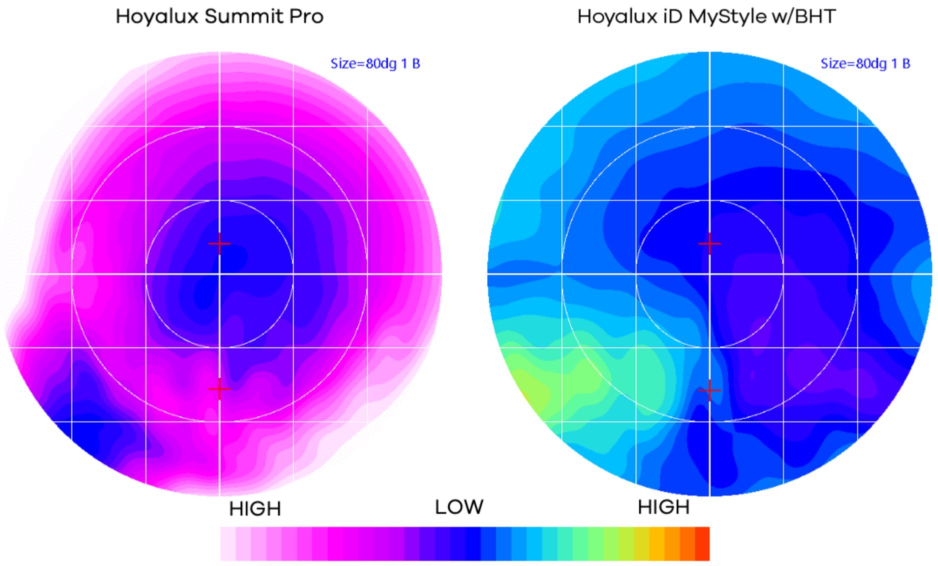
The lens pair shown in the comparison is:
R: S +2.00D L: S +4.00D
Addition 2.50, PD 32+32mm

The lens pair shown in the comparison is:
R: S +2.00D L: S +4.00D, Addition 2.50, PD 32+32mm Corridor 14mm

Fig 5

Accommodation Demand Difference (binocular). The Accommodation Demand Difference is the amount of focusing ability needed by the eyes to see an object at different distances. It depends on factors like the distance of the object, the power of the spectacle lens when light passes through it, and the prescription.

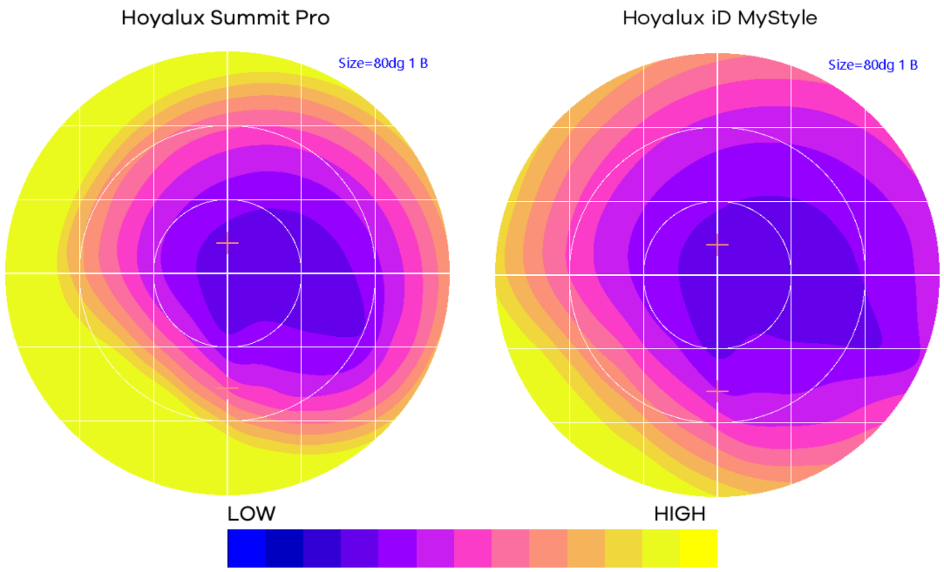
This map of Accommodation Demand Difference (binocular) uses the difference in mean power between the right and left eye and the binocular object distance to define how much each eye must accommodate to achieve a sharp, focused image for the relevant object distance. Because a calculation can be made for both eyes, the result can be presented as a difference in accommodation demand between the right and left eye. A difference in accommodation demand of 0.00D can be achieved when the power along the corridor (umbilical line) is matched between the right and left eye. This is possible with Binocular Harmonization Technology. As shown in Figure 6, Hoyalux iD MyStyle spectacle lens presents with minimal Accommodation Demand Difference as compared to the traditional PAL lens (Hoyalux Summit Pro). Sometimes several smaller areas with unequal Accommodation Demand may remain, however, those areas are not used often as they are mainly located at the peripheral parts of the lens. This is because the Astigmatic Error is often higher in the periphery. Because half of the astigmatic error is combined with the spherical power to achieve the mean power, the resulting power can lead to further differences between the right and left prescription, which lead in turn to a difference in the accommodation demand.



The lens pair shown in the comparison is:
R: S +2.00D L: S +4.00D, Addition 2.50, PD 32+32mm Corridor 14mm

Fig 6 – One color change step equates to a 2% increase/ decrease in magnification difference. Dark blue indicates a difference of 0%.

Magnification Difference (binocular). The Magnification Difference displays the difference of spectacle lens magnification between the right and left eye. The amount of spectacle lens magnification mainly depends on the power of the lens, its front curvature, and its thickness at the center. Because the brain has difficulty in merging two images of different sizes, a smaller magnification difference between the two images results in better and more stable binocular vision. Even though the overall magnification difference cannot be influenced (due to the difference in prescribed power), improvements can still be achieved in different parts of the lens. Figure 6A represents the magnification difference between lenses of different powers with and without optimized for binocular magnification difference.



Hoyalux Summit Pro

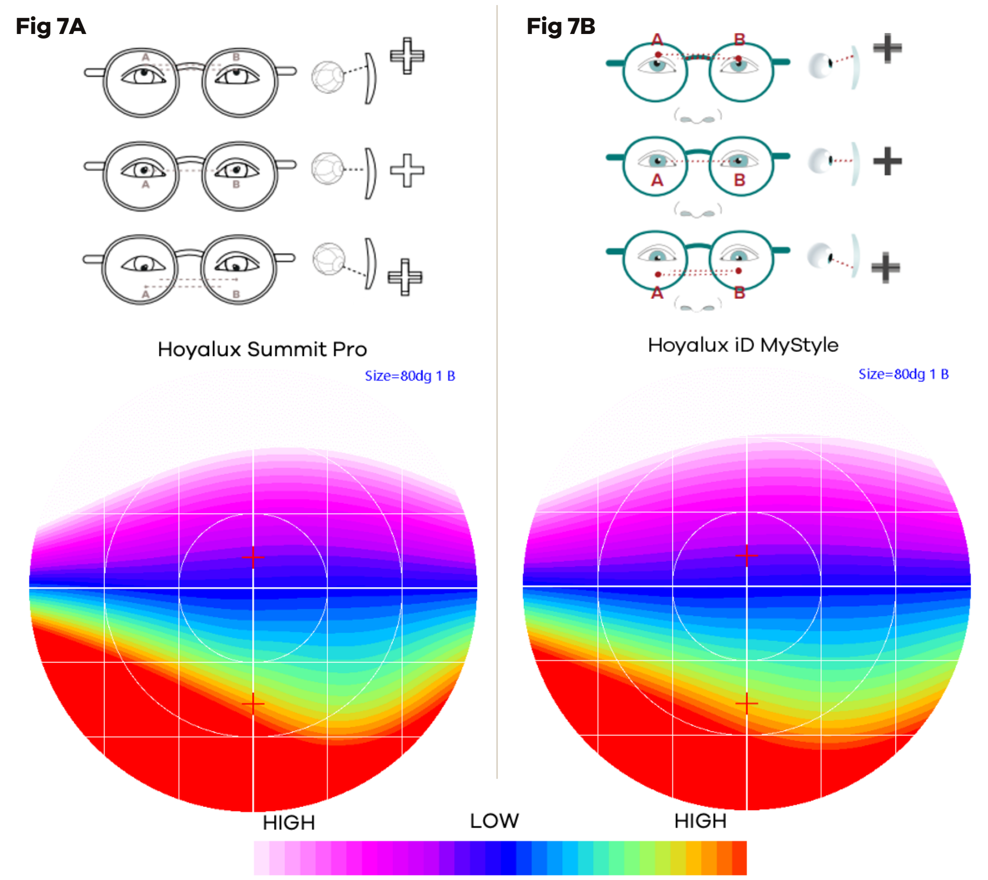
Hoyalux iD MyStyle

The lens pair shown in the comparison is:
R: S +2.00D L: S +4.00D, Addition 2.50, PD 32+32mm Corridor 14mm

Fig 6A

Vertical Prismatic Difference (binocular). In addition to the Convergence Distance map referred to previously (which focuses on horizontal eye movement), the Vertical Prismatic Difference represents the different prismatic effects of the pair of spectacle lenses in the vertical direction. While the general problem remains in anisometropic cases (the prismatic side-effects of the spectacle lens are still different), the Vertical Prismatic Difference can be controlled to a certain extent by adjusting the progressive power distribution for each eye individually based on the known power value for each eye. If the power distribution is changed, the actual power at a specific point also changes, thereby resulting in a different prismatic side-effect. Clearly, the only part of the spectacle lenses where the Vertical Prismatic Difference is equal is the area around the prism reference point, particularly in cases of anisometropia.

In Figure 7, the Vertical Prismatic Difference (binocular) in Hoyalux iD MyStyle (Fig 7B) is reduced significantly as compared to Hoyalux Summit Pro (Fig 7A).



Hoyalux Summit Pro

Hoyalux iD MyStyle

The lens pair shown in the comparison is:
R: S +2.00D L: S +4.00D, Addition 2.50, PD 32+32mm Corridor 14mm

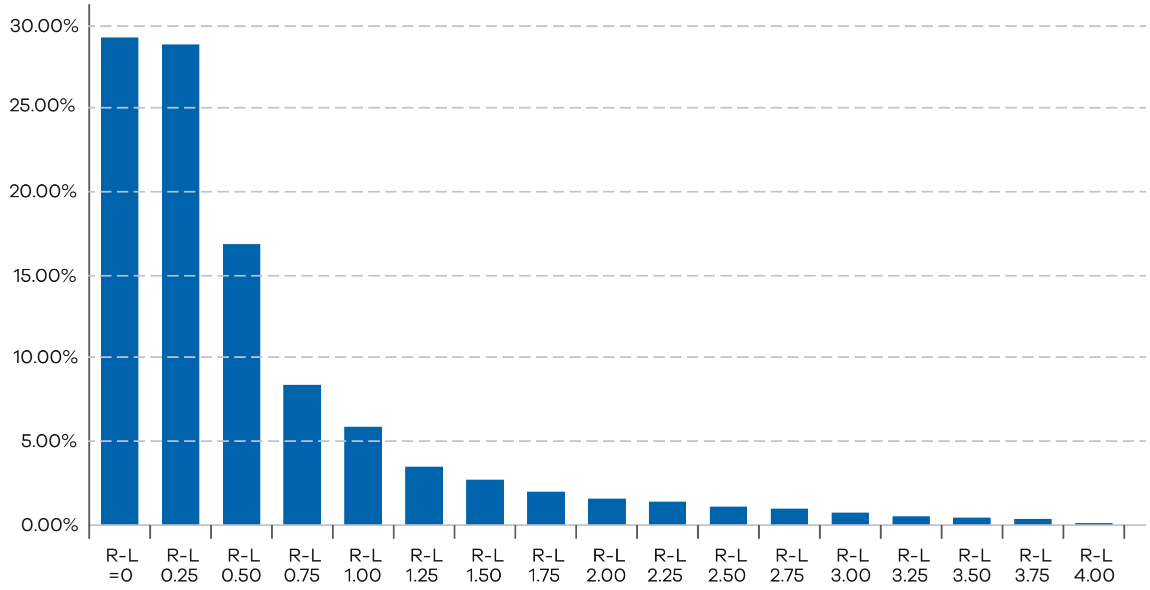
Fig 7

Binocular Harmonization Technology

Even the smallest prescription difference in the right and left eye (anisometropia) means that the light rays pass through the lens at different positions for each eye. This results in a visual imbalance that can cause asthenopic complaints, such as tired and burning eyes and headaches. Symptoms of this type are often vague, not directly noticed by the wearer, or considered to be linked to their glasses. This problem is caused by the prismatic side-effect of an ophthalmic lens and cannot be compensated by the wearer.

Anisometropia is actually very common – over 70% of the population has a difference in power between the two eyes (Figure 8). When this happens, the images sent back to the brain will be perceived as different sizes. This size difference makes it difficult for the brain to fuse the two images together, thus hindering binocularity.

Difference in total power between right and left eyes*



*HOYA data in file. European progressive lens orders 2007-2013.

Fig 8

Anisometropia can be significantly bothersome, especially while using a progressive addition lens design. When there is a power difference between the two eyes and we look away from the optical center of the spectacle lens, a prismatic shift occurs, causing the two images to disassociate. This is especially noted when viewing up and down (Figure 9A and 9B).

Fig 9A

Fig 9B

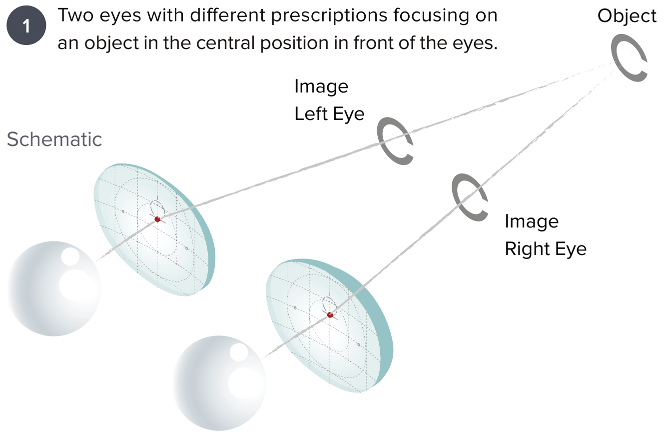
HOYA's Binocular Harmonization Technology (BHT) considers the prescription for the right and left eye as individual components to calculate the optimal binocular spectacle lens design, ensuring that the power distribution and progressive corridor of each lens is exactly according to the needs of each eye. This results in perfect and effortless focusing, constant stability and excellent depth of vision.

The result of different prescriptions for the right and left eye is that each eye uses a different area of the spectacle lens, as illustrated by Figure 10. While this is not a major problem when wearing single vision spectacle lenses, it does become more serious when progressive lenses are used. We can gain a good understanding of this phenomenon by using ray tracing for an initial rough assessment and by considering a pair of single vision spectacle lenses with an object at infinity, and with an object 4 meters away at an angle of 30 degrees to the right.

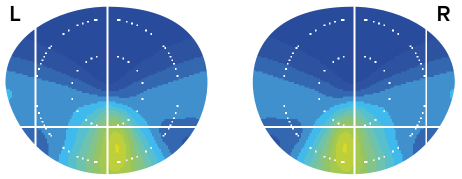
BHT helps bring binocular relief to a progressive lens wearer with anisometropia by taking the prescription for both eyes into consideration, adjusting the power distribution and lens curvatures to match the accommodative support when both eyes rotate through the corridor powers. BHT creates the spectacle lens designs from both eyes' prescriptions, adjusting the power distribution in the progressive corridor so both eyes focus equally together, thus improving binocularity with balanced accommodation while working at near and intermediate distances.

Introduction on Progressive Lenses

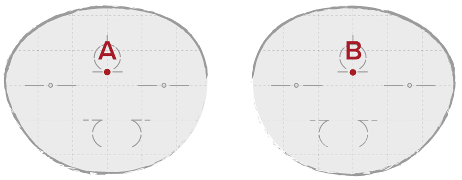
1 Two eyes with different prescriptions focusing on an object in the central position in front of the eyes.



Progressive lenses feature different addition powers in different parts of the lenses.



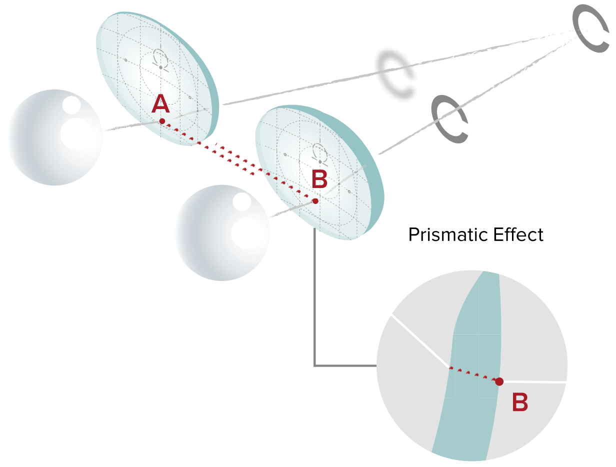
If both eyes are in the central position, light rays pass through the lenses at the same point. Therefore both eyes experience the same power.



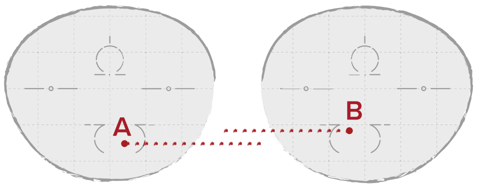
A and B: position where light ray is refracted through the lenses

---

2 Two eyes with different prescriptions focusing on an object close by.



Due to different prismatic effects, are deviated at different rates for the right and left eye.



Therefore the eyes experience different addition powers

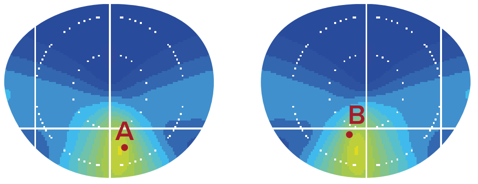
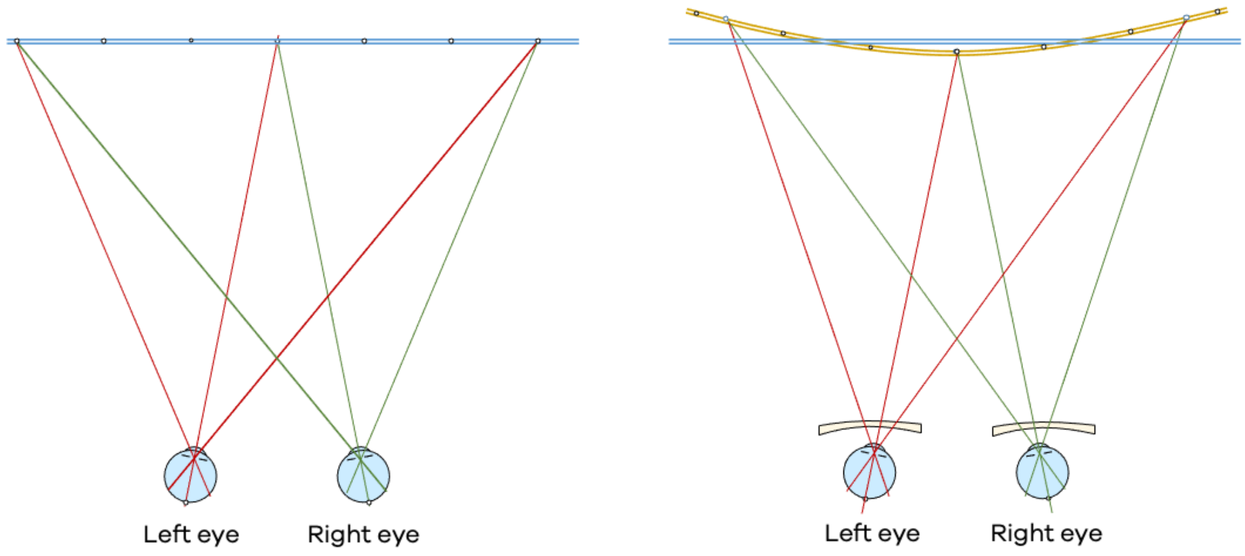


Fig 10

3D Binocular Vision

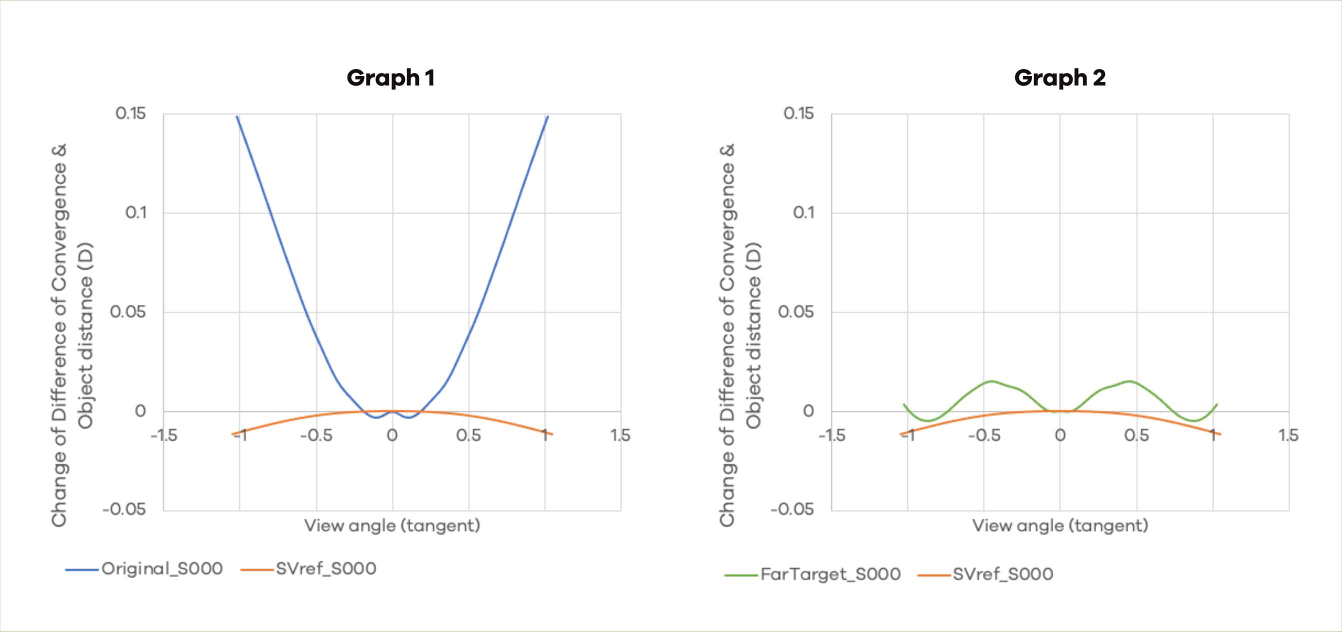
The advantages of using HOYA's 3D Binocular Vision enables the improvement of retinal imaging in the peripheral part, leading to faster adaptation. This creates a stable viewing area and therefore a decrease in the feeling of swaying. Additional advantages from the advanced depth perception and the reduction of unwanted prismatic effect that leads to a high rate of adaptation compared to regular PAL lenses. (Figure 11).



When looking at e.g. straight line without spectacles, it appears without deformation.

When the same line is viewed through spectacle lens it deforms, especially whilst looking through peripheral parts of progressive lenses.

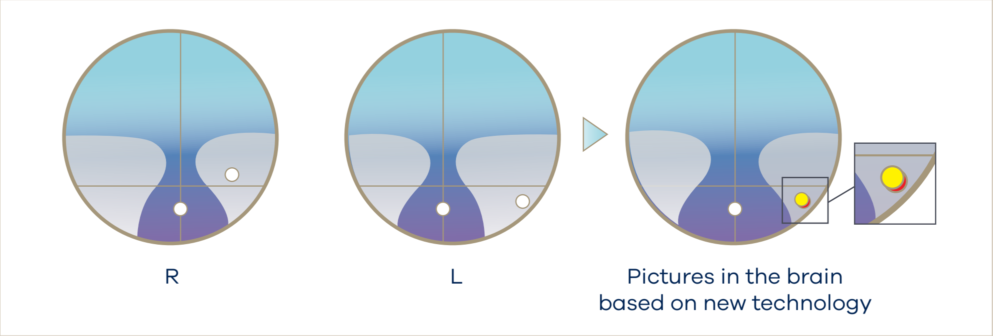
Fig 11

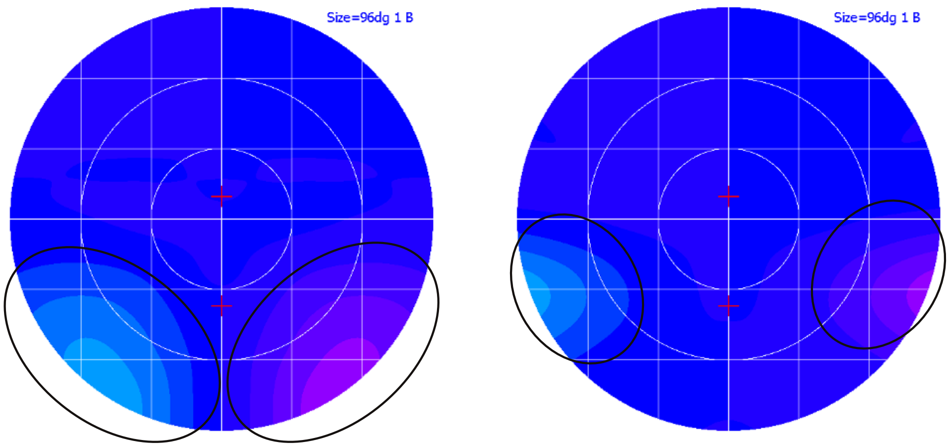


Graph 1 on the left side shows the change of difference of convergence and object distance, while passing through the near vision point, while wearing SV (orange) or progressive lens without 3D Binocular Vision (blue). Horizontal axis shows the horizontal view angle. The gap between the blue line and orange line shows the amount of distortion along depth direction.

Graph 2 on the right side shows the change of difference of convergence and object distance, passing near vision point, while wearing SV (orange) or wearing PAL with 3D Binocular Vision (green). The gap is very small, and it means less distortion.

3D Binocular Vision is an improvement of the unwanted prismatic effects or prism imbalance between the right and left eye induced by progressive distribution. Due to improvement of vertical prism imbalance, vertical imbalance is reduced, and the user enjoys stable vision.





Without 3D Binocular Vision

With 3D Binocular Vision

Fig 12

Figure 12 demonstrates how much vertical prismatic state is induced by progressive lenses. Lighter colors indicate more amount of vertical phoria (up/down). The figure on the left is without 3D Binocular Vision, and the figure on the right is with it. With 3D Binocular Vision, vertical phoria state induced by prism imbalance is improved in areas close to the principal line (white vertical line).

HOYA's 3D Binocular Vision reduces the occurrence of unwanted prismatic effects for near and peripheral vision, leading to improvements in comfortable, stable vision due to the improvement of the peripherical distortions in the near and intermediate areas. This results in less swaying effects when moving and a more natural way of viewing, with a higher clarity of vision.

Conclusion

In conclusion, the development of the upgraded progressive addition lenses with Binocular Vision Technology by HOYA represents a significant breakthrough in addressing the common problems faced by many wearers of progressive lenses. With the incorporation of three patented binocular vision technologies, this premium tier of progressive lenses are designed to enhance the wearer's focusing and adaptation abilities. HOYA's commitment to real-life verification using its patented Binocular Eye Model, Binocular Harmonization Technology, and 3D Binocular Vision has been thoroughly evaluated and optimized for maximum effectiveness. Overall, this new spectacle lens design concept represents an exciting advancement in progressive addition lens technology and offers a promising solution for individuals struggling with focusing and clarity issues.

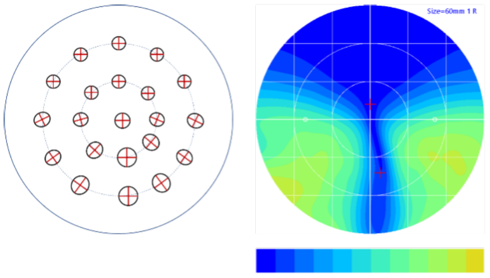
Appendix

Appendix compares the Binocular Eye Model compared to that traditional monocular evaluation of lens design.

Monocular Evaluation Methods

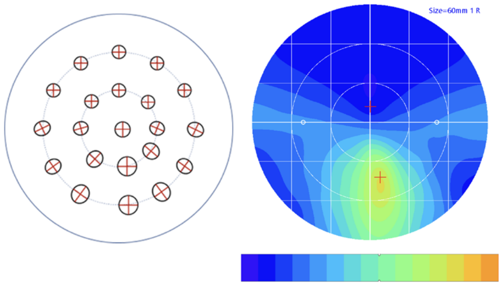
Astigmatic Error – the unwanted astigmatism which is induced by the lens. This is not related to the prescribed cylinder power, only to unwanted astigmatism.

Powers through different position of the lens. Red lines represent maximum and minimum powers and their directions. Difference between maximum and minimum power is the astigmatic error.



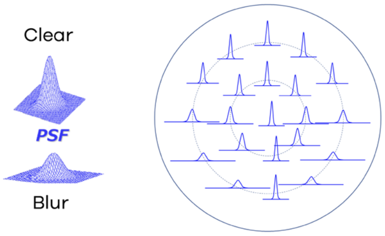
Mean Addition Power – this method allows us to read the offset from the mean far distance power, scaled to 0.00D.

Powers through different position of the lens. Red lines represent maximum and minimum powers and their directions. Size of power ellipse represents Mean Addition Power.



Clearness Index – describes how clearly the wearer sees an image through the spectacle lens.

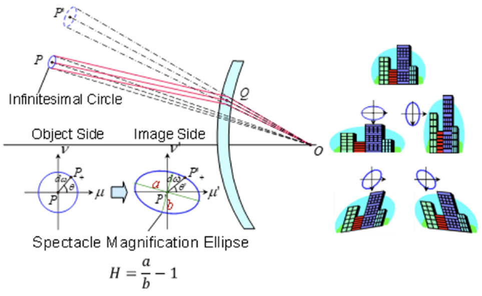
Clearness index indicates how sharp the image is seeing through a lens position. The higher the peak of PSF, the narrower the range of light distribution from the target, resulting in better visual acuity.



Deformation Index – At each position on lens there is a magnification ellipse defined to describe the deformation seen. The amount of deformation at each position on a lens accumulates to form the whole image distortion.

Skew Deformation Index – is the direction of the spectacle magnification ellipse.

Dynamic Deformation Index – while the Deformation Index and the Skew Deformation Index focus on the deformation that occurs at a single specific point of the lens, the Dynamic Deformation Index considers the change in deformation when moving from one point on the lens to the adjacent point.



References

1. Alvarez TL, Kim EH, Granger-Donetti B. Adaptation to Progressive Additive Lenses: Potential Factors to Consider. Sci Rep. 2017 May 31;7(1):2529. doi: 10.1038/s41598-017-02851-5. PMID: 28566706; PMCID: PMC5451391.
2. Han Y, Ciuffreda KJ, Selenow A, Ali SR. Dynamic interactions of eye and head movements when reading with single-vision and progressive lenses in a simulated computer-based environment. Invest. Ophthalmol. Vis. Sci. 2003;44:1534–45. doi: 10.1167/iovs.02-0507. [PubMed] [CrossRef] [Google Scholar]
3. Vale A, Scally A, Buckley JG, Elliott DB. The effects of monocular refractive blur on gait parameters when negotiating a raised surface. Ophthalmic Physiol Opt. 2008;28(2):135-142. doi:10.1111/j.1475-1313.2008.00543.x

www.hoyavision.com

HOYA

FOR THE VISIONARIES