Varilux S series – breaking the limits

Cyril Guilloux, Soazic Mousset, Christian Miege, and **Andy Hepworth** describe a new series of lenses which incorporates some novel developments in progressive design

Performance of progressive addition lenses has improved a lot since the first generation was launched by Essilor in 1959. Nevertheless, there are still some limitations considered as inherent to the very concept of power variation across the progressive lens surface.

Flawless vision should be simple. Yet, wearers still encounter limitations even with premium progressive lenses such as: 'I feel wary when going down the stairs'; 'When I move my head, I feel everything moves and yet nothing should move'; 'I need to constantly move my head to target what I am looking at'.

These limitations are due to the fact that progressive lenses are based on a compromise between wide fields of vision and limited swim effect. Very few articles can be found dealing with the link between field of vision and the line distortion that causes the swimming effect and have their limitations.[1,2]

In-lab analysis of the main premium lenses on the UK market shows that each manufacturer manages this compromise differently (Figure 1). Either the lenses provide wide fields of vision, but suffer higher swim effect, or lenses provide reduced swim effect, with narrower fields of vision.

From an historical view, designs coming from the Far East are relatively 'soft' with limited fields exempt from aberrations. European designers, however, pay more attention to field of vision at the cost of a relatively high level of swim effect.

Based on advances in optics and knowledge of wearer physiology and protected by 11 new patents, Essilor aims to break this progressive lens compromise with the introduction of the Varilux S series.

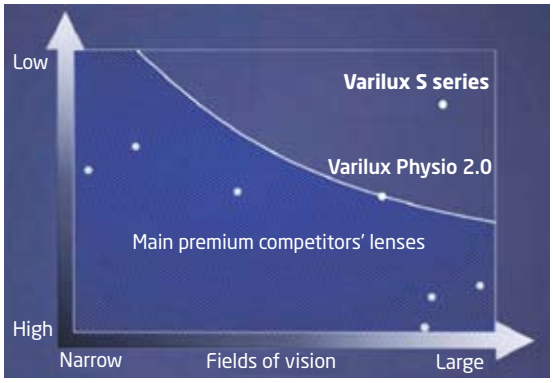

Figure 1 In-lab R&D measurements of Varilux and main premium competitors[1]

The Varilux S series achieves this advance in progressive lens correction through two innovations:

- SynchronEyes: a lens design which takes into account the exact physiological differences between both eyes, optimising binocular fields of vision to deliver wide-angle vision
- Nanoptix: lens technology which redefines the fundamental lens structure, virtually eliminating the swim effect to deliver more balance when a wearer moves.

This article first details the scientific background at the heart of each of these two technologies, and concludes with results of Varilux S series wearer tests.

Natural binocular vision

A human's eyes are separated by a short interpupillary distance (63mm on average) so that an extensive region of the outside world is seen simultaneously with both eyes from slightly different points of view. Each retina transmits its monocular image through the visual pathway to the visual cortex which analyses and transforms both into a three-dimensional perception of the world.

Impact of progressive lenses on natural binocular vision

Studies show that balanced (similarly shaped and sized) right and left retinal images are needed for good binocular summation and depth perception (Figures 1 and 2). Progressive lenses, however, disturb the right and left

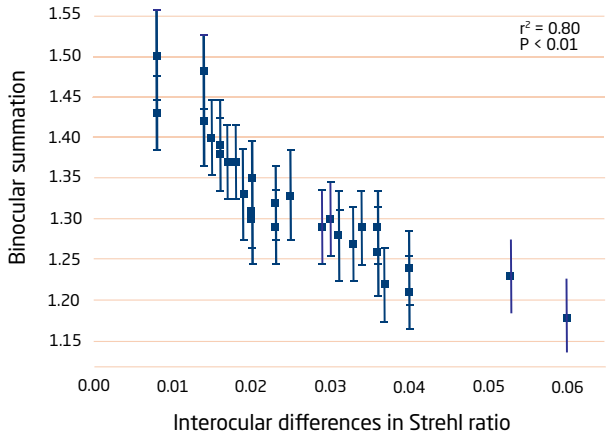

Figure 2 Influence of interocular differences in the Strehl ratio on binocular summation[3]

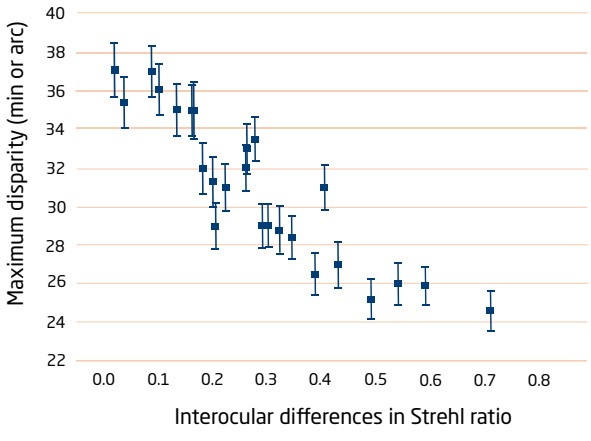

Figure 3 Retinal image quality and maximum disparity[4]

natural retinal image balance. This can lead to difficulties in image fusion, depth perception, and to significantly reduced binocular fields of vision.

Current PAL efforts to manage binocular vision

The management of binocular vision in ophthalmic products has been a challenge for many years. In terms of optical design, two techniques are currently used to improve right and left retinal image balance:

- The first is the location of vision zones that correspond to the needs of convergence. The near vision zones of the lens design have to be centred along a meridian line, which represents the main gaze directions used by a wearer to see through the lenses at all distances and passes from the distance vision zone through the intermediate to the near vision zone. In particular, the near vision zone has to be horizontally inset compared to the distance vision zone, in order to take into account prismatic effects and the eye's convergence at near: the inset can be calculated as a function of several measurements:
  - Mono PD
  - Frame fitting parameters
  - Near working distance
  - Distance and Near Rx.

- The second technique is the distribution of power and aberrations all over the lens, which should be considered in the case of off-centred vision. To preserve right and left retinal image balance, manufacturers have claimed for years good nasal/temporal designs will fix this, even in case of astigmatic prescriptions.

However, whatever the method, lens calculation is based on a monocular conception which takes into account a monocular referential centred on the estimated eye rotation centre, considered wearer prescription and required design performance. It ensures performance for each eye, but it doesn't guarantee the balance between right and left retinal images.

SynchronEyes

SynchronEyes takes into account the physiological differences between the two eyes (the optical design for each given eye, the prescription of the other eye) to guarantee similar retinal images between the both eyes. The prescriptions of both eyes are thus still essential to order even a single lens (although it must be noted in this instance only the required lens will be produced).

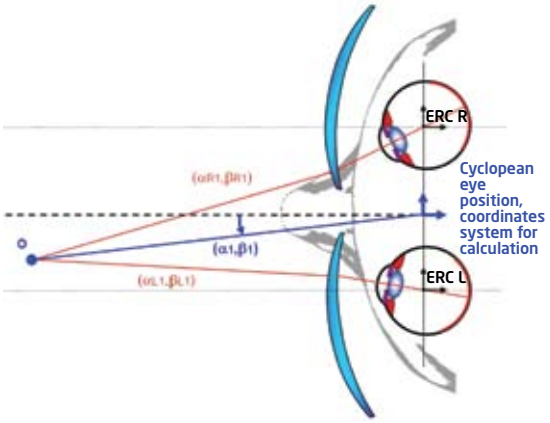

Figure 4 Cyclopean coordinate system

To calculate lenses with SynchronEyes, Essilor designers use a binocular optical system based on three elements:

- The cyclopean eye: just like the Cyclops of Greek mythology, humans see the world as though from a single cyclopean eye situated between the two eyes. The cyclopean eye is placed at mid-distance from the two eye rotation centres
- A 3D environment, which describes the distance of the objects seen as a function of the gaze direction
- A cyclopean coordinate system (Figure 4); for each gaze direction (α1,β1) of the cyclopean eye, the 3D environment provides a given object point O. From object point O, ray tracing provides the right eye gaze direction (αR1,βR1) as well as the left eye gaze direction (αL1,βL1). Right and left gaze directions cross zones of respectively right and left lenses called 'corresponding zones'.

Contrary to monocularly designed lenses, SynchronEyes produces similar right and left 'corresponding zones' and thus right and left similar retinal images through three steps (Figure 5):

- **Step 1:** measurement of the wearer personalised parameters to build his own binocular optical system
- **Step 2:** definition of a binocular optical target, according to the wearer parameters and the binocular system
- **Step 3:** applying binocular optical design to both eyes thanks to the optimisation of the right and left lenses according to the binocular optical target

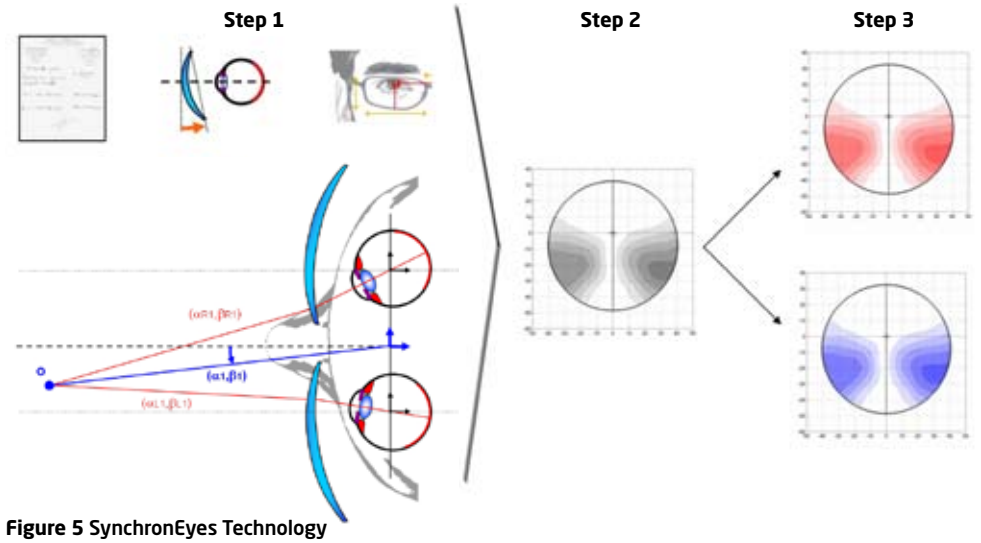

Figure 5 SynchronEyes Technology

SynchronEyes benefits

Let's compare the impact SynchronEyes has by comparing Varilux S series benefiting with a current PAL (Figure 6):

- For a standard lens, the right and left lenses are calculated independently. When looking peripherally, the wearer's gaze crosses the right and left lens through zones with different optical performance. Right and left retinal images are of different quality, resulting in binocular imbalance. Wearers perceive reduced fields of vision, even more so when the distance Rx difference between the two eyes increases
- With Varilux S series, for the first time ever, the right and left lens calculations are synchronised. When looking peripherally, the wearer's gaze crosses right and left lens zones with extremely similar optical performance. Right and left retinal images are of similar quality, ensuring binocular balance. Wearers experience wide angle vision.

SynchronEyes benefits have been demonstrated in laboratory research and development analysis. Results show that Varilux S series lenses deliver up to 50 per cent wider

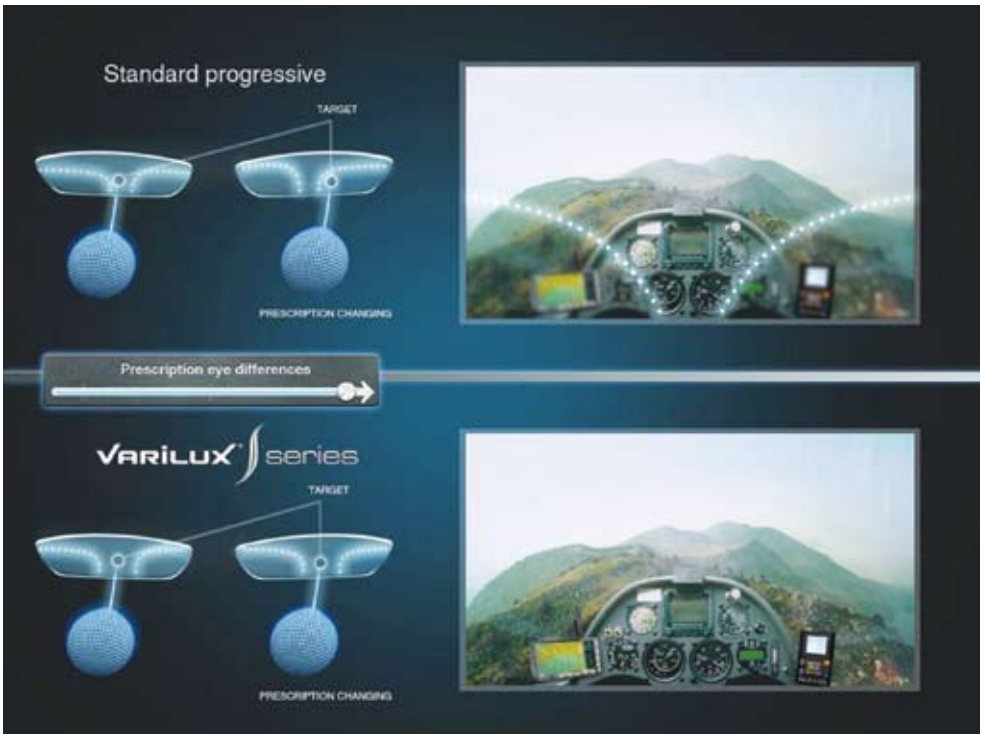

Figure 6 Varilux S series versus a standard progressive lens

binocular fields of vision compared to other premium progressive lenses.

Distortion and swim effect definition

Wearers most often relate their swim effect experience with progressive addition lenses when going down the stairs.

Technically speaking, this swim effect causes deformation of space perception. This deformation occurs first in static vision, when the wearer and surrounding environment are motionless – images appear sharp but distorted. Wearers say, for example, that 'straight lines look curved'. Swim effect appears in dynamic vision when the wearer or their surrounding environment moves: the distortion of the image varies in the field of view depending on movements. Wearers confirm that, when moving their head, they feel everything moves, yet nothing should.

How progressive addition lenses induce swim

A lens generates ray or prismatic deviations:

- In static central vision, ray deviation makes objects 'appear' delocalised (Figure 7)
- In static peripheral vision, ray deviation varies with gaze direction: each object point of a given field of view appears with its own delocalisation and the image is perceived as distorted
- In dynamic vision, this leads to a swim effect which can be simulated through real ray tracing (Figure 8). The wearer is looking in central vision at the point O of the grid and perceives other points of the grid through their peripheral vision; each peripheral point B of the initial grey grid is seen as coming from B', due to ray deviation D generated by the lens. As a whole, for all gaze directions, for a progressive lens, ray tracing shows that the grey grid is seen as coming from the red grid (Figure 9). Deviation varies between upper and lower portions of the progressive lens, inducing mixed image distortion. This leads to the aforementioned swim effect.

Current PAL efforts to reduce swim effect

In first approximation, according to Prentice's law, ray deviation depends on gaze eccentricity and local power: ray deviation increases when gaze direction moves further from the optical centre and/or power increases.

As a consequence, Prentice's law derivation further shows that ray deviation depends on power variation. Therefore on optical design, the higher the power variation, the higher the deviation. A first option to reduce ray deviation and thereby swim effect is to reduce the power variation, that is to say to soften the lens design. However, managing the swim effect through softening of the design also leads to reduced fields of vision.

The classical Prentice's law is only an approximation. To be more correct, it should be completed with a term linked to the lens shape including local front surface curvature as well as thickness and vertex distance.

By optimising these parameters, it is possible to reduce ray deviation, while preserving the power distribution, along with optical design over the lens.

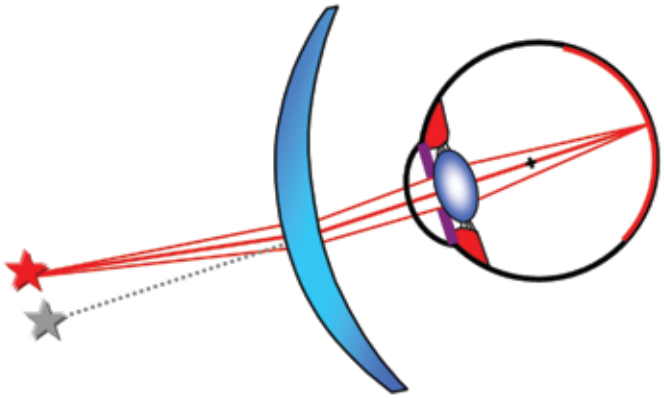

Figure 7 In static central vision, ray deviation makes objects 'appear' delocalised

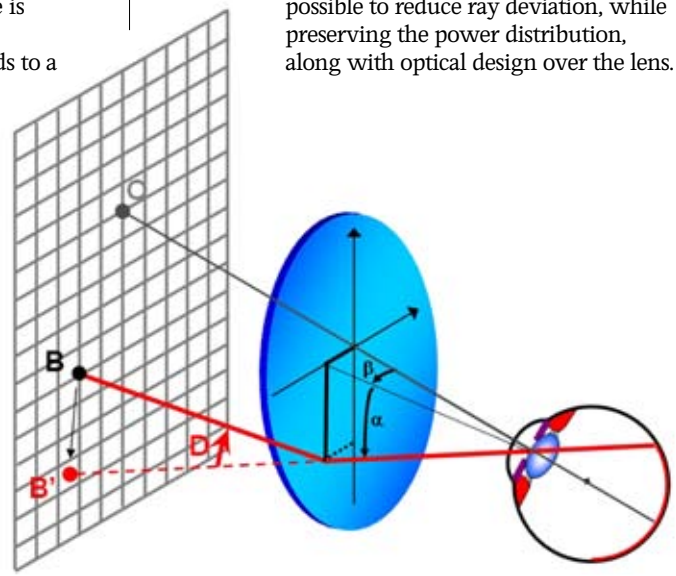

Figure 8 Ray deviation simulation with ray tracing

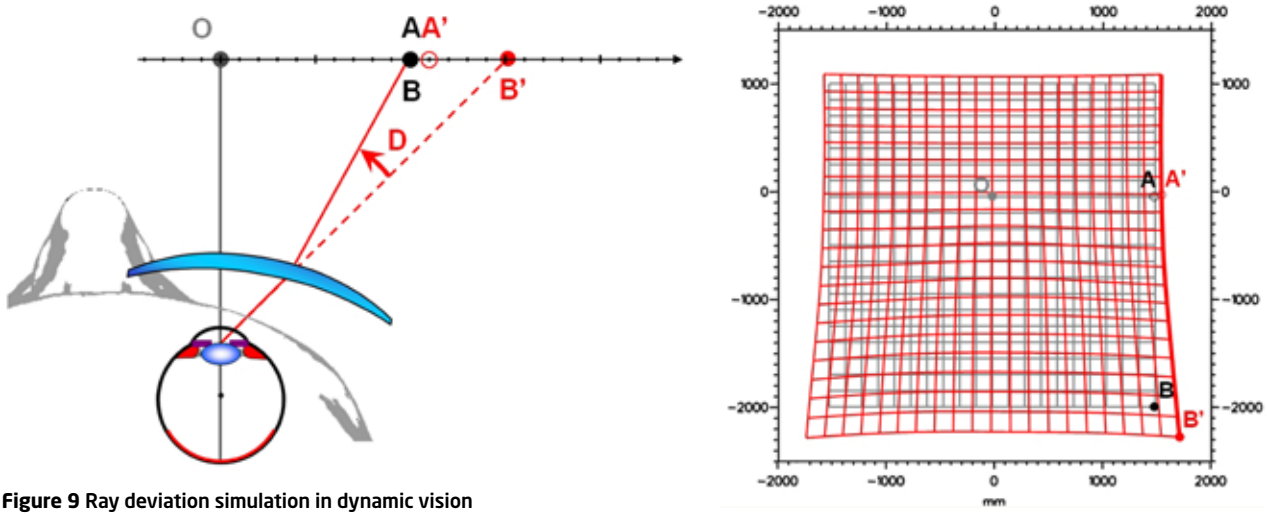

Figure 9 Ray deviation simulation in dynamic vision

Nanoptix calculation

Nanoptix entirely re-engineers the fundamental structure of the lens during the calculation, opening up new degrees of freedom in swim effect management. Instead of considering the lens as a whole shape, the Varilux S series is the first lens to be calculated from thousands of tiny virtual elements (Figure 10).

During Varilux S series calculation, length and position of each element is optimised:

- Each element position is calculated to match the ideal local lens shape (curvature)
- Each element length is calculated to correspond to the required local optical design and dioptric power.

Element by element, the lens is being built to ensure the best lens performance at the end of the calculation.

Let's compare Varilux S series with a current premium progressive lens:

- **A current lens is calculated as a whole:** the base curve of the lens and the power increase simultaneously between distance and near vision. Ray deviation is not stabilised: deviation varies between distance and near vision, wearers will experience swim effect. And this gets even worse when the prescribed near addition increases.
- For the first time with Varilux S series, local shape and power are managed element by element, leading to an exclusive geometry. Ray deviation is controlled element by element to dramatically reduce it. Wearers will feel far more balanced when moving and this remains true even for high near additions.

Wearer tests: Nanoptix

Nanoptix wearer benefits have been backed up by a number of subjective experiments.

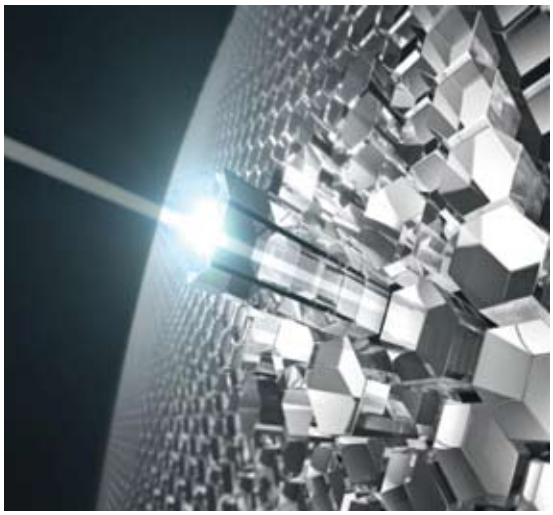

Figure 10 Varilux S series is calculated from thousands of tiny virtual elements

Tests have show that Varilux S series benefits from up to 90 per cent of swim effect reduction compared to other premium progressive lenses.[2]

Nanoptix benefits have also been tested through an Essilor R&D virtual lens simulator experiment showing that Nanoptix technology is clearly preferred by the vast majority of wearers compared to the classical technology.[7]

S digital surfacing

As both the Synchroneyes and Nanoptix exclusive calculations lead to extremely complex surfaces, Essilor's whole manufacturing process has evolved. S Digital Surfacing, a new patented process, benefits from the full performance of digital surfacing and is up to five times more accurate thanks to an exclusive close loop process.

Since 2004, Essilor has conducted systematic wearer tests on its leading brands Varilux, Crizal and Xperio before launching them into the market, placing the wearer at the heart of product performance. As with all previous Varilux generations, Varilux S series has been tested by real wearers around the world in real-life conditions, through independent external third party studies.

These wearer tests highlighted Varilux S series excellence versus existing lenses including Varilux Physio 2.0: Varilux S series was ranked number one on every lens feature.[4] In particular:

- Varilux S series is 'number one' when surroundings move
- Varilux S series is 'number one' for quality and fields of vision
- Wearer comments include: 'Less sensation of movement when I turn my head', 'Overall distortion not here anymore', 'Less head movement to find focus', 'Incredible clearness, everything remains clear until eyes can't turn anymore'.

Conclusion

Wearers around the world have highlighted the excellence of Varilux S-Series including Professor Mo Jalie who says: 'Even people who in the past have been unsuccessful with progressive lenses should now find the new features of these new lenses very easy to adapt to.'

With SynchronEyes and Nanoptix every presbyopic client can enjoy ultimate vision.

References

A list of references is available on from william.harvey@rbi.co.uk

● **Cyril Guilloux** is R&D director, **Soazic Mousset** European strategic marketing director and **Christian Miege** European professional relations director at Essilor. **Andy Hepworth** is Essilor UK professional relations manager