Varilux Physio Enhanced™

Technical Paper and Comparative Studies

From Varilux® Physio® to Varilux Physio Enhanced™: Raising the Bar in Progressive Lens Design

Varilux Physio Enhanced™

Until now, progressive lens wearers had to accept the fact that their quality of vision declined noticeably in dim lighting conditions. This meant tolerating decreased visual acuity while driving at night, using the stairs in dimly lit buildings, going on evening walks, or engaging in other everyday activities. Because the Varilux Physio Enhanced™ lens uses a mathematical model that optimizes the lens based on ametropia, age, object distance, and light condition, each lens is custom-designed to optimize vision in any lighting condition. It is no wonder that wearer studies find Varilux Physio Enhanced preferred by 82% of patients with a preference over a lens without this enhancement.[4] Simply put, Varilux Physio Enhanced lenses provide the sharpest possible vision at all distances and in all lighting conditions.

When they were first introduced, Varilux® Physio® lenses set a new standard, bringing progressive lens wearers an unprecedented level of sharpness at near, distance, and intermediate. Now, Essilor has taken the Varilux Physio design process a step further to create Varilux Physio Enhanced™ lenses, which eliminate even more lens distortion and provide sharper vision over a wider range of lighting conditions. Key to this development is a sophisticated, multifactorial mathematical model that enables optical engineers to design lenses that provide sharper vision, even in low light conditions. As we shall see, vision of this quality in low light is unprecedented in the history of progressive lens design.

In addition to exceptional clarity, Varilux Physio Enhanced lenses provide wide fields of vision and can be used in frames that require fitting heights as low as 14 mm, so patients don't have to sacrifice fashion to get the lenses they want. At the same time, Varilux Physio Enhanced provides a competitive edge to eyecare professionals, who can offer this high-performance lens to patients without making any special measurements or having to buy complex new equipment.

The Evolution of Varilux® Lenses

Ever since 1959, when Essilor introduced Varilux®, the world's first progressive lens, the company has been dedicated to refining and improving progressive lens design. All progressive lenses aim to provide clear vision for distance, near, and intermediate objects without the use of visible lines or segments, but progressive optics are complex and have their own set of challenges.

Over the decades since 1959, lens designers have focused on reducing the peripheral astigmatism associated with progressive optics. But little was accomplished in the control of the higher-order aberrations found in the central zones of the lens. These aberrations decreased sharpness of vision and the ability to distinguish objects at low contrast.

The effects of higher-order aberrations were particularly noticeable to patients with small refractive errors—they sometimes commented that their vision seemed "sharper" without their glasses. Still, the most pressing problem was peripheral distortion, and that problem occupied optical engineers until the beginning of the current century.

Enter Wavefront Technology

Then, in 2006, Essilor introduced Varilux Physio lenses with W.A.V.E. Technology™: Wavefront Advanced Vision Enhancement. Essilor adapted the wavefront technology developed first by astronomers to eliminate distortions introduced when light from stars passed through earth's atmosphere. This

is also the technology used to drive the lasers in wavefront-guided refractive surgery—in LASIK, the effect of the eye's optical system on a beam of light entering the eye is analyzed, and this data is then used to program the laser which corrects the cornea to eliminate both large and small optical errors.

W.A.V.E. Technology does something very similar. It provides wearers of Varilux Physio and Varilux Physio Enhanced lenses with sharper vision by analyzing the entire beam of light as it passes through the progressive lens (Figure 1). Essilor engineers then identify the specific wavefront distortions and correct them—managing the quality of the wavefront passing through the lens to achieve optimal acuity.

This has resulted in a dramatically improved lens performance: In a 2006 report, McDonald and colleagues compared the capabilities of Varilux Physio with those of conventional progressive lens designs, including the Varilux® Panamic®. Compared with the Varilux Panamic lens, Varilux Physio had 3 times fewer higher-order aberrations in the distance field, a 30% wider field of comfortable intermediate vision, and a 10% reduction in maximum defocus in the near zone for a broadened field of near vision acuity.[1] Moreover, comparisons to other progressive lens designs showed consistent, and often greater, performance gains at distance, intermediate, and near for Varilux Physio (see Figure B in sidebar on page 5).[1]

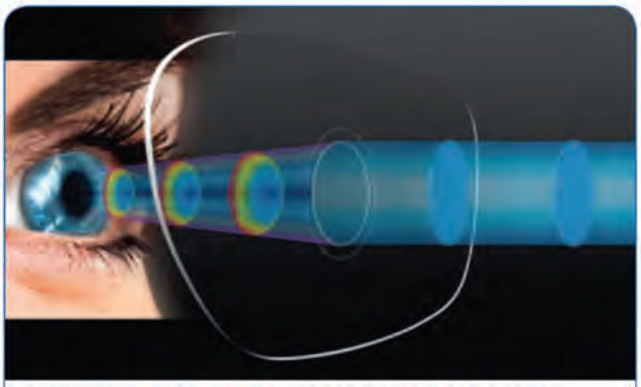


FIGURE 1 With W.A.V.E. Technology™, the entire beam of light passing through each area of the progressive lens is analyzed so that wavefront distortions can be identified and eliminated.

Patients See the Difference

W.A.V.E. Technology has enabled Varilux Physio lenses to provide clinically proven superior visual performance, and only lenses with W.A.V.E. Technology can provide the sharpness and contrast found in Varilux Physio lenses. This is clearly demonstrated in the studies presented in this compendium.

For example, when 81 wearers rated their experiences with Varilux Physio vs a different digitally surfaced progressive addition lens with identical frames and fitting parameters, wearers preferred the Varilux Physio lenses in seven out of eight performance categories, and patients with a preference showed a 20-to-1 greater preference for Varilux Physio.[2] When asked about their plans to buy progressive lenses, 79% chose Varilux Physio.[2]

In a comparative, double-masked dispensing study, 70 patients compared the performance of Varilux Physio against that of an individualized, digitally surfaced PAL for everyday use.[3] Participants evaluated these designs based on several criteria, including near, intermediate, and distance vision, as well as parameters that relate specifically to progressive lens wear, such as zone transition. Because adaptation is an important consideration, wearers were also asked to rate how easily they adjusted to each lens.

Overall, wearers preferred the Varilux Physio 4-to-3 over the individualized PAL. As a group, they rated the Varilux Physio lens superior to the individualized PAL in six out of seven categories, including zone transition, near and distance vision, and adaptation to the lens.[3] It's worth reiterating that in this study, Varilux Physio, which needs no specific measurements, was preferred to a digitally surfaced *individualized* lens.

The Arrival of W.A.V.E. Technology 2™

Progressive lens technology advanced again in 2010 when Essilor introduced W.A.V.E. Technology 2™. This exciting new technology employs Essilor's sophisticated mathematical model to determine pupil size across a range of add powers, lighting conditions, and viewing distances (Figure 2). By then optimizing the lens design for the expected pupil size, engineers can create a lens that lets patients see optimally in any lighting condition—including the dim light conditions that have traditionally challenged progressive lens wearers.

In fact, most progressive lenses perform adequately under normal daylight conditions when pupils are small, but quality of vision declines noticeably in dim light. This happens because when pupils enlarge, they let in a larger beam of light. This enlarged beam passes through a larger area of the progressive lens, picking up higher order aberrations from the lens. Thus, the larger the beam, the more lens surface it passes through, and the more aberrated it becomes.

To address this problem, Essilor scientists used data from thousands of wearer tests to create the computer model that predicts pupil size over a range of viewing distances and lighting conditions for each patient's prescription and add combination (Figure 2).

Wavefront Technology Improves Vision by Reducing Aberrations in Progressive Lenses

Marguerite B. McDonald, MD, FACS*, and the Essilor Study Group**

PURPOSE

To determine, using both optical and clinical criteria, whether a new wavefront-optimized progressive lens, Varilux® Physio™ (Essilor), provides better vision than conventional progressive lens designs. The ultimate goal is to provide data that will allow physicians to make evidence-based spectacle lens dispensing decisions for presbyopes.

Applying Wavefront Optics to Progressive Lens Design

The minute power variations that occur across the surfaces of a progressive lens make it a very complex refracting device. The characteristics of the wavefront produced as light passes through a progressive lens depend on the local properties (material, thickness, dioptric power, curvature, etc) in each gaze direction (near, intermediate, far, peripheral, etc). Therefore, the process of characterizing the wavefront that a given progressive lens design will produce when executed in a given prescription and a given material involves a point-by-point analysis of the combined front and rear surfaces of the lens. This provides the information needed to 1) identify the lower and higher order aberrations (HOAs) inherent in a given lens design and 2) correct these aberrations by altering the design. The result is an optimized wavefront produced by the lens—and received by the eye.

Varilux Physio represents the combined application of wavefront measurement and digital surfacing technologies to the optimization of progressive lens optics. Using a patented design and manufacturing process called W.A.V.E. (wavefront advanced vision enhancement) Technology, engineers created Varilux Physio by:

- Analyzing the wavefront rather than individual rays
- Measuring the lens-induced aberrations
- Fine-tuning the lens design to eliminate or reduce aberrations that affect visual acuity and quality of vision
- Assuring precise reproduction of the highly complex, mathematically-defined three-dimensional lens shapes by using digital surfacing that is accurate to 0.1 micron

As a result, the Varilux Physio lens enhances the quality of the wavefront that reaches the presbyope's eye, no matter the direction of gaze.

METHODS

The wavefront-optimized Varilux Physio lens was compared to Varilux® Panamic® (Essilor), a market-leading premium progressive lens considered by many to be the gold standard for conventional design and performance. The wavefront analyses involved:

- Lenses of identical prescription (plano with a +2.00 D add) and material (1.67 index) in each design
- Assumed pupil sizes consistent with human ocular function when viewing objects at distance (6-mm pupil), intermediate (5 mm), and near (4 mm)
- Collection of wavefront data from identical locations on each lens surface in the distance, intermediate, and near zones
- Distance zone: assessment of higher order aberrations, particularly coma. The HOA level was calculated by averaging data taken from five locations: at the fitting cross and from 4 mm above, 2 mm under, and 3 mm on each side.
- Intermediate zone: assessment of residual astigmatism level and its orientation. Deviation of astigmatism from the vertical axis (90°) was calculated by averaging data taken from three locations: 8, 10, and 12 mm below the fitting cross.
- Near zone: assessment of average maximum defocus (stability of power control). The maximum defocus of power was calculated by averaging data taken from three locations: 16, 17 (near-vision point), and 18 mm below the fitting cross. Astigmatism at 90° and ± 45° was measured.

Additionally, clinical comparisons of the two lenses from several studies provided corroboration for the laboratory findings.

RESULTS and DISCUSSION

Distance

Higher order aberrations, particularly coma, are often present in the distance field of progressive lenses. HOAs introduce visual distortion and limit, in subtle but important ways, the sharpness of focus that can be achieved with conventional progressive lens designs, particularly as the eye moves to the lens periphery (**Figure 1**).

The HOA level of the wavefront-optimized lens (0.07 microns) was 3 times lower than that of the conventional control lens (0.21 microns; **Figure 1**). Additional comparisons against other conventional progressive lens designs demonstrated that the wavefront-optimized lens provided up to 6.6 times lower HOA and the lowest HOA level of all evaluated lenses (**Figure 2**).[1] By minimizing coma in the distance portion of the lens, Varilux Physio offers wearers better acuity across a widened field of vision.

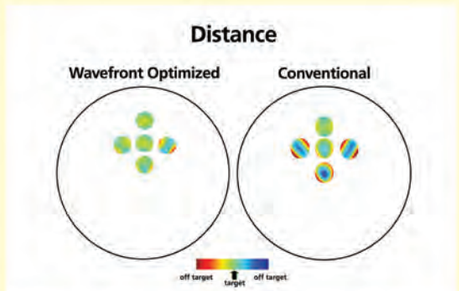


FIGURE 1 Wavefront analysis through a 6-mm pupil showed that the wavefront-optimized progressive lens design (left) exhibited a reduction in HOA in the distance field compared to the conventional lens (right). Quantitatively expressed, the wavefront-optimized lens had an HOA level 3× lower than the conventional design.

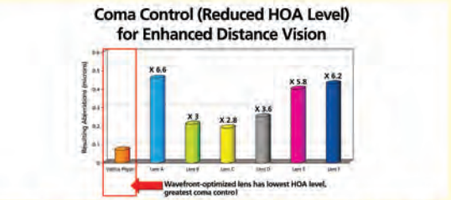


FIGURE 2 The HOA level in the distance field of the wavefront-optimized lens (in orange) was 2.8 to 6.6× lower than measured in conventional progressive lens designs.[1]

Intermediate

Unwanted astigmatism is an unavoidable consequence of the progressive lens curve and increases with the add power of the lens. To provide patients with a functional intermediate zone, designers aim to "push" the unwanted astigmatism as far as possible to either side of the progressive channel. Various studies have shown, however, that both the amplitude and the axis of astigmatism affect visual perception.[2-5] For example, the human visual system can more easily "ignore" or accommodate astigmatism when it occurs in the vertical axis. An optimal optical design is one that reduces the amplitude of the lens' astigmatism and directs its axis to a vertical position.

With an average deviation measure of 0°, the wavefront-optimized lens provided the greatest astigmatism control (**Figure 3, left**), ie, an axis of astigmatism that demonstrates little to no deviation from vertical in the intermediate zone. In contrast, the conventional lens demonstrated an average deviation of 10° (**Figure 3, right**). Additional comparisons against other conventional progressive lens designs demonstrated that Varilux Physio provided the greatest astigmatism control (eg, least average deviation from vertical orientation; **Figure 4**).[1] The wavefront-optimized lens also evidenced a lower amplitude of astigmatism with an axis of ± 45° compared to the conventional lens (**Figure 5**). As a result, the intermediate zone of the wavefront-optimized design is 30% wider than that of the conventional lens.

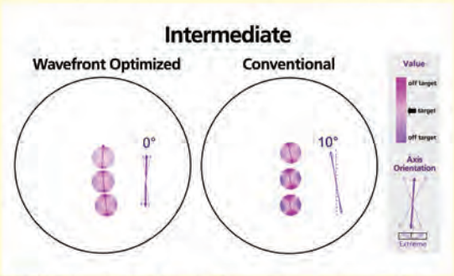


FIGURE 3 Wavefront analysis of the intermediate zone through a 6-mm pupil showed that the wavefront-optimized progressive lens design (left) exhibited lower levels of residual astigmatism (as indicated by lighter shades of purple) and consistent vertical alignment of the axis of astigmatism compared to the conventional lens (right).

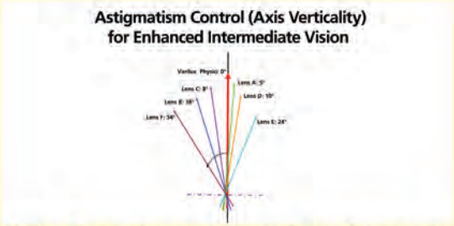


FIGURE 4 The human visual system can more easily "ignore" or accommodate astigmatism when it occurs in the vertical axis. The wavefront-optimized lens (in red) provided optimal orientation of residual astigmatism in the intermediate zone, while the average deviation from the vertical 90° axis for conventional progressive designs ranged from 5–34°.[1]

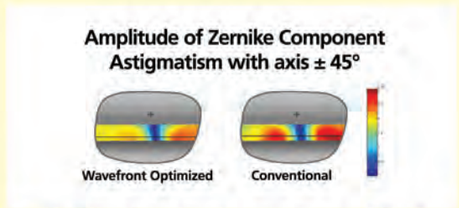


FIGURE 5 The wavefront-optimized progressive lens design (left) had a lower amplitude of astigmatism (axis: ± 45°) than the conventional lens (right), thus evidencing better control of the residual astigmatism associated with the intermediate corridor. The result is a 30% wider area that is free of unacceptable distortion and, therefore, a 30% wider field of usable intermediate vision.

Near

R&D studies conducted by Essilor show that progressive lens wearers tend to utilize the full vertical length of the near zone. However, the subtle variations in sphere (ie, defocus) that occur along this length can cause eye strain. A design that maintains an even power distribution within the near zone, ie, greater power control that results in less variation in sphere power, will enhance wearer comfort and extend the vertical area of functional near vision.

The wavefront-optimized lens demonstrated 10% greater power control compared to the conventional progressive design, as determined by the average maximum defocus. Additional comparisons against other conventional designs demonstrated that the wavefront-optimized lens provided approximately 2 to 7 times greater power control in the near zone (**Figure 6**).[1] The reduction in defocus achieved through wavefront optimization of the Varilux Physio lens enhances wearers' viewing comfort by extending the vertical reach of the reading zone and by making it more uniform in power. The net result is a more generously proportioned area of consistently crisp and comfortable near vision that is easier for the wearer to access.

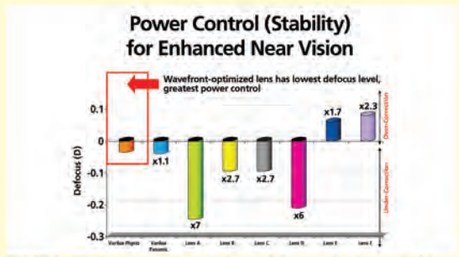


FIGURE 6 The average maximum defocus of the wavefront-optimized lens (in orange at left) was 1.1 to 7× lower than for conventional progressive lens designs, indicating improved add power stability along the near zone.[1]

Wearer Studies Corroborate Wavefront Findings

In a multicenter European study designed to evaluate if a wavefront-optimized design provides better vision than conventional progressive designs, Varilux Physio was dispensed to 609 randomly selected presbyopes with corrections from –10.00 to +6.00 D, up to 4.00 D of cylinder, and add powers from 0.75 to 3.50 D.[6] The patients, all of whom paid for their lenses, were surveyed at 3 weeks. For near, intermediate, and distance, respectively, subjects reported "clearly wider/wider" fields (50%, 53%, and 50%) and "clearly better/better" (72%, 65%, and 67%) vision with the wavefront-optimized lens compared to their conventional lenses. Seventy-two percent rated their overall quality of vision as "clearly better/better" with the wavefront-optimized lens than with their prior lenses.

Similar findings were reported for pooled results of clinical and market studies conducted in the US, Canada, Europe, Australia, and Singapore (N = 2,000).[7] Of those who had worn a Varilux Panamic lens prior to the study, 67% — or 2 out of 3 — preferred wavefront-optimized Varilux Physio. Of those who had previously worn other conventional progressive lens designs, 3 out of 4 preferred the wavefront-optimized design. Preference for the wavefront-optimized designs was consistent, regardless of ametropia, subject's age, or previous type of lens.

CONCLUSIONS

Compared to a leading conventional progressive lens design, Varilux Panamic, the wavefront-optimized Varilux Physio lens provided:

- **Three times less higher order aberration at distance**
- **Reduced amplitude and enhanced orientation of residual astigmatism in the intermediate zone resulting in a 30% wider field of comfortable intermediate vision**
- **A 10% reduction in maximum defocus in the near zone for improved power control along a greater vertical area, resulting in an expanded field of near vision acuity**

Additional comparisons against other conventional progressive lens designs showed consistent — and often greater — performance gains at distance, intermediate, and near. Clinical studies indicate that the advances in progressive lens design achieved through wavefront optimization correlate to an improved visual experience for presbyopes.

REFERENCES

1. Using the same study methodology, wavefront data were also collected for premium conventional designs of other progressive lens manufacturers.
2. Fauquier C, Bonnin T, Miege C, Roland E: Influence of combined power error and astigmatism on visual acuity. *Ophthalmic and Visual Optics Technical Digest* (Washington, DC: Optical Society of America, 1995), Vol. 1:151-154.
3. Miege C: Etude de la fonction accommodative de l'eril humain, Thèse de Doctorat, 1988.
4. Charman WN, Whitefoot H: Astigmatism, accommodation, and visual instrumentation. *Applied Optics*. 1978; 17(24):3903-3910.
5. Garcin G, Lafay C, Le Saux G, et al: Application of a deflectometry method to deep aspheric ophthalmic surfaces testing. *Optical Fabrication and Testing* (Europto Series Proceedings, 1999), Vol. 3739:291-295.
6. Lazuka-Nicoulaud E, Llopis Garcia S: Varilux Physio — introducing "high resolution vision." *Points de Vue*. Spring 2006; no. 54.
7. Data on file, Essilor.

* The author has no financial interest in the products/companies referenced.

** The Essilor Study Group, largely based in Europe, comprises independent researchers as well as researchers employed by Essilor International, S.A..

This poster was presented at the American Academy of Ophthalmology Meeting in 2006 and won the Best Poster award.

Factoring Pupil Size Changes into a Wavefront-optimized Progressive Lens Design Improves Vision in Low Light Conditions

Marguerite B. McDonald, MD, FACS*, and the Essilor Study Group**

PURPOSE

Varilux Physio Enhanced™ (Essilor) is a new wavefront-corrected progressive lens that incorporates pupil size modeling data into its design. The study evaluates whether this lens provides better vision, especially in low light conditions, than other progressive lens designs.

Effects of Pupil Size on Progressive Lens Performance

A healthy pupil dilates and constricts in response to light levels and distance to the target of regard. This pupillary response is affected by patient-related factors, such as age and ametropia.[1,2] Natural fluctuations in pupil size pose a problem for progressive lens performance. When pupil size increases, as it does in mesopic and scotopic conditions, the wavefront received by the eye is more highly aberrated because the beam of light entering through an enlarged pupil passes through a larger area of the lens surface (Figure 1). This results from the fact that a level of higher order optical aberration, particularly coma, is inherent in progressive lens design. Thus, the greater the spectacle lens area utilized, the poorer the quality of the wavefront that reaches the retina. Spectacle lens-induced aberrations diminish contrast sensitivity and visual performance. The effect is most pronounced in dim light—in fact, progressive lens wearers' most common visual complaint is their quality of vision in low light conditions.[3]

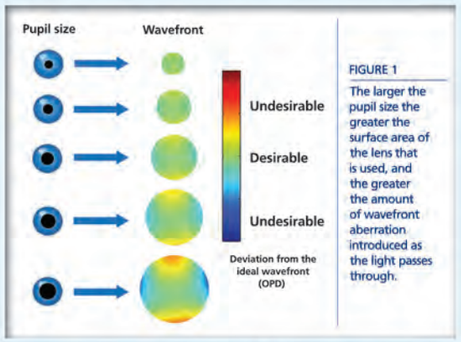


FIGURE 1
The larger the pupil size the greater the surface area of the lens that is used, and the greater the amount of wavefront aberration introduced as the light passes through.

Factoring Pupil Size Changes into Progressive Lens Design

To address performance issues posed by natural pupillary dynamics, a complex computer model was developed to predict pupil size for any given lens prescription and add power combination under a range of specific viewing distances and lighting conditions (Figure 2). For each pupil size, the model calculates the corresponding area of the lens surface that will be utilized. Then, taking the largest predicted pupil sizes (since these place the greatest constraints on progressive lens performance), the targeted areas of the original wavefront-optimized Varilux® Physio® lens are redesigned to minimize aberration in the area of the lens being used. The resulting design enhancement aims to minimize the spectacle lens aberrations associated with reductions in contrast sensitivity and visual performance.

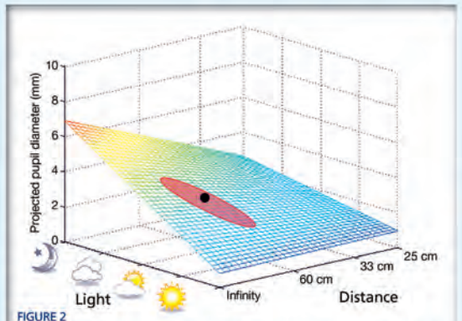


FIGURE 2
The area of the progressive lens surface that would be in use given the size of the pupil under the specific lighting level and viewing distance combination being modeled is represented in red. The model also takes into account the Rx, add power, and direction of gaze.

METHODS

A double-masked, randomized, non-dispensing wearer test compared the new Varilux Physio Enhanced lens to the original Varilux Physio wavefront-corrected design.

Subjects (N = 30):

- Average age: 52.9 years
- Spherical error: −6.25 to +3.25 D; average = −1.60 D
- Cylinder: up to 5.50 D; average = 0.70; 6 subjects >1.00 D
- Add: 0.75 to 2.75 D; average = 1.90 D
- BSCVA: 20/25 or better in each eye

Prior primary means of correction:

Test Protocol

Subjects received two pairs of identical eyewear, one with Varilux Physio Enhanced and one with Varilux Physio lenses. After testing with the first lens (randomized order), patients crossed over and tested the other lens design for comparison. Consistent fitting parameters were used (eg, monocular PDs, a minimum fitting height of 18 mm).

Subjects performed a series of real-world tasks in variable-controlled environments under both standard (100 cd/m²) and dim (25 cd/m²) lighting conditions (Table I). After concluding the tasks, subjects stated their "global overall" lens preference under each of the two lighting conditions.

TABLE I
Evaluative tasks conducted in standard (100 cd/m²) and dim (25 cd/m²) light

Vision type	Tasks	Functionalities assessed
Near	Accessing small-print features on: – digital camera – cell phone – restaurant menu	– Ease of use (camera, phone) – Clarity of vision (all) – Width of field (menu)
Intermediate	Reading and typing tasks: – LCD monitor set at 60 cm distance	– Clarity of vision – Width of field
Distance	Reading scrolling text at a minimum distance of 10 feet: – two LCD monitors, one positioned centrally, the other peripherally	– Sharpness of text – Ease of switching between central and peripheral monitor – Width of field
Changing Focus	– Near newsprint – Intermediate-distance LCD monitor – Far-distance LCD monitor	– Speed/ease of changing focus – Clarity of vision
Dynamic	Viewing while moving: – grocery shelves – stairs	– Finding items and reading labels (grocery shelves) – Confidence (stairs) – Maintenance of natural posture (stairs)

RESULTS AND DISCUSSION

Statistically Significant Preference for PAL that Uses Pupil Size Data to Optimize Wavefront

Subjects preferred the Varilux Physio Enhanced lens in both standard (71%; $P = 0.08$) and dim (82%; $P = 0.006$) lighting (Table II). The most frequently recorded subject comments referred to "better sharpness/clarity/focus" being experienced with the Varilux Physio Enhanced lens. A similar comparative study of 35 presbyopes confirmed that wearers experienced higher levels of visual performance for all measured criteria with the Varilux Physio Enhanced lens (Figure 3).

TABLE II
Subjects preferred the design (Varilux Physio Enhanced) that accounts for pupil dynamics

	Varilux Physio Enhanced	Varilux Physio	*P*-value
Standard Lighting (100 cd/m²)	71% (15)	29% (6)	0.08
Dim Lighting (25 cd/m²)	82% (18)	18% (4)	0.006

Note: Results for subjects who noted a lens preference in either the standard (21/30) or dim (22/30) lighting test scenario.

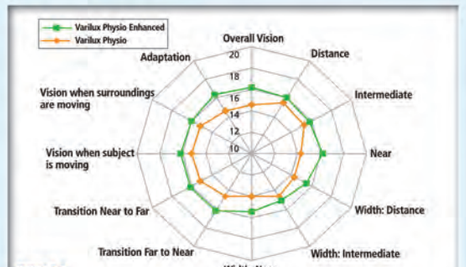


FIGURE 3
Subjects expressed higher levels of satisfaction with the Varilux Physio Enhanced lens for all performance criteria (as indicated by the wider diameter plot of mean responses in green) than for the Varilux Physio design (in orange). Scale: very poor (1) to very good (20)

Wearer Studies Confirm Optical Bench Test Findings

These wearer comparison outcomes corroborate optical bench test results that showed the Varilux Physio Enhanced lens exhibited reduced wavefront aberration levels (Figure 4) and improved contrast function (Figure 5) when compared to four other progressive lenses of identical prescription and material.[4] These tests showed Varilux Physio Enhanced offered:

- The lowest level of aberration in the portion of the lens utilized
- Highest modulation transfer function in dim and standard lighting

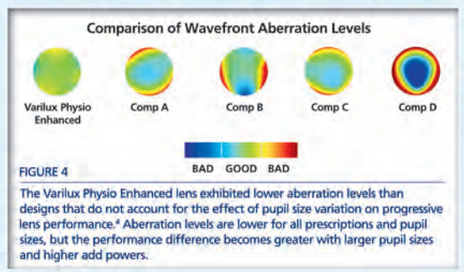


FIGURE 4
The Varilux Physio Enhanced lens exhibited lower aberration levels than designs that do not account for the effect of pupil size variation on progressive lens performance.[4] Aberration levels are lower for all prescriptions and pupil sizes, but the performance difference becomes greater with larger pupil sizes and higher add powers.

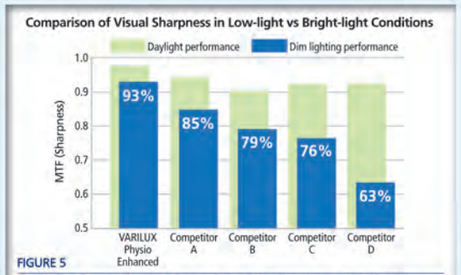


FIGURE 5
The Varilux Physio Enhanced lens maintained better contrast sensitivity in both low-light and bright-light conditions as indicated by a higher modulation transfer function (MTF). Evaluation based on a −4.00 D lens with +2.00 D add and pupillary diameters of 3 mm (bright light) and 8 mm (dim light).[4]

CONCLUSIONS

The Varilux Physio Enhanced design, which accounts for pupil dynamics, provides improved vision, particularly in low light.

Cumulative results from a double-masked wearer study and optical bench testing indicate that the Varilux Physio Enhanced lens, which is designed to account for the natural changes in pupil size that occur in response to lighting levels and the individual's accommodative state, provides improved vision in low light conditions when compared to progressive lenses that do not incorporate pupil size modeling data into their design.

The data show that the Varilux Physio Enhanced lens

- **Is globally preferred, with preference achieving statistical significance in dim light situations**
- **Has fewer aberrations than other progressive designs tested**
- **Preserves 93% of image sharpness in dim light for improved contrast sensitivity**

REFERENCES
1. Winn B, Whitaker D, Elliott DB, et al. Factors affecting light-adapted pupil size in normal human subjects. *Invest Ophthalmol Vis Sci*. 1994; 35(3): 1132-7.
2. Myers GA, Barez S, Krenz WC, et al. Light and target distance interact to control pupil size. *Am J Physiol*. 1990; 258 (3): 813-9.
3. Nielsen on-line study of 300 interviewees in France and Germany, 2009. Data on file, Essilor International, S.A.
4. Comparative data were collected for the following progressive lens designs: Zeiss Individual™ (Lens A), Shamir Autograph II® (Lens B), Zeiss SOLAOne™ HD (Lens C), Hoyalux iD MyStyle (Lens D).

* The author has no financial interest in the products/companies referenced.

** The Essilor Study Group comprises independent researchers contracted to Essilor International, S.A.

This poster was recognized by the American Academy of Ophthalmology at its annual meeting in 2010.

Clinical Evaluation of **Varilux® Physio® vs Digitally Surfaced "Dual Surface" PAL**

PURPOSE

To compare the performance of two PAL design technologies:

1. Varilux® Physio®—introduced in 2006—has a front surface digitally molded progression with W.A.V.E. Technology™: Wavefront Advanced Vision Enhancement which reduces and controls higher order aberrations
2. Digitally Surfaced "Dual Surface" PAL—introduced in 2004—has progression digitally surfaced on both the front and the back of the lens to reduce skew distortion

METHODS

Subject masked, randomized design, dispensing (duration = 3 weeks/design), identical frames and fitting parameters, AR coated, high-index substrate (1.67 Varilux Physio, 1.60 DS PAL)

Fitting parameters:

- Monocular Pds
- FRP at center pupil
- Minimum fitting height = 18 mm

Each subject subjectively compared designs for:

- Distance (overall preference)
- Intermediate (overall preference)
- Near (overall preference)
- Dynamic Vision (object/subject in motion)
- Visual Fatigue
- Adaptation
- Overall Preference

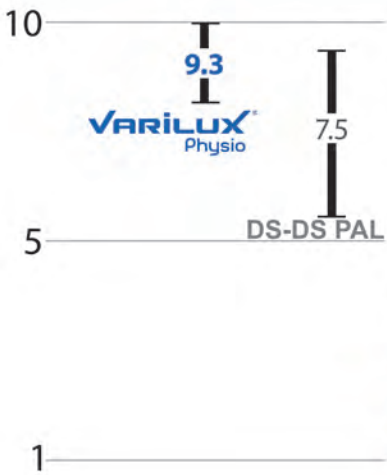
SUBJECTS

N = 81 subjects	
By ametropia	**27 Myopes** (maximum Rx -6.00)
	27 Emmetropes
	27 Hyperopes (maximum Rx +3.75)
By astigmatism	23 Spherical Rx
	34 Cylinder < 1.00 D
	24 Cylinder 1.00 to 2.00 D
Mean ADD = +2.25 (r = +1.00 to +3.00)	
Mean Fitting Height = 21 mm (18 to 25 mm)	
Current Primary Correction Type	23 = PALs (none wearing either PAL assessed)
	5 = SV (DVO or NVO)
	5 = Contact Lenses (1 monovision, 1 multifocal)
Inclusion Criteria: BVA 20/20 or better in each eye	

Research conducted by an independent third party —
grant provided by Essilor of America

STATISTICAL RESULTS

N = 81	Varilux Physio	DS DS PAL	No Pref.	*P*-value
Distance Vision	31	1	49	**<0.001**
Intermediate Vision	37	0	44	**<0.001**
Near Vision	53	0	28	**<0.001**
Dynamic Vision	39	2	40	**<0.001**
Adaptation	12	14	55	0.556
Visual Fatigue	11	3	67	0.061
Overall Performance	40	2	39	**<0.001**



Final Mean Evaluation
Wearers rated satisfaction significantly higher ($P < 0.01$) for Varilux Physio.

10 = Highly satisfactory
1=Very unsatisfactory

Varilux Physio = 9.3 (± 0.8)
DS-DS PAL = 7.5 (± 1.9)

Average satisfaction rating for Varilux Physio lenses was higher and showed greater consistency.

CONCLUSIONS

- Varilux® Physio® lenses were preferred in 7 out of 8 areas measured. The results were significantly in favor of Varilux Physio for: distance vision ($P < 0.001$), intermediate vision ($P < 0.01$), near vision ($P < 0.01$), dynamic vision ($P < 0.01$), and most significantly, **subjects with a preference preferred Varilux Physio overall 20:1** ($P < 0.01$).
- Additionally, when questioned regarding intent to purchase, 79% chose to purchase Varilux Physio.

Clinical Evaluation of **Varilux® Physio® vs Individualized DS PAL**

PURPOSE

To evaluate and compare the performance of Varilux® Physio® and an individualized DS PAL for everyday use:

1. Varilux Physio — 1.67 traditionally surfaced with W.A.V.E. Technology™: Wavefront Advanced Vision Enhancement
2. Individualized DS PAL — 1.67 digitally surfaced with design individualized to fitting characteristics

METHODS

Comparative, double-masked, dispensing study (each lens design worn 3 weeks)

Evaluation of each lens design recorded through questionnaire after wearing period and comparative questionnaire at the end of the test

Fitting parameters:

- Monocular Pds
- FRP at center pupil
- Individualized lens was individualized according to manufacturer's paramaters (PD, vd, panto, near dist.)

Each subject subjectively compared designs for:

- Distance Vision
- Intermediate Vision
- Near Vision
- Dynamic Vision (subject moving/world moving)
- Visual Fatigue
- Zone Transition
- Adaptation
- Overall Preference

SUBJECTS

<table>
<tr><th colspan="3">N = 70 subjects</th></tr>
<tr><td colspan="3">Refractive Condition</td></tr>
<tr><td rowspan="3">Myopes
Total 25</td><td colspan="2">5 (–6.00 to –4.00)</td></tr>
<tr><td colspan="2">9 (–4.00 to –2.00)</td></tr>
<tr><td colspan="2">11 (<–2.00)</td></tr>
<tr><td rowspan="3">Hyperopes
Total 45</td><td colspan="2">2 (+6.00 to +4.00)</td></tr>
<tr><td colspan="2">13 (+4.00 to +2.00)</td></tr>
<tr><td colspan="2">30 (<+2.00)</td></tr>
<tr><td colspan="3">Mean ADD = +2.00 ADD (r = +0.75 to +2.75)</td></tr>
<tr><td rowspan="3">Inclusion Criteria</td><td colspan="2"><± 0.50 change from previous Rx</td></tr>
<tr><td colspan="2">Corrected VA 6/6 (10/10) each eye</td></tr>
<tr><td colspan="2">PAL wearer for > 6 months</td></tr>
<tr><td rowspan="2">Exclusion Criteria</td><td colspan="2">Systemic condition having influence on visual acuity</td></tr>
<tr><td colspan="2">Medical treatment/medication influencing visual acuity</td></tr>
</table>

Research conducted by independent eyecare research organization (London, UK) May 2006–June 2007

STATISTICAL RESULTS

Figure 1

N = 70	Varilux Physio	Individualized PAL	No Pref.	*P*-value
Adaptation	27	14	29	**0.0609**
Distance Vision	25	17	28	**0.2812**
Intermediate Vision	18	21	31	**0.5218**
Near Vision	29	17	24	**0.1048**
Dynamic Vision	27	18	23	**0.2330**
Visual Fatigue	21	18	31	0.7488
Zone Transition	25	15	30	0.1547
Overall Preference	36	27	7	**0.3135**

Figure 2

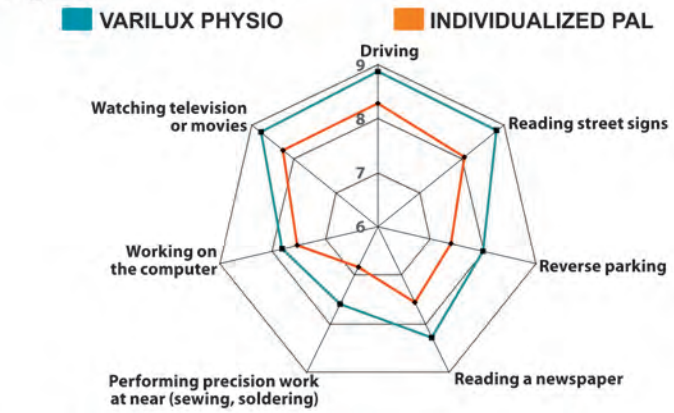
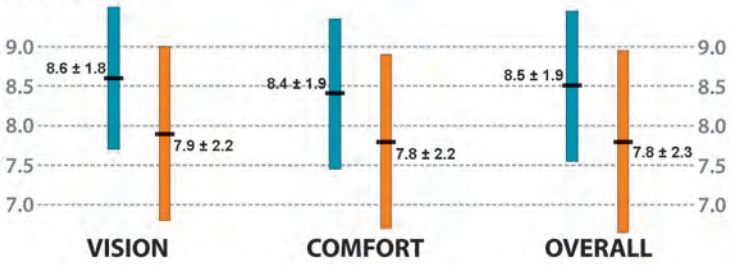


Figure 3



CONCLUSIONS

- Overall, subjects preferred Varilux® Physio® 4 to 3 over individualized PAL.
- Varilux Physio was also preferred by more subjects in 6 out of 7 specific areas measured (Figure 1). Qualitatively, subjects had a higher evaluation of Varilux Physio for every specific activity measured (Figure 2). Qualitative evaluations were significantly better for vision, comfort, and overall satisfaction (Figure 3).

The data indicates Varilux Physio provides superior performance for everyday visual activities when compared to the individualized DS PAL.

Effectiveness of W.A.V.E. Technology 2™ — A Wearer Study

PURPOSE

To discern if the claimed benefit of W.A.V.E. Technology 2 (improved vision in all lighting conditions by customizing control of wavefront aberrations) is noticeable in "real life" conditions by actual subjects by comparing the performance of Varilux Physio Enhanced™ to Varilux® Physio®.

METHODS

Double-masked, non-dispensing, randomized

Fitting parameters:

- Monocular Pds
- FRP at center pupil
- Minimum fitting height = 18 mm
- Minimum 10 mm between FRP and superior edge of lens

Each subject evaluated designs for "global overall preference" — in the environments described below under two lighting conditions:

- "Standard" lighting (100 cd/m^2)
- "Dim" lighting (25 cd/m^2)

Initial Adaptation

- Walking stairs
- Scanning shelves

Distance—scrolling text on two LCD monitors

- Sharpness of text
- Ease of changing focus from central to peripheral monitor
- Width of field

Intermediate—typing text into a Word document imaged on a LCD monitor set at a distance of 60 cm

- Sharpness/clarity of monitor
- Width of field (measured on map displayed on LCD)

Near—use of digital camera, cell phone, restaurant menu

- Ease of use (camera controls, cell functions)
- Clarity (menu, camera, cell)
- Width of field (menu)

Changing Focus—(distance LCD monitor, intermediate LCD monitor, near newsprint)

- Clarity
- Speed/ease of changing focus

Dynamic Vision—(grocery shelves, stairs)

- Finding and reading grocery items and labels
- Confidence on stairs
- Ability to maintain natural posture on stairs

Research conducted by an independent third party — *sponsored by Essilor of America*

SUBJECTS

N = 30 subjects		
Average age = 52.9		
Avg Dist. Rx (OD)		–1.60 sph (range = –6.75 to +3.25)
		–0.70 cyl (range = sph to –2.50)
Myopes		**21** (11 > –2.00)
Hyperopes		**9** (1 > +2.00)
Astigmats		**21** (6 > –1.00)
Avg. ADD = +1.90 (range = +0.75 to +2.75)		
Avg. Fitting Height = 20.2 mm (r = 18 mm to 29 mm)		
Current Primary Correction Type	17	PALs (6 currently wearing Varilux® Physio®)
	6	SV (DVO or NVO)
	5	Contact lenses
	2	No currently worn correction
All subjects BVA 20/25 or better in each eye.		

FINDINGS

In standard lighting conditions (100 cd/m²), subjects preferred Varilux Physio Enhanced over Varilux Physio. Of the subjects who had a preference, 71% preferred Varilux Physio Enhanced. This preference approached statistical significance ($P = 0.08$).

In dim lighting conditions (25 cd/m²), subjects significantly preferred Varilux Physio Enhanced over Varilux Physio ($P < 0.01$). Of the subjects who had a preference, 82% preferred Varilux Physio Enhanced.

During the study, the comments of subjects were recorded. The most frequently occurring comment referred to the "better sharpness/clarity/focus" of the Varilux Physio Enhanced lenses.

Preference and Findings

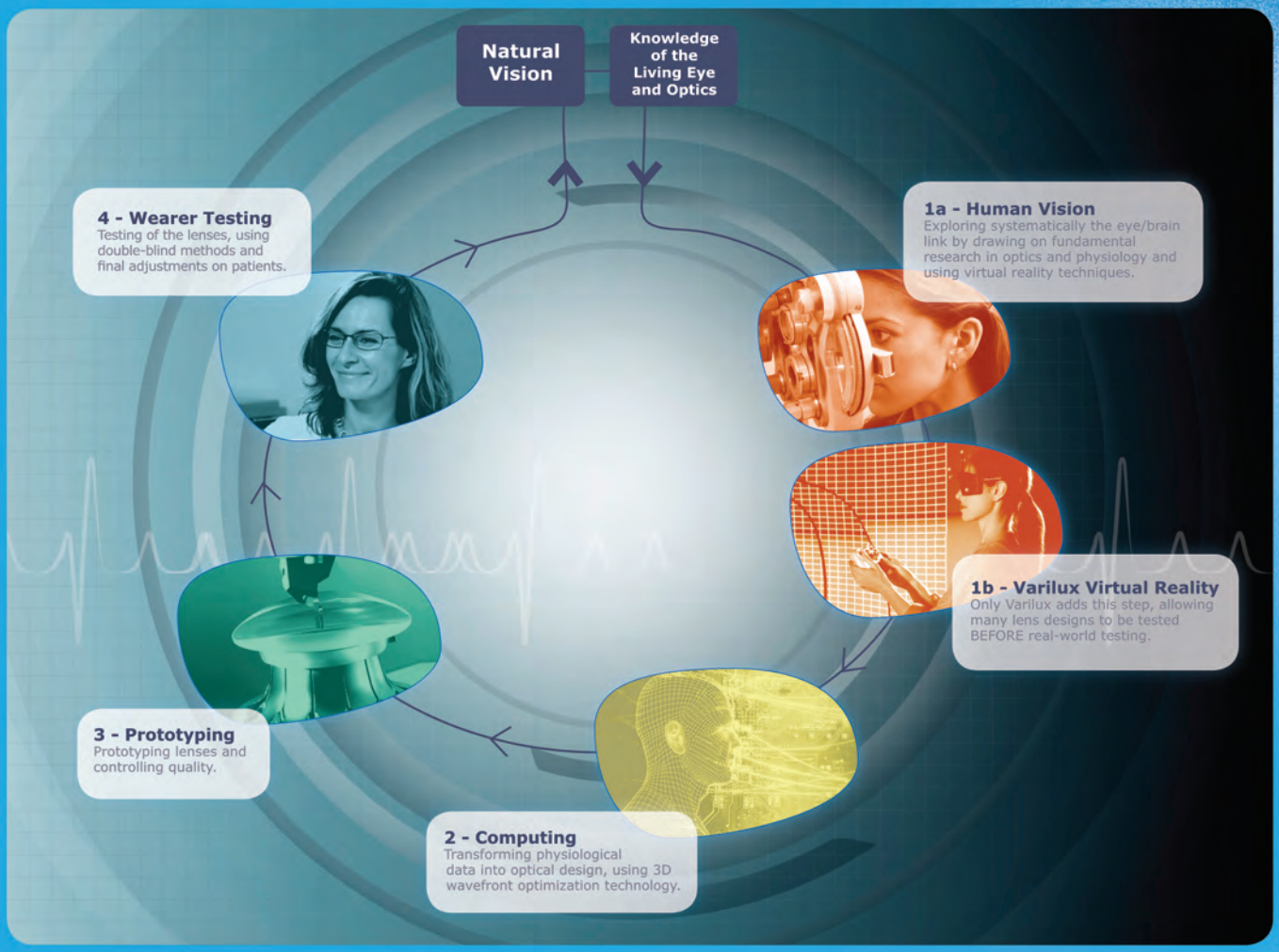
	Varilux Physio Enhanced	Varilux Physio	No Pref.	*P*-Value
Standard Lighting (100 cd/m²)	15 *50%*	6 *20%*	9 *30%*	0.08
Dim Lighting (25 cd/m²)	18 *60%*	4 *13%*	8 *27%*	0.006

CONCLUSIONS

- Varilux Physio Enhanced™ is globally preferred to Varilux® Physio® in all lighting conditions—with preference gaining significance in dim lighting conditions.
- **These findings are consistent with the claimed benefit of W.A.V.E. Technology 2™ (customized control of higher order aberrations).**

Varilux® Live Optics

Only the Varilux® R&D process integrates the results of wearer testing at each stage of lens design, guaranteeing the highest level of patient satisfaction.



essilor

Seeing the world better

Essilor International is the world leader in the design, manufacture and customization of ophthalmic lenses. Active on five continents, Essilor offers a wide range of lenses under the flagship Varilux®, Crizal®, Definity®, Xperio® and Essilor® brands to correct presbyopia, myopia, hyperopia and astigmatism.

©2010 Essilor of America, Inc. All rights reserved. Unless indicated otherwise, all trademarks are the property of Essilor International and/or its subsidiaries. LVAR200836 BST/ETHIS 12/10