

**NEW PROGRESSIVE LENSES
FOR ALL-DAY-LONG VISION COMFORT,
SUPPORTED BY A BREAKTHROUGH IN
LENS DESIGN EVALUATION**

WHITE PAPER

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INTRODUCTION

Due to the higher complexity of our visual environment, Progressive Addition Lens (PAL) users can encounter various adaptation challenges. Essilor® discovered that people facing near-vision challenges can overcome these issues by using a PAL that offers greater postural flexibility, to:

- **better keep up with their active lifestyles;**
- **allow them to frequently change positions during a prolonged visual task.**

Essilor®, dedicated to innovation, reaffirms its leadership in this comfort territory with a new generation of mid-range premium PAL offer: Varilux® Comfort Max lens. Supported by Flex Optim™ technology, this new lens design provides PAL users a stretched useful vision zone and a broader range of head movements.

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1. THE MARKET IN PERSPECTIVE



Among the 2.1 billion presbyopes worldwide, 85% are not corrected with progressive lenses¹. Moreover, 3 in 5 people over 40 years old have not tried PAL yet². The reason? Although price may be an obstacle, the main reasons why people do not buy PALs or abandon them are discomfort and non-adaptation³. With the launch of its first generation in 1993, Varilux[®] Comfort lens has become a reference in the market^{4,5}. Essilor[®] is indeed dedicated to

85% of presbyopes are not corrected with progressive lenses¹

continuing to push the limits of innovation so as to help people deal with the increasingly complex visual environment that surrounds them.

2. WEARERS NEEDS AND BEHAVIOUR

Studies have shown that individuals wearing PALs may experience issues and discomfort^{6,7}. This is due especially to the recent proliferation of mobile digital devices and, hence, the higher complexity of their visual environment.

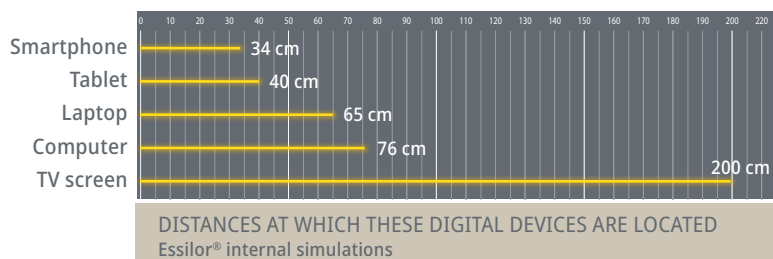
Head posture has to be variable and flexible to avoid **musculoskeletal disorders**.

This complexity is related to:

- the diversity of distances at which these devices are located
- the significantly extended duration of use

related to fluctuations in diurnal arousal¹⁰. A larger useful vision zone on the progressive lens will allow the wearer to better cope with these normal daily fluctuations.

Adaptation to progressive lenses requires not only eye movement adjustments but also new strategies of head positioning.



Several studies showed that during prolonged tasks, the wearer may progressively experience more and more difficulty in performing fine-tuned gaze changes. The results have been shown especially in computer⁸ use and driving⁹.

The restriction of head positions due to optical constraints related to PAL may lead to frozen and uncomfortable head postures and eventually musculoskeletal disorders. Ergonomics principles consider that there is no ideal posture for a given visual task. The ideal posture is: "the next one" as regularly changing one's posture during a task helps prevent muscle tension and reduce stress on the body.

Air and train travel provides a good illustration of this phenomenon. Sitting in a plane or a train with very restricted legroom, one can have a comfortable position at the very beginning of the travel (following usual ergonomics criteria), but eventually, this rigid position will become uncomfortable.

Furthermore, eye movement accuracy is not constant throughout the entire day there are variations

Motor variability plays a crucial role in people's adaptive behaviours, characterized by the fine-tuning of body movements during interactions with various and/or changing environments¹¹.

Locomotion provides a good illustration of such a process, the individual having to constantly adapt each step to the previous one, and every step being different¹².

Motor variability is important not only for efficient gait control but also for ensuring a comfortable posture during the long-lasting use of digital devices. There is a growing body of evidence which indicates that prolonged static posture is one of the factors involved in the correlation between intensive smartphone and computer use and musculoskeletal disorders^{13,14,15}. Indeed, it was demonstrated that, even with a comfortable head position, maintaining an overly static neck posture during long periods of time may act against the anatomical nature and physiological needs of the cervical spine¹⁶. Long-lasting static head postures may cause musculo-

skeletal disorders¹⁷. Dynamic mechanical load is essential to managing the balance of fluids inside the intervertebral discs¹⁷. Regular small head movements and micro breaks during intensive digital usage may therefore help to preserve postural comfort^{17,18}.

With this in mind, the aim of Varilux® Comfort Max lens conception was to optimize the optical design so as to provide the wearer with a wider useful vision zone and a larger area for head movement enabling multiple and varied head postures, especially during prolonged tasks.

Varilux® Comfort Max lens is the most recent development in the evolution of Varilux® Comfort 3.0 lens, building off the base design of Essilor's® iconic best-seller Varilux® Comfort lens.

3. THE CONCEPTION OF VARILUX® COMFORT MAX LENS

SUPPORTED BY NEW FLEX OPTIM™ TECHNOLOGY TO GO FURTHER IN LENS DESIGN INDIVIDUALIZATION



The development of a vision profile takes the principles of the Live Optics™ process as a starting point.

Live Optics™ was introduced for the first generation of Varilux® Comfort lens in 1993 and places the wearer at the heart of the lens design conception. Live Optics™ always follows the same steps (Figure 1):

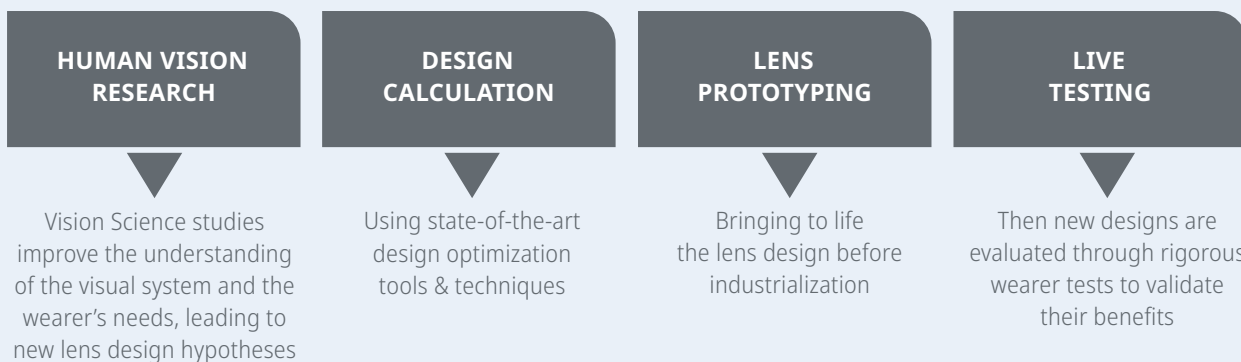


Figure 1: Live Optics™ process

Conception process

A progressive lens product is commonly computed for a range of prescriptions (Sphere, Cylinder, Axis, Addition), resulting in numerous combinations of different lenses.

At Essilor®, different lenses are derived from an original 'vision profile', which represents the basic optical parameters of the product.

Each vision profile addresses specific ranges of prescriptions.

This approach brings additional performance:

- by providing different solutions,
- for different segments of populations,
- in response to their specific visual needs.

Precious feedbacks from wearers were studied to conceive the vision profiles of Varilux® Comfort Max lens design

Varilux® Comfort Max lens design relies on scientific data as well as results from a range of wearer tests. In fact, at the end of each Live Optics™ loop, wearers' responses give precious feedback about their specific visual needs.

Thus, Essilor® has acquired solid knowledge from analyzing more than 1225 wearers who participated in 26 wearer tests and from deep diving into wearers' testimonials about their lens experience. Furthermore, Essilor® carried out several research studies investigating differences in visual perception and visuomotor interaction related to ametropia^{19,20,21}.

In light of this knowledge, Essilor® has developed distinct vision profiles that meet the specific needs of each ametropia segment.

Based on the above mentioned test results, a total of 15 different vision profiles were defined and made available (Figure 2).

Varilux® Comfort Max lens vision profiles are categorised by addition and by ametropia, meaning that each wearer is associated with the vision profile that best matches his/her visual needs based on his/her refractive error and addition power.

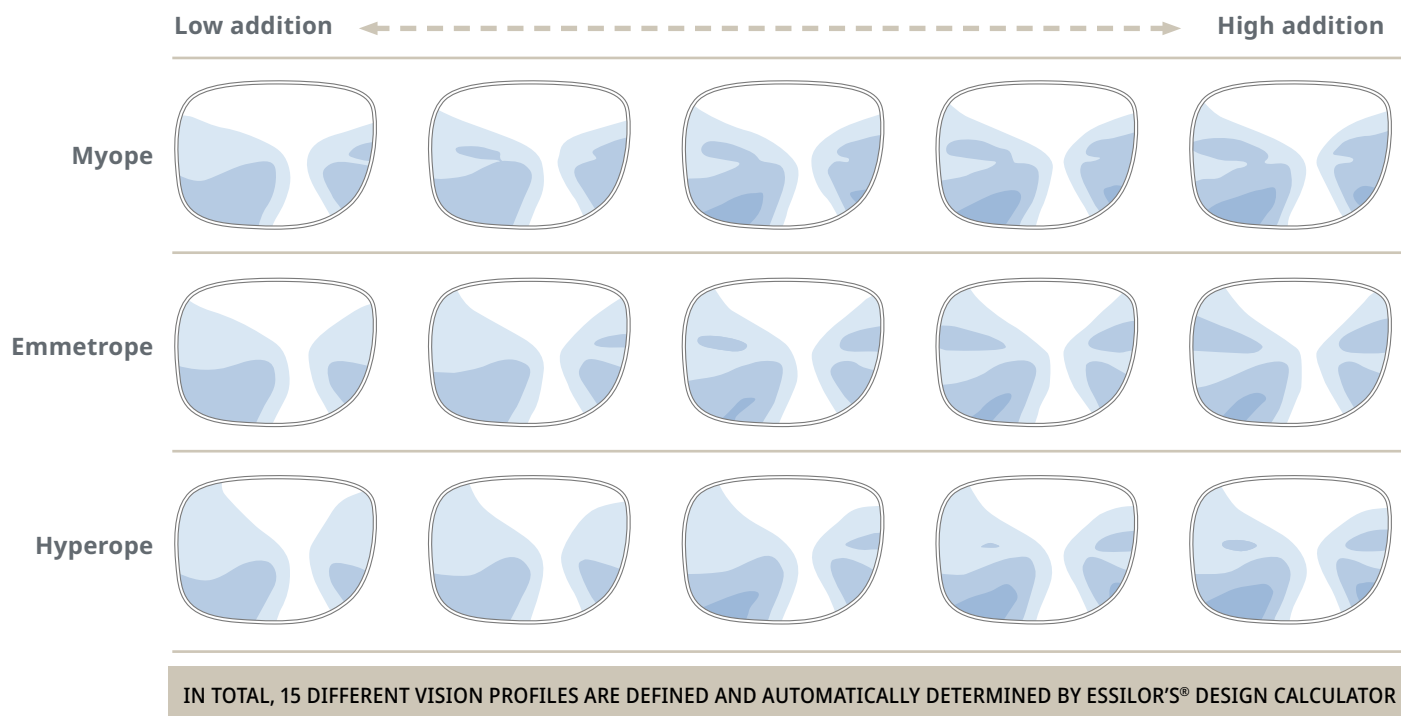


Figure 2: Varilux® Comfort Max lens 15 vision profiles

Varilux® Comfort Max lens vision profiles aim to ensure that each wearer is associated with the vision profile that best matches his/her needs.

Optimal balance thanks to Flex Optim™ technology

Flex Optim™ technology has been designed to provide good all-around visual performances, by maximising the wearer's postural flexibility: it adjusts the lens progression profile to each individual wearer, going beyond the vision profile to ensure a tailor-made solution.

Flex Optim™ technology provides the best trade-off at all viewing distances and notably improves the intermediate vision performances of Varilux® Comfort 3.0 lens without significantly affecting far and near vision performances.

This makes the new Varilux® Comfort Max lens design attractive for PAL wearers in terms of versatility and all-around performance (Figure 3).

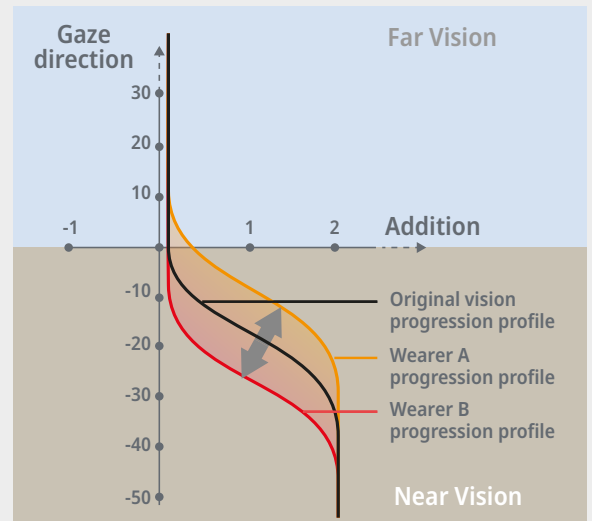


Figure 3: Flex Optim™ technology progression profile adjustment. The progression profile is modified individually for each wearer (A and B): examples of target design progression profiles (colored lines) adjusted for individual wearers, based on the same visual profile progression profile (black line).

Stretched useful vision zones

The useful vision zone criterion makes it possible to visualise some of the performance improvements of the Varilux® Comfort Max lens design.

The useful vision zone is defined as the domain of gaze directions (α , β) for which the visual acuity loss is lower than 0.15 logMAR. Visual acuity loss is determined from lens aberrations for a given gaze direction and object distance, thanks to a model developed internally by Essilor®²².

Useful vision zones are computed for a range of viewing distances. Each simulation considers one fixed object distance and all possible gaze directions.

Starting from the wearer's vision profile, Flex Optim™ technology adjusts the progression profile to his/her prescription and needs, so as to provide an optimal equilibrium across vision zones. The resulting Varilux® Comfort Max lens design offers a stretched useful vision zone, particularly for intermediate viewing activities.

Figure 4 illustrates this improvement for an intermediate distance of 60 cm, where the useful vision zone for Varilux® Comfort 3.0 lens is significantly smaller. For the same conditions, Varilux® Comfort Max lens provides a larger useful vision zone that can be accessed lower down on the lens surface.

Varilux® Comfort Max lens has a significantly larger useful vision zone in intermediate vision compared to Varilux® Comfort 3.0 lens, without a significant reduction in far and near vision.

Thus, the vision profiles and Flex Optim™ technology enable the new design to provide a better balance of visual performances at all distances compared to Varilux® Comfort 3.0 lens.

As a result, Varilux® Comfort Max lens ensures better all-around performance.

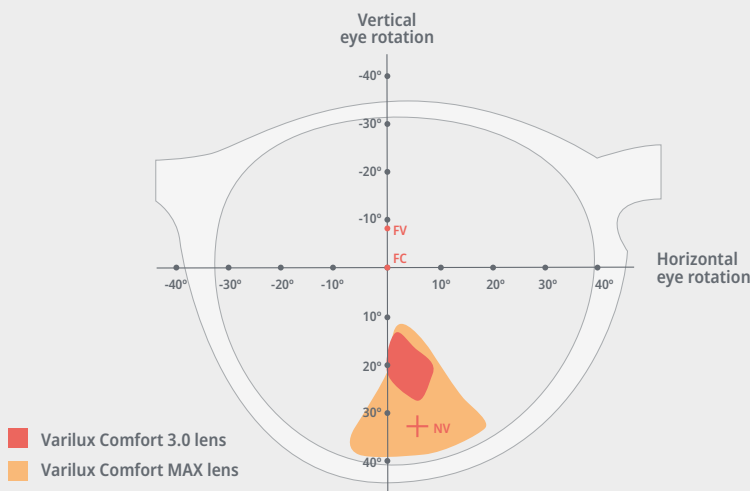


Figure 4: Varilux® Comfort Max lens (orange) vs Varilux® Comfort 3.0 lens (red) useful vision zone. Prescription = Plano Add 2.0. Distance = 60 cm.

4. THE NEW ESSILOR[®] R&D AVATAR MODEL:

A BREAKTHROUGH IN LENS DESIGN EVALUATION

Limitations of the lens design evaluation method used for previous generations of Varilux[®] Comfort lenses

The performance of the previous generations of Varilux[®] Comfort lenses was assessed by generating optical maps such as mean power or resulting astigmatism maps. This method of evaluating a progressive lens design had several drawbacks.

1 The method assessed data that were not directly related to the wearer's perception i.e. sharp or blurry vision, high or low contrast; in other words: visual acuity.

2 It took only one eye into account while in the visual system, both eyes work together to provide a vision of the wearer's environment.

3 It did not consider the variety of tasks that a wearer could undertake in its daily life.

The new avatar model

To overcome these limitations, and as part of the Live Optics[™] process, Essilor[®] developed the avatar, a new simulation model that provides a more realistic indication of wearer perception.

This new model aims to measure the performance of a visual equipment and evaluate the design before prototyping and live testing. The approach consists in modeling the wearer's experience with his/her visual equipment in a 3D environment.

It is a breakthrough in the way we think about lens design evaluation.

Essilor[®] R&D's avatar model relies on the following components:

- A 3D model of the scene
- A model of the visual task
- A model of the wearer

The model of the scene describes the 3D objects in the environment, in a 3D reference frame.

It advantageously replaces the traditional model of an environment where each gaze direction corresponds to a single object distance, in a continuous fashion.

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A typical example of a 3D environment and visual task model is represented in *Figure 5*.

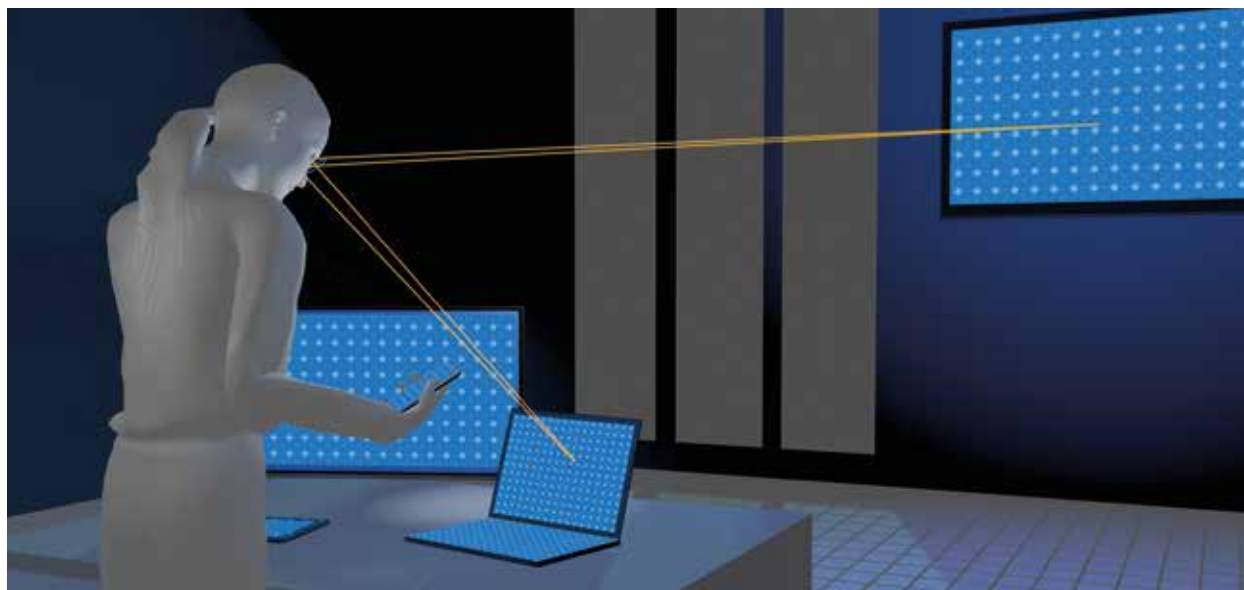


Figure 5: 3D environment and possible fixation points of a visual task



Figure 6: Wearer model

The model of the wearer consists of two eyes and a head. Each eye can rotate in various gaze directions. The head itself can rotate with respect to the wearer's torso (Figure 6).

In Essilor® R&D's avatar model, the visual task is executed by the avatar. Physical measurements such as head rotation angle, eye rotation angle, optical aberrations and so on can be determined for each fixation point.

Essilor® R&D's avatar contains perceptual models which relate physical measurements to performance indicators (Figure 7):

- Visual acuity as a function of lens aberrations;
- Head and gaze efforts as a function of head and gaze angles;
- Accommodation effort as a function of accommodation value.

Thanks to this new approach, the performance of the lens design can be evaluated in a more comprehensive manner than it has ever been done before.

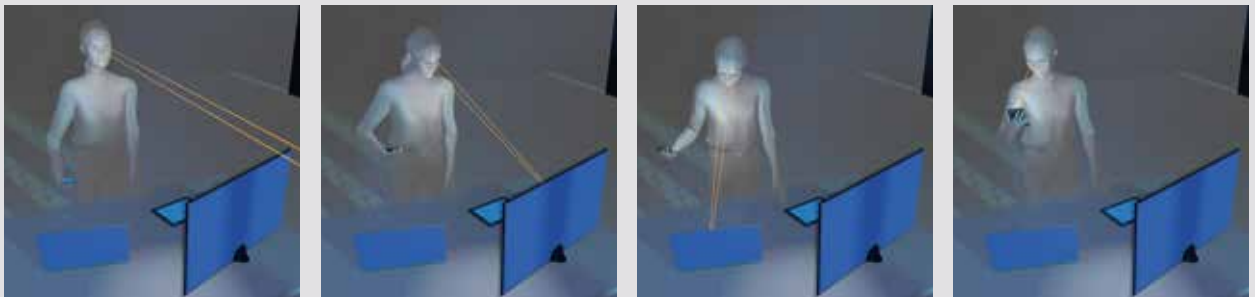


Figure 7: Visual task execution by Essilor® R&D's avatar for various fixation points

5. NEW OPTICAL CRITERIA: POSTURAL FLEXIBILITY MEASUREMENT

As mentioned in the introduction, people facing near vision challenges need a PAL that offers more postural flexibility to:

- better keep up with their active lifestyles.
- allow them to frequently change positions during a prolonged vision task.

Superior postural flexibility

Essilor® R&D's avatar model has been used to evaluate the Varilux® Comfort Max lens design with new performance indicators including postural flexibility.

Postural flexibility is defined as the range of head motions available to the wearer while maintaining his fixation on a given object point (Figure 8).

More specifically, the postural flexibility corresponds to the number of possible head positions (in head lowering and azimuth) so that the binocular visual acuity loss is less than 0.15 logMAR (ie 7.8/10), assuming a best-corrected visual acuity 10/10 for each eye.

The greater the postural flexibility, the higher the number of different head positions the wearer can adopt to look at a given fixation point, then the easier it will be for the wearer to change his posture during prolonged vision tasks and the more comfortable s/he will be.

The greater the postural flexibility, the easier for the wearer to change his/her posture during prolonged vision tasks and the more comfortable s/he will be.



Figure 8: Multiple possible head positions for fixing a given object point

The postural flexibility criterion was computed for a large number of configurations:

- 5 different wearer models, differing in prescription or wearer characteristics:

Prescription	Sphere [D]	Addition [D]
Rx1	0	1.0
Rx2	0	2.0
Rx3	0	3.0
Rx4	-4.0	2.0
Rx5	4.0	2.0

- 72 different fixation points (i.e. visual tasks) corresponding to 9 fixation points per object on 8 different objects.

The list of objects and corresponding distances are detailed in the table below:

Object	Size (mm)	Distance (cm)	Direction (deg)
Smartphone	70 x 150	34	(38, 0)
eBook	110 x 160	38	(30, 0)
Tablet	250 x 180	40	(30, -30)
Paper	210 x 297	42	(28, 0)
Laptop	340 x 220	65	(22, 0)
Computer	570 x 340	76	(7, 30)
TV	1200 x 700	200	(0, 0)
Far zone	2000 x 2000	1000	(0, 0)

Over 360 situations were simulated to ensure a thorough comparison of the design performances.

Varilux® Comfort Max lens vs other lens designs

The postural flexibility criterion has been assessed for Varilux® Comfort Max lens, Varilux® Comfort 3.0 lens and main competitors.

The number of possible head postures for Varilux® Comfort Max lens and Varilux® Comfort 3.0 lens for Plano Add 2.0 prescriptions is summarised in the table below for intermediate vision tasks.

Target	Varilux® Comfort Max lens	Varilux® Comfort 3.0 lens	Gain with Varilux® Comfort Max lens
Computer	193	98	+97%
Screen	302	170	+52%

The average gain of Varilux® Comfort Max lens across vision tasks is summarized in the table below.

Reference design	Gain with Varilux® Comfort Max lens
Varilux® Comfort 3.0 lens	+43%
Competitor A	+44%
Competitor B	+75%
Competitor C	+30%
Competitor D	+12%

The Figure 9 shows the overall superiority of Varilux® Comfort Max lens when compared to its main competitors.

Varilux® Comfort Max lens provides the best all-around performance at all distances in terms of postural flexibility.

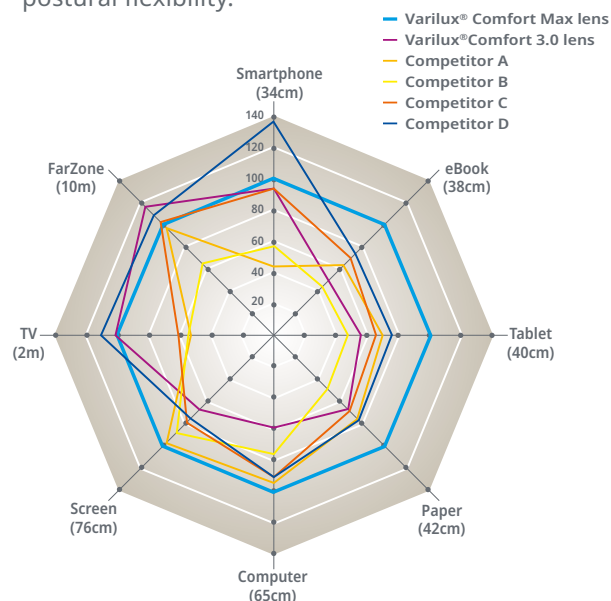


Figure 9: The number of possible postures allowing the wearer to see sharply when performing a given vision task

6. VARILUX® COMFORT MAX LENS TESTED BY WEARERS

Varilux® Comfort Max lens performances

To evaluate the subjective visual performances of Varilux® Comfort Max lens, a wearer test was conducted in the UK in 2018-2019 by two independent centers²³.

Sixty-seven presbyopes aged between 41 and 70, participated in this multi-center wearer test. This study was designed to allow the subjects to assess Varilux® Comfort Max lens design performances in real-life conditions.

The participants were instructed to wear Varilux® Comfort Max lens for the whole duration of the study, that is for at least 2 weeks, 5 days a week and, 5 hours per day.

The PALs prescribed for the test had a distance refractive power within the range of [-4.00 to +4.00 D] (average of OD and OS equivalent spheres), a cylindrical component within the range of [0 to -2.00 D] in both eyes and an addition for near distance within the range of [+0.75 to +2.50 D].

A 0-10 scale evaluation questionnaire was completed by each subject. It asked questions about topics like:

- specific aspects of the participants' experience while wearing Varilux® Comfort Max lenses;
- the quality of vision at various viewing distances (far, intermediate and near);
- the ease of transition between the different visual zones of the lens, the quality of vision in motion and adaptation.

8 OUT OF 10 WEARERS
experience easy adaptation

Key results:

- Varilux® Comfort Max lens design was very well accepted and obtained high satisfaction rates
- Wearer's subjective experience shows that there is a balance across vision zones (8/10 rating), which indicates that Flex Optim™ technology really works.
- Evaluations of Varilux® Comfort Max lens design were at the expected level (Figure 10):
 - Overall performance rating of 8.7/10,
 - Intermediate Vision rating of 8.3/10,
 - Distance Vision and Near Vision ratings respectively of 8.8/10 and 8.5/10.

The wearers confirmed that Varilux® Comfort Max lens is a very good all-round lens that provides balanced performances for all viewing distances and situations.

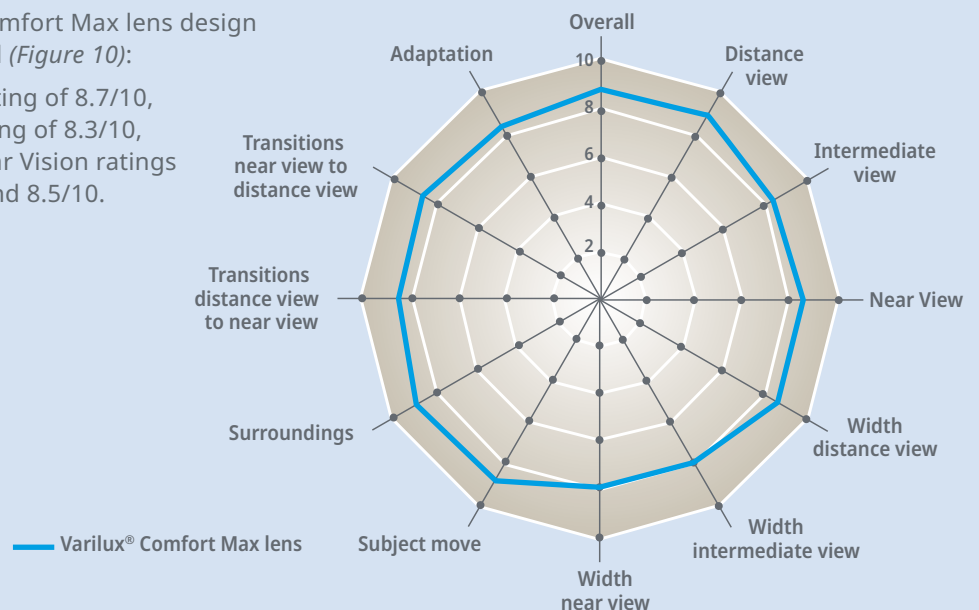


Figure 10: Means of the individuals ratings (N=67 participants)

Varilux® Comfort Max lens among new progressive lenses wearers

In order to assess the benefits of the Varilux® Comfort Max lens for people who had not worn progressive lenses before, a specific study has been conducted with a third independent party²⁴ in France.

53 presbyopes, aged from 38 to 54, were given Varilux® Comfort Max lenses and wore them instead of their normal visual solutions (readers and single vision for near, single vision for far only, 2 pairs of single vision for far and near distance, non-wearers).

The benefits and adaptation for participants were monitored from the delivery and after 2 weeks, in real-life and in key usage situations.

Varilux® Comfort Max lens received very positive feedback from the new progressive lens wearers, with:

- **83%** preferring Varilux® Comfort Max lens to their normal visual solution.
- **9/10** wanting to continue wearing Varilux® Comfort Max lens at the end of the test period.

CONCLUSION

While most wearers adapt to progressive lenses rapidly and effortlessly, some may struggle for a couple of days or weeks before getting fully comfortable.

This adaptation delay may happen especially for new PAL wearers and for those who use a wide diversity of digital displays. Indeed, adaptation to PALs requires motor regulation in terms of eye and head movements, in order to find the right zone of vision according to the distance of the given object.

Essilor® developed Flex Optim™ technology to provide to wearers with wider useful vision zones and greater postural flexibility, enabling them to adopt multiple and variable head postures during prolonged vision tasks.

Essilor® R&D's avatar simulations gave a first assessment of Varilux® Comfort Max lens performances in virtual environments.

Then, wearer tests confirmed that:

- Varilux® Comfort Max lens design obtained high grades for distance, near and intermediate vision, making it a good all-around progressive lens.
- Even people who had not worn a PAL before gave Varilux® Comfort Max lenses a very high rating.

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