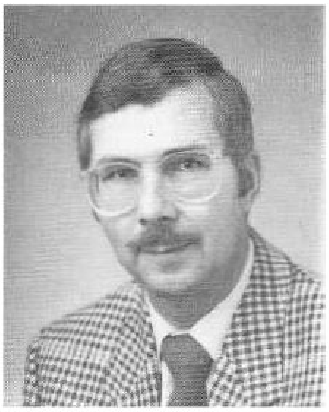

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Varilux Comfort

1. Historical review

The very first patents describing the modern-style progressive lens date back to the year 1953. The inventor, B. Maitenaz, did not just specify the geometric-optical structure of the new type of lens, but also the revolutionary production process. In 1959, with the launch of Varilux, the first progressive lens was born. The breakthrough for progressive lenses took place in 1972 with the Varilux 2. The construction of this 2nd lens generation considered the special requirements for peripheral, dynamic and binocular vision. This was how the „physiological progressive lens" was created which offered spectacle wearers significantly improved visual comfort. In 1988, the Multi-Design concept opened up opportunities to improve optical performance further with the progressive lens. The Varilux MD was the first type of lens characterised by a specific surface design for each individual addition .

The physiological, optical and aesthetic advantages of the progressive lens caused a turbulent development. The number of progressive lenses sold increases by more than 10% each year. In France, penetration in multifocal lenses is approximately 75% (France is the global leader with this rate), 40 % in Europe and around 20% worldwide (market data 1991). Nowadays, this market is divided into approximately 50 different progressive lens products. With each of these versions, the manufacturers generally try to put their concepts into practice and increase the performance, in comparison with previous types. This means that the quality of the top products has now reached a significant level and the margin for further improvement seems to have become slight. This is especially due to the fact that very probably these efforts are restricted by fundamental physicaloptical principles.

2. Development concept for a new lens generation

In depth analysis and research does however show that there is still noticeable potential for developing progresive lenses further. However, the condition is that optimsation of the surfaces is not reduced down to minimising aberrations alone. This can only be one of several aspects if the quality is to be improved further.

The concept for improvement consists of two phases:

- Analysis of how a progressive lens changes the viewing habits of spectacle wearers;
- Concept for a surface which reduces these restrictions and allows a more natural vision.

At first it is surprising to read „analyse how a progressive lens changes the viewing habits of spectacle wearers". Don't we usually say that the spectacle wearer can see with this lens as naturally as before presbyopia when presenting the progressive lens to the customer? The fact that this is not completely realistic becomes immediately apparent if we compare the reading habits of a young emmetrope with those of a spectacle wearer with progressive lenses (figure 1). When the emmetropic person begins to read the top section of a document, the head is inclined by approximately 45°, while the eye is lowered noticeably less, by around 15°. The behaviour of a spectacle wearer with progressive lenses is considerably different. He lowers his eyes to a much stronger level, by around 30°, in order to be able to see well through the

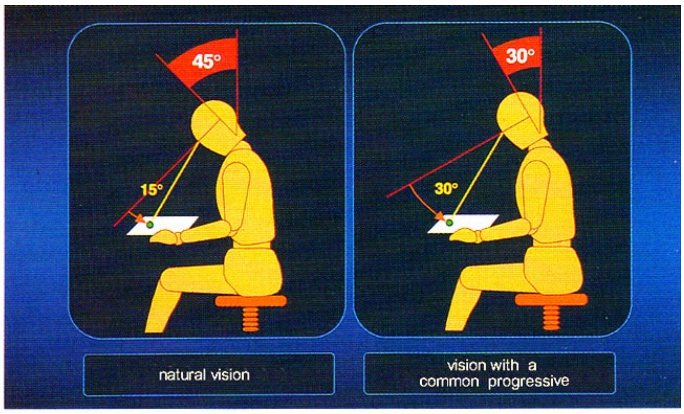

Figure 1 Head position for near vision

low positioned near portion in the progressive surface. In order to be able to read the top section of the document despite the stronger lowering of his eyes, the person is forced to raise his head which means that the progressive lens wearer inclines his head less than with natural vision.

There is also another difference in the viewing behaviour of a presbyope corrected with progressive lenses. When the emmetrope reads a page of A4 paper from top to bottom, the person only lowers the eyes and the head remains in practically the same position (figure 2). He lowers his eyes by approximately 20°. This obviously means that also the wearer of progressive lenses has to incline his eyes by this amount in order to be able to read the full length of the document. But lowering the eyes is a strain from a physiological point of view. Due to the fact that the low near portion of the classic progressive lens already requires an initial inclination of the optical axis by 30°, he is no longer

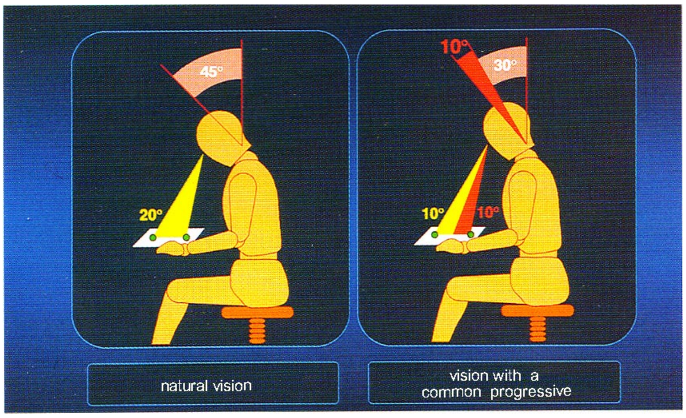

Figure 2 Head and eye movements for near vision

capable of fully applying this additional strain. He therefore lowers the eyes by only approximately 10° and applies the remaining 10° by inclining the head. The spectacle wearer moves his head when reading with progressive lenses. However, progressive lenses do not just influence the viewing behaviour in a vertical direction; horizontal viewing behaviour also changes. If, for example, an object suddenly appears in the person‘s periphereal view, in natural viewing conditions the person only turns his eyes (figure 3). In contrast, a spectacle wearer with progressive lenses cannot follow the object by only

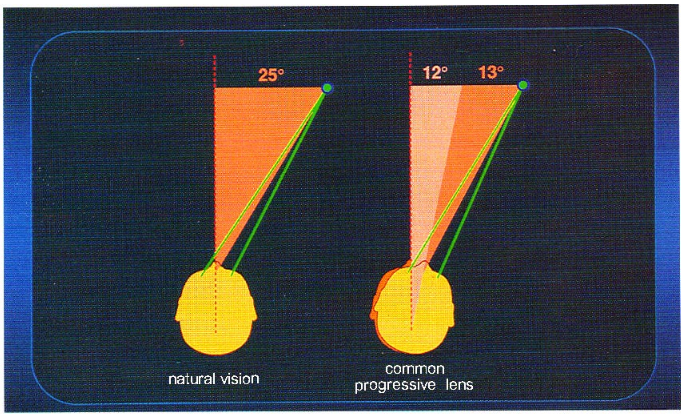

Figure 3 Peripheral vision (intermediate distances: object excentricity 25°)

turning the eyes because of the aberrations in the lens periphery. This means that he compensates the reduced eye rotation by turning his head.

This analysis of the viewing habits of a spectacle wearer allows us to formulate conditions in order to make still today progressive lenses noticeably better. Figure 4 represents very simple specifications with just two requirements for further improvement: Reduced need for lowering the eyes when viewing an object in near and intermediate distances which means a near vision zone positioned high in the lens; this is the first requirement. The second condition is a very soft surface periphery to allow larger lateral eye movements. Although this specification is simply structured, it represents a big challenge to research and development teams. There are two conditions which have to be fulfilled at the same time, which seemed to be incompatible until now.

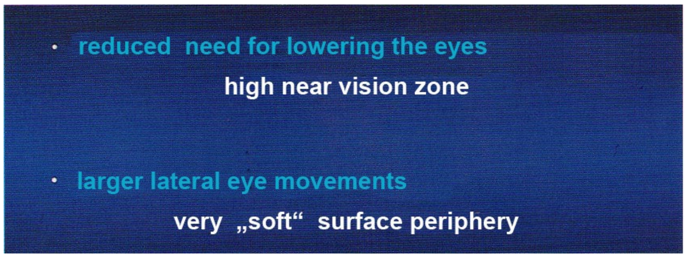

Figure 4 Specifications for „Varilux new“

3. Characteristics of the new surface

In-depth physiological-optical investigations and further development of the already complex computing technology were required in order to initiate the project.

3.1 Near and intermediate zones

Raising the near zone of the progressive lens usually means for surface designers an increase of the aberrations in the periphery, which represents a discrepancy with the second condition. So the top priority was to design a near zone which avoids an extremely short progression and offers visual comfort that comes as close as possible to natural vision. For this purpose, the near visual comfort had to be defined in figures; the measurement layout in figure 5 serves this purpose. LEDs are attached in front of the test person at a constant distance of 40 cm. The different levels of the luminous points define different angles of inclination of the eyes. Lowering the eyes, and

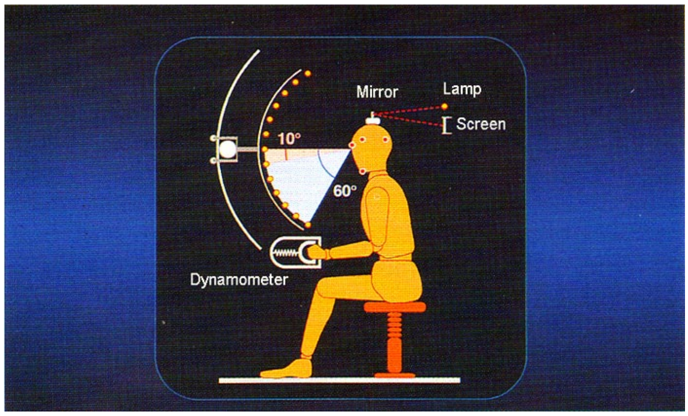

Figure 5 Measurement of ocular strain when lowering the eyes

thereby converging, represents a strain from a physiological point of view. Reading is comfortable when the eyes only have to be lowered slightly but is very tiring if the line of sight has to be inclined heavily. The strain which the test person subjectively senses is shown by a weaker or stronger pull on the spring measurement system. If these results are entered in a graph, we receive curves with constant strain (figure 6). The most favourable conditions prevail when lowering the eyes by around 15°, which precisely corresponds with the situation of natural vision.

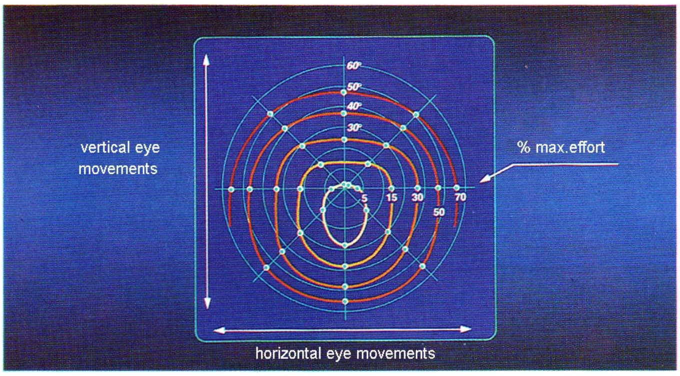

Figure 6 Curves with constant strain

Our aim was now to design the near portion so that it

1. can be used in the upper area with no more than 5% of the maximum possible strain and
2. an A4 sheet of paper can be read by lowering the eyes alone, whereby 15% of the maximum possible strain may not be xceeded.

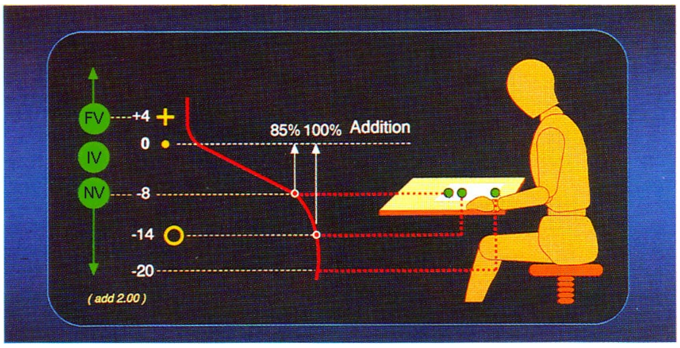

Figure 7 Varilux Comfort: power increase

Figure 7 shows the power profile of the newly developed progressive lens with the brand name Varilux Comfort. The power increase between the distance and near vision zones is very quick at the beginning, and already 12 mm below the centering cross begins the near zone (corresponding with lowering the eyes by 25°). For this height, the power increase reaches 85% of the addition which is sufficient to comfortably read the top section of a piece of A4 paper. The power then increases more slowly which allows the spectacle wearer to read the document from top to bottom, only by lowering the eyes. The near zone of Varilux Comfort begins higher up than for other progressive lenses, as illustrated in the comparison of (figure 8). As a result, 40% of the people taking part in the wearer tests spontaneously established that the position of the head when reading and viewing at near distance is more natural with the new lens (figure 9). Presbyopes do not have to lower their eyes as much as for common progressive lenses, and they therefore take on a more natural, slightly more inclined head position.

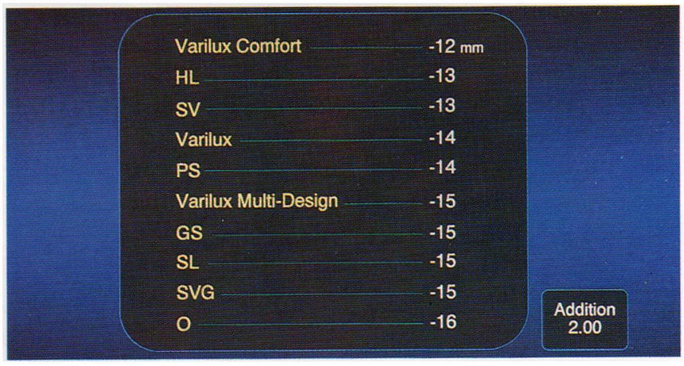

Figure 8 Beginning of the near vision zone (distance between centering cross and point IV with 85% of the addition)

In order to use the near portion of a common lens, the table shows that the spectacle wearers have to lower their eyes by 2 to 3 mm, i.e. by an angle of 4 to 6° more than with the Varilux Comfort. This may seem like a minor difference, but in actual fact a significant additional strain has to be applied.

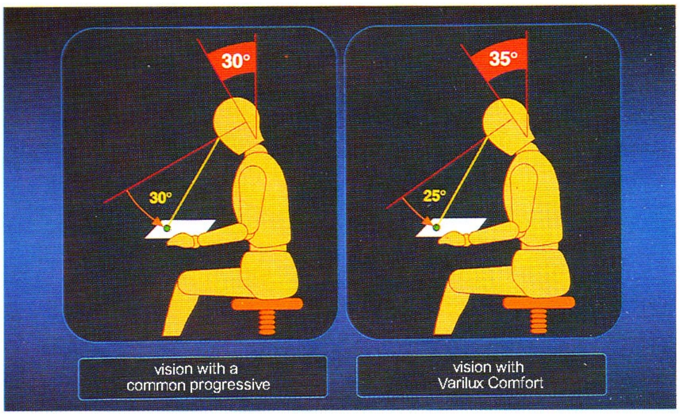

Figure 9 Head position for near vision

The graph in figure 10 shows the measurement results in simplified form representing the strain involved with different levels of downward gaze. The strain that has to be applied increases slowly at first, then rapidly, almost exponential. This means that for the 2 to 3 mm in which

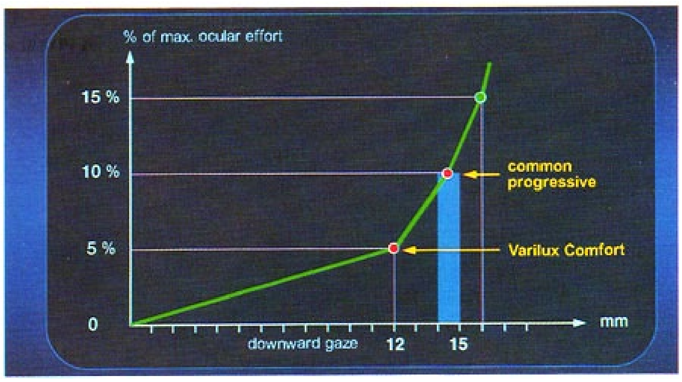

Figure 10 Ocular strain when lowering the eyes

the near zone starts lower with common progressive lenses, double the amount of strain has to be applied to reach the near zone. The result is that the spectacle wearer can lower his eyes easier with Varilux Comfort than with other progressive lenses when reading a text from top to bottom. With the new lens, he almost reads like the young emmetropic person; primarily only using eye movements, and head movements are significantly reduced in comparison to classic progressive lenses (figure 11). The test people commented that when viewing at near and intermediate distances with Varilux Comfort, less head movements and head position corrections were necessary.

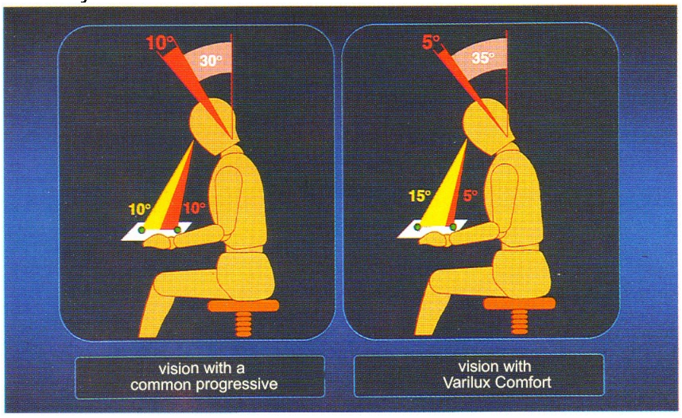

Figure 11 Head and eye movements in near vision

Without a doubt, the higher position of the near portion is a very original solution to the near vision problems of the presbyope which, alongside the comfort of a natural head position, offers another advantage. The maximum width of the near portion of a progressive lens is always several millimetres below the beginning of the near zone due to construction reasons. Due to the fact that the near zone starts higher up with the Varilux Comfort, the portion of maximum width can be achieved more easily and used better, which means that the spectacle wearer has a very wide near section.

3.2 Surface periphery

Which impacts do these improvements for near vision have on the quality of the surface periphery? How can the simultaneous demand for usable lateral zones be turned into reality? For this purpose, our researchers have investigated the factors that are decisive for the quality of peripheral vision. Figure 12 shows the measu-

Figure 12 Measurements of head and eye rotation

ring apparatus which registers a person's reactions to objects appearing in their peripheral view. The measurement graphs in figure 13 confirm that the young emmetrope is practically only moving the eyes and the head practically remains still, whereby with the progressive lens, increased head rotations can be registered.

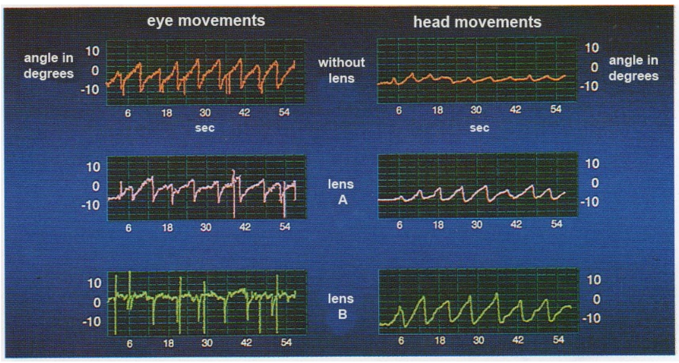

Figure 13 Eye and head movements with/without progressive correction

The reason is that eye movements are restricted by aberrations in the lens periphery. For this reason, with the second lens (B), which is of significantly poorer quality, eye rotations are even more reduced and replaced even more by head movements than with the first tested progressive lens (A). With this method, various surface geometries can be compared with each other. It was thereby proven that two factors are decisive for peripheral vision:

- First of all, the amount of peripheral aberrations, therefore the surface astigmatism, has to remain low and
- Secondly, the optical characteristics may only change slowly from surface point to surface point, which means that the rate of change must be low.

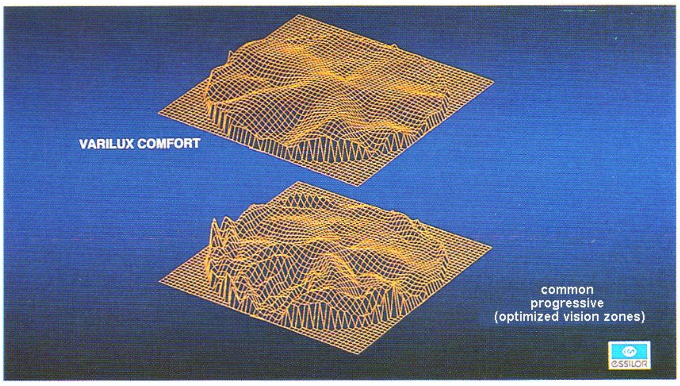

Figure 14 Peripheral visual comfort (rate of power change)

In relation to this, significant improvements can still be made to the performance of progressive surfaces. With the newly developed lens, the optical characteristics of the surface vary very gradually and regularly. It is one of the secrets of the new concept that the surface in each individual element is designed aspherically, whereby aberrations do not exceed certain threshold values in the central lens areas for foveal vision. These threshold values are the result of in-depth physiological-optical investigations. The diagrams in figure 14 compare the rate of change for the optical power for Varilux Comfort with a lens where the various optical zones have been optimised with common means. The improvements achieved are striking.The graphics in figure 15 highlight the exceptional quality of the new development. Compared with the lens with the softest surface design available on the market at present, the Varilux Comfort has a geometry which is even more regular and harmonious. Due to the very good peripheral quality, the spectacle wearer experiences a larger and better lateral field of view. This led to the test people spontaneously noting that less head rotations are required with the Varilux Comfort. Measurements reinforce this state-

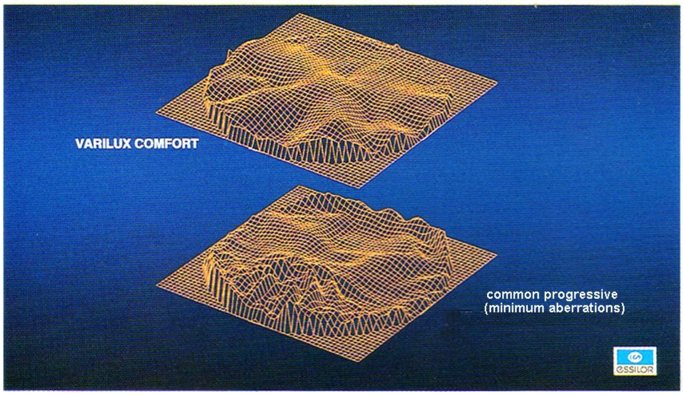

Figure 15 Peripheral visual comfort (rate of power change)

ment: the angle of head rotation for looking to the side is approximately half the angle of a common progressive lens (figure 16).

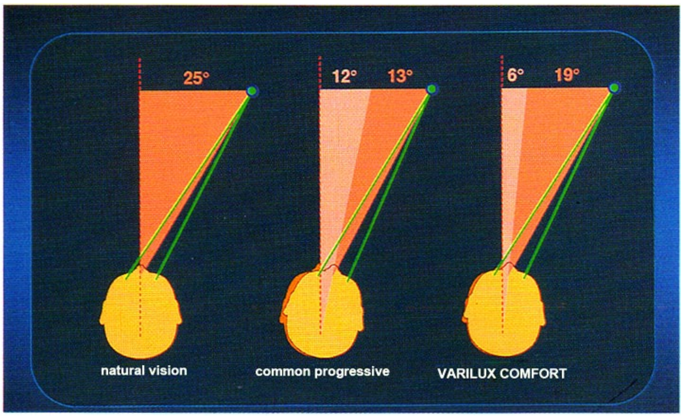

Figure 16 Peripheral vision (intermediate distances: Object excentricity 25°)

3.3 Two essential innovations

Two essentiall observations can be made in an initial summary. With Varilux Comfort, the spectacle wearer has a lens which offers more natural vision, as well for horizontal/vertical eye movements as for the peripheral perception, than other progressive lens types, which means a more natural head posture and less head movements.

This represents a new surface concept: until now, there have only been designs with either a very large near portion, but with reduced peripheral comfort (the so-called "hard" design) or very „soft surfaces" with relatively narrow zones for foveal vision. Varilux Comfort lens combines the advantages of both concepts, which means that it combines a very wide near vision zone with a very soft periphery.

3.4 Other design characteristics

Varilux Comfort has a distinctive asymmetric structure, to ensure the best possible binocular vision. A fundamental parameter for this binocular balance is the vertical prismatic difference between corresponding (homologous) points of the right and left lens. This parameter is plotted in both graphics in figure 17 for the Varilux Comfort as well as for a symmetrical progressive lens. Although the symmetrical lens is optimised for binocular vision, the characteristics are visibly poorer. In figure 18 an asymmetrical lens is selected as a reference which has been specially conceptualised for binocular comfort. The comparison shows that the Varilux Comfort is at least of equivalent value with respect to binocular quality.

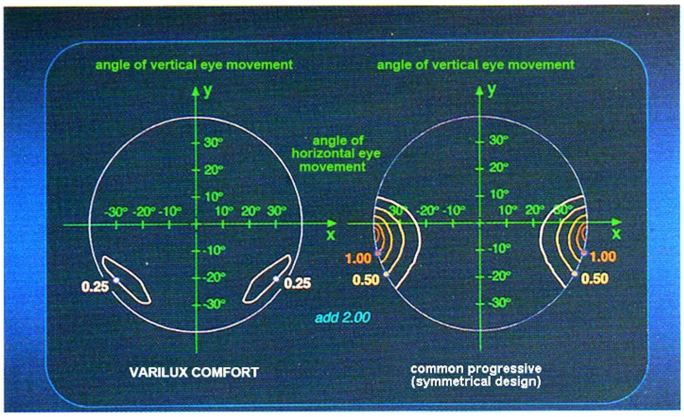

Figure 17 Binocular visual comfort :vertical prismatic difference

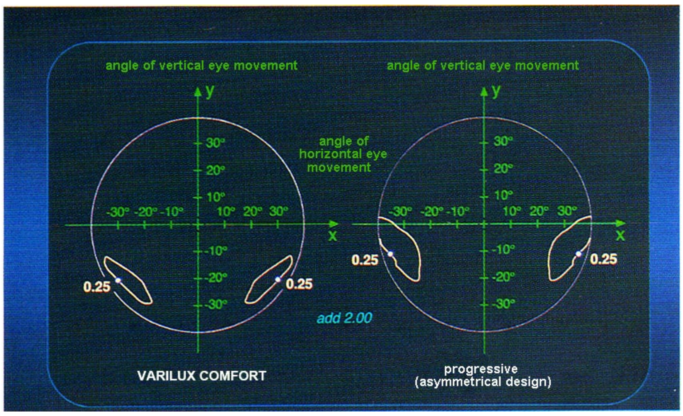

Figure 18 Binocular visual comfort: vertical prismatic difference

Varilux Comfort is constructed according to the Multi-Design concept, which means that, for each addition, the surface design is customised to the special requirements of the respective age level. The correlation between age, addition, reading distance, available accommodation and convergence was investigated. The results showed that the older the presbyope, the closer he brings the reading material towards the eye in order to compensate for the loss of visual acuity with age. With the new design, this circumstance is taken into account by a near portion decentration, which increases with the addition. (figure 19). Furthermore, the geometry of the whole meridian is aligned to the power increase so that a perfect balance of convergence/accommodation exists for all viewing distances.

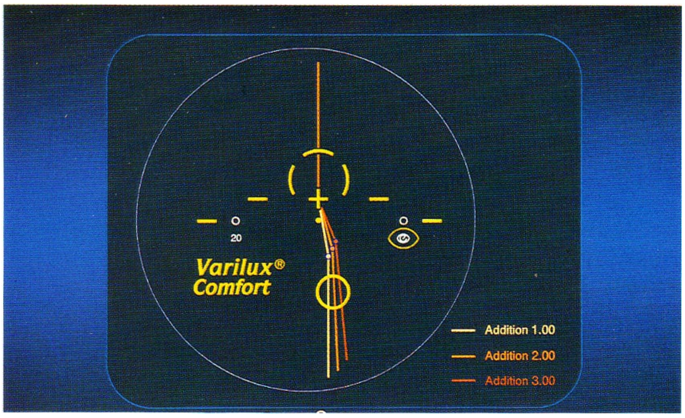

Figure 19 Varilux Comfort: Variable near vision zone decentration

The Multi-Design character of the lens can also be seen in the progression of the power profile (figure 20). For lower additions, the power increase begins lower in the lens in order to offer the young presbyope a clear distance portion and a smooth transition between distance and near. For high additions, the power increase begins slightly higher but the near zone can be reached with less inclination of the eye, which offers a noticeable advantage for the older presbyope. With the Varilux Comfort, the design changes with the addition, in order to guarantee constant visual comfort to the best possible extent: an aim which could be confirmed with wearer tests.

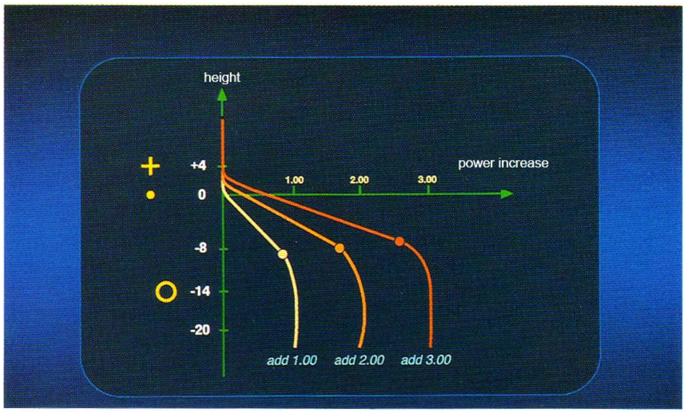

Figure 20 Varilux Comfort: power progression

4. Wearer tests

In order to test the spectacle wearers' reaction to the new concept, wearer tests were carried out. These were organised according to a double-blind testing method, which means that neither the client nor the test organiser know the identity of the submitted lenses throughout the test. Over a period of 8 months, more than 60 persons compared 3 different types of lenses with each other. In order to receive the results, almost 6500 responses had to be analysed. In the test, the Varilux Comfort was compared with two very well-known and frequently prescribed lenses which were marked with the codes A and B. The result: 70 percent of the test people preferred the new lens to the older concepts (figure 21). This is certainly an impressive result if you know that when comparing the quality of good progressive lenses using a wearing test, the preference for one lens or another generally does not exceed significantly 50% .

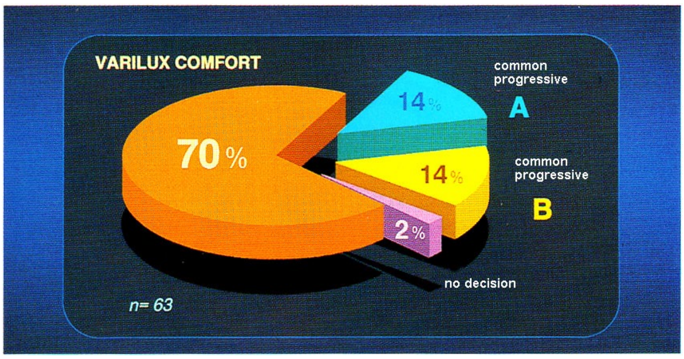

Figure 21 Spectacle wearers' preferences

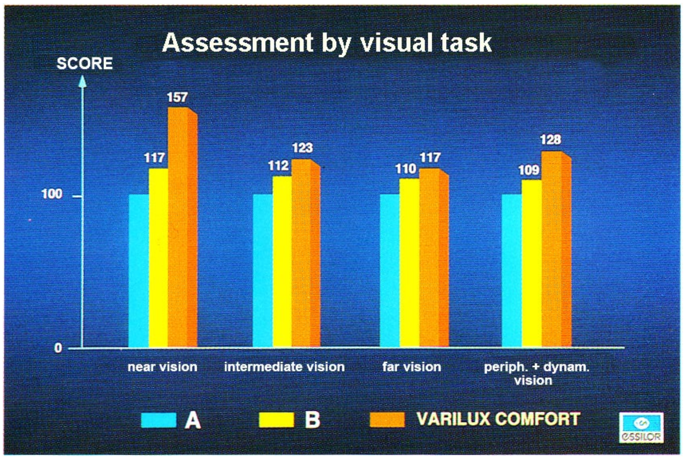

Figure 22 Assessment by visual task

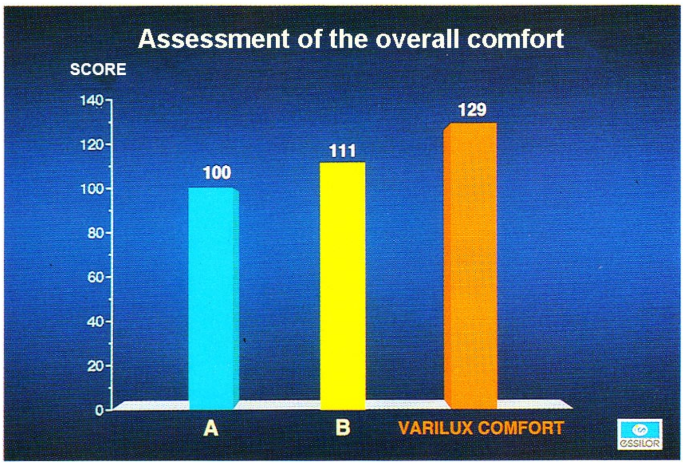

Figure 23 Assessment of overall comfort

Another result of these tests is the assessment of the performance of the different vision zones by the test people (figure 22). Distance, near and intermediate vision as well as the periphery were given separate marks in this test. The Varilux Comfort achieves the best results across the board. The predominance for vision at close range and in the peripheral areas matching the development concept was particularly distinctive. The overall comfort of the new lens is evaluated significantly better than for the older concepts (figure 23).

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