VARILUX® X SERIES™ LENSES

NEAR VISION BEHAVIOR PERSONALIZATION

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Near Vision Behavior (NVB) personalization aims to ensure lenses are designed and tailored as closely as possible to the wearer’s specific posture and behavior during near vision work. The process involves two phases: first, the individual’s postural behavior must be measured and analyzed; second, a personalized design must be computed.

As measurement must be representative of the wearer’s typical NVB, the task that is used to determine it and personalize the lenses constitutes perhaps the most common near vision activity: reading.

KEYWORDS:
- near vision behavior
- NVB measurement
- postural behavior
- eye saccades
- eye-head behavior
- pseudo-reading task
- near vision optimization
- personalized premium progressive lens
- eyecode™
- Visioffice™
- Varilux® X series™
1. THE PHYSIOLOGY OF READING

A significant part of our daily lives is taken up by the activity of reading. In effect, our eyes are constantly looking at letters and words whether they be in books, magazines, advertisements or on screens found on laptops, smartphones and tablets. Nevertheless, it remains a recent activity when considered on the scale of human evolution (Dehaene, 2009).

In terms of vision, it is highly defined and requires specific movements. For example, an English text must be read from left to right to be understood, but such an absolute direction is simply not found in nature. Moreover, it requires the reader to make use of their fovea, the part of the retina that affords accurate vision. To be able to read words, the reader must move their eyes so as to sequentially place the words on the fovea. They do so in small rapid jerky movements from one fixation to another. Those saccades entail the eye changing direction repeatedly to fixate on different parts of the text to gather visual information.

For Western languages, most saccades are from left to right and top to bottom. However, about 10 to 15% of them run in the other directions, allowing the reader to reprocess elements of the text: those are known as regressive saccades (Rayner, 1998).

Despite the obvious centrality of the eyes for reading, people very often also make use of their heads. In effect, the head supports eye movements, allowing the individual to train their eyes effectively on different targets (Kowler et al., 1992; Lee, 1999; Proudflock, Shekhar & Gottlob, 2003).

Whether it is books, magazines or tablets, individuals often use their hands for reading, modulating both the distance between the text and the eyes, and the relative angles between the head and the words. The interaction between eye movements, the posture of the head and the overall position of the body is expressed by the reading distance, the downward gaze and also the lateral offset.

While the base pattern for reading is the same among different individuals, there are differences in postural behavior. But, as Proudflock and Gottlob (2007) explain, though humans show a remarkable degree of flexibility in eye-head coordination strategies, individuals will often demonstrate stereotypical patterns of eye-head behavior for a given visual task.

Despite this, there are differences in terms of reading distance, downward eye direction and dynamic aspects (Paililé, Perrin & Debieuvre, 2015; Bababekova et al. 2011; Wu, 2011; Hartwig et al. 2011).

2. THE USE OF PSEUDO-TEXTS

Knowing the postural behavior of a reader is unquestionably valuable when selecting progressive lenses. The goal is to determine the individual’s natural posture, i.e. the posture they would adopt if no optical correction were necessary. It follows, then, that measuring it can be problematic for the simple reason that to read most wearers need to use their optical correction. This gives rise to two problems: the correction may no longer be accurate, and the individual might be modifying their posture (Han et al., 2003).

To resolve this, Essilor has developed a method based on a task which can be carried out without corrected vision (it can be performed with myopia up to -10 diopters and hypermetropia up to +1.5 diopters) or which can be done with corrected vision in the case of contact lens wearers. It entails a blue dot displayed on a tablet computer against a white background. As it moves around the screen, the subject must follow it with his gaze. This is referred to as pseudo-reading.

The duration and position of a followed visual stimulus affects both head and eye coordination (Oommen, Smith & Stahl, 2004).

The shifting pattern of the dot is similar to an average reading pattern. Mean fixation durations and saccades were defined based on data obtained and compiled by Rayner (1998). In Essilor’s model the mean fixation of an adult reader is 233 ms and the mean saccade size is 6.3 characters long.

The duration of the pseudo-reading is set to 17 or 18 seconds, depending on how long the fixations last. Moreover, its pattern is not the exact reproduction of the pattern of a reading eye in so far as it does not contain backward saccades. This is to make the task as predictable as possible.

The successive positions of the dot are always reproduced on the screen by a pattern of gray dots to guide the subject in their eye fixations and make the next target highly predictable (FIGURE 1). This enables voluntary saccades just like in real reading (Walker, Walker, Husain & Kennard, 2000), influencing head movements. A key advantage of the method is it can be easily adapted to languages other than English.

3. THE NVB MEASUREMENT METHOD

The NVB measurement aims to determine the parameters of the habitual near vision postural behavior of the reader. It does so by recording their eyes and head movements while performing the pseudo-reading task.

The NVB measurement records the way a wearer holds the tablet during the task, with the NVB posture component calculated as the mean posture throughout the pseudo-reading task.

More specifically, four distinct parameters are measured. Three are related to the wearer posture (MEASURED):

- **The Downward Gaze Angle**
- **Lateral Offset**
- **Reading Distance**

The downward gaze angle is the downward direction of gaze throughout the pseudo-reading task. It is measured relative to the horizontal plane.

The lateral offset is the horizontal distance of the gaze from the center of the screen.

The reading distance is the distance between the table and the eyes. It is measured relative to the distance at which the subject reads in a typical situation.

The NVB method has been shown to be effective in determining the posture of the reader during near vision tasks. It is a valuable tool for lens manufacturers to select the type of corrective lenses that best suit the individual’s posture.
The fourth parameter is related to wearer behavior:

**NVB RATIO**

This represents how the wearer uses their gaze during the pseudo-reading task. The NVB ratio is close to 0 for a wearer with a large tendency to move their eyes, in particular lowering their gaze after each line return. It is close to 1 when a wearer has a vertical static gaze throughout the entire pseudo-reading task (Figure 3).

A tablet with an 8 to 10 inch screen is used to display the pseudo-text and a frontal camera to record the head position. The camera records the wearer's head movements, enabling it to evaluate the directions of the individual's gaze during the pseudo-reading task (Figure 4).

**FAR VISION REFERENTIAL**

Gaze directions are expressed in the far vision referential (Figure 5) in order to apply ray-tracing optimization when the lens is calculated. The far vision referential is defined by the following:

- **ORIGIN O**: The cyclops Eye Rotation Center (ERC) position (ERC right and left barycenter)
- **AXIS OX**: The axis from Cyclops ERC to right ERC
- **AXIS OZ**: The axis from Cyclops ERC, normal to the Ox axis in a horizontal plane and oriented backward
- **AXIS OY**: The axis from Cyclops ERC, vectorial product of OZ and Ox, oriented upward

Expressing data in a unique head referential allows ray tracing optimization to be carried out.

**4. THE MEASUREMENT PROCEDURE**

The first step in the measurement process is to obtain the wearer’s far vision reference position to compute the downward gaze direction, allowing the 0° position to be defined. All angle values are then calculated from this.

For the full version, the reference posture is obtained using the traditional Visioffice™ column procedure, with both front and three-quarter pictures. Following the Visioffice™ column measurement, the wearer is asked to sit on a chair (it is recommended they keep the frame and clip on). In the connected version, ERC right and left are used for the reference posture.

With respect to the standalone version, the eye care professional (ECP) attaches the clip to the frame. They then use the tablet to take two photos with the camera, both front and three-quarter views. We obtained in that configuration the cyclops Eye Rotation Center (ERC) position without knowing ERC right and left but by using statistical values. Ideally, measurement should be performed in a room with a normal ceiling light and not a spotlight, for example, which could blind the camera.

NVB measurement is not recommended for myopia greater than -10 diopters or hyperopia plus addition of more than +7.50 diopters (except if the individual wears contact lenses).

A demonstration should be performed to allow the wearer to familiarize themselves with the task. The speed can be adjusted to the individual’s liking.

**5. VALIDATION**

We set up an experiment (Poulain, Pérrin & Escalier, 2016) where the downward gaze angles and reading distances of 28 ametropes and presbyopes were obtained and compared for two conditions: pseudo-reading with no correction and normal reading with contact lenses. The order of the conditions was counterbalanced and each measurement was repeated three times (Figure 8).
NVB is a technology which enables the ECP to tailor the near vision position of the progressive lens design to the wearer's behavior during a near vision task and optimize the shape of the near vision zone. NVB output is an alphanumeric code which combines two aspects:

- **THE NVB POINT**, representing the barycenter measurement results of near vision stimuli in the ERC referential
- **THE NVB RATIO**, which denotes the measurement dispersion around the NVB point of the wearer's response to the stimuli

The first step of the calculation is to decode the NVB output. As a result, the NVB point and the NVB ratio are obtained as input parameters for optimization.

NVB design optimization initially consists of making use of the physiological characteristics of the wearer (e.g. the interpupillary distance, the ERC and the prescription), the characteristics of the frame (e.g. the shape, size and position) and the characteristics of the future lens (e.g. the front surface, geometry and index). The data decoded from the NVB measurement in the visual space is also taken into account.

The next step is to optimize the near vision zone of the lens by using real ray tracing with the postural component of NVB. The idea is to achieve the best compromise from the available data: the frame, the fitting parameters, NVB measurement, the prescription and the lens characteristics. This step includes specific treatment linked to ametropia and the prismatic deviations of the lens.

As binocular optimization, it will determine the final near vision position of the lenses.

The third step is the progression profile optimization with respect to the NVB ratio. The goal is to adjust the available vertical area in near vision and design the shape of the near vision zone. This can provide the wearer with dynamic eye movement in a larger zone.

**FIGURE 5** shows the effects of the second and third steps on an acuity map.

The position of the near vision is a direct result of the optimization. It is possible to measure the near vision point on the final lens and provide a progression length value and inset value. Compared to current personalization of progressive addition lenses, these values result from the NVB optimization and are not an input parameter as it is for a fit option.

While NVB in itself is a major breakthrough, if the near vision zone of the lenses is not well placed in the frame, its benefits will be cancelled out. This is why securing the near vision zone within the frame is an essential part of Essilor’s NVB personalization option.

If the fitting height, frame size B and pupillary distance are used, the NVB calculation ensures 100% of the lens with near vision is secured in the frame based on available data from the order (on condition the fitting height and frame size are compatible with the minimum progression length available with the Varilux® X series™ lenses).
ECPs need to be reassured by measurement reproducibility, especially when it comes to behavior and postural measurement. Moreover, as the output data are encoded, the measurement reproducibility must be illustrated.

Essilor developed a new graph (Figure 10) to illustrate postural data, behavior data and the optical design impact. On the X axis, the postural data represent the downward gaze direction and on the Y axis the behavior data constitute the NVB ratio. The optical design impact is represented by a color. The difference between two measurements is therefore illustrated by the difference in two colors.

The color mapping was calculated to have no impact on the optical design if the difference of color for the two measurements cannot be perceived. On the other hand, if it can be perceived clearly, it has an impact on the optical design.

For a repeatable measurement, the points are close together. The lens parameters will be identical and no difference will be visible for a wearer. For example, the wearer represented by Figure 11 below has three measurements with different NVB output, but the position of the points and the color are identical, which means the optical designs are the same.

The position of each point will be distinct for non-repeatable measurements. The lens parameters are different and are visible to the wearer. The wearer represented by Figure 12 has three measurements, with one apart. The color differences are visible, signaling a difference in optical design.

NVB measurement is dependent on a far vision referential. In the standalone case, the application has to create its own far vision referential, while the ECP takes the wearer’s far vision referential by measuring the fitting height.

An inconsistency between the two measurements can occur. To ensure a consistent referential, the ECP can take the far vision referential in the same posture as for the fitting height measurement. To do so, fitting height data and frame height (B size) must be indicated.

Guidelines will appear during the far vision measurement process on the tablet to help the ECP set the wearer posture in the same posture as for the fitting height measurement (Figure 13).
Essilor carried out an international multicenter study looking at the overall performance and key benefits of the Varilux® X series™ lenses with NVB personalization. As can be seen from Figure 15, an overwhelming percentage of wearers enjoyed high-quality vision, whether distance, intermediate or near vision. For overall and dynamic vision, wearers gave a rating on a 10-point scale from ‘not clear at all’ to ‘very clear’. With respect to distance, intermediate and near vision, wearers gave a rating using the same scale, plus a 10-point scale ranging from ‘very narrow’ to ‘very wide’; for each distance, the average of the ratings from both scales was calculated to obtain a global visual quality criterion. In both cases, 7 to 10 on the scales represented good visual quality.

The study also looked at the key benefits, comparing the personalized Varilux® X series™ NVB lens to the non-personalized lens. For adaptation easiness, wearers gave a rating on a 10-point scale from ‘very difficult’ to ‘very easy’. ‘Easy adaptation’ is from 7 to 10, ‘very easy’ from 8 to 10. A full 90% of wearers experienced an easy adaptation.

Using the same scale, wearers gave a rating for their ease of transition between zones (Figure 16). ‘Easy transition’ is from 7 to 10, ‘very easy’ from 8 to 10. 94% of wearers experienced easy transition from distance to near.

For quickness of adaptation (Figure 17), wearers chose from “immediately”, “minutes only”, “hours only”, “days or weeks” and “I am still not used to them”. 82% of wearers found that they adapted quickly, in less than a day.
NVB technology is the perfect complementary feature to the Varilux® X series™ lenses (please refer to White Paper “Varilux® X series™ Lenses, Extended Ranges of Vision” published at www.pointsdevue.com), providing the ultimate personalization tailored to the wearer’s needs.

It is based on a completely new and user-friendly measurement procedure, which the ECP can carry out on site. NVB technology optimizes design calculation to ensure the highest level of satisfaction for the wearer when using their progressive lenses.

When NVB technology is combined with measurement of the eyecode® and Visioffice® columns, both the ECP and the wearer will become active participants in the most comprehensive design protocol available for progressive addition lenses.