TESTING THE VISUAL FIELD

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INTRODUCTION

This chapter includes a review of:

- Testing the visual fields
    - Purpose/indications
    - General terminology
- Theory of visual field testing
    - Units of measure
    - Threshold
    - Kinetic vs. Static
    - Screening vs. Threshold
    - Variables in VF testing
    - Stimulus factors
    - Response factors
    - Clinical variable

TESTING THE VISUAL FIELDS

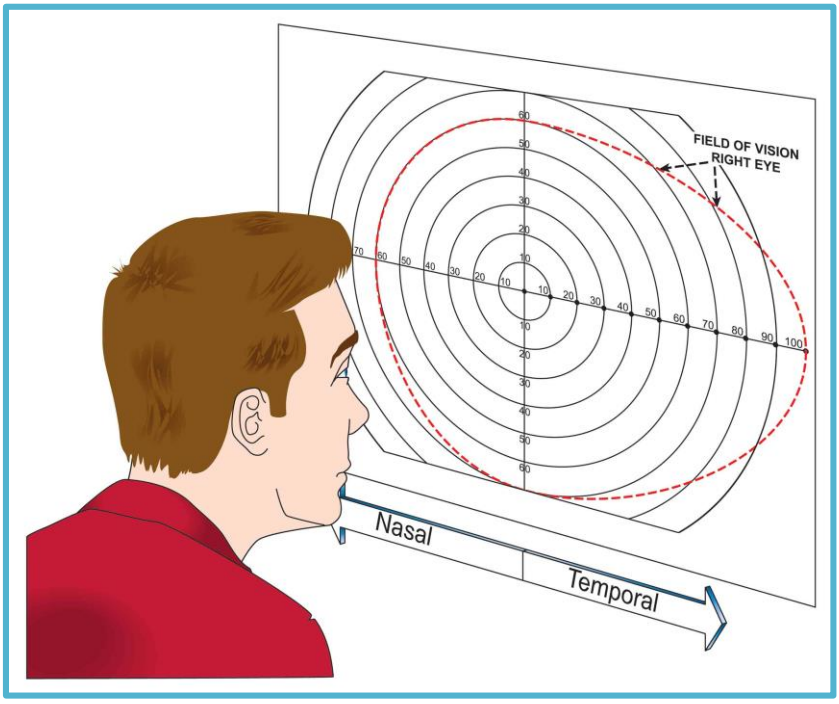

Figure 5.8: *Testing the visual field*

Inspired by Anderson, D., Testing The Field of Vision, The C.V. Mosby Company, St-Louis, Mi, 1982.

PURPOSE/INDICATIONS

Certain characteristic VF variations, termed **VF defects or VF losses,** can occur as a result of abnormalities or diseases affecting the visual pathway. Interpretation of these variations will allow the optometrist to **detect, localize, diagnose, and manage** various conditions. The numerous conditions that may indicate the need for visual field testing in an optometric setting are outlined in table 5.2.

VF testing is an integral part to the assessment of the visual, ocular and physical health of patients. A form of VF screening test should be performed on every patient presenting for an eye examination. With any of the signs & symptoms presented below, more elaborate VF testing procedures are needed. VF assessment is an absolutely indispensable requirement to the practice of primary care optometry.

General medical problems

- Vascular diseases (e.g. diabetes)
- Demyelinating diseases (e.g. multiple sclerosis)
- Infectious diseases (e.g. syphilis, TB, etc.)

Neurological problems

- Unexplained headache
- Unexplained orbital pain
- Paresthesias, numbness
- Transient weakness of limbs
- Head injury

Ophthalmic problems

- Diplopia
- Poor vision on one side of the body
- Bumping into objects on one side
- Difficulty reading (inability to find or keep on line)
- Visual hallucinations
- Potentially toxic medications (e.g. chloroquine, ethambutol)

Ocular findings

- Unexplained loss of vision
- Proptosis
- Abnormal confrontation fields
- Pupil abnormalities
- Motility abnormalities
- Pigment dispersion syndrome
- Exfoliation syndrome
- Ocular hypertension (OHT)
- Anomalous discs (FLD)
- C/D asymmetry (OD vs. OS)
- C/D asymmetry (vertical vs. horizontal)
- Notching
- Disc hemorrhage
- Baring of the circumlinear vessel
- NFL defects
- Swollen ONH
- Disc pallor
- Retinal/choroidal disease

Screening / Baseline information

Table 5.2: *Indications for visual field testing*

GENERAL TERMINOLOGY

A **scotoma** is an area of blindness (relative or absolute) surrounded by normal VF. An **absolute scotoma** is a scotoma in which vision is entirely absent in the affected area; a **relative scotoma** is a VF loss in which the vision is partially reduced or depressed with respect to the surrounding vision (Fig. 5.9). There is blindness to some stimuli but not to others.

The term **depth** is used to refer to the severity of a relative scotoma. A **deep scotoma** indicates that the sensitivity within it is low and that only stronger stimuli can be seen ; a **shallow scotoma** indicates that the sensitivity within the scotoma is slightly reduced.

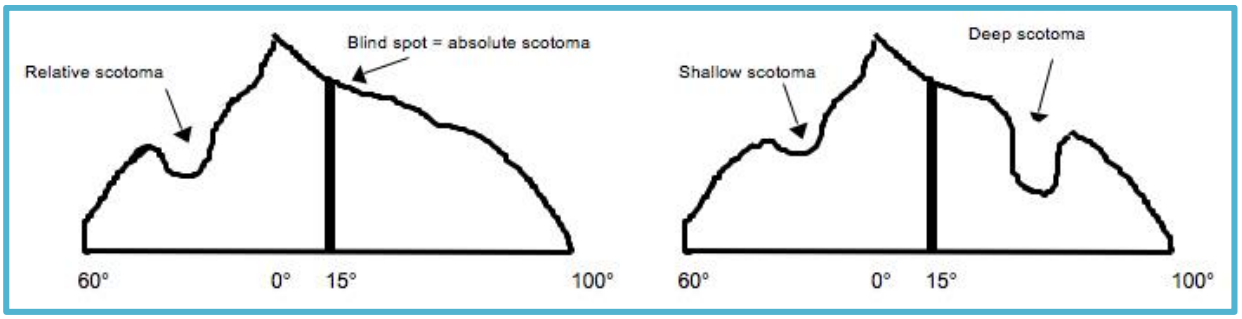

Figure 5.9: *Relative scotomas and depth of relative scotomas*

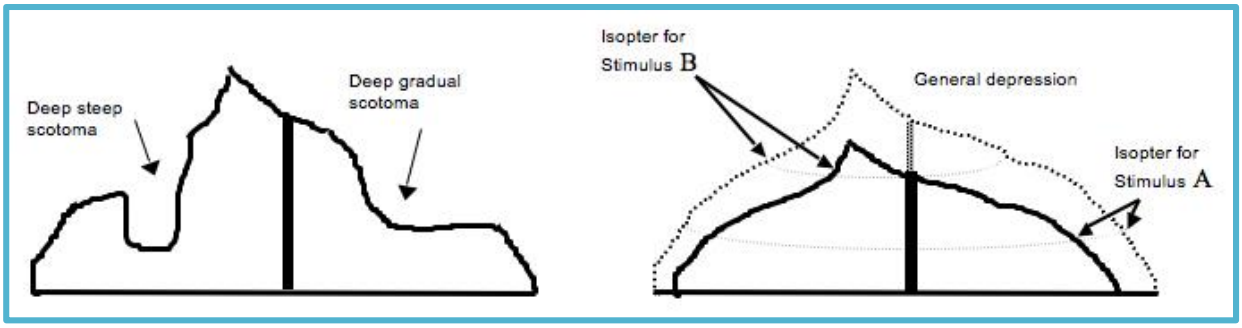

Figure 5.10: *Characterizing scotomas*

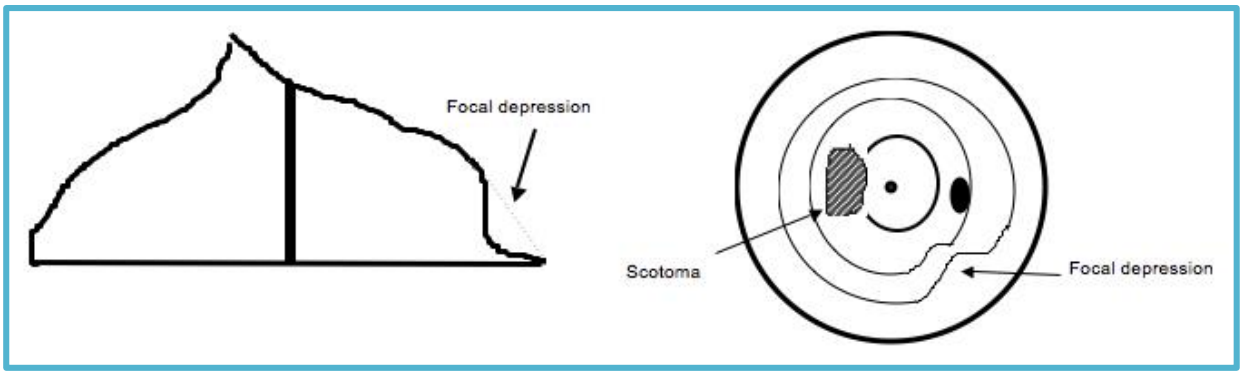

Figure 5.11: *Characterizing scotomas*

A **negative scotoma** is a VF loss of which the person is unaware (e.g. the physiological blind spot); **a positive scotoma** is one where the patient is aware of the visual loss.

Central VF refers to the central 30° visual area; **Peripheral VF** usually refers to eccentricities of greater than 30°.

A **central scotoma** involves the fixation area (fovea) (Fig. 5.12a). A **cecocentral** scotoma is a VF defect that extends from the blind spot (cecum) to the central area (fixation) (Fig. 5.12b). A **paracentral scotoma** involves the area within 10° of fixation but does not include fixation (Fig. 5.12c). A **pericentral scotoma** surrounds fixation without involving it (Fig. 5.12d).

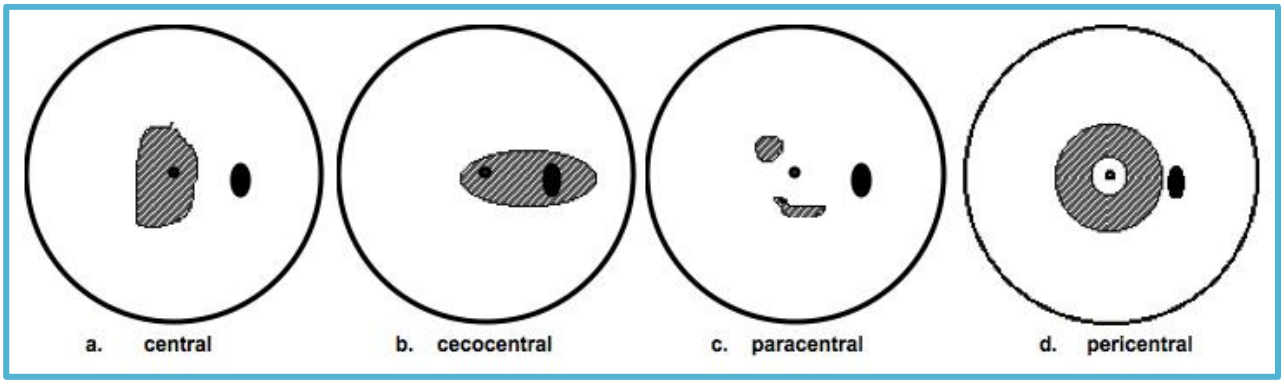

Figure 5.12: *Various types of scotomas*

An **arcuate scotoma** is an arc-shaped defect that arches into the nasal field and follows the course of the **retinal nerve fiber bundles** (Fig. 5.13a). Also known as **Bjerrum's, Seidel's, "scimitar" or comet scotoma**, the nerve fiber bundle scotoma leaves the blind spot as a thin relative VF loss and becomes wider and deeper as it arches around the fixation point usually between 10°-20° and heads towards the nasal horizontal raphe. Arcuate scotomas most often occur in glaucoma.

A nasal step is a step-like defect in the nasal field (typically associated to glaucoma), caused by asymmetrical involvement of the retinal nerve fibers on either side of the horizontal raphe (Fig. 5.13b)**.**

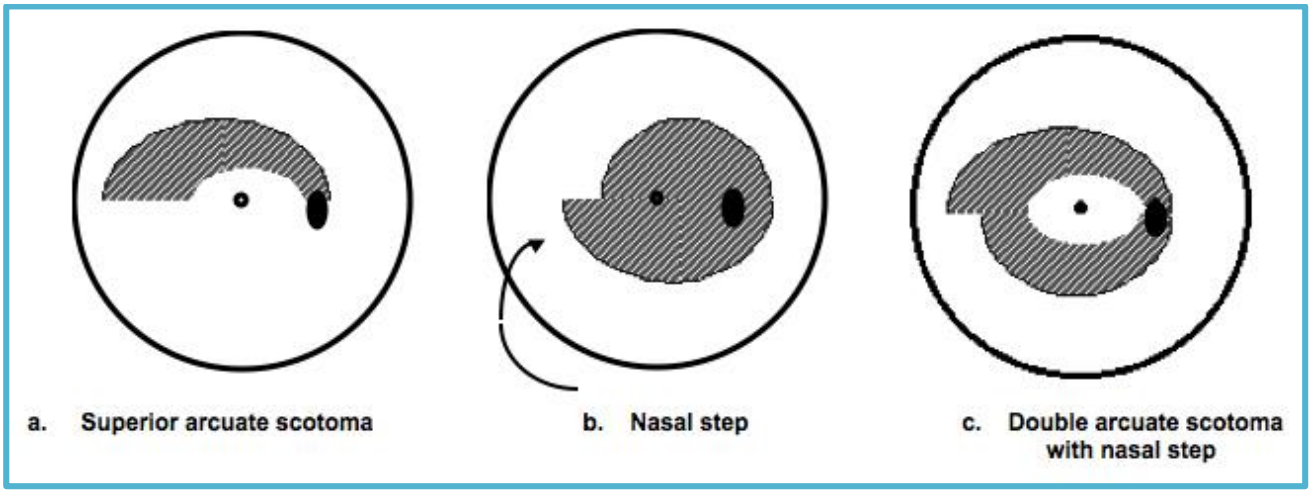

Figure 5.13: *Various types of scotomas*

An **enlarged blind spot** as the name suggests indicates an apparently larger blindspot (Fig. 5.14a).

An **altitudinal defect** involve the 2 quadrants of the upper or lower halves of the VF (Fig. 5.14b). The defect can be complete or incomplete (Fig. 5.14c).

Split fixation indicate a VF loss of either the upper or lower half of the VF across the horizontal through fixation.

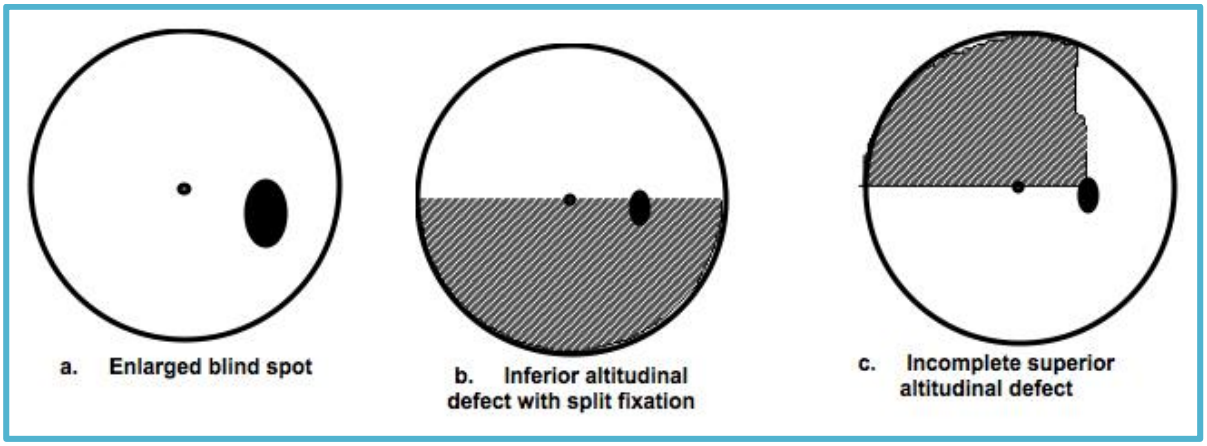

Figure 5.14: *Various types of scotomas*

Hemianopsia (or hemianopia) is a loss of vision in 1/2 of the VF of one eye (unilateral hemianopsia) or of both eyes (bilateral hemianopsia) with respect of the **vertical midline**.

Quadrantanopsia (or quadranopia) is a loss of vision in 1/4 of the VF of one eye (unilateral quadranopia) or of both eyes (bilateral quadranopia) with respect of the vert. & horiz. **Midlines** (Fig. 5.15a).

Heteronymous refers to a **hemianopic or quadrantanopic** defect that occurs in opposite side of the VF. Hence a heteronymous hemianopsia involves either both nasal (**binasal hemianopsia**) (Fig. 5.15e)or both temporal halves (**bitemporal hemianopsia**) of the VF of the 2 eyes.

Homonymous refers to a **hemianopic or quadrantanopic** defect that occurs in the same side of the VF. Hence a homonymous quadranopia involves the nasal side of the VF of one eye and the temporal side of the VF of the other eye.

Complete and incomplete terms are used to define the extent of the hemianopic or quadranopic defect. Hence a complete hemianopia implies a defect of the entire right or left hemifield; an incomplete hemianopia implies that a portion of the right or left hemifield is affected.

Congruous and incongruous are terms used to denote the similarity of the defects in both eyes. A congruous hemianopia or quadranopia is identical in size, shape and position in both eyes (Fig. 5.15c); it follows that incongruous hemianopia or quadranopia are defects that are different in the 2 eyes (Fig. 5.15b).

A **crossed** defect refers particularly to a quadranopia that involves the upper field in one eye and the lower in the other.

Macular sparing indicates that the central 5° to 15° is spared in both eyes in the presence of a homonymous hemianopia (Fig. 5.15d).

A **junctional scotoma** indicates the loss of VA or VF in one eye with a superior temporal defect in the opposite eye (Fig. 5.15e).

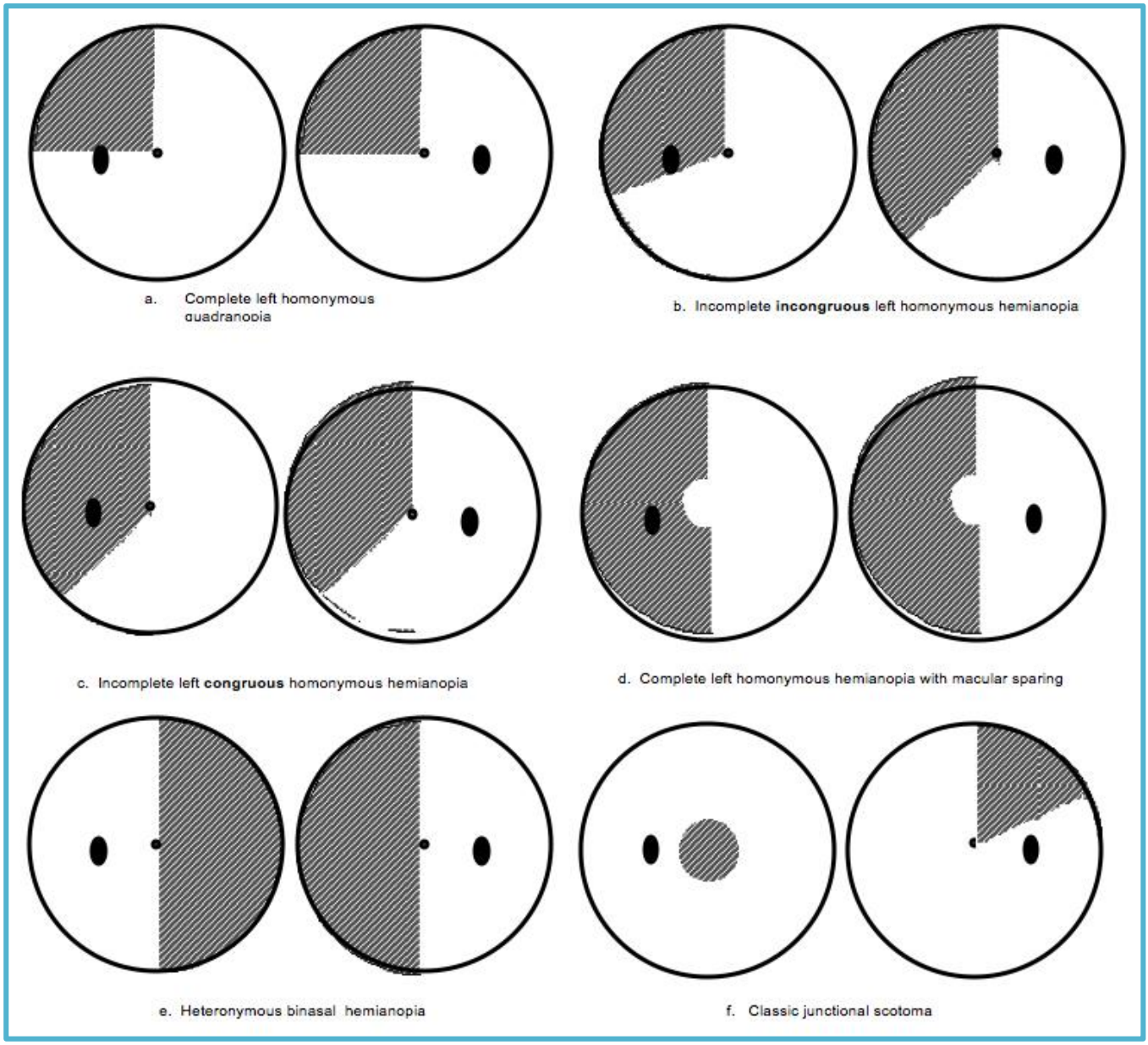

Figure 5.15: *Various types of scotomas*

THEORY OF VISUAL FIELD TESTING

UNITS OF MEASURE

VF testing is a measure the ability of the visual system to detect a difference in contrast between the background and the target luminance. It is a measurement of the sensitivity of the visual system to brightness differences. VF are therefore described in units of light brightness.

The **Apostilb (asb)** is the unit of luminance used to denote the amount of light reflected from a surface (1 asb = 1lumen/m^2). The brightness of the target and background are measured in apostilbs. The higher the value, the brighter the surface. To give an idea, a healthy human can under optimal conditions perceive a 1asb stimulus at the macula.

The **Log units** (LU) is often used to denote the apostilb brightness of stimuli to reduce the large range of luminance of testing instruments and the sensitivity of the visual system to a more usable form. For example, the range of the Humphrey VF has a 10 000 - 0.08 asb. This simply reduces to a range of 5.1 LU (log 10000 - log 0.8 = 5.1).

The **Decibels (dB)** is used to denote sensitivity. The decibel scale is a logarithmic scale that is reciprocally related to brightness. A 10 dB increase (1LU) indicates that the stimulus is 10X dimmer **(10 dB = 1 LU → 10 X). Thus the higher the dB numeric value, the dimmer the target, the higher the sensitivity**.

The dB scale is a relative scale and the dB numbers on different VF instruments do not have comparable brightness values (table. 5.3). On a given instrument, the maximal brightness of the target is assigned a value of 0 dB. With each LU decrease in illumination from the brightest value, an increasingly higher decibel number is obtained. Hence the decibel scale value will represent a different apostilb value on the two different testing units if the maximal brightness is different. For example, the Humphrey VF has a maximum target brightness of 10,000 asb, while the Goldmann VF has a maximum of only 1,000 asb. Hence 20 dB on the Humphrey unit is equal in brightness to 10 dB on the Goldmann unit.

E.g.	Humphrey	VF	Goldmann	VF
Brightest target	10,000 asb =	0 dB	1000 asb =	0 dB
10X (1 UL) reduced	1000 asb =	10 dB	100 asb =	10 dB
100X (1 UL) reduced	100 asb =	20 dB	10 asb =	20 dB
1000X (1 UL) reduced	10 asb =	30 dB	1 asb =	30 dB
10000X (1 UL) reduced	1 asb =	40 dB	0.1 asb =	40 dB
100000X (1 UL) reduced	0.1 asb =	50 dB		
…				

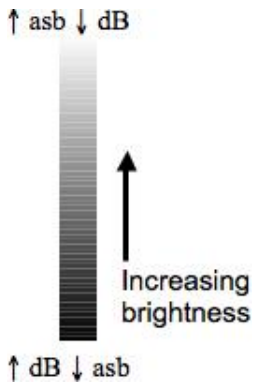

Table 5.3: *Relationship between dB scale and asb on different instruments of visual field testing*

Note that a sensitivity of 0 dB indicates that the maximal stimulus for a given instrument is not perceived. The sensitivity is very low, but it is not necessarily an absolute zero sensitivity (i.e. blind area). A stronger stimulus than what the instrument can maximally produce may be perceptible at the given tested area.

THRESHOLD

VF testing is a measure of the ability of the visual system to perceive targets against their background. The visibility of a stimulus at a given location in the VF depends on a number of factors such as stimulus intensity, size, colour, duration, etc. If a given stimulus is not visible, one of the factors (usually size or intensity) can be adjusted until it becomes visible.

At the borderline between visibility and invisibility, the patient's response will be uncertain or inconsistent, so a borderline stimulus is sometimes seen and sometimes not. This borderline stimulus can be adjusted to change the percentage of time that it is seen by the patient.

The **frequency-of-seeing-curve** (Fig. 5.16) is a plot of the stimulus visibility versus the percentage of times that it is seen. The **threshold** is defined as the target that is perceived 50% of the times that it is presented at a given discrete point.

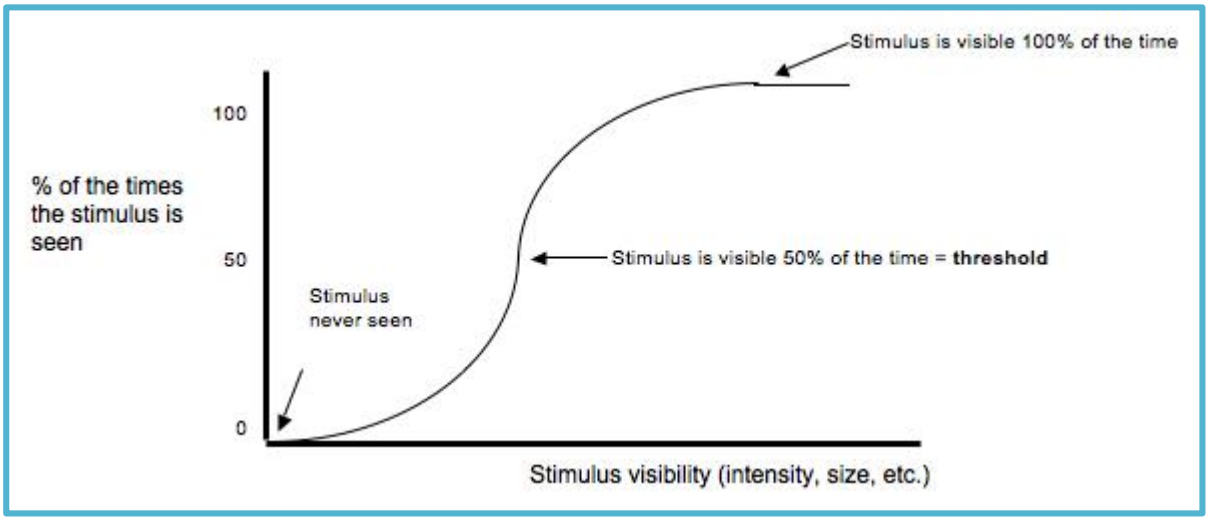

Figure 5.16: *Frequency-of-seeing curve*

Hence the threshold is defined as the dimmest or smallest stimulus that a person can perceive 50 % of the times that it is presented. **Threshold is therefore inversely related to sensitivity: the lower the threshold, the higher the sensitivity.** The fovea at the top of the hill of vision would have the lowest threshold (highest sensitivity) and see the dimmest & smallest stimuli.

KINETIC VS. STATIC

In a clinical setting, it is impractical (impossible!) to establish a frequency of seeing curve for each stimulus at every point in space. Instead, one can reasonably approximate the threshold by using a static or a kinetic approach.

The **static** (not moving!) approach uses a "bracketing" strategy to determine the threshold of a **fixed point**. The intensity or size of the stimulus is decreased or increased in a step-wise staircase fashion until it reaches a point adequately close to threshold. Most commonly, a 4-2 dB algorithm is used. Suprathreshold stimuli are decreased in 4dB steps until they are no longer seen. The stimulus intensity is then increased in 2 dB steps until the stimulus is seen again. The threshold estimate is recorded as the weakest stimulus seen or the average of the weakest seen and the weakest not seen. When this is repeated at a number of locations in the visual field, the hill of vision can be reasonably mapped out (Fig. 5.17).

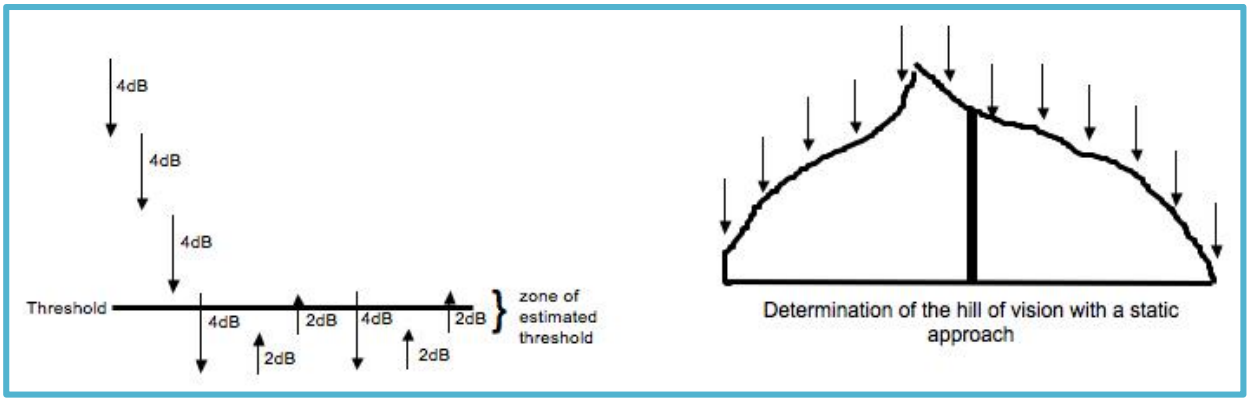

Figure 5.17: *Determination of threshold using the static approach*

The **kinetic** method involves the determination of **isopters** by moving a **constant stimulus** from non-seeing areas to seeing areas (Fig. 5.18). The stimulus used to determine the isopter can roughly be taken as the threshold stimulus along the edge of the isopter.

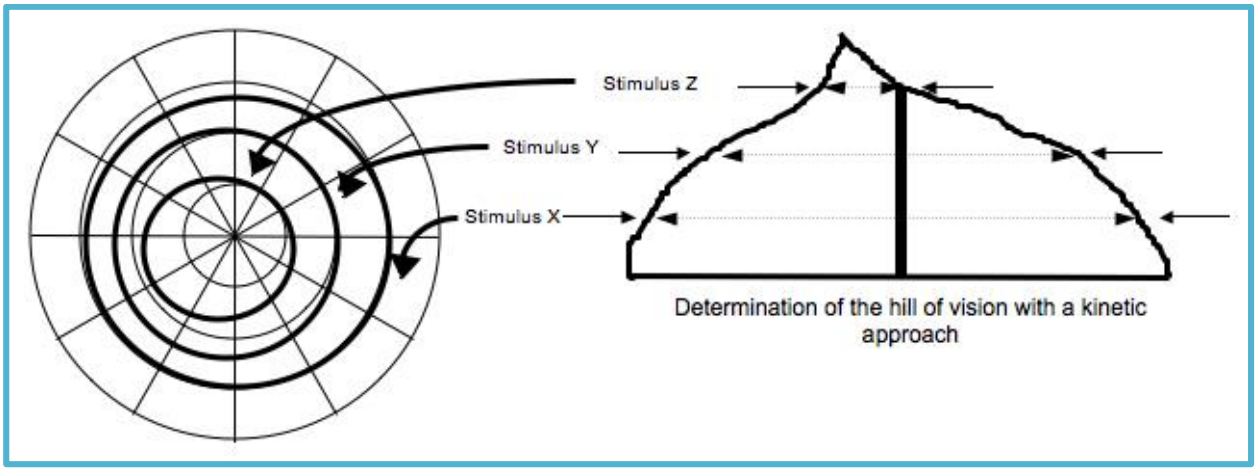

Figure 5.18: *Determination of threshold using the kinetic approach*

The static method is sensitive & more precise than the kinetic approach. However, static testing is very laborious in manual VF testing and for this reason kinetic is the preferred approach. In automated perimetry, however, the kinetic method is facilitated and preferred since it provides quantifiable and analyzable data.

SCREENING VS. THRESHOLD

VF can be globally assessed using either a thresholding or screening approach. Thresholding implies that the threshold is determined as precisely as possible as described above for a number of points in space. Each threshold value can then be mapped on a 2 or 3-dimensional graph to numerically represent the hill of vision. Obviously this method is more precise but more time consuming especially in manual VF testing.

Screening simply involves the use of a single stimulus to test the VF. Usually a suprathreshold target that is several dB higher than the expected hill of vision is used. The target can be presented either statically at a number of locations or kinetically to determine if it becomes invisible at some points. Obviously this method is much more efficient than static. However, it is less precise and small relative defect can easily be missed (Fig. 5.19), especially if the interval between the suprathreshold stimulus and the hill of vision is large.

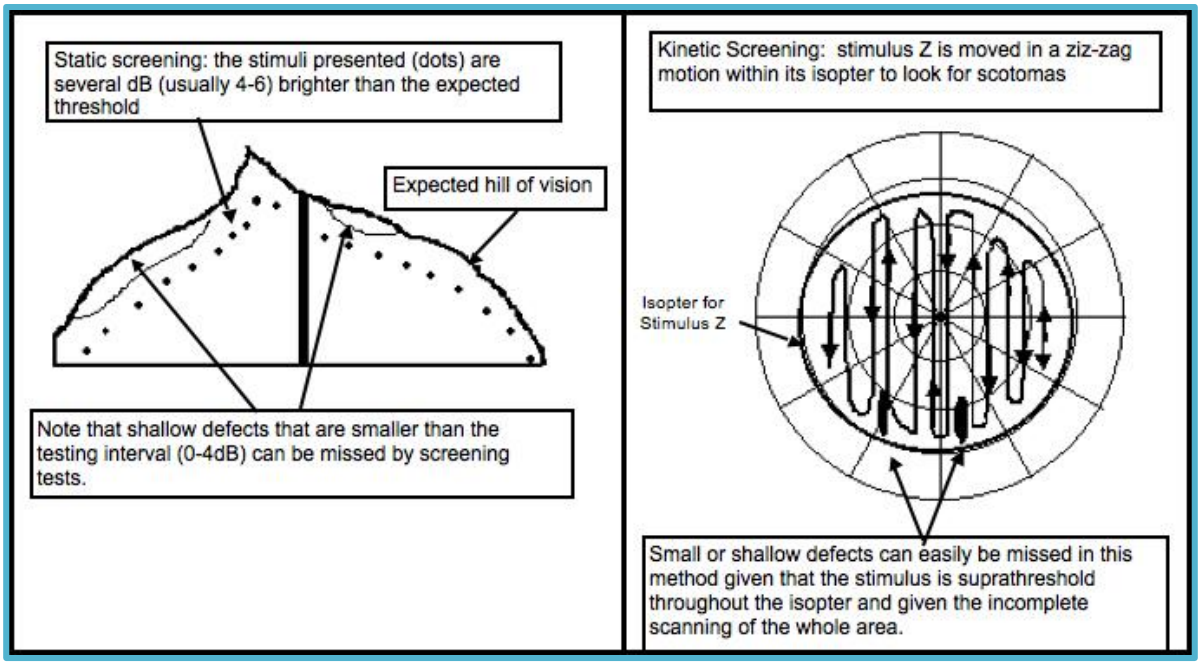

Figure 5.19: *Determination of threshold using the kinetic approach*

VARIABLES IN VF TESTING

VF results will depend considerably on a number of factors that may be related to stimulus, response or clinical variables. The clinician must understand the effect that each element may have on VF, consider them during the procedure and bear them in mind during VF interpretation. Table 5.4 summarizes the variables involved in VF testing that are discussed more extensively below.

Stimulus Factors	Response Factors	Clinical Factors
Luminance	Patient psyche	Target blur
Stimulus size	Instructions/examiner's personality	Spectacle correction
Duration	Response criterion	Pupil size
Kinetic/Static target	Reaction time	Media clarity
Speed of kinetic target	Fixation	Physical Limitation
Colour	Learning curve	Age
	Fluctuation	
	Psychogenic factors	

Figure 5.4: *Variables involved in VF testing*

STIMULUS FACTORS

Luminance

The **target brightness** will affect its visibility. Obviously the brighter the target the more visible it is.

The **background luminance,** which is the brightness of the surface onto which the stimulus is projected, affects the sensitivity by setting the level of retinal adaptation. In the photopic range (>3 asb), the cones are active and the sensitivity is maximal (island of vision is high). In scotopic (0-0.003 asb) and mesopic (0.003-3 asb) levels, the cone activity is reduced and the central sensitivity will be depressed (hill of vision will appear flattened). The low photopic range is preferred in most perimeters (~31.5 asb).

The **contrast,** which truly denotes the light difference of a stimulus from the background, will naturally affect the VF measurement. According to Weber's law, the "just noticeable difference" in stimulus intensity (stimulus minus background) divided by the background intensity is constant over a wide range of photopic conditions.

$$\textbf{Constant} = \frac{\textbf{stimulus} - \textbf{background}}{\textbf{background}}$$

Therefore, the stimulus will remain equally visible even if the absolute intensities of the target and background are changed, as long as the constant in the above formula is maintained. In VF testing, the background is kept constant and the contrast is altered by increasing the stimulus intensity.

Stimulus Size

For a given stimulus intensity, a large stimulus is more easily seen than a small one due to **spatial summation**. Size, however, can be compensated for by increasing the light intensity of a stimulus. The relationship is expressed by the following mathematical expression:

$$\textbf{luminous intensity X (area of stimulus)}^{k} \textbf{ = threshold for a given location}$$

One can therefore increase the intensity of a small stimulus to make it as visible as a bigger but dimmer stimulus. "k" is a constant that varies with retinal position, adaptation level, individual characteristics, etc. so the relationship can only be approximated. Although variable if necessary, the standard stimulus size used in most modern VF testers is the **Goldmann size III target (0.43° = 4mm^2).**

DURATION

Because of **temporal summation**, a static stimulus presented for 20 msec. is more visible than one presented for 10 msec. After a **critical duration**, however, temporal summation is complete and a stimulus presented for a longer period of time will not become more visible. The critical duration depends on a number of target factors such as size and luminance. In general, however, the temporal summation phenomenon begins to decline after 60msec and is completed by **100 msec**. Therefore a stimulus presented for 500 msec. will not be more visible than if presented 150 msec.

Below the critical duration, **Block's Law** states:

contrast X time of presentation = constant threshold

This implies that you can maintain the same threshold for a dimmer stimulus if you increase the time of presentation. In order to avoid, this variable in VF testing, the time of presentation is best if kept above the critical duration.

The latency for saccadic movements, however, is 180-250msec. If the time of presentation exceeds the latency period, tested subjects may attempt to fixate the presented targets. Hence the ideal time of presentation falls between the critical duration and the latency of saccadic eye movements. Automated VF testers will have presentation times between 100-200msec. Manual VF systems, unfortunately, have a presentation time between 0.5-1.0sec which is greater than the saccadic eye movement latency.

Kinetic vs. Static Target

Static VF are established with the use of non-moving stimuli presented a varying intensities to bracket the threshold value. **Kinetic VF** are established by moving the stimuli from non-seeing areas into seeing areas until they hit the hill of vision and are perceived. A moving target is always more visible than a static stimulus. For a similar stimulus, therefore, the sensitivity to the static stimulus will appear lower than to the kinetic one (Fig. 5.20).

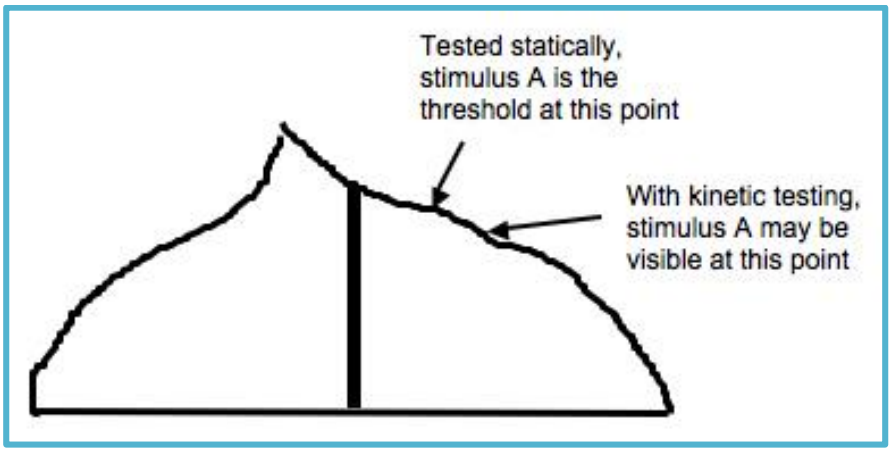

Figure 5.20: *Threshold difference between static and kinetic targets*

Speed of kinetic target

In kinetic VF testing, the target's speed may introduce variability and error in the obtained isopters. A target that is moved faster will have moved in a much further distance than one moving slower during the reaction time period. For instance, with a 1sec. response delay, a target moving at 15°/sec will be noted 13° further than a target moving at 2°/sec. The speed effect is more critical in the central 30° area. A high speed target of 15°/sec and a reaction time of 1 sec may reduce a peripheral isopter from 75° to 60°, but it will reduce a central isopter from 20° to 5°!

In performing kinetic VF in clinical practice, the **ideal rate of a moving target is 2-4°/sec**.

Colour

VF can be performed using coloured targets and backgrounds. Naturally VF will vary due to a number of factors such as selective photoreceptor testing and adaptation levels. Colour VF are not clinically widespread because of the inconsistent and variable results obtained with the use of non-standardized parameters (colours, filters, light sources, etc.). They are also controversial with regards to the exact nature of the psychophysical end points, the question being whether the point of achromatic perception (target awareness) or the true chromatic recognition (colour awareness) is established.

With the advent of standardized automated VF testers, however, colour perimetry is gaining popularity and can be used clinically. **Red stimulus** VF testing is typically used to measure threshold in **central 10° to check for drug toxicity** (e.g. chloroquine, ethambutol). Current research may render blue-yellow VF testing useful in the early detection of glaucoma as well.

RESPONSE FACTORS

Patient's psyche

The state of mind is crucial to the performance of any difficult task. This is particularly true for VF testing which is in general a very difficult procedure to complete for any individual. Factors such as **mental status, anxiety/stress, level of attentiveness, cooperation** as well as **intelligence** may all play an important role in the results of the VF test. Whenever possible, these variables should be qualitatively assessed, noted and kept in mind during VF analysis.

Instructions/examiner's personality

The instructions given to the patient and the **examiner's personality** are extremely influential in the patient's state of mind and performance. As in any physical, psychological or psychophysical task, the quality of instructions will play a significant role in motivating the subject to perform well, be attentive and answer the test as accurately as possible. Additionally, proper instruction and guidance serve to establish the **patient's expectations** towards the performance by clarifying what exactly is required in performing the test and what the possible outcomes may be.

Response criterion

The **response criterion**, which directly influences the appearance of VF, is uncertain to many patients. A patient with a strict criterion will be unwilling to answer unless the target is seen for sure. In comparison, another individual with a more relaxed criterion may respond to a vague stimulus that is only possibly seen. Once again, the examiner's instruction can help minimize, but not eliminate completely, discrepancies between response criterion.

Reaction time

Reaction time is more relevant to kinetic VF testing than to static methods. An increased response time will allow the stimulus to travel a further distance before the patient signals its presence. Hence, an isopter for a given stimulus may appear smaller.

Reaction time will depend on the retinal location and the patient's physical and mental status. In general, the reaction time is longer for stimuli that are presented more peripherally. However, reaction time is more critical in the central 30° area where small time delays make a more significant difference on the VF results. A 1 sec delay on a target that is moving at 15°/sec will reduce a peripheral isopter from 75° to 60°, but it will reduce a central isopter from 20° to 5°!

Although not clinically controllable, one must factor the reaction time in VF results especially in older individual where response time is increased.

Fixation

Steady fixation is crucial to the production of accurate VF. Unstable fixation leads to increased variability and inaccurate results while shifted fixation results in displaced isopters. Even in healthy subjects, drifts and micro eye movements tend to increase during VF testing due to fatigue, stress and the tendency to fixate peripheral stimuli. Fixation needs to be constantly monitored while performing VF testing.

Learning curve

As with many psychophysical tests, a **learning curve** is observable in VF testing. VF can change and improve dramatically during the first few times that the test is repeated. The learning effect is greatest between the first and second time but learning may be observable at the third or fourth times as well especially with advanced automated VF tests. **Therefore, first VF fields, and perhaps second as well, should always be interpreted with caution.**

Fluctuation

Short term fluctuation is the variability of the patients responses during a short lasting exam (minutes). The short term fluctuation can make results vary by as much as **+/- 3dB** over a few moments in normal individuals. Short term fluctuation increases mildly with age but it may increase dramatically in disease processes.

Long term fluctuation is the normal variability of the patients responses over several exams (days or years). Like many physiological functions, sensitivities are not fixed over time and individuals can manifest different VF results from one test time to another.

Psychogenic factors

Psychogenic factors such as hysteria and malingering may also result in unusual VF results. In fact, some VF results may be pathognomonic of psychogenic conditions. The clinician should always bear in mind this possibility in the analysis of VF results.

CLINICAL VARIABLES

Target blur

When a spot is blurred or defocused, it becomes dimmer due to its apparent decreased density and edge contrast. A blur can therefore yield an apparently reduced sensitivity and hill of vision. For each diopter of defocus the sensitivity decreases by approximately **1.5dB**. Uncorrected refractive error will therefore adversely affect VF results. The effect is greater in the central field and is minimal with larger targets. **Central VF must therefore always be performed with the patient fully corrected.**

A non-uniform retinal topography that may exist in certain conditions (e.g. staphyloma, macular edema) can induce areas of relative defocus and result in **refractive scotomas**.

Media clarity

Light scattering effects by disturbed ocular media can decrease target contrast with the background. Media opacities can also reduce the amount of light reaching the retina. As a result, retinal sensitivity will appear reduced and depressions (focal or generalized) may be noted on VF testing.

Spectacle correction

High spectacle corrections can result in variable VF results due to the prismatic effects produced by spectacle lenses. **High plus** prescriptions used for aphakes or high hyperopes can produce a **compressed VF** where the blind spot is closer to fixation and smaller (Fig. 5.21). Alternatively **high myopic** corrections will show **expanded VF** where the blind spot is further out and bigger. Contact lenses are recommended to perform VF when high refractive errors (> +/- 10.00D) are present.

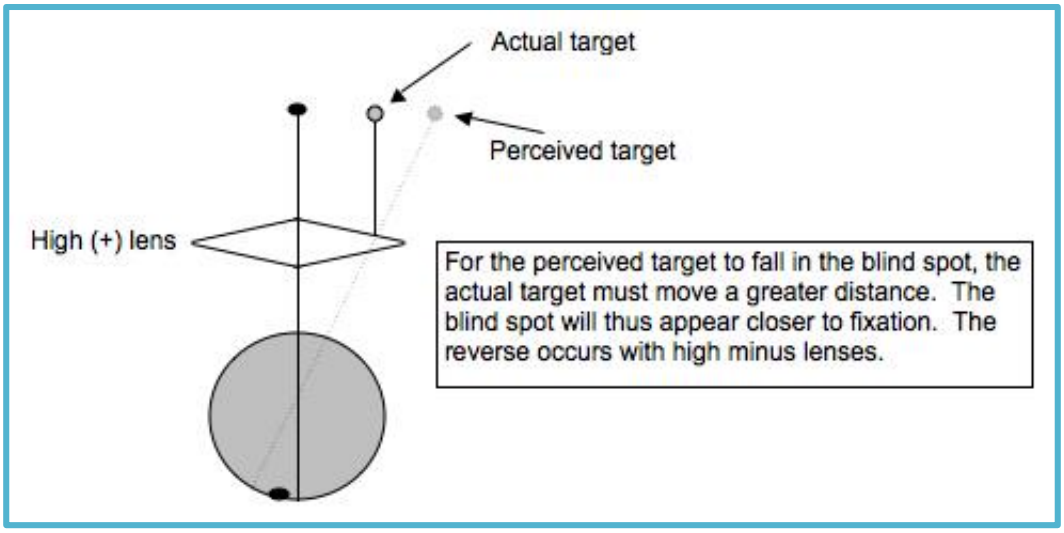

Figure 5.21: *Prismatic effect of high prescription lenses on the visual field*

Pupil size

The amount of light entering the eye is proportional to the area of the pupil. Miosis produces an increased threshold by decreasing the amount of illumination reaching the retina **and** by changing the level of retinal dark adaptation. Remember that in mesopic conditions the retinal sensitivity is reduced.

Miosis can also induce **diffraction** effects especially if the pupil diameter is less than 2.4 mm. Diffraction produces a target blur at the retinal level that increases threshold.

A small pupil will therefore produce a generalized depression of the VF. Pupils that are less than 3mm should be dilated before performing VF testing.

Alternatively, large pupils can induce VF changes by producing aberrations that adversely affect the light entering the eye.

The pupil diameter, therefore, should always be **documented** when performing VF testing in order to keep track of “abnormal” results that may result from pupil size.

Physical limitations

A number of physical factors can affect the VF result. Overhanging eyebrows, ptosis of upper lid and large noses are the most common ones. Droopy lids may need to be taped up should they limit the VF significantly. Trial lens frames and glasses can also limit the extent of visual fields. Trial lenses and glasses need to be placed as close as possible to the eye during central VF testing and need to be removed for peripheral evaluations. In cases of large (+/-10.00D) refractive errors, contact lenses can be used to test the peripheral VF.

Age

Aging has dramatic effects on the VF. The overall hill of vision decreases with age at a rate of ~ 0.5 dB per decade, as if the hill of vision is sinking in the sea of blindness. The reduction is due to nerve fiber loss normally associated with aging. Other associated aging changes such as the mental health (delayed reaction time, reduced attention span, increased variability, fatigue, etc.), the general status (physical fatigue, diseases, instability, etc.) and ocular conditions (miosis, ptosis, media opacities) all contribute to adversely affect VF measurements.