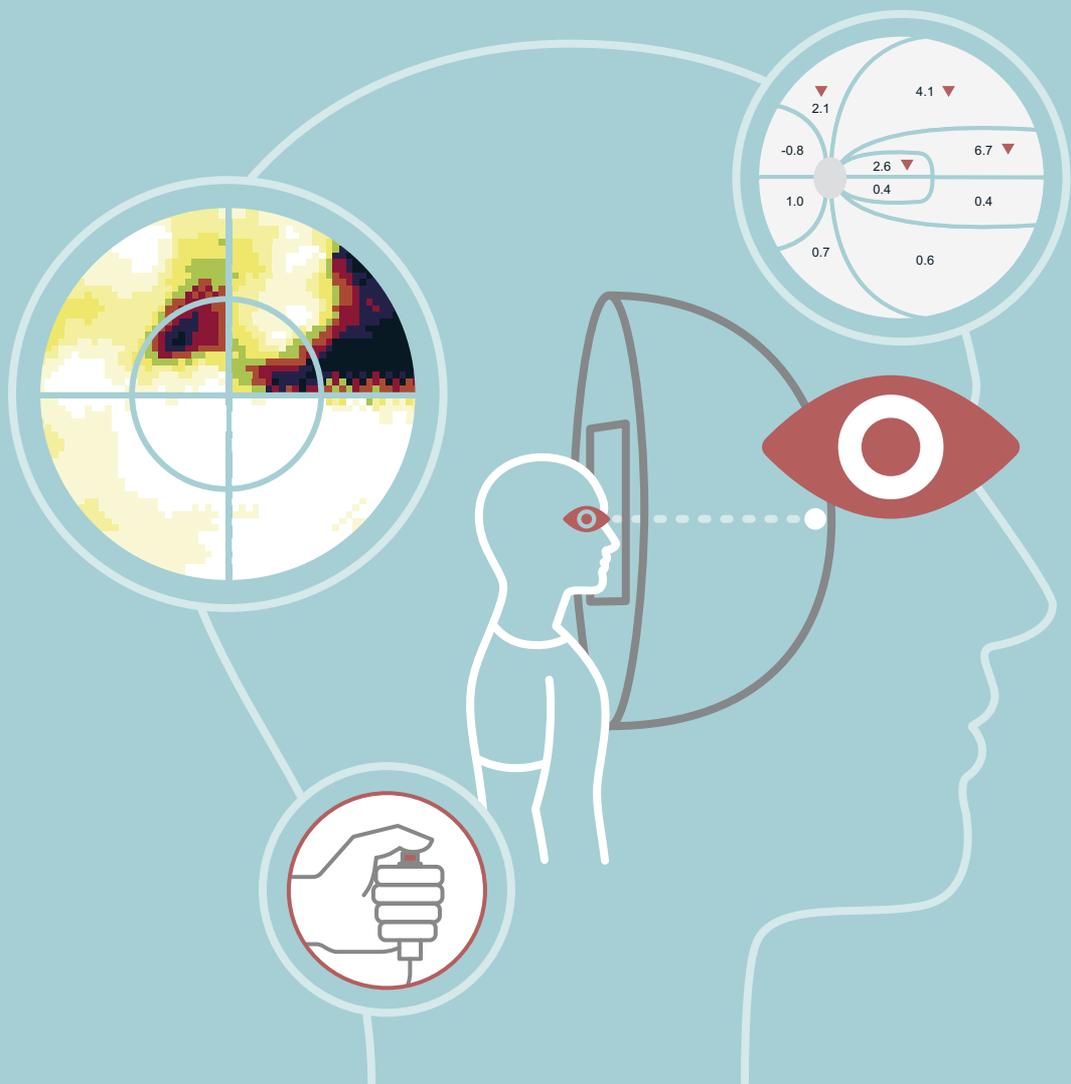


# VISUAL FIELD DIGEST

A guide to perimetry and the Octopus perimeter



Lyne Racette, Monika Fischer, Hans Bebie,  
Gábor Holló, Chris A. Johnson, Chota Matsumoto

Illustrated by Philip Earnhart

8th edition

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# PREFACE

Since the introduction of the manual Goldmann perimeter in 1946, perimetry has become an indispensable tool in any eye care practice. In the last ten years, clinicians' expectations regarding visual field testing and analysis have significantly increased. In today's busy and fast-paced clinics, maximizing the trade-off between result accuracy, test duration and the effort required from both the patient and the examiner is more important than ever before.

While the basic testing principles used in perimetry today have remained largely unchanged since the introduction of the manual Goldmann perimeter in 1946, Octopus perimeters have pioneered numerous important changes in perimetry. The development of the first automated perimeter in 1974, the Octopus 201, by Fankhauser, Spahr und Jenni, opened the door for automated perimetric testing as we know it today. In addition, the Octopus perimeter's introduction of semi-automation in kinetic perimetry over 20 years ago has facilitated kinetic testing.

Since then, knowledge on how to best select, perform and interpret perimetric tests in clinical practice has increased considerably. Normative databases, global indices such as Mean Defect, the Defect Curve and many other useful tools for analyzing the measured sensitivity thresholds were first introduced on Octopus perimeters before becoming worldwide standards for visual field interpretation.

In the last decade, several advances in testing with Octopus perimeters have been achieved. EyeSuite Progression Analysis has been developed into a powerful tool for assessing progression. In addition, both Cluster Analysis and Polar Analysis are helpful features for establishing a relationship between functional and structural results.

In 2016, Haag-Streit published the completely reviewed 6<sup>th</sup> edition of the Visual Field Digest, with greater emphasis on the challenges and possible pitfalls associated with visual field testing in clinical practice and guidance on how to avoid and overcome them.

This book was written with the intention of making visual field testing accessible to everyone, including clinicians, residents, researchers, examiners, students and those without previous knowledge of perimetry. Much effort has been invested in creating instructive illustrations to support the text's key points. At the same time, it provides in-depth information for anyone wanting to know more about visual field testing theory.

The 6<sup>th</sup> and the subsequent 7<sup>th</sup> edition – containing minor corrections and updates – have been highly appreciated by visual field testing students, technicians, clinicians and experts. Since 2016, all ten thousand hardcopies of this book have been distributed, which calls for a slightly amended 8<sup>th</sup> edition with updated references and minor corrections.

We wish to thank our readers for all the positive feedback we have received in the last three years with regards to both the content and Philip Earnhart's easy-to-understand graphics. Furthermore, this book would not have been possible without the unfailing support of Haag-Streit AG, for which we are grateful. Finally, we should like to thank our contributors for providing us with the clinical cases used throughout the book to illustrate various aspects of perimetry and for sharing their knowledge with us.

We hope that this book on perimetry in general, and on the Octopus perimeter in particular, is not only comprehensive but also enjoyable to read for anyone interested in visual field testing. We are convinced that the information shared in the pages ahead will be useful to clinicians and ultimately to their patients, whose sight we deeply care about. We wish you an enriching and pleasant reading experience.

Lyne Racette, Monika Fischer, Hans Bebie, Gábor Holló,  
Chris A. Johnson, Chota Matsumoto.

September 2019

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# CHAPTER 1

## INTRODUCTION

### WHY READ THIS BOOK

The Visual Field Digest is a comprehensive guide to perimetry and the Octopus perimeter. It explains core concepts and provides details about the Octopus visual field machine. It also places great emphasis on the clinical challenges and pitfalls of visual field testing and gives guidance on how to avoid and overcome them.

Thanks to its many instructive illustrations to explain key points, this book will make visual field testing accessible to anyone and has been enjoyed by tens of thousands of eye care professionals since its first publication in 1983.

### WHO SHOULD READ THIS BOOK

This book has been written for any current or future eye care professional who perform or interpret visual field examinations as part of their diagnostic routine. This group not only includes clinicians in optometry and ophthalmology, but also visual field examiners who administer perimetric tests to patients.

A wide range of users will find useful information in this book. It has been created for students with limited knowledge in perimetry and therefore explains fundamentals in perimetry in an easy to understand manner. In addition, it has been composed for experienced eye

care professionals and provides many practical tips and tricks to get even more out of their perimetric testing. And last, it has been written for researchers and expert users of perimetry who are interested in the scientific background of perimetry and the Octopus perimeter.

While this book provides in-depth information about the design and use of the Octopus perimeters, it is also very useful reading for users of other perimeter brands, as the fundamental concepts of perimetry are comparable among perimeter brands and are illustrated in this book in an easy to understand way.

# HOW TO READ THIS BOOK

To cater to the needs of readers with different experience levels as well as different learning styles, this book can be read in several ways.

For students and inexperienced users in perimetry, this book is structured in a way that, when read from beginning to end, it allows the content to be followed with minimal prior knowledge. For this reason, the book starts with fundamentals of perimetry such as, what the test does, how to administer the test and how to choose test parameters, before moving on to visual field interpretation and special topics like kinetic perimetry or function-specific perimetry. To tie the learning to real clinical situations, this book concludes with a case presentation section.

For more experienced users, individual chapters or sections in this book can also be read individually, as each chapter is structured in a way that it is self-explanatory, or if not, a clear reference to another chapter is given.

To find and understand key information quickly, all essential concepts are graphically illustrated to support a quick understanding of the concept. With more than 200 graphics available in this book, it is thus possible to grasp key information just by looking at the graphics and reading the captions.

If several choices or methods are compared, overview tables are provided for quick comparison between them. Sometimes, in-depth background information

## KEY ELEMENTS USED IN THIS BOOK

51

TABLE Provides a quick overview and contrasts different concepts/methods

COMPARISON BETWEEN STATIC AND KINETIC TABLE 4-1

	STATIC	KINETIC
<b>ADVANTAGES</b>	Clinical gold standard High precision sensitivity thresholds Fully automated	High spatial resolution Fast peripheral testing Provides information about other visual functions Highly interactive, flexible and adaptable
<b>WHAT IT IS BEST AT DETECTING</b>	Small changes in sensitivity thresholds Changes in the central area	Small changes in spatial extent of a defect Peripheral changes Remaining vision in advanced diseases
<b>COMMON USES</b>	Glaucoma Macular diseases Visual ability testing	Neuro-ophthalmological conditions Peripheral retina diseases Low vision Children Patient with cognitive impairment

STIMULUS TYPE: STANDARD OR NON-CONVENTIONAL

STANDARD WHITE-ON-WHITE PERIMETRY

The standard perimetric stimulus is white on a white background, and this type of perimetry is commonly referred to as white-on-white perimetry, or Standard Automated Perimetry (SAP).

The white color stimulus offers the advantage of stimulating all different retinal cell types. As a result, white light allows visual field testing from early to advanced disease (i.e., it offers a large dynamic testing range). By convention, the standard stimulus used is round, with a diameter of 0.43°, which is also the Goldmann stimulus size III, based on the definition of Professor Hans Goldmann. For more information on Goldmann stimulus sizes, refer to BOX 4B.

TEXT Full presentation of a topic

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Chapter 4 | Key examination parameters

BOX 4B GOLDMANN SIZES I TO V

The size conventions used today to describe a perimetric stimulus are derived from the work of Professor Hans Goldmann, who developed the Goldmann perimeter in 1946. He defined standard sizes for perimetric stimuli, and the Goldmann sizes I to V are still widely used. Each step corresponds to a change in diameter by a factor of 2 and in area by a factor of 4. Size III is several times smaller than the physiological blind spot and was considered to be an accurate measurement size.

BLIND SPOT

BOX Provides expert knowledge

FUNCTION-SPECIFIC PERIMETRY

Function-specific perimetry uses different stimulus types to stimulate different visual functions (e.g., motion, or color vision), but they all have the same purpose: measuring a subset of the visual system individually, to get more sensitive responses for early disease detection. Different Octopus perimeter models offer different function-specific stimuli (FIG 4-3): a blue stimulus on a yellow background (Short-Wavelength Automated Perimetry, or SWAP); a white flickering stimulus on a white background (Flicker Perimetry); or a pulsating stimulus with concentric rings changing in both spatial resolution and contrast (Pulsar Perimetry). They are described in more detail in Chapter 10.

FIGURE 4-3 Stimuli used in function-specific perimetry from left to right: Short-Wavelength Automated Perimetry and Pulsar Perimetry.

FIGURE Illustrates key information in an easy to understand way

**FIGURE 1-1** To accommodate the preferences of different readers, different structural elements are used in the Visual Field Digest. To highlight key information, there are Figures and Tables; to provide a full overview of a topic, there is full text; and to provide in-depth expert knowledge, there are Boxes.

is of interest to some readers, but not crucial for good clinical practice. Such information is provided in a light blue box and can be read for interest but does not inter-

fere with the flow of the book. The elements described above are shown in **FIG 1-1**.

## CONTENT AT A GLANCE

In this section, a brief overview of the content of each chapter is presented.

### CHAPTER 2 – WHAT IS PERIMETRY?

Chapter 2 provides essential information on perimetry as a technology which is valid for any perimeter brand. It shows how and why visual field testing is performed,

provides a general introduction on how the data is displayed, and highlights common challenges associated with visual field testing.

### CHAPTER 3 – HOW TO PERFORM PERIMETRY YOU CAN TRUST

Chapter 3 focuses on information relevant to visual field technicians and those people instructing them. It stresses the importance of the visual field technician in obtaining trustworthy visual field results and explains the essential steps of visual field testing. In a second part, common pit-

falls in perimetry such as learning effects, fatigue effects, set-up errors and artifacts are presented, along with the procedures for avoiding these problems. How to detect whether a visual field is trustworthy is later presented in Chapter 8.

### CHAPTER 4 – KEY EXAMINATION PARAMETERS

Chapter 4 focuses on fixed examination parameters and the key patient-specific parameters a clinician needs to decide about. Key questions to be answered regarding patient-specific test parameters are the following:  
1) Static or kinetic perimetry? 2) Which stimulus type?  
3) Which test pattern? 4) Which strategy?

The idea is to provide an introduction to what these parameters are and how to make appropriate testing decisions. The key parameters will be described in depth in subsequent chapters.

## CHAPTER 5 – SELECTING A TEST PATTERN

Chapter 5 presents all available test patterns on Octopus perimeters. The chapter is organized according to pathology or test (i.e., it starts with glaucoma, and continues with neuro-ophthalmic and retinal diseases).

Performance evaluations such as driving and visual disability tests as well as ptosis test patterns are described towards the end of the chapter.

## CHAPTER 6 – SELECTING A TEST STRATEGY

Chapter 6 presents all available test strategies on Octopus perimeters and shows that there is always a trade-off between test duration and accuracy in order to guide the

clinician in selecting one of the various quantitative or qualitative test strategies.

## CHAPTER 7 – OVERVIEW OF VISUAL FIELD REPRESENTATIONS

Chapter 7 introduces all visual field representations available on Octopus perimeters and shows their respective relationships. Further, each representation is explained in detail, including a clear definition of all the symbols used

in each representation and further information about the design of the representation. For clinicians, this chapter can serve as a glossary.

## CHAPTER 8 – CLINICAL INTERPRETATION OF A VISUAL FIELD

Chapter 8 is a key chapter in this book, guiding clinicians through visual field interpretation in an easy to follow workflow. It starts by showing six visual field examples and their respective representations across all stages of disease to provide a graphical reference on what visual field results look like in a given situation. The same cases are also provided as a poster that can be removed from the book as a reference in daily clinical practice.

Further, this chapter highlights those representations most useful in answering specific clinical questions, and shows how to interpret these representations in clinical practice. Clinical examples are frequently provided to illustrate the benefits of each respective representation in a certain clinical situation.

## CHAPTER 9 – INTERPRETATION OF VISUAL FIELD PROGRESSION

Chapter 9 focuses on the use of EyeSuite Progression Analysis to assess visual field progression. It explains the fundamentals of the trend analysis approach used to

determine whether a visual field series is stable or not. Further, it shows the benefits and interpretation of the various trend representations, including Global Trend

Analysis, Cluster Trend Analysis and Polar Trend Analysis, which not only allow it to be determined whether a visual field series is progressing and at which rate, but also whether progression is diffuse or local, the area of

the visual field in which progression is occurring and, in case of glaucoma, where to look for a spatial relationship with structural results.

## CHAPTER 10 – NON-CONVENTIONAL PERIMETRY

Chapter 10 focuses on other stimulus types besides the standard Goldmann size III used in perimetry. The chapter starts with function-specific perimetry designed for early glaucoma detection and provides background in-

formation about Pulsar, SWAP and Flicker perimetry. The chapter then concludes with the benefits of using a larger stimulus V for low-vision patients.

## CHAPTER 11 – KINETIC PERIMETRY

Chapter 11 focuses on kinetic perimetry. Similar to the static perimetry chapter, the basic examination parameters and when to choose each one are discussed. General approaches on how to perform kinetic perimetry are

presented and illustrated in a real clinical case. Towards the end, the benefits of different levels of automation are also discussed.

## CHAPTER 12 – TRANSITIONING TO A DIFFERENT PERIMETER MODEL

Chapter 12 focuses on specific challenges associated with transitioning from one perimeter model to another. It focuses both on the transition to a different Octopus model, as well as the transition from a Humphrey to an Octopus model. It highlights the importance of normative databases for minimizing the differences between pe-

rimeter models and shows the impact of patient-related fluctuation. To support a smooth transition from an HFA perimeter to an Octopus perimeter, guidance in relation to known HFA perimeter terminologies is provided on the selection of test parameters as well as the interpretation of the perimetric result.

## CHAPTER 13 – CLINICAL CASES

To support the interpretation of visual field results in clinical practice, 23 clinical cases are presented, showing typical visual fields of patients with glaucoma, neuro-ophthalmic disease and retinal disease. All these cases

contain key patient information, as well as visual field results and other relevant diagnostic results such as IOP, fundus images, OCT scans and MRIs.

---

## CHAPTER 2

# WHAT IS PERIMETRY?

## INTRODUCTION

### PERIMETRY – A STANDARD TEST IN OPHTHALMOLOGY

Perimetry is a standard method used in ophthalmology and optometry to assess a patient's visual field. It provides a measure of the patient's visual function throughout their field of vision. The devices used to perform this evaluation are called perimeters. Perimetry is performed for several reasons: 1) detection of pathologies; 2) evaluation of disease status; 3) follow-up of pathologies over time to determine progression or disease stability; 4) determination of efficacy of treatment and 5) visual ability testing.

Any pathology along the visual pathway usually results in a loss of visual function. Perimetry can identify deviations from normal, and consequently the associated pathologies. Perimetry is most commonly used to diag-

nose glaucoma, but it is also often used to assess visual loss resulting from retinal diseases, as well as optic nerve, chiasmal or post-chiasmal damage due to trauma, stroke, compression and tumors.

Additionally, perimetry is used regularly for visual ability testing. Its most common use is to test a person's visual ability to drive. Furthermore, it is used to provide a quantitative measure of visual function in order to determine eligibility for a pension for visual impairment, and also to assess the benefits of ptosis surgery.

In sum, perimetry is a universally available diagnostic method to assess a patient's visual field or visual function.

# THE NORMAL VISUAL FIELD

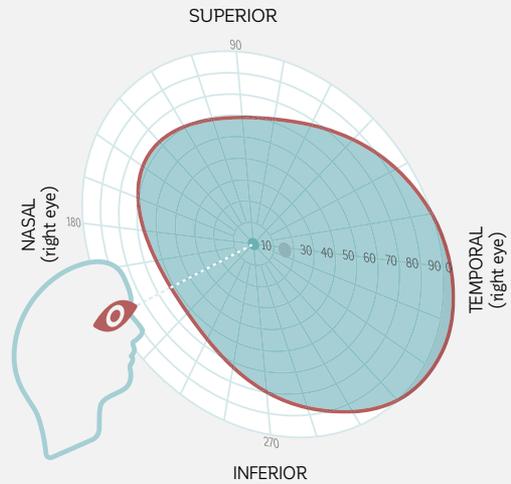
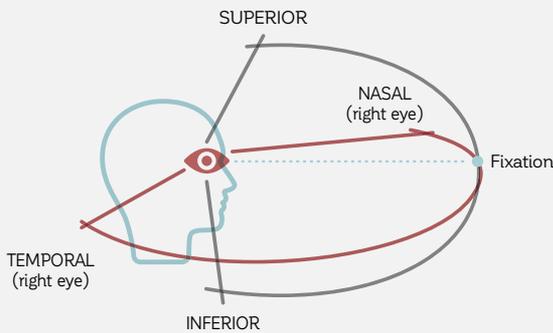
## SPATIAL EXTENT OF THE VISUAL FIELD

The visual field of a person is defined as the area in which a person can see at a given moment relative to the direction of fixation, without head or eye movement (i.e., it defines the boundaries of the area beyond which

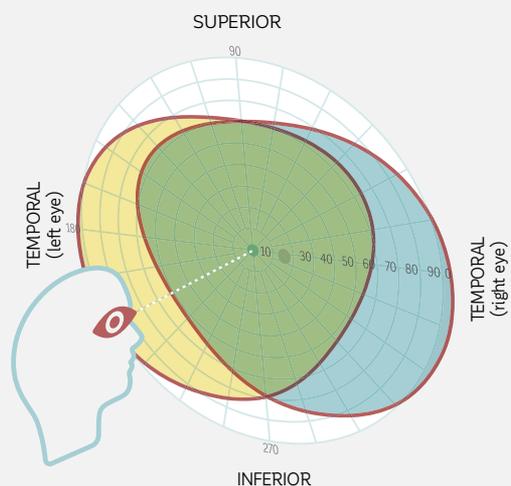
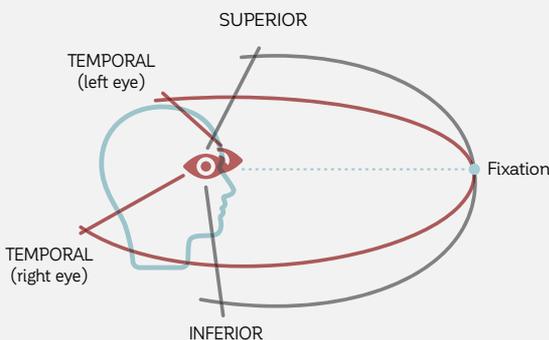
nothing can be seen). The extent of the visual field is an essential part of one's visual function, because a constricted visual field has a significant negative impact on activities of daily living, and as a result on quality of life.

### SPATIAL EXTENT OF A NORMAL VISUAL FIELD

#### A) MONOCULAR VISUAL FIELD



#### B) BINOCULAR VISUAL FIELD



**FIGURE 2-1** The monocular visual field of one eye is limited by the eye socket, nose, brow and cheekbones (A). The binocular visual field of two eyes overlaps in the central area (B).

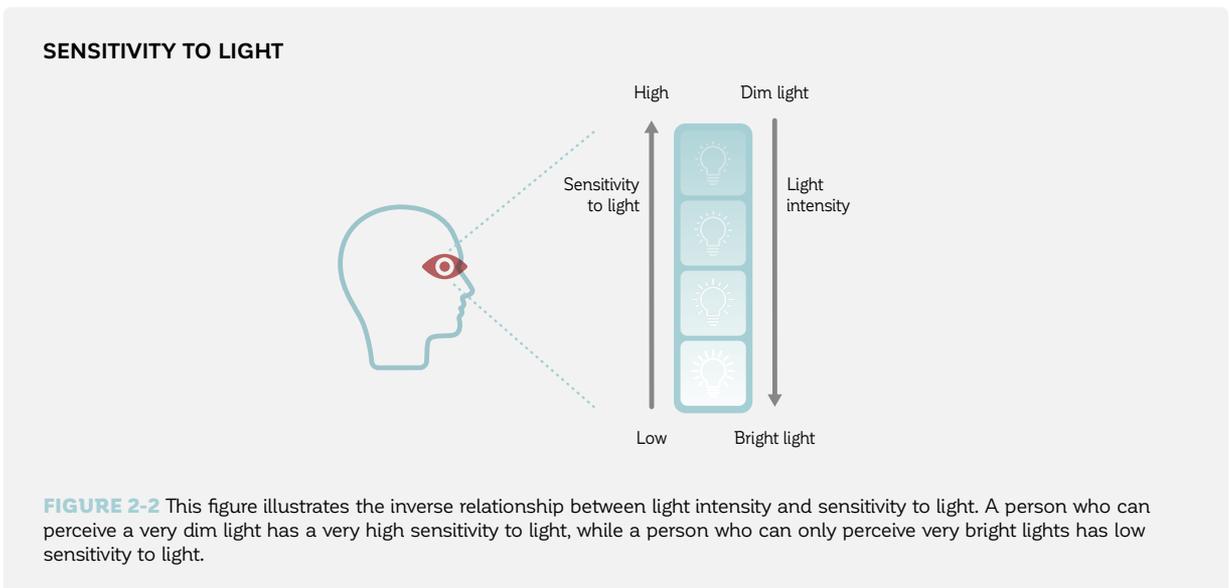
The visual field of one eye is called the monocular visual field (**FIG 2-1A**). Its spatial extent in people with normal vision is limited by the facial anatomy of the person, with the eye socket, nose, brow and cheekbones, which outlines the limits of the visual field. On average, the monocular visual field extends from 60° nasally to approximately 90° or more temporally, and from approximately 60° superiorly to 70° inferiorly.

In people with normal vision, the visual field is binocular (**FIG 2-1B**). This means that it contains input from both eyes, with integration and mapping of information from the two eyes, allowing for stereo acuity and depth perception. Visual information in the central 60 degrees of the visual field is processed by both eyes.

## SENSITIVITY TO LIGHT IN THE VISUAL FIELD

The area in which a person can see (extent of the visual field) does not suffice to describe a person's vision. It is also important to have a measure of sensitivity to light. But what is a person's sensitivity to light? One can imagine a room in which 100 people are present. The room is dim, with an adjustable light bulb at its lowest

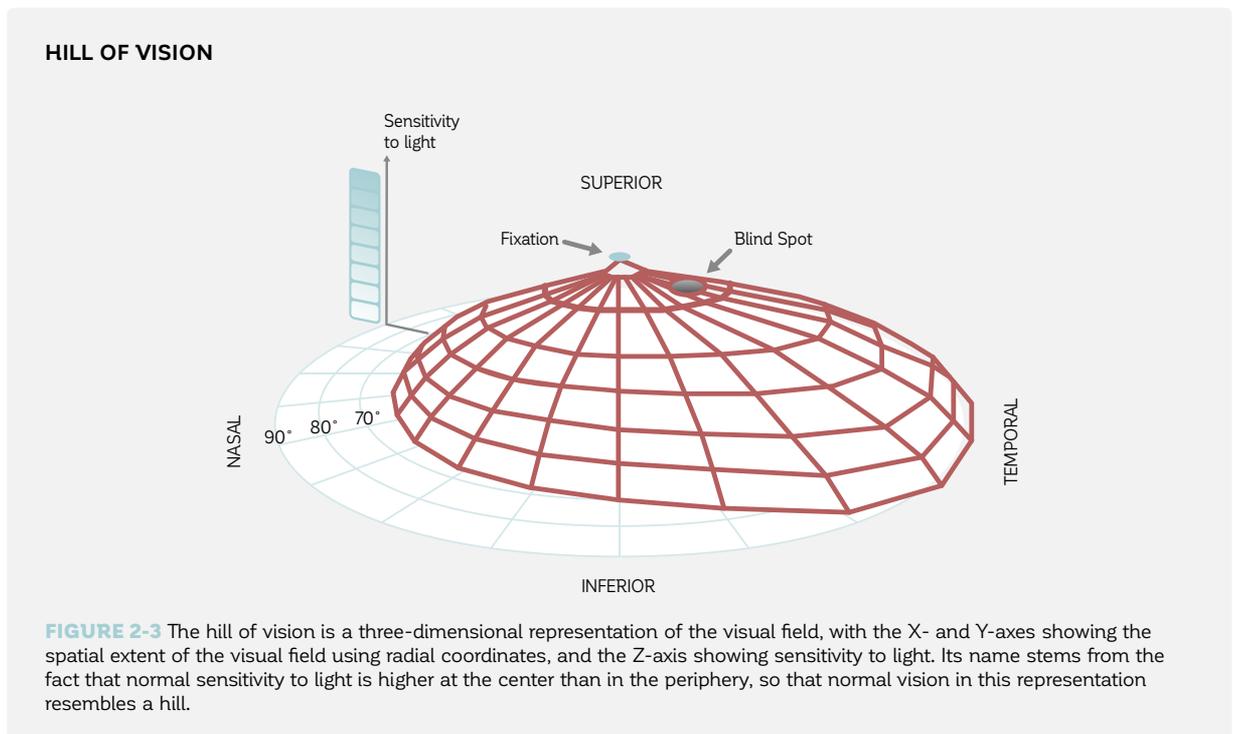
level hanging from the ceiling. In that room, only a few people can see. As the light intensity of the bulb is increased, an increasing number of people will be able to see in the room. The people who could see even the very dim light bulb have a very high sensitivity to light, while the others have a lower sensitivity to light (**FIG 2-2**).



## THE HILL OF VISION – A VISUALIZATION OF VISUAL FUNCTION

Sensitivity to light is not uniform across the spatial extent of the visual field and depends on location within the visual field. For normal eyes and in typical daytime illumination, sensitivity is highest in the central area of the visual field and decreases gradually towards the periphery. To visualize this, sensitivities across the visual field can be drawn as a three-dimensional graph, with

the X- and Y-axes representing the visual field locations and the Z-axis representing the sensitivity to light. Since this representation resembles a hill, it is commonly referred to as the hill of vision, which is a visualization of a person's visual function. Areas within the hill of vision represent areas of seeing, and areas outside the hill of vision represent areas of non-seeing (**FIG 2-3**).

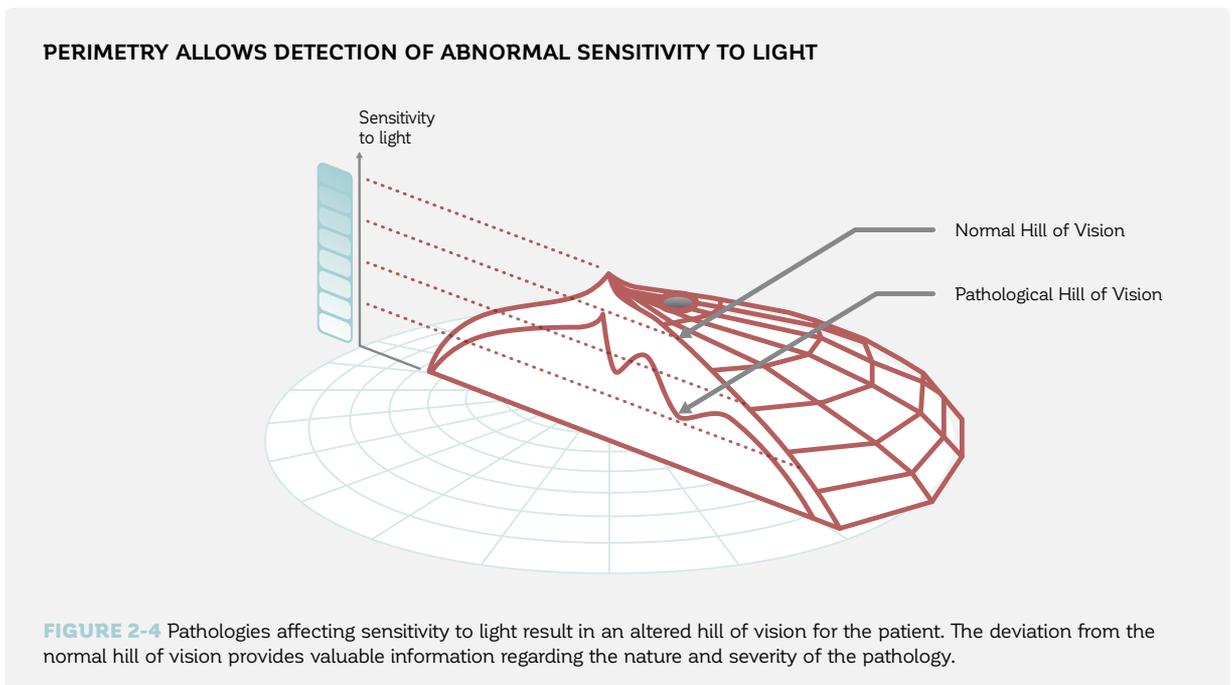


# MEASURING SENSITIVITY TO LIGHT ACROSS THE VISUAL FIELD

## PERIMETRY ALLOWS QUANTIFICATION OF ABNORMAL SENSITIVITY TO LIGHT

Deviations from the normal hill of vision provide valuable clues regarding visual field loss and the underlying pathologies. The pattern and shape of visual loss can be identified by investigating deviations from the normal hill of vision. Differences in the visual field between the two eyes can also be identified by inspecting deviations from the normal hill of vision. These deviations from normal

can be either constrictions of the boundaries of the visual field, or depressions of sensitivity. Such depressions can be present throughout the visual field (widespread lowering of sensitivity), or localized in specific areas of the visual field (scotomas). It is thus desirable to quantify a patient's hill of vision with high accuracy and to identify its deviation from a normal hill of vision (FIG 2-4).



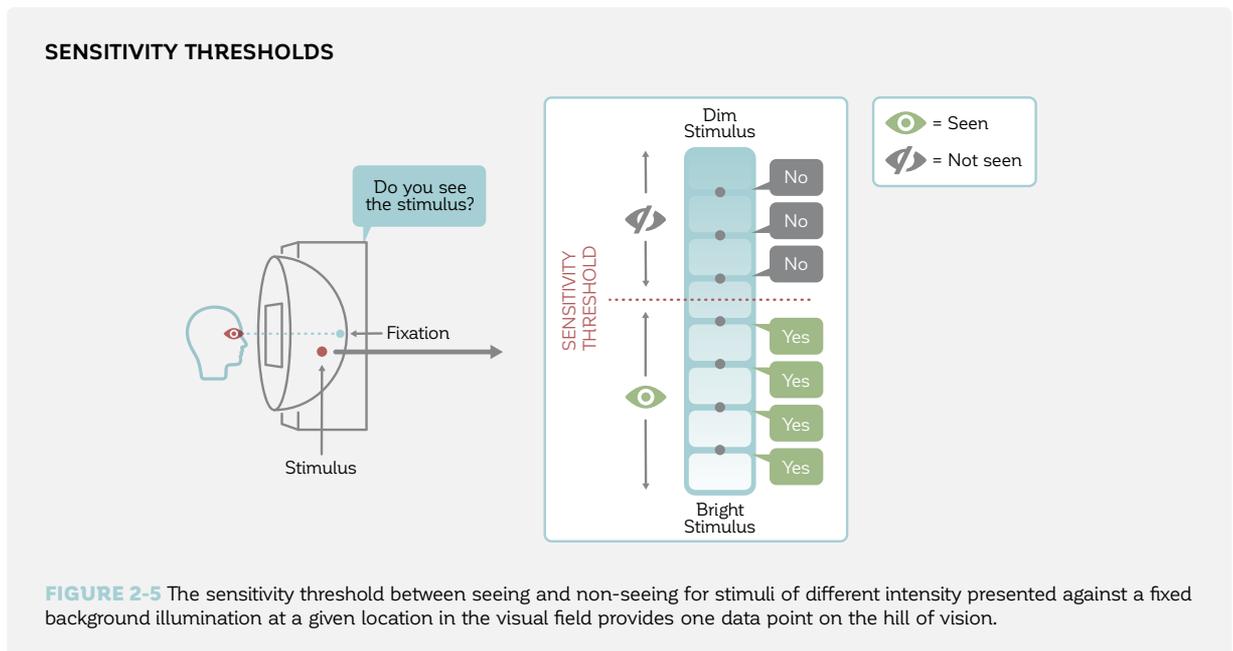
## THE PERIMETRIC TEST

Perimetry accurately quantifies a patient's sensitivity to light throughout the visual field in a systematic, highly standardized manner. To assess the visual field, a hemispheric cupola is typically used to project small light stimuli across the entire area of the visual field. These stimuli, and the uniform background onto which the stimuli are projected, are highly standardized in terms of shape, size, color, light intensity and duration, to ensure high reproducibility. The most commonly used test conditions project a round, white stimulus on a background, which is also white, but dimmer than the stimulus. The luminance (i.e., the reflected light intensity) of the stimulus can be altered from very low to very high. More detailed information on key examination parameters is provided in Chapter 4.

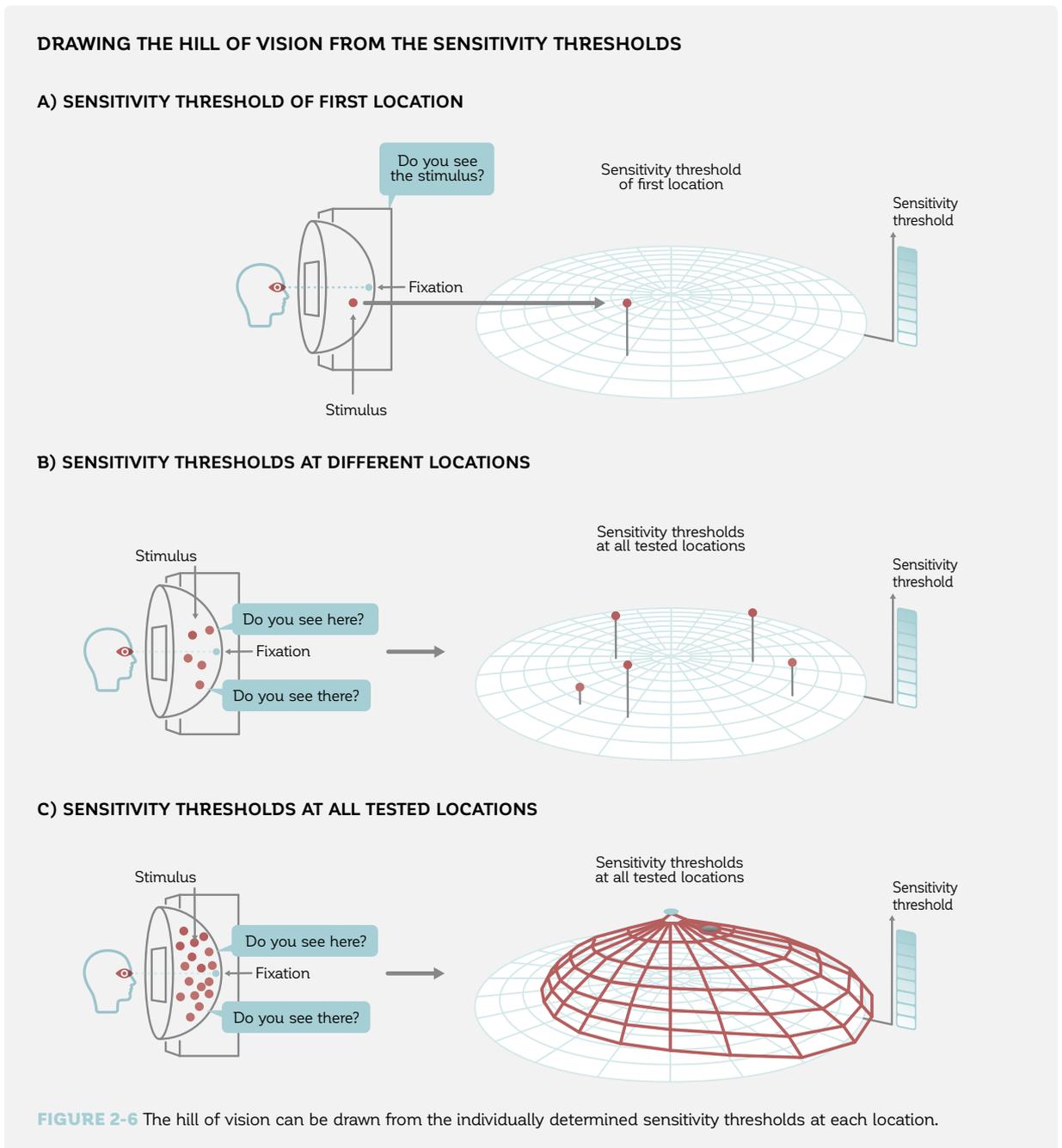
To perform a perimetric test, patients are asked to sit in front of the cupola with their head stabilized, to fixate onto a target in the center, and to indicate seeing a

stimulus anywhere in their visual field by pressing a response button. Conceptually and to simplify things, one can imagine that at the first location the luminance of the stimulus is increased from the "off" position to the dimmest level of an adjustable light bulb. If the patient cannot see the stimulus when it is off or very dim, another stimulus is shown later, at a higher level of light intensity. Once the stimulus reaches a certain light intensity, the patient can see it and presses the button. It should be noted that the stimulus is always turned off before the next stimulus is presented.

This minimum light intensity that can be seen defines the patient's sensitivity to light (i.e., the threshold between non-seeing and seeing) (FIG 2-5). Due to this evaluation method, in perimetry the word threshold is often used, instead of sensitivity to light. For ease of understanding, "sensitivity threshold" is the term used throughout this book.



The sensitivity threshold at the first test location provides the first data point to characterize the hill of vision (FIG 2-6A). To determine the patient's hill of vision, the aforementioned procedure is then repeated at many locations across the visual field (FIG 2-6B). By connecting the sensitivity thresholds at all tested locations, a patient's hill of vision can be drawn (FIG 2-6C).



While the process used to determine sensitivity thresholds is easy to understand, it would be much too time-consuming to test each location of the hill of vision in this manner. Therefore, more efficient strategies are used in perimetry and they will be discussed in depth in Chapters 4, 5 and 6. Additionally, the order of stimulus presentation is randomized throughout the visual field, to avoid patients becoming accustomed to a certain presentation pattern.

# DISPLAY OF SENSITIVITY THRESHOLDS

## THE DECIBEL SCALE USED IN PERIMETRY

In clinical practice, visual field information needs to be easy to interpret and should directly correspond to the clinical situation. For that purpose, perimetry employs the decibel scale, with its unit of measurement being the decibel (dB). The decibel range depends on perimeter type and typically ranges from 0 dB to approximately 32 dB in the fovea. A sensitivity threshold of 0 dB means that a patient is not able to see the most intense perimetric stimulus that the device can display, whereas values close to 32 dB represent normal foveal vision for a 20-year-old person. While the decibel scale is intuitive to understand and use in clinical practice, the underlying considerations and formulas are less intuitive and of limited relevance for clinical practice. For those interested, they are explained in **BOX 2A**.

### BOX 2A

#### THE RATIONALE FOR THE USE OF THE DECIBEL SCALE

The intensity of the light that is reflected on the perimetric surface is called luminance and can be measured objectively with a light meter. It is expressed in candelas per meter squared ( $\text{cd}/\text{m}^2$ ) or in the older unit, the apostilb (asb), with  $1 \text{ cd}/\text{m}^2$  corresponding to 3.14 asb. The measurement indicates light flux per unit area.

In theory, sensitivity thresholds could be expressed in luminance units. While this would be correct, it would be impractical in clinical practice for the following reasons:

**1. Large number of discrete luminance levels**

The human eye can adjust to a large range of luminance levels over at least 3-4 orders of magnitude (e.g., from almost 0 asb to 10,000 asb in normal daytime lighting conditions). This would make certain threshold values very large and impractical to display.

**2. The relationship between visual function and luminance is not linear**

Visual function is not linear with regard to the light intensity levels. For example, while an increase of 90 asb is likely to be noticed when luminance is increased from 10 to 100 asb, this same absolute increase in luminance (90 asb) would hardly be noticeable when luminance is increased from 1,000 to 1,090 asb.

**3. Inverse relationship between luminance and sensitivity to light**

There is an inverse relationship between stimulus luminance and a patient's sensitivity to light. A patient with high sensitivity to light only needs a stimulus with low luminance to be able to see it, while a patient with low sensitivity to light needs a stimulus with high luminance. For clinical

use, a scale defining visual field loss as low and good vision as high would be more intuitive than the inverse luminance scale.

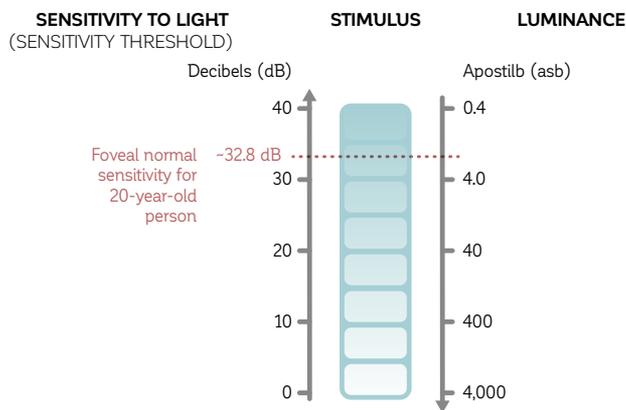
#### 4. Lack of definition of complete visual field loss

Since luminance and sensitivity to light are inversely related, complete visual field loss would be a very high luminance number. This number would be limited by the maximum stimulus the perimeter is able to display, potentially resulting in large differences between different perimeter models.

### THE DEFINITION OF SENSITIVITY TO LIGHT USING THE DECIBEL SCALE

The decibel scale addresses all of these issues and uses luminance levels solely as input variables. The relationship between the decibel scale and the luminance scale in apostilbs is shown below.

#### RELATIONSHIP BETWEEN SENSITIVITY TO LIGHT AND LUMINANCE



The decibel scale is used to express sensitivity to light. This figure shows the relationship between sensitivity to light and luminance. The maximum stimulus brightness, which is used as a default in recent Octopus perimeter models, is 4,000 asb. It is a logarithmic scale and is inversely related to the linear luminance scale in apostilbs (asb). Note that the maximum stimulus brightness might be different in different perimeter models.

The sensitivity to light in decibels is defined using the formula below

$$dB = 10 * \log (L_{max}/L)$$

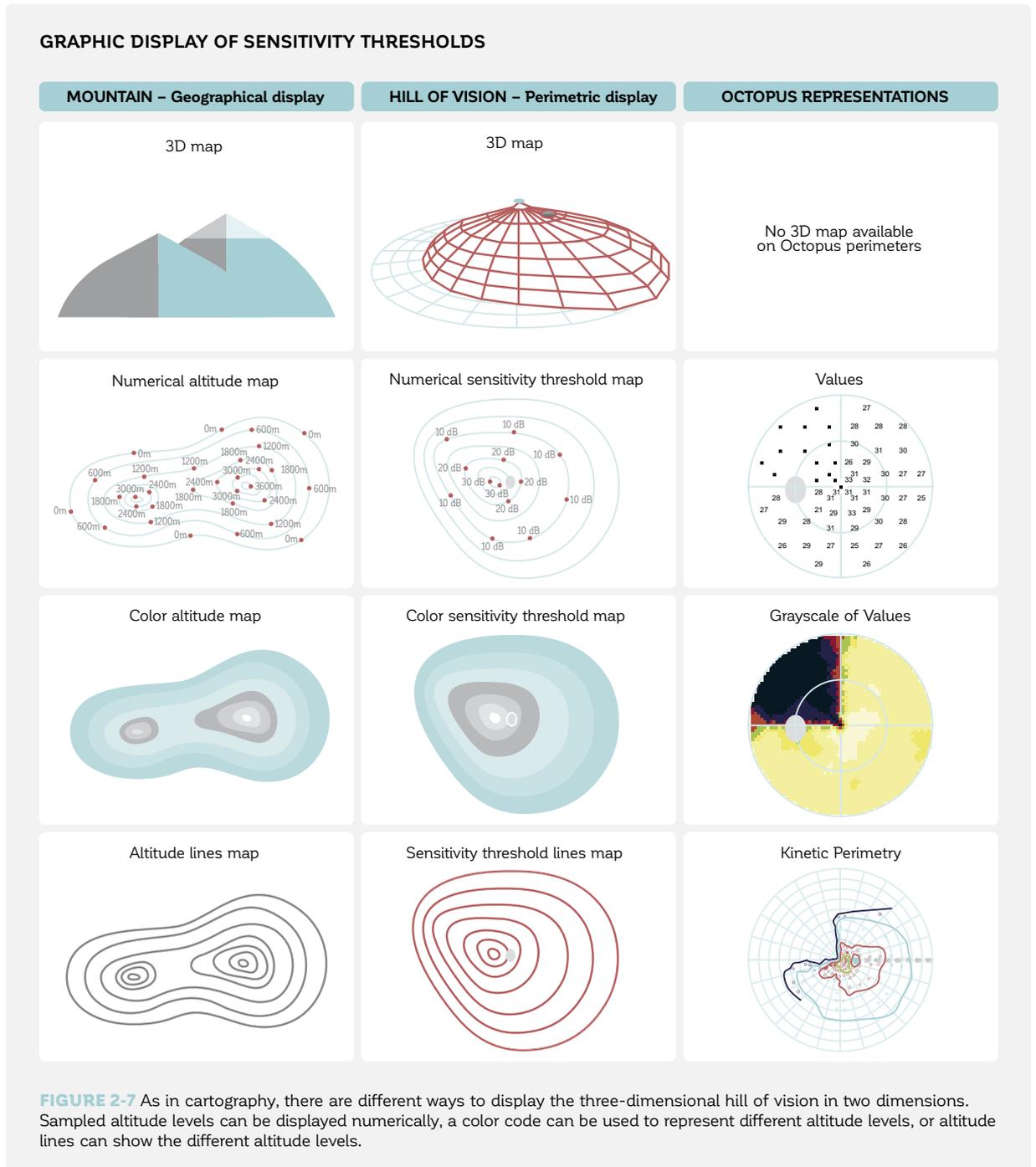
where dB is the sensitivity threshold,  $L_{max}$  is the maximum luminance the perimeter can display, and L is the luminance of the stimulus at the threshold (both expressed in apostilbs).

The logarithmic scale is used to address the large range of luminance values and to relate this range more linearly to visual function. To address the inverse relationship between luminance and sensitivity to light, the inverse of luminance ( $1/L$ ) is used in the formula; and to make sure that near complete visual field loss equals 0 dB, which is intuitive, the maximum stimulus luminance  $L_{max}$  is added to the equation.

Since 0 dB refers to the maximum intensity that the perimeter can produce, its interpretation in terms of stimulus luminance may be different for various visual field devices. This should be kept in mind when switching between different perimeter models. Chapter 12 will focus on how to deal with differences between perimeters in clinical practice.

## GRAPHIC DISPLAY OF SENSITIVITY THRESHOLDS

The three-dimensional hill of vision contains large amounts of information. It may therefore be challenging to appropriately display all aspects of a patient’s visual function from the three-dimensional representation. Cartographers face similar challenges when displaying three-dimensional mountains or hills, and have used



**FIGURE 2-7** As in cartography, there are different ways to display the three-dimensional hill of vision in two dimensions. Sampled altitude levels can be displayed numerically, a color code can be used to represent different altitude levels, or altitude lines can show the different altitude levels.

two-dimensional maps as a solution. Similar display strategies are used to display the hill of vision in two dimensions.

As in geographical maps (FIG 2-7), the various sensitivity thresholds can be displayed numerically (i.e., by sampling certain altitudes to give a feel for the overall shape of the hill or mountain). Color codes for different altitude levels are also often presented on geographical maps. Last but not least, lines of the same altitude level can

provide a good representation of a hill on a map. For perimetry, these lines of equal altitude are referred to as isopters (lines of equal sensitivity).

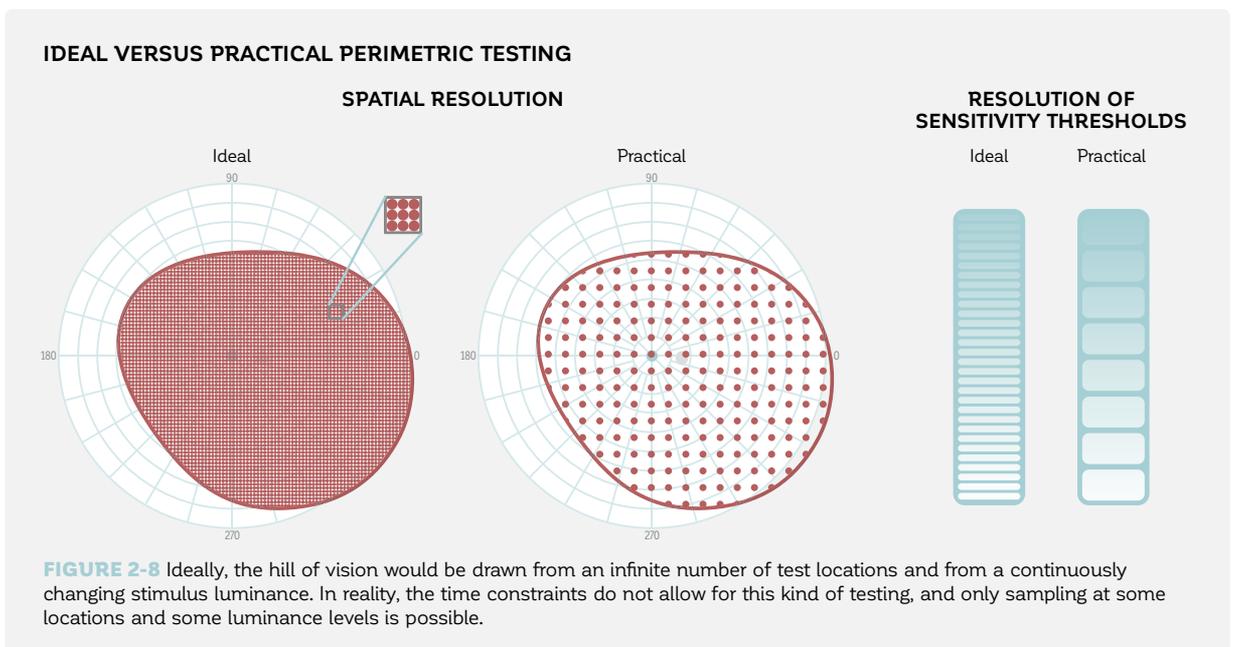
It should be noted that whichever display form is used, there is always some information lost. All three versions are used to display perimetric results, as each emphasizes different clinical information. For more details of the various representations, see Chapters 7, 8, and 11.

# CHALLENGES IN VISUAL FIELD TESTING AND INTERPRETATION

## PERIMETRIC TESTING HAS LOW RESOLUTION

So far, this book has presented perimetry as a very accurate way of continuously showing the stimuli of increasing intensity for the patient. It has also been assumed that thresholding is performed at all locations across the visual field.

From a practical point of view, however, it is nearly impossible to test each location within the visual field (spatial resolution) using each possible light intensity (luminance resolution). This would take too long to be useful in a clinical setting. Therefore, referring back to



the example of the light bulb in a room, the dimmer only has a set number of discrete levels, such as high, medium and low, and there are only a few bulbs to illuminate the room (FIG 2-8).

For perimetry, this means that stimuli are presented at a fixed number of key locations and that only a limited num-

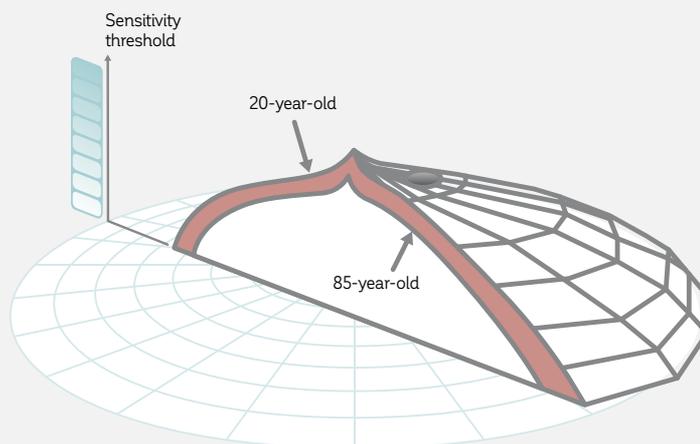
ber of light intensity levels are presented. This approach introduces inaccuracies in the perimetric test. In order to still be able to receive the information necessary for good clinical decision-making, a number of elaborate processes are used in perimetry. This maximizes clinical information and offers a good trade-off between testing time and accuracy. These are described in Chapters 4, 5 and 6.

## NORMAL SENSITIVITIES DEPEND ON AGE AND TEST LOCATION

As already illustrated in the section about the hill of vision, normal sensitivity thresholds depend on the test location and are higher at the center than in the periphery. In addition, the normal hill of vision is affected by age. Normal sensitivity to light in decibels decreases approximately linearly with increasing age, beginning at the age of 20.<sup>1-3</sup> Thus, the hill of vision of a 20-year-old is typically higher than the hill of vision of an 85-year-old person (FIG 2-9).

For these reasons, sensitivity thresholds are challenging to interpret directly in the clinic, because the representations of normal and abnormal values depend on testing- and patient-specific factors. For correct clinical assessment of sensitivity thresholds, a clinician would have to keep normal reference values in mind for all age groups and test locations, in order to correctly interpret the results. That would be a challenging task.

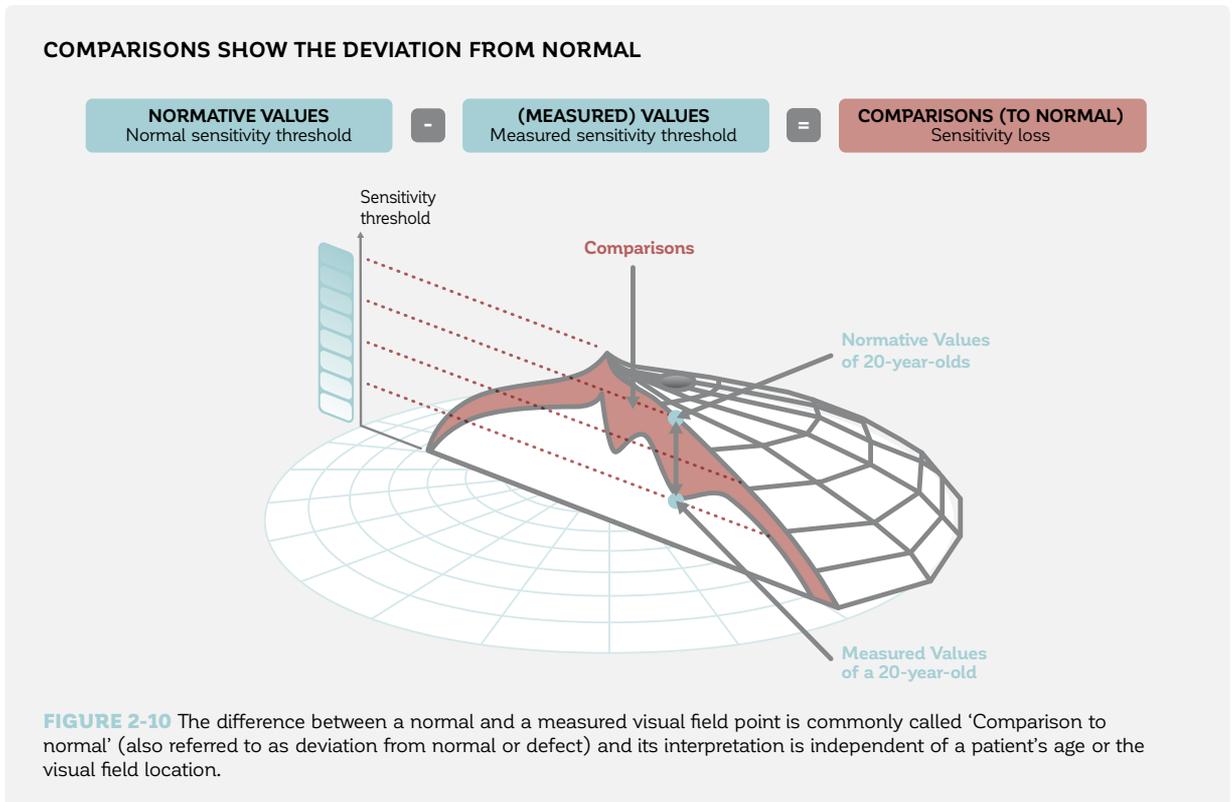
### HILL OF VISION IS AGE- AND LOCATION-DEPENDENT



**FIGURE 2-9** The normal hill of vision shows the highest sensitivity thresholds at the center, with decreasing sensitivity thresholds towards the periphery. Similarly, there is also a decrease in sensitivity thresholds with increasing age at all test locations.

Therefore, distinct normative databases have been developed for most modern perimeters and these databases are used to facilitate clinical visual field interpretation. Normative databases contain normal reference values for each age group and test location (BOX 2B). They are used to compare any measured sensitivity threshold

to the respective normative value for someone of that age. The calculated Comparisons to normal are clinically meaningful, as they relate directly to sensitivity loss (FIG 2-10). Alternative expressions that are commonly used are deviation from normal or defect.



Due to their ease of use, most representations in the Octopus perimeters are based on the Comparisons to

normal and not on the measured sensitivity thresholds. For more information, refer to Chapter 7.

**BOX 2B****NORMATIVE DATABASES IN OCTOPUS PERIMETERS****DESIGN OF A NORMATIVE DATABASE**

By definition, the normative database of a perimeter consists of a pool of visual field data from people with normal vision in all age groups. The challenge associated with generating this pool is to ensure that these normal visual fields are truly normal and that there are sufficient visual fields to account for individual differences.

The standards to be fulfilled for a perimetric normative database are described exhaustively in the ISO norm «Ophthalmic instruments - Perimeters (ISO 12866:1999/Amd1:2008); Amendment A1, Appendix C». All normative databases of Octopus perimeters comply fully with these standards. The typical process to comply with the standards is to perform a clinical study that includes a thorough eye examination and repeated visual field testing.

**DISTINCT NORMATIVE DATABASES FOR DIFFERENT DEVICES AND EXAMINATION PARAMETERS**

Since particular perimeter models vary in design and might use different examination parameters, a stimulus of the same light intensity may be perceived differently on various perimeter models. Therefore, there are distinct normative databases for different perimeter types and settings.

## PERIMETRY HAS OBJECTIVE AND SUBJECTIVE COMPONENTS

In the interest of simplicity, perimetry has been treated as a purely objective procedure, with exact measurements and distinct sensitivity thresholds at each test location. This is true for the equipment and the test conditions. However, there is a subjective element to perimetry, due to the subjectivity of the patients undergoing the test. As a result, there is always a certain amount of normal fluctuation both among different normal individuals, as well as between different measurements of the same individual over a short period of time. The accuracy of the test results is highly dependent on several factors, including the cooperation of the patients, their cognitive and physical abilities, and their decision criteria.<sup>4-6</sup> If the

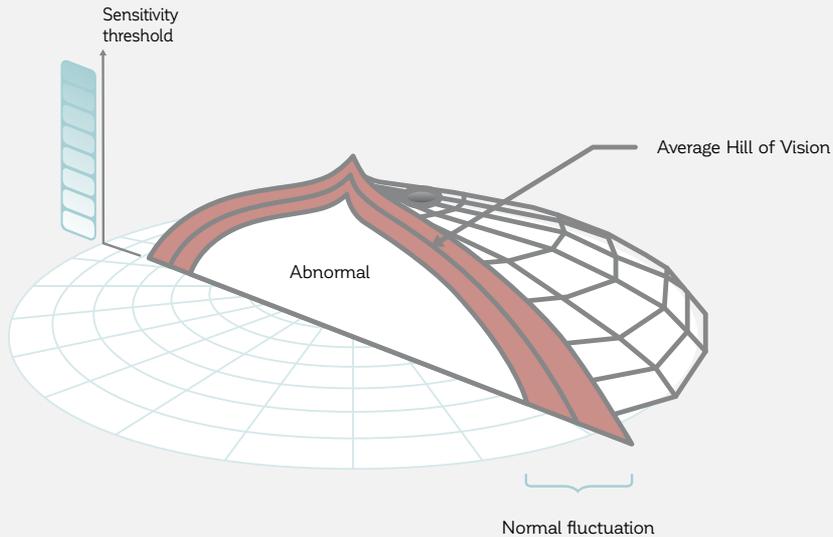
patient does not understand the test, does not pay attention or does not focus continuously on the central target, then the results of the test will be difficult to interpret. Additionally, some patients may be very conservative in their judgements, requiring a more intense stimulus for detection, while other patients may be liberal and accept a less intense stimulus for detection. The most important person to maximize the performance of the patients is the visual field examiner (e.g., a perimetrist or technician). Chapter 3 focuses on potential sources of unreliable and thereby highly fluctuating visual fields and provides practical guidance on how to minimize these factors.

## NORMAL FLUCTUATION DEPENDS ON TEST LOCATIONS AND DISEASE SEVERITY

A further complication in visual field interpretation is the fact that normal fluctuation is not uniformly distributed across the visual field (**FIG 2-11**). Instead, normal fluctua-

tion is smaller at the center of the visual field than in the periphery and is also smaller in areas of good vision than in areas of poor vision.<sup>1,7</sup>

### NORMAL FLUCTUATION IN PERIMETRY



**FIGURE 2-11** Since perimetry contains a subjective, patient-related component, there is always normal fluctuation. Its magnitude depends on both the test location and disease severity.

These two factors must be kept in mind when making clinical decisions based on visual field results. To objectively measure fluctuation around a sensitivity threshold, the frequency-of-seeing (FOS) curve may be used (BOX 2C).

### THE FREQUENCY-OF-SEEING (FOS) CURVE

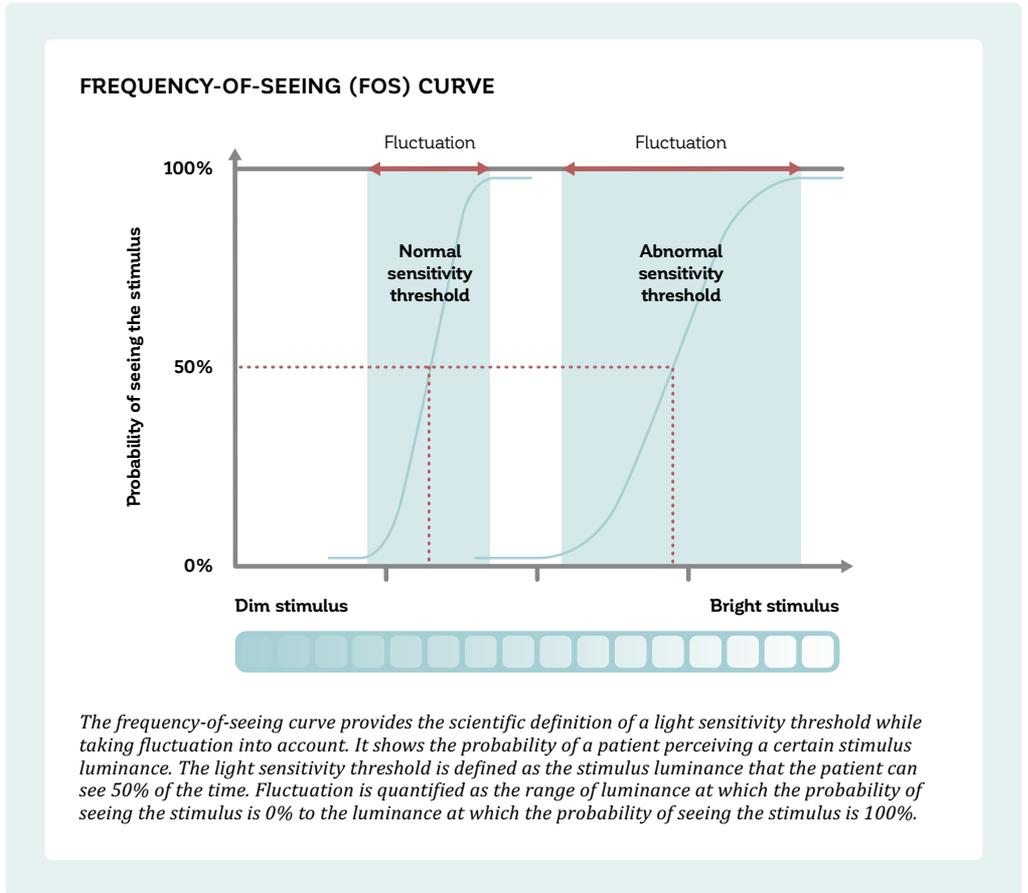
#### BOX 2C

Due to fluctuation, distinct sensitivity thresholds at a given test location cannot be measured precisely. In reality, the same patient always shows slightly varying responses in repetitive testing. In other words, the likelihood of seeing or not seeing a stimulus is probabilistic.

As the luminance (i.e., the light intensity of the stimulus) increases, there is a gradual increase from “unseen” to “seen” responses, so that the probability that a patient will perceive a stimulus changes gradually from 0% to 100%. Because of this, sensitivity thresholds are defined as the stimulus luminance that is perceived with a probability of 50%.

To get a measure of fluctuation, one can show a stimulus of a certain luminance to a patient many times at a given test location and determine how often the patient is able to see it. The probability of perceiving a stimulus can be mapped in a graph as a function of stimulus luminance. When doing this for many different luminance levels, one can generate a frequency-of-seeing (FOS) curve, which describes the probability that a patient will perceive a target as a function of stimulus luminance. This is a useful tool to illustrate the variability associated with the determination of thresholds.<sup>8</sup> In areas of normal sensitivity, the FOS curve is typically steep, indicating that there is less variability. In other words, the patient has a high probability of seeing stimuli that are slightly more intense than the luminance at the threshold, and also a high probability of not seeing stimuli that are slightly less intense than those at the threshold. This is illustrated on the left side of the figure by the steep shape of the FOS curve.

In areas where defects are present, the FOS curve is typically shallow, indicating that there is greater variability. In other words, there is a gradual change in the probability of detecting stimuli that are higher and lower than the luminance at threshold. This is illustrated on the right side of the figure by the shallow shape of the FOS curve.



## CLINICAL STANDARD FOR VISUAL FUNCTION TESTING

Even though perimetry has low resolution and contains subjective, patient-related components resulting in normal fluctuation, perimetric testing is useful to assess visual fields in clinical practice. It remains highly important because visual field function is most directly related to a patient's quality of life and ability to perform activities of

daily living, which are the most important factors for the patient. Additionally, slowly progressing diseases such as glaucoma can be followed accurately through all stages of the disease. Perimetry is therefore an indispensable tool for every glaucoma specialist.

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## CHAPTER 3

# HOW TO PERFORM PERIMETRY YOU CAN TRUST

## INTRODUCTION

### PERIMETRY – A SUBJECTIVE TEST

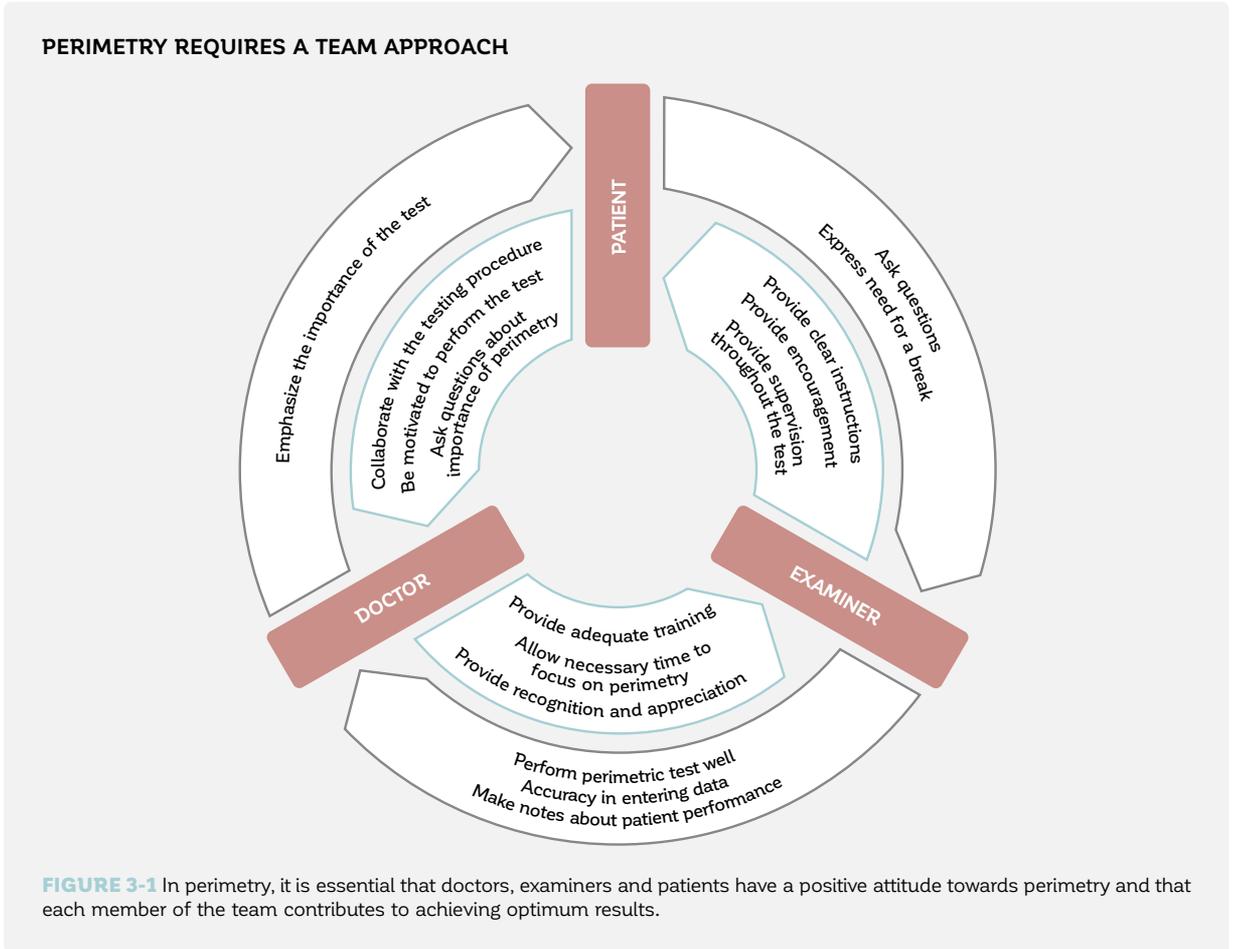
Perimetry is an elaborate test that depends, to a great extent, on subjective factors such as the patient's cooperation and comfort, as well as on using the correct patient information and set-up. Due to this subjective component, untrustworthy visual field tests are common. The extent of untrustworthy results largely depends on how well perimetry is performed in clinical practice and has been reported to range from 3% to 29% of all visual field tests performed.<sup>1-5</sup>

In view of the relatively high occurrence of untrustworthy visual fields, it is extremely important to make sure that the time invested in perimetry is well spent, because poorly performed perimetric tests have hardly any diagnostic value. It therefore pays to take the time and care necessary to obtain trustworthy results by following certain rules to avoid the most common pitfalls.

## PERIMETRY – NEED FOR A TEAM APPROACH

Three key players are involved in perimetry: the patient, the examiner and the eye doctor. All three should work collaboratively to obtain optimal perimetric test results.

FIG 3-1 shows how each member of the team can contribute. When this approach is successfully implemented, perimetry can be performed in a positive atmosphere.



## THE IMPORTANT ROLE OF THE DOCTOR

### THE DOCTOR-PATIENT RELATIONSHIP

Patients who understand why perimetry is needed and its importance to their eye care are likely to be more motivated to undergo a perimetric test. Due to the relationship

and trust they establish with their patients, doctors are in the best position to convey the importance of perimetry to their patients.

## THE DOCTOR-EXAMINER RELATIONSHIP

Eye doctors should also clearly convey the importance of perimetry to the visual field examiners who work with them in the clinic. For example, the doctor is responsible for ensuring that the visual field examiners understand the importance of trustworthy perimetric results to the clinical decision-making process. The visual field examiners should know that the doctor has a genuine interest in building their perimetric knowledge and skills. Towards

this goal, the doctor must provide training and give feedback to the examiners. It is also crucial for the doctor to have reasonable expectations in terms of the time required to perform trustworthy perimetric tests. Doctors should arrange for their visual field examiners to be able to dedicate time exclusively to performing perimetric tests. This means that they should be free of other tasks that might reduce the examiner's focus on the patient.

## THE IMPORTANT ROLE OF THE VISUAL FIELD EXAMINER

The visual field examiner is in a unique position to have an impact on the quality of the perimetric results in two ways. Not only are examiners responsible for correctly

setting up the perimeter, they also directly oversee the patient during the test.

### ROLE IN CORRECTLY SETTING UP THE PERIMETER

The visual field examiner is responsible for entering the correct patient information in the perimeter. This is crucial because this information has a direct impact on whether the results of the test can be trusted. Diligence

in performing this aspect of perimetry can significantly reduce the number of untrustworthy tests and interpretation errors. The examiner is also responsible for ensuring that an adequate refractive lens is used.

### THE EXAMINER-PATIENT RELATIONSHIP

A crucial role of the visual field examiner is to ensure that the patients perform perimetry to the very best of their capacity each time they take a test. To give their best performance, patients need to be comfortably positioned at the perimeter, they need to know what is expected of them, and they need to understand how to perform the test. A competent examiner will ensure that the patient is not only correctly positioned, but also comfortable. Similarly, a good examiner will convey what is expected of the patient and will give clear instructions on how to perform the test. The examiner can also provide brief rest periods by pausing the test if this will be helpful to the

patient. Additionally, the patient should be encouraged to communicate to the examiner any difficulties or problems encountered, and when a brief rest period would be beneficial.

There is more, however, to the role of a visual field examiner. Outstanding examiners will have taken perimetric tests themselves and will understand how the patient feels during the test. This compassionate approach will go a long way in ensuring patient cooperation and will allow the examiner to give genuine encouragement to the patient when needed during the test.

# HOW TO PERFORM VISUAL FIELD TESTING

## SETTING UP THE PERIMETER

Perimetry should be performed in a distraction-free environment, to enable the patient to concentrate on the perimetric test (FIG 3-2). The room should be quiet, with no activity distracting the patient, and should be at a comfortable room temperature. The cupola should be kept clean and free of dust and particles. Additionally, the room should be dimly lit, to prevent stray light from influencing the perimetric result. A dimly-lit environment is essential when a cupola perimeter, such as the Octopus 900 is used, but is also helpful for non-cupola perimeters.

Ideally, perimetry should be performed in a room dedicated solely to this purpose. However, if the layout of the clinical practice does not offer a stand-alone perimetry

room, opaque curtains around the perimeter and earmuffs offer a cost-effective alternative.

The perimeter is automatically calibrated each time it is turned on. It is important for the calibration to take place in the same lighting conditions as those used during perimetric testing. Calibration can take up to two minutes and should be performed prior to testing patients. Thus, the perimeter should be turned on prior to the patient visit.

Ideally, patient data (date of birth, refraction, etc.) are entered before the patient enters the room. If an electronic medical record system is in use, it will automatically populate the information to the perimeter.

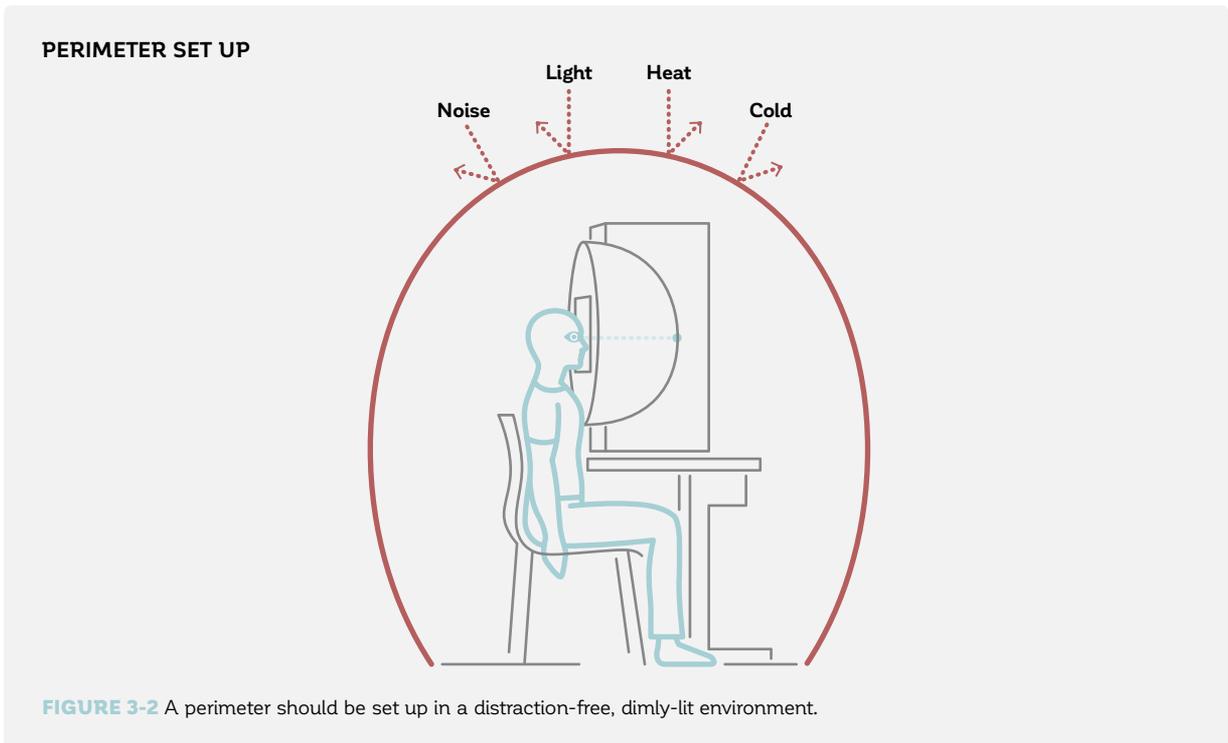


FIGURE 3-2 A perimeter should be set up in a distraction-free, dimly-lit environment.

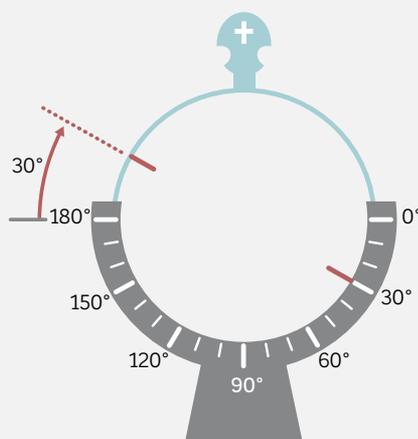
## PLACING AN ADEQUATE TRIAL LENS

The trial lens calculator is helpful in determining the adequate spherical and cylindrical trial lenses, based on the patient's current refraction and age. It is vital to ensure that the patient's refractive data is up-to-date and it is best practice to determine this prior to each test. The correct trial lens should be put into the trial lens holder prior to seating the patient. Trial lenses with a narrow metal rim should be used, to prevent the rim of the trial lens from blocking the patient's field of view. If more

than one trial lens is used, the spherical correction should be placed closest to the patient's eye. Special attention should be given to the orientation of cylindrical lenses, which should be oriented in the angle of the astigmatism (FIG 3-3).

To confirm that adequate refraction is used, the examiner should position the patient and ask whether the fixation target is clearly visible.

### PLACEMENT OF CYLINDRICAL TRIAL LENSES



**FIGURE 3-3** Placement of a cylindrical lens for a patient with a cylindrical correction of 30°, seen from the examiner's perspective.

## INSTRUCTING THE PATIENT

Due to the subjective components involved in perimetry, careful patient instruction is fundamental to achieving trustworthy results. Patients will be able to cooperate more effectively and produce more consistent results if they understand what is expected of them and why the test is being performed.

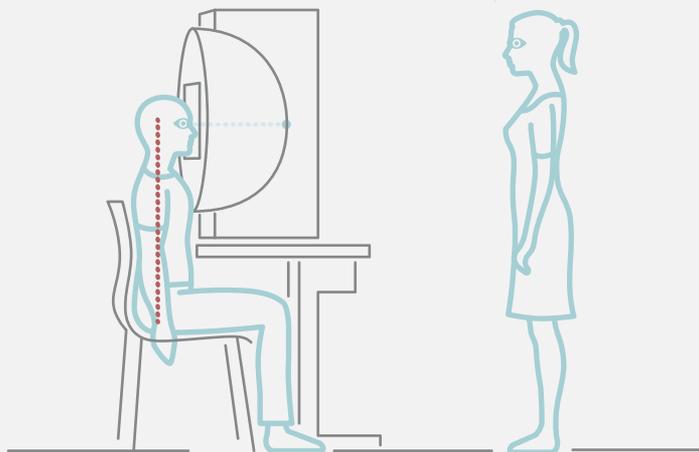
The visual field examiner should therefore take the time to explain the aim of the test, what the patient should expect to see, and what the patient is expected to do (FIG

3-4). It can be helpful for examiners to take a perimetry test themselves, in order to gain a better understanding of what patients are experiencing.

It is fundamental to ensure that the patients know that they are not expected to see all stimuli and that sometimes no stimuli are presented. This will help to reduce some of the potential anxiety experienced by patients, who should also know that they can pause the test if they experience fatigue or have questions.

### STEP-BY-STEP PATIENT INSTRUCTIONS

1. Perimetry tests your central and peripheral vision.
2. Be relatively still once positioned.
3. Always look straight ahead at the fixation target.  
Do not look around the bowl for stimuli.
4. Press the response button whenever you see the stimulus.
  - a. The stimulus is a flash of light.
  - b. Only one stimulus is presented at a time.
  - c. The stimulus might appear anywhere.
  - d. Some stimuli are very bright, some are very dim,  
and sometimes no stimulus is presented.
  - e. You are not expected to see all stimuli.
  - f. Do not worry about making mistakes.
5. Blink regularly to avoid discomfort.
  - a. Don't worry about missing a point, the device does not  
measure while you blink.
6. If you feel uncomfortable or are getting tired
  - a. Close your eye for a moment, the test will automatically stop.
  - b. The test will resume once you open your eye.
7. If you have a question
  - a. Keep the response button pressed; this will pause the test.



**FIGURE 3-4** Proper instructions to the patient are essential for the patient to understand their task and consequently to perform perimetry well. The sequence of instructions listed in this Figure can be used.

## SETTING UP AND POSITIONING THE PATIENT

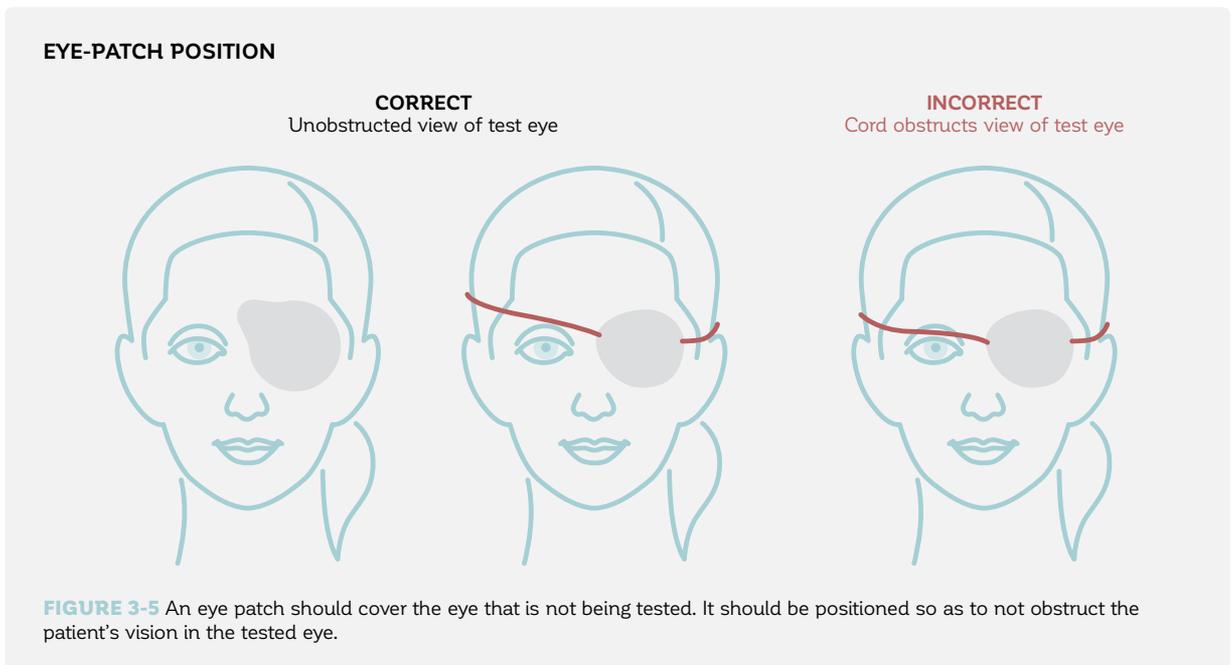
Trustworthy and accurate perimetric results are more likely to be obtained when the patient is comfortable during the test. It is also important to ensure that the pa-

tient is correctly positioned and that the non-tested eye is covered. The optimum ways to ensure patient comfort and correct alignment will be discussed in this section.

### CORRECT EYE PATCH POSITION

Before fully positioning the patient, the eye not being tested should be covered with an eye patch that allows the patient to blink freely (FIG 3-5). If the eye patch is maintained in place with a cord, it is important to ensure that the cord does not obstruct the patient's field of view

for the tested eye. If an adhesive eye patch is used, it is important to make sure that it adheres well all around the eye. All eye patches should be translucent, to avoid adaptation to the dark by the untested eye, which would alter the results of subsequent testing of that eye.<sup>6</sup>

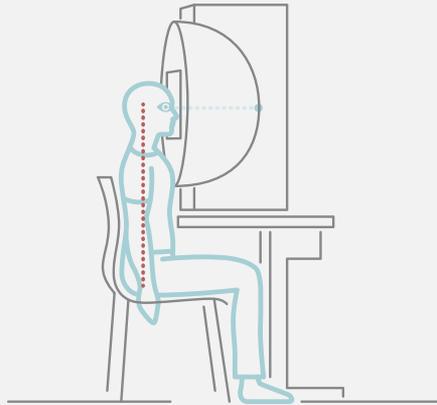


### CORRECT PATIENT POSITION

The patient should be seated in a comfortable position that can be easily maintained throughout the test. A height-adjustable chair with a backrest and, if available, armrests should therefore be used. The perimeter should be placed on a height-adjustable table to ensure that the

patient is comfortable. Different Octopus models offer different types of positioning: the Octopus 900 offers a straight-upright patient position and the Octopus 600 offers a forward-leaning position.

**STRAIGHT-UPRIGHT POSITION**



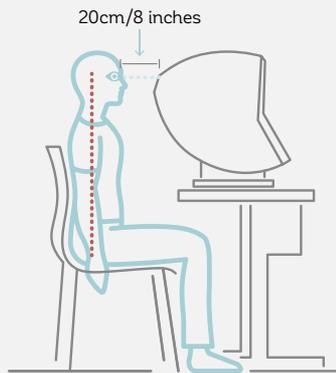
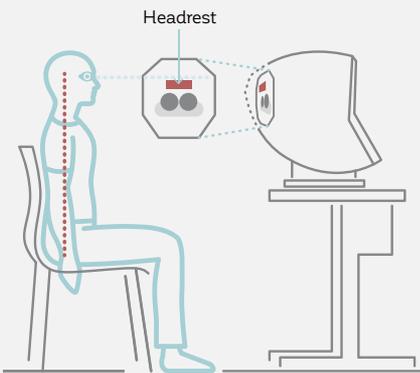
**FIGURE 3-6** This drawing illustrates the correct straight-upright patient position recommended for the Octopus 900 and older Octopus models.

For the Octopus 900 and all older Octopus models, the patient should sit as close as possible to the device. Then the height of the table should be adjusted until the patient's forehead touches the headrest. The patient should place

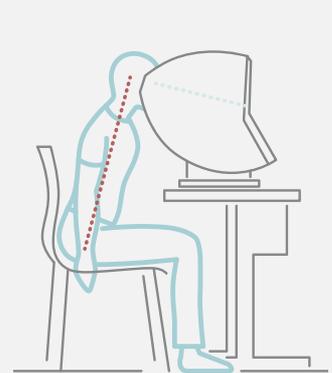
his or her chin on the chin rest and forehead on the headrest (FIG 3-6). It is important to ensure that the patient maintains direct contact with the device throughout testing.

**FORWARD-LEANING POSITION**

**1. PREPARATION**



**2. FINAL POSITION**



**FIGURE 3-7** This drawing illustrates the correct forward-leaning patient position recommended for the Octopus 600.

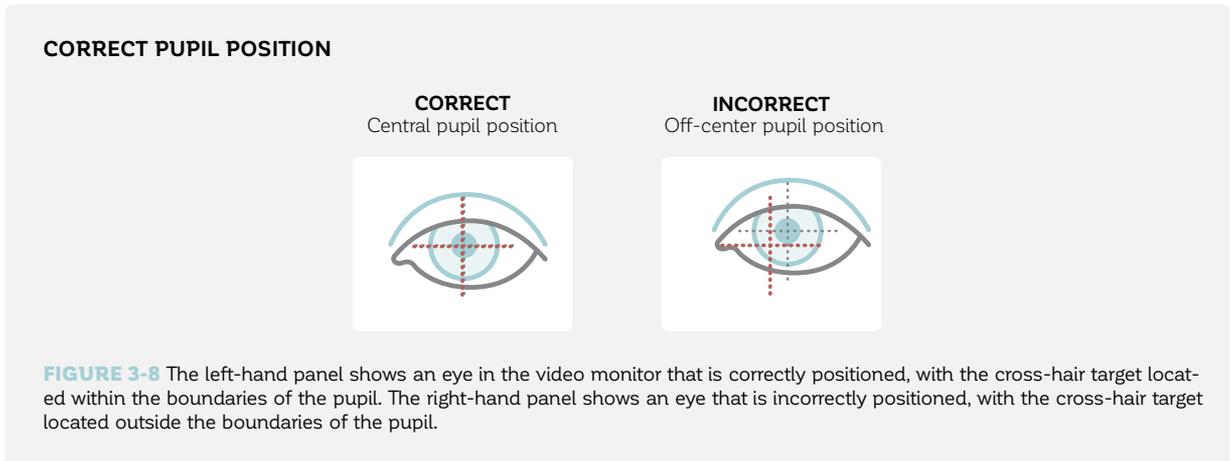
For the Octopus 600, the patient is positioned in a forward-leaning and downward-gazing position (FIG 3-7). The correct position is obtained by first seating the patient in an upright position at a distance of approximately 20cm/8 inches, with the eyes at the upper level of the

headrest, to allow enough space to lean forward. By inclining from this position, the patient is automatically positioned at the correct height. The patient's head leans in fully onto the headrest, providing stable fixation.

### CORRECT EYE POSITION

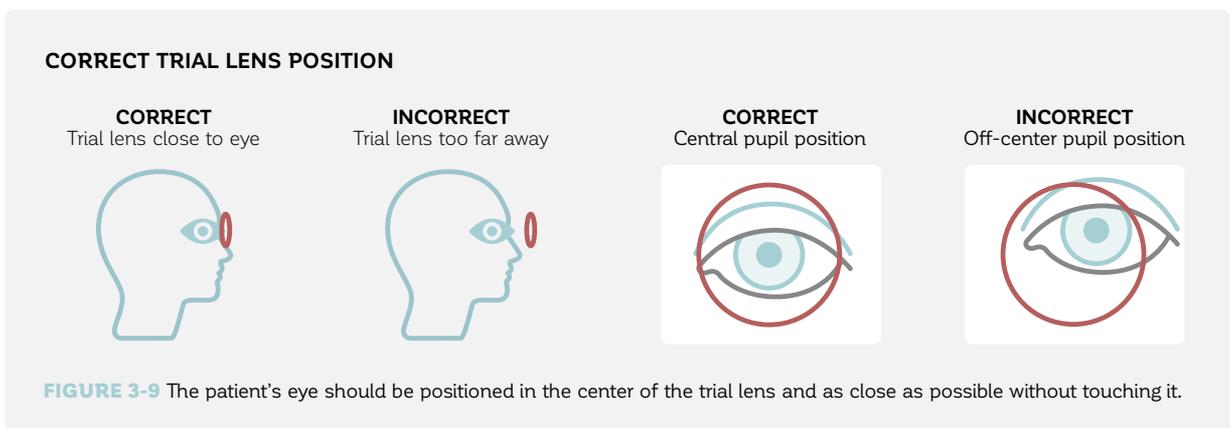
Once the patient is correctly positioned in the device, it is important to ensure that the eye is also correctly positioned. Overall, the eye should be well-aligned with the fixation target and should be relatively close to the trial

lens. However, the lens should not touch the eyelashes, allowing the patient to blink freely and avoiding the lens being smeared with make-up.



The Octopus perimeters provide a video monitor so that the examiner can see the patient's eye. When the patient looks straight at the fixation target, the pupil should be aligned with the cross-hair target provided on the video

monitor. The patient is correctly positioned when the cross-hair target is within the boundaries of the pupil (**FIG 3-8**). The position of the pupil can be adjusted by changing the position of the chin rest.



It is important for the patient's eye to be as close as possible to the trial lens, in order to avoid the typical "ring" defect (i.e., trial lens rim artifact) that occurs when the

patient is positioned too far away from the trial lens (**FIG 3-9**). The eyelashes should not touch the lens, however.

When a visual field test assesses both the central and the peripheral visual fields, it will be necessary to remove the trial lens for the part of the test that covers the periphery,

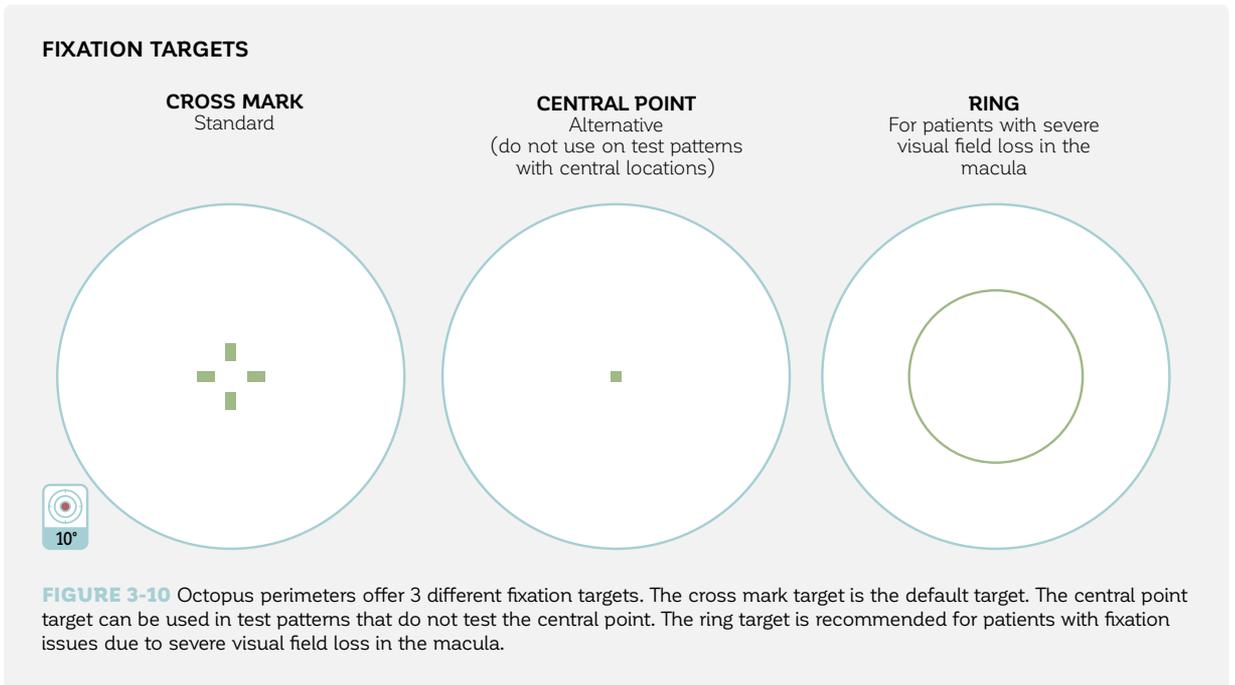
in order to avoid trial lens rim artifacts. Also, visual fitness to drive is assessed binocularly (both eyes open). In this case, no trial lens should be used.

**CORRECT FIXATION**

It is essential for patients to maintain steady fixation throughout the test. The Octopus perimeters offer three different fixation targets (FIG 3-10) to promote steady fixation in as many patients as possible. Most patients will be able to maintain fixation using the standard cross mark fixation target. If patients have difficulty understanding where to look when the cross mark fixation target is used, the central point fixation target can be used, provided that the test pattern does not test the central point. For this reason, the central point fixation

target is not recommended for the G, M, N and D patterns (see Chapter 5) and for any pattern where the foveal threshold function is turned on.

Finally, some patients with severe visual field loss in the macula region may not be able to see the standard cross mark fixation target. In these patients, the use of the larger ring target is recommended, to provide an estimate of the location of the fixation target.



**FIGURE 3-10** Octopus perimeters offer 3 different fixation targets. The cross mark target is the default target. The central point target can be used in test patterns that do not test the central point. The ring target is recommended for patients with fixation issues due to severe visual field loss in the macula.

## MONITORING THE PATIENT DURING THE EXAMINATION

To ensure good patient cooperation and trustworthy results, it is essential to monitor patients throughout the examination and not leave them unattended and unmonitored. During the test, it is helpful to encourage patients by telling them that they are doing well and by letting them know how much of the test they have already completed. This will help them to remain attentive and may reduce anxieties that might negatively influence the results.

Particular attention should be paid during the first minute of the test, to ensure that patients have understood what they are expected to do during the test. If a patient shows an unusual response (e.g., no response at all, a re-

sponse even if there is no stimulus, or unsteady fixation), the test should be interrupted and the patient should be reinstructed. If the results seem compromised, it is recommended to start a new test and discard the compromised one. It is important to note, however, that patients with impaired vision often do not respond due to their condition and not because they answer unreliably.

If a patient shows inconsistent behavior, the examiner should make a note of this on the examination file, to communicate this information to the clinician. The knowledge that the test has reduced reliability may influence the interpretation of the test.

### USE OF FIXATION CONTROL

Loss of fixation is a primary reason for unreliable visual field results. Therefore, all current Octopus devices have a built-in Fixation Control for static testing that can track the patient's pupil at all times and prevent fixation errors. With Fixation Control, the test is stopped automatically if the patient loses fixation (due to blinking, searching for stimuli or head movements) and automatically restarted once proper fixation is regained. Missed stimuli are automatically repeated later during the test. If fixation loss occurs for more than just a few seconds, a warning message will alert the examiner to properly reposition and reinstruct the patient.

Fixation Control consists of several separate control mechanisms, as outlined in [FIG 3-11](#), which can be turned on and off. It is recommended to keep each of the Fixation

Control mechanisms active. However, since some patients might not be able to maintain steady fixation for pathological reasons (i.e., reduced central vision, unsteady pupil or nystagmus), individual mechanisms within Fixation Control can be turned off individually, to make patient testing possible. If it is necessary to turn off some mechanisms, careful patient monitoring is key and it is good practice to make a note in the patient file about the patient's ability to maintain fixation. The clinician should then interpret the results in the light of this information and should consider that the test might have reduced reliability.

[FIG 3-11](#) provides more information about the different control mechanisms of Octopus Fixation Control. Note that the configuration depends on the Octopus model.

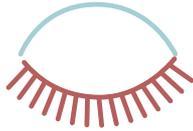
**FIXATION CONTROL PREVENTS FIXATION LOSSES**

**BLINK CONTROL**

**RUNNING**



**PAUSED**



**Prevents fixation loss due to blinking.**

- Detects eye closure due to blinking or falling asleep
- Testing occurs only if the patient’s eye is open
- Allows the patient to blink normally
  - Prevents dry eyes
  - Increases patient comfort
- Ensures that no stimuli are missed due to blinking

**CONTACT CONTROL**

**RUNNING**



**PAUSED**

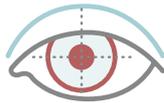


**Prevents loss of contact with the perimeter.**

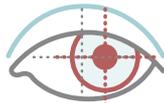
- Detects contact with the headrest or chin rest
- Testing occurs only if the head is in contact with the device
- Ensures that the head remains close enough to the device to minimize lens rim artifact

**PUPIL POSITION CONTROL**

**RUNNING**



**PAUSED**



**Prevents fixation losses due to incorrect pupil position.**

- Detects off-centered pupils due to incorrect fixation or head movement
- Testing occurs only if the pupil is correctly centered
- Ensures correct gaze direction

**DART CONTROL**

**RUNNING**



**PAUSED**

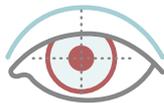


**Prevents fixation loss due to rapid eye movement.**

- Detects rapid eye movement when the patient is searching for stimuli
- Testing occurs only if the pupil is steadily fixating
- Ensures correct gaze direction

**AUTOMATED EYE TRACKING (AET)**

**RUNNING**



**ADJUSTING POSITION**



**Automatically adjusts the patient’s eye position.**

- Moves the headrest and chin rest to keep the eye in the center of the trial lens
- Maintains optimum position even if the patient is moving around slightly
- Reduces trial lens rim artifacts due to off-centered eye position

**FIGURE 3-11** Fixation control prevents fixation losses by automatically pausing the test during blinks, loss of contact with the device, off-centered pupils and rapid eye movements. The test is automatically restarted once optimum conditions are achieved. Further, Automated Eye Tracking automatically centers the pupil. Note that not all mechanisms are available on the different Octopus perimeter models.

# COMMON PITFALLS TO AVOID

There are many factors that can lead to visual field tests that cannot be trusted. By paying attention to and managing these factors, a well-trained examiner will have a substantial positive influence on the quality of the visual field results and on the subsequent clinical decisions. Therefore, this section is dedicated to the most common pitfalls in perimetry and provides guidance on how to avoid them.

Patient behavior (i.e., lack of patient cooperation), errors

in the set-up procedure, and external obstructions blocking the stimuli from reaching the retina, are all commonly occurring sources of untrustworthy visual field results. Many of these pitfalls can be avoided by paying close attention to the set-up procedure, by observing the patient carefully during testing, and by making adjustments or repeating instructions if necessary, which is the focus of this section. Chapters 7 and 8 provide information on how to detect visual field results that cannot be trusted after the test is completed.

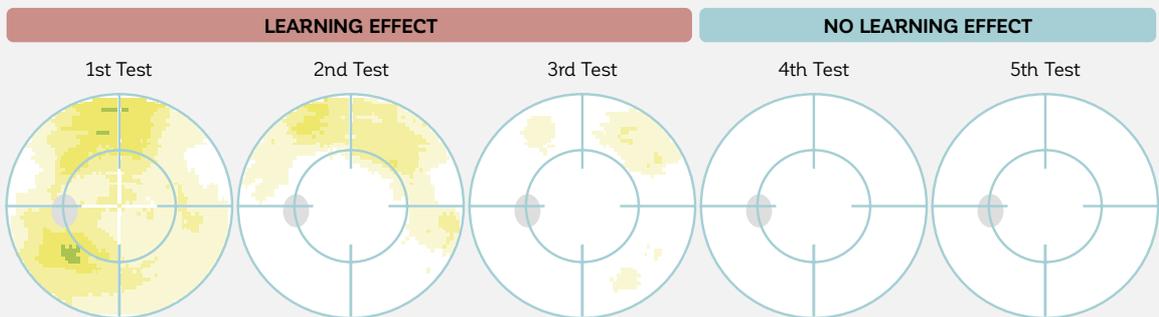
## INCONSISTENT PATIENT BEHAVIOR

### LEARNING OR PRACTICE EFFECT

When taking their first tests, patients often do not fully understand the nature of the test and hesitate to press the button when seeing faint stimuli near the sensitivity threshold. This translates into visual field results that are worse than the patient's true visual field, as illustrated in [FIG 3-12](#). In subsequent testing, the patients then perform better and their visual field results resemble their true visual function more closely.

While learning and practice effects most often occur for patients taking their first visual field examination, they can also occur when switching from one perimeter to another, due to small differences in the design (see Chapter 12).

#### EXAMPLE OF A LEARNING EFFECT



**FIGURE 3-12** Example of a patient with normal vision with a strong learning or practice effect from the first to third visual field tests. The fourth and fifth tests represent the true visual field of the patient.

While learning or practice effects cannot always be prevented, their frequency can be reduced by careful patient instruction and observation. Running a practice test prior to real testing is a good procedure if time allows. Careful observation during the first minute of the test is

also helpful. If a patient does not understand the task of performing perimetry, the patient will often be hesitant during the first part of the test, or will not press the response button at all. If this is observed, it is recommended to interrupt the test and reinstruct the patient.

### FATIGUE EFFECT

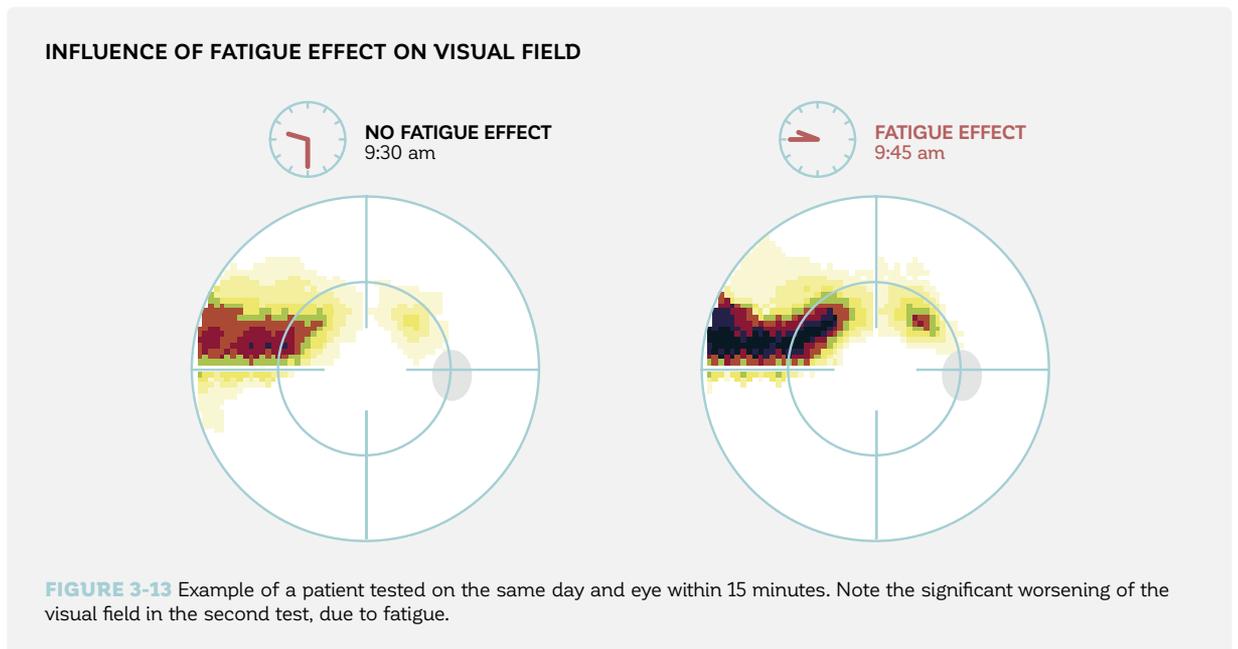
Visual field tests require alertness and attention. When patients become tired, their attention level may decrease and their answers may become less consistent, resulting in a visual field that is worse than the patient’s true visual field (FIG 3-13).<sup>7-11</sup>

To reduce fatigue effects for patients who have difficulty concentrating for long periods of time, it may be appropriate to use tests that are shorter in duration, despite the associated loss of accuracy. This may generate more meaningful visual field results by reducing the unreliability due to the fatigue effect. Individual differences exist in how quickly patients experience fatigue, and this should be considered when selecting a test.

To further reduce fatigue effects, patients should be ad-

vised to blink regularly to avoid dry eyes and discomfort, given that Fixation Control is active. Artificial tear drops prior to the test may also reduce fatigue effects due to dry eyes. Additionally, patients should be encouraged to take brief rests, by closing their eyes to relax, if they feel that they are getting tired. Usually, this adds only a few seconds to the test duration, but significantly improves the reliability of the results. Furthermore, using a beeping sound upon each stimulus presentation may help the patients to concentrate better on the test. BOX 3A provides more information about the advantages and disadvantages of this option.

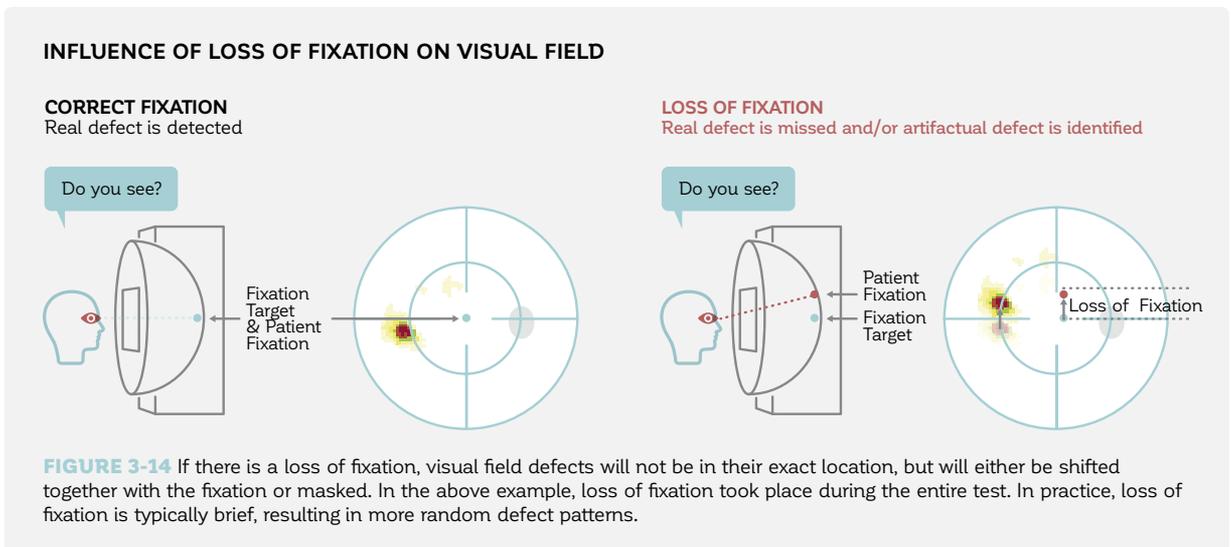
Sometimes fatigue is noticeable as drooping eyelids. In such cases, it is best to actively interrupt the test for a while and to allow the patient to rest before continuing testing.



## LOSS OF FIXATION

If a patient does not consistently fixate on the central target, the test will lose its reference point and it will not be possible to identify the location of abnormal visual field points (FIG 3-14). This is called fixation loss and is one of the most common sources of unreliable fields.<sup>12</sup> It occurs especially if the patient is insecure about his or her performance and starts looking around, searching for stimuli. To avoid fixation losses, it is therefore crucial to explain carefully to the patient that it is perfectly normal not to be able to see all of the stimuli.

The Octopus Fixation Control should be enabled whenever possible, to avoid unreliable visual fields due to fixation losses. It should only be turned to a lower setting or completely turned off if a patient is not able to maintain steady fixation, for pathological reasons (i.e., reduced central vision, unsteady pupil or nystagmus). Direct observation of the patient's fixation behavior early in the test can also be helpful in this regard.



## ADVANTAGES AND DISADVANTAGES OF USING SOUNDS UPON STIMULUS PRESENTATION

### BOX 3A

A beeping sound upon stimulus presentation may be helpful for some patients, to maintain their attention during the perimetric test, because it provides them with a steady rhythm to follow. Additionally, it provides reassurance to the patient that the test is running and everything is working normally.

However, the beeping sound may also encourage patients to press the response button even though they cannot see a stimulus. This may increase false answers, resulting in unreliable visual fields. In addition, if more than one perimeter is in a room, the beeping sound of neighboring machines may be distracting.

By default, it is thus recommended to turn the beeping sound off and to only use it for selected patients that have difficulties with maintaining concentration throughout the test.

### LACK OF PATIENT ATTENTION

Visual field tests require the patient's full attention. Distractions such as noise can negatively influence the patient's test performance. In addition, some patients experience anxiety when performing visual field tests, due to fear that they are not performing well, or anxiety about the outcome.

Soothing and encouraging words from the visual field technician can strongly reduce these anxieties and increase the reliability of the results. Distractions should also be reduced to a minimum. If the clinic layout does not offer a stand-alone perimetry room, light-dimming curtains around the perimeter and ear muffs can offer a cost-effective alternative.

### TRIGGER-HAPPY PATIENTS

Some patients, consciously or unconsciously, want to positively influence the result of the visual field test (e.g., if their ability to drive is at stake, or if they fear a bad diagnosis). These patients may be trigger-happy, pressing the response button even if they do not see a stimulus. False positive trials where no stimuli are presented are used to detect trigger-happy patients (for more details, see Chapter 7). It is important to watch for false positive

answers carefully during the examination. If a patient responds to more than one false positive stimulus during the test, it will be helpful to interrupt the test immediately and reinstruct the patient, in order to avoid an unreliable result. Note that a beeping sound upon stimulus presentation may encourage trigger-happy patients to press the response button and it is thus recommended not to use this, except in specific situations.

## MISTAKES IN THE SET-UP PROCEDURE

### ACCURATE ENTRY OF PATIENT INFORMATION

Patient data, such as date of birth and refraction, need to be entered in the perimeter. It is important to ensure that this information is accurate. For example, if the wrong date of birth is entered, most representations of the visual field test will be inaccurate, because each set of

measured sensitivities is compared to the data for an average normal person of the same age, rather than an average normal person who is younger or older. **FIG 3-15** illustrates the influence of incorrect patient age on the patient's visual field.

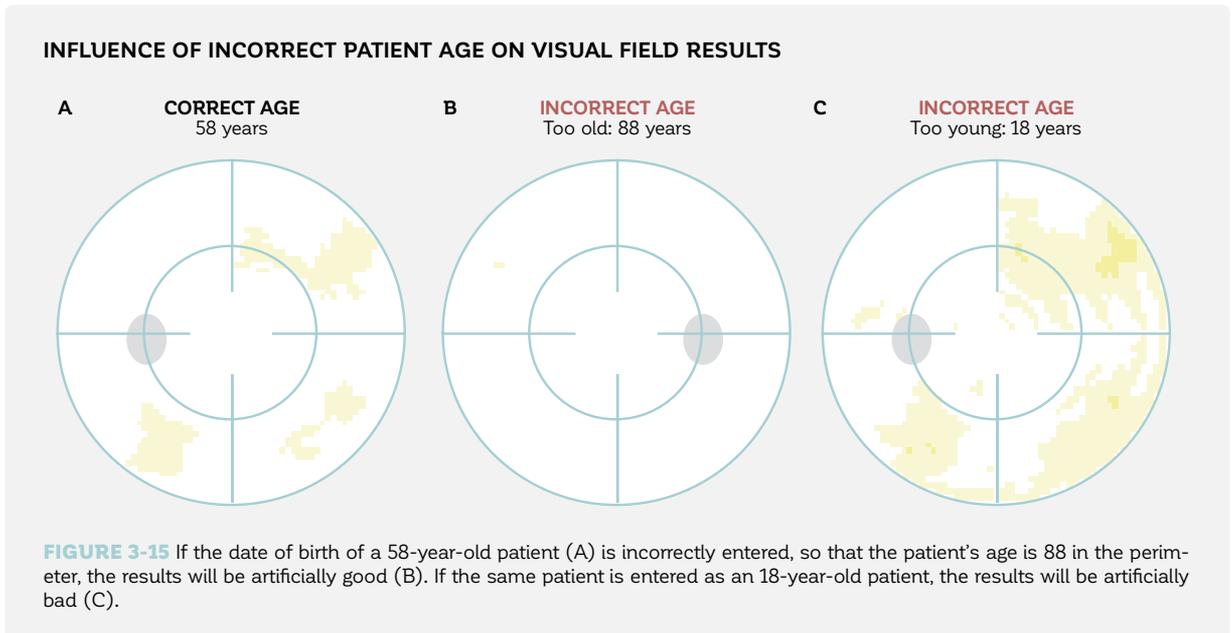
### INADEQUATE CORRECTION OF REFRACTIVE ERROR

Inadequate correction of refractive error can lead to a blurring of the stimulus. If the patient does not have a sharp image of the stimulus, the visual field results will be worse than the patient's true visual field. Additionally, a lens with too much plus power can lead to an artificially enlarged visual field, while a lens with too much minus power will have the opposite effect.

refraction for a patient. To avoid this, it is recommended to check the refraction on the same day as the perimetric test. Even if the patient's refraction has been checked previously, it is possible that it may have changed since then, especially among older patients.

The first source of error is that the patient has been incorrectly refracted, or that the examiner uses the wrong

The second source of error is the incorrect choice of trial lens. It is important to consult the user manual for the respective perimeter, as the choice of trial lens depends on the perimeter model. The paragraphs below describe



the choice of trial lens for the current Octopus models 900 and 600.

Patients need their far-distance correction for relaxed vision. Depending on age, an added near-distance correction for presbyopia is also needed, because perimeters test at near distances. It is important to use the adequate correction for presbyopia proposed by the perimeter's manufacturer, and not the patient's reading glass prescription. Special attention should be given to noting the sign (plus or minus) of the correction. If a minus lens is employed when a plus lens should have been used, the patient's vision may become blurry.

To save time and avoid mistakes, it is recommended to always use the built-in trial lens calculator to determine the required refractive lens. The trial lens calculator always uses the patient's actual best far-distance correction. It then automatically calculates the necessary age-dependent near-distance correction. It determines and recommends the trial lens with the lowest possible power, in order to minimize the risk of artifacts. **BOX 3B** presents the underlying assumptions of the trial lens calculator.

It is best practice to ask each patient prior to starting the test whether they can see the fixation target sharply and, if necessary, adjust the refraction so as to avoid inadequate correction of the refractive error.

## RATIONALE USED IN THE DESIGN OF THE TRIAL LENS CALCULATOR

### BOX 3B

### DETERMINATION OF APPROPRIATE SPHERICAL LENS

The current Octopus perimeter models 600 and 900 present stimuli at a distance of 30 cm (11.8 inches) from the eye. This corresponds to an approximate refraction of + 3.25 diopters (D), as calculated using the following formula:

$$\text{Power (D)} = 1/\text{stimulus distance (m)} = 1/0.3 = 3.33$$

To enable the patient to focus at this distance, the patient's far-distance refraction values are needed. Depending on the patient's refraction, different scenarios occur:

**Normally sighted patients:**

Young emmetropic patients can accommodate at 30cm, so they do not need an additional trial lens. With increasing age, patients gradually lose their ability to accommodate their eyes (i.e., to change their lens power) to objects presented at near distances. To facilitate near optical correction, additional diopters (D) of refractive power are needed depending of the age of the patient (see table below).

**Hyperopic and presbyopic patients:**

Hyperopic patient may have difficulty to focus at 30 cm. For these patients, a trial lens is needed, corresponding to their refraction (R). As with emmetropic patients who are older, additional diopters (D) are needed to support their near optical correction (presbyopia) (see table below).

**Myopic patients:**

Near sighted patients of up to -3 D do not necessarily need corrective lenses, as they can focus at 30 cm. Patients with strong myopia (greater than -3 D) will have difficulty focusing at 30 cm and need additional correction. For refractive values above -3 D, add 3.25 D to the refractive value (e.g., for R = -4 D; use a -0.75 D lens). As for presbyopic and emmetropic patients, with increasing age, near optical correction is more difficult and additional diopters are needed.

**Corrections in the cupola perimeter of Octopus 900**

Cupola perimeters allow for full-field peripheral testing that extends beyond the range of a trial lens. Therefore, all lenses and the lens holder must be removable to allow for peripheral testing. No trial lens should be used for testing beyond 30° eccentricity. The Octopus 900 has a built-in trial lens calculator to determine which trial lens should be used. The following look-up table shows the outputs of the Octopus trial lens calculator.

Age	Hyperopic		Emmetropic		Myopic				
	R > 0 D	R = 0 D	R = -0.5 D	R = -1 D	R = -1.5 D	R = -2 D	R = -2.5 D	R = -3 D	R < -3 D
< 30	R	No lens	No lens	No lens	No lens	No lens	No lens	No lens	R + 3.25
30 – 39	R + 1.0 D	+1	+0.5	No lens	No lens	No lens	No lens	No lens	R + 3.25
40 – 44	R + 1.5 D	+1.5	+1.0	+0.5	No lens	No lens	No lens	No lens	R + 3.25
45 – 49	R + 2.0 D	+2.0	+1.5	+1.0	+0.5	No lens	No lens	No lens	R + 3.25
50 – 54	R + 2.5 D	+2.5	+2.0	+1.5	+1.0	+0.5	No lens	No lens	R + 3.25
55 -59	R + 3.0 D	+3.0	+2.5	+2.0	+1.5	+1.0	+0.5	No lens	R + 3.25
>= 60	R + 3.25 D	+3.25	+2.75	+2.25	+1.75	+1.25	+0.75	No lens	R + 3.25

**Correction in the central field perimeter of the Octopus 600**

In order to simplify the clinical workflow, the Octopus 600 perimeter has a built-in +3.25 D lens that covers the central 30° of the visual field. All patients, irrespective of age, therefore receive the maximum correction for presbyopia. Only their actual refraction (R) is needed. If younger patients are over-corrected, they are able to compensate by relaxing their lens without negative effect on their visual field.

**DETERMINATION OF APPROPRIATE CYLINDER LENS****Cylinder Correction (Octopus 900)**

A cylinder correction can be discarded when the prescription is 0.25 D or less, because it does not alter the result of the visual field test. For cylinders from 0.5 to 1 D, the spherical equivalent is used and added to the spherical lens needed for each patient. The spherical equivalent is calculated using the following formula:

$$\text{Spherical equivalent} = \frac{1}{2} * \text{cylinder correction}$$

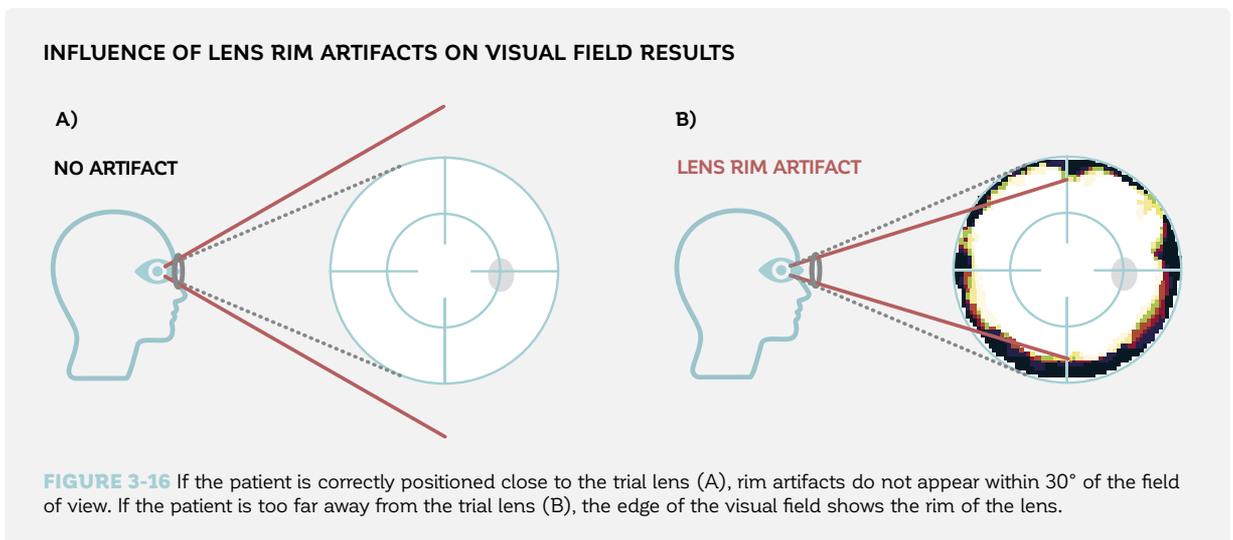
This formula is an approximation that adequately corrects for small cylinders, but does not sufficiently correct for cylinders larger than 1 D. For cylinders larger than 1 D, a cylindrical correction is needed. Remember to get the cylinder axis oriented to the proper angle on the lens holder. (For the special case of the Octopus 600 refer to the user manual).

## EXTERNAL OBSTRUCTIONS BLOCKING STIMULI FROM REACHING THE RETINA

### LENS RIM ARTIFACTS

If the edge of the trial lens blocks the patient's view (FIG 3-16), the visual field results will be adversely affected and will show absolute defects at the edges. To avoid trial lens rim artifacts, the patient should be positioned

so that the eye is as close as possible to the trial lens without touching it, and aligned in the center of the trial lens holder. The Octopus 900 provides a measurement function to warn if the lens is too far from the eye.



### FACIAL STRUCTURE OF THE PATIENT

It is important to observe the physiognomy (facial structure) of the patient. A prominent nose, a heavy brow or long eyelashes can alter the field of view, leading to misinterpretation of the visual field results. If there is a prominent facial structure, it is recommended to turn or tilt the patient's head to the side slightly, without losing fixation.

Droopy lids (ptosis) and droopy lid skin (dermatochalasis) might also obstruct the patients' upper field of view (FIG 3-17). To avoid artifacts caused by ptosis, tape can be used to lift the eyelid. Care should be taken to leave enough freedom to allow blinking.

### DIRTY CONTACT LENS

Since very high corrections can lead to peripheral distortions, it is advisable for a patient with very high corrections to wear contact lenses. Patients with moderate myopia may also leave their contact lenses in. If contact

lenses are used, they must be inspected before the test. Dirty contact lenses reduce the amount of light entering the eye, resulting in a diffuse defect. This will also appear in the Defect Curve as a downward shift of the entire curve.

## PUPIL SIZE

The amount of light entering the eye is controlled by the diameter of the pupil. As a rule, the pupil must have a diameter of at least 3 mm for the results of the test to be trustworthy. Small pupils decrease the amount of incident light on the retina and result in a uniform depression of the visual field (**FIG 3-18**).<sup>13,14</sup> Increasing diffraction around the margin of the pupil may also be

observed. These artifacts may simulate glaucomatous visual field defects. To avoid this, patients with a pupil size of less than 3 mm, as measured in a dimly-lit room, may be dilated before the perimetric examination. Highly artificially dilated pupils may, however, occasionally lead to mild peripheral visual field distortions.

### INFLUENCE OF FACIAL STRUCTURE ON VISUAL FIELD

#### A) PTOSIS



#### B) PTOSIS WITH LID TAPED UP



**FIGURE 3-17** Ptosis (droopy lid) results in external superior obstruction of the visual field that is not related to any pathology of the eye (A). Patients with severe ptosis or dermatochalasis should therefore be tested with the lid taped up (B), in order to assess the visual field without the effect of ptosis, as seen in the example below.

### INFLUENCE OF SMALL PUPIL SIZE ON VISUAL FIELD

#### SMALL PUPIL SIZE



#### NORMAL PUPIL SIZE



Light Source

**FIGURE 3-18** If a patient's pupil is too small, the overall sensitivity to light will be reduced, resulting in a visual field with diffuse defect.

## CLINICAL RELEVANCE OF UNTRUSTWORTHY VISUAL FIELDS

Obtaining reliable results is important in order to interpret the visual fields correctly. Unreliable visual fields unfortunately occur relatively frequently in clinical practice. In more controlled conditions such as the large Ocular Hypertension Treatment Study (OHTS), fixation losses were the most frequently observed cause of unreliable visual fields, accounting for 70% of all unreliable visual fields.<sup>2</sup>

The second most frequent cause of unreliable visual fields was false positive errors, which accounted for 18% of all unreliable visual fields.<sup>2</sup> Of all the visual field hemifields included in the OHTS, 0.4% had rim artifacts,<sup>12</sup> while superior and inferior depressions due to facial features accounted for only 0.2% of all hemifields. In less controlled conditions, these numbers may be significantly higher.

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# CHAPTER 4

## KEY EXAMINATION PARAMETERS

### FIXED EXAMINATION PARAMETERS

Perimetric testing must be as standardized as possible, in order to allow comparisons over time and across different eye care providing offices. Therefore, many examination parameters are fixed by the perimeter used and are not specifically selected by the user of the perimeter. These fixed parameters typically include background color and luminance, maximum stimulus luminance and stimulus duration.

Different perimeter models use different fixed settings. Therefore, when switching from one device to another, it is important to consider their influence on the perimetric

results. Chapter 12 provides an overview of the most common differences between devices and provides practical advice on how to successfully master the transition.

For the sake of completeness, a summary of the most essential fixed examination parameters of current Octopus perimeters and the rationales behind them is provided in **BOX 4A**. Note that the settings presented below apply to Standard Automated Perimetry. In special situations, other fixed examination parameters are chosen. They are discussed in the respective chapters.

#### FIXED EXAMINATION PARAMETERS

##### BACKGROUND INTENSITY AND COLOR

Background luminance (i.e., the reflected light intensity of the background) determines the contrast between the stimulus presented and the background, and thus has a considerable influence on stimulus perception. To achieve comparable test results, it must be kept constant.

The ideal background luminance of a perimeter should not be too bright, in order to allow display of very dim stimuli for a large dynamic testing range. Neither should it be too dark, to avoid time-consuming dark adaptation of the eye. It should stimulate selected cell types.

The standard background luminance of current Octopus models consists of white light with a luminance of 31.4 asb, which equals 10 cd/m<sup>2</sup>. This luminance level is at the low end of photopic vision (i.e., the visual system used in normal daylight conditions) and does not require time for dark adaptation, but still provides a high dynamic testing range. White light is used because it is detected by all cell types in the retina and is therefore non-selective.

##### MAXIMUM STIMULUS LUMINANCE

As seen in Chapter 2, the maximum stimulus luminance (i.e., the maximum stimulus intensity) of a perimeter defines the luminance associated with 0 dB on the decibel scale. It is also part of the formula to calculate a decibel value from the stimulus luminance. If the maximum stimulus luminance were to change, then the whole decibel scale would shift, so it must be kept constant for comparable results to be achieved.

In order to offer a large dynamic testing range from normal to impaired vision, the maximum stimulus intensity value should be as high as possible. However, when the maximum stimulus intensity is

#### BOX 4A

too high, a part of it will be reflected from the back of the eye (stray light) and will then be detected by neighboring cells, which will produce inaccurate test results. Empirically, a maximum stimulus luminance of 4,000 asb has been shown to offer a large dynamic range, while minimizing stray light effects.<sup>1,2</sup>

#### STIMULUS DURATION

In order to reduce fixation losses, the perimetric stimulus duration (i.e., exposure time) is kept below the reaction time of the human reflex of quick eye movements towards rapidly appearing stimulus (i.e., saccadic eye movement). As the reaction time of the saccadic eye movement is around 200 ms, the stimulus duration should be shorter, but still sufficiently long to be seen. For that reason, Octopus perimeters use a standard stimulus duration of 100 ms.

## PATIENT-SPECIFIC EXAMINATION PARAMETERS

As described in Chapter 2, there is always a trade-off between testing time and accuracy in perimetric examinations. In this respect, it is very important to maximize the clinically relevant information, while at the same time minimizing test duration. As perimetry has a wide range of applications, there is no “one parameter fits all” approach for all situations. Each Octopus perimeter thus contains a library of standardized examination parameters from which the optimum set can be chosen for each patient. These patient-specific examination parameters thus have to be selected for every patient.

In essence, there are four essential questions each clinician must answer, in the order shown below, prior to ordering a perimetric test:

1. Which **type of perimetry** should be used: static or kinetic perimetry?
2. Which **type of stimulus** should be used: standard white-on-white, function-specific or low-vision?
3. Which **test pattern** should be used?
4. Which **test strategy** should be used?

The first two questions are typically easy to answer. Indeed, static and standard perimetry are indicated for the needs of patients in most clinical practices and are by far the most commonly used types of perimetry. With regard to test strategy and test pattern, various selections are commonly employed, and these decisions must be made individually.

## TYPE OF PERIMETRY: STATIC OR KINETIC PERIMETRY

### STATIC PERIMETRY

For reasons of simplification, so far this book has concentrated on static perimetry. In static perimetry, stimuli of varying luminance levels are used to determine visual sensitivity thresholds at a specified number of fixed locations

(**FIG 4-1A**). With this type of perimetry, it is possible to detect small changes in sensitivity thresholds with relatively high accuracy. For this reason, static perimetry is the standard for slowly progressing diseases such as

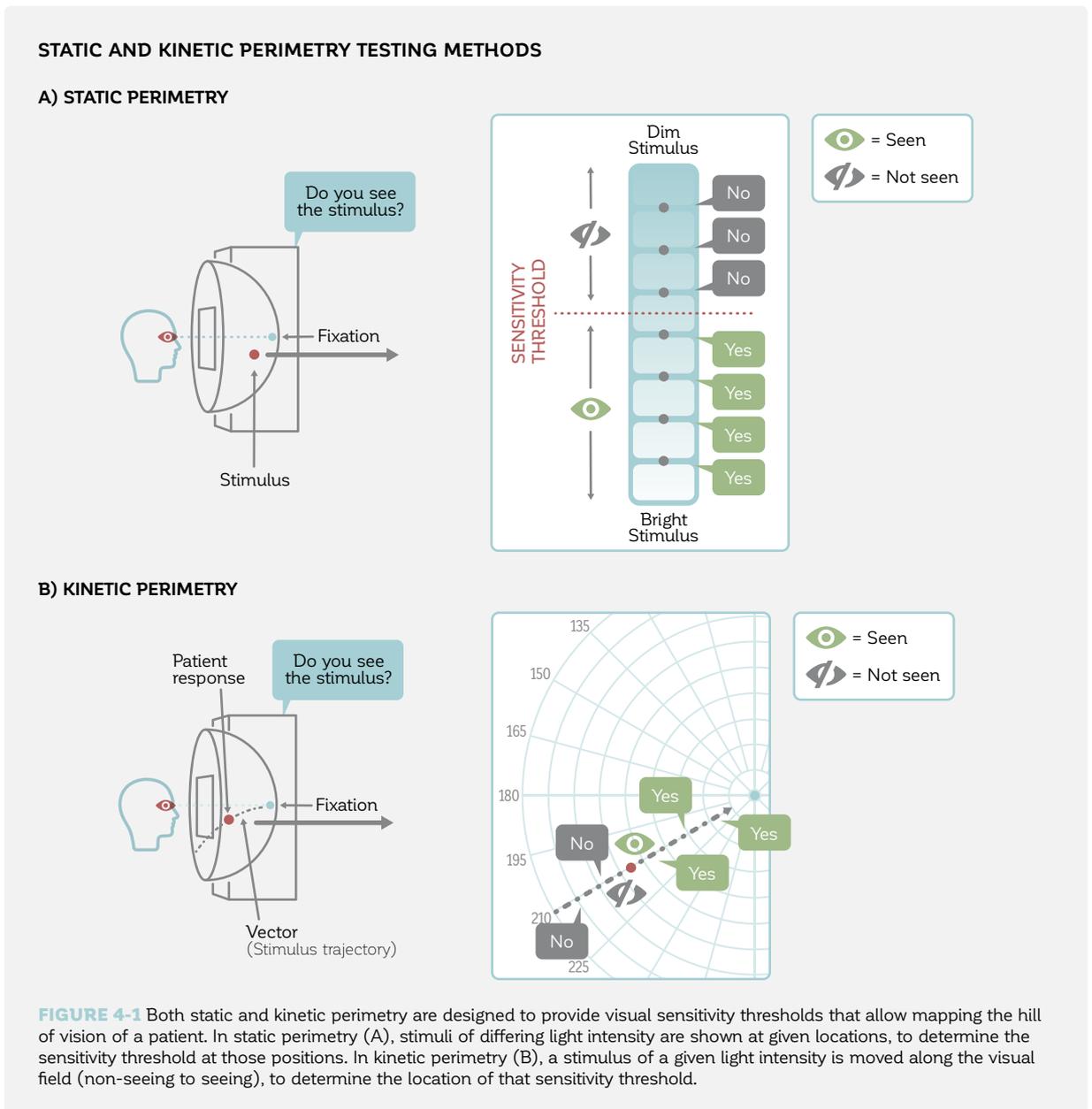
glaucoma. Since it is fully automated, it is also easy to use in clinical practice.

As the majority of visual field tests are performed for glaucoma, static perimetry is the most commonly used type of perimetry today.

**KINETIC PERIMETRY**

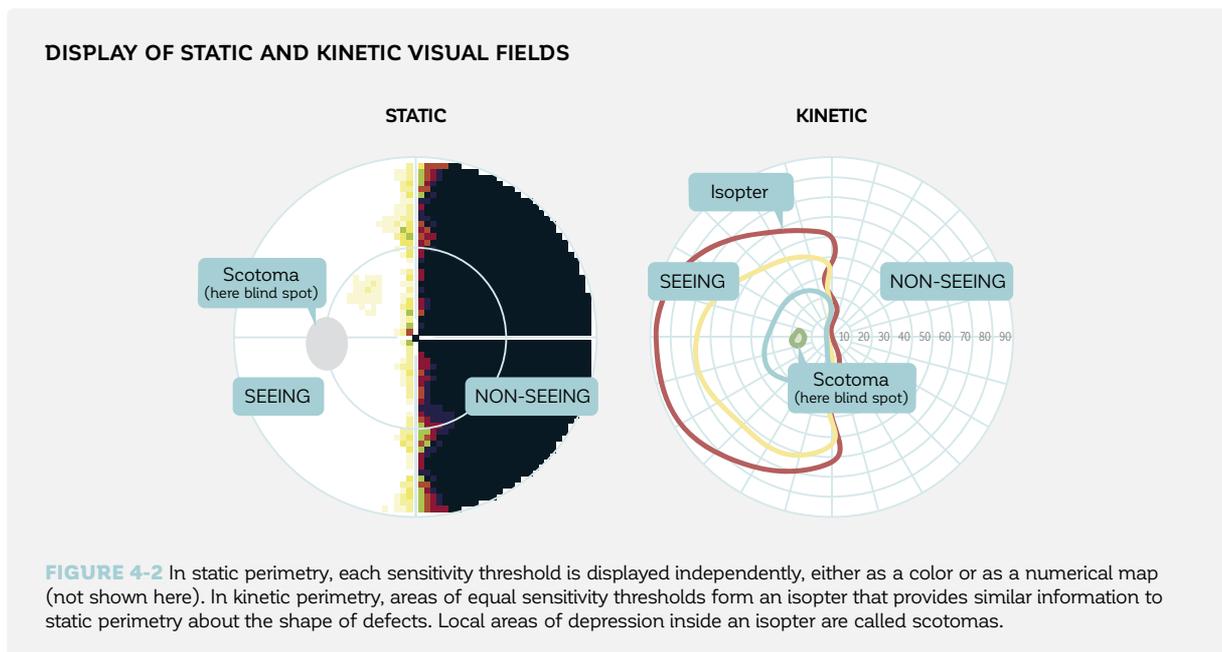
Kinetic perimetry was the first quantitative method of performing visual field testing and is an alternative to static perimetry. In kinetic perimetry, moving stimuli of pre-determined light intensities are moved from

non-seeing to seeing areas. The patient response then defines the visual field location of the specific light sensitivity threshold (FIG 4-1B).



After repeating this process for a specific stimulus size and intensity across the entire visual field, the visual sensitivity thresholds can be connected to form an isopter (line of equal sensitivity). An isopter marks the boundary between seeing and non-seeing around the hill of vision

for a given stimulus size and intensity and is similar to an altitude line on a geographical map. Local regions of reduced sensitivity inside the isopter are identified in the same way and are called scotomas. FIG 4-2 shows how static and kinetic perimetry results are displayed.



Since the patient can report seeing the stimulus at any location along the trajectory of the stimuli, kinetic perimetry provides high spatial resolution and fast testing over a large area. It is therefore beneficial for diseases affecting the periphery and sharp-edged defects and is frequently used to evaluate neurological diseases and peripheral retinal diseases. As moving stimuli are easier to see than non-moving ones in the periphery, kinetic perimetry is also often used for children and for patients with cognitive impairment or severe visual field loss. However,

kinetic perimetry is currently not fully automated, making it more challenging in everyday use.

As the majority of visual field tests are performed to assess glaucoma and due to the ease of use of automation, static perimetry is by far the most commonly used type of perimetry today. For that reason, all of the following paragraphs and chapters focus on static perimetry, while kinetic perimetry will be discussed in depth in Chapter 11. The key differences between static and kinetic perimetry are summarized in TABLE 4-1.

COMPARISON BETWEEN STATIC AND KINETIC PERIMETRY

TABLE 4-1

	STATIC	KINETIC
<b>ADVANTAGES</b>	<ul style="list-style-type: none"> <li>Clinical gold standard</li> <li>High precision sensitivity thresholds</li> <li>Fully automated</li> </ul>	<ul style="list-style-type: none"> <li>High spatial resolution</li> <li>Fast peripheral testing</li> <li>Provides information about other visual functions</li> <li>Highly interactive, flexible and adaptable</li> </ul>
<b>WHAT IT IS BEST AT DETECTING</b>	<ul style="list-style-type: none"> <li>Small changes in sensitivity thresholds</li> <li>Changes in the central area</li> </ul>	<ul style="list-style-type: none"> <li>Small changes in spatial extent of a defect</li> <li>Peripheral changes</li> <li>Remaining vision in advanced diseases</li> </ul>
<b>COMMON USES</b>	<ul style="list-style-type: none"> <li>Glaucoma</li> <li>Macular diseases</li> <li>Visual ability testing</li> </ul>	<ul style="list-style-type: none"> <li>Neuro-ophthalmological conditions</li> <li>Peripheral retina diseases</li> <li>Low vision</li> <li>Children</li> <li>Patient with cognitive impairment</li> </ul>

## STIMULUS TYPE: STANDARD OR NON-CONVENTIONAL

### STANDARD WHITE-ON-WHITE PERIMETRY

The standard perimetric stimulus is white on a white background, and this type of perimetry is commonly referred to as white-on-white perimetry, or Standard Automated Perimetry (SAP).

The white color stimulus offers the advantage of stimulating all different retinal cell types. As a result, white

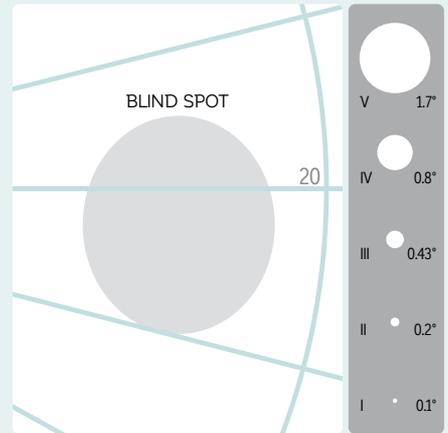
light allows visual field testing from early to advanced disease (i.e., it offers a large dynamic testing range). By convention, the standard stimulus used is round, with a diameter of  $0.43^\circ$ , which is also the Goldmann stimulus size III, based on the definition of Professor Hans Goldmann. For more information on Goldmann stimulus sizes, refer to **BOX 4B**.

**BOX 4B**

**GOLDMANN SIZES I TO V**

The size conventions used today to describe a perimetric stimulus are derived from the work of Professor Hans Goldmann, who developed the Goldmann perimeter in 1946. He defined standard sizes for perimetric stimuli, and the Goldmann sizes I to V are still widely used. Each step corresponds to a change in diameter by a factor of 2 and in area by a factor of 4. Size III is several times smaller than the physiological blind spot and was considered to be an accurate measurement size.

The Goldmann stimulus sizes I to V are presented in relation to the size of the physiological blind spot.

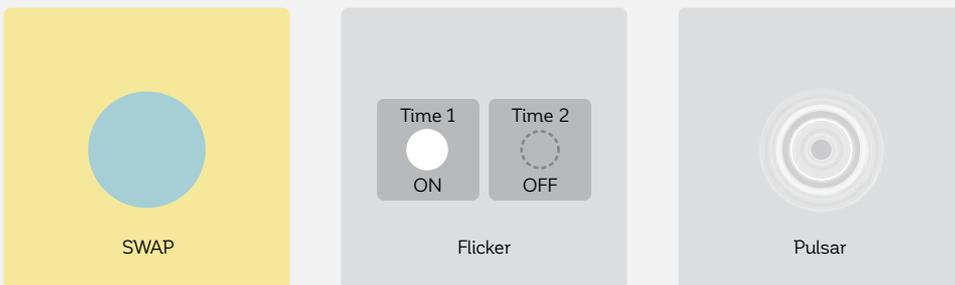


**FUNCTION-SPECIFIC PERIMETRY**

Function-specific perimetry uses different stimulus types to stimulate different visual functions (e.g., motion, or color vision), but they all have the same purpose: measuring a subset of the visual system individually, to get more sensitive responses for early disease detection. Different Octopus perimeter models offer different function-specific stimuli (FIG 4-3): a blue stimulus on a yellow

background (Short-Wavelength Automated Perimetry, or SWAP); a white flickering stimulus on a white background (Flicker Perimetry); or a pulsating stimulus with concentric rings changing in both spatial resolution and contrast (Pulsar Perimetry). They are described in more detail in Chapter 10.

**FUNCTION-SPECIFIC PERIMETRY**



**FIGURE 4-3** Stimuli used in function-specific perimetry from left to right: Short Wavelength Automated Perimetry (SWAP), Flicker Perimetry and Pulsar Perimetry.

## PERIMETRY FOR LOW VISION

There is a limit to the visibility of the standard size III white perimetric stimulus in patients with significantly impaired visual sensitivity. In order to increase the dynamic range into the low vision region and to make the stimulus more visible to these patients, the Goldmann

stimulus size V is typically used, instead of the standard size III. It is 16 times larger in area and is therefore more detectable. Chapter 10 provides more information about stimulus size V.

OVERVIEW OF DIFFERENT STIMULUS TYPES

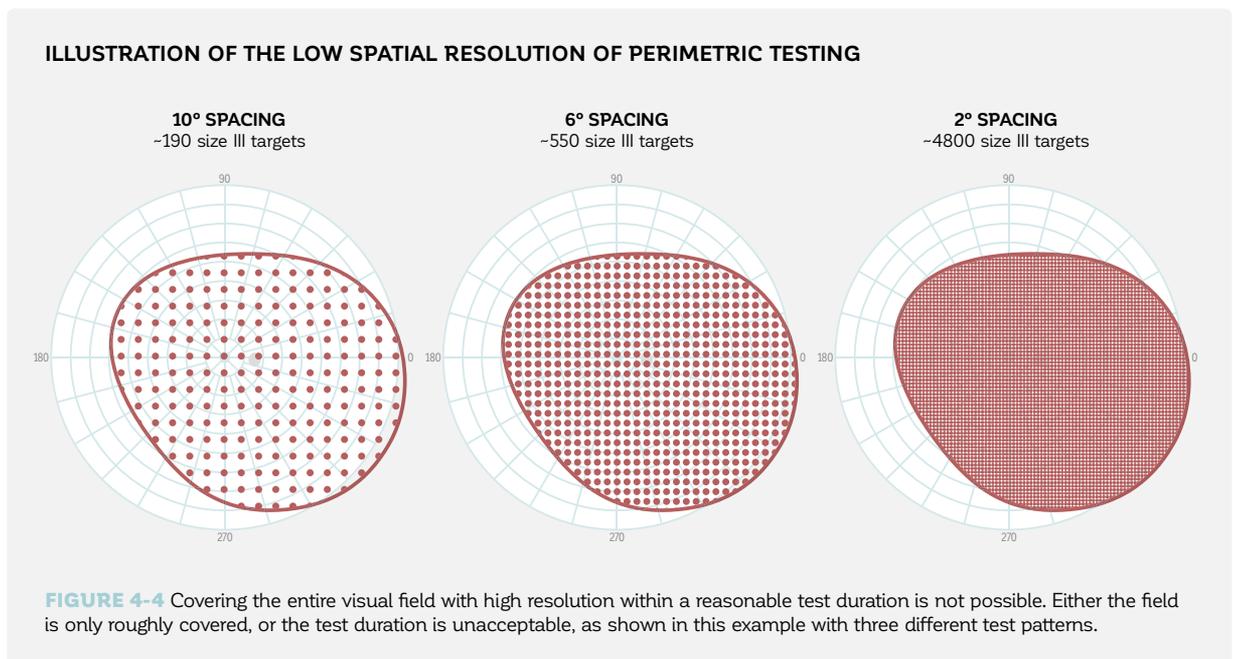
TABLE 4-2

	STANDARD <hr/> White-on-white, stimulus III	FUNCTION-SPECIFIC <hr/> Pulsar, Flicker, SWAP	LOW VISION <hr/> White-on-white, stimulus V
<b>ADVANTAGES</b>	Clinical standard	Earlier detection in some patients  Provides information about other visual functions	Better visibility for patients with significant visual field loss
<b>WHAT IT IS BEST AT DETECTING</b>	Follow-up of a disease from early to late stage	Early loss in some patients	Advanced visual field loss
<b>COMMON USES</b>	Glaucoma  Macular diseases	Confirm defects observed on standard perimetry  Identify defects in glaucoma suspects who do not show defects on standard perimetry	Advanced glaucoma or other ocular or neurological diseases

## TEST PATTERN

In clinical practice, patients can sometimes become tired quickly during perimetric testing, which significantly limits the number of test locations that can be reliably tested.<sup>3-6</sup> A reasonably dense grid of test locations, covering the entire visual field with 2° spacing, would require around 4,800 size III stimuli, and a grid with 6° spacing would require approximately 550 test locations. A very

rough grid with 10° spacing between the stimuli would require approximately 190 test locations, but would be highly inaccurate, as there would be only 5 test points in the central 10° of vision, which is an important area for visual functions such as reading and identifying objects (FIG 4-4).

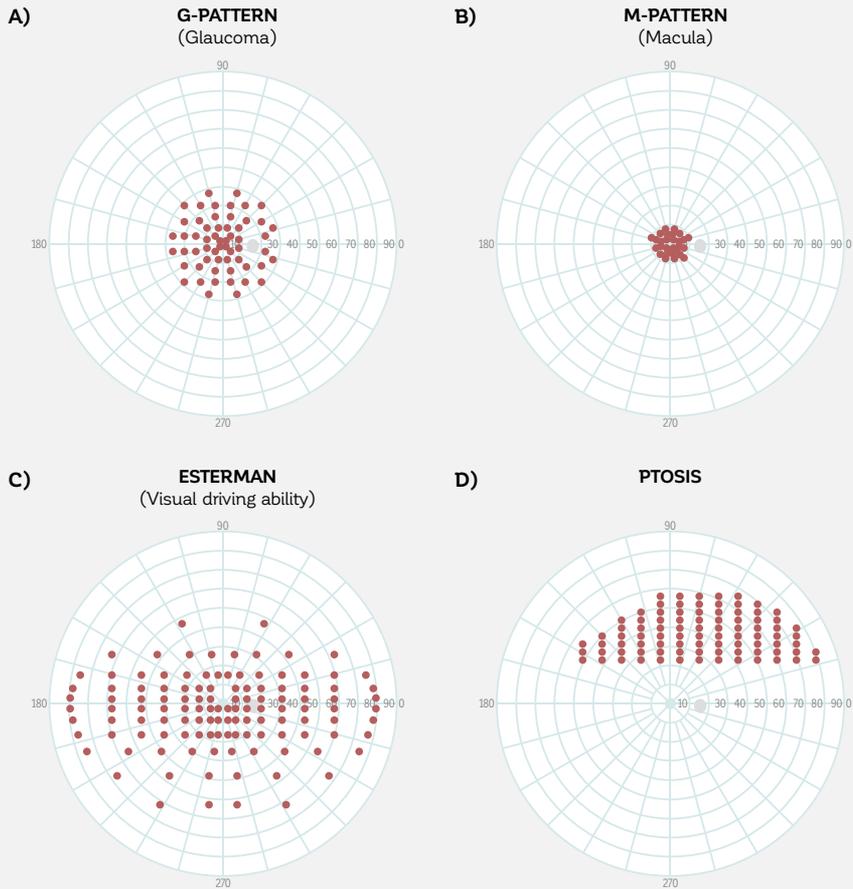


In order to maximize perimetric information and minimize test duration, a test pattern should be chosen with a high density of test locations in the area of high interest and a low density of test locations in areas of low interest (FIG 4-5). For that reason, Octopus perimeters

offer a large library of testing patterns for common perimetric applications.

The most commonly used test patterns available on the Octopus perimeter and the rationale for which to select are described in depth in Chapter 5.

### EXAMPLES OF DIFFERENT TEST PATTERNS



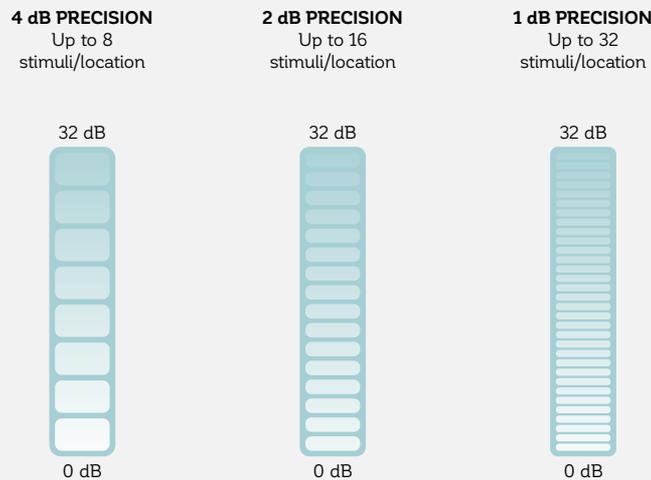
**FIGURE 4-5** Examples of test patterns for various clinical perimetric applications are presented. Each pattern maximizes the relevant information for that clinical situation, while minimizing the test duration by only evaluating the most relevant areas. (A) The G-pattern for glaucoma tests within 30° at locations that follow the retinal nerve fibre bundle patterns. (B) The M-pattern for the macula tests within the central 10°. (C) The Esterman tests binocularly for visual fitness to drive (120° horizontally and 60° vertically). (D) The Ptosis test pattern only evaluates the upper hemifield along common eyelid locations.

## TEST STRATEGY

For the detection and follow-up of a disease, the sensitivity thresholds should be determined with high accuracy. However, in clinical practice, even very cooperative and reliable patients experience fatigue, which limits the number of stimulus luminance levels that can be presented during a perimetric test. If we were to sample the entire range in steps of 1 dB, from 0 dB (maximum

stimulus luminance) to 32 dB (approximate foveal sensitivity threshold of a 20-year-old on the Octopus 900), 32 stimuli would have to be presented at one test location. Performing the same procedure in 2 dB steps would require 16 stimuli, while 4 dB steps would still require the presentation of 8 stimuli (**FIG 4-6**).

### ILLUSTRATION OF THE LOW RESOLUTION OF SENSITIVITY THRESHOLDS IN PERIMETRIC TESTING



**FIGURE 4-6** Determining a sensitivity threshold with high precision with a sequence of stimuli of increasing intensity is not possible. Either too many stimuli are required, or the step sizes are too large, as the example with three different step sizes demonstrates.

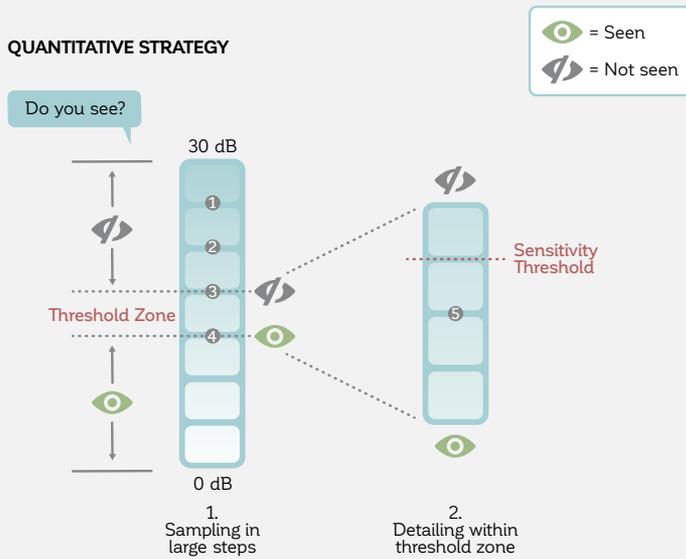
Instead of using the strategy of increasing stimulus intensity step by step until the sensitivity threshold is reached, an efficient strategy is therefore needed that maximizes precision but minimizes test duration.

Octopus perimeters offer several test strategies with different trade-offs between test duration and accuracy for different clinical situations. Some strategies are quantitative, which means that they are used to determine a sensitivity threshold (**FIG 4-7**). Qualitative strategies are also offered in which the testing time is reduced, because

they only assess whether stimuli are seen or unseen (**FIG 4-8**). Qualitative strategies are commonly used in legal visual ability evaluations, such as in the tests used to assess visual fitness to drive. Examples of a quantitative and a qualitative test strategy are given in **FIG 4-7** and **FIG 4-8**, for the sake of illustration.

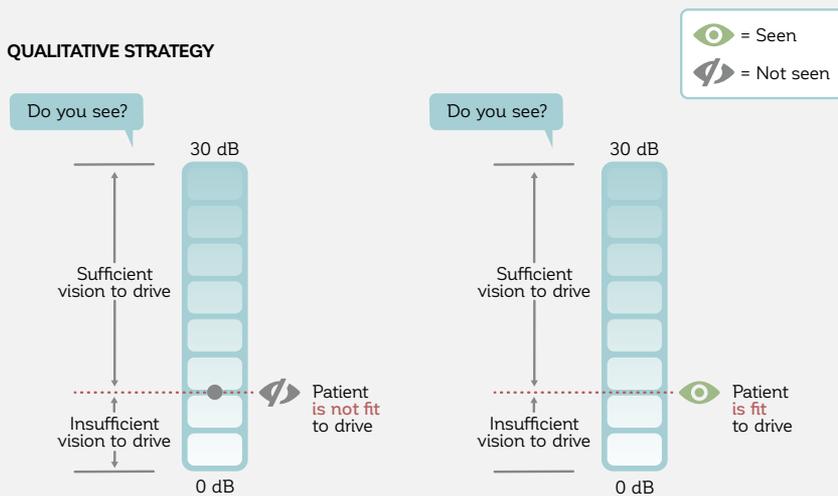
The most commonly used strategies available on the Octopus perimeter and the rationale for which strategy to select are described in depth in Chapter 6.

**EXAMPLE OF A QUANTITATIVE STRATEGY**



**FIGURE 4-7** Example of a quantitative thresholding strategy: The visual field is first scanned with stimuli with large steps in light intensity, in order to identify a suspected threshold zone. Once that zone has been identified, further testing inside that zone will allow for determination of an accurate threshold with minimal test duration.

**EXAMPLE OF A QUALITATIVE STRATEGY**



**FIGURE 4-8** Example of a qualitative strategy: For visual driving ability, one stimulus is shown at the fixed stimulus intensity which is the minimum needed to drive safely. If a person sees that stimulus at a required number of test locations, this means that the person fulfills the visual field criteria to be able to drive.

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# CHAPTER 5

## SELECTING A TEST PATTERN

### INTRODUCTION

Depending on the pathology or type of ability testing that is to be performed, certain test locations are far more relevant than others. As there is always a trade-off between test duration and accuracy in any perimetric test, a test pattern should be chosen with locations in the relevant area.

For this reason, all Octopus perimeters offer a library of a variety of test patterns for each application. In order for test results to be comparable between different sessions, between different patients and even between

different eye care providing offices, test patterns are standardized. However, various patterns have been developed and different patterns can be used for the same purpose. Octopus perimeters offer all of the most commonly used patterns, to allow for testing continuity.

The following section focuses on the most commonly used patterns and provides rationales for which to choose in specific situations. **TABLE 5-1** provides a summary of the most commonly used Octopus test patterns.

COMMONLY USED TEST PATTERNS FOR VARIOUS INDICATIONS

TABLE 5-1

INDICATION	RECOMMENDATION	COMMON ALTERNATIVES
GLAUCOMA/CENTRAL FIELD	G (Glaucoma)	32, 30-2, 24-2
MACULA	M (Macula)	10-2
FULL FIELD (NEURO, RETINA)	07	Kinetic
FOVEA	F (Fovea)	
BLIND SPOT	B (Blind spot)	Kinetic
LOW VISION	M, G, 07 depending on pathology	Kinetic
SCREENING FOR ABNORMAL VISION	Screening 28	
DRIVING	ET (Esterman)	FG (Führerscheingutachten), Kinetic
BLEPHAROPTOSIS	BT (Blepharoptosis)	Kinetic
BLINDNESS	BG (Blindengutachten)	

# TEST PATTERNS FOR GLAUCOMA

## TYPICAL VISUAL FIELD DEFECTS IN GLAUCOMA

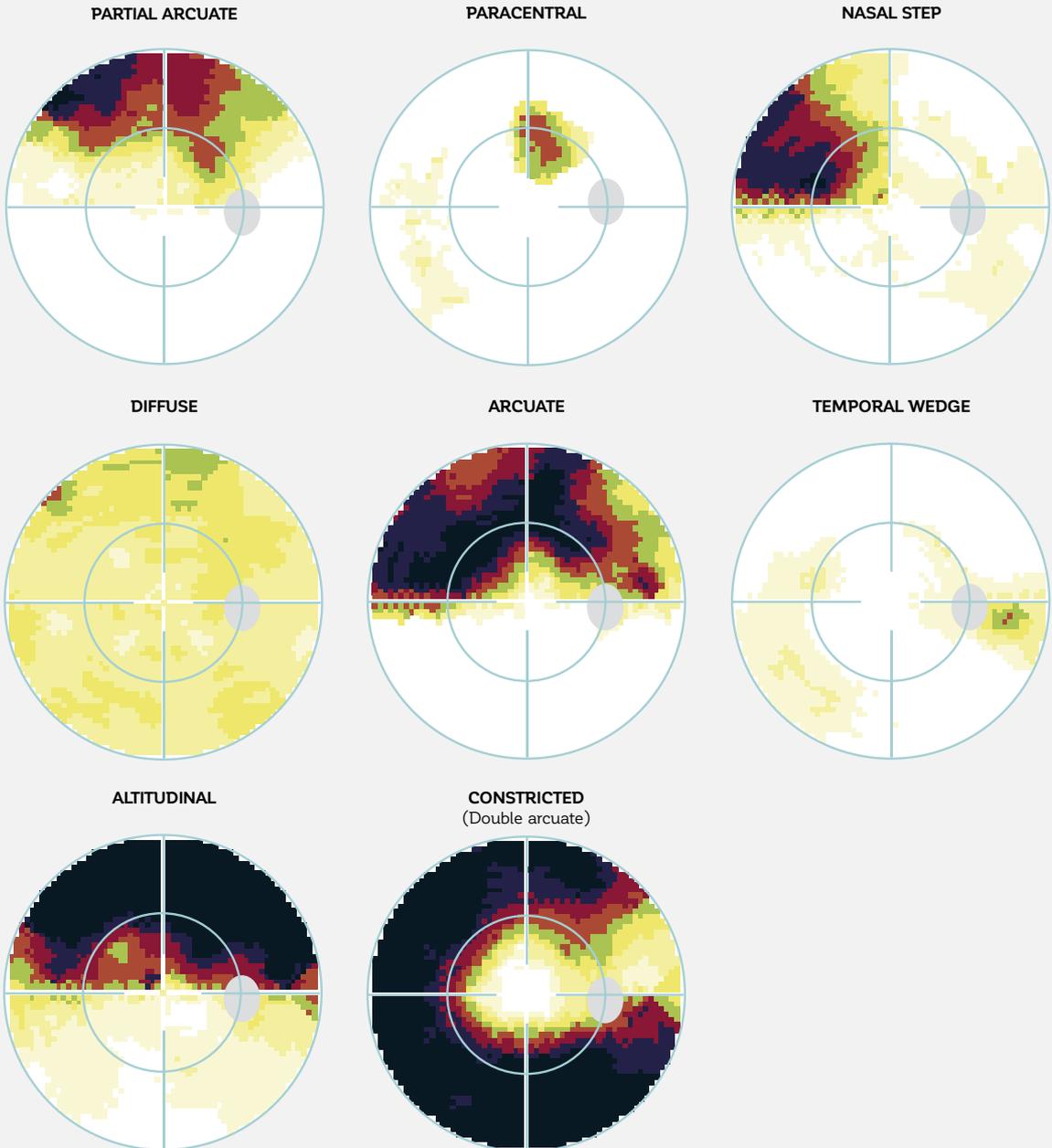
Glaucoma is a disease resulting in the degeneration of retinal nerve fiber bundles in the eye. Since the largest proportion of retinal nerve fibers is located within the central 30°,<sup>1-4</sup> most early to moderate glaucoma visual field loss occurs within the central 30°. Typical defect patterns follow the distribution of the retinal nerve fiber bundles and there is a clear separation along the superior and inferior hemifields at the horizontal meridian. The typical patterns of visual field loss due to glaucoma are partial arcuate, paracentral, nasal step, arcuate, temporal wedge and altitudinal defects (**FIG 5-1**).<sup>5</sup>

Since glaucomatous visual field defects typically occur within the central visual field, the best trade-off between test duration and accuracy is achieved by using a central

30° test pattern, which has become the standard for visual field testing in glaucoma today. Conversely, the periphery is rarely affected in isolation in glaucoma,<sup>6</sup> so that peripheral testing is less common in cases of glaucoma for diagnostic reasons and, if used at all, is aimed to assess a patient's quality of life.

In very advanced glaucoma, the visual field usually constricts to a macular visual field<sup>7</sup> and testing outside the macula does not provide any further diagnostic information. Therefore, it is common to switch to a 10° macular test pattern in advanced glaucoma, in order to track residual vision in that area with higher resolution<sup>7,8</sup> for the same test duration.

**TYPICAL VISUAL FIELD DEFECTS IN GLAUCOMA**



**FIGURE 5-1** The typical visual field defects in glaucoma are the partial arcuate, paracentral, nasal step, diffuse, arcuate, temporal wedge, altitudinal and constricted in advanced glaucoma (ordered according to frequency of occurrence). All manifest themselves within the central 30° visual field, so that central 30° testing in glaucoma care is standard.

## STANDARD TEST PATTERN IN GLAUCOMA CARE

The standard perimetric stimulus is white, and is presented on a white background. This type of perimetry is commonly referred to as white-on-white perimetry, or Standard Automated Perimetry (SAP).

The white color stimulus offers the advantage of stimulating all different retinal cell types. As a result, white

light allows visual field testing from early to advanced disease (i.e., it offers a large dynamic testing range). By convention, the standard stimulus used is round, with a diameter of  $0.43^\circ$ , which is also the Goldmann stimulus, size III, based on the definition by Professor Hans Goldmann. For more information on Goldmann stimulus sizes, refer to **BOX 4B**.

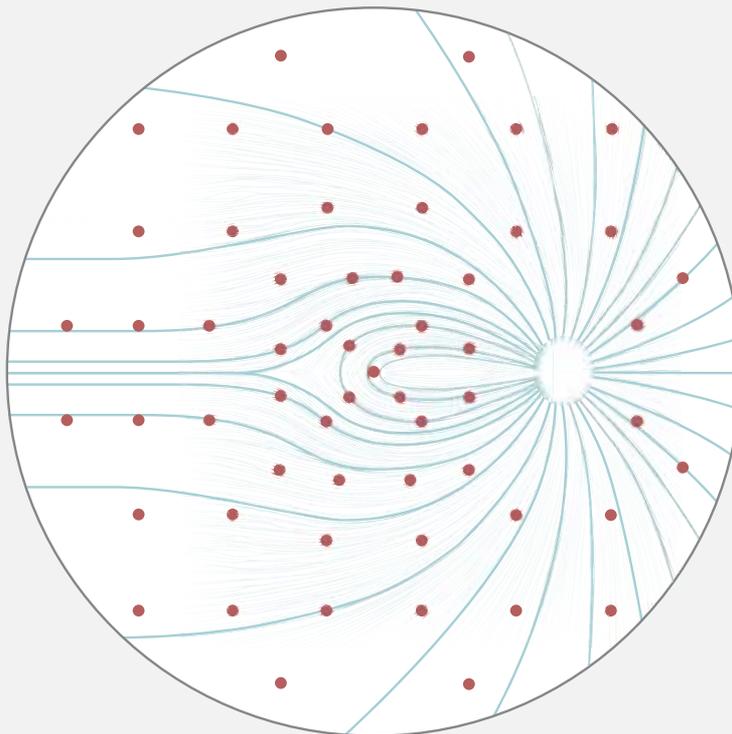
### G PATTERN

The G pattern was designed to serve as a multi-purpose test and offers an excellent trade-off between test duration and accuracy.<sup>9-12</sup> There are 59 different locations within the central  $30^\circ$  of the visual field and they are distributed in a pattern that facilitates not only the de-

tection of visual loss associated with glaucoma, but also neuro-ophthalmological and macular diseases.

To maximize the detection of glaucomatous visual loss, the test locations are distributed along the retinal nerve fiber bundles, where visual loss is most likely to occur (**FIG 5-2**).

#### THE G PATTERN FOR GLAUCOMA

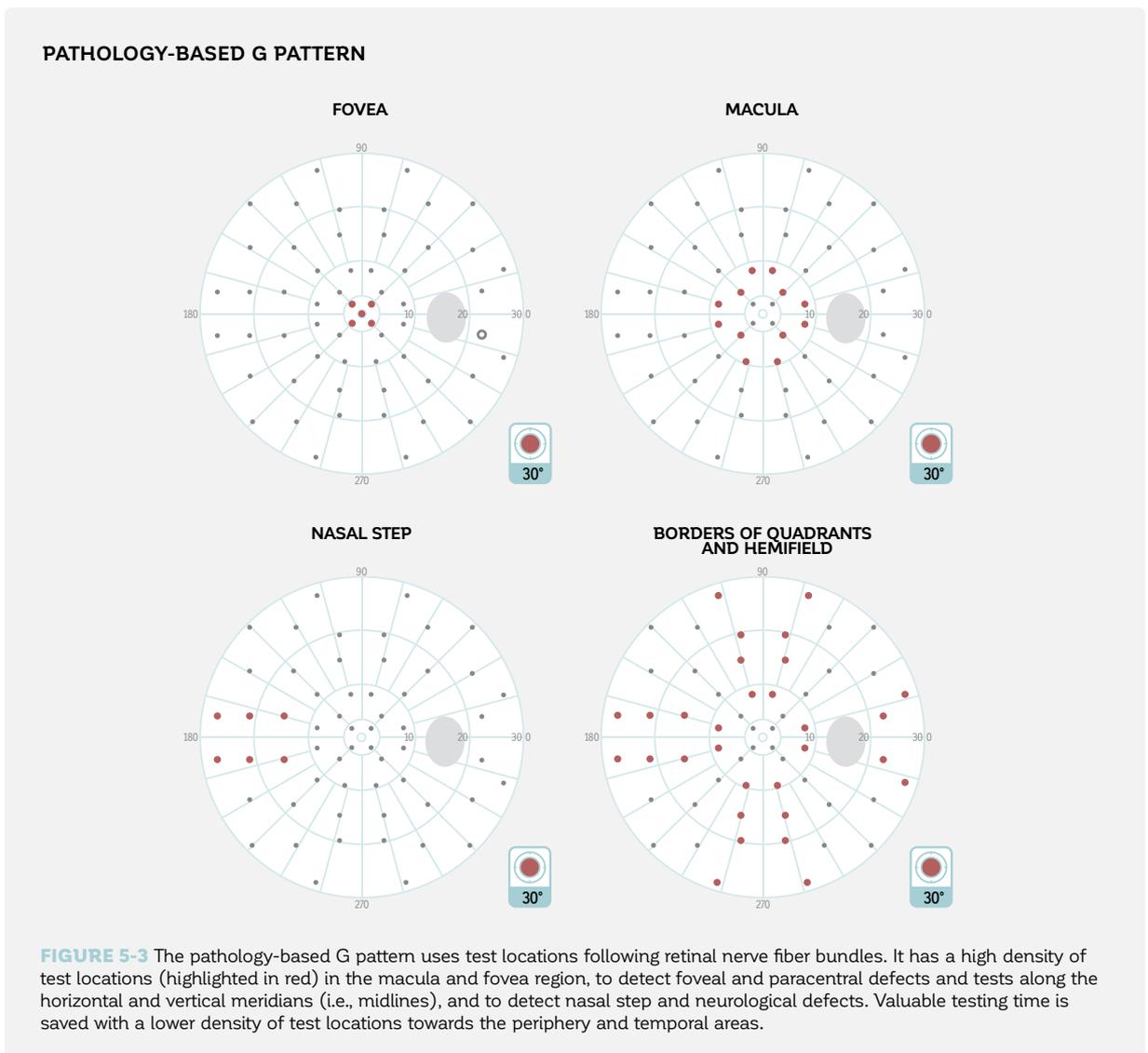


**FIGURE 5-2** The distribution of the test locations in the G pattern follows the retinal nerve fiber bundles.

The G pattern (**FIG 5-3**) offers a high density of points in the paracentral area (down to  $2.8^\circ$  spacing), to facilitate detection of paracentral scotomas, which are common in glaucoma, yet sometimes missed by other patterns.<sup>12-14</sup> The test grid also accentuates the nasal step and overall has more test points nasally than temporally – partly due to the presence of the blind spot, but also to account for the higher frequency of nasal visual field loss in glaucoma.

With 5 central points in the fovea and a total of 17 test locations in the macula, it focuses on the most import-

ant area of visual function for reading and object identification and allows for additional detection of macular diseases. Additionally, many recent reports indicate that there are structural and functional deficits which occur in the macula of glaucoma patients.<sup>15,16</sup> To detect common neurological diseases such as hemianopias and quadrantanopias, there are no points located on the vertical and horizontal meridians in the G pattern. Time is saved by not testing in the immediate region of the blind spot, where unreliable results typically tend to be observed.



## ALTERNATIVE TEST PATTERNS FOR THE CENTRAL 30°

### 32/30-2 AND 24-2 PATTERNS

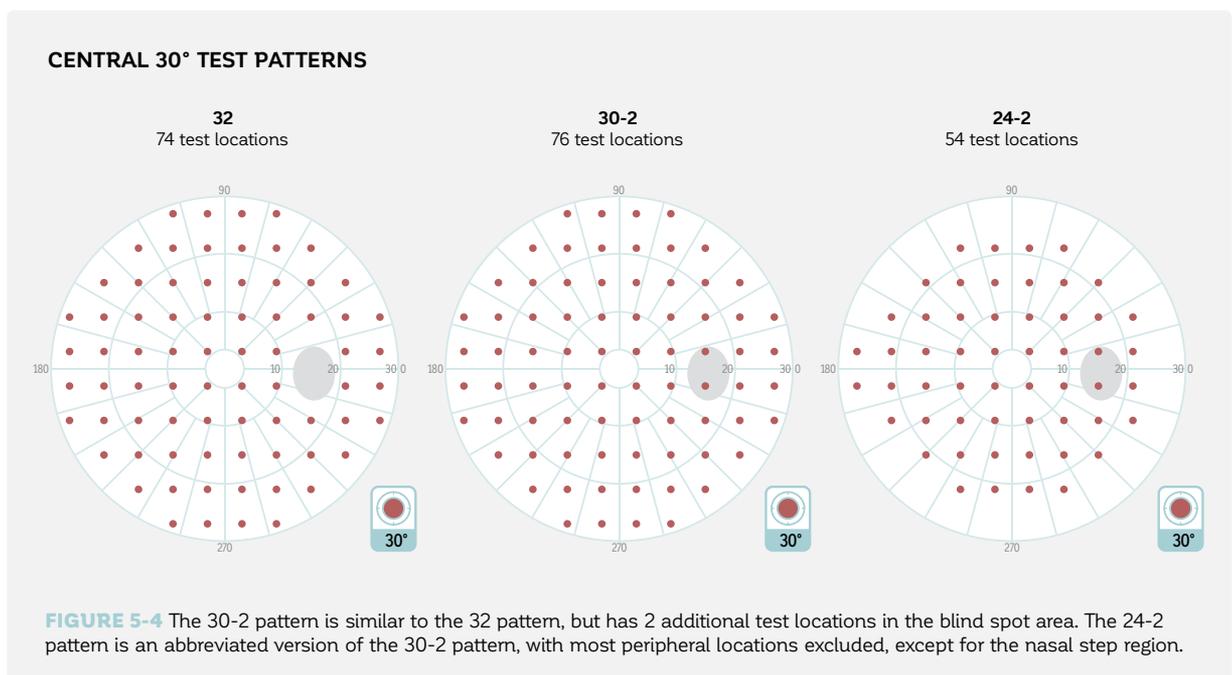
The 32, 30-2 and 24-2 patterns (**FIG 5-4**) are similar to the G pattern in that they cover the central visual field and respect the vertical and horizontal meridians. In contrast however, they are not optimized for specific pathologies. Instead, all test locations are equidistant from each other and separated by 6°.

Historically, the 32 pattern<sup>17</sup> was initially used in the first series of Octopus perimeters in 1977, while the 30-2 pattern was among the first central patterns used on the Humphrey Field Analyzer. These patterns are nearly identical to each other. The sole difference is that the 30-2 pattern has 2 extra test locations in the blind spot, which are omitted in the 32 pattern. With their 74 or 76 test locations respectively, the 32/30-2 patterns take

longer to complete than the G pattern without providing considerably more meaningful clinical information.

The 24-2 pattern is based on the 30-2 pattern, but the most peripheral ring of test locations is removed, except for the two nasal points. With only 54 test points, the test duration of the 24-2 pattern is as short as that of the G pattern, but the test pattern is not optimized for typical pathologies.

Since it is optimized for pathology and quicker, the G pattern is recommended for new patients. However, the 32/30-2 and 24-2 patterns are recommended when a large set of existing data taken from one of these patterns is available for a patient, and the eye care provider wishes to have continuity in the testing procedure.



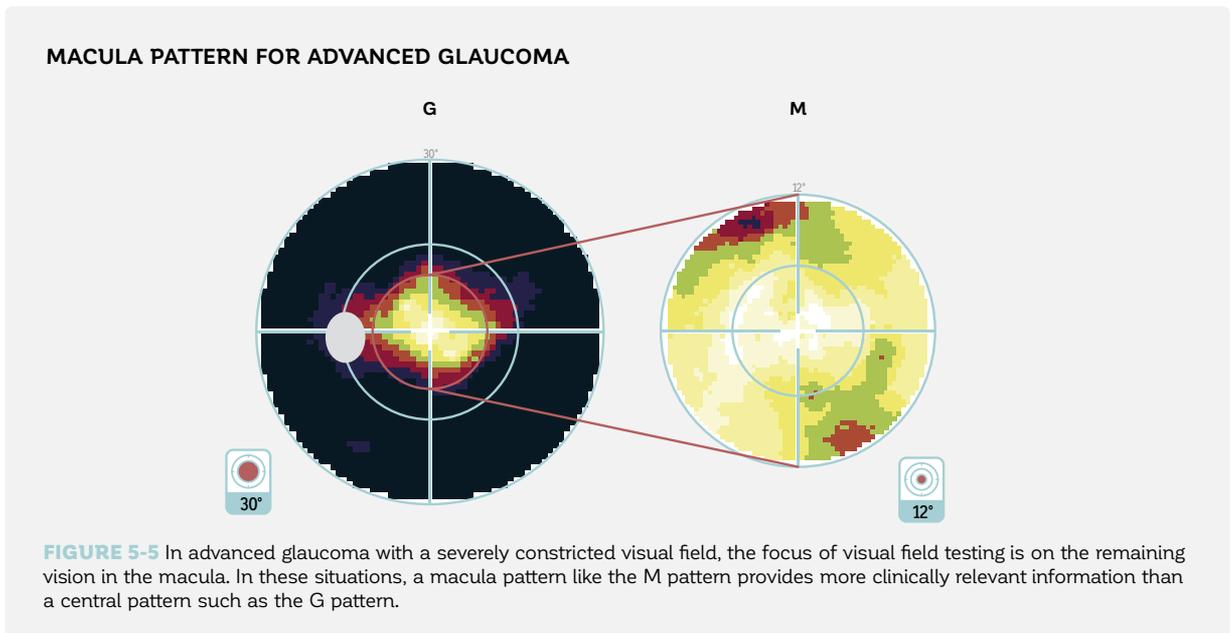
## FURTHER TEST PATTERNS FOR GLAUCOMA

### MACULA TESTING PATTERNS FOR ADVANCED GLAUCOMA

In advanced glaucoma, the visual field is typically constricted to the macular area. In these situations, testing the full 30° will not offer a good trade-off between test duration and the clinical information received, because more than 65% of the locations will be in known areas of non-seeing (FIG 5-5). To further maximize useful clinical

information, it is common to switch to testing patterns that solely evaluate the area of the macula.<sup>7,8</sup>

For further information on macula patterns, please see the section on the macula testing patterns M or 10-2.



### KINETIC PERIMETRY FOR ADVANCED GLAUCOMA

Since static testing is challenging for patients with advanced glaucoma,<sup>18-20</sup> kinetic perimetry is a good

alternative to static testing in such cases. For more information, please see Chapter 11 on kinetic perimetry.

### PERIPHERAL TEST PATTERNS TO ASSESS QUALITY OF LIFE

Even though the periphery is rarely affected in isolation in glaucoma,<sup>21-23</sup> there may still be a need to assess the peripheral vision, in order to evaluate the patient's overall quality of life.

be an add-on to the standard G pattern. The G-Peripheral pattern places strong emphasis on the nasal step area, as this is the most relevant peripheral location in glaucoma.<sup>21,24</sup>

In these situations, the G-Peripheral pattern (FIG 5-6) is a very time-effective peripheral screening pattern, with only 14 test locations in the periphery, and is intended to

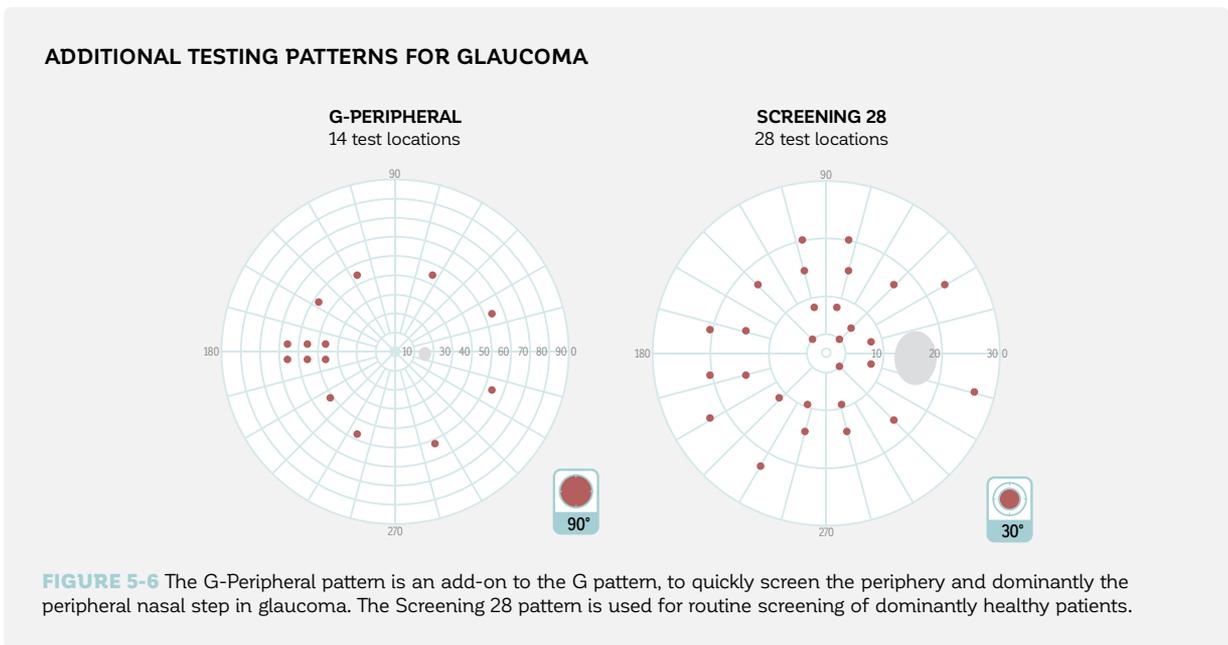
For an in-depth and efficient assessment of the periphery in low-vision patients, the use of kinetic perimetry should be considered.

### ABBREVIATED G PATTERN FOR SCREENING

In some instances, a screening visual field test is a convenient procedure for every patient, to make sure that visual field loss is not missed as part of a routine eye examination.

For screening of a presumed healthy population, the Screening 28 pattern offers a good trade-off between test

duration and accuracy. It is an abbreviated version of the G pattern with only 28 test locations (FIG 5-6). The locations have been chosen on the basis of their ability to predict glaucoma and other commonly occurring eye diseases, such as macula defects, quadrantanopias and hemianopias.<sup>25,26</sup> The Screening 28 pattern is recommended to be used with the screening-P95 strategy.



# TEST PATTERNS FOR NEUROLOGICAL VISUAL FIELD LOSS

## TYPICAL VISUAL FIELD DEFECTS IN NEURO-OPHTHALMIC CONDITIONS

Neurological conditions lead to a large variety of typical visual field defect patterns which are very specific, depending on the location at which the visual pathways are affected (FIG 5-7).<sup>27</sup> Lesions of the optic disc and optic nerve lead to unilateral (i.e., only affecting one eye) visual field defects. Common optic nerve and nerve head diseases include disc edema, optic neuropathies, optic neuritis, compressive lesions such as those caused by idiopathic intracranial hypertension, and a number of congenital abnormalities, such as optic nerve head drusen. Typical visual field defect patterns appear in the central 30° and include foveal and macular defects, enlarged blind spots, or patterns similar to those occurring in glaucoma. However, deficits in the far peripheral visual field beyond 30° also frequently occur.

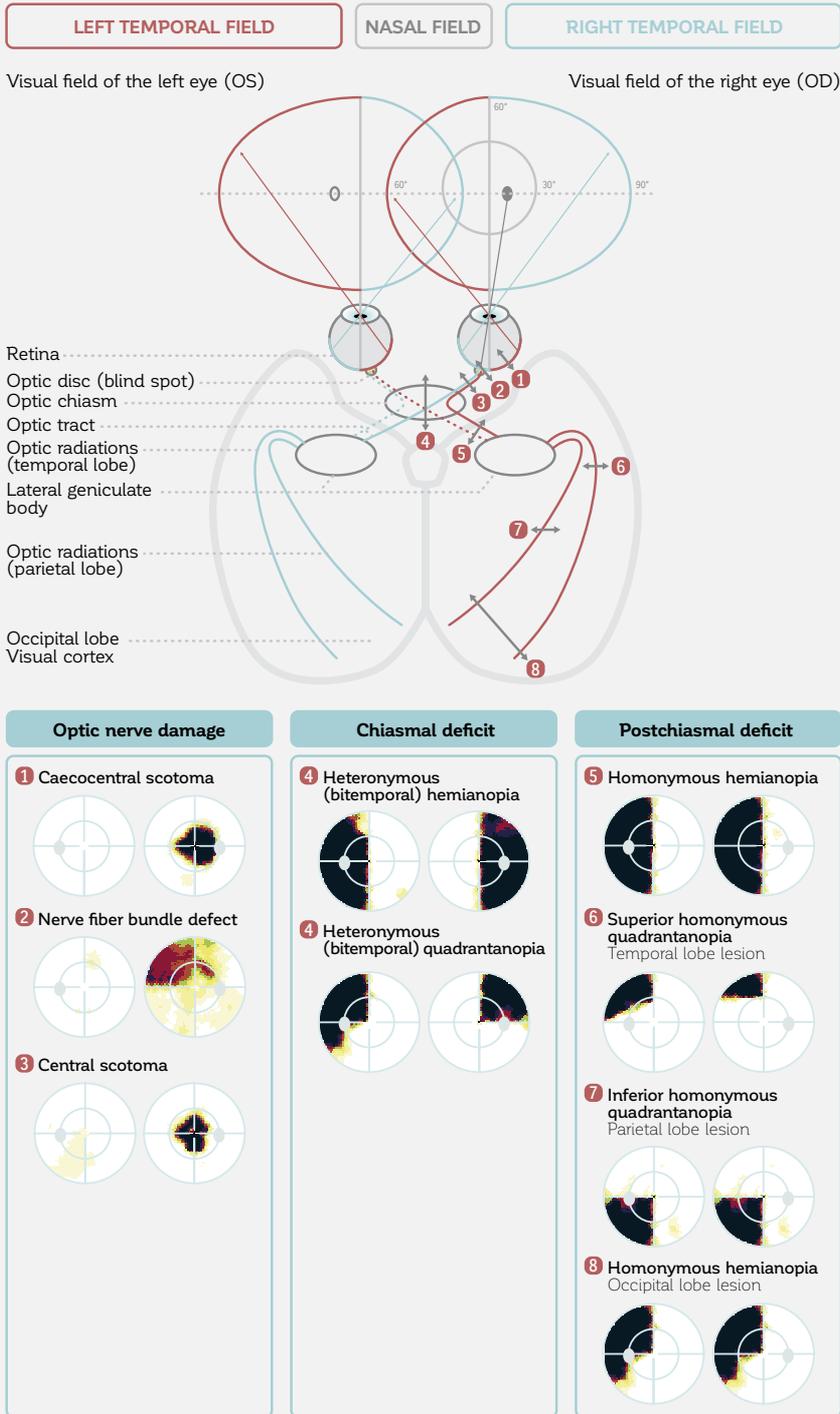
Chiasmal lesions resulting from diseases such as pituitary adenomas and related lesions typically result in bitemporal (i.e., left and right eye defects are mirrored) hemianopias, which progress from the superior to the inferior hemifield, but always respect the vertical midline. Damage can be more pronounced in one eye than the other. Postchiasmal lesions typically lead to homonymous (i.e., left and right eye defects are on same side of

vision) visual field defects, with congruity (similarity in location, size and magnitude of the deficit) between the two eyes being most common further back in the visual pathways at or near the occipital lobe. Large lesions result in complete hemianopias, although quadrantanopias and wedge-like defects are also common. While large lesions also affect the central visual field, small lesions may not extend to the central 30°. It should also be noted that a complete homonymous hemianopia only indicates that the deficit is post-chiasmal and that all visual pathway fibers leading back to the occipital lobe have been damaged.

To cover all of the aforementioned visual field defects, the full visual field needs to be thoroughly tested, with a high density of test locations in the macula, the blind spot and the central field. Therefore, thorough neurological visual field tests are time-consuming. If the type of disease is identified, then the focus of testing can be in the area affected by the disease, in order to reduce the test duration.

To maximize perimetric information and minimize test duration, kinetic perimetry should also be considered.

**TYPICAL VISUAL FIELD DEFECTS IN NEUROLOGICAL DISEASES**



**FIGURE 5-7** Typical visual field defects in diseases are unilateral if the optic nerve is damaged, heteronymous (the two eyes are mirror images) around the chiasm and homonymous (the two eyes show non-mirror symmetry) beyond the chiasm. Both hemianopias (vertical hemisphere defect) and quadrantanopias (quadrant defects) are typical neurological visual field defects.

## THOROUGH ASSESSMENT OF NEUROLOGICAL VISUAL FIELD DEFECTS

Given the wide variety of defect patterns in neuro-ophthalmic diseases, several test patterns are required to test all relevant locations.

### N PATTERN

The N pattern is designed to test the full visual field. It is useful to detect any kind of neurological disease. It extends from 40° nasally to 67° temporally and 40° vertically. With its 54 test locations in the central visual field and an additional 17 locations in the peripheral visual field, it offers an excellent trade-off between test duration and accuracy in the detection of central and early peripheral neurological defects.

### F PATTERN

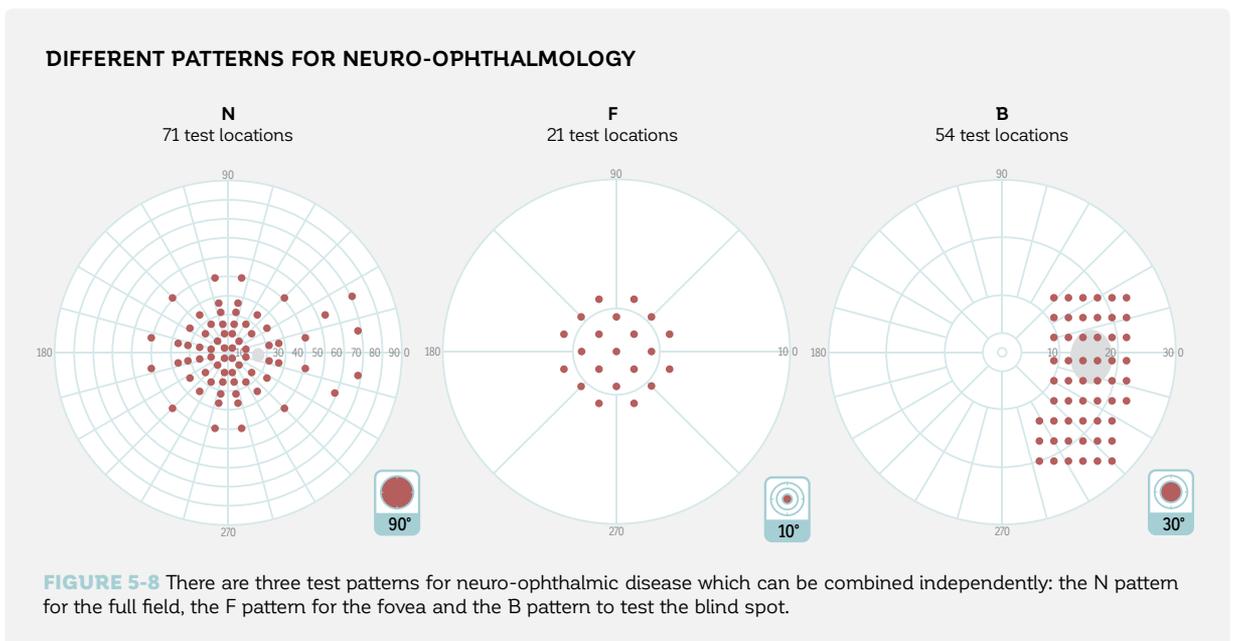
The F pattern is designed to detect foveal defects, such as nerve compressions, with high accuracy and should be used when this kind of pathology is suspected. With

These patterns are presented in (FIG 5-8) and can be independently combined as needed.

its 21 test locations extending from 0 to 3°, it provides a rapid assessment of the important foveal region and can also be useful for other indications in which the fovea is affected.

### B PATTERN

The B pattern is designed to detect the boundaries of the blind spot with adequate accuracy to check for blind spot enlargements. It covers the area around the blind spot from 9 to 19° horizontally, and 9.5° superiorly to 19° inferiorly in 2.5° steps. To account for tilted discs, extra points are added at the superior, temporal corner and the inferior nasal corner. With its 54 test locations, it takes a relatively long time to complete, while spatial resolution is limited to 2.5°.



## 07 PATTERN

The 07 pattern is an alternative to the N pattern. With its 130 test locations it is more thorough than the N pattern, but also takes considerably longer. It

is further described in the section on test patterns for retinopathies.

## KINETIC PERIMETRY

Since static testing is time consuming in the periphery and provides only a limited spatial resolution, kinetic perimetry is a very good alternative to static testing in

neurological diseases. For more information, see Chapter 11 on kinetic perimetry.

# TEST PATTERNS FOR RETINOPATHIES

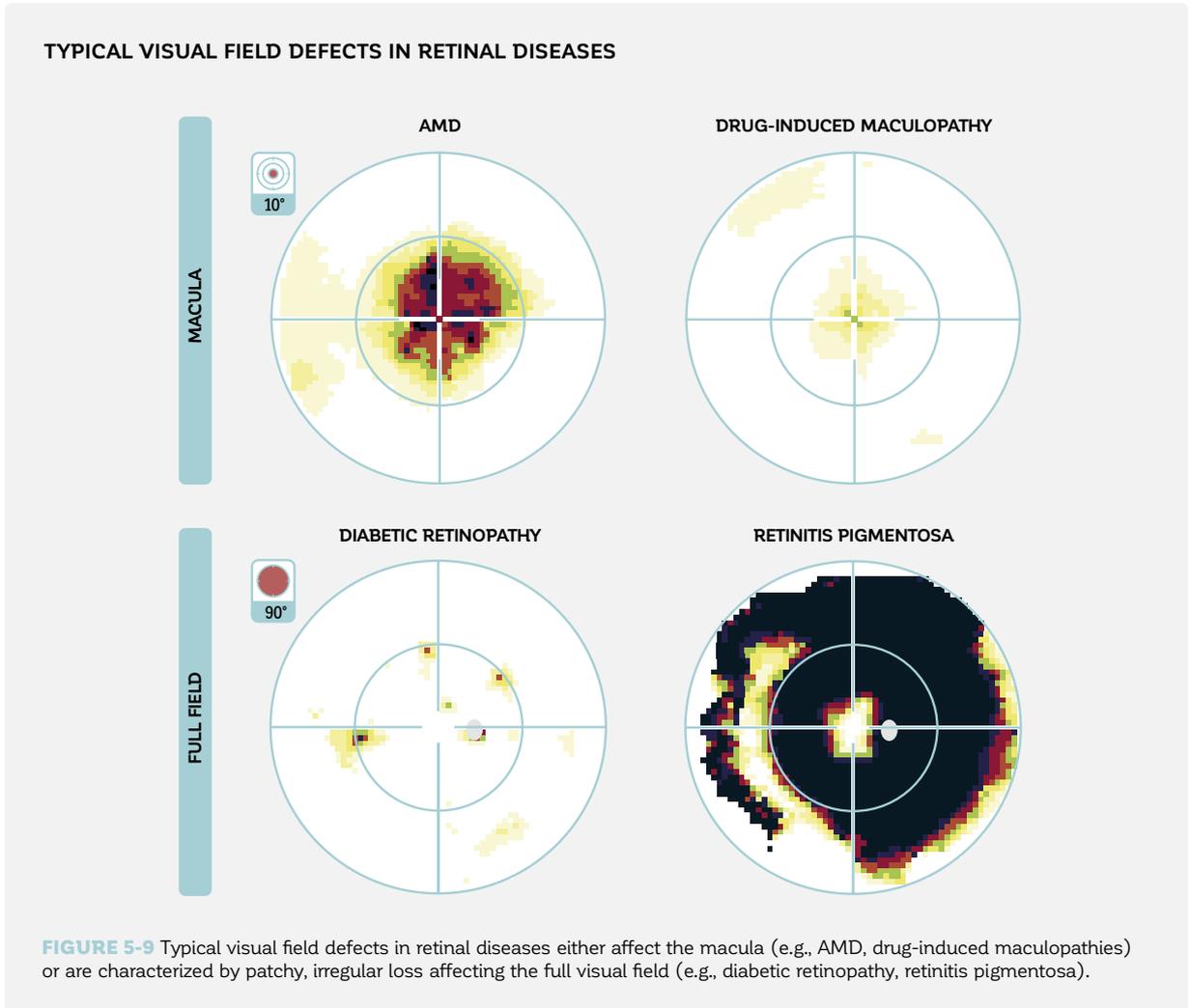
## TYPICAL VISUAL FIELD DEFECTS IN RETINOPATHIES

Retinal diseases lead to a variety of typical visual field defects (FIG 5-9). Diseases such as age-related macular degeneration (AMD) or drug-induced maculopathies lead to macula field defects and consequently require a macula testing pattern for visual field testing.

Other commonly occurring retinopathies often affect the far peripheral visual field. For these conditions, a test pattern covering the entire visual field is essential. The visual field defect patterns observed in retinopathies are usually irregular. While diabetic retinopathy results in small patchy peripheral visual field defects, retinal detachments and retinoschises result in one rather large cohesive defect, and retinitis pigmentosa shows a ring defect in early to moderate disease stages. Due to the irregularity of these defect patterns, a testing pattern with a high spatial distribution of test locations is necessary, which by definition is a more time-consuming test. To maximize perimetric information and minimize test duration, kinetic perimetry should also be considered. This may be the most efficient method of evaluating the far periphery.

For many reasons, perimetry is typically not the main diagnostic tool to detect and follow up retinopathies. Firstly, retinal lesions are easily identified by fundus examination or imaging. Secondly, perimetry requires the patient to maintain steady fixation, which is challenging for patients with advanced pathologies affecting the macula. Many of these patients will also have a non-foveal preferred retinal locus for fixation. And thirdly, many retinopathies require peripheral testing and a high spatial resolution of the visual field pattern, making this a challenging test for patients to undergo.

Nevertheless, perimetry is a key test to assess visual function in patients with retinopathies and therefore continues to play a role in the management of retinal diseases. Additionally, retinal diseases may occur in combination with other common pathologies such as glaucoma, so a good understanding of retinal visual field defects remains essential.



## TEST PATTERNS FOR THE MACULA

### M PATTERN

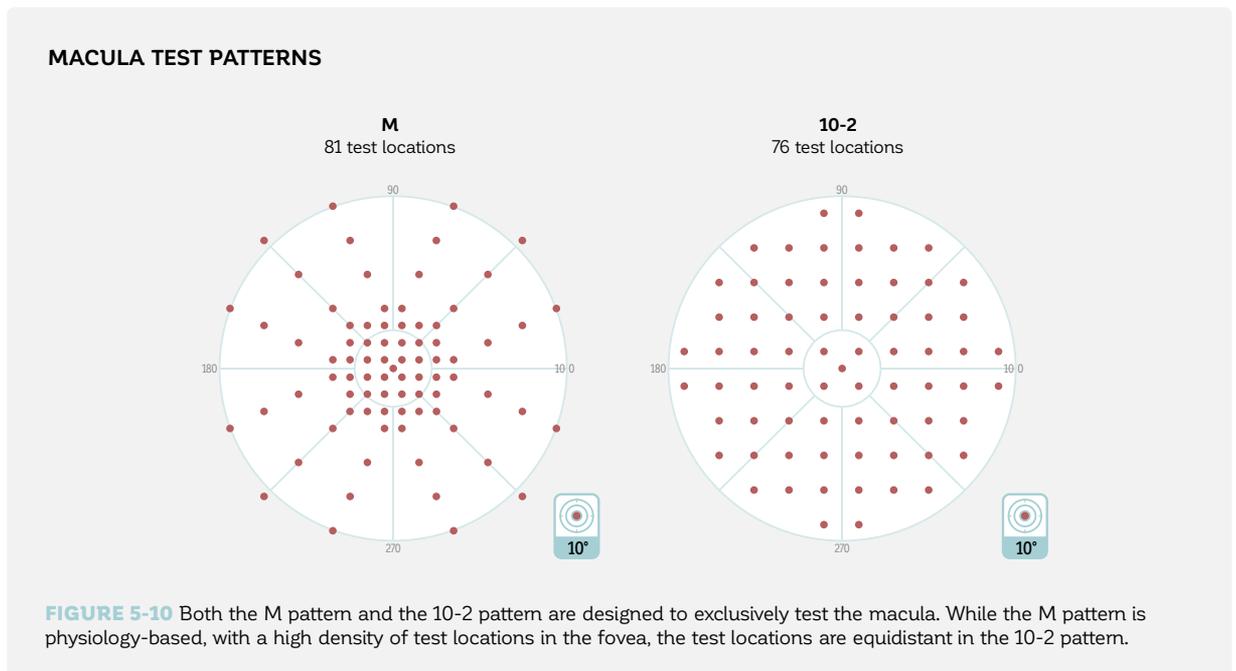
The M pattern is the recommended pattern for macula visual field evaluation.<sup>28</sup> With its 45 equally spaced test locations, with 1° spacing in the fovea (central 4°), it offers the highest density of test locations in the most essential area for visual function.<sup>28</sup> The remaining 36 of the 81 test locations in total are radially arranged outside the fovea (**FIG 5-10**).

The M pattern is most commonly used for the testing of drug-induced maculopathies, to follow up advanced-stage glaucoma patients, and for visual function testing in patients with AMD or other macular dysfunction.

### 10-2 PATTERN

The 10-2 pattern is the alternative to the M pattern, but is not physiology-based (i.e., there is no emphasis on the fovea). Instead, all 76 test locations are equidistant, being separated from each other by 2° (FIG 5-10). Its test duration is comparable to the M pattern.

The 10-2 grid is identical to that used on the Humphrey Field Analyzer, thereby allowing for continuity when transitioning from the Humphrey to the Octopus perimeter.



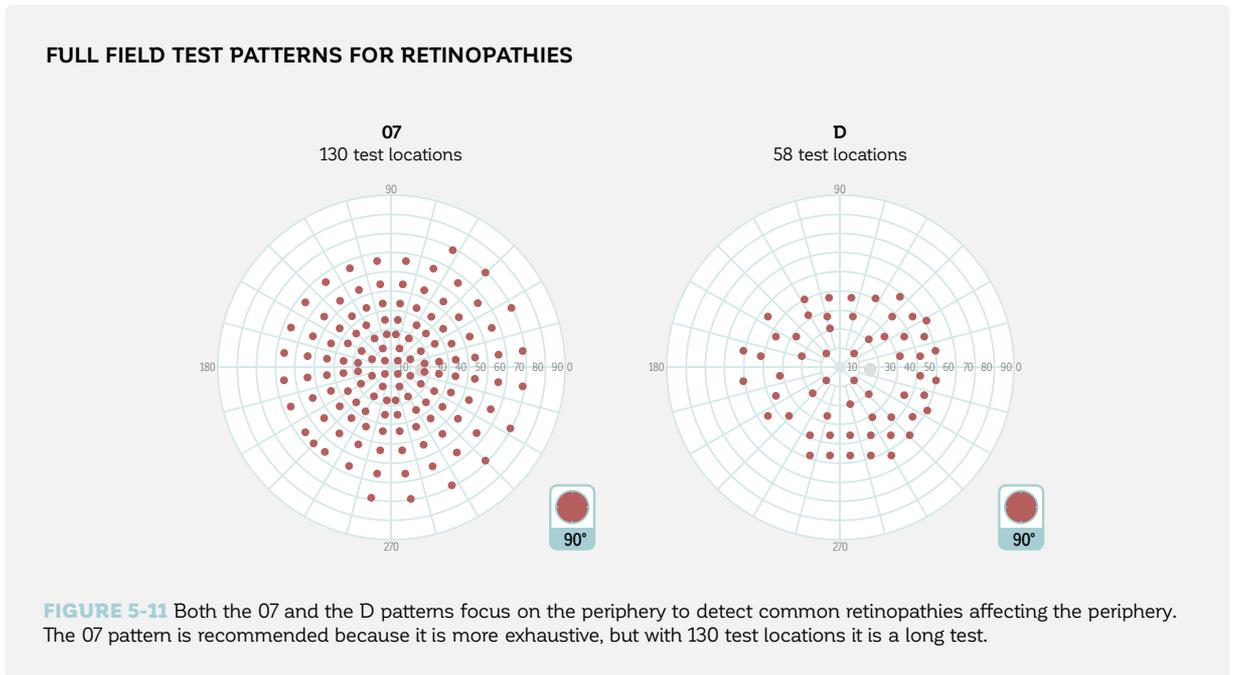
## TEST PATTERNS FOR THE FULL FIELD

### 07 PATTERN

The 07 pattern is the recommended static testing pattern to identify the patchy peripheral visual field loss associated with a variety of retinal diseases, such as diabetic retinopathy, retinoschisis, retinal detachment and retinitis pigmentosa.

It has 130 test locations, extending from 70° temporally to 55° nasally, arranged radially with 15° spacing<sup>29</sup> (FIG 5-11).

It provides reasonably high spatial resolution to be able to identify larger retinal lesions with a test duration that is acceptable for most patients. Nevertheless, the test duration using a quantitative strategy is long, so that a qualitative test strategy offers a good trade-off between test duration and accuracy (more details on quantitative and qualitative tests are provided in Chapter 6).



### **D PATTERN FOR DIABETIC RETINOPATHY**

The D pattern has been designed specifically for diabetic retinopathy. With only 58 test locations, only extending to 50° in the periphery, it has a lower resolution than the 07 pattern (FIG 5-11). This allows for a significantly

shorter test duration than the 07 pattern, but it may miss smaller, localized patchy loss if used for diabetic retinopathy in the early stages.

### **KINETIC PERIMETRY**

Since static peripheral testing is time consuming and provides only limited spatial resolution, kinetic perimetry is a very good alternative to static testing in

peripheral retinopathies. For more information, see Chapter 11 on kinetic perimetry.

# TEST PATTERNS FOR VISUAL ABILITY TESTING

Visual ability testing is often performed in a legal context, for example to assess a person's visual ability to drive, eligibility for a pension or presence of visual disability. Therefore, highly standardized visual field tests are prescribed by local law and must be adhered to strictly. While certain legislation sets very specific

requirements and defines test conditions in great detail, other legislation sets broader requirements. It is therefore essential to be familiar with the statutory requirements in one's own country and to choose a testing pattern that adheres to these regulations.

## TEST PATTERNS FOR VISUAL ABILITY TO DRIVE

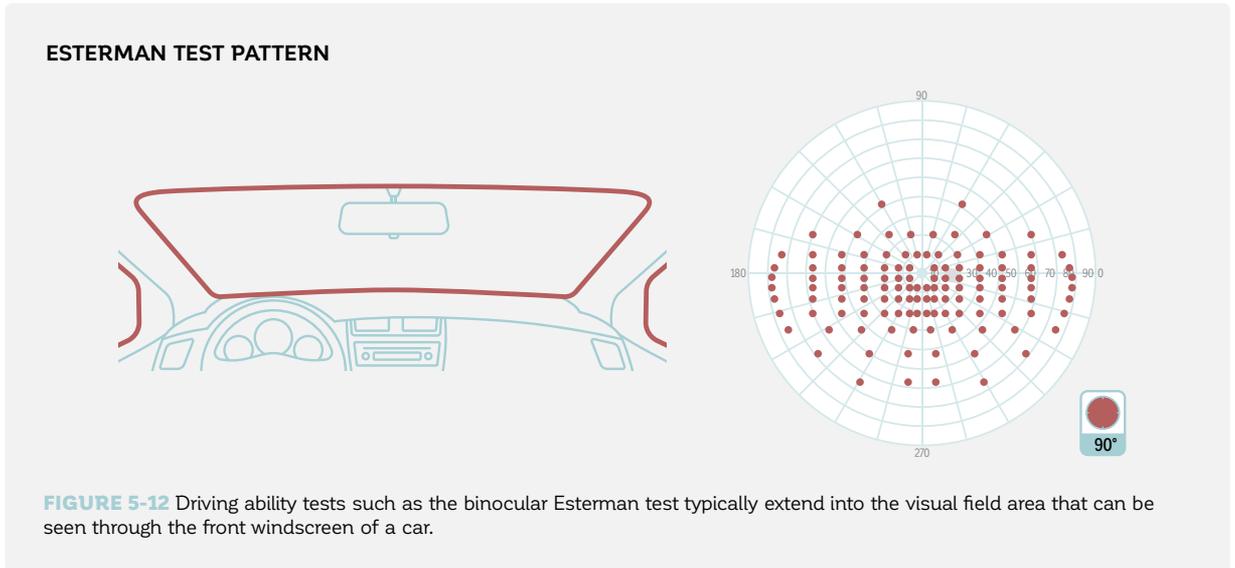
Safe driving requires a large horizontal field of view, to be able to notice other cars coming from the side, and a fairly intact central field of view, to be able to notice obstacles ahead. As driving is performed with both eyes open, the binocular field of view is relevant for safe driving.

By law, in many countries visual ability to drive tests are mandatory to obtain and maintain a driver's license. While the precise requirements differ according to local legislation, often a visual field test is required. While the legislation in some countries is rather vague, in other countries a specific test is requested.

### **ESTERMAN TEST**

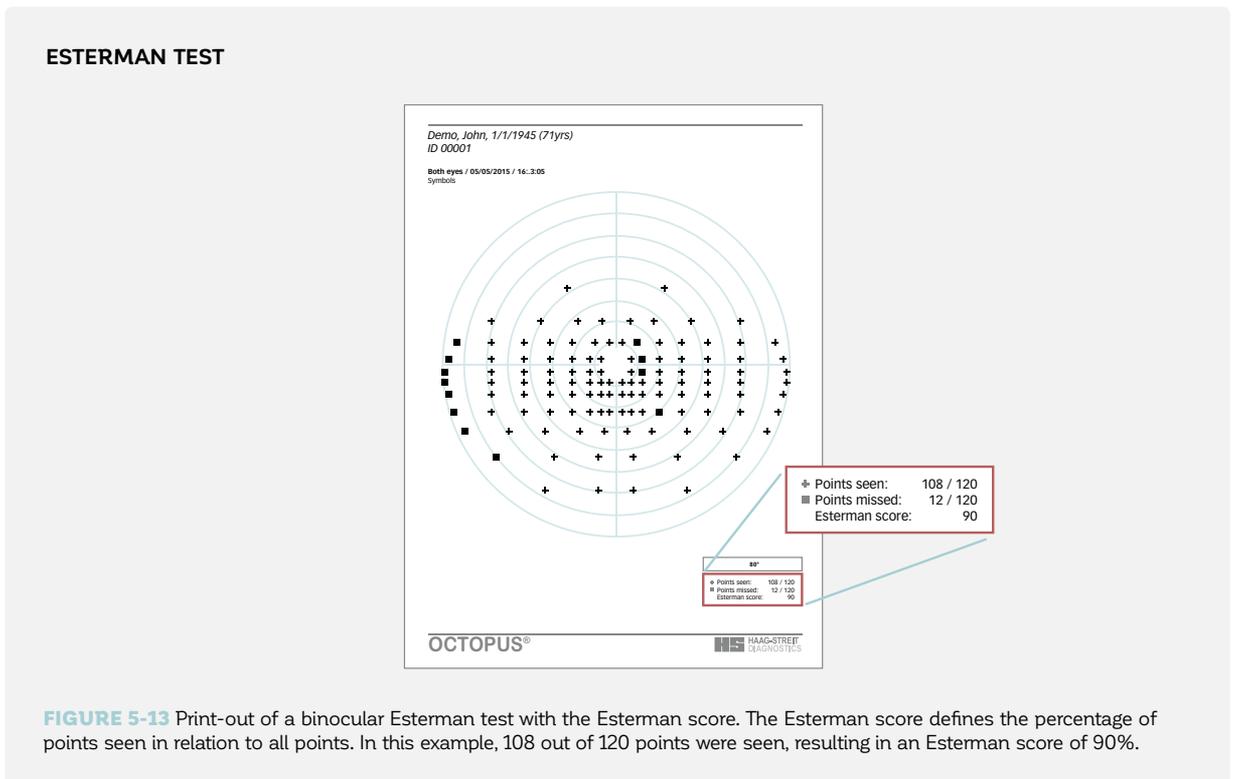
The Esterman test was developed by Ben Esterman<sup>30</sup> and has become an accepted standard visual field test for driving ability that is available in most modern perimeters. While this test must be used in countries that require it by law, it is also commonly used in countries in which there are broader statutory requirements.

The Esterman test contains 120 test points. It horizontally spans 160°, and vertically from 30° superior to 60° inferior (**FIG 5-12**). It is typically a binocular test since driving is undertaken binocularly, but a monocular version is also available.



As this test has to meet legal requirements, the test parameters are clearly outlined and similar for all perimeters. Each point is tested using a stimulus intensity of 1,000 asb on a background intensity of 31.4 asb. Points that are seen are marked with a plus sign and points

that are missed are marked with filled squares. The percentage of seen points relative to all points results in the Esterman score (FIG 5-13). The Esterman score needed to fulfill driving requirements varies in different legislations.



### ADDITIONAL DRIVING ABILITY TESTS

Octopus perimeters also offer the German driving ability test FG (Führerscheingutachten). Additional driving ability test patterns can be created using the custom test function.

Some legislations also accept driving ability tests performed with kinetic perimetry. For more information on kinetic perimetry, see Chapter 11.

## TEST PATTERNS FOR BLEPHAROPTOSIS

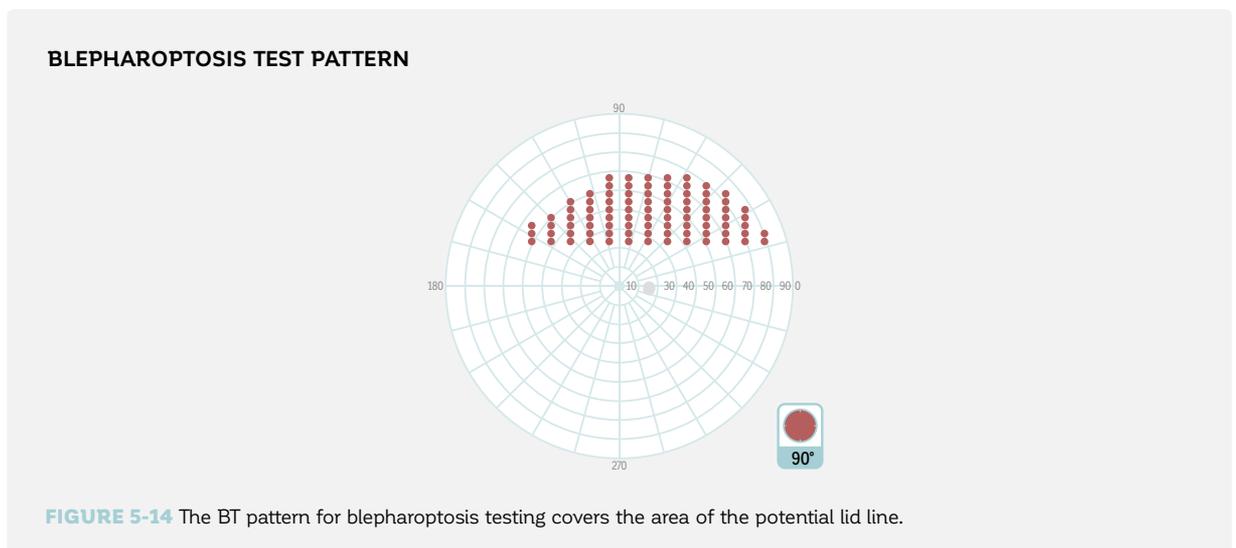
Visual field testing for blepharoptosis is performed in order to objectively quantify the influence of ptosis on visual function. If it is significant, many insurance companies accept blepharoplasty as a medically required surgery, instead of a cosmetic surgery, and will cover the cost. The acceptance criteria are not standardized and local legislation, as well as the respective insurance company, should be consulted.

To objectively assess the potential benefits of blepharoplasty for visual function, the affected eye is typically tested twice: once under normal conditions, and once with the lid taped up to mimic visual function after surgery (FIG 5-15). The difference in the superior visual field between the taped and non-taped eye is then used to determine the benefits of blepharoplasty.

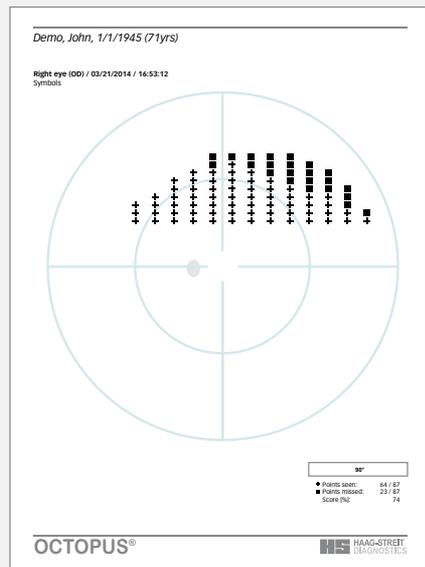
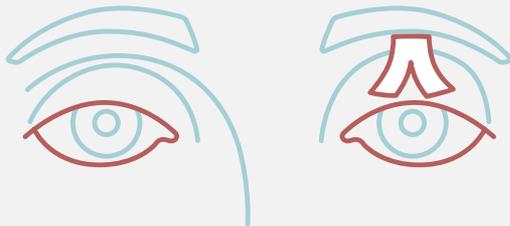
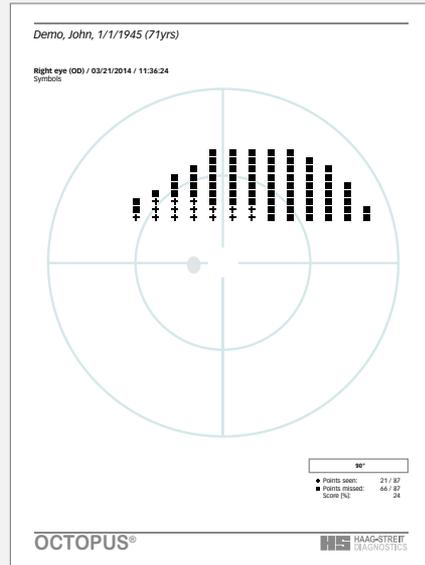
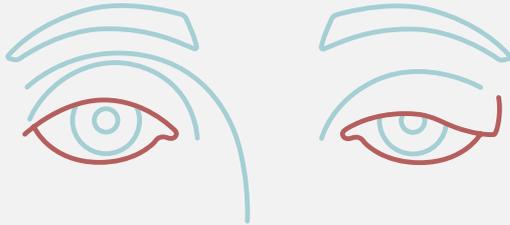
### BT PATTERN FOR BLEPHAROPTOSIS

The BT pattern is designed specifically for blepharoptosis testing and covers the area of the lid lines in the superior

field (FIG 5-14).<sup>31</sup> As there is no vision underneath the lid line, qualitative testing (seen, not seen) is sufficient.



**VISUAL FIELD TESTING FOR BLEPHAROPTOSIS**



**FIGURE 5-15** Visual field testing for blepharoptosis is typically performed twice. Once under normal conditions and once with the lid taped up to mimic post-surgery condition. The difference between the two visual field tests determines the potential benefits of blepharoplasty for visual function.

**KINETIC PERIMETRY**

Since static peripheral testing is time-consuming, kinetic perimetry is a more time-efficient method to perform

visual field testing in blepharoptosis. For more information, see Chapter 11 on kinetic perimetry.

## TEST PATTERN FOR VISUAL IMPAIRMENT

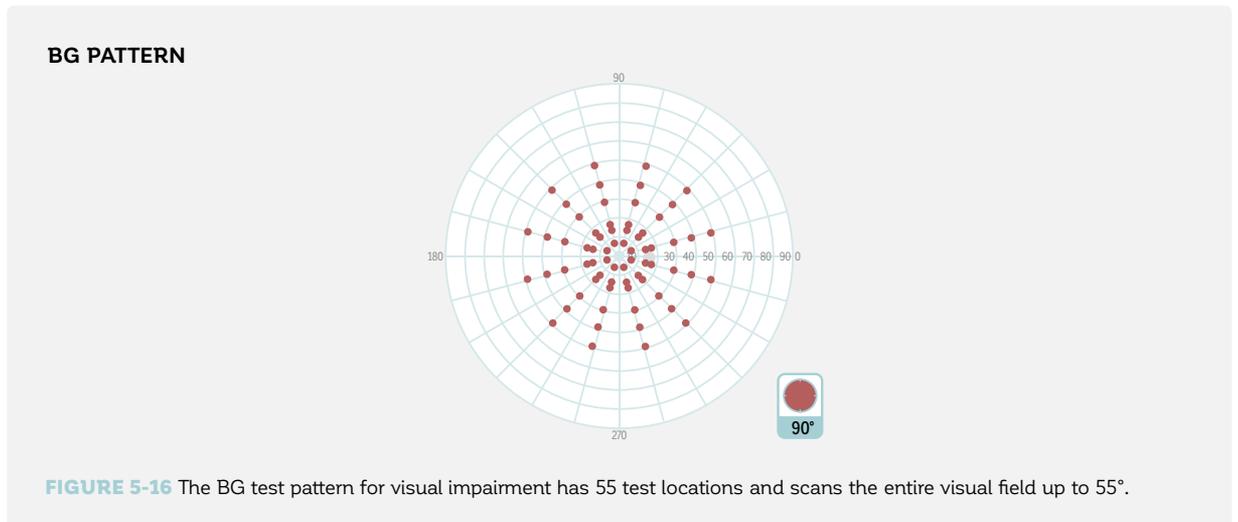
In many countries, there is a pension system to support visually impaired people. In order to determine a person's eligibility for such a pension, an objective visual function test is required that is related to a patient's

quality of life. Typically, test patterns for visual impairment exhaustively test the central visual function and also extend into the periphery.

### BG PATTERN

The German examination to assess legal blindness, BG (*Blindengutachten*) tests at 55 locations extending radially out to 55° (FIG 5-16). This test was designed based

on legal requirements in Germany, but can also be useful in other countries in which the legislation is less specific.



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## CHAPTER 6

# SELECTING A TEST STRATEGY

## INTRODUCTION

As illustrated in Chapter 4, determining sensitivity thresholds by assessing all levels of stimulus intensity (e.g., stimulus luminance) is not practical because of the time it would require. Several strategies have therefore been developed to minimize test duration while maximizing clinically relevant information. Some strategies are quantitative, providing a good estimate of the local sensitivity thresholds, while others are qualitative and can only determine whether a stimulus of a given intensity is seen or not.

The optimal strategy for a given test situation depends on a number of factors. The patient's ability to reliably complete the test is a crucial factor. A test that is designed to be very accurate can lead to inaccurate perimetric results if the patient is only able to perform reliably during a portion of the test. In such situations, a potentially less

accurate but shorter test may yield more useful visual field results.

Another important factor is the reason for which the test is being performed. For example, in order to detect and follow pathologies such as glaucoma, it is important to be able to detect small changes in sensitivity thresholds with high accuracy. To achieve this, an accurate quantitative strategy is needed. On the other hand, areas with no clinically meaningful information such as the blind spot or the area under the lid in ptosis testing can be identified equally well with a qualitative test that simply determines whether stimuli are seen or not seen. Qualitative test strategies are also often sufficient in legal performance ability tests to assess, for example, whether someone fulfills the visual field requirements to drive. **TABLE 6-1** summarizes the differences between qualitative and quantitative testing strategies.

CHARACTERISTICS OF QUANTITATIVE AND QUALITATIVE STRATEGIES			TABLE 6-1
	QUANTITATIVE STRATEGIES (THRESHOLDING)	QUALITATIVE STRATEGIES (SCREENING)	
<b>ADVANTAGES</b>	Quantification of sensitivity thresholds and visual field losses Higher accuracy	Faster compared to most quantitative strategies	
<b>WHAT IT IS BEST AT DETECTING</b>	Small changes in sensitivity Ocular and neurologic pathologies	Normal versus abnormal vision Compliance with legally required visual field criteria (e.g., ability to drive) Absolute defects	
<b>COMMON USES</b>	All pathologies (e.g., glaucoma, age-related macular degeneration)	Visual ability tests (e.g., driving, legal blindness, ptosis) Pathologies with predominantly absolute defects (e.g., blind spot enlargement, certain neuro-ophthalmological and retinal pathologies) Screening of eyes for abnormality	

Finally, it is also important to consider patient comfort. Tests of short duration are easier to perform and may motivate patients to come regularly for follow-up testing.

All quantitative and qualitative test strategies available on the Octopus perimeters are described in more detail in the following sections.

## QUANTITATIVE STRATEGIES

Quantitative sensitivity threshold strategies are used to obtain sensitivity thresholds at various locations within the visual field. They are commonly used to detect and follow pathological visual field defects. One exception is the detection and follow-up of pathologies that result in sharp absolute defects such as blind spot enlargements, which can be equally well detected with a qualitative strategy.

Two types of quantitative sensitivity threshold strategies are available. In the first type, there is a systematic sampling of the entire range of light intensities in large steps, with further detailing within the expected sensitivity threshold zone using smaller steps. This approach is designed to

offer higher accuracy, but it also has longer test duration.

In the second type of quantitative sensitivity threshold strategy, predetermined estimates (e.g., educated guesses) are made about the sensitivity thresholds at each location based on information obtained from other neighboring visual field locations. Systematic sampling at each location is not performed. This approach is used in the Tendency-Oriented Perimetry (TOP) strategy, a shorter test with reduced accuracy in some situations.

The characteristics of these strategies are summarized in **TABLE 6-2** and are further detailed in the next paragraphs.

CHARACTERISTICS OF THE TOP, DYNAMIC, LOW VISION AND NORMAL STRATEGIES

TABLE 6-2

	TOP	DYNAMIC	LOW VISION	NORMAL
<b>TEST DURATION*</b>	2–4 minutes	6–8 minutes	6–8 minutes	10–12 minutes
<b>WHAT IT IS BEST AT DETECTING</b>	Contiguous defects (central 30°)	Contiguous defects Isolated defects Peripheral defects Mild sensitivity threshold changes	Contiguous defects Isolated defects Peripheral defects Sensitivity thresholds with low sensitivity	Contiguous defects Isolated defects Peripheral defects Mild sensitivity threshold changes
<b>BEST SUITED FOR</b>	Patients struggling with fatigue Busy practices	Patients with mild changes in sensitivity thresholds Patients with good cooperation and attention	Low vision patients	Patients with excellent cooperation, attention and minimal fatigue
<b>COMMON USES</b>	Glaucoma Macula	Glaucoma Macula Periphery (Neuro, Retina)	Low vision	Clinical research
<b>METHODOLOGY</b>	Spatial relationship among sensitivity thresholds of neighboring zones	Sampling with increasing step size (2 – 10 dB)	Sampling with 4 dB step size Start at 0 dB sensitivity	Sampling with 4-2-1 dB step size
<b>ACCURACY IN dB</b>	n/a	From $\pm 1$ dB (normal vision) to $\pm 5$ dB (Low vision)	$\pm 2$ dB	$\pm 1$ dB

\*Test duration estimates are provided for the 30° G pattern with 59 test locations.

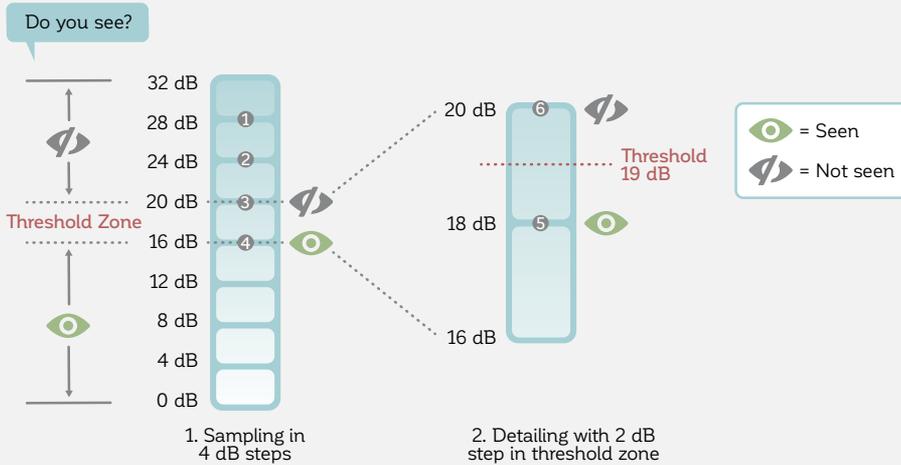
## NORMAL STRATEGY

The normal strategy was the first quantitative testing strategy built into Octopus perimeter. It provides the determination of sensitivity thresholds with an accuracy of about 1 dB.<sup>1,2</sup> This strategy takes approximately 10 to 12 minutes per eye for the G pattern.<sup>3</sup> Due to its relatively long test duration and the availability of quicker tests, this strategy is no longer recommended for standard testing. The long test duration can lead to fatigue, and many patients show significantly reduced reliability in spite of the higher accuracy of this strategy. It is still available, however, and can be useful in clinical research

projects or used to detect early and shallow defects in younger patients who have the endurance necessary to perform reliably on longer tests.

The normal strategy uses a 4-2-1 dB sampling procedure to determine sensitivity thresholds. In this sampling procedure, stimuli are first presented in 4 dB steps to find the threshold zone. Further detailing occurs in 2 dB steps and the sensitivity threshold is determined as the average between the last seen and not seen stimuli.

**NORMAL STRATEGY**



**FIGURE 6-1** An example of the procedure used in the normal strategy is presented. The 4-2-1 bracketing procedure of the normal strategy proceeds by first presenting stimuli in 4 dB steps (stimuli 1 to 4) to find the threshold zone, then further details in 2 dB steps (stimuli 5 and 6), and finally determines the sensitivity threshold as the average between the last seen and not seen stimuli.

Because the widely used dynamic strategy is a variation of the normal strategy, understanding the details of the normal strategy, outlined in **BOX 6A**, is helpful for grasping the dynamic strategy.

**BOX 6A**

**THE DETAILS OF THE NORMAL STRATEGY**

The normal strategy initially tests one anchor point location in each of the four quadrants to determine sensitivity thresholds at one position in each quadrant. Using this information as an initial stimulus for neighboring locations, it then uses a 4-2-1 dB sampling procedure. This sampling procedure is also referred to as bracketing, and is performed using the staircase procedure in which two response reversals (first from “not seen” to “seen” and then from “seen” to “not seen”) are required. For example, the test begins by presenting a stimulus at an intensity that corresponds to a given sensitivity threshold (e.g., 28 dB). If this stimulus is not seen, the next stimuli are presented in decreasing 4 dB steps, until the stimulus is seen (e.g., 16 dB; **FIG 6-1**). At this point, the procedure switches to a second crossing of the threshold, but now in steps of 2 dB. The initial stimulus of that sequence is presented at 18 dB. If it is “seen”, the following stimuli are presented in increasing 2 dB steps until “not seen” (second response reversal); however, if the 18 dB stimulus is “not seen”, the following stimuli are presented in descending 2 dB steps until “seen”. In both cases, the sensitivity threshold is calculated as the mean of the last “seen” and “not seen” stimuli (**FIG 6-1**). It is expressed in dB with an uncertainty of approximately  $\pm 1$  dB.

Except for the anchor points, the level of the initial stimulus is determined from the results already obtained at neighboring test locations, in order to further reduce test duration. It is important to note that even though information from neighboring test locations is used, each sensitivity threshold is determined independently of the neighboring sensitivity thresholds with the sampling procedure described above. Typically, the procedure requires about 4–5 stimuli per test location.

It is possible for the patient’s sensitivity threshold to be above the level of the initial stimulus. This occurs when the first stimulus presented is seen. In this situation, the next stimulus is presented in increasing 4 dB steps until “not seen”. The rules for the second crossing of the threshold remain the same.

## DYNAMIC STRATEGY

The dynamic strategy is a widely used procedure because it offers an excellent trade-off between test duration and accuracy.<sup>4,5</sup> It provides detailed information about each visual field location and has been shown to detect early visual field loss and isolated visual field defects reliably.<sup>6</sup> It is also a relatively quick test, taking an average of 6 to 8 minutes per eye when using the G pattern.<sup>7</sup> Furthermore, this strategy can be used with all test patterns.

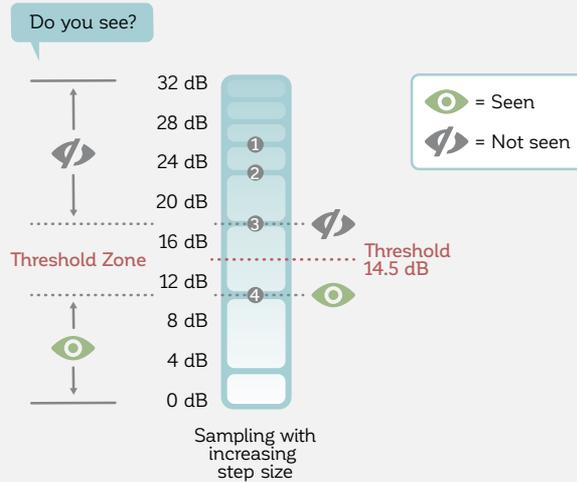
The dynamic strategy is based on the normal strategy, but it has been optimized to shorten test duration while missing only a minimal amount of clinically relevant information.<sup>4,8</sup> Similar to the normal strategy, it narrows in on the sensitivity threshold by using a modified staircase sampling procedure.

In comparison to the normal strategy, the dynamic strategy step size is smaller in regions of normal sensitivity and larger in areas where defects are present, ranging from 2 dB to 10 dB (FIG 6-2). This saves considerable time when significant visual field loss is present. The variable step size is justified, as fluctuation has been shown to increase with increasing defect depth.<sup>9</sup> Testing can therefore be performed using a step size tailored to the degree of fluctuation.<sup>4</sup>

In the dynamic strategy, the determination of the level of the first stimulus at a given test location follows the same rules as the normal strategy (i.e., anchor points and information from neighboring locations). Test time is saved mainly because the sensitivity threshold is crossed only once (i.e., only one reversal). Depending on whether the first stimulus is seen or not, the next stimulus is presented in increasing or decreasing steps until the threshold is crossed. The threshold is determined as the average between the last seen and unseen stimuli. In areas of the visual field that are near the normal range, an accuracy of approximately  $\pm 1$  dB is achieved to support early disease detection. In areas of advanced defects, an accuracy of approximately  $\pm 5$  dB is achieved.

While the sensitivity thresholds may not be as accurate as those obtained using the normal strategy in more advanced disease, various clinical studies have shown that the dynamic strategy is adequate for low-vision patients. This is because more accurate testing is not possible due to an increase in fluctuation.<sup>4,8,10</sup>

## DYNAMIC STRATEGY



**FIGURE 6-2** An example of the procedure used in the dynamic strategy is presented. The dynamic strategy samples with increasing step size (from 2 to 10 dB from normal sensitivity threshold) after the first stimulus is not seen until a stimulus is seen without any further detailing. As a result, the accuracy is between  $\pm 1$  and  $\pm 5$  dB, depending on the step size.

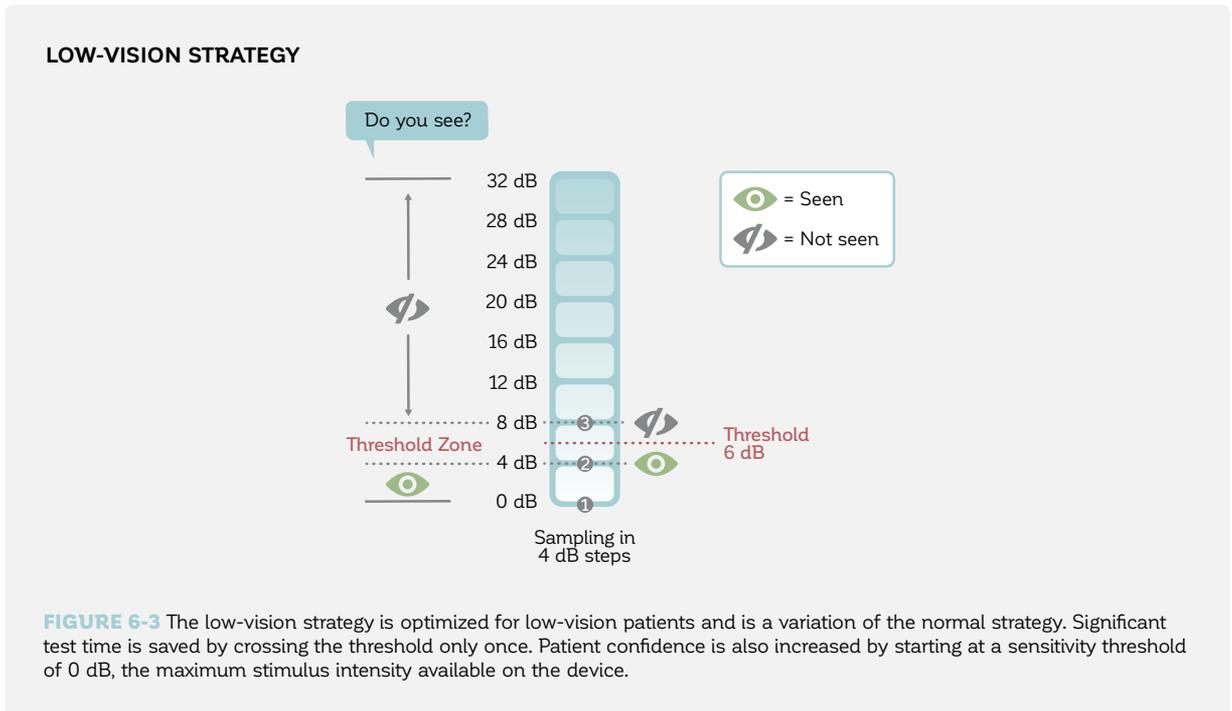
## LOW-VISION STRATEGY

The low-vision (LV) strategy is useful for assessing patients with end-stage diseases, when only limited visual field function remains. It employs a methodology similar to the normal strategy, but only performs one threshold crossing (4-2 bracketing), which reduces test duration. While an accuracy of only approximately  $\pm 2$  dB can be achieved, this is justified by the large fluctuation in areas of low vision.<sup>9</sup> In addition, the low-vision strategy starts testing at a sensitivity threshold of 0 dB (FIG 6-3). This means that the initial stimulus used is at the maximum stimulus intensity because of the inverse relationship between light intensity and sensitivity threshold, as outlined in FIG 2-2. This approach further reduces test duration when a visual field contains a large number of locations with absolute defects. For such situations, testing with the dynamic or normal strategy would take

longer because more stimuli would be presented in locations where there is no sensitivity.

Besides saving test time, the low-vision strategy is also more patient-friendly for low-vision patients, because starting the test with the maximum stimulus intensity increases the likelihood that the initial stimulus will be seen. This allows patients to feel confident about their performance in the initial stage of the test.

In order to extend the dynamic testing range into the low-vision area and also to make the target easier to see for low-vision patients, the low-vision strategy is typically used in combination with a stimulus size V that is presented for 200 ms (see Chapter 10 for more information on stimulus size V for low-vision patients).



## TENDENCY-ORIENTED PERIMETRY (TOP) STRATEGY

The Tendency-Oriented Perimetry (TOP) strategy is a widely used and fast procedure. It takes only two to four minutes per eye for a complete sensitivity threshold examination with the G pattern.<sup>3,11-13</sup> Because of its short duration, it is especially recommended for patients unable to maintain concentration for long periods, such as the neurologically impaired or children.<sup>14</sup> For these patients, fatigue or lack of concentration in a longer test would lead to unreliable results.<sup>15,16</sup> The TOP strategy is also useful as a practical routine method for testing and following patients of all age groups, especially in busy practices.<sup>16</sup>

The TOP strategy takes advantage of the fact that sensitivity thresholds at each location of the visual field are

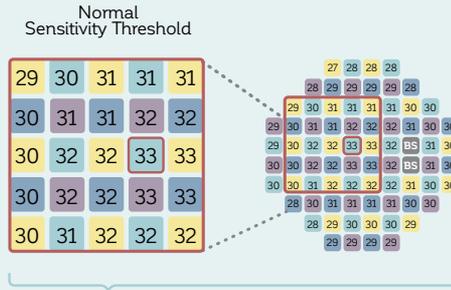
related to the sensitivity thresholds at nearby locations (i.e., there is a spatial correlation among adjacent test locations). During the test, answers at any given location are taken into account to adjust the expected sensitivity thresholds at neighboring locations. The test starts by presenting stimuli at 50% of normal sensitivity thresholds at a quarter of the test locations. If the stimulus at a certain location is missed, the stimuli at immediately adjacent locations are presented at lower sensitivity thresholds. However, if the stimulus is seen, the initial stimuli at neighboring locations are presented at higher sensitivity thresholds. This procedure is repeated for all test locations with answers from neighboring test locations leading to an adaptation of all test locations. See **BOX 6B** for more details.

**BOX 6B**

**TOP STRATEGY – STEP-BY-STEP PROCEDURE**

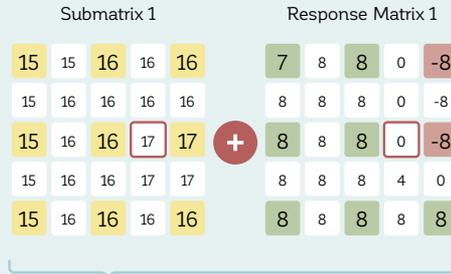
**STEP 0**

- Baseline: normal sensitivities at each test location
- Test pattern divided into 4 sub-test patterns



**STEP 1A**

- Submatrix 1 =  $\frac{1}{2}$  of normal sensitivity
- Stimulus presentation on 1<sup>st</sup> sub-test pattern



**STEP 1B**

- **Seen:** Add  $\frac{1}{4}$  of normal sensitivity
- **Not seen:** Subtract  $\frac{1}{4}$  of normal sensitivity

**STEP 1C**

Calculate responses for sub-test patterns 2–4 from average of neighboring locations by interpolation

**STEP 2A**

- Submatrix 2 = Submatrix 1 + Response Matrix 1
- Stimulus presentation on 2<sup>nd</sup> sub-test pattern



**STEP 2B**

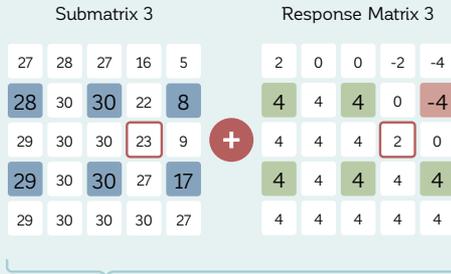
- **Seen:** Add  $\frac{1}{16}$  of normal sensitivity
- **Not seen:** Subtract  $\frac{3}{16}$  of normal sensitivity

**STEP 2C**

Calculate responses for sub-test patterns 1, 3, 4 from average of neighboring locations by interpolation

**STEP 3A**

- Submatrix 3 = Submatrix 2 + Response Matrix 2
- Stimulus presentation on 3<sup>rd</sup> sub-test pattern

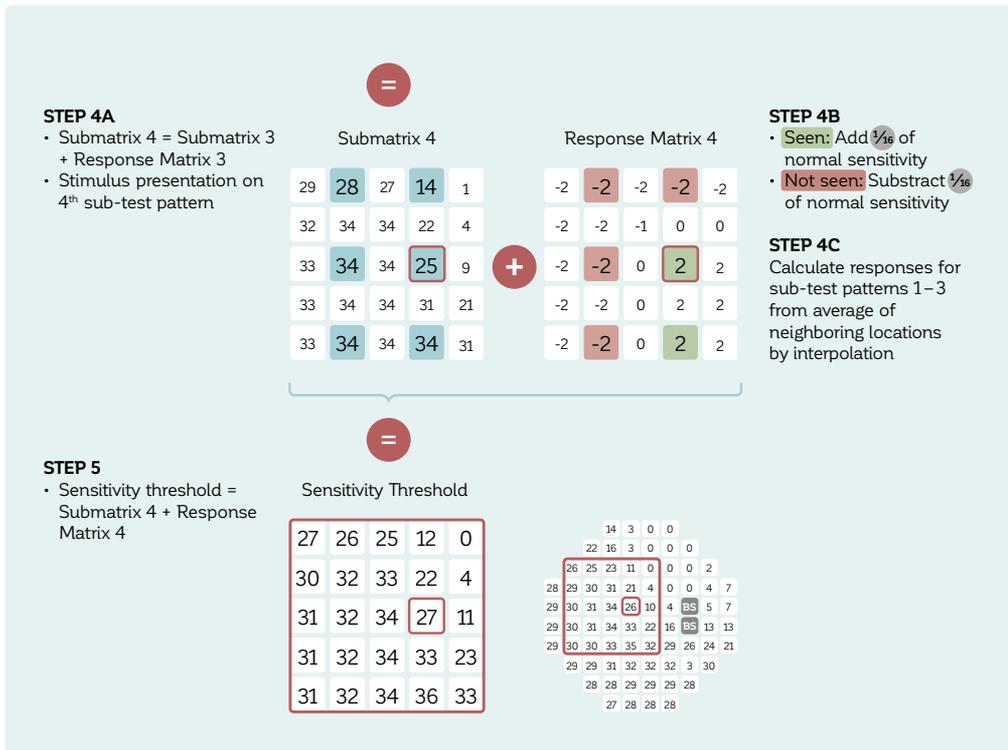


**STEP 3B**

- **Seen:** Add  $\frac{1}{16}$  of normal sensitivity
- **Not seen:** Subtract  $\frac{3}{16}$  of normal sensitivity

**STEP 3C**

Calculate responses for sub-test patterns 1, 2, 4 from average of neighboring locations by interpolation

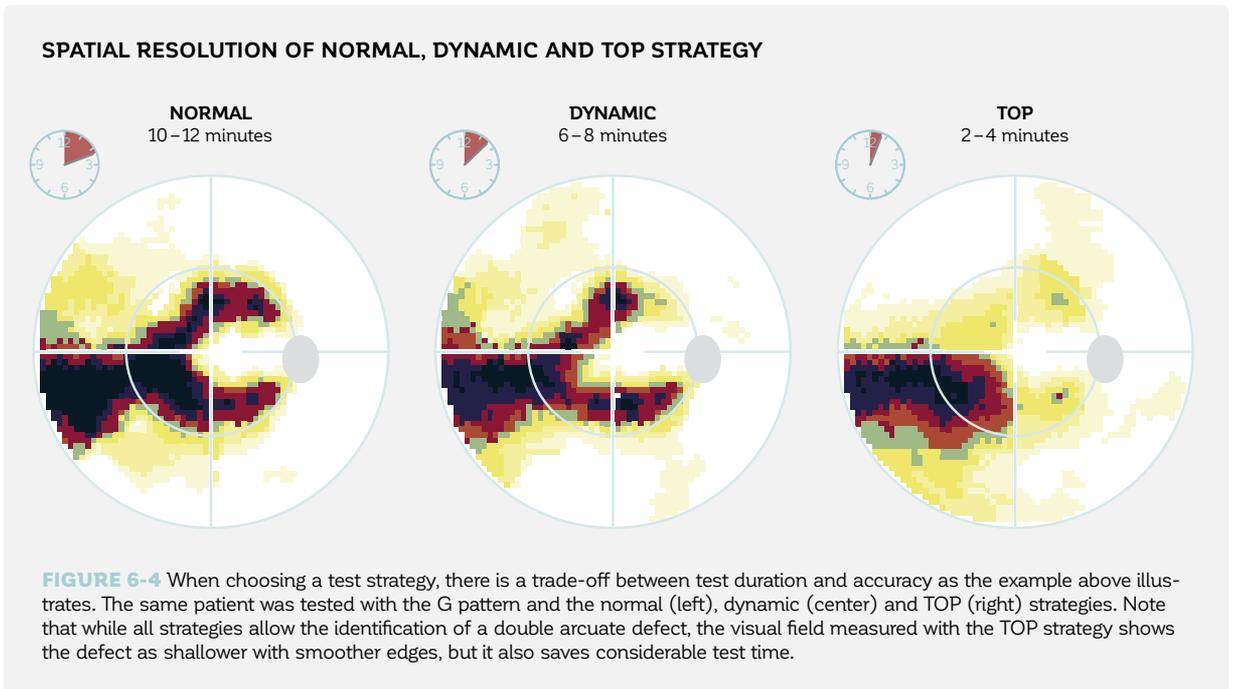


Because the initial stimuli are presented at a lower sensitivity threshold – and thus higher light intensity (see FIG 2-2 for the inverse relationship between light intensity and sensitivity threshold) – in the TOP strategy than in the dynamic or normal strategies, the likelihood of seeing most of the initial stimuli is increased. This allows patients to feel confident about their performance for the initial stage of the test, resulting in a shorter patient learning curve, increased reliability for the initial examinations, and possibly greater motivation for patients to return for follow up testing.

While the advantages of the TOP strategy, in terms of reduction of test duration and fatigue effects, can lead to

increased accuracy,<sup>15</sup> this strategy also has some shortcomings related to accuracy. The TOP strategy can reliably detect large contiguous scotomas such as those present in glaucoma.<sup>13,16,17</sup> However, it smoothes the edges of the scotomas<sup>18</sup> (FIG 6-4) and is less sensitive to small, localized defects compared to a systematic sampling procedure such as the dynamic strategy.<sup>6,11,12</sup> These factors should be kept in mind when making clinical decisions.

In addition, the TOP strategy requires a reasonably dense test grid to justify the assumption that there is a spatial correlation between the test points. Therefore, it is only available for the central 30° patterns G, 32, 30-2 and 24-2 and the macula test patterns M and 10-2.



## QUALITATIVE STRATEGIES

Qualitative strategies are useful and time-efficient when the quantification of a patient's sensitivity threshold is not necessary. These strategies are used for visual field performance ability testing including driving,<sup>19</sup> legal blindness and ptosis examinations. They are also sometimes used for pathologies that result in absolute defects. For example, qualitative strategies can be used to assess the vision of patients with neurological conditions that result in hemianopia, quadrantanopia<sup>20</sup> and blind spot enlargements. Furthermore, they can also be useful in

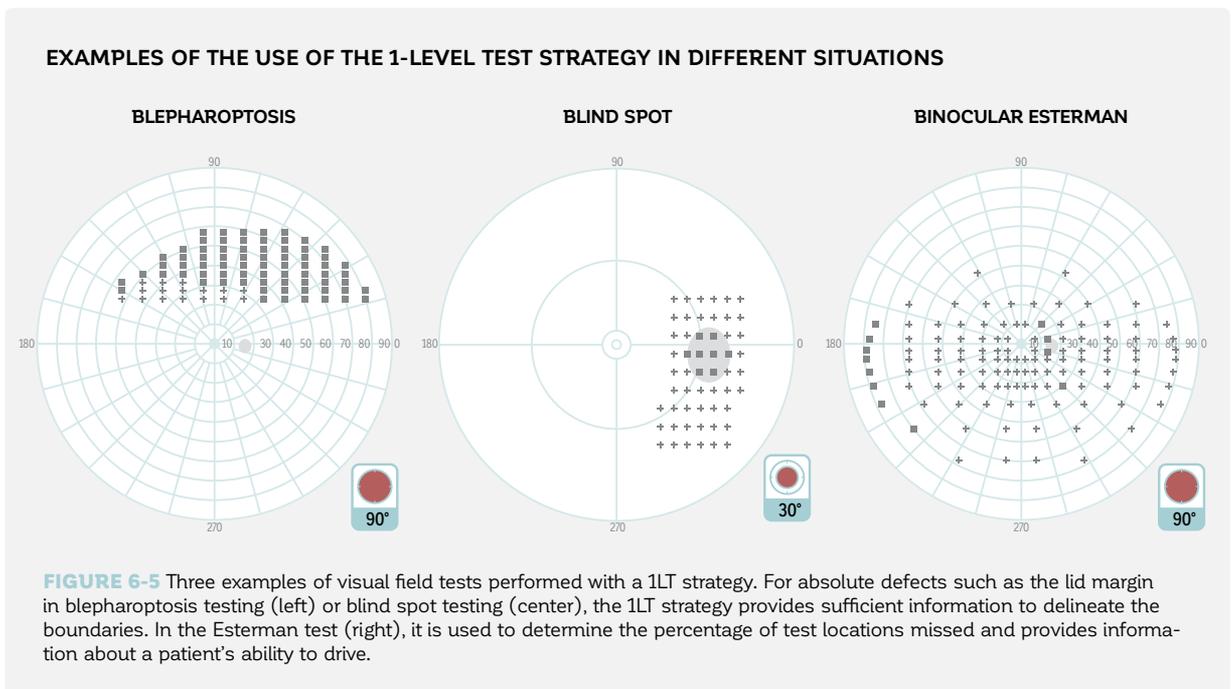
assessing the vision of patients with certain retinal pathologies. Finally, they can be used to quickly screen patients with assumed normal vision.

The answers obtained with these strategies are always qualitative (e.g., seen/not seen or normal visual field/abnormal visual field). Octopus perimeters offer several qualitative strategies for different purposes, as described below.

## 1-LEVEL TEST STRATEGY (TWO-ZONE STRATEGY)

The 1-Level Test (1LT) is a fast test strategy most commonly used for legal performance ability tests to assess whether someone fulfills the minimal visual field criteria to drive or to perform other daily tasks. In addition, it is

used to assess absolute visual field defects such as blind spot enlargements or the lid margin in blepharoptosis testing (FIG 6-5).

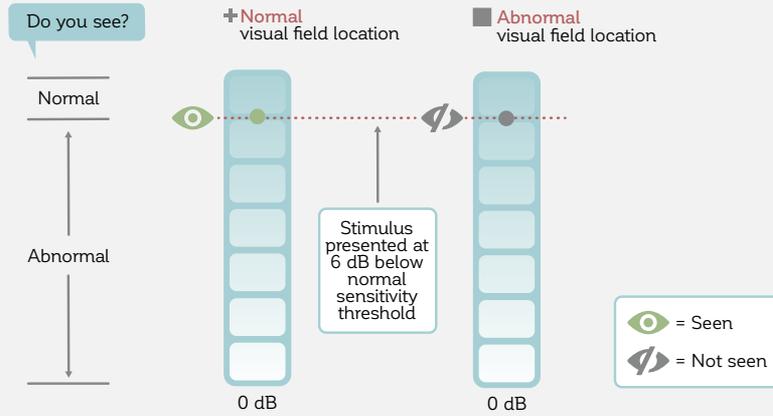


With the 1LT strategy, only one stimulus is presented at each test location at the predetermined intensity level of 6 dB below the normal sensitivity threshold. The patient either sees or misses these stimuli (FIG 6-6). The visual field is consequently divided into two zones, seen (represented by a “+” sign) and not seen (represented by a “■” symbol). As a result, this strategy is sometimes referred to as a two-zone strategy. Clinically, visual field locations with the “+” sign can be interpreted as normal and those with the “■” symbol as abnormal. Note that when used with the Esterman pattern, the 1LT strategy

displays stimuli at a fixed stimulus luminance of 1000 asb (this is equal to 10 dB at a maximum stimulus luminance of 10000 asb) to comply with the legal requirements of the test.

Be aware that typically more than one abnormal visual field location showing a disease-specific pattern is required to classify a visual field as abnormal. For more detailed information on the distinction between normal and abnormal visual fields, see FIG 7-9, 7-10, 8-14 and 8-15.

### 1-LEVEL TEST STRATEGY



**FIGURE 6-6** With the 1LT strategy, the visual field is divided into areas of likely normal and abnormal visual field locations.

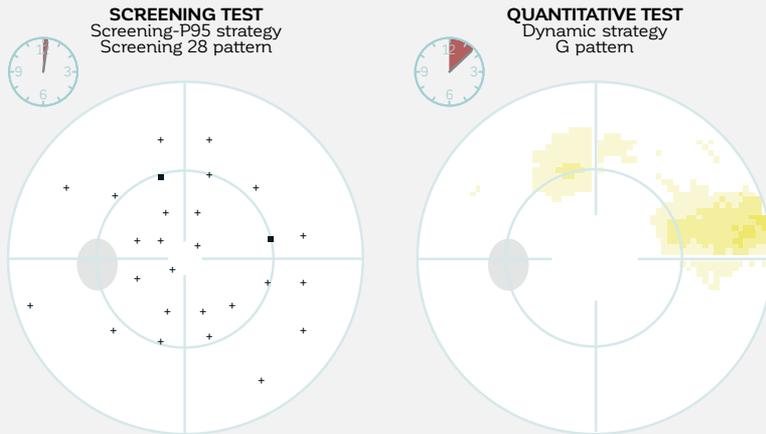
## SCREENING-P95 STRATEGY

The screening-P95 strategy is used to quickly distinguish between people with normal and abnormal visual fields. It is a very fast strategy and patients with normal visual fields can typically complete it within one minute. It is designed to be used with the Screening 28 pattern.

The screening-P95 strategy is useful and time-effective when routine visual field testing is performed on every patient to identify pathologies that would otherwise be missed

with a routine eye examination. In that context, the screening-P95 strategy together with the Screening 28 pattern offers a very good trade-off between testing time and accuracy by being fast while at the same time allowing the identification of patients with abnormal visual fields.<sup>21</sup> If a visual field abnormality is detected during routine screening, further quantitative testing is recommended to assess the extent and depth of visual field loss (FIG 6-7).

**EXAMPLE OF THE USE OF THE SCREENING-P95 STRATEGY**

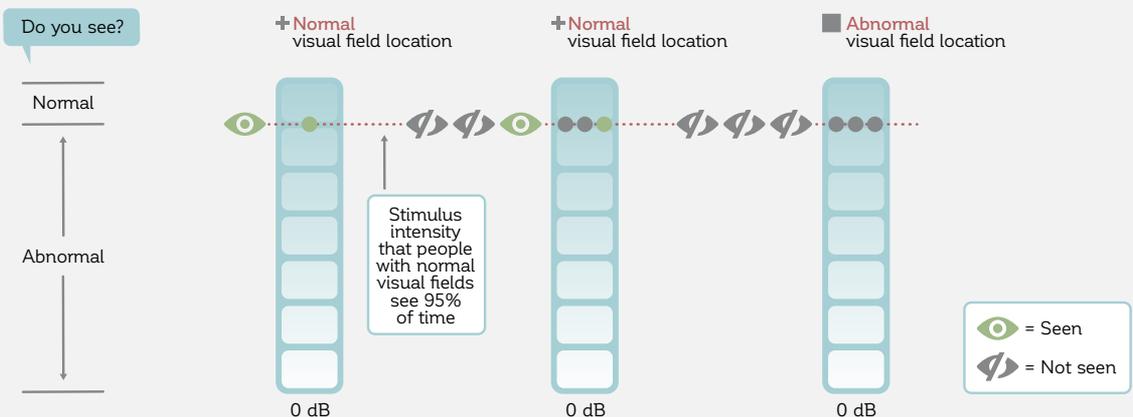


**FIGURE 6-7** The routine testing with the screening-P95 strategy and the short Screening 28 pattern allows the identification of potentially unnoticed visual field defects with minimal test duration. This can identify patients who require a more detailed evaluation. In the case presented above, a patient with early glaucoma was detected during routine screening, and consequent quantitative visual field testing confirmed the existence of the previously unnoticed partial arcuate defect.

The screening-P95 strategy is a modified version of the 1-Level Test strategy (FIG 6-8). The first stimulus at each location is presented at the intensity that an average subject with a normal visual field would see 95% of the time. If the point is seen, the location is designated as normal. If it is not seen however, the same point is repeated twice to confirm suspected abnormalities and to avoid false negative errors, which are common in patients inexpe-

rienced with visual field testing. If the patient sees the stimulus on any of these repetitions, the location is designated as normal (represented by a “+” sign), otherwise it is recorded as abnormal (represented by a “■” sign). Because unseen points are tested three times, the likelihood of obtaining false negative errors is reduced. This approach results in better specificity for the screening test.<sup>22</sup>

**EXAMPLE OF THE USE OF THE SCREENING-P95 STRATEGY**



**FIGURE 6-8** The screening screening-P95 distinguishes between normal and abnormal visual fields by presenting a stimulus at an intensity that people with normal visual fields would see 95% of the time.

## 2-LEVEL TEST STRATEGY (THREE-ZONE STRATEGY)

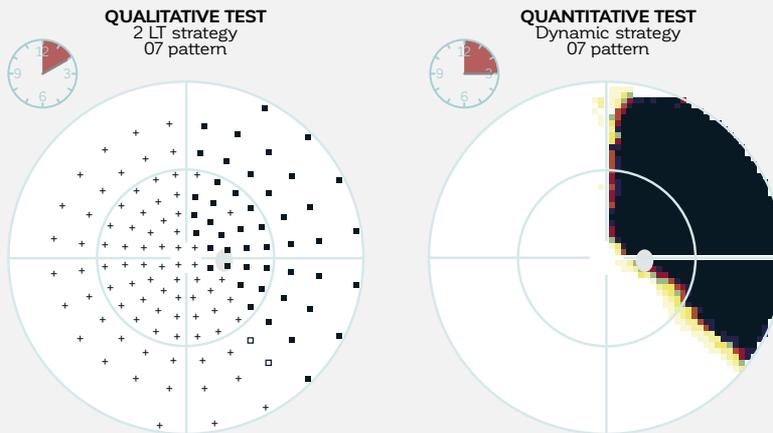
The 2-Level Test (2LT) strategy is similar to the 1LT, but presents stimuli at two sensitivity thresholds. It consequently divides the visual field into three zones and is thus also referred to as a three-zone strategy.

The 2LT strategy is commonly used as an alternative to the quantitative dynamic strategy to assess the full visual field in pathologies that result in hemianopia, quadrantanopia or certain retinal conditions such as diabetic retinopathies, retinal detachments and retinoschisis. Because these pathologies affect a significant portion of the visual field and often contain a meaningful number of absolute defects, quantitative testing with a reasonably dense test pattern can be too time-consuming and consequently lead to unreliable results in some patients due to

fatigue. In such situations, the 2LT strategy offers a good trade-off between test duration and accuracy, often with only minimum loss of clinical information (**FIG 6-9**).

The 2LT strategy provides only a rough indication of the status of the visual field. It is designed to distinguish between areas of normal visual field, areas with relative defects (i.e., with reduced sensitivity thresholds) and areas with absolute defects (i.e., with a sensitivity threshold of 0 dB, where the maximum stimulus intensity of the perimeter cannot be seen). This information is often clinically sufficient to identify diseases whose diagnosis is based on the shape of the defect rather than on small changes in sensitivity.

### QUALITATIVE TEST WITH 2LT STRATEGY VS QUANTITATIVE TEST

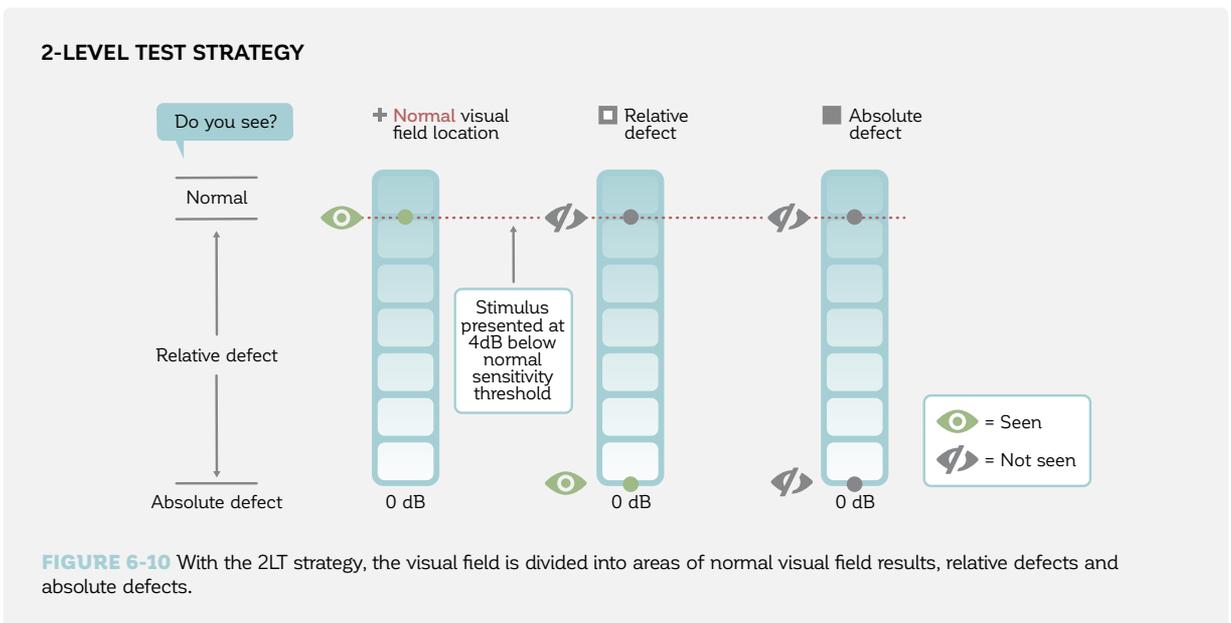


**FIGURE 6-9** The qualitative 2LT strategy allows distinction of areas of normal vision and relative and absolute defects with minimal test duration (left) and provides valuable information about the shape of defects. Quantification of the same test pattern with the dynamic strategy reveals the same pattern as well as detailed information about the sensitivity thresholds, but at the expense of a longer test (right). In this example, because the visual field shows an absolute defect, the amount of information provided by the 2LT strategy is comparable to the more detailed information provided by the quantitative dynamic strategy.

The 2LT strategy starts with the presentation of a stimulus 4dB below the normal sensitivity threshold at each location. When this stimulus is seen, it is designated as normal (represented by a “+” sign). When this stimulus is not seen, a second stimulus is presented at a sensitivity threshold of 0 dB, which corresponds to the maximum stimulus intensity that the perimeter can present (FIG 6-10). If this is seen, the location is marked as having a relative defect (represented by a “□” sign) and if it is not

seen, it is marked as having an absolute defect (represented by a “■” sign).

Note that typically more than one abnormal visual field location showing a disease-specific pattern is required to classify a visual field as abnormal. For more detailed information on the distinction between normal and abnormal visual fields, see FIG 7-9, 7-10, 8-14 and 8-15.



**FIGURE 6-10** With the 2LT strategy, the visual field is divided into areas of normal visual field results, relative defects and absolute defects.

# RECOMMENDATIONS ON KEY EXAMINATION PARAMETERS

There is always a trade-off between test duration and accuracy, but depending on the pathology or visual ability test performed, certain test parameter combinations offer better trade-offs than others. **TABLE 6-3** presents recommended combinations of test patterns and strategies for a variety of visual field testing situations that maximize clinical information and minimize test duration.

RECOMMENDED TEST PATTERN AND STRATEGY COMBINATIONS		TABLE 6-3
	TEST PATTERN	RECOMMENDED STRATEGIES
<b>GLAUCOMA/CENTRAL FIELD</b>	G, 32, 30-2, 24-2	Dynamic or TOP
<b>MACULA</b>	M, 10-2	Dynamic or TOP
<b>FULL FIELD (NEURO, RETINA)</b>	07	Dynamic or 2LT
<b>FOVEA</b>	F	Dynamic
<b>BLIND SPOT</b>	B	1LT
<b>LOW VISION</b>	M, G, 07 depending on pathology	Low Vision
<b>SCREENING FOR ABNORMAL VISION</b>	Screening 28	Screening-P95
<b>DRIVING</b>	Esterman	Fixed parameters (1LT, stimulus duration 500 ms)
	German Legal Driving (Führerscheingutachten FG)	Fixed parameters (2LT, stimulus duration 200 ms)
<b>BLEPHAROPTOSIS</b>	BT	1LT
<b>BLINDNESS</b>	BG	Fixed parameters (1LT, stimulus duration 500 ms)

This does not mean that these settings are the best for each visual field test; an expert user may prefer other combinations for certain situations. Therefore, Octopus perimeters offer the flexibility to customize examination parameters. However, there are two exceptions: 1) because the TOP strategy requires test locations to be relatively

close to each other, it can only be used with the sufficiently dense central 30° and macula test patterns; 2) legally prescribed ability tests such as the Esterman test are offered only with their standardized settings to ensure that the legal requirements are met.

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## CHAPTER 7

# OVERVIEW OF VISUAL FIELD REPRESENTATIONS

## INTRODUCTION

Perimetry determines sensitivity thresholds throughout the visual field. However, it can be challenging to correctly interpret the raw data in clinical practice because 1) normal sensitivity thresholds vary with age and eccentricity of test location; 2) visual field testing contains a subjective component due to the patient decision processes, which contributes to fluctuation; 3) both visual field location and disease severity influence fluctuation; and 4) in some patients, more than one disease may be present. For more information on these points, see Chapter 2.

For these reasons, Octopus perimeters offer several representations that are based on the measured sensitivity thresholds, but highlight specific aspects of the visual field, in order to support clinical decision-making. In this chapter, a systematic presentation of all visual field representations and indices is offered, with their definitions, design and relationships. While a detailed understanding of these characteristics is not necessary for correct clinical interpretation, some readers will find this information useful. The clinical meaning and interpretation of these same visual field representations are subsequently discussed in a clinical step-by-step workflow in Chapter 8, which also includes several examples.

## RELATIONSHIP AMONG OCTOPUS VISUAL FIELD REPRESENTATIONS

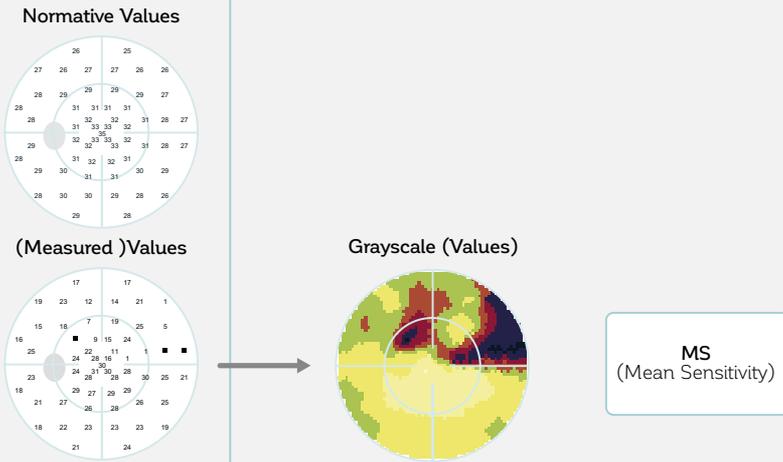
Most visual field representations on Octopus perimeters are based on the following three key representations: 1) Values (the sensitivity thresholds); 2) Comparisons (the comparison of the sensitivity thresholds with age-matched normative data); and 3) Corrected Comparisons (the comparison of the sensitivity thresholds with age-matched normative data, with a correction that eliminates

the influence of diffuse or widespread defects). **FIG 7-1** provides an overview of these relationships.

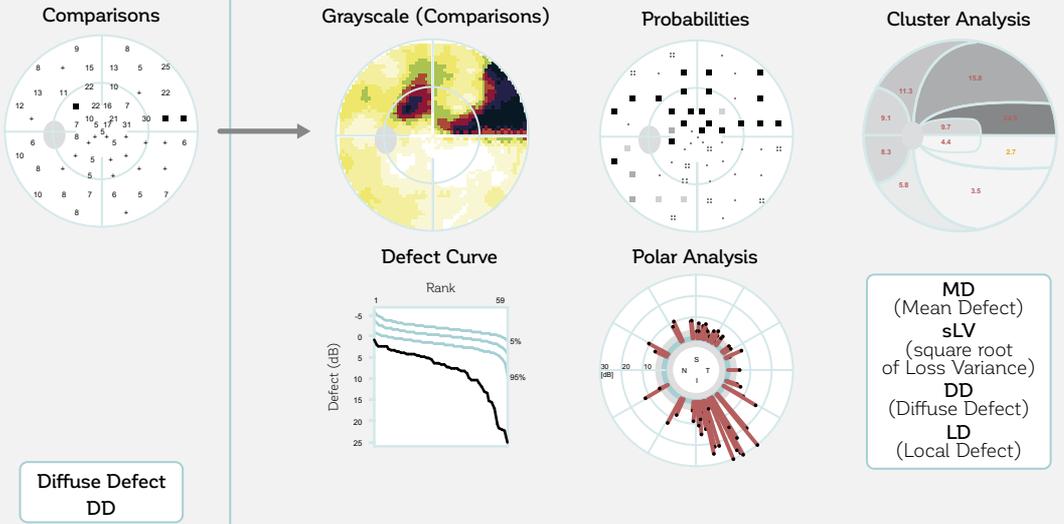
In addition, Octopus perimeters determine several indicators of visual field reliability, to assess whether a visual field test is trustworthy or not. These are presented at the end of this chapter.

**RELATIONSHIP AMONG DIFFERENT VISUAL FIELD REPRESENTATIONS**

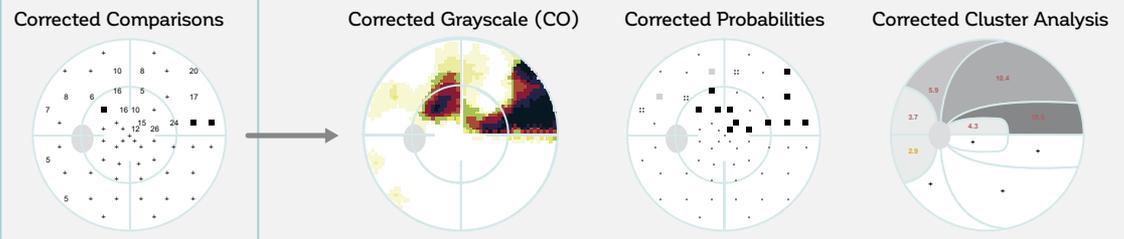
**SENSITIVITY THRESHOLDS**



**SENSITIVITY LOSS**



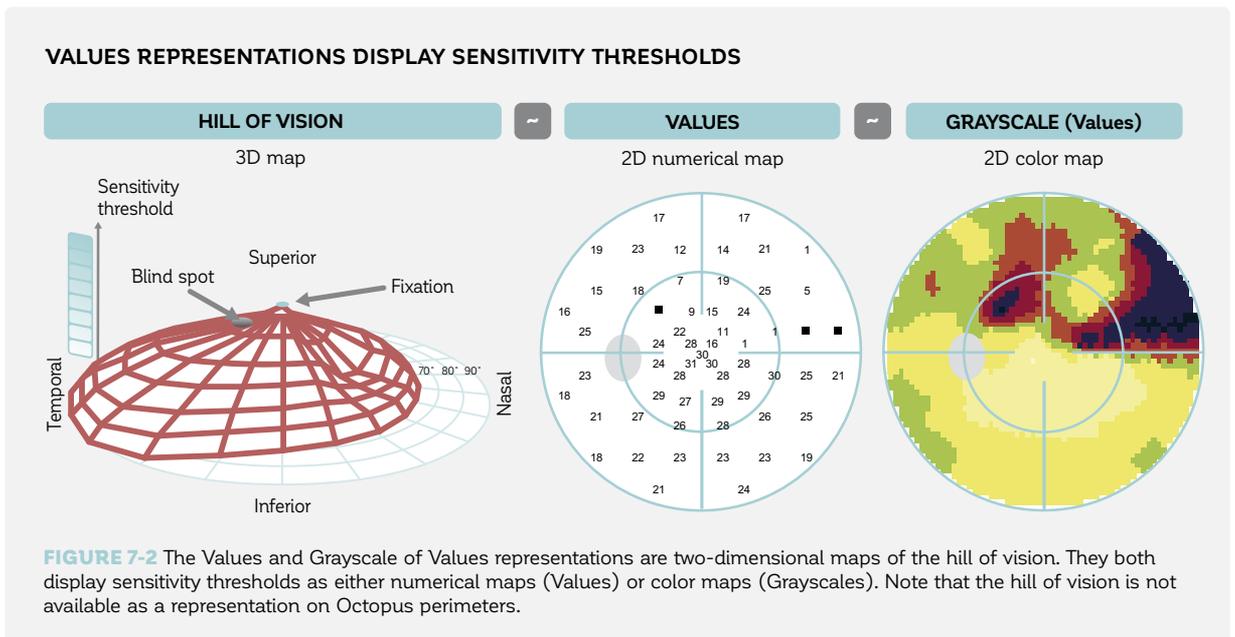
**LOCAL SENSITIVITY LOSS**



**FIGURE 7-1** All visual field representations are based on the measured sensitivity thresholds (i.e., Values) and are mostly compared to age-matched normative data (top), resulting in representations that show sensitivity loss (center). Some representations also only display local sensitivity loss (bottom) because they are additionally corrected to eliminate the influence of diffuse or widespread defects.

# REPRESENTATIONS DISPLAYING SENSITIVITY THRESHOLDS

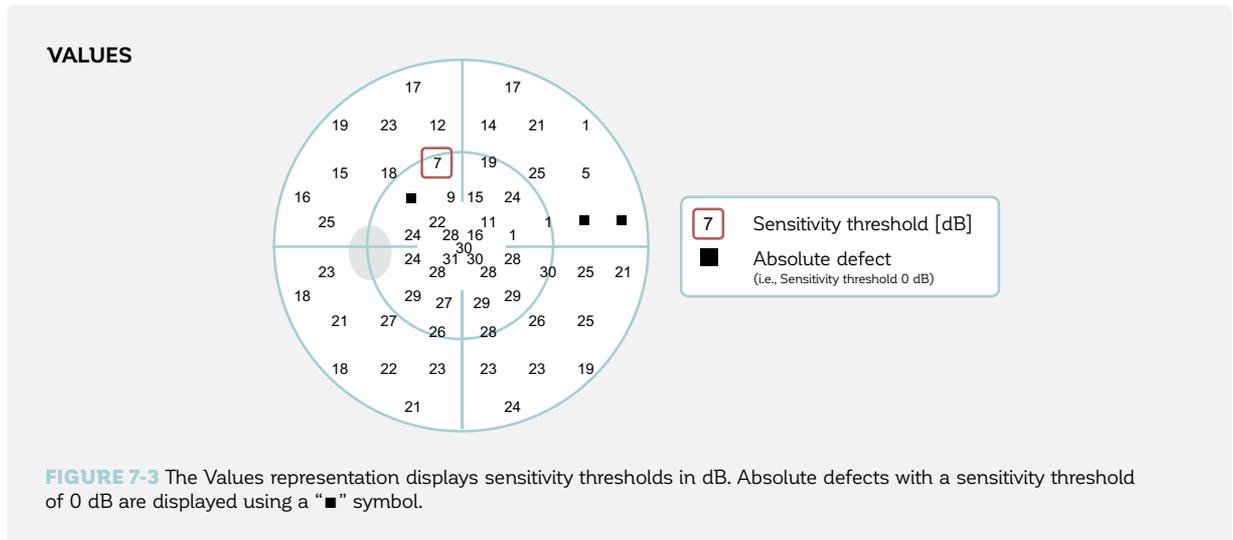
Some representations display sensitivity thresholds values. The key representations and their relationship as they are measured, without reference to normal values, are shown in **FIG 7-2**.



## VALUES

The Values representation shows the sensitivity thresholds at each test location and is presented in **FIG 7-3**. It represents the raw data of visual field testing and is a two-dimensional numerical map of a patient's hill of vision. Sensitivity thresholds are displayed in dB and absolute defects are displayed using a "■" symbol.

This representation is of limited diagnostic value, due to the dependence of sensitivity thresholds on patient age and eccentricity of test location, as shown in **FIG 2-9**.

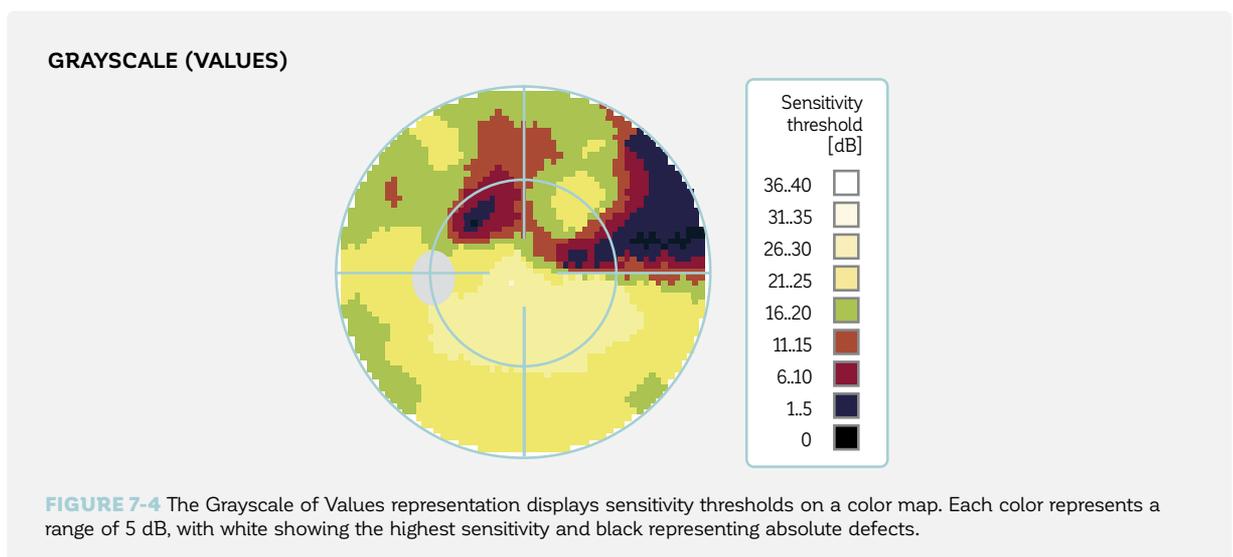


## GRAYSCALE OF VALUES

The Grayscale of Values representation displays the same information as the Values representation (i.e., sensitivity thresholds), but as a two-dimensional color map, as shown in FIG 7-4. Each color represents sensitivity thresholds within a range of 5 dB. White represents sensitivities of 36 – 40 dB, while black represents the other end of the scale, showing sensitivity thresholds of 0 dB. Areas between test locations are interpolated (i.e., the gaps between test locations are filled with “probable” information).

Even though a color scale is used, the representation has kept its historic name (i.e., Grayscale), which was given at a time when no color screens or printers were available.

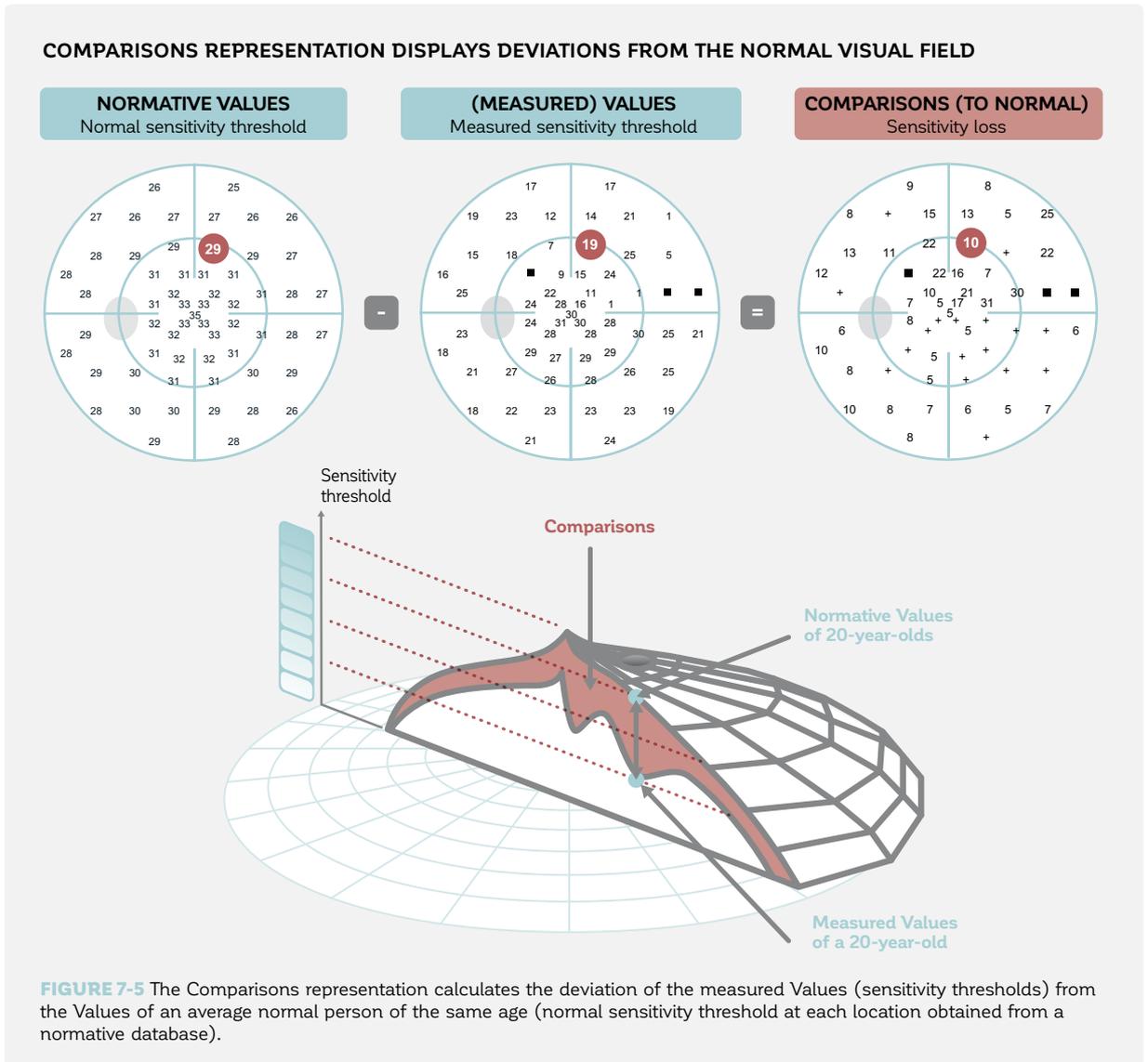
The color representation allows for a more intuitive assessment of the three-dimensional shape of the hill of vision than the numerical Values representation. However, the limitations of the Values representation also apply to the Grayscale of Values representation.



# REPRESENTATIONS BASED ON COMPARISONS WITH NORMAL

## COMPARISONS

The Comparisons representation allows direct assessment of the shape and magnitude of disease-related change in sensitivity. In contrast to the Values representation, its interpretation is independent of the age and eccentricity of test locations. For that reason, it is the most widely used in clinical practice, and most visual field representations are based on it.

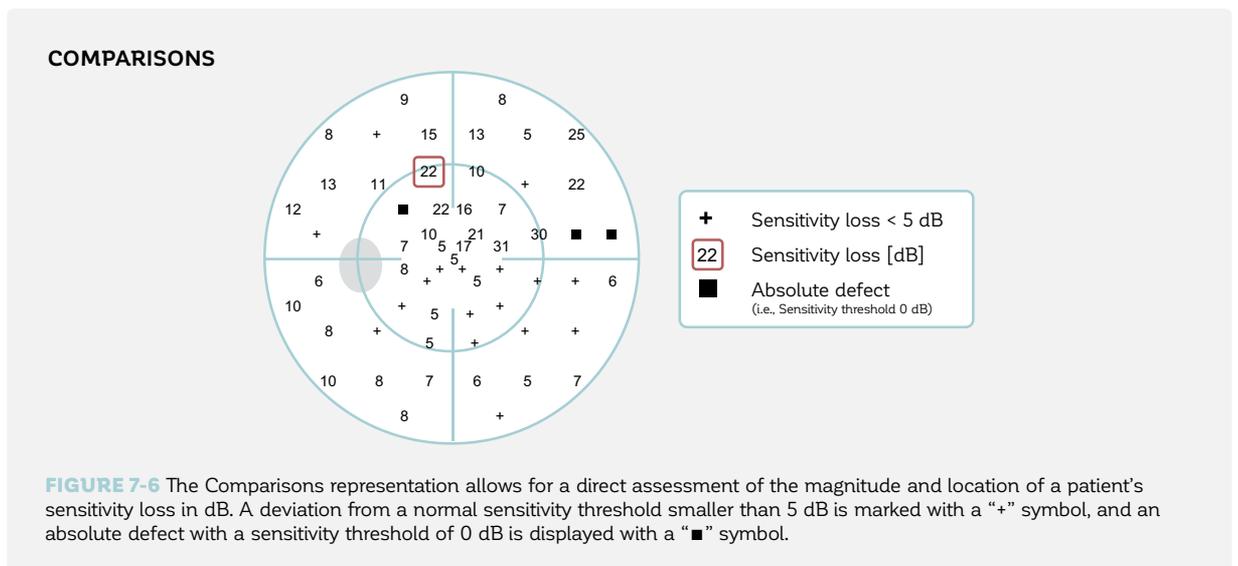


The Comparisons representation is defined as the individual deviation from the average normal visual field (stemming from the normative database) of the respective age group. The difference in the normative value minus the measured value at each test location is also termed sensitivity loss, loss value or defect value. This principle is shown in FIG 7-5. More information on normative Values is given in BOX 2B.

Deviations from a normative visual field are displayed for each location in dB. While the Comparisons are calculated at all visual field locations, their numerical values are not necessarily presented at all locations, as shown in FIG 7-6.

Deviations smaller than 5 dB in magnitude are displayed with “+” symbols, because as a rule of thumb, they can be considered to be approximately within the normal range of fluctuation within the central 30 degrees of the visual field. Consequently, these small numerical values are not meaningful for the interpretation of the visual field. Test locations with a sensitivity threshold of 0 dB have reached the floor of perimetric testing and are marked with a “■” symbol.

Similar representations in non-Octopus devices are alternatively called defect map, total deviation (see TABLE 12-5) or deviation from normal.

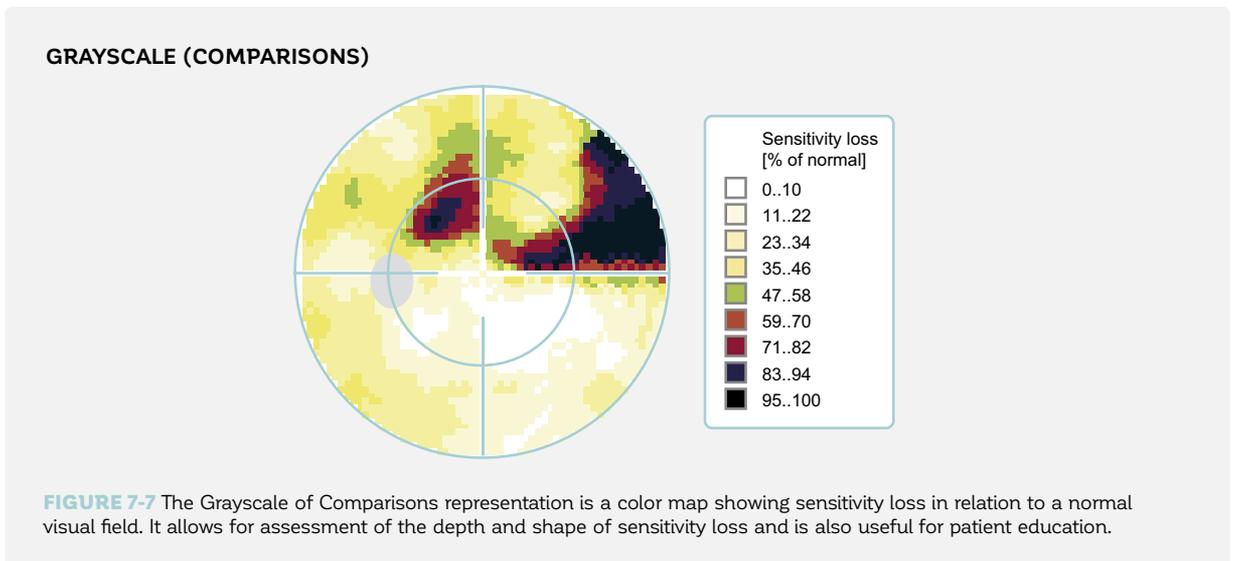


## GRAYSCALE OF COMPARISONS

The Grayscale of Comparisons is used clinically to intuitively assess the magnitude and shape of sensitivity loss. It is also useful for patient education because it is easy to understand.

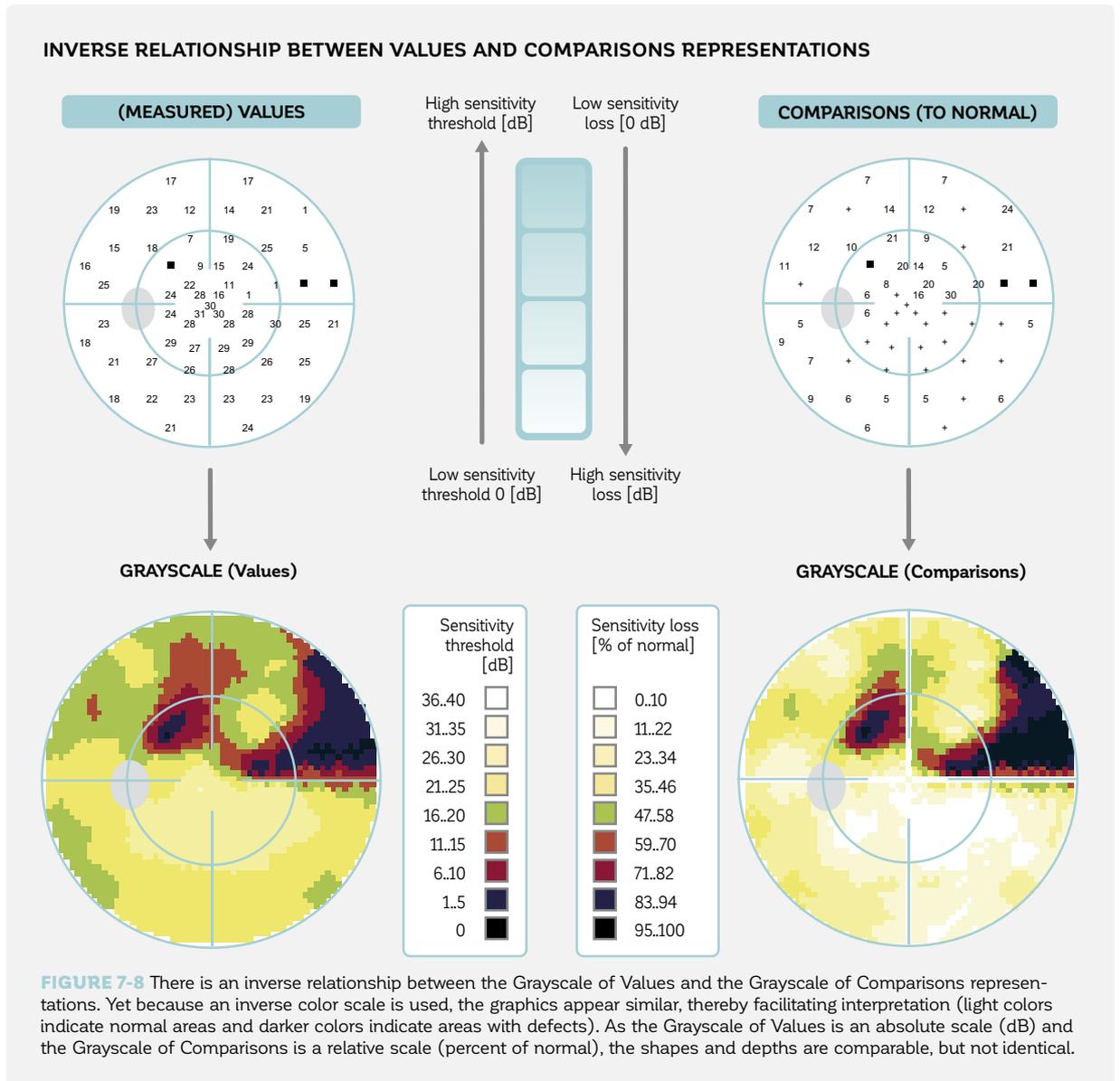
It is a color map in which the areas between test locations are interpolated (i.e., the gaps in between test locations are filled with “probable” information) (FIG 7-7). Since it is

based on the Comparisons representation, it is independent of both patient age and eccentricity of test locations. A color scale is used to display sensitivity loss in % in relation to a normal visual field, with different colors used for different levels of change in sensitivity. For example, a 0% to 10% change in sensitivity is displayed in white, 47% to 58% sensitivity loss is shown in green, and 95% to 100% change in sensitivity is displayed in black.



There is an inverse relationship between the sensitivity thresholds displayed in the Grayscale of Values and the sensitivity loss displayed in the Grayscale of Comparisons. In other words, a high sensitivity threshold means that there is a small, or no loss of sensitivity (i.e., virtually no difference from normal). To facilitate the interpretation of

the Grayscales, similar colors are used to display close to normal visual fields or fully defective visual fields. Since the Values scale is absolute, showing ranges in dB, and the Comparisons scale is relative, showing visual field loss in percent, the patterns show marginal differences. FIG 7-8 demonstrates this relationship.



It should be noted that the Grayscale of Comparisons provides more clinically meaningful information than the Grayscale of Values because it is not affected by patient age or the eccentricity of test location, and thus shows a patient's visual field loss. When comparing Grayscales of Values for younger and older controls, the Grayscales of the older person are likely to show more loss, because normal age effects are not taken into account. The

Grayscale of Values also shows more severe loss in the peripheral area compared to the central area, due to the effect of eccentricity. The Grayscale of Comparisons adjusts for age and eccentricity. For clinical purposes, it is therefore recommended to always use the Grayscale of Comparisons, which is part of the standard printouts of Octopus perimeters.

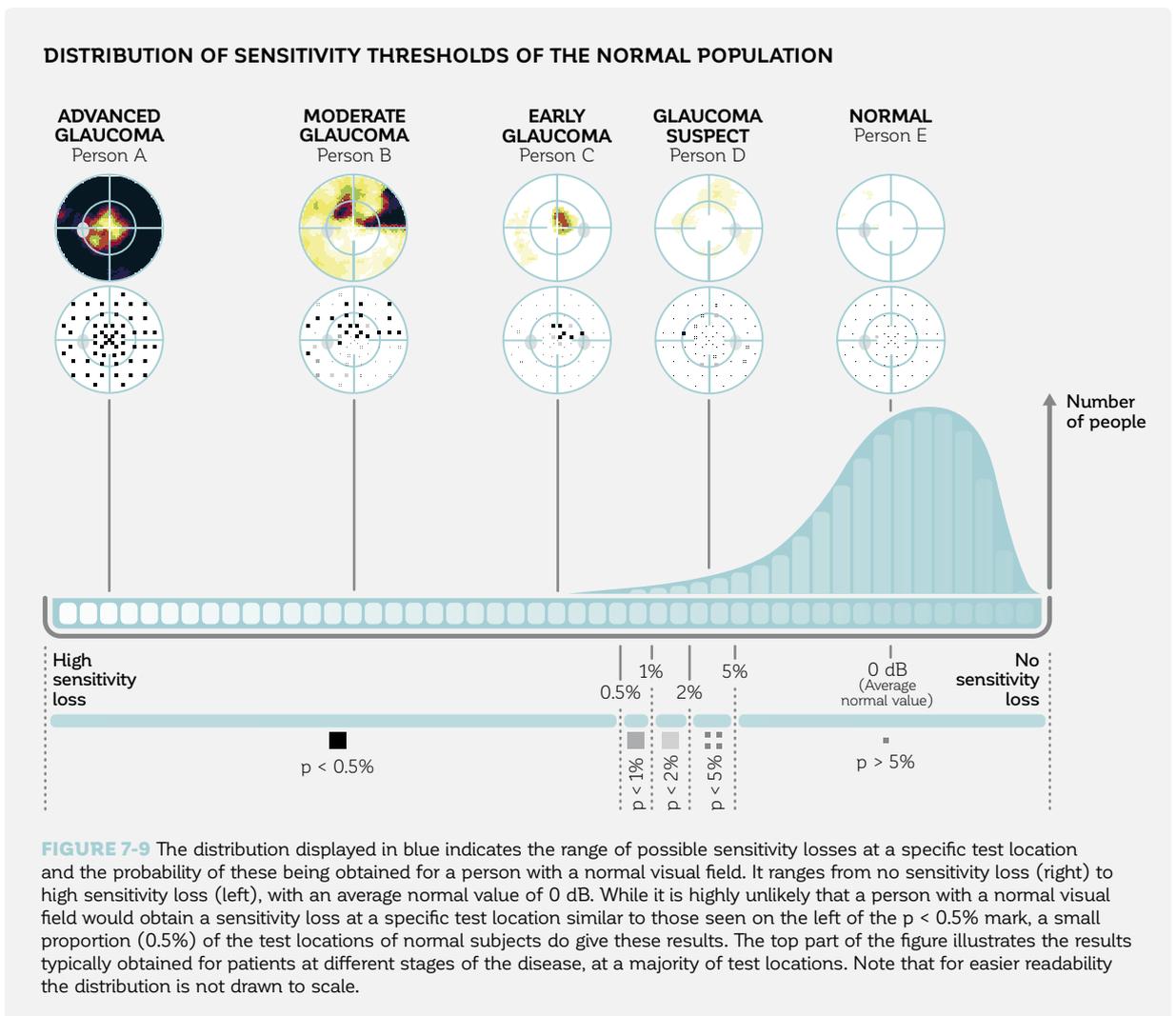
## PROBABILITIES

The Probabilities representation is used clinically to distinguish between normal and abnormal visual field locations. This representation is needed because normal fluctuation is not uniformly distributed across the visual field; instead, it is smaller in the center and larger towards the peripheral visual field. It is therefore not possible to use the same numerical cut-off point (e.g., 6 dB sensitivity loss, representing an abnormal visual field location) for all visual field locations.

The Probabilities representation uses symbols that are associated with the statistical distribution of normative

data. More precisely, they show the probability that a given sensitivity threshold would be obtained at the respective location for a person of the same age as the patient with a normal visual field.

For example, a person with a normal visual field has a high probability of having little to no sensitivity losses. But there is also a small probability that a person with a normal visual field would obtain some sensitivity loss. **FIG 7-9** illustrates this and also displays examples of patient visual fields in relation to normal visual fields.



The Probabilities representation shows the probability ( $p$ ) that a normal population shows a given sensitivity loss. When the sensitivity loss is high, the likelihood that it comes from a person with a normal visual field is low. From a clinical perspective, one could assume that it is more likely that the sensitivity loss comes from the patient population.

Increasingly darker symbols are used to show the decreasing probability that a person with a normal visual field would show a given sensitivity loss at a certain test location (FIG 7-10):

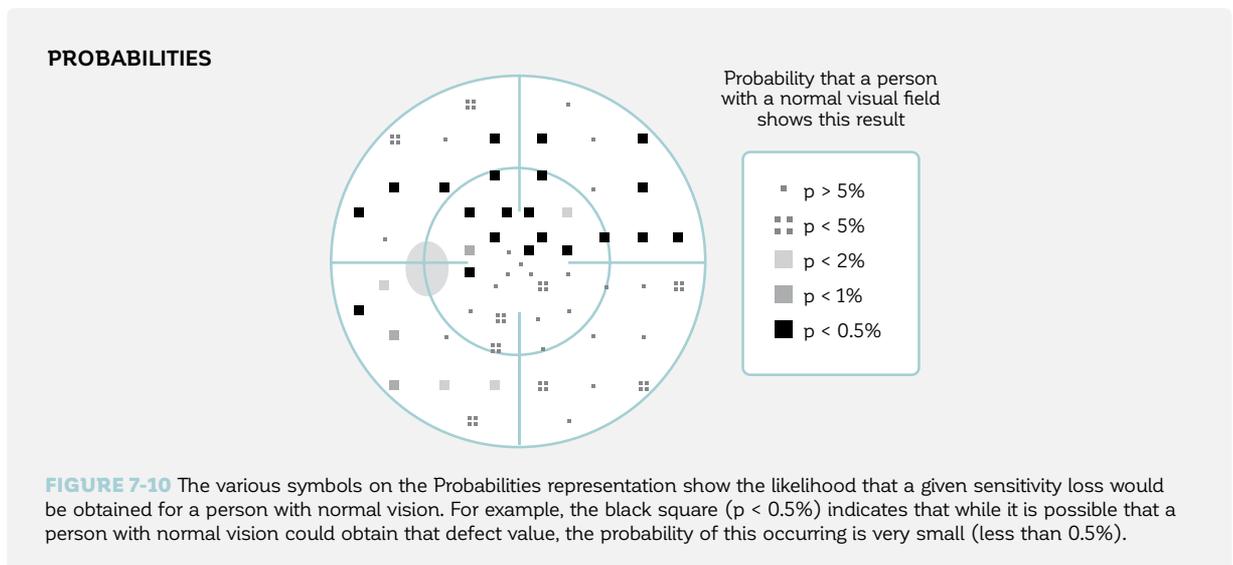
- ( $p > 5\%$ ): there is a high probability that a person with a normal visual field would show this sensitivity loss.

- ▣ ( $p < 5\%$ ): there is a smaller than 5% (and larger than 2%) chance that a person with a normal visual field would show this sensitivity loss.

- ( $p < 2\%$ ): there is a smaller than 2% (and larger than 1%) chance that a person with a normal visual field would show this sensitivity loss.

- ( $p < 1\%$ ): there is a smaller than 1% (and larger than 0.5%) chance that a person with a normal visual field would show this sensitivity loss.

- ( $p < 0.5\%$ ): there is a smaller than 0.5% chance that a person with a normal visual field would show this sensitivity loss.



It should be noted that caution is essential in the clinical interpretation of the Probabilities representation. This is due to the fact that a small number of isolated test locations at a level of significance of  $p < 5\%$  is likely to show up, even in normal visual fields. For example, in a G pattern, which has 59 test locations, by definition a  $p$  value of  $p < 5\%$  should occur in 1 out of 20 locations (i.e., on average

for 3 locations). The same is true for a level of significance of  $p < 2\%$ , which by definition occurs in 1 out of 50 test locations (i.e., on average for one location in the G pattern). A level of significance of  $p < 0.5\%$  is even expected to occur in one out of three normal visual fields. More information on how to clinically interpret the Probabilities representation is given in FIG 8-15.

## DEFECT CURVE

The Defect Curve (also called Bebie Curve<sup>1</sup>) is a graphical representation that alerts the clinician to the presence of diffuse defects. It provides a summary of the visual field and makes it possible to distinguish between local and diffuse defects at a glance. For more information on its design, see **BOX 7A**.

### DESIGN OF THE DEFECT CURVE

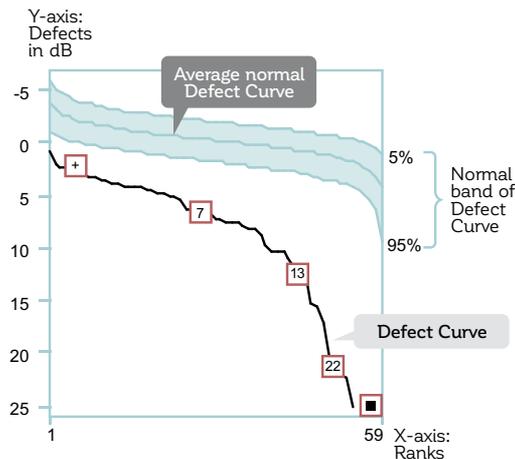
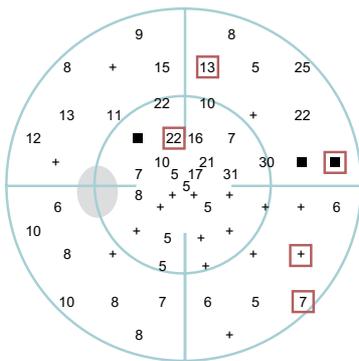
The Defect Curve is based on the Comparisons representation (i.e., the sensitivity loss in comparison to the normal visual field). The Comparisons are first ranked according to their magnitude, from the smallest to the largest defect. The Defect Curve is drawn by plotting the defects (Y-axis) as a function of their rank (X-axis). To give an example, the 28<sup>th</sup> smallest defect in the figure below is about 7 dB. The Y-axis ranges from -5 to 25 dB. It must be noted that negative values indicate that there was no defect compared to normal and that the sensitivity is higher than the average normal value. This typically happens randomly at a few locations in every normal visual field, and therefore the average normal visual field shows negative values in the first ranks.

This procedure generates the Defect Curve, which by definition always starts from the top left and moves to the bottom right. Note that spatial information is lost. The average normal Defect Curve is displayed to serve as a reference, flanked by upper and lower limits that show the area in which 90% of normal Defect Curves lie.

### BOX 7A

#### DEFECT CURVE

##### COMPARISONS (TO NORMAL)

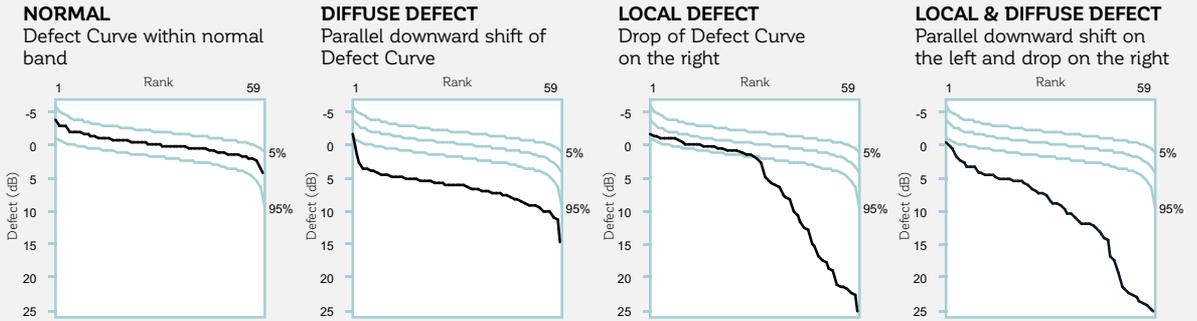


*The Defect Curve is a representation that ranks individual defects according to their size from left to right. Normal visual fields have a Defect Curve within the normal band, while the Defect Curve in abnormal visual fields lies outside the normal band.*

The interpretation of the Defect Curve is straightforward. Parallel downward shifts of the Defect Curve represent diffuse defects; a drop on the right-hand side of the curve represents local defects and Defect Curves within the normal band are considered to be normal. In many

instances, a combination of diffuse (or widespread) loss and local visual field loss is present. **FIG 7-11** shows these four main situations, while more examples are provided in **FIG 8-10**.

### DEFECT CURVE



**FIGURE 7-11** The Defect Curve is helpful to distinguish intuitively between diffuse and local sensitivity loss. The four main situations: normal, diffuse defect, local defect, and local plus diffuse defect, are shown here.

## CLUSTER ANALYSIS

Cluster Analysis has been designed specifically for glaucoma and is very sensitive to detection of subtle glaucomatous defects. It capitalizes on the fact that typical glaucomatous defects consist of a cluster of adjacent defective visual field locations that correspond to the path followed by the retinal nerve fiber bundles in the retina.<sup>2</sup>

For Cluster Analysis, visual field locations corresponding to the same retinal nerve fiber layer (RNFL) bundle are grouped and used to calculate a mean cluster defect (Cluster MD). In total, the visual field is divided into ten clusters, as shown in **FIG 7-12**.

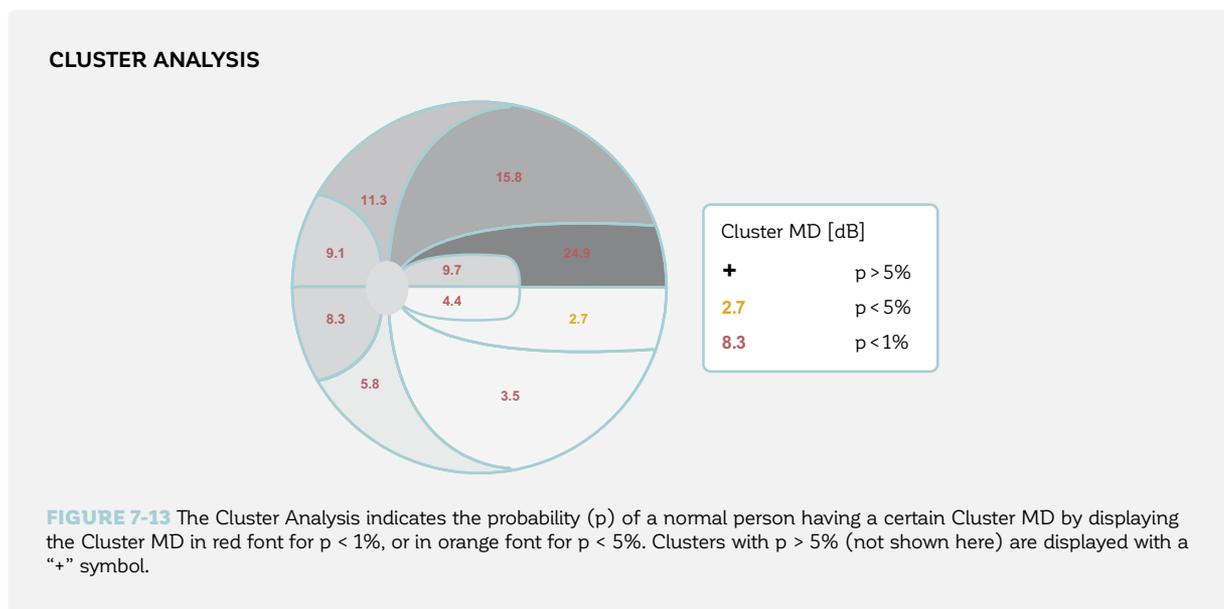
### CLUSTER ANALYSIS DISPLAYS TEN CLUSTER MEAN DEFECTS



**FIGURE 7-12** The Cluster Analysis displays 10 visual field clusters that spatially correlate with retinal nerve fiber bundles. In each Cluster, the average sensitivity loss is calculated and presented as a Cluster Mean Defect (MD). In this example, the superior paracentral cluster is highlighted in red and its corresponding sensitivity losses are written in red font.

The concept of Probabilities, as presented in the section about the Probabilities representation, is also used in Cluster Analysis (FIG 7-13). Cluster MDs with a significance of  $p > 5\%$  are displayed with a “+” symbol and indicate that for an average person with a normal visual field there is a high probability of this cluster MD value being obtained. A cluster MD in orange font

has a significance of  $p < 5\%$  (and  $p > 1\%$ ) and a cluster MD in red font has a significance of  $p < 1\%$ . The latter is thus more likely to be abnormal than the former. Additionally, the degree of shading indicates the deviation from normal values for the clusters, with lighter shading representing lower cluster MDs, and darker shading representing higher cluster MDs.



A major advantage of Cluster Analysis is that it is more sensitive to detection of significant early glaucomatous change than single point representations such as the Comparisons or Probabilities graphs. This is because single test locations are subject to considerable normal fluctuation. The averaging procedure used in the Cluster Analysis significantly reduces the amount of fluctuation within each

cluster.<sup>3</sup> The normal ranges for Cluster MDs are therefore much smaller, with significant change being identified earlier.<sup>4-6, 15</sup> For more information on the high sensitivity of Cluster Analysis<sup>15</sup> for glaucoma detection, see **BOX 8B**.

Additional information on the design of the Cluster Analysis is provided in **BOX 7B**.

**BOX 7B**

**DESIGN OF CLUSTER ANALYSIS**

The Cluster Analysis is based on the distribution of retinal nerve fibers in the retina. To design the Cluster Analysis, all test locations of the G pattern were superimposed over the RNFL map described by Hogan et al.<sup>2</sup> Next, visual field locations were grouped into 22 sectors. Test locations whose respective RNFL bundles entered the optic disc in close spatial proximity were grouped into the same cluster. This procedure yielded clusters with 2 to 4 test locations. It was noted that the test locations in each cluster were part of the same 5° sector at the optic disc.

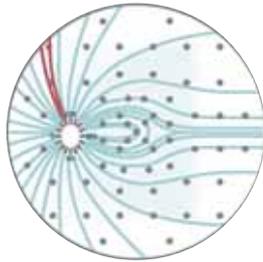
Since some of the clusters contained too few test locations to significantly reduce variability, these 22 clusters were further grouped to yield the 10 clusters used in the Cluster Analysis. These 10 clusters have been shown to correlate well with structural findings.<sup>7-10</sup>

The arithmetic mean of all defects within one cluster results in the Cluster Mean Defect (MD). This number is displayed within each cluster. It should be noted that while the clusters are not strictly symmetrical, a symmetrical graph is used on the printout, for the sake of simplicity.

**DESIGN OF CLUSTER ANALYSIS**

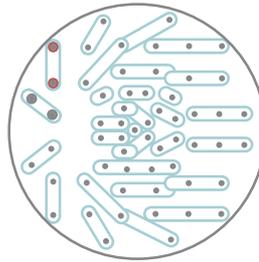
**GROUPING OF VISUAL FIELD LOCATIONS**

Based on entry of RNFL bundles into optic disc



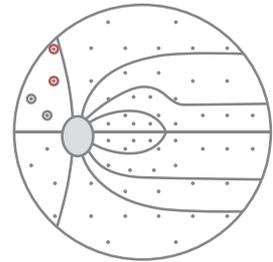
**22 VISUAL FIELD CLUSTERS**

Each containing 2-4 locations



**10 VISUAL FIELD CLUSTERS**

Combining the 22 clusters (at least 4 test locations per cluster)

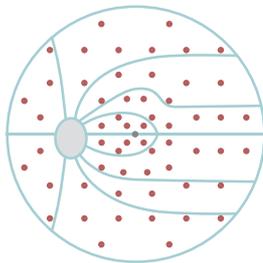


*The ten Clusters used in the Cluster Analysis are generated by superimposition of the test pattern onto an RNFL map and segmentation into sectors at the optic nerve head (left). Clustering of the visual field locations included in these sectors leads to 22 initial clusters in the G pattern (center), which are further combined into 10 clusters (right).*

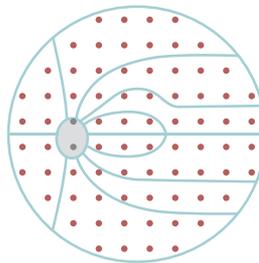
By using the cluster boundaries defined for the G pattern, Cluster Analysis has been designed for the 32/30-2 and the 24-2 patterns. All cluster maps are based on the principle explained above.

**CLUSTER ANALYSIS FOR DIFFERENT TEST PATTERNS**

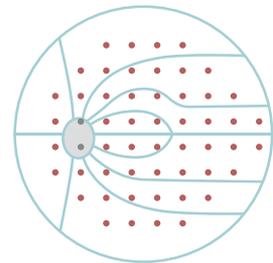
**G**



**32/30-2**



**24-2**



*Cluster Analysis is available for the G, 32, 30-2 and 24-2 patterns. Note that the central test locations in the G pattern and the two test locations inside the blind spot in the 30-2/24-2 patterns (test locations shown in gray) are not included in any cluster.*

As with the interpretation of the Probabilities representations, however, some caution is essential in the clinical interpretation of the Cluster Analysis representation. This is due to the fact that one cluster defect at a significance of  $p < 5\%$  is likely to show up in one out of two normal visual fields (1 out of 10 clusters at  $p < 5\%$  occurs

in 50% of normal visual fields), and one cluster at  $p < 1\%$  in one out of 10 normal visual fields (1 out of 10 clusters at  $p < 1\%$  occurs in 10% of normal visual fields). A significant cluster defect is thus far more clinically meaningful if it is spatially correlated with another significant cluster defect,<sup>5,6</sup> or if it correlates with a structural defect.

## POLAR ANALYSIS

The Polar Analysis has been designed specifically for glaucoma.<sup>11</sup> It provides information about where structural defects are to be expected at the optic disc, by displaying visual field results using structural coordinates. It is based on the known relationship between structure and function and capitalizes on the fact that each visual field location corresponds to a specific retinal nerve fiber bundle in the retina (i.e., a superior visual field location corresponds to an inferior retinal location and a nasal visual field location corresponds to a temporal retinal location).<sup>2</sup> For more information on the relationship between structure and function, see **BOX 8C**.

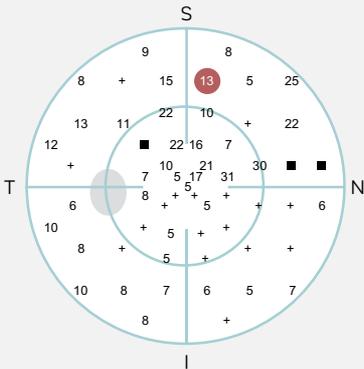
Similar to the Cluster Analysis, the Polar Analysis is based on a superimposition of the test pattern onto Hogan's<sup>2</sup> RNFL map (**FIG 7-14**). Since the superior visual field corresponds to the inferior retina, the visual field is first flipped across the horizontal axis.

Once the visual field has been flipped across the horizontal axis, each sensitivity loss obtained from the Comparisons representation is mapped onto the nerve fiber that corresponds to it. The nerve fiber projects to the optic disc and enters at a specific angle around the optic disc. The angle of entry of each nerve fiber is determined and used to place each test location as a radial bar on the Polar Analysis representation. The length of the bar shows the sensitivity loss in dB from the Comparisons representation. Note that if two or more test locations map onto the nerve fibers that enter at the same angle, the values of the corresponding test point locations are averaged.<sup>11</sup> To facilitate interpretation, a gray band ranging from +4 dB to -4 dB provides a rough indication of a normal range. The definitions of the Polar Analysis are shown in **FIG 7-15**.

### DESIGN OF THE POLAR ANALYSIS

#### VISUAL FIELD ORIENTATION

##### COMPARISONS



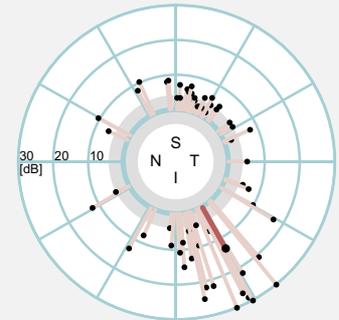
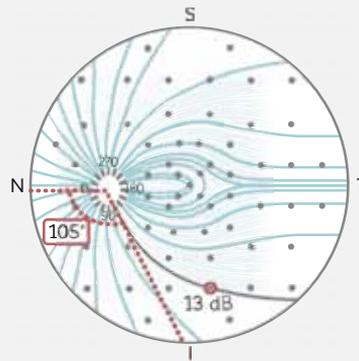
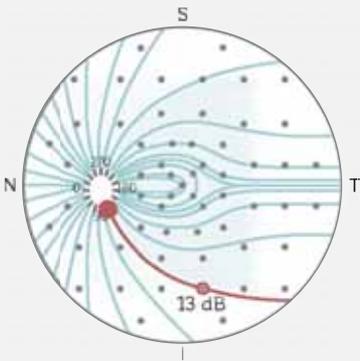
#### STRUCTURAL ORIENTATION

1. Locate nerve fiber entry site at optic disc

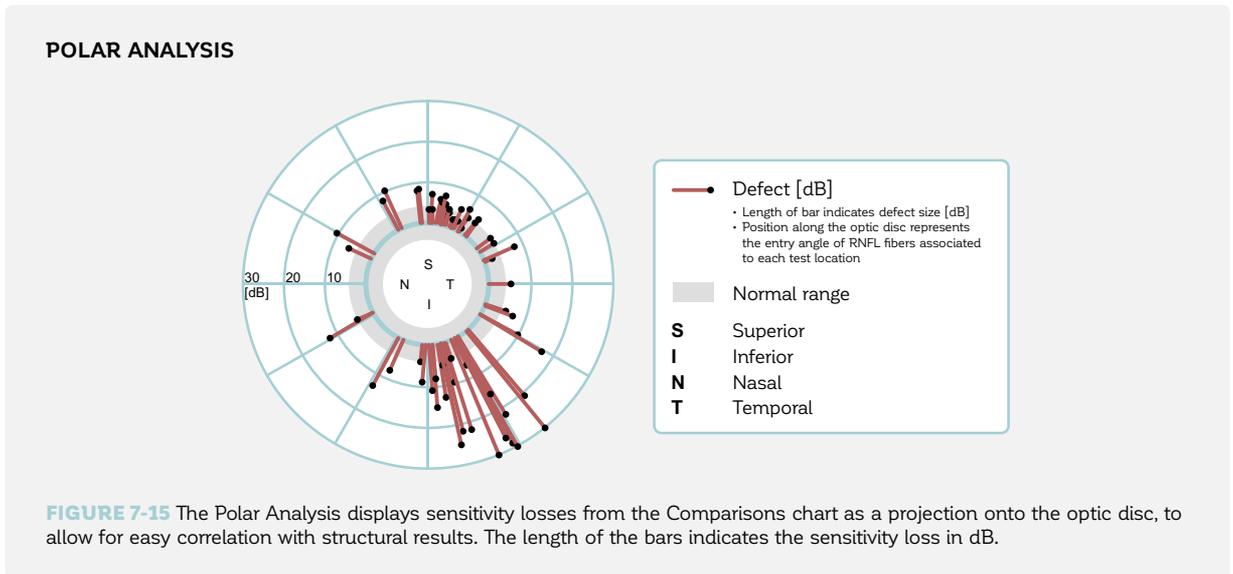
2. Define nerve fiber entry angle at optic disc

3. Draw polar bar at previously determined location  
(Length corresponds to defect size)

4. Repeat for all test locations



**FIGURE 7-14** The Polar Analysis orients visual field results (top) like a structural result (bottom), flipping the results across the horizontal meridian. It projects a sensitivity loss from the Comparisons chart (e.g., 13 dB, highlighted in red, top) along the corresponding retinal nerve fibers on the retina to the optic disc (red circle, bottom left). At the nerve fiber entry site a red bar is drawn at the angle at which the nerve fiber enters the optic disc (here 105°, bottom middle), with the length of the bar corresponding to the magnitude of the sensitivity loss (i.e., 13 dB, bottom right). By repeating this procedure for all visual field locations, the Polar Analysis is drawn (all red bars, bottom right). (S: Superior; I: Inferior; N: Nasal; T: Temporal)



The Polar Analysis is a very useful tool to link structural and functional results because it allows direct side-by-side comparison of the structural and functional results, as can be seen in **FIG 8-24**. It has been shown to correlate

well with structural results<sup>12</sup> and usefully assists the identification of the spatially corresponding structural (RNFL) defects.

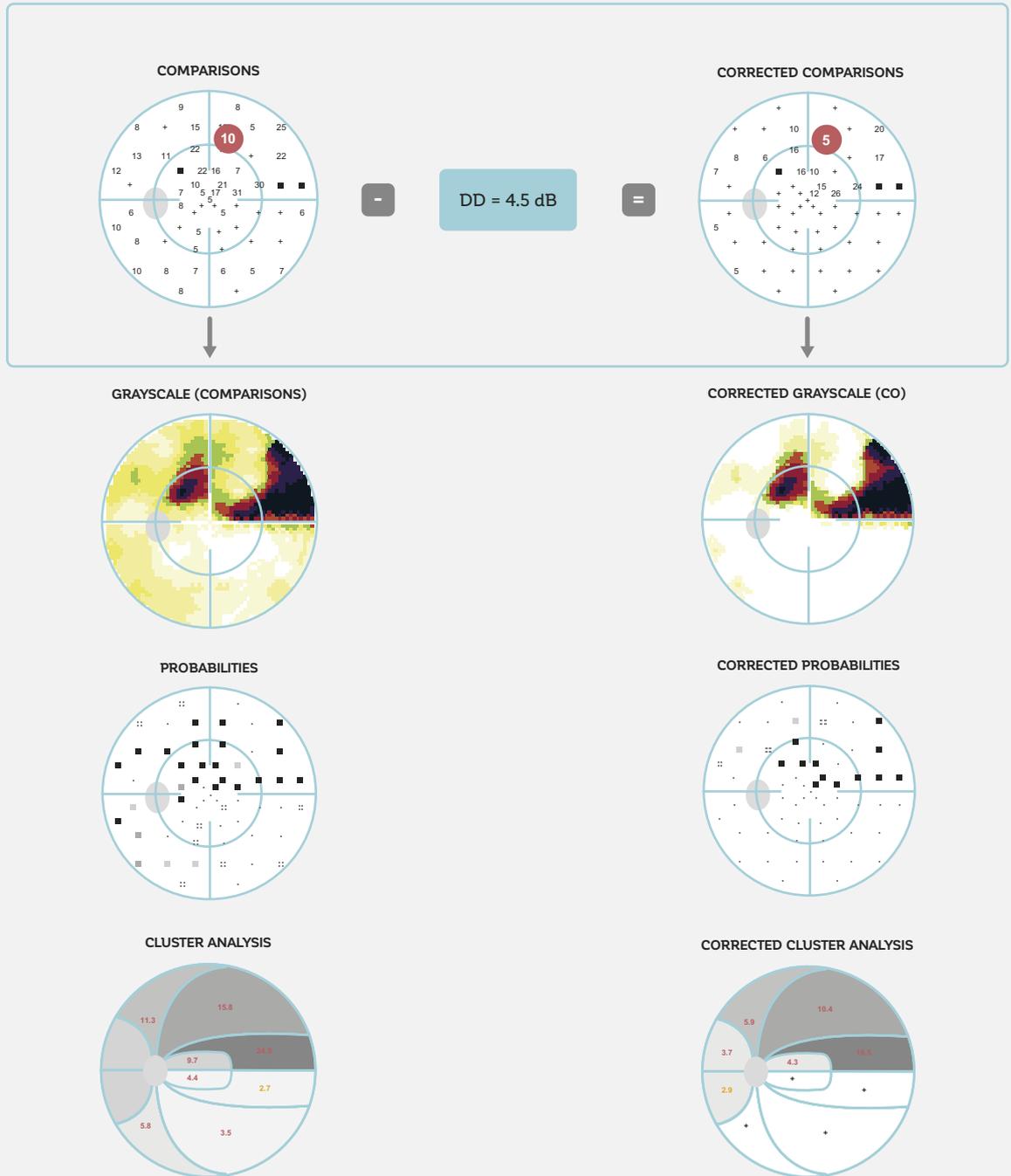
# REPRESENTATIONS BASED ON COMPARISONS WITH NORMAL, CORRECTED FOR DIFFUSE DEFECTS

## CORRECTED COMPARISONS

It is useful to analyze localized visual field defects independently of diffuse defects, which in many cases are caused by cataract. To do so, the Comparisons, Grayscale of Comparisons, Probabilities and Cluster Analysis representations are all available in a corrected version. This corrected version removes diffuse or widespread defects and displays only localized visual field loss. All “corrected” representations are based on the Corrected Comparisons

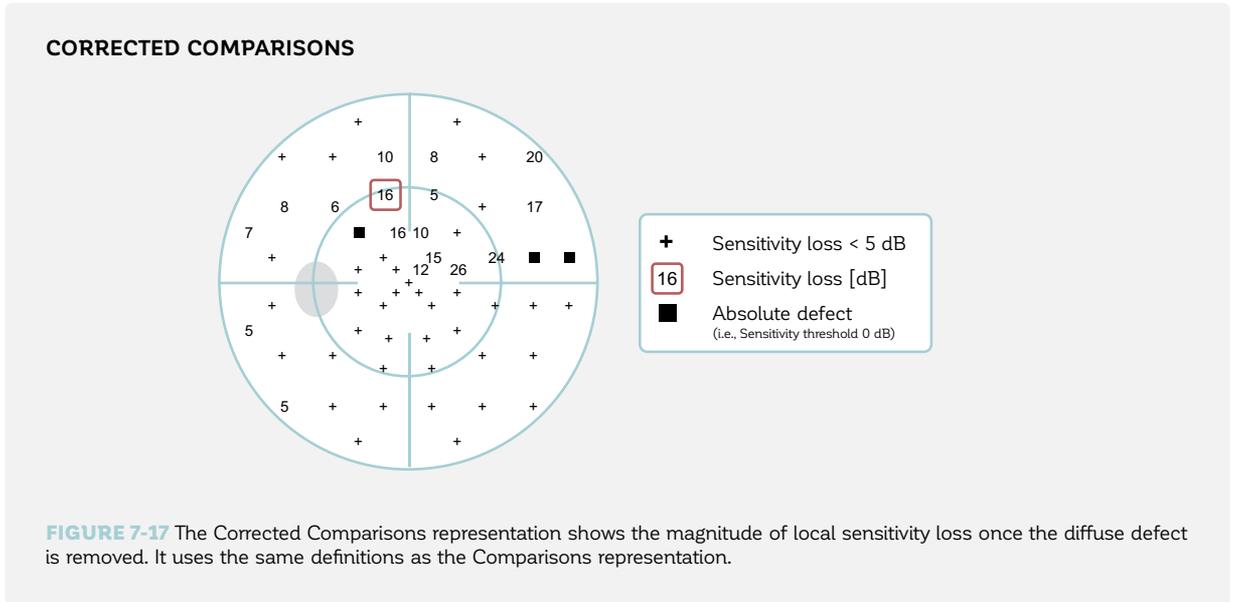
representation. The correction applied to the Corrected Comparisons is based on the DD global index, which represents the magnitude of diffuse defect. The DD is subtracted from the sensitivity losses displayed in the Comparisons representation. The DD is explained in detail in the section on global indices. **FIG 7-16** illustrates how the corrected representations are calculated.

**CORRECTED COMPARISONS AND ITS RELATIONSHIP WITH OTHER CORRECTED REPRESENTATIONS**



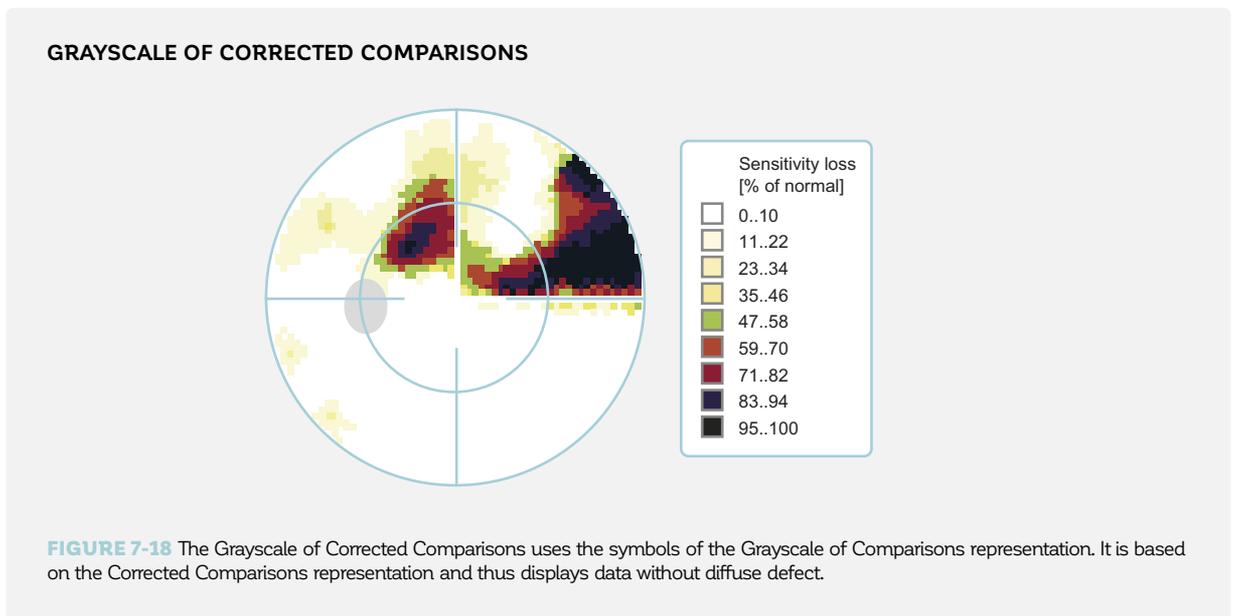
**FIGURE 7-16** The Corrected Comparisons representation is calculated by subtracting the magnitude of the diffuse defect expressed in the DD index from each sensitivity loss in the Comparisons representation. It allows for the assessment of localized visual field loss without the influence of diffuse defects and is the basis for the calculation of all the corrected representations.

The Corrected Comparisons representation is similar to the Comparisons representation and uses the same symbols to show sensitivity loss once the diffuse defect is removed (FIG 7-17).



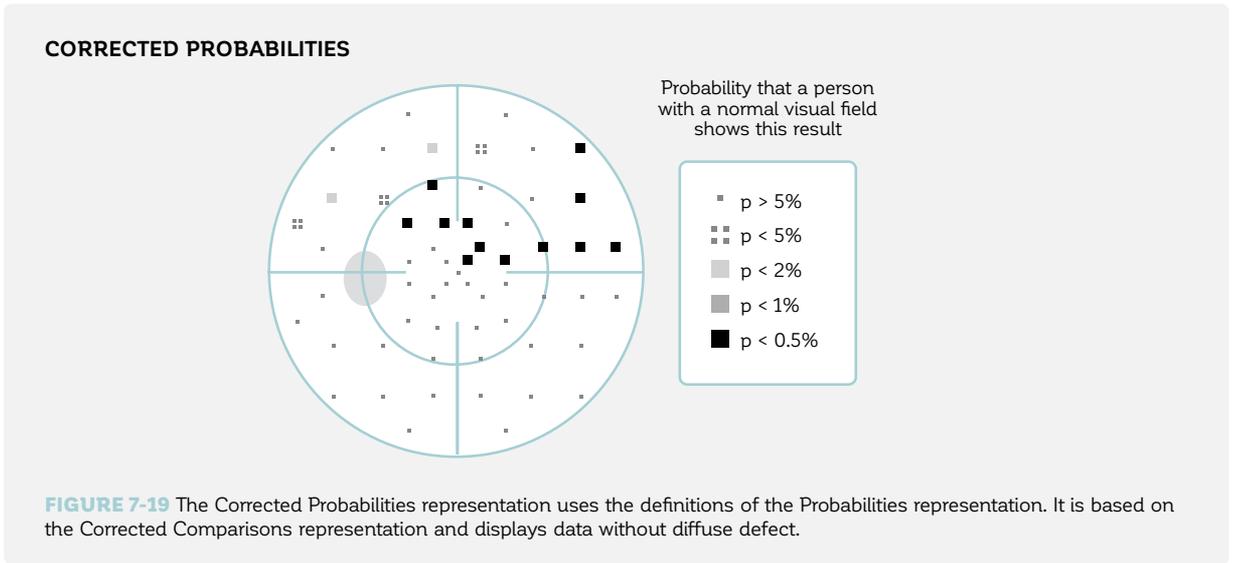
## GRAYSCALE OF CORRECTED COMPARISONS

The Grayscale of Corrected Comparisons representation uses the definitions of the Grayscale of Comparisons representation as shown in FIG 7-18. It displays sensitivity loss as a color map without diffuse defect.



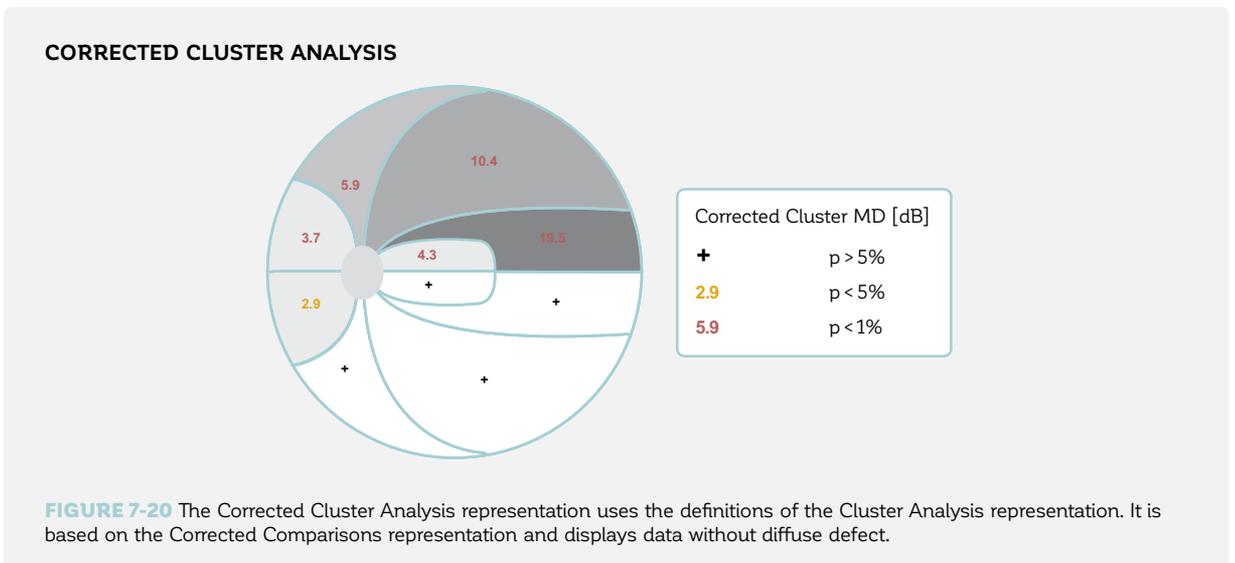
## CORRECTED PROBABILITIES

The Corrected Probabilities representation is very similar to the Probabilities representation and shows the probability that a person with a normal visual field shows this corrected sensitivity loss at various significance levels, as shown in **FIG 7-19**.



## CORRECTED CLUSTER ANALYSIS

The Corrected Cluster Analysis is very similar to the Cluster Analysis, but is based on the Corrected Comparisons. It shows the probability that a person with a normal visual field shows this corrected Cluster Mean Defect in dB at various significance levels, as shown in **FIG 7-20**.



# GLOBAL INDICES

Global indices are useful numerical summaries of the entire or an aspect of the visual field.<sup>13</sup> They 1) provide a summary of the status of the visual field, 2) are useful to objectively assess the severity of visual field loss and 3) are helpful in the evaluation of change over time. The formulae used to calculate each global index are shown in **TABLE 7-1**.

GLOBAL INDICES AVAILABLE FOR OCTOPUS PERIMETERS

TABLE 7-1

INDEX	FORMULA	VARIABLES
<b>MEAN SENSITIVITY (MS)</b>	$FP = \frac{n_c}{n_{sum}}$ $FN = \frac{n_m}{n_{sum}}$ $RF = \frac{n_c + n_m}{n_{sum}}$	<p><math>N</math>: Total number of test locations</p> <p><math>x_i</math>: Sensitivity threshold at test location <math>i</math>, or mean of two repeated measurements <math>x_{i1}, x_{i2}</math> at test location <math>i</math></p>
<b>MEAN DEFECT (MD)</b>	$MD = \frac{1}{N} \sum_{i=1}^N d_i$ $d_i = n_i - x_i$	<p><math>n_i</math>: Normal value at test location <math>i</math></p> <p><math>d_i</math>: Sensitivity loss at test location <math>i</math></p>
<b>SQUARE ROOT OF LOSS VARIANCE (sLV)</b>	$sLV = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (d_i - MD)^2}$	
<b>CORRECTED SQUARE ROOT OF LOSS VARIANCE (CsLV)</b>	$CsLV = \sqrt{sLV^2 - \frac{1}{2} \frac{1}{N-1} \sum_{i=1}^N (x_{i2} - x_{i1} - ME)^2}$ $ME = \frac{1}{N} \sum_{i=1}^N x_{i2} - x_{i1}$	$ME$ : Mean Error

## MEAN SENSITIVITY (MS)

The Mean Sensitivity (MS) is the arithmetic mean of the sensitivity thresholds displayed in the Values representation. It represents a patient's average sensitivity to light with respect to the locations that are tested. MS is based on the

Values and its diagnostic value is therefore limited because it is dependent on patient age and on the spatial distribution of the test locations.

## MEAN DEFECT (MD)

The Mean Defect (MD) is the arithmetic mean of the sensitivity loss displayed in the Comparisons representation. It represents the average visual field loss of a patient derived from the locations that are tested and is thus often used to

assess visual field severity.<sup>13</sup> It is a key index used in the progression analysis available on Octopus perimeters (see Chapter 9).

# SQUARE ROOT OF LOSS VARIANCE (sLV)

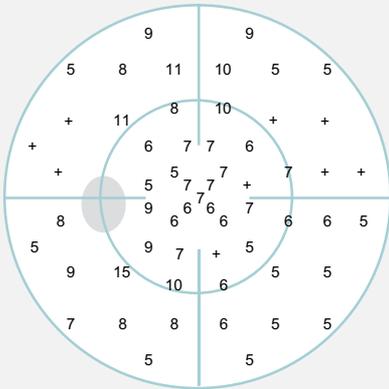
The square root of Loss Variance (sLV) represents the standard deviation of the individual defects at all visual field locations and provides a measure of variability across the visual field.<sup>13</sup> This index is useful because the Mean Defect (MD) does not provide any information about whether visual field loss is uniformly distributed

(i.e., diffuse) or localized at some locations. The sLV index thus further summarizes the characteristics of a visual field. The sLV index is large in inhomogeneous visual fields (localized defects) and small in homogeneous visual fields (diffuse defects), as shown in FIG 7-21.

## SQUARE ROOT OF LOSS VARIANCE (sLV)

DIFFUSE DEFECT

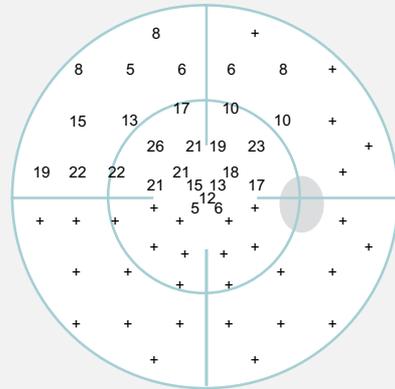
COMPARISONS



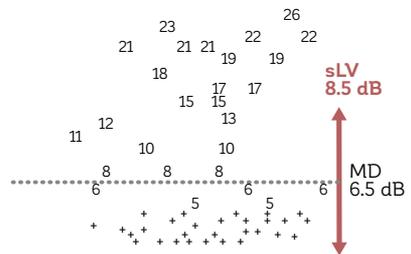
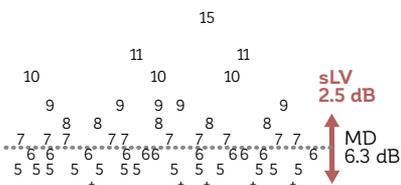
MD 6.3 dB  
sLV 2.5 dB

LOCAL DEFECT

COMPARISONS



MD 6.5 dB  
sLV 8.5 dB



**FIGURE 7-21** The sLV provides a measure of the inhomogeneity of a visual field. This is illustrated in this figure, which shows a homogeneous visual field with diffuse defect (left) and a heterogeneous visual field with localized defect (right). If the visual field is homogeneous, the sensitivity losses at specific test locations (shown on the Y-axis in the bottom part of the figure) do not deviate strongly from MD, and sLV is small (left). If the visual field is heterogeneous, some locations deviate strongly from MD, and therefore sLV is large (right). Note that sLV is the standard deviation of the local defects and thus does not span the full range of determined sensitivity losses.

## CORRECTED SQUARE ROOT OF LOSS VARIANCE (CsLV)

The Corrected square root of Loss Variance (CsLV) is similar to the sLV, with an added correction factor to account for the variability of patient responses that occurs during a perimetric test. It is a useful index to distinguish between a truly heterogeneous visual field and a visual field that is heterogeneous due to Short-term Fluctuation.<sup>13</sup>

The reliability index used for CsLV is Short-term Fluctuation (SF), which is explained in detail in the section about reliability indices. Note that CsLV is only displayed if SF is actively determined during the visual field test by repeated testing at all test locations.

## DIFFUSE DEFECT (DD)

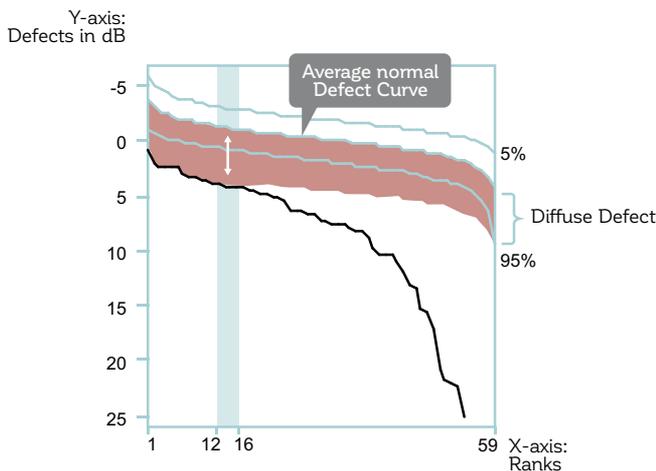
### DEFINITION OF DIFFUSE DEFECT (DD)

As shown in the section about the Defect Curve, diffuse defects result in a parallel downward shift of the Defect Curve. The magnitude of that shift is measured by assessing the distance between the Defect Curve and the average normal Defect Curve at a representative location along the curve. This generates the index DD.

As the Defect Curve may not be fully parallel with the average normal Defect Curve, it is essential to measure at a location that represents diffuse visual field loss. DD is calculated from the 20<sup>th</sup> to the 27<sup>th</sup> percentile of the ranks. For the G pattern, which includes 59 test locations, this translates into the range from the 12<sup>th</sup> to the 16<sup>th</sup> rank from the left. This area is neither too close from the left to be meaningfully affected by random abnormally high sensitivity responses, nor too close to the right to be meaningfully affected by local defects. To be less influenced by variability, an average of the deviations of the respective ranks from the median Defect Curve is used.

### BOX 7C

#### DIFFUSE DEFECT (DD)



*In the Defect Curve, all individual defects are ranked from 1 to the total number of test locations (e.g., the 59 locations of the G pattern are shown here). The DD is calculated from the magnitude of the downward shift of the Defect Curve at the ranks from the 20<sup>th</sup> to the 27<sup>th</sup> percentile (for the G pattern, ranks 12 to 16).*

The index DD allows quantification of diffuse defect in dB and is derived from the Defect Curve, as explained in **BOX 7C**. It is mainly used to calculate the Corrected Comparisons representation, which is discussed in the previ-

ous section of this chapter. It is also used in the progression analysis available on Octopus perimeters to identify the presence of diffuse progression (see Chapter 9).

## LOCAL DEFECT (LD)

The index LD allows quantification of the mean local defect in dB and is also derived from the Defect Curve, as explained in **BOX 7D**. It is used in the progression analysis

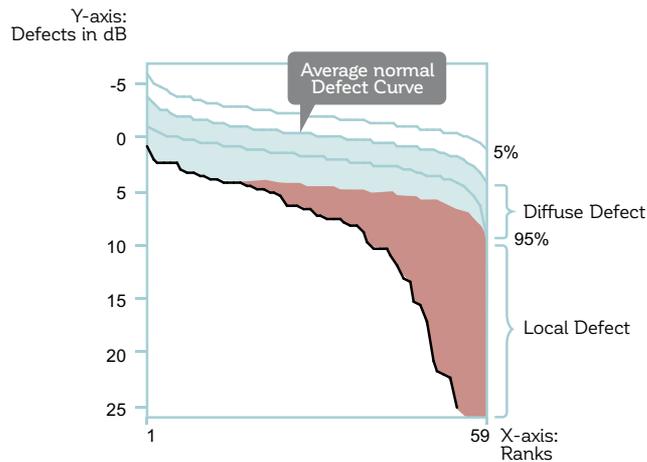
available on Octopus perimeters to identify the presence of local progression.

**BOX 7D**

**DEFINITION OF LOCAL DEFECT (LD)**

Any point on the Defect Curve outside normal limits represents an abnormal visual field point. Shifting down the average normal Defect Curve by the amount of the diffuse defect DD yields a curve representing the diffuse defect. Any further deviation of the individual Defect Curve downwards indicates local defects. The local defect index LD is defined as the average of these deviations measured between the 14<sup>th</sup> and 59<sup>th</sup> ranks for the G pattern. In more general terms and also applicable to other test patterns, the LD index is defined as the average of these deviations measured between the 23<sup>rd</sup> percentile of ranks and the last rank.

**LOCAL DEFECT (LD)**



*The LD index represents the magnitude of the average local defect and is derived from the Defect Curve. It is calculated from the deviation between the Diffuse Defect and the Defect Curve, as indicated by the red area.*

# RELIABILITY INDICES

Due to the subjective component of perimetric testing, unreliable visual field results occur and it is essential to identify them in clinical practice. Octopus perimeter provides several indicators of visual field reliability.

These are presented below with their respective formula, shown in **TABLE 7-2** at the end of this section. For more information on how to clinically interpret reliability indices, see the section on reliability in Chapter 8.

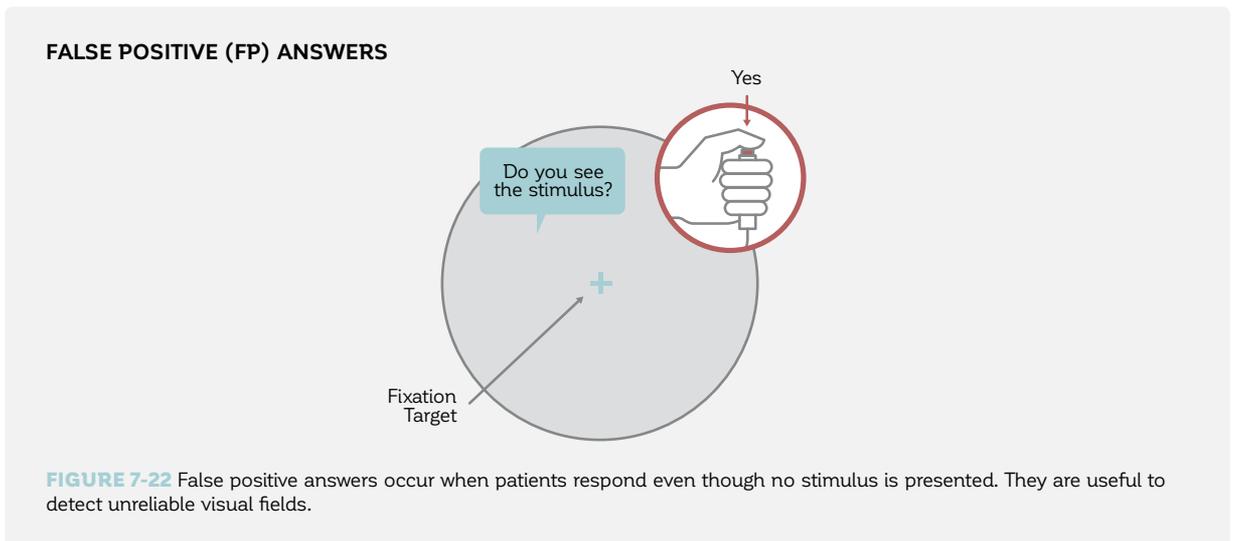
## FALSE POSITIVE (FP) ANSWERS

False positive (FP) answers are used to detect trigger-happy patients. These are patients who respond even when no stimulus is presented. This type of patient behavior occurs if patients do not understand the nature of the test, or if they wish to positively influence the result.

in the natural rhythm of perimetric testing in which no stimulus is presented. If a patient responds, this is marked as a false positive answer (**FIG 7-22**).

Positive catch trials are used to identify false positive answers. Positive catch trials consist of a gap introduced

The false positive rate is calculated as the ratio of false positive answers to the total amount of positive catch trials presented. A false positive rate above 15% is highlighted in orange color, and a false positive rate above 33% is highlighted in red color.



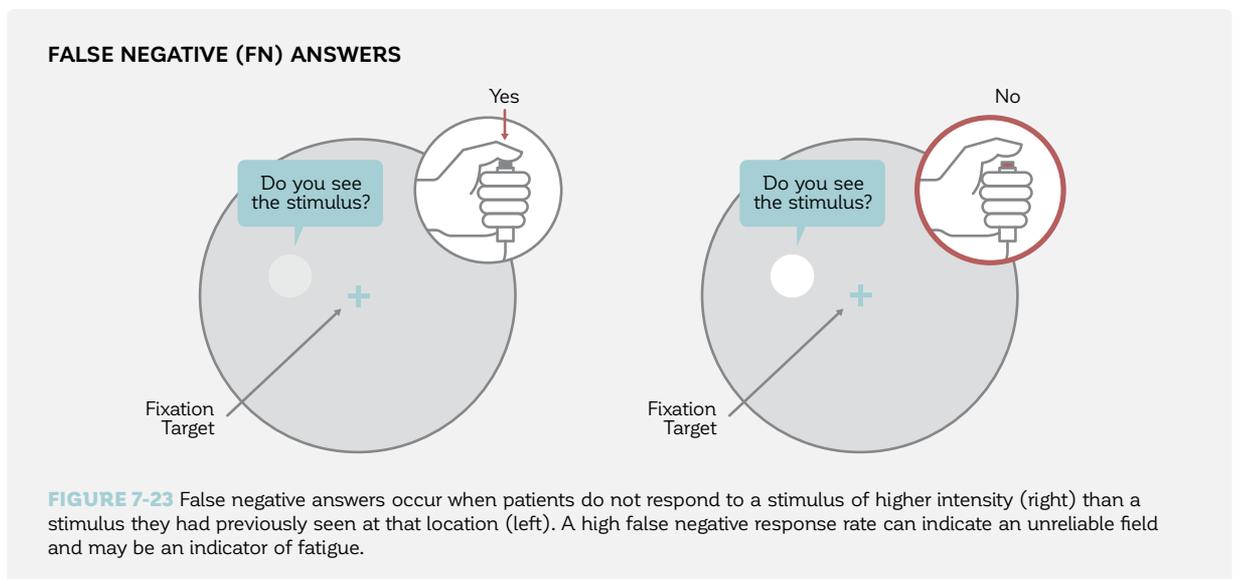
## FALSE NEGATIVE (FN) ANSWERS

False negative answers are used to detect fatigue, loss of attention and potential fixation loss during perimetric testing.

Negative catch trials are used to identify false negative answers. Negative catch trials consist of stimuli that are presented at a higher intensity than the patient has previously seen. Patients who perform the test reliably

should be able to see these bright stimuli, and when they are missed, this is marked as a false negative answer (FIG 7-23).

The false negative rate is calculated as the ratio of false negative answers to the total amount of negative catch trials presented. A false negative rate above 15% is highlighted in orange color, and a false negative rate above 33% is highlighted in red color.



## RELIABILITY FACTOR (RF)

The Reliability Factor (RF) summarizes the false positive and false negative answers. RF is calculated as the ratio of both false positive and false negative answers to the sum of positive and negative catch trials presented.

## SHORT-TERM FLUCTUATION (SF)

The Short-term Fluctuation (SF) index provides a measure of the variability of patient responses that occurs during a perimetric test.<sup>13</sup> In order to determine SF, the sensitivity thresholds are measured again at the end of the test, and the deviations between the first and second sensitivity thresholds are determined. SF is defined as the standard deviation of the distribution of the results of repeated measurements of the same threshold.<sup>14</sup>

RELIABILITY INDICES AVAILABLE ON OCTOPUS PERIMETERS

TABLE 7-2

INDEX	FORMULA	VARIABLES
FALSE POSITIVE (FP) ANSWERS [%]	$FP = \frac{n_{f+}}{n_{tot+}}$	$n_{f+}$ : Number of false positive answers $n_{tot+}$ : Total number of positive catch trials presented
FALSE NEGATIVE (FN) ANSWERS [%]	$FN = \frac{n_{f-}}{n_{tot-}}$	$n_{f-}$ : Number of false negative answers $n_{tot-}$ : Total number of negative catch trials presented
RELIABILITY FACTOR (RF) [%]	$RF = \frac{n_{f+} + n_{f-}}{n_{tot+} + n_{tot-}}$	
SHORT-TERM FLUCTUATION (SF)	$SF = \sqrt{\frac{1}{2N} \sum_{i=1}^N (x_{i2} - x_{i1})^2}$	$x_{i1}$ : Sensitivity threshold at test location $i$ determined in 1st of two repeated measurements $x_{i2}$ : Sensitivity threshold at test location $i$ determined in 2nd of two repeated measurements $N$ : Total number of test locations

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## CHAPTER 8

# CLINICAL INTERPRETATION OF A VISUAL FIELD

## INTRODUCTION

Octopus perimeters offer a variety of visual field representations that are based on the raw data (i.e., the sensitivity thresholds). Each of them focuses on different clinically relevant aspects of visual field interpretation, to facilitate clinical decision-making. While there is often overlap in the information provided by the different representations, there is typically one representation that is best suited to provide information about a certain clinical aspect of a visual field.

This chapter provides a systematic approach on how to interpret visual fields in a clinically meaningful way and highlights particular representations to answer specific clinical questions. To illustrate how the various representations can be used in clinical situations, this chapter starts by presenting six typical visual fields at different stages of disease severity (**FIG 8-1**). The examples include

a normal and a borderline visual field, as well as visual fields with localized loss, diffuse loss, and both local and diffuse loss, and a visual field with advanced loss. These examples provide an excellent starting point to become familiar with the various representations and their behavior in standard clinical situations and are referenced throughout the book. A removable poster of these examples is also included in the back cover of this book.

Thereafter, this chapter presents the various representations in a step-by-step workflow. Because this chapter focuses on how to interpret visual fields for clinical purposes, only an introduction to the definitions, design and relationships between the representations is presented. Detailed information about each representation is provided in Chapter 7 and should be consulted as required.

EXAMPLES OF SIX TYPICAL VISUAL FIELDS

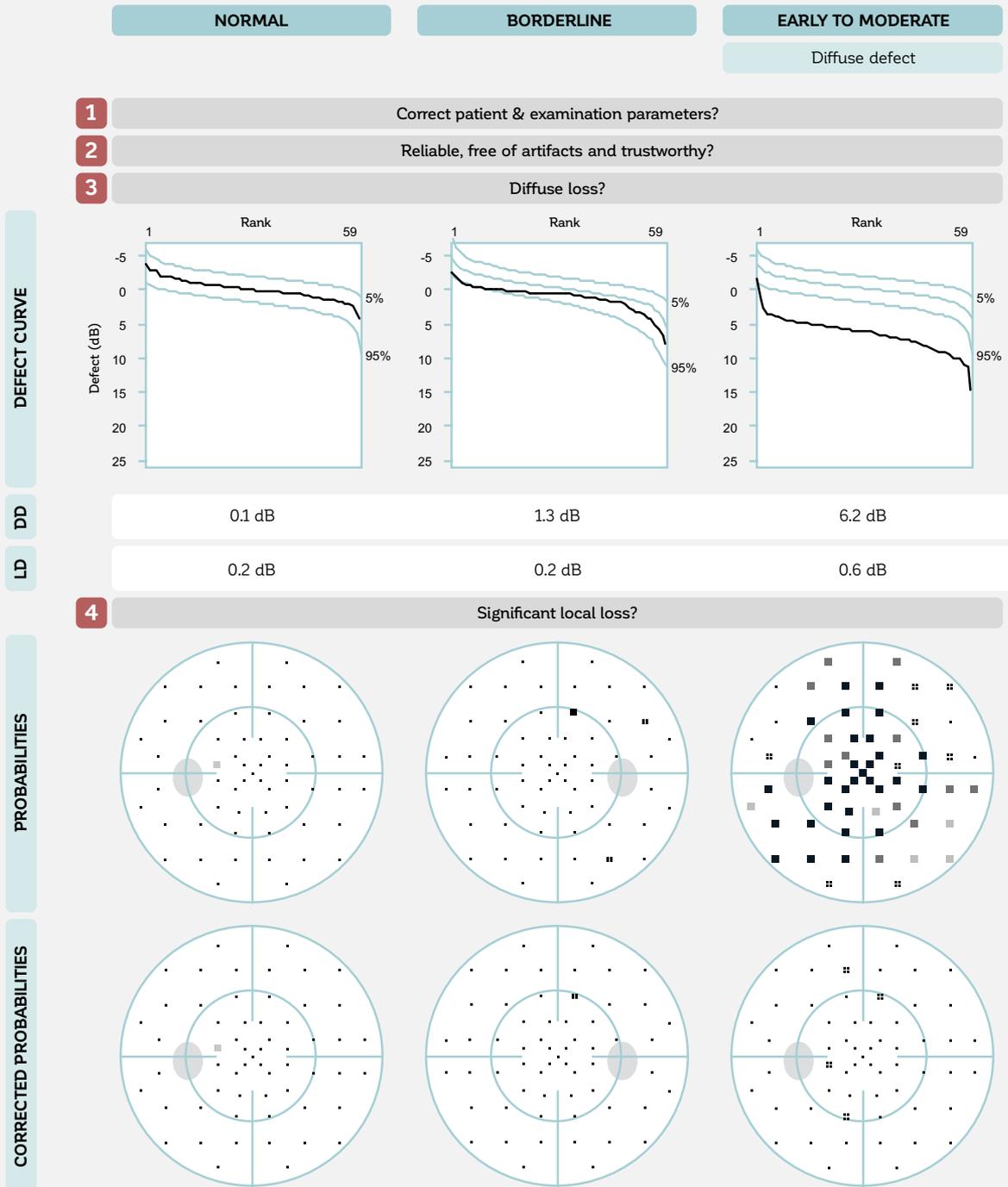


FIGURE 8-1 A systematic approach to visual field interpretation is recommended and this workflow can be used as a guide (this figure is also included as a poster in the back cover of this book).

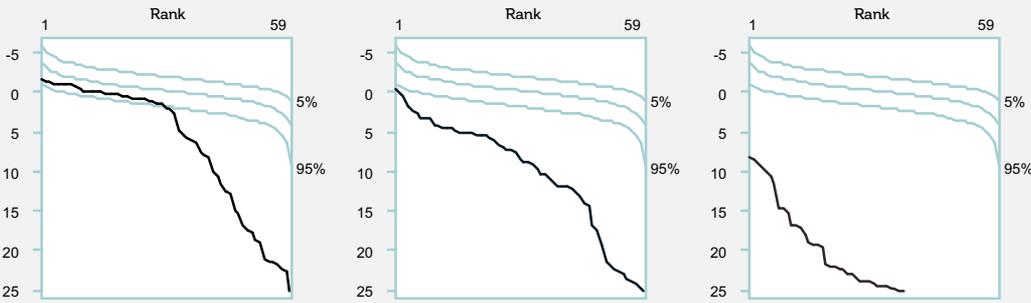
**EARLY TO MODERATE** **ADVANCED**

Local defect      Local & diffuse defect

Correct patient & examination parameters? **1**

Reliable, free of artifacts and trustworthy? **2**

Diffuse loss? **3**



13 dB

5.9 dB

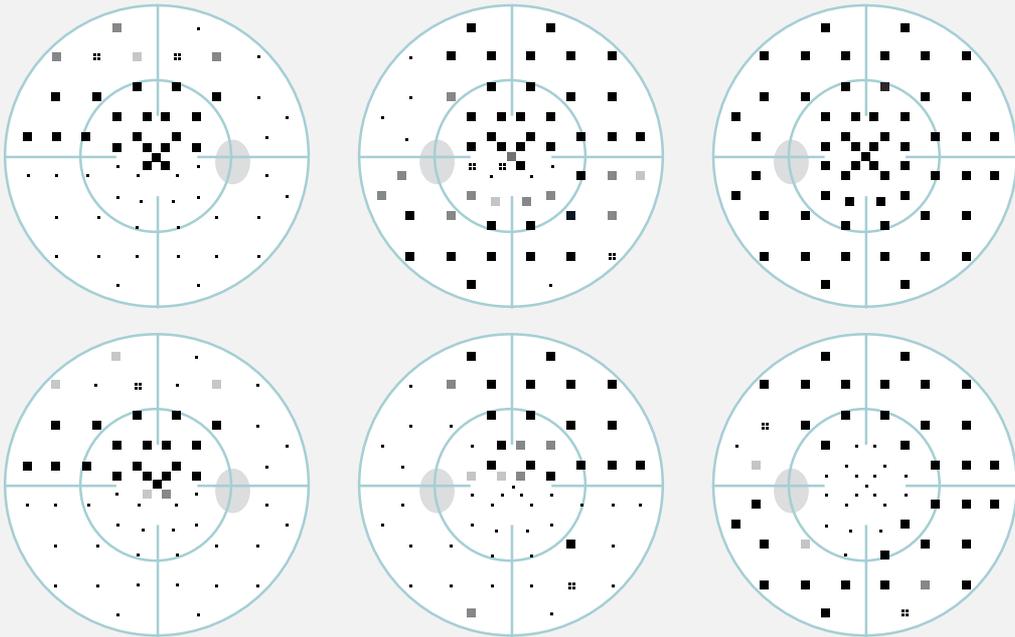
19.3 dB

7.0 dB

6.1 dB

4.7 dB

Significant local loss? **4**



DEFECT CURVE

DD

LD

PROBABILITIES

CORRECTED PROBABILITIES



EARLY TO MODERATE

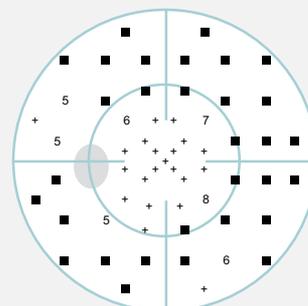
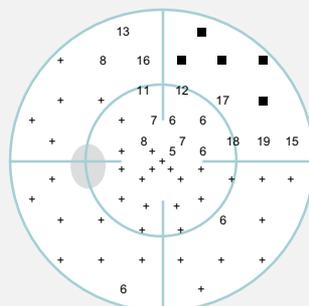
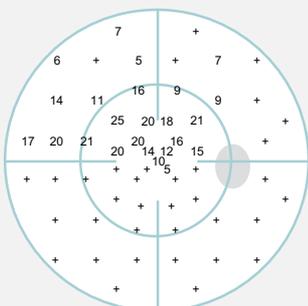
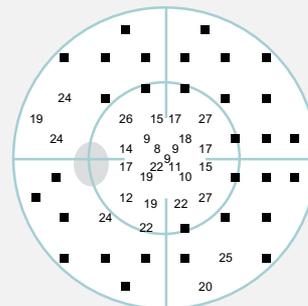
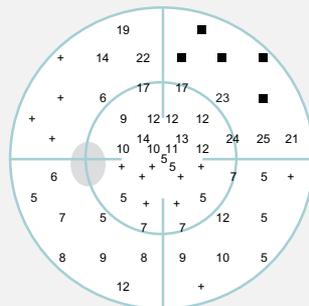
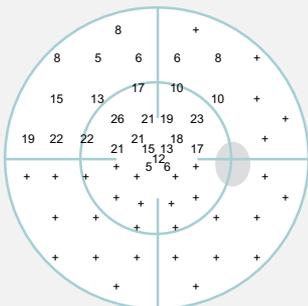
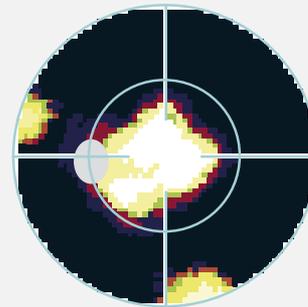
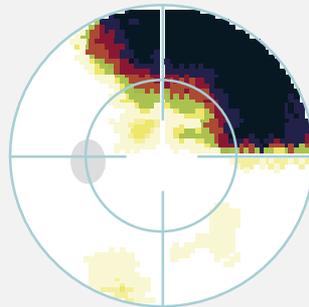
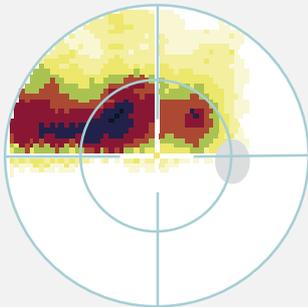
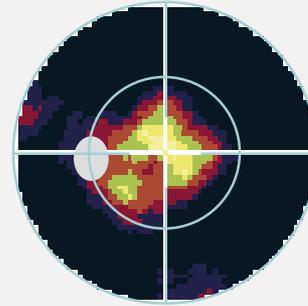
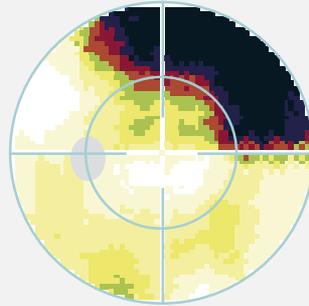
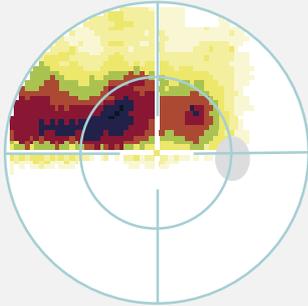
ADVANCED

Local defect

Local & diffuse defect

Assess shape & depth of defect.

5



GRAYSCALE (COMPARISONS)

CORRECTED GRAYSCALE (CO)

COMPARISONS

CORRECTED COMPARISONS

EXAMPLES OF SIX TYPICAL VISUAL FIELDS (CONTINUED)

NORMAL

BORDERLINE

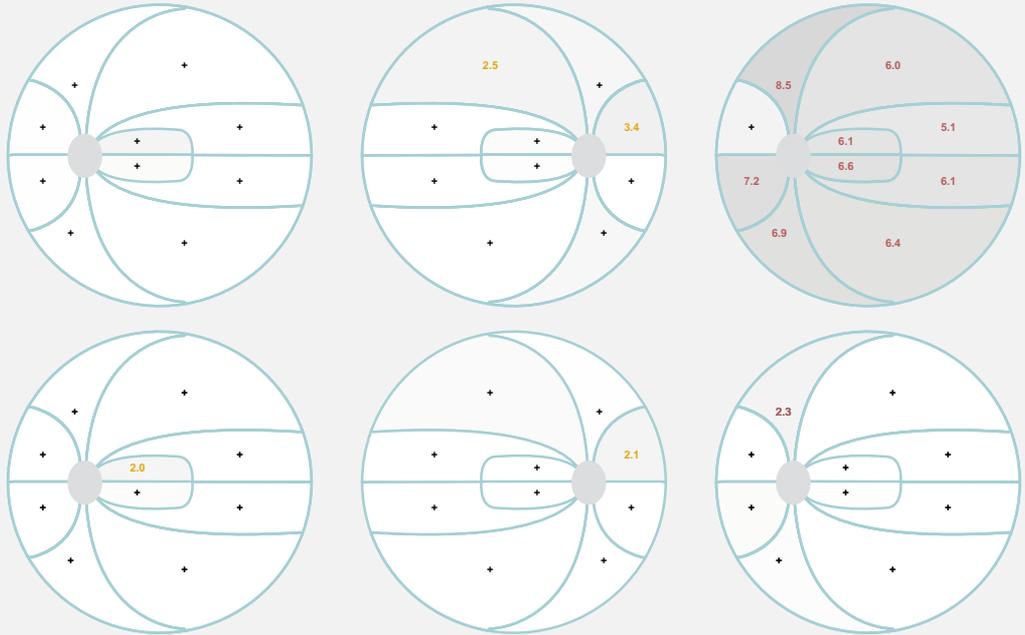
EARLY TO MODERATE

Diffuse defect

6

For glaucoma: Significant cluster defects?

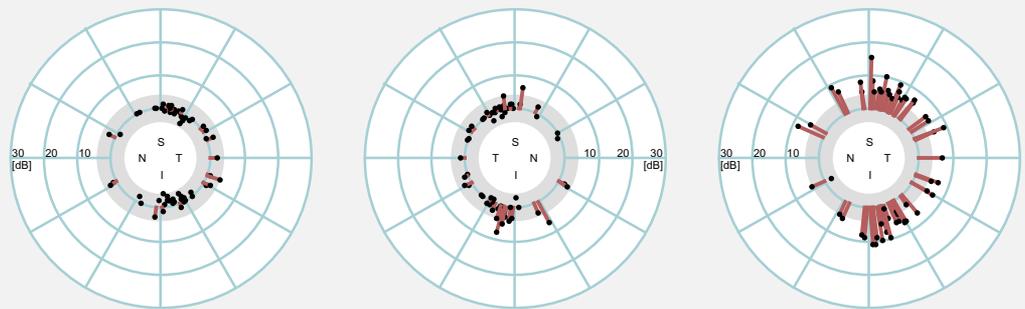
CLUSTER ANALYSIS



7

For glaucoma: Where to look for structural defects.

POLAR ANALYSIS



8

Severity?

MD

-0.2 dB

1.0 dB

6.3 dB

sLV

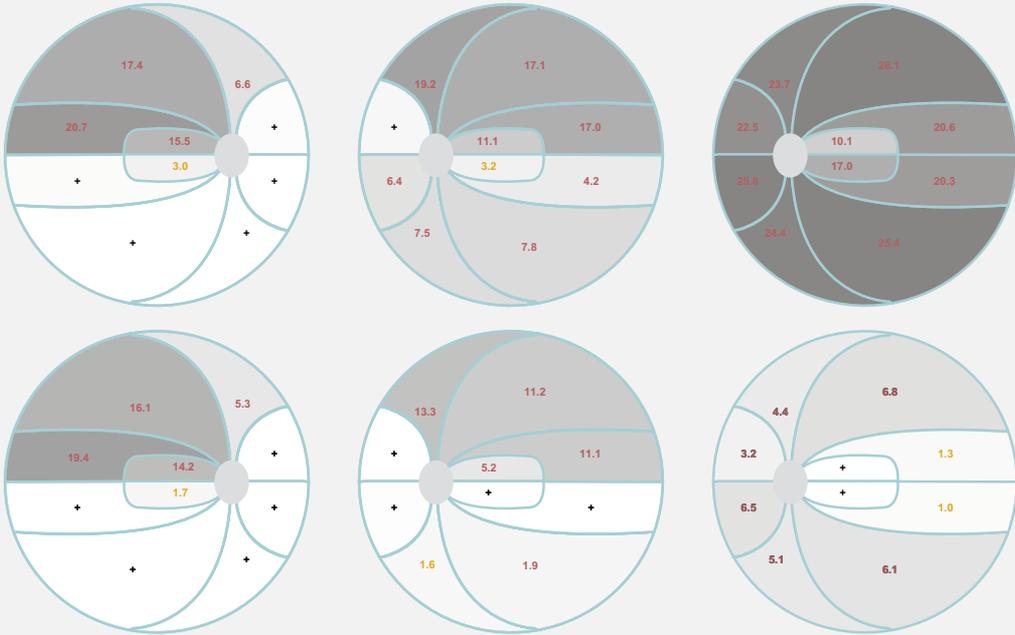
1.5 dB

1.9 dB

2.5 dB

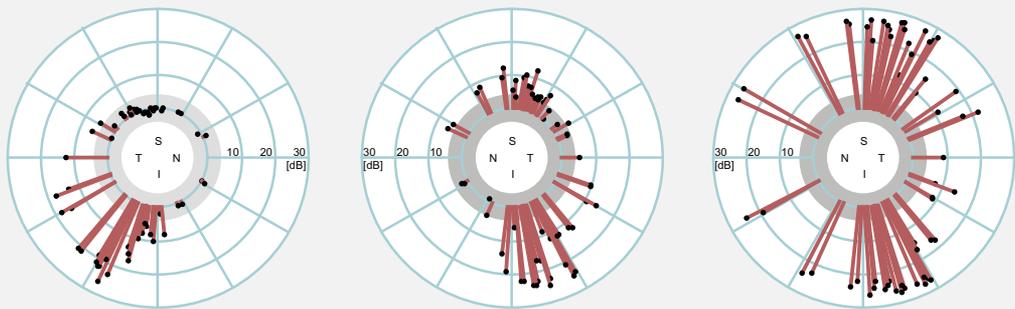
EARLY TO MODERATE		ADVANCED
Local defect	Local & diffuse defect	

For glaucoma: Significant cluster defects? 6



CLUSTER ANALYSIS  
CORRECTED CLUSTER ANALYSIS

For glaucoma: Where to look for structural defects. 7



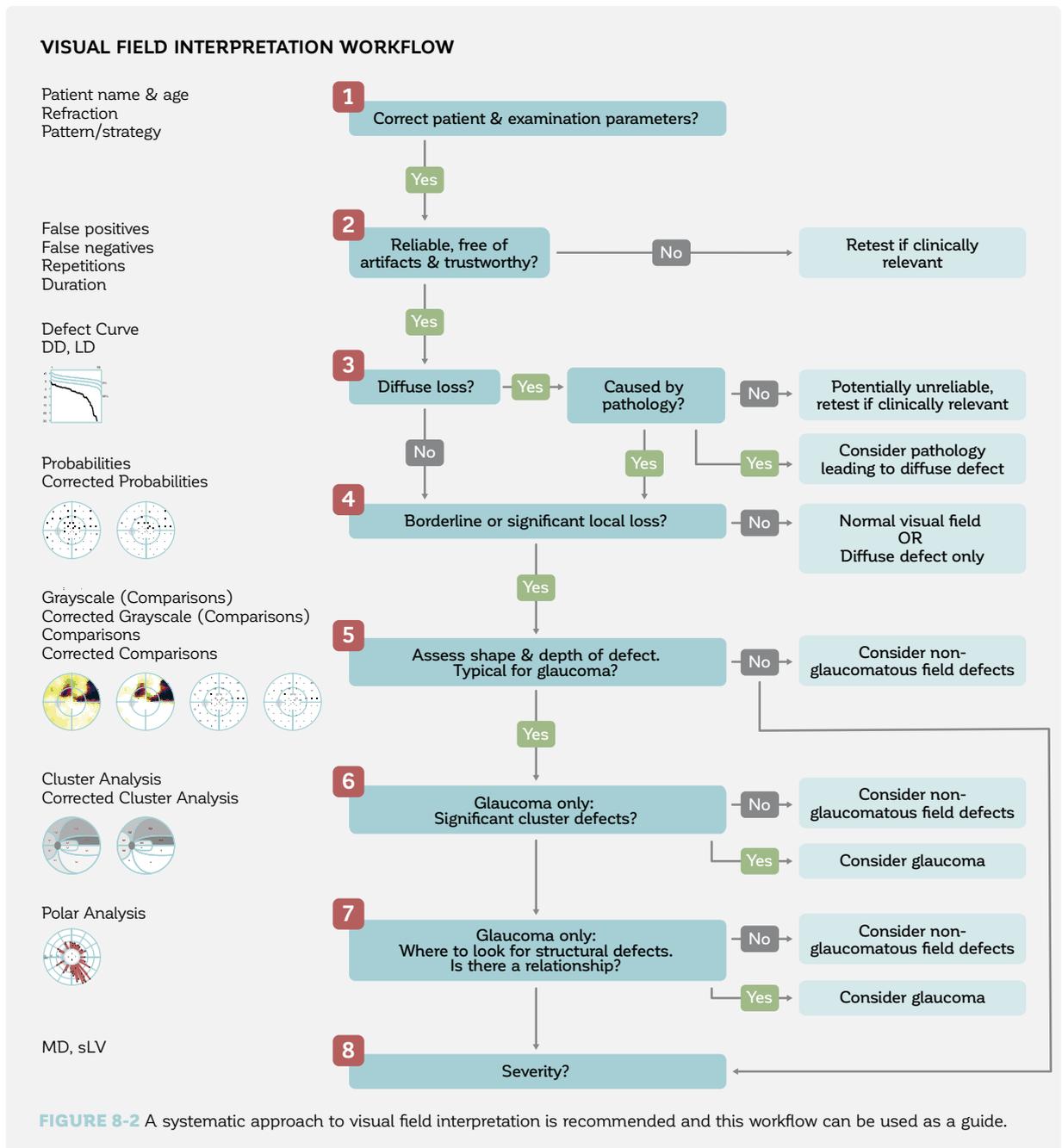
POLAR ANALYSIS

Severity?		
6.5 dB	10.1 dB	21.7 dB
8.3 dB	7.2 dB	5.6 dB

MD  
SLV

# STEP-BY-STEP INTERPRETATION OF A VISUAL FIELD

## OVERVIEW OF STEP-BY-STEP WORKFLOW



**FIGURE 8-2** A systematic approach to visual field interpretation is recommended and this workflow can be used as a guide.

This chapter provides a systematic step-by-step approach on how to interpret visual fields in a clinically meaningful way and highlights particular representations to answer specific clinical questions. This suggested sequence has been validated by many experts and can serve as an excellent starting point to interpret visual field results. Different sequences may, however, be equally valid or even more adequate in specific cases and should be used accordingly. An overview of that workflow is presented in **FIG 8-2**.

## STEP 1 – CONFIRM PATIENT AND EXAMINATION PARAMETERS

### IMPORTANCE OF CONFIRMING PATIENT AND EXAMINATION PARAMETERS

It is essential to confirm that the correct information is used for each test, in order to make accurate clinical decisions.

#### STEP 1 – CONFIRM PATIENT AND EXAMINATION PARAMETERS

##### 1 Correct patient & examination parameters?

**FIGURE 8-3** Before interpreting visual field results, it is important to confirm that the correct patient data has been entered and that the correct examination parameters have been used during the test.

Octopus perimeters display key patient and examination parameters for all visual fields (**FIG 8-4**). Special attention should be paid to patient age and refraction. If these are incorrect, this can lead to non-pathological diffuse visual field loss. The following parameters are displayed:

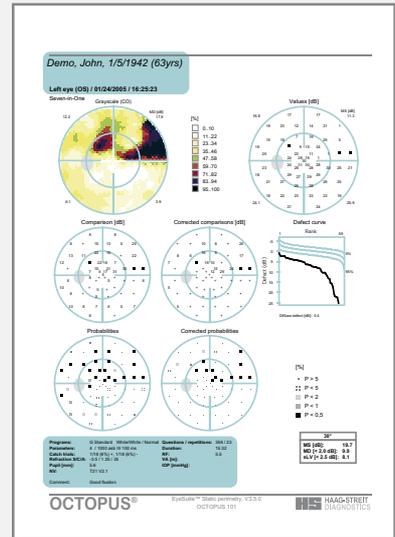
- Patient's name and identification number
- Patient's date of birth and age
- Tested eye
- Date and time of examination
- Test pattern and strategy
- Stimulus type
- Maximum stimulus intensity and background luminance
- Refraction entered or trial lens used
- Pupil size

**OVERVIEW OF PATIENT AND EXAMINATION PARAMETERS**

*Demo, John, 1/5/1942 (63yrs)*

**Left eye (OS) / 01/24/2005 / 16:25:23**

<b>Programs:</b>	G Standard White/White / Normal	<b>Questions / repetitions:</b>	356 / 23
<b>Parameters:</b>	4 / 1000 asb III 100 ms	<b>Duration:</b>	15:32
<b>Catch trials:</b>	1/18 (6%) +, 1/18 (6%) -	<b>RF:</b>	5.5
<b>Refraction S/C/A:</b>	-3.5 / 1.25 / 35	<b>VA [m]:</b>	
<b>Pupil [mm]:</b>	5.6	<b>IOP [mmHg]:</b>	
<b>NV:</b>	T21 V2.1		
<b>Comment:</b>	Good fixation		



**FIGURE 8-4** All patient and examination parameters are displayed for every perimetric result.

## STEP 2 – DETERMINE WHETHER THE VISUAL FIELD CAN BE TRUSTED

### IMPORTANCE OF ASSESSING WHETHER THE VISUAL FIELD CAN BE TRUSTED

Due to the subjective, patient-related component of perimetric testing, unreliable visual field tests, tests with artifacts or tests that cannot be trusted for other reasons can occur frequently, must be identified and should not be clinically interpreted.

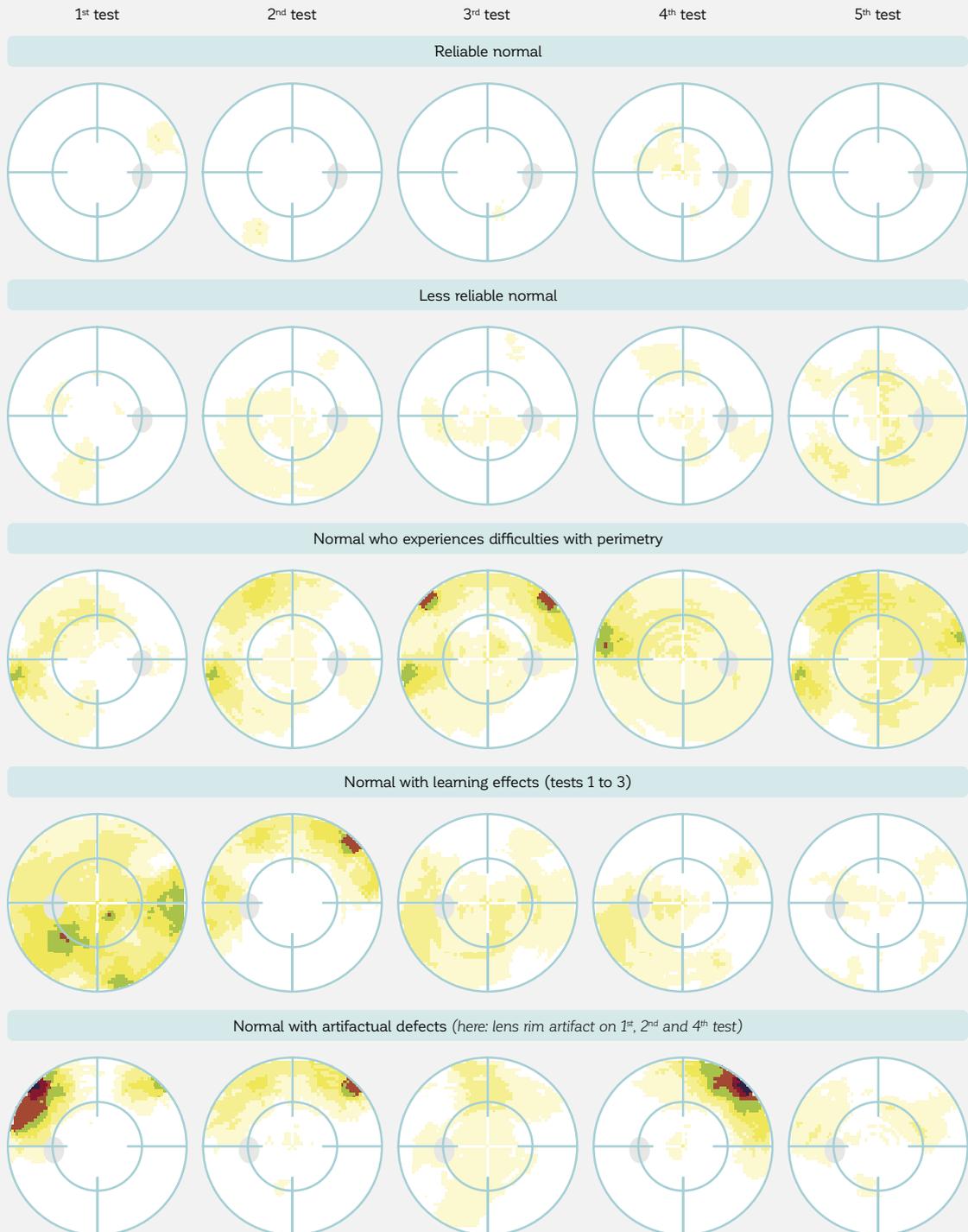
### STEP 2 – ASSESS WHETHER THE VISUAL FIELD CAN BE TRUSTED

- 2** Reliable, free of artifacts & trustworthy?

**FIGURE 8-5** Before interpreting visual field results, it is important to confirm that the visual field can be trusted. Visual fields that are not reliable, contain artifacts or cannot be trusted for other reasons should be retested if this is clinically relevant.

Visual field results that cannot be trusted may occur for a number of reasons, as shown in Chapter 3. They can be caused by inconsistent patient behavior resulting from fatigue, learning effects, distraction, lack of understanding of the task to perform, or a desire to influence the results. Untrustworthy tests can also occur following set-up errors, for example when incorrect test parameters or inadequate refraction are used, or when the incorrect

### UNTRUSTWORTHY VISUAL FIELD TESTS CAN SHOW SIGNIFICANT DEFECTS



**FIGURE 8-6** The examples above show several visual field series from different individuals with clinically confirmed normal visual fields and no pathology. Note that while some individuals perform perimetric testing consistently, some show improvement over time due to learning effects, and some perform variably from one examination to the next. This results in untrustworthy visual field results, which may be misinterpreted.

date of birth is entered. In addition, artifacts stemming from incorrect positioning of the patient, droopy eyelid or incorrectly centered correction lenses can also lead to untrustworthy results. While a well-trained and observant visual field examiner can significantly reduce the amount of untrustworthy visual fields in a clinical practice, some patients are simply unable to perform perimetric testing consistently.

**FIG 8-6** shows the impact of unreliable visual field tests, inconsistent patient behavior and set-up errors on the vi-

ual field results of several individuals with clinically confirmed normal visual fields and no pathology.

Since visual fields that cannot be trusted may not represent the true status of a patient's visual field, they may be clinically meaningless. It is thus essential to identify them as a first step in visual field interpretation. The reliability indicators provided by Octopus perimeters, as well as further indicators of whether a visual field can be trusted, should be used. These are presented in this section.

### FALSE POSITIVE AND FALSE NEGATIVE ANSWERS

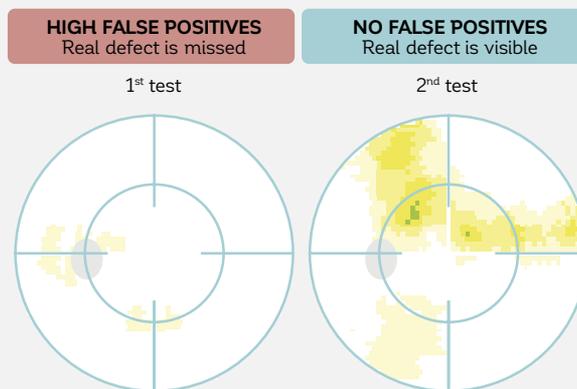
Octopus perimeters offer several indicators to detect unreliable visual fields (see **TABLE 7-2** for the definitions of each of these indicators). The two most important indicators of unreliability are the false positive (see **FIG 7-22**) and false negative answers (see **FIG 7-23**).

False positive answers occur when the patient presses the response button when no stimulus is presented. Patients who respond in the absence of a stimulus are referred to as trigger-happy, and may have visual field results that are better than their true visual field status, as shown in **FIG 8-7**. When the false positive answer rate exceeds 15%,<sup>1,2</sup> the results are marked in orange color. This means they should

interpreted with caution and the test should ideally be repeated if it is essential for clinical decision-making. Because most clinical studies do not accept false positive rates above 20 to 33%<sup>2-7</sup>, a false positive answer rate above 33% is marked in red color. This means the visual field should be repeated if essential for clinical decision making.

Note that if only a few positive catch trials are presented (e.g., the default setting of the G TOP test contains only six positive catch trials), one accidentally missed positive catch trial has a great impact on the false positive rate. In this situation, more lenient acceptance criteria may be appropriate.

#### IMPACT OF FALSE POSITIVE ANSWERS ON VISUAL FIELD RESULT

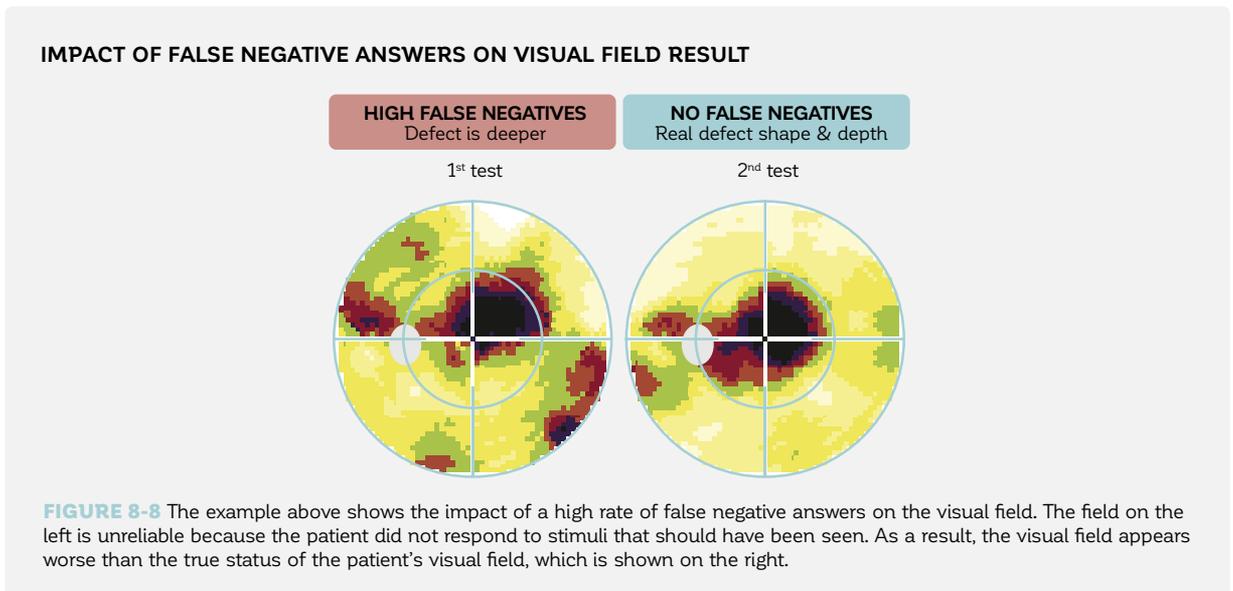


**FIGURE 8-7** The example above shows the impact of a high rate of false positive answers on the visual field. The field on the left is unreliable because the patient responded in the absence of a stimulus. As a result, the visual field appears better than the true visual field of the patient, which is shown on the right.

False negative answers occur when patients do not respond to stimuli that they should be able to see. Patients who do not respond to stimuli they should be able to see may experience fatigue or a loss of attention, and may have results that are worse than their true visual field status, as shown in **FIG 8-8**. For most patients, clinical studies often exclude results with false negative rates above 20 or 30%.<sup>2,5</sup> In patients with severe vision loss, however, false negative errors are not a meaningful indicator of reliability because there is a large increase in fluctuation with increasing visual field loss. This can

result in false negative rates above 50%, even though the visual field test is performed without any subjective mistakes.<sup>8</sup> False negative answers should thus be interpreted with care in more advanced vision loss. To provide orientation, a false negative answer rate above 15% is marked in orange color and one above 33% is marked in red color:

Note that if only a few negative catch trials are presented, more lenient acceptance criteria may be appropriate, as explained in the section on false positive answers.



### CONSISTENCY OF RESULTS WITH FURTHER DIAGNOSTIC TESTS

Any drastic inconsistency in the location of a visual field defect in repeated testing can suggest that some of the visual field tests may not be trusted. This is because pathologies lead to characteristic visual field defect patterns in specific locations. While these defects may deepen, expand or in some instances also improve over time, they are usually consistently located at the same position in repeated visual field testing. If defect patterns shift to different locations on repeated testing, as can be seen in some of the examples shown in **FIG 8-6**, this is typically a sign of an untrustworthy visual field test. Therefore it is good clinical practice to base a clinical decision on two to three visual field tests, in order to confirm or discard an initially observed visual field

defect.<sup>9</sup> These visual field tests can be used in the future to evaluate progression or stability.

Furthermore, if a visual field defect corresponds to the results of another diagnostic test, this strongly supports the decision that the visual field result can be trusted. For example, if a patient shows a visual field defect characteristic of glaucoma and shows a related RNFL thinning or rim thinning at the related optic disc location, as well as high IOP, it will be highly likely that the patient has glaucoma and that the visual field result is thus trustworthy. The results of visual field tests should therefore always be interpreted in light of the full clinical profile.

### OTHER INDICATORS TO DETERMINE WHETHER VISUAL FIELD TESTS CAN BE TRUSTED

In addition to the false positive and false negative answers, other indicators are also useful to determine whether visual field test results can be trusted. One of the most powerful indicators remains the visual field examiner's direct observation of the patient during the test. Examiners should note their observations in the patient's chart.

In addition, besides the false positive answers, the Defect Curve can also be helpful to identify trigger-happy patient behavior. See **FIG 8-10** for more information on how to

detect trigger-happy behavior using the Defect Curve.

Test duration can be a further indicator of whether visual field results can be trusted. Abnormally long test durations can indicate that a patient is struggling with the task of performing perimetry.<sup>2</sup>

Finally, if a patient can sustain prolonged testing, one can also retest the determined visual sensitivity thresholds to determine Short-term Fluctuation (SF), a further index defined in **TABLE 7-2**.

## STEP 3 – IDENTIFY DIFFUSE VISUAL FIELD DEFECTS

### NEED FOR THE DETECTION OF DIFFUSE DEFECTS

It is helpful to be alerted to the presence of diffuse defects early in the process of visual field interpretation, because although they are commonly caused by pathology (e.g.,

cataracts, glaucoma, retinal and neurological diseases), they may also indicate the presence of untrustworthy visual field results.

#### STEP 3 – IDENTIFY DIFFUSE VISUAL FIELD LOSS

3

Diffuse loss?



**FIGURE 8-9** Diffuse visual field loss should ideally be identified early on, as it can be a sign of both a pathology leading to diffuse defects or an untrustworthy visual field.

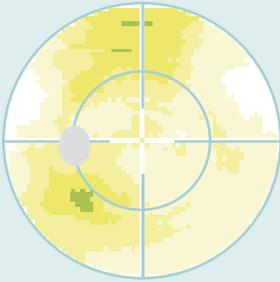
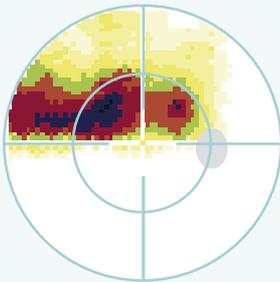
Diffuse defects are present when most visual field locations show defects of approximately the same magnitude (i.e., there is no apparent visual field loss pattern). Conversely, a visual field with a local defect is characterized by a specific defect pattern in which certain visual field points are affected more than others. Diffuse loss can also occur in the presence of a local

defect. The etiology of diffuse and local visual field defects is presented in **TABLE 8-1**.

In clinical decision-making it is essential to clarify the cause of diffuse defects. If pathology can be ruled out, the visual field should be treated as potentially untrustworthy and should be retaken, if clinically relevant.

THE ETIOLOGY OF DIFFUSE AND LOCAL VISUAL FIELD DEFECTS

TABLE 8-1

	EXAMPLES OF PATHOLOGIES	EXAMPLES OF UNTRUSTWORTHY RESULTS
<p><b>DIFFUSE (WIDESPREAD) DEFECT</b></p> 	<ul style="list-style-type: none"> <li>• Lens opacity (e.g., cataract)</li> <li>• Cornea opacity (e.g., Fuchs dystrophy)</li> <li>• Dense vitreous opacity</li> <li>• Any advanced pathology resulting in severe visual field loss (e.g., advanced glaucoma)</li> </ul>	<ul style="list-style-type: none"> <li>• Incorrect refraction</li> <li>• Incorrect patient age</li> <li>• Small pupil size</li> <li>• Learning effect</li> <li>• Distraction</li> <li>• Fixation loss</li> <li>• Fatigue</li> </ul>
<p><b>LOCAL DEFECT</b></p> 	<ul style="list-style-type: none"> <li>• Glaucoma</li> <li>• Age-related macular degeneration</li> <li>• Hemianopia</li> <li>• Quadrantanopia</li> <li>• Vitreous opacity</li> </ul>	<ul style="list-style-type: none"> <li>• Lens rim artifact</li> <li>• Lid artifact</li> </ul>

It is important to note that when advanced visual field loss is present (e.g., MD > 20 dB), most visual field locations are affected. As a result, diffuse loss is always present.

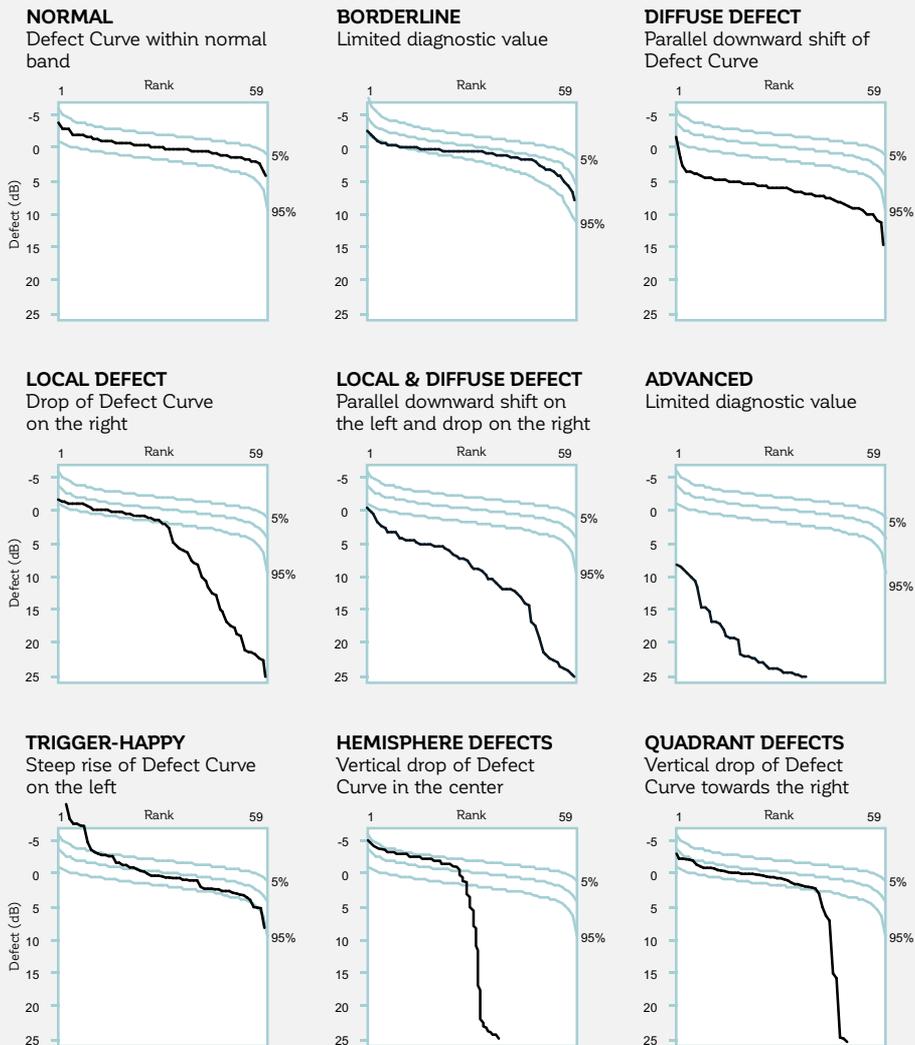
To quickly identify the presence of diffuse defects, the Defect Curve is useful.

**DEFECT CURVE**

The Defect Curve is a graphical representation that provides a summary of the visual field and distinguishes between local and diffuse defects.<sup>10</sup> In clinical practice it is very helpful in alerting the clinician to the presence of diffuse defects that may be missed by looking at other

representations, and also provides other clinically valuable information, as shown in FIG 8-10. For more details of the design and definitions of the Defect Curve, see BOX 7A.

## DEFECT CURVE – INTERPRETATION AID



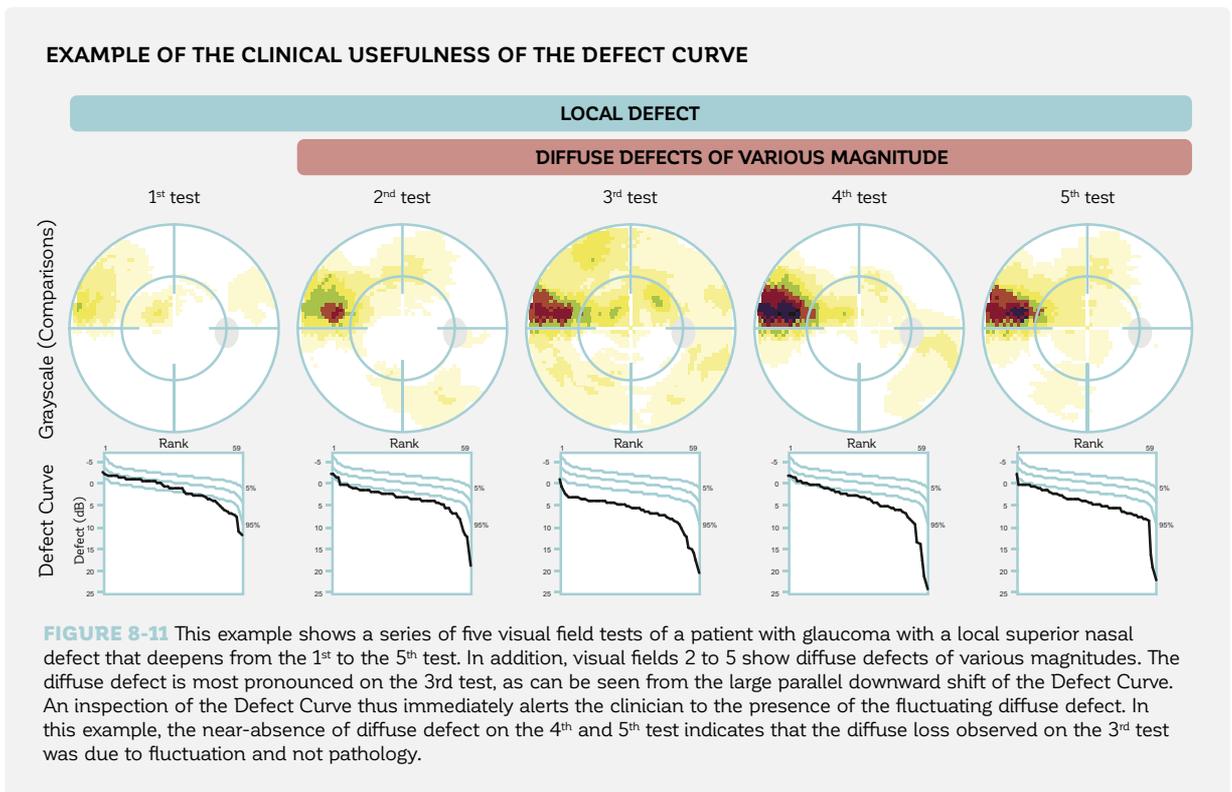
**FIGURE 8-10** The Defect Curve alerts the clinician to the presence of diffuse defects and allows a rapid distinction to be made between local and diffuse defects in early to moderate disease. It furthermore allows the identification of trigger-happy patients and has a characteristic shape for localized hemisphere and quadrant defects. Note that it is of limited diagnostic value in borderline (i.e., suspect) situations or in advanced pathology.

The interpretation of the Defect Curve is based on its graphical representation and is straightforward. A visual field is normal when the entire Defect Curve lies within the normal band (i.e., the 90% confidence interval). Diffuse defects are present when there is a parallel downward shift of the Defect Curve. Alternatively, only

local defects are present when there is a drop on the right-hand side of the Defect Curve (steepening of the downward slope), while the left side remains within the normal band. If both local and diffuse defects are present, there is both a parallel downward shift on the left and a drop on the right.

The Defect Curve can also identify trigger-happy response behavior, which results in a steep slope above the normal band on the left. Hemisphere and quadrant defects, on the other hand, usually show a characteristic

nearly vertical drop at a given location along the curve. **FIG 8-11** illustrates the usefulness of the Defect Curve in a clinical situation.



While the Defect Curve is very helpful and straightforward to interpret in early to moderate disease, it has limited clinical usefulness in suspect situations or advanced disease. In suspect situations, all visual field points typi-

cally remain within the normal band. In severe pathology, most visual field points are affected to some extent and absolute defects are not drawn on the Defect Curve. As a result, the Defect Curve lies in the lower left-hand corner.

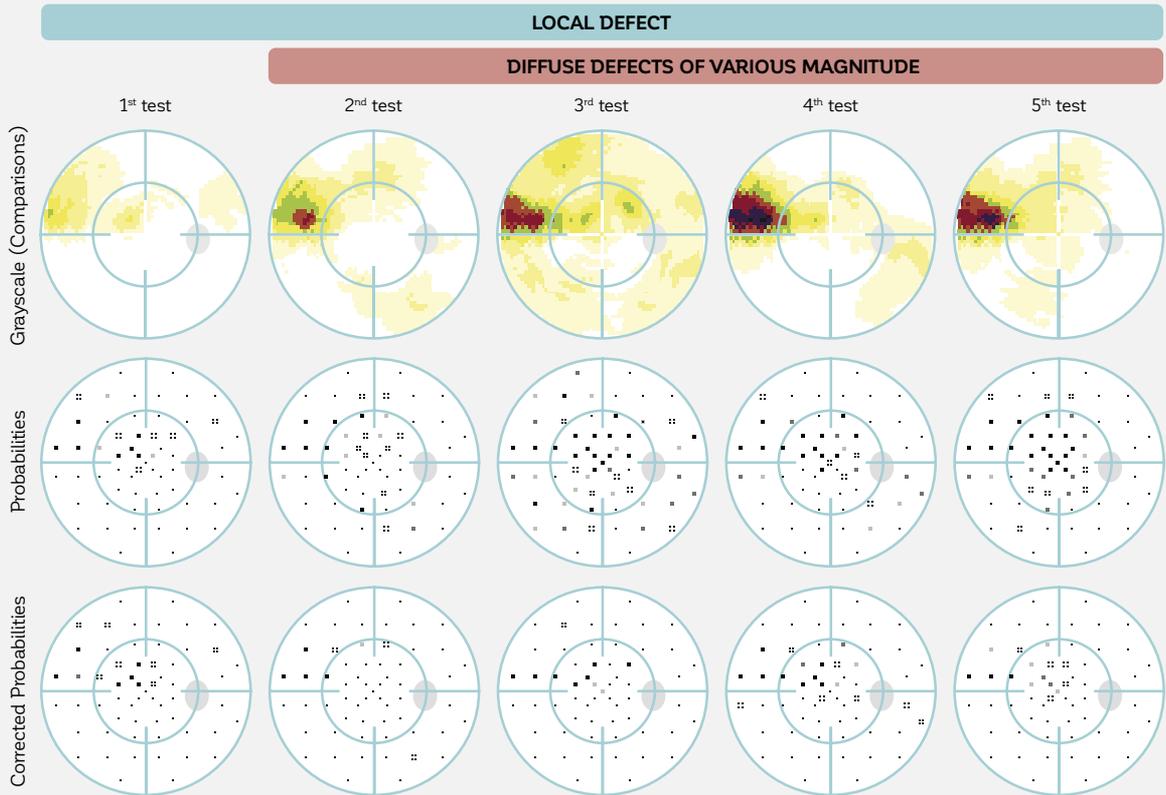
### CORRECTING FOR DIFFUSE DEFECTS

Local and diffuse defects may occur together, for example in glaucoma patients who also have cataracts. In such cases, the diffuse defects may mask localized defects. It is therefore desirable to distinguish between the local and diffuse visual field components, in order to analyze the local visual field loss independently. To achieve this, Octopus perimeters offer corrected representations, in

which the unspecific, diffuse defect is removed, as shown in **FIG 7-16**.

The corrected representations provide very helpful clinical information to determine whether there is local loss when diffuse loss is also present, as illustrated in **FIG 8-12**.

### EXAMPLE OF THE CLINICAL USEFULNESS OF THE CORRECTED REPRESENTATIONS



**FIGURE 8-12** Example of the glaucoma patient with a local superior nasal defect presented in Figure 8-11. Due to the presence of fluctuating diffuse defects of various magnitudes, the extent of the local defect is difficult to judge. This is the purpose of the Corrected Probabilities representation, which eliminates the influence of diffuse defect and allows the identification of local defects.

The corrected representations are very helpful when diffuse loss is present or suspected, as can be seen in the borderline, diffuse loss and diffuse and local loss examples in **FIG 8-1**. However, when mainly local defects are present, the corrected representations are very similar to the uncorrected representations and thus provide only limited additional information, as is visible in the normal and local loss examples shown in **FIG 8-1**.

When there is advanced visual field loss (e.g., MD > 20 dB), correcting the visual field for diffuse loss does not provide clinically useful information, because most visual field locations are relatively severely affected. Local defects no longer exist in this situation, because the entire visual field is affected. This can be seen in the advanced example of a constricted glaucoma visual field in **FIG 8-1**.

## STEP 4 – DISTINGUISH BETWEEN NORMAL AND ABNORMAL VISUAL FIELDS

### NEED TO DISTINGUISH BETWEEN NORMAL AND ABNORMAL VISUAL FIELDS

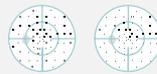
Distinguishing between normal and abnormal visual fields is challenging because 1) there is fluctuation in healthy eyes, 2) this fluctuation is not uniformly distributed across the visual field, as shown in [FIG 2-11](#), and 3) subtle visual field defects, as they occur in early glaucoma, are often

smaller than normal fluctuation. In sum, the challenge is to detect faint signals within noise. For example, there are borderline fields which may remain stable and normal, while others, although appearing the same, have already undergone the first steps towards pathology.

### STEP 4 – DISTINGUISH BETWEEN NORMAL AND ABNORMAL VISUAL FIELDS

4

Borderline or significant local loss?



**FIGURE 8-13** Before analyzing a visual field in detail, statistical analysis is used to assess whether a visual field is within normal limits, or is abnormal. The Probabilities and Corrected Probabilities are used to achieve this essential step, which results from the normal fluctuation present in perimetry.

In view of the challenges mentioned above, there is a need for representations that allow for the distinction between normal and abnormal visual field locations. This is the purpose of the Probabilities and Corrected Probabilities representations, which employ statistical analysis to distinguish between normal and abnormal visual fields. These representations are especially useful in borderline situations or to detect subtle visual field change in which

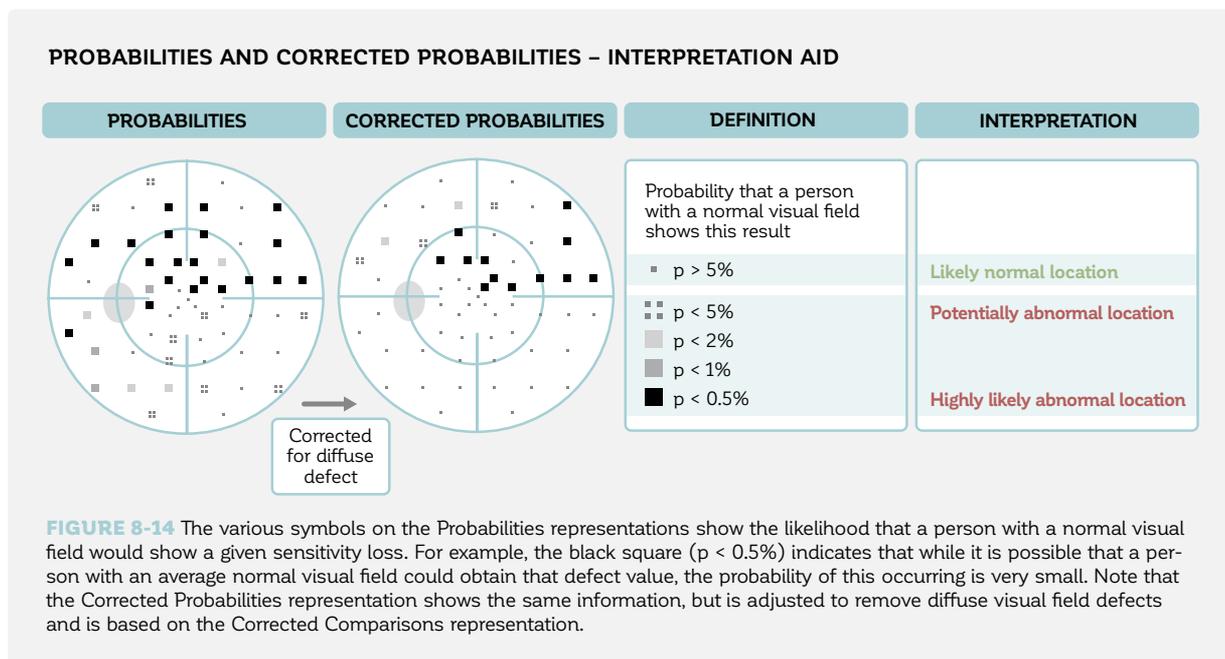
the direct assessment of the visual field sensitivity thresholds can be very challenging.

It is thus worth looking at these representations prior to performing an in-depth analysis of the visual field in order to 1) avoid spending unnecessary time on analysis of a normal visual field and 2) avoid confusion between normal fluctuation and truly abnormal visual fields.

### PROBABILITIES AND CORRECTED PROBABILITIES

The Probabilities and Corrected Probabilities representations serve the purpose of distinguishing between normal and abnormal visual fields. They show the probability ( $p$ ) that a person of the same age with an average normal visual field (or one with a visual field corrected for diffuse loss in the case of the Corrected Probabilities representation) has a certain visual field result at a

given test location. Increasingly darker symbols are used to show the decreasing probability that a given visual field result would be obtained for a person with an average normal visual field ([FIG 8-14](#)). For more details on the definitions used in the Probabilities representations, see [FIG 7-9, 7-10 and 7-19](#).

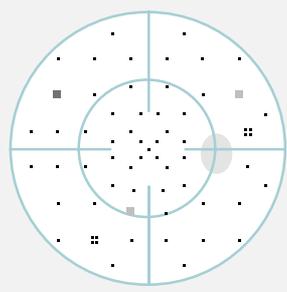
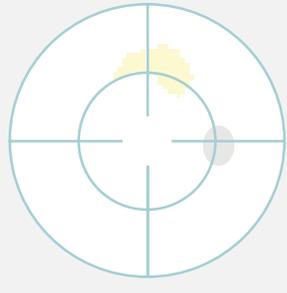
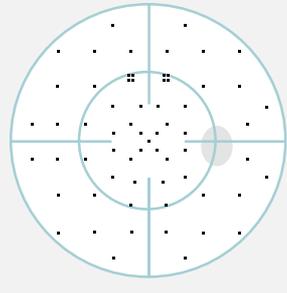
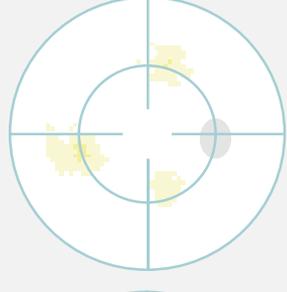
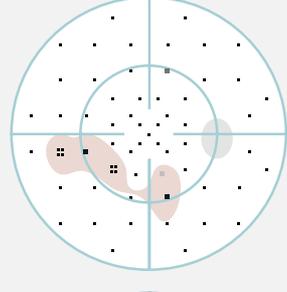
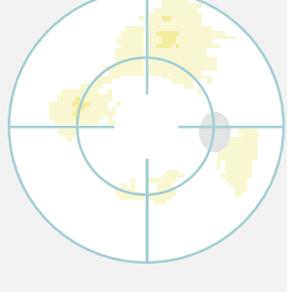
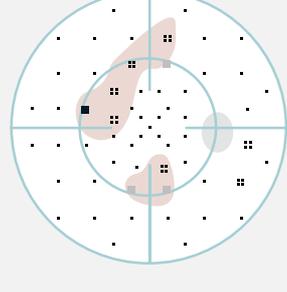


The clinical interpretation of the Probabilities representation is straightforward in that it is easy to see the pattern of visual field loss marked by dark symbols. However, there are some factors to be aware of in clinical decision-making. Firstly, there are no criteria allowing for an unambiguous distinction between normal and abnormal visual fields. Secondly, it is common to have a few random test locations that show a  $p$  value lower than 5% in normal visual fields. For further details concerning these points, see **FIG 7-9** and **7-10**.

Due to these factors, the Probabilities representation must be clinically interpreted with care. Depending on the pathology, different clinical guidelines are available to define visual field abnormality and severity.<sup>11,12</sup> To

determine a visual field as abnormal, these guidelines typically require the presence of one or more clusters of abnormal visual field locations that are consistent with the expected visual field loss pattern of a disease. This is because it is highly unlikely that such clusters would form in normal visual fields. If, however, the distribution of a few likely abnormal test locations is random and does not correspond with a disease pattern, this can often be attributed to normal fluctuation. **FIG 8-15** illustrates how to clinically interpret the Probabilities plots of several visual fields with potential early glaucomatous visual field loss, in which the magnitude of visual field loss, as illustrated in the Grayscale of Comparisons representation, is similar.

**CLINICAL INTERPRETATION OF PROBABILITIES IN BORDERLINE SITUATIONS**

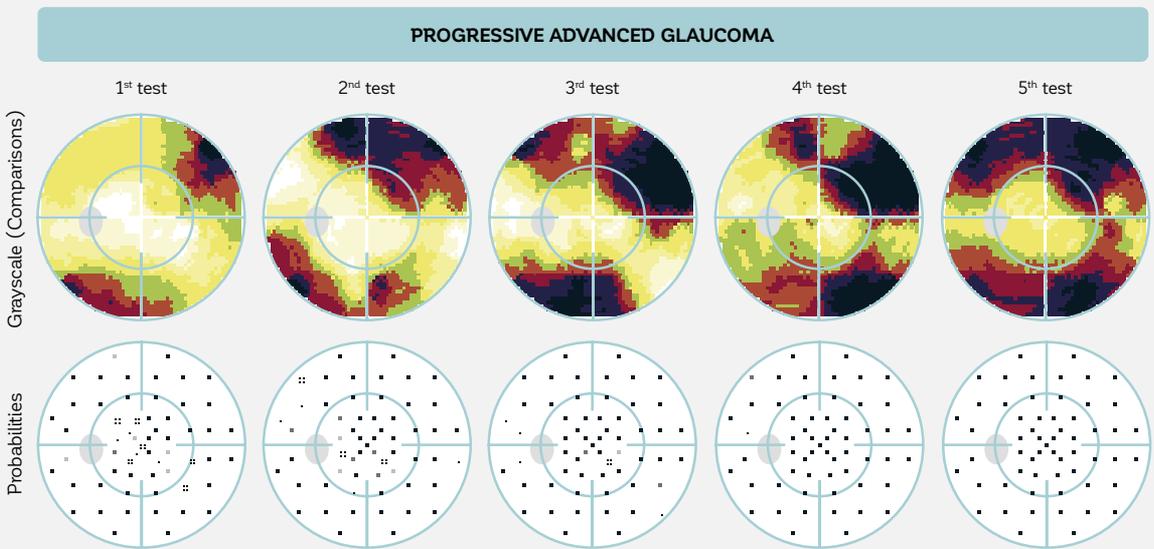
GRAYSCALE (Comparisons)	PROBABILITIES	DESCRIPTION	INTERPRETATION
		<p>Number of locations at  <math>p &lt; 5\%</math> 2  <math>p &lt; 2\%</math> 2  <math>p &lt; 1\%</math> 1</p> <p>Random distribution of likely abnormal locations</p>	<p>Likely normal</p>
		<p>Number of locations at  <math>p &lt; 5\%</math> 2</p> <p>Two adjacent likely abnormal test locations, no cluster</p>	<p>Likely normal</p>
		<p>Number of locations at  <math>p &lt; 5\%</math> 2  <math>p &lt; 2\%</math> 1  <math>p &lt; 1\%</math> 1  <math>p &lt; 0.5\%</math> 2</p> <p>Five likely abnormal locations clustered in an inferior partial arcuate defect pattern</p> <p>One likely abnormal location at random position</p>	<p>Likely abnormal Investigate further</p>
		<p>Number of locations at  <math>p &lt; 5\%</math> 7  <math>p &lt; 2\%</math> 3  <math>p &lt; 0.5\%</math> 1</p> <p>Six likely abnormal locations clustered in a superior partial arcuate defect pattern</p> <p>Three likely abnormal locations clustered in an inferior, paracentral defect pattern</p>	<p>Likely abnormal Investigate further</p>

**FIGURE 8-15** The visual field results obtained from four potential early glaucoma cases are presented. They are challenging to interpret by simply looking at the relative sensitivity loss, which is marked with yellow in the Grayscale of Comparisons representation. In the two examples at the top, the few randomly distributed test locations with a probability smaller than 5% also occur frequently in normal visual fields. The absence of clusters of likely abnormal visual field locations suggests that these two examples can be interpreted as likely normal. In the two examples at the bottom, the few test locations with a probability smaller than 5% are organized in clusters and may be interpreted as likely abnormal.

The Probabilities representation is the key graph to look at in borderline situations because it is better suited than other representations to distinguish between normal and abnormal visual fields, as illustrated in FIG 8-15. In early to moderate disease, it is mainly helpful to detect subtle change, as sensitivity loss is also apparent from the Comparisons representations, as can be seen in the examples shown in FIG 8-1.

In more advanced disease, however, the Probabilities representation loses diagnostic value because once the disease has progressed to a certain level, most visual field points are highly unlikely to be normal at a significance of  $p < 0.5\%$ . Even though there might still be visual field worsening, it may no longer be apparent from the Probabilities representation, as illustrated in FIG 8-16. Methods offered to detect and measure progression are given in Chapter 9.

#### LIMITATIONS OF THE PROBABILITIES REPRESENTATION IN ADVANCED DISEASE



**FIGURE 8-16** Example of a series of visual fields from a patient with progressing advanced glaucoma. Even though the visual field is worsening over time, the change is not apparent in the Probabilities representation because most visual field locations already show a probability of  $p < 0.5\%$  in the 1<sup>st</sup> of the 5 tests.

In case of diffuse loss, the Corrected Probabilities representation should also be consulted to assess abnormal localized loss independently of the diffuse defect, as is shown in FIG 8-12.

## STEP 5 – ASSESS SHAPE AND DEPTH OF DEFECT

### NEED FOR ASSESSING SHAPE AND DEPTH OF DEFECT

Once it has been determined that a visual field is trustworthy and abnormal, the shape of the defect area and the depth of the defect should be assessed. Since different pathologies show different disease patterns, these characteristics are helpful to determine the possible cause and

severity of the visual field defect, and to indicate potential further diagnostic tests. Typical visual field defects for glaucoma, neuro-ophthalmic and retinal diseases are presented in [FIG 5-1](#), [5-7](#) and [5-9](#).

### STEP 5 – ASSESS SHAPE AND DEPTH OF DEFECT

5

Assess shape & depth of defect.  
Typical for glaucoma?



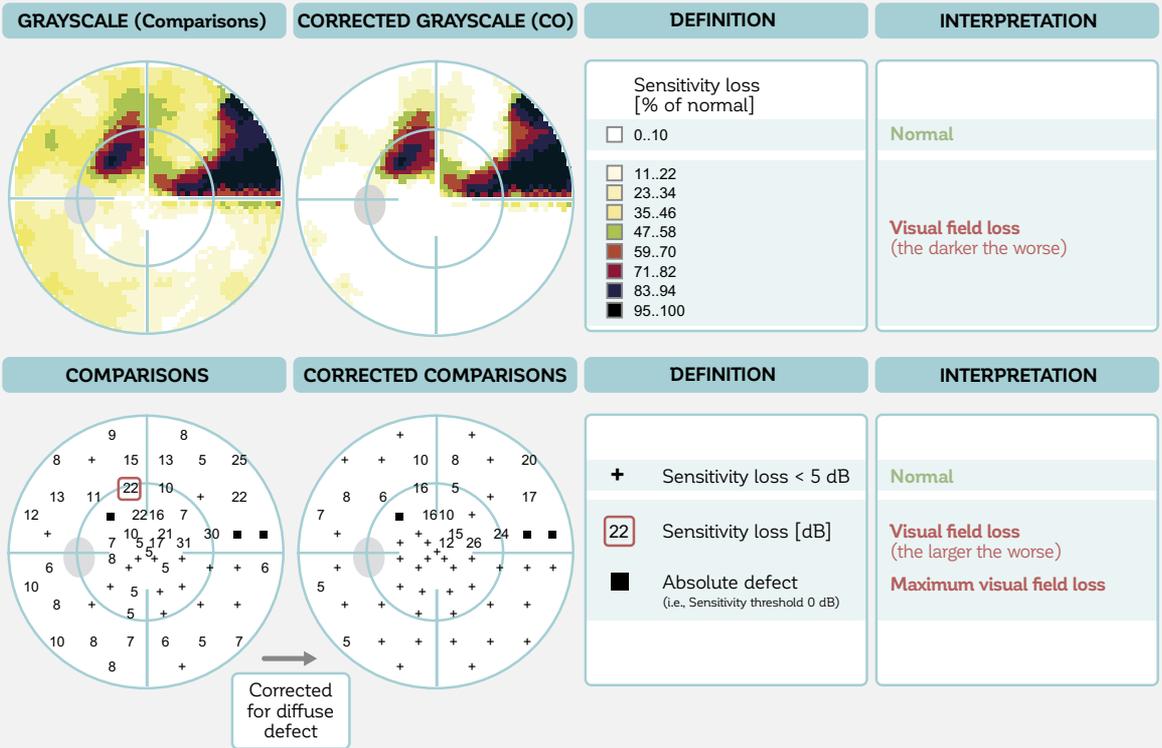
**FIGURE 8-17** The shape and depth of a defect provide valuable clues to identify and characterize pathology. They can be analyzed from a graphical (Grayscale of Comparisons and Grayscale of Corrected Comparisons) or numerical (Comparisons and Corrected Comparisons) map.

### GRAYSCALE OF (CORRECTED) COMPARISONS AND (CORRECTED) COMPARISONS

The Comparisons representations are key in that they provide a thorough analysis of both the depth and shape of defects, thus providing information about the possible causes of the visual field loss. They do so by comparing the measured sensitivity thresholds to a normal visual field, as shown in [FIG 7-5](#).

Four representations are available. The Grayscale of Comparisons and the Grayscale of Corrected Comparisons are color maps of a patient's visual field loss. The Comparisons and Corrected Comparisons representations show the same information using numerical maps. An overview of how to clinically interpret them is provided in [FIG 8-18](#). For further details, see [FIG 7-6](#), [7-7](#), [7-17](#) and [7-18](#).

**GRAYSCALE OF COMPARISONS, COMPARISONS AND CORRECTED COMPARISONS – INTERPRETATION AID**



**FIGURE 8-18** The Grayscale of Comparisons and the Grayscale of Corrected Comparisons are color maps that are especially useful to determine the shape of the sensitivity loss, whereas the Comparisons and Corrected Comparisons representations are numerical maps showing sensitivity loss in dB. The Grayscale of Corrected Comparisons and the Corrected Comparisons representations show localized loss only. All representations are key to identifying possible causes of disease.

The Grayscale of Comparisons representation is ideally suited to assess defect shapes and to gain a quick first impression of a patient’s overall visual field loss. Since it is intuitive to understand, it is also very useful for patient education.

Since it is based on the Comparisons representation, which eliminates the effect of patient age and eccentricity of test locations (see FIG 2-9 for more information), it represents a patient’s true sensitivity loss, as shown in FIG 7-7 and 7-8.

The Grayscale of Corrected Comparisons shows very similar information, but contains a correction factor that eliminates diffuse defects. It is useful to assess localized sensitivity loss independently of diffuse loss, as explained in FIG 7-16 and FIG 7-18.

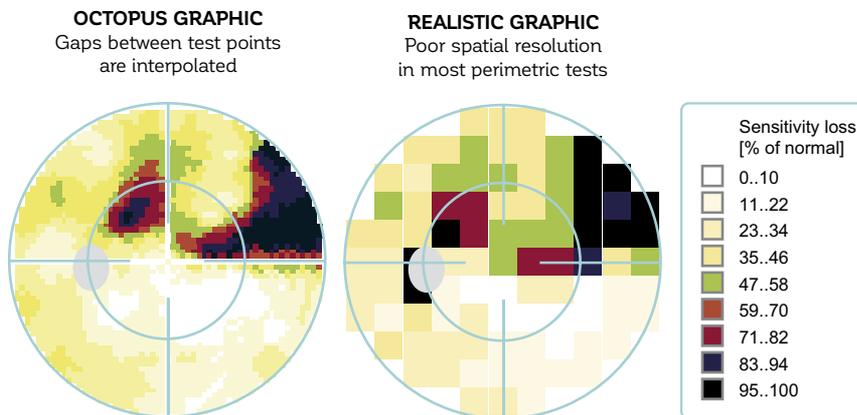
However, caution is essential when interpreting the precise boundaries of the two Grayscale representations, as their high spatial resolution might give the impression that the detailed boundaries of a defect are known, which is not true, as explained in BOX 8A.

## BOUNDARIES OF GRAYSCALE OF COMPARISONS CAN BE MISLEADING

### BOX 8A

It is important to remember that in perimetric testing only a discrete number of locations are tested, as illustrated in FIG 4-4. As a result, there are large gaps between test points for which no information is available. These gaps are filled with interpolated (i.e., probable or likely) information in the Grayscale of Comparisons and Grayscale of Corrected Comparisons representations. The boundaries of a visual field defect shown in those representations are thus only estimated and may not reflect the exact boundaries. The resolution of a test is only as good as that of the test pattern. This is important to remember when interpreting the two Grayscale maps, to avoid incorrect interpretation of a slightly changing defect pattern.

### GRAYSCALE REPRESENTATIONS ARE INTERPOLATED COLOR MAPS



It is essential to be aware that the Grayscale representations are interpolated visual field maps, where gaps between visual field points are filled by interpolation (left). Their true spatial resolution is much poorer, as illustrated in the panel on the right.

Conversely, both the Comparisons and Corrected Comparisons representations are better suited to assess precise defect depth than the Grayscale representations because they show visual field loss in 1 dB steps. Even small sensitivity loss can be seen in these representations. While the Comparisons representation shows the actual local visual field loss (deviation of measured sensitivity threshold from normal), the Corrected Comparisons representation shows localized visual field loss only, as explained in FIG 7-16 and 7-17.

The Comparisons representations should be looked at in all clinical situations, as the shape and depth of defect are key information sources in any clinical situation, from early to advanced disease, as shown in the examples in FIG 8-1. An exception may be borderline visual fields in which defect depth is small and thereby challenging to distinguish from normal fluctuation. In those situations, the Probabilities representations are better suited to identify the shape and depth of a potential defect.

## STEP 6 - ASSESS CLUSTER DEFECTS IN GLAUCOMA

### NEED TO ASSESS CLUSTER DEFECTS IN GLAUCOMA

Typical glaucomatous defects (just like other neurological defects caused by localized retinal nerve fiber damage) consist of a cluster of adjacent defective visual field locations (FIG 5-1) that correspond to the path followed by

the retinal nerve fiber bundles in the retina. Thus, in the assessment of glaucomatous visual field defects, one is looking for a cluster of affected visual field locations both in the Probabilities and Comparisons representations.

### STEP 6 – ASSESS CLUSTER DEFECTS IN GLAUCOMA

6

Glaucoma only:  
Significant cluster defects?



**FIGURE 8-19** Assessment of visual field defects in clusters is helpful for the detection of subtle glaucomatous changes. This is the purpose of the Cluster and Corrected Cluster Analysis.

Many glaucomatous visual field changes, however, are smaller than the normal range of fluctuation and are not marked as abnormal. In those cases, the Probabilities representation may not be sensitive enough to detect very subtle glaucomatous visual field loss. In addition, it is time consuming, subjective and not sufficiently sensitive

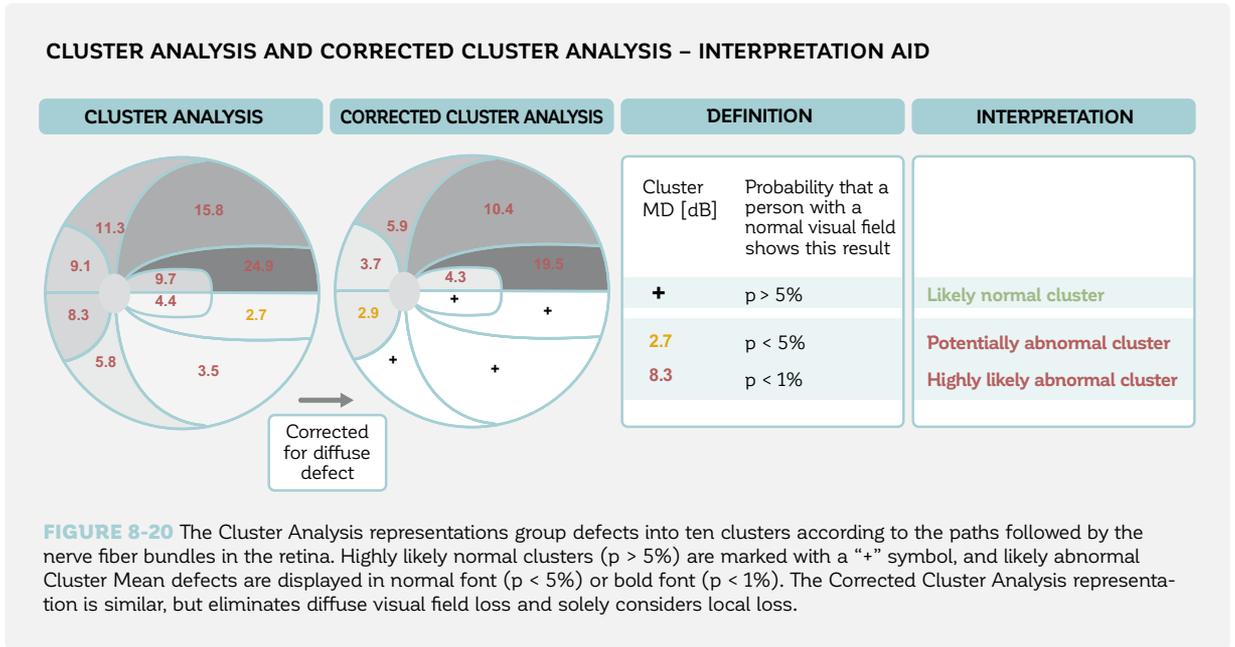
and specific to analyze individual test locations to identify clusters of visual field defects.

Therefore, further representations are offered to facilitate the interpretation of localized glaucomatous visual field loss. The Cluster Analysis and the Corrected Cluster Analysis were developed for this purpose.

### CLUSTER ANALYSIS AND CORRECTED CLUSTER ANALYSIS

The Cluster Analysis and the Corrected Cluster Analysis have been designed specifically for glaucoma and are very sensitive to detect subtle glaucomatous visual field defects. In Cluster Analysis, visual field locations corresponding to the same retinal nerve fiber layer (RNFL) bundle are grouped in 10 visual field clusters and used to calculate the respective average Cluster Mean Defects (Cluster MDs).

Similar to the Probabilities representation, they show the probability ( $p$ ) that a person with a normal visual field (or one with a visual field corrected for diffuse loss in the case of the Corrected Cluster Analysis) would have a given Cluster MD. They thus provide clinical information as to whether a visual field cluster is likely to be normal or not. This is summarized in FIG 8-20. For further details of the design and the definitions of both Cluster and Corrected Cluster Analysis, see FIG 7-12, 7-13 and 7-20, and BOX 7B.



Clustering visual field defects according to the paths followed by the nerve fiber bundles in the retina is more sensitive to detect glaucoma and some other optic neuropathies than using individual test locations in the

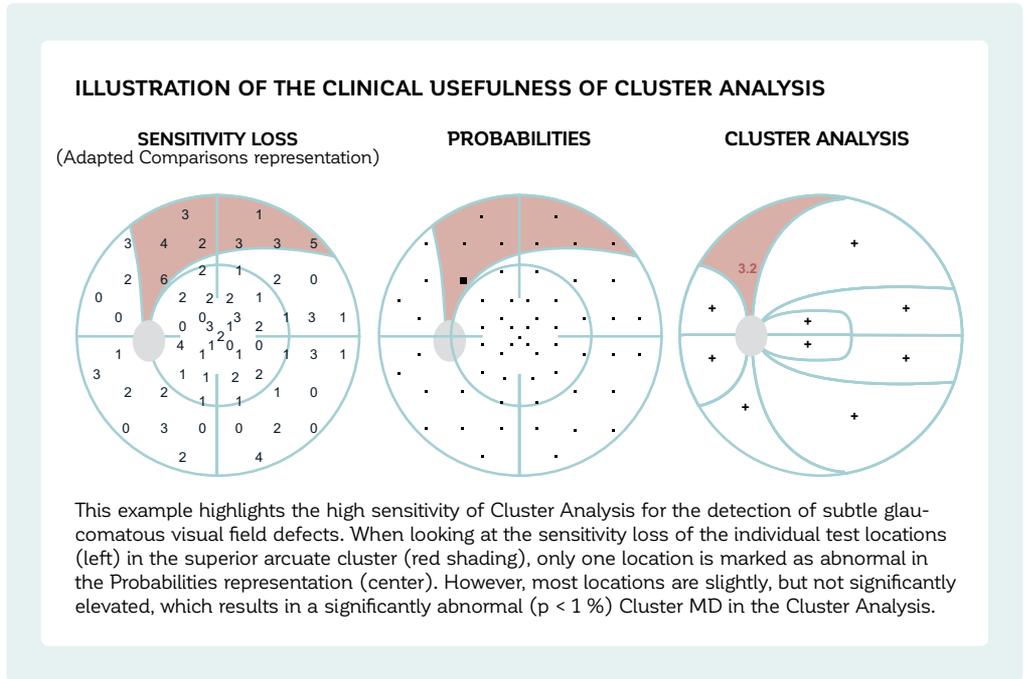
Probabilities representations.<sup>13-15,21</sup> This is due to the fact that the clustering and averaging procedure significantly reduces the influence of normal fluctuation.<sup>16</sup> This is further explained in **BOX 8B**.

#### CLUSTER ANALYSIS IS HIGHLY SENSITIVE TO DETECT GLAUCOMA

#### BOX 8B

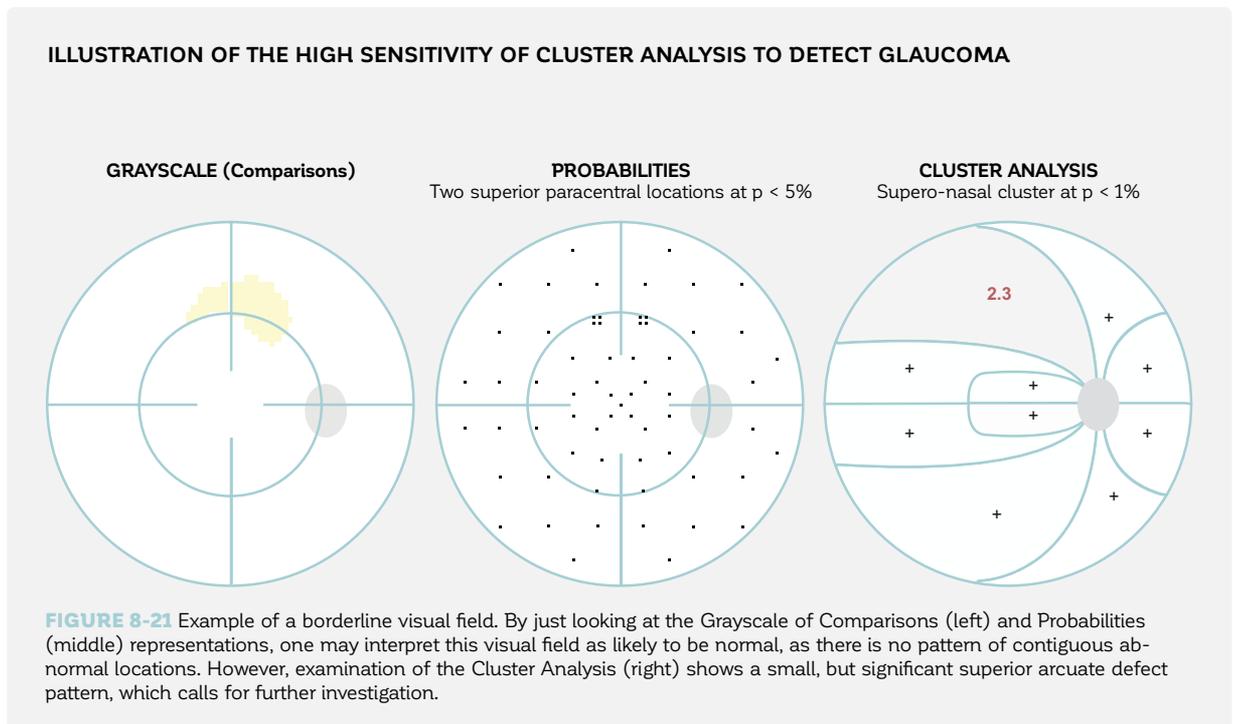
Cluster Analysis has been shown to be more sensitive to detect subtle glaucomatous change<sup>13-15,21</sup> than looking at individual test locations, due to the reduction of the influence of normal fluctuation. For example, in the clinical situation shown in the figure included in this box, most test locations in the supero-nasal cluster show a small numerical sensitivity loss (as shown in the adapted Comparisons representation, which is not available on Octopus perimeters). This sensitivity loss is on average larger than the one in the infero-nasal cluster. However, when looking at the sensitivity losses at a specific test location in the supero-nasal segment, most of these sensitivity losses are too small to manifest as a likely abnormal visual field location in the Probabilities representation. As a result, such a visual field would be considered as normal, as shown in **FIG 8-15**.

However, it is highly unlikely that all test locations within the same cluster show such a degree of sensitivity loss. By averaging the sensitivity losses of all test locations within the cluster, this cluster is very likely not to be normal at a significance of  $p < 1\%$ . As a consequence, it can be concluded that the visual field is likely to be abnormal. Note that the Cluster Analysis uses an idealized graphical display. Consult **BOX 7B** for the real boundaries of the Cluster Analysis.



Besides being more sensitive than the Probabilities representation to detect early glaucomatous visual field loss (FIG 8-21), the Cluster Analysis is also easier to read and avoids having to spend time identifying and counting

potentially abnormal locations to detect clusters of abnormal visual field locations. This makes the Cluster Analysis a fast and useful tool in clinical practice.



As with the interpretation of the Probabilities representations, some caution is essential in the clinical interpretation of the Cluster representation. This is because one random cluster showing a p value smaller than 5% is expected to occur frequently, also in normal visual fields.

Thus, clinicians can be more confident that a cluster at  $p < 5\%$  is truly abnormal when a contiguous cluster is also abnormal,<sup>14-15</sup> or when there is a spatially corresponding structural defect.

## STEP 7– WHERE TO LOOK FOR STRUCTURAL DEFECTS

### NEED TO IDENTIFY RELATIONSHIP BETWEEN FUNCTIONAL AND STRUCTURAL DAMAGE IN GLAUCOMA

When an eye is investigated for glaucoma, both functional alterations and structural damage (neuroretinal rim tissue loss; decrease of retinal nerve fiber layer thickness, RNFLT) should be considered.

In clinical practice, spatially corresponding structural and visual field alterations are necessary to detect glaucoma and to separate glaucoma from other diseases. This is par-

ticularly difficult in eyes with early stages of the disease. A mild alteration in the visual field has more clinical value for decision-making if a spatially corresponding structural alteration is also detected, and vice versa. However, it is not quite straightforward to understand the geometric relation between the usual presentation of the visual field (perimetry) and the structural results (i.e., fundus photography or optical coherence tomography OCT).

#### STEP 7 – WHERE TO LOOK FOR STRUCTURAL DEFECTS

7

Glaucoma only:  
Where to look for structural defects.  
Is there a relationship?



**FIGURE 8-22** Knowing where to look for structural defects to identify a spatial relationship between structural and functional results is helpful for the detection of subtle glaucomatous changes. This is the purpose of the Polar Analysis.

Glaucomatous structural damage occurs at the optic disc and results in a degeneration of the nerve fibers that connect the damaged disc location to the retina. Perimetric testing presents stimuli at various retinal locations along the defective layer and is able to identify the defect.

While there is a correspondence between the structural and functional defect locations, the reference coordinates are different. Different conventions are therefore used to display structural and functional results. See **BOX 8C** for more information on the spatial relationship between structural and functional results.

**BOX 8C**

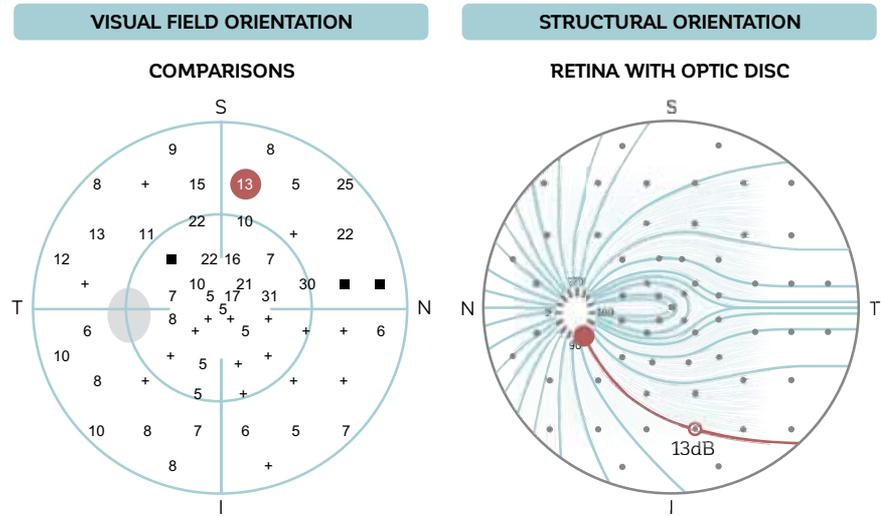
**ANATOMICAL RELATIONSHIP BETWEEN STRUCTURAL AND FUNCTIONAL RESULTS**

Glaucomatous structural damage can be observed at the level of the optic disc and results in a degeneration of the nerve fibers that connect from the damaged disc location to the retina. As a result, light entering the retina anywhere along the defective nerve fiber bundle cannot be processed and this results in visual field defect at the respective retinal location.

Furthermore, while visual field results are oriented like a real-world image associated with post-processing in the brain, the real world image is flipped both horizontally and vertically when passing through the lens and entering the retina, and thus the structural and visual field results are also flipped horizontally and vertically. This means that a superior visual defect is produced by inferior optic nerve head damage and a nasal visual field defect is produced by temporal optic nerve head damage.

In addition, while visual fields are oriented from a patient’s view, structural results are oriented from a doctor’s view, looking onto a patient’s retina. Due to these different viewpoints, the graphical representations of structural and functional results appear like mirror images flipped at the horizontal axis, as is illustrated in the graphic below.

**SPATIAL RELATIONSHIP BETWEEN VISUAL FIELDS AND STRUCTURAL RESULTS**



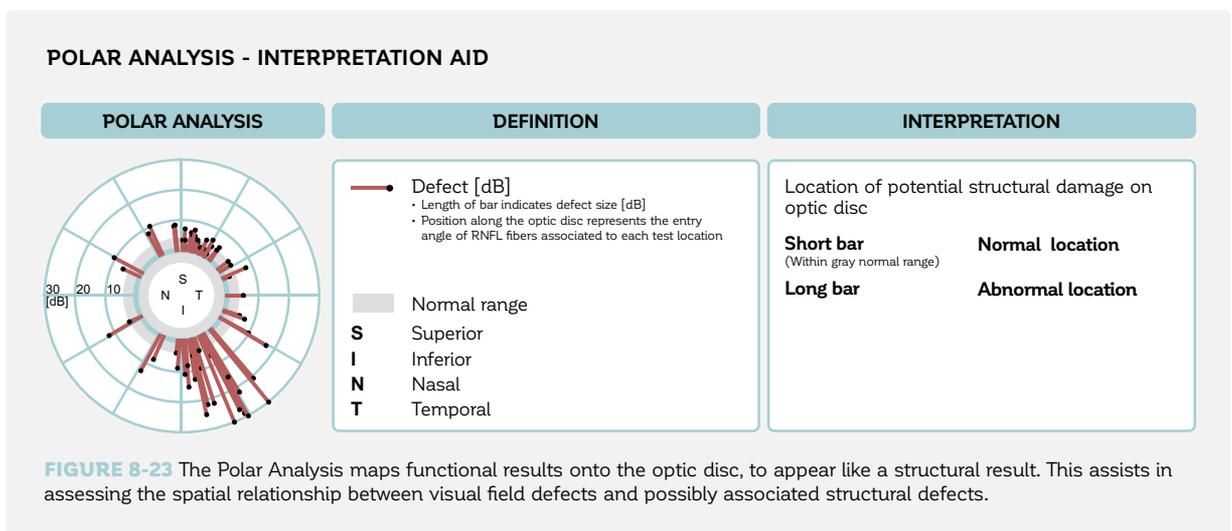
Structural damage and visual field results are flipped across the horizontal midline (i.e., a superior visual field defect corresponds to an inferior structural defect at the corresponding location at the optic disc). Note that even though structural and functional results are also flipped across the vertical midline, the defects are displayed on the same side because of the different viewing directions of the patient (visual field) and the observing clinician (structure).

Due to the different coordinates used to display structural and functional results it is useful to have an analysis tool that facilitates finding the relationship between structural and functional representations in an intuitive way, to save valuable time. This is the purpose of the Polar Analysis.

## POLAR ANALYSIS

The Polar Analysis representation is designed to facilitate the identification of the spatial relationship between structural and functional results by mapping visual field defects onto the optic disc in the same orientation as a structural result. This allows intuitive side-by-side comparison between structural and functional results.

The Polar Analysis displays individual visual field defects as red bars along the perimeter of the optic disc. The location of the bar indicates the corresponding structural area, and the length of the bar shows the amount of sensitivity loss in dB, with longer bars indicating greater magnitude of defect, as shown in FIG 8-23. For more information on the design of the Polar Analysis, see FIG 7-14.

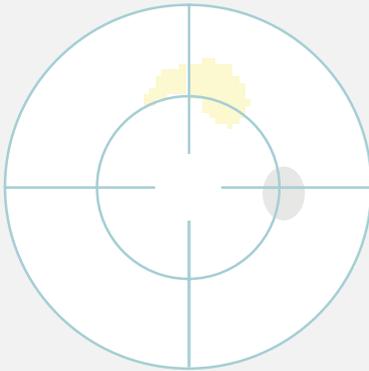


Clinical use of the Polar Analysis is straightforward. After placing it next to a structural result taken during the same time period, a clinician should look for locations in the Polar Analysis with a cluster of red bars that are outside of normal range. This allows clinicians to see the significantly deviating visual field test locations that may correspond to structural regions of the optic nerve head rim where

losses have occurred. Using this graphical representation, the visual field results can be related to structural results, thereby making detailed and accurate comparison of damaged segments much easier (see FIG 8-24 for an example). The results of the Polar Analysis have been shown to correlate well with structural OCT results.<sup>17</sup>

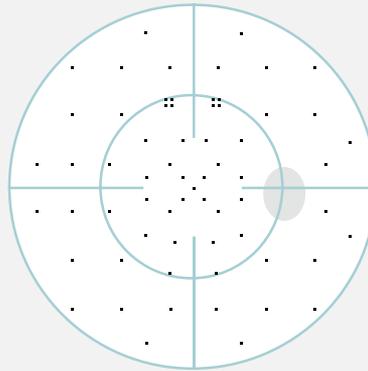
**ILLUSTRATION OF THE CLINICAL USEFULNESS OF THE POLAR ANALYSIS**

**GRAYSCALE (Comparisons)**



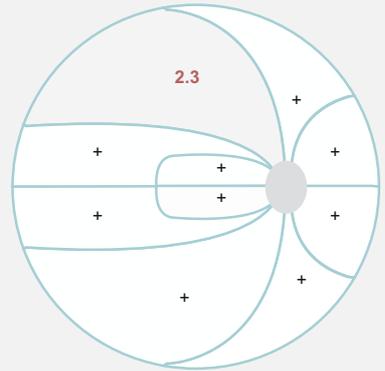
**PROBABILITIES**

Two superior paracentral locations at  $p < 5\%$



**CLUSTER ANALYSIS**

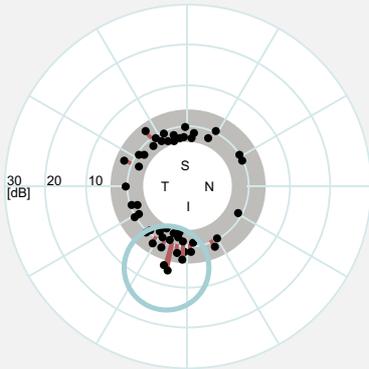
Supero-nasal cluster at  $p < 1\%$



**STRUCTURAL ORIENTATION**

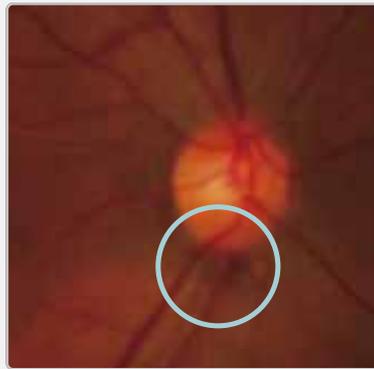
**POLAR ANALYSIS**

Subtle visual field loss at 7 o'clock position



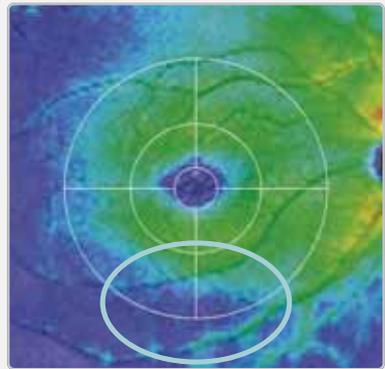
**FUNDUS IMAGE**

Splinter hemorrhage and subtle RNFL loss at 7 o'clock position



**OCT MACULA MAP**

Retinal ganglion cell loss at 7 o'clock position



**FIGURE 8-24** Patient with suspected very early glaucoma. While the Probabilities representation is not sensitive enough to show significant visual field loss, the Cluster Analysis shows that the supero-nasal cluster is likely abnormal at  $p < 1\%$ . The Polar Analysis shows a potential defect at the 7 o'clock position of the optic disc, where a very subtle disc hemorrhage is also found in the fundus photo (darker area within the blue circle). The Macula map picks up the loss of retinal ganglion cells at a comparable location. Due to the spatial relationship between the subtle defect in the visual field (Polar Analysis) and structural measurements (Fundus Image and Macula Map), glaucoma is confirmed.

## STEP 8 – ASSESS SEVERITY

### NEED TO ASSESS SEVERITY OF VISUAL FIELD LOSS

A key element prior to clinical decision-making is to assess the severity of visual field loss in an objective manner, in order to decide on an adequate clinical intervention. This is challenging to perform from the representations discussed so far because there is a wide variety of visual field defect patterns and depths.

It is desirable to have summarizing quantitative measures (i.e., global indices) that allow for a characterization of a visual field in a few words. Summarizing global indices<sup>15</sup> are needed for visual field severity staging systems, but they are also very useful when patients are referred, and they also find use in clinical studies or guidelines. An overview of the design and definitions of available global indices is provided in [TABLE 7-1](#).

#### STEP 8 – ASSESS VISUAL FIELD SEVERITY

8

Severity?

**FIGURE 8-25** Global indices provide useful information to quickly characterize a visual field and to assess disease severity.

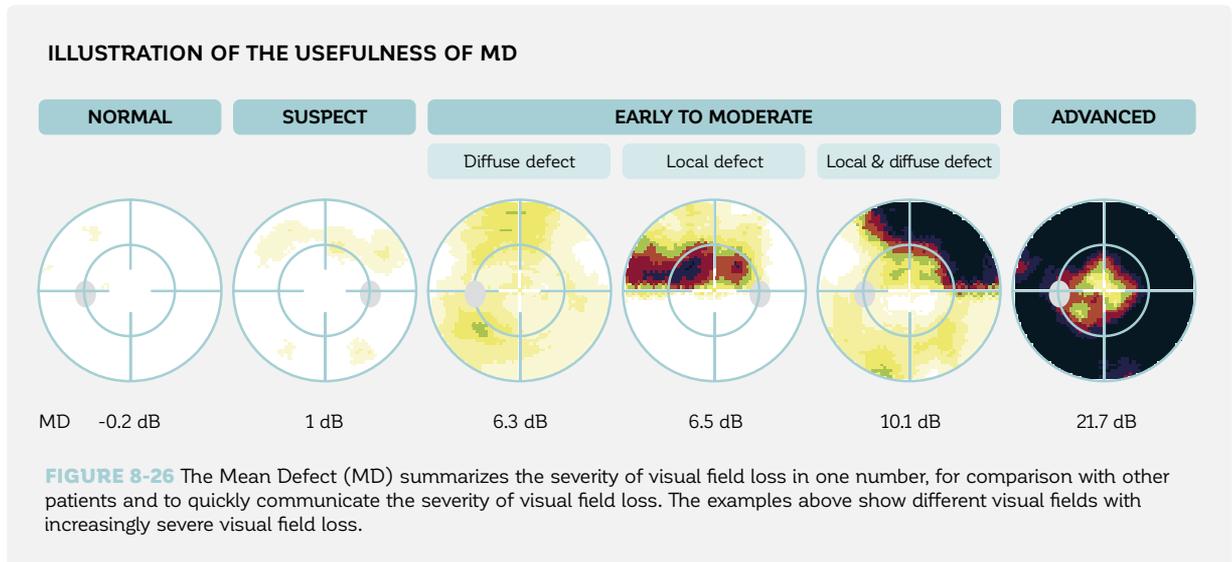
### MEAN DEFECT (MD)

The Mean Defect (MD) provides a summary of the overall severity of visual field loss, which is useful to assess overall disease severity and essential to judge disease progression.<sup>18</sup> If a visual field defect worsens, independent of whether it is a local or a diffuse defect, MD will worsen too. As a general interpretation rule, it can thus be said that the higher the MD, the greater the visual field damage.

As its name suggests, the MD is a mathematical representation of the average of the individual visual field

defects of all test locations, expressed in decibels. Its calculation formula is shown in [TABLE 7-1](#) and its clinical relevance is illustrated in [FIG 8-26](#).

The MD is an essential index used in both the Brusini and Hodapp-Parrish-Anderson glaucoma staging systems.<sup>11,12,19,20</sup> In the Hodapp-Parrish-Anderson system, early visual field defects are characterized by an MD of up to 6 dB, moderate visual field defects are characterized by an MD ranging from 6 to 12 dB, and severe visual field defects have an MD worse than 12 dB.



### SQUARE ROOT OF LOSS VARIANCE (sLV)

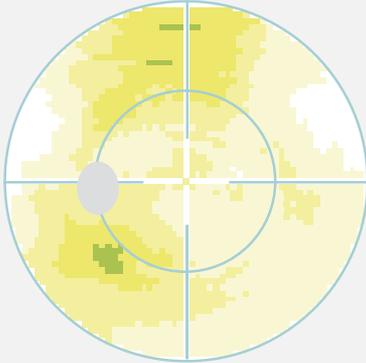
In clinical practice, local and diffuse defects typically have very different causes, as shown in [TABLE 8-1](#), and therefore require different clinical management. However, the global index MD does not distinguish between them, because it is based on an average visual field defect. For example, two visual fields with similar MD ([FIG 8-27](#)) can look completely different, depending on whether there is diffuse or local loss.

It is thus useful to use an additional global index to distinguish between local and diffuse loss. This is the purpose of the square root of Loss Variance (sLV) which provides a measure of variability of local loss across all test locations. The formula used to calculate it is shown in [TABLE 7-1](#). Note that sLV is merely the standard deviation of the local defect values.

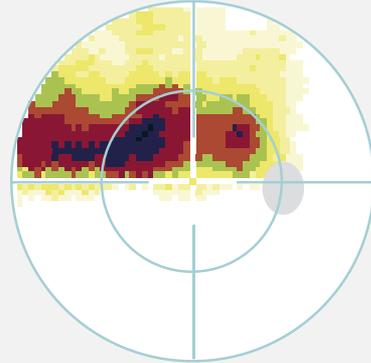
Clinical interpretation is straightforward. If sLV is small, a visual field is homogeneous (i.e., all defects have approximately the same size), suggesting that the visual field is normal, or that the deterioration is predominantly diffuse, or that the visual field has advanced, severe visual field loss. However, if sLV is larger, then the visual field is heterogeneous, which means that the individual defects vary substantially. The larger the sLV, the greater the variability among the different defects. It is noteworthy to mention that in early to advanced glaucoma, sLV becomes increasingly higher; but in very advanced glaucoma, sLV is low, since in this stage most visual field locations are very severely damaged and the defect pattern is therefore diffuse.

**ILLUSTRATION OF THE USEFULNESS OF sLV**

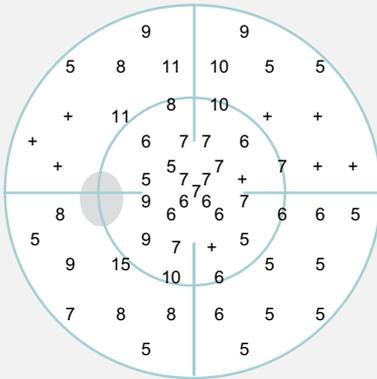
**DIFFUSE DEFECT**



**LOCAL DEFECT**

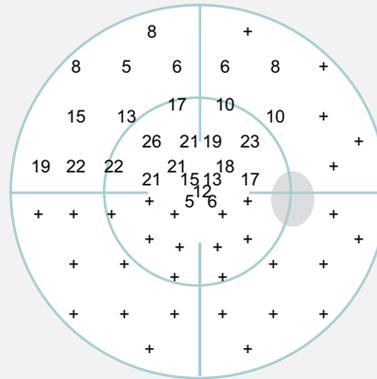


**COMPARISONS**

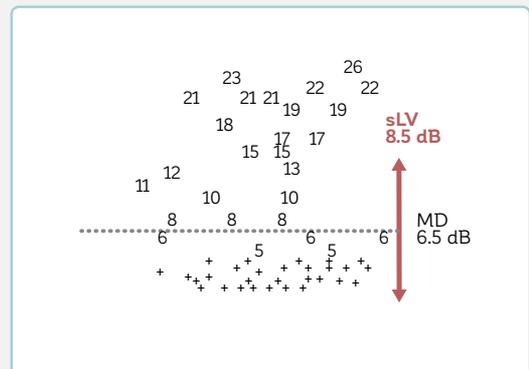
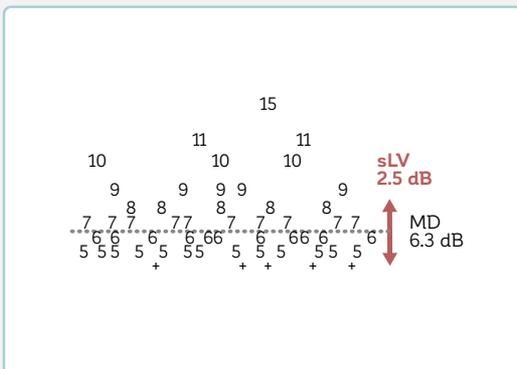


**MD 6.3 dB**  
**sLV 2.5 dB**

**COMPARISONS**



**MD 6.5 dB**  
**sLV 8.5 dB**



**FIGURE 8-27** Visual fields with either diffuse defects (left) or local defects (right) appear fundamentally different, but can have similar MD values, as this example illustrates. The square root of Loss Variance (sLV) is then useful to distinguish between the two situations, as sLV is smaller in the case of homogeneous or diffuse visual field defects and larger in the case of heterogeneous or local visual field defects. In short, sLV is a measure of how much the defects at different test locations differ from the mean defect, as illustrated in the graphic at the bottom.

sLV is an essential index used in the Brusini Glaucoma Staging System<sup>12, 19, 20</sup> in combination with MD to divide visual field loss into 5 stages, and is also commonly used to judge local disease progression in glaucoma. For more information on how to judge disease progression, see Chapter 9.

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## CHAPTER 9

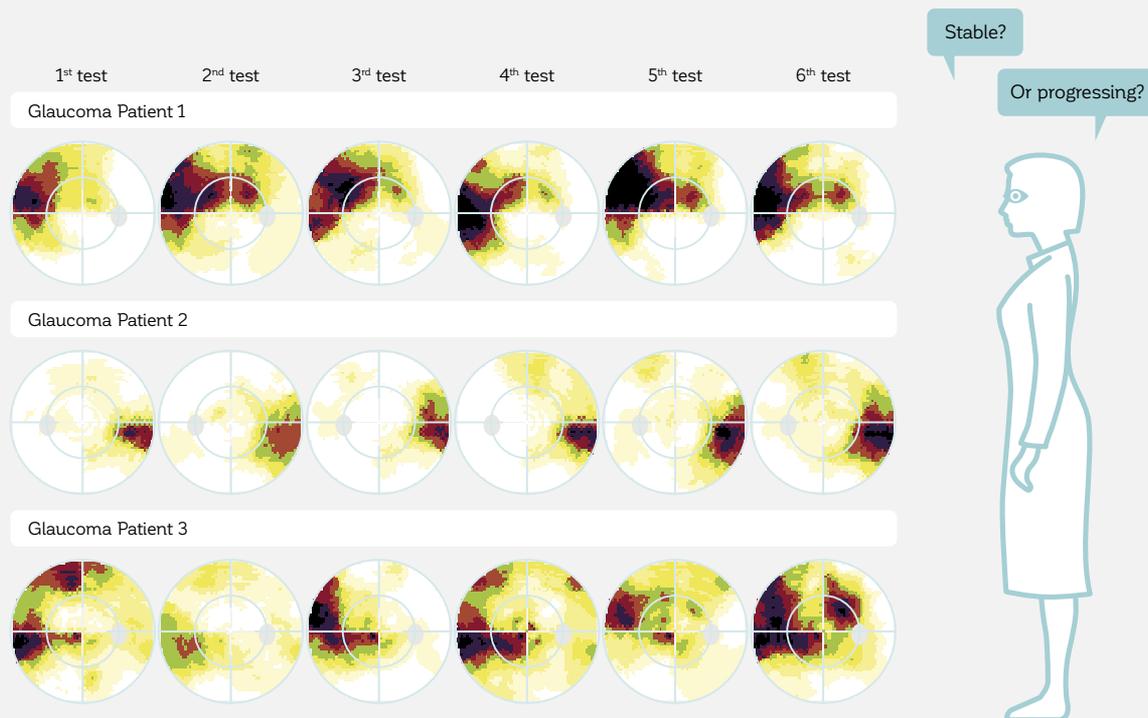
# INTERPRETATION OF VISUAL FIELD PROGRESSION

## INTRODUCTION

Vision-related quality of life is severely diminished both when diffuse deterioration within the central 30-degrees of the visual field (increase of MD) reaches a critical level and when localized progression prevents the performance of normal daily activities (e.g., due to severe progression of a localized inferior paracentral scotoma). In clinical practice, it is essential to detect progression and to measure its speed (i.e., rate of progression expressed as change per year in dB) as early as possible to make decisions about potential interventions before significant visual field loss develops.

Because progression in diseases such as glaucoma is typically slow, the magnitude of fluctuation can be larger than the annual rate of progression. Identifying disease progression from a series of visual fields is therefore a challenging and time-consuming task in clinical practice (**FIG 9-1**). As a result, expert agreement is moderate at best (45% to 65%).<sup>1-5</sup> Statistical progression analyses greatly support the assessment of progression that is needed for clinical decision-making. The use of progression software options was shown to improve expert agreement,<sup>1-5</sup> but to also reduce overall visual field analysis time.<sup>4</sup>

### CHALLENGES ASSOCIATED WITH ASSESSING VISUAL FIELD PROGRESSION



**FIGURE 9-1** Determination of whether visual fields are stable over time or whether they are progressing can be challenging, especially when the change is small and there is considerable fluctuation. This is illustrated with the visual field series of three different patients.

The EyeSuite Progression Analysis function of the Octopus perimeters has been designed to assess visual field progression in an effective and efficient way. It includes the following three types of progression analysis: Global Trend Analysis (GTA), (Corrected) Cluster Trend Analysis (CTA and CCTA), and Polar Trend Analysis (PTA) are shown in **FIG 9-2**.

The Global Progression Analysis measures and statistically classifies long-term change in the global indices, namely Mean Defect (MD), Diffuse Defect (DD), Local Defect (LD) and square Root of Loss Variance (sLV). It not only assesses whether a series of visual fields is stable or shows significant change, but also provides information about the rate of change in dB/year and on the local, diffuse or combined nature of progression.

The Cluster Trend Analysis and Polar Trend Analysis have been specifically designed to detect subtle glaucomatous change. The Cluster Trend Analysis assesses cluster-specific progression within ten nerve fiber bundle regions separately, which is particularly useful in glaucoma in which localized (cluster) progression and stability occur at different locations independently from each other in the same eye. Furthermore, the Polar Trend Analysis facilitates the detection of spatially corresponding structural and visual field changes.

The different types of progression analyses make a statement about whether a visual field series is stable or not and also show the location of progression. However, it is also important to know the shape, location and depth of a defect. For example, a deep defect approaching

the fovea solicits a much more aggressive treatment than a shallow defect in the periphery. To provide this information, the Grayscale of Comparisons represen-

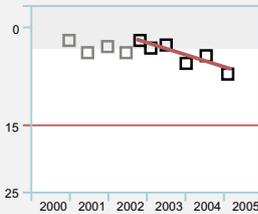
tations of all visual field tests are also displayed as a default and may be changed to any other single field representation such as the Cluster Analysis.

**PROGRESSION ANALYSIS TOOLS AVAILABLE IN OCTOPUS PERIMETERS**

**EYESUITE PROGRESSION ANALYSIS**

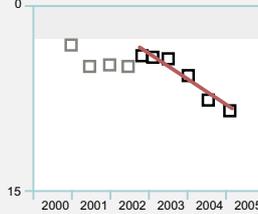
**GLOBAL TREND ANALYSIS**

**MD**  
Stable or overall progression? ▼



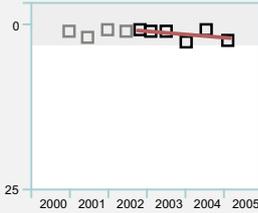
Slope: 1.9 dB / Yr (p < 0.5%)

**sLV**  
Increasing/decreasing inhomogeneity? ▼



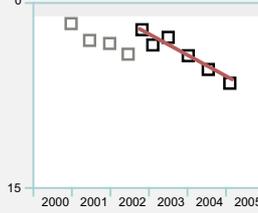
Slope: 2.1 dB / Yr (p < 0.5%)

**DD**  
Diffuse progression?



Slope: 0.6 dB / Yr

**LD**  
Local progression? ▼



Slope: 1.8 dB / Yr (p < 0.5%)

**(CORRECTED) CLUSTER TREND ANALYSIS**

Cluster MD progression?

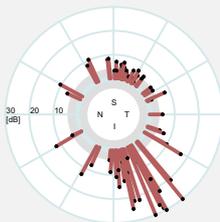


Corrected Cluster MD progression?



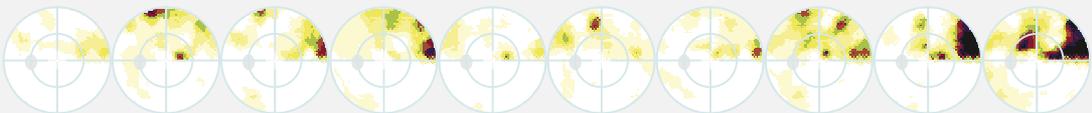
**POLAR TREND ANALYSIS**

Where to look for structural progression?



**SERIES OF VISUAL FIELDS**

Defect location & depth?



**FIGURE 9-2** Octopus perimeters offer 3 types of progression analysis to assess visual field change over time. A Global Trend Analysis based on the four global indices MD, sLV, DD and LD, and, for glaucoma, both Cluster (and Corrected Cluster) Trend Analysis and Polar Trend Analysis. In contrast to simply looking at a series of visual fields, most of these analyses employ statistical methods to determine progression. To provide orientation about both defect location, shape and defect depth, the series of Grayscale representations is also provided.

# ASSESSMENT OF GLOBAL VISUAL FIELD CHANGE

## CHANGE OF MEAN DEFECT (MD) AS A MEASURE OF GLOBAL CHANGE

To judge whether a current treatment strategy is effective as well as to make a clinical decision about future interventions, it is essential to know whether, overall, a visual field series is stable, worsening or improving. This can be achieved by analyzing the change of the global index Mean Defect (MD) over time.

The global index MD summarizes the sensitivity loss over

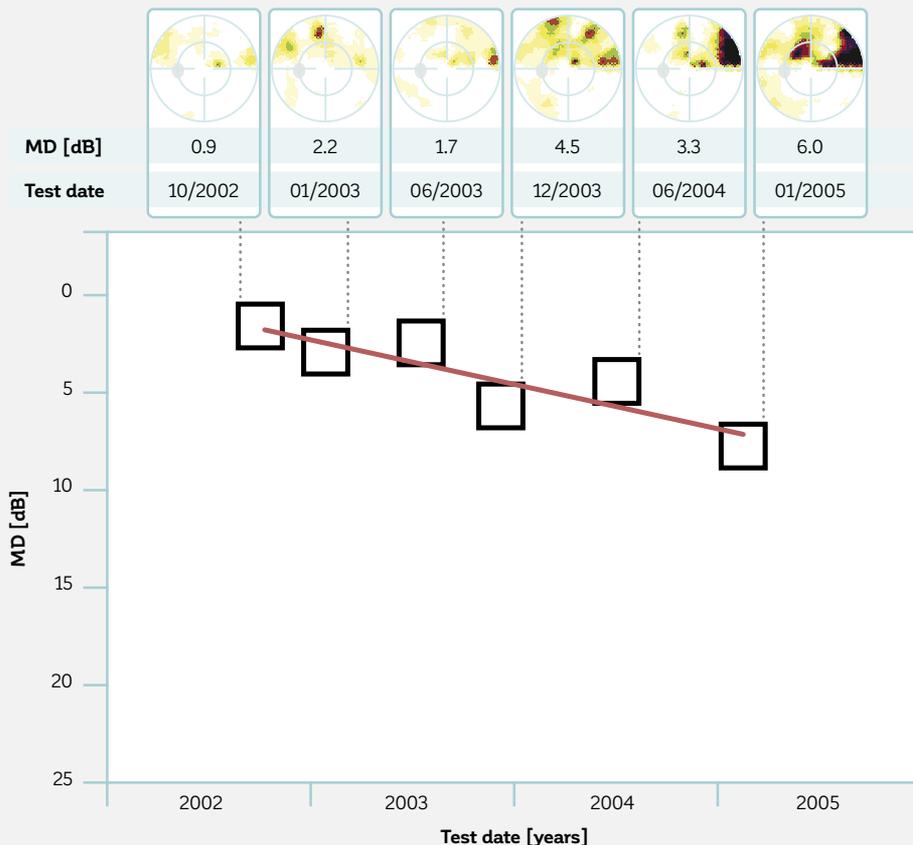
the area of the visual field that was tested. It is the average of all individual sensitivity losses and is expressed in dB. Consequently, if any visual field location worsens or improves, MD will also change accordingly, even though the change may be small. This makes MD a good index to track overall visual field change. For more information on the definition of the index MD see [TABLE 7-1](#), and for more information on its clinical interpretation see [FIG 8-26](#).

## TREND ANALYSIS FOR THE VISUALIZATION OF CHANGE

The simplest way to assess MD change is to plot the MD of each visual field test in a two-dimensional graph. The MD is plotted on the Y-axis and test date is plotted on the X-axis. This allows graphical assessment of visual field change over time as shown in [FIG 9-3](#). Because an increasing MD represents visual field worsening, it is most intuitive to use a scale showing the smallest MD at the top and the largest at the bottom.

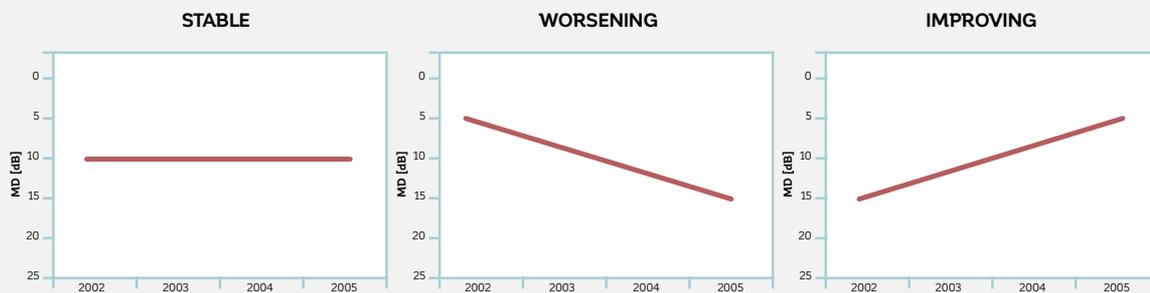
If there is no fluctuation and the change in MD over time is sufficiently large, it is simple to graphically determine whether a series of visual fields is stable, worsening or improving by drawing a trend line. Intuitively, the trend line corresponds to the line that provides the best linear fit for all the MD points. If this line is flat, then the visual field series is stable, if it is sloping upwards, then the series is improving and if it is sloping downwards, then the series is worsening ([FIG 9-4](#)).

**TREND ANALYSIS FOR DISPLAYING OVERALL CHANGE**



**FIGURE 9-3** A simple way to assess visual field change over time is to draw a two-dimensional graph with the test date of each visual field test on the X-axis and the corresponding MD on the Y-axis. By drawing a trend line that provides the best linear fit for the individual MD points (red line), it is easy to see that this visual field series is worsening (downward slope).

**GRAPHICAL INTERPRETATION OF A TREND LINE**

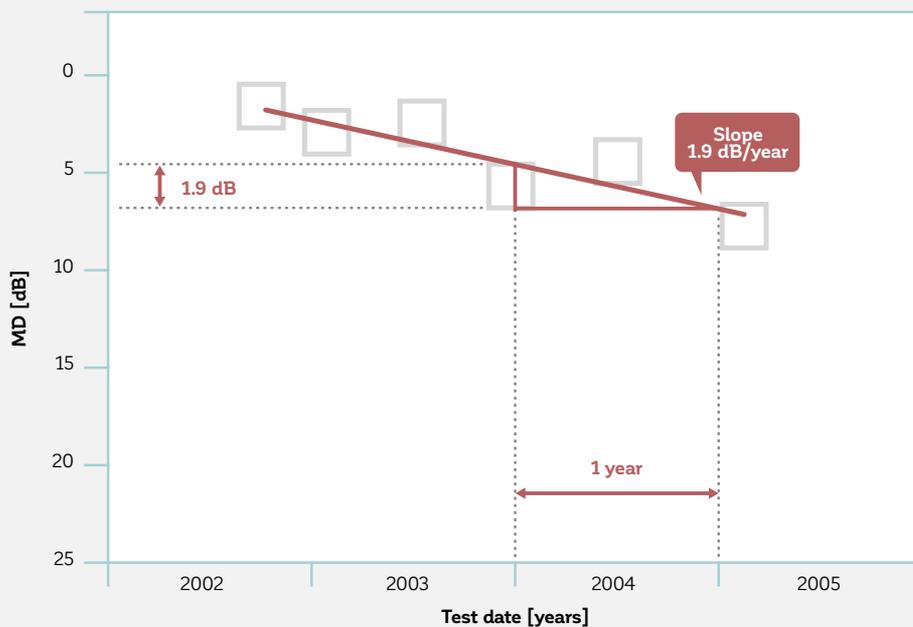


**FIGURE 9-4** If visual field change is sufficiently large, just looking at the red trend line allows one to intuitively assess whether a visual field series is stable (flat line, left) worsening (downward sloping line, middle) or improving (upward sloping line, right) over time.

This approach is referred to as trend analysis and is used for all representations that are part of the EyeSuite Progression Analysis. To best fit the trend line to the measured MD values, linear regression analysis with the ordinary least squares fit is used. For more details on this approach as well as key characteristics of trend analysis, refer to **BOX 9A**.

The steepness of the line is referred to as the slope and is used to assess the rate of change in MD over time. The rate of change is expressed in dB per year and is derived by determining the amount of change in MD (Y-axis) that occurs over the selected period of time (X-axis). In **FIG 9-5**, the rate of change for MD is 1.9 dB/year.

#### SLOPE OF TREND ANALYSIS PROVIDES RATE OF CHANGE



**FIGURE 9-5** To determine the rate of overall visual field change, the best-fit line is drawn through the MD data points in the Global Trend Analysis. Once this trend line is drawn, the actual data points can be discounted and the rate of change can be determined using the slope of the trend line. The rate of change is automatically expressed in dB per year. In this example, the slope or rate of change is 1.9 dB/year.

## USING PROBABILITIES TO DISTINGUISH BETWEEN STABLE AND CHANGING VISUAL FIELD SERIES

A key challenge in the assessment of visual field progression is the distinction between a series of visual fields that is truly changing and one that is stable but shows fluctuation. This challenge is greater in cases in which the magnitude of the change is small and the amount of fluctuation is large, which is a common situation when assessing glaucomatous progression.

In clinical practice, the trend line alone is not sufficient to distinguish between stable and changing visual fields. This is because most visual field series will show at least a small trend upwards or downwards. The challenge is to determine whether this trend is significantly different from a flat line (i.e., one with a slope of zero).

To distinguish between a stable and a truly changing series of visual fields, a t-test is used. The t-test is a statistical test of hypothesis that allows the determination of whether two sets of data are significantly different from each other. For trend analysis, the t-test is applied to the observed slope to determine whether it is significantly different from a slope of zero (e.g., flat line showing no change over time, which represents the typical situation of a stable visual field series). The concept of probability is then used to determine the probability ( $p$ ) that a stable visual field series with an assumed slope of zero would show a given slope (see **BOX 9A**). Its interpretation is similar to the  $p$  values used in the Probabilities plot (see **FIG 7-9** and **7-10**). If there is a low probability that a stable visual field series would look like the series in question, then that series is unlikely to be stable and consequently it is likely that the visual field series is changing.

To facilitate interpretation, the EyeSuite Progression Analysis uses red downward arrows to show significant worsening and green upward arrows to show significant improvement at two probability levels and also marks floor effects using the following symbols:

▼ Worsening at  $p < 5\%$ : this visual field series shows overall worsening. There is a smaller than 5% (and larger than 1%) chance that a stable visual field series would look like the series in question, which means there is a high likelihood that the visual field series is worsening.

▼ Worsening at  $p < 1\%$ : this visual field series shows overall worsening. There is a smaller than 1% chance that a stable visual field series would look like the series in question, which means there is very high likelihood that the visual field series is worsening.

▲ Improvement at  $p < 5\%$ : this visual field series shows overall improvement. There is a smaller than 5% (and larger than 1%) chance that a stable visual field series would look like the series in question, which means there is a high chance that the visual field series is improving.

▲ Improvement at  $p < 1\%$ : this visual field series shows overall improvement. There is a smaller than 1% chance that a stable visual field series would look like the series in question, which means there is a very high chance that the visual field series is improving.

▾ Floor effect: There is more than 20 dB sensitivity loss in the visual field series and no significant change, which means that the determination of progression or stability is not possible due to the advancement of the disease.

If there is no symbol, then there is a probability of  $p > 5\%$  that a stable visual field series would look like the series in question or in other words that the data do not show change at the levels mentioned above. This either means that the visual field is stable, or that the data available are not sufficient to capture change. This is often the case when only a few visual field tests are available and progression is slow or when fluctuation is large as explained in **BOX 9A**.

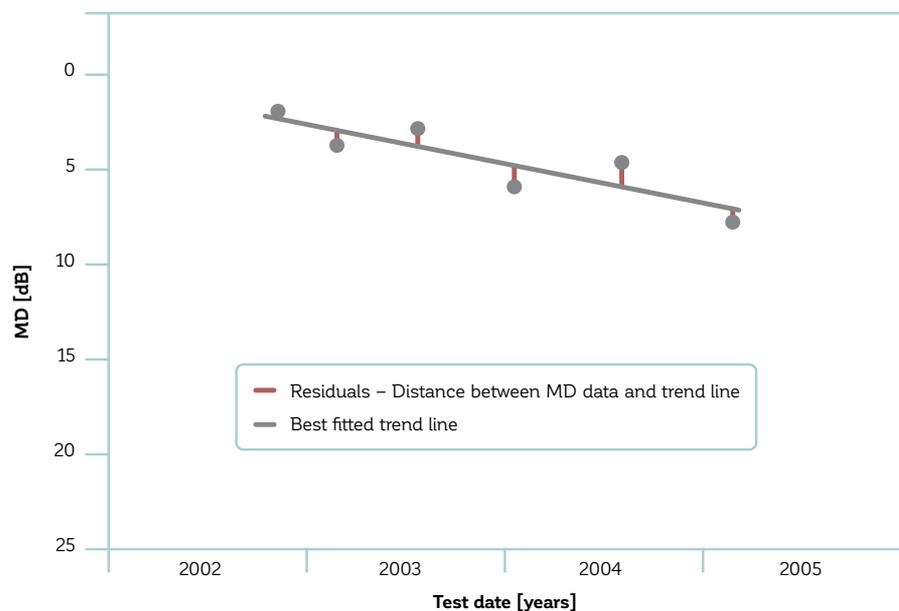
## BOX 9A

## GENERAL CHARACTERISTICS OF TREND ANALYSIS

## LINEAR REGRESSION ANALYSIS WITH ORDINARY LEAST SQUARES ESTIMATES TO DETERMINE THE TREND LINE

To determine the trend line, EyeSuite Progression Analysis uses linear regression analysis with least squares estimates. Linear regression analysis is a statistical approach for modeling the relationship between two variables using a straight line. An excellent fit for the trend line is obtained using the least squares method, which is a commonly used approach to fit the regression line. The best fit of the trend line is achieved by minimizing the sums of squared residuals (i.e., the vertical distance between each data point and the fitted regression line).

## OCTOPUS PERIMETERS USE LEAST SQUARES LINEAR REGRESSION TO BEST FIT A TREND LINE



The least squares linear regression approach determines a best fitted trend line by minimizing the vertical distance between the individual test points and the trend line. This vertical distance is called the residual and is depicted by the red lines in this example. If the fit were perfect, all individual test points (gray dots) would fall exactly on the trend line (gray line).

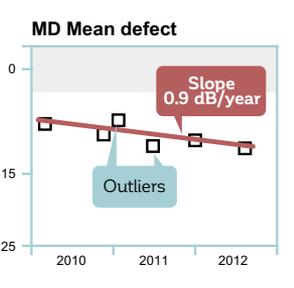
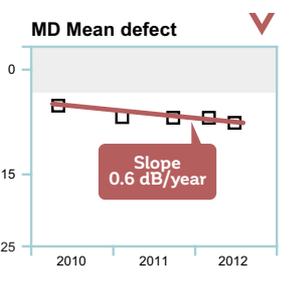
## SIGNIFICANCE IS INFLUENCED BY THE AMOUNT OF FLUCTUATION

The trend line describes the data and allows for the determination of the slope. However, this is not sufficient to distinguish between a stable and changing visual field series because there is typically at least some positive or negative slope (even if it is very small) due to the fluctuation of the variable (e.g., MD) over time.

Therefore, it is necessary to determine whether the observed slope corresponds to a true change, or whether it may be explained by fluctuations in the data. The t-test is used to determine whether the observed slope is significantly different from zero (as would be expected if the series of visual fields was stable) using two levels of significance ( $p < 5\%$  and  $p < 1\%$ ).

The amount of fluctuation is taken into account by the t-test. This is necessary because the same slope may indicate a significant trend when the fluctuations are small, but may not be significant when fluctuations are large. In other words, a larger slope is needed to detect true change for the same number of tests and the same follow-up length when large fluctuations are present.

**ILLUSTRATION OF THE INFLUENCE OF FLUCTUATION ON SIGNIFICANCE**

TREND ANALYSIS	DESCRIPTION	INTERPRETATION
	<p>No symbol indicating change</p> <p>Slope 0.9 dB/year</p> <p>Outliers in 3<sup>rd</sup> &amp; 4<sup>th</sup> test</p>	<p><b>NO PROGRESSION</b></p> <p>Large slope</p> <p>Considerable fluctuation</p> <p><b>Stable series</b></p> <p><b>Considerable fluctuation may prevent a change to be declared significant</b></p>
	<p>Significant worsening at <math>p &lt; 5\%</math></p> <p>Slope 0.6 dB/year</p> <p>Test data close to trend line</p>	<p><b>WORSENING</b></p> <p>Smaller slope</p> <p>Consistent results</p> <p><b>Progressing series</b></p>

In this figure, the visual field series from two different patients are shown over a comparable time period with approximately the same amount of test data. In the example on top, fluctuation is large because the 3<sup>rd</sup> and 4<sup>th</sup> test are outliers. As a result, even the relatively large slope (0.9 dB/year) is insufficient to indicate significant change and the series appears to be stable (no symbol). More visual field tests may be needed to identify whether the series is truly stable or progressing. However, when there is less fluctuation in the visual field data (bottom), even a small slope (0.6 dB/year) suffices to detect significant change (red downward arrow) and the series is confirmed as progressing.

**SIGNIFICANCE IS INFLUENCED BY THE NUMBER OF VISUAL FIELD TESTS**

The number of visual field examinations (n) included in a trend analysis is important because it influences the outcome of the t-test. The EyeSuite Progression Analysis can be performed with a minimum of three visual field tests. However, if there are only three or four visual field tests included in the analysis, the slope must be quite steep to be able to separate true change from fluctuations. On the other hand, if there are many visual field tests included, even a visual field series with a shallow slope can identify significant change. For typical progressing visual fields, trends will not become significant before five or six examinations are included in the analysis. Guidelines on glaucoma treatment<sup>6</sup> typically recommend a minimum of six visual fields in the first two years to reliably detect glaucomatous visual field progression. However, if fluctuation is large and the slope is small, an even larger number of visual field tests are required to detect progression.<sup>7,8</sup>

### THE INFLUENCE OF THE NUMBER OF VISUAL FIELD TESTS ON SIGNIFICANCE

TREND ANALYSIS	DESCRIPTION	INTERPRETATION
<p style="text-align: center;"><b>MD Mean defect</b></p> <p style="text-align: right; color: red; font-weight: bold;">6 Tests</p> <p style="text-align: center;">Slope 0.9 dB/year</p>	<p>No symbol indicating change</p> <p>Slope 0.9 dB/year</p> <p>Outliers in 3<sup>rd</sup> &amp; 4<sup>th</sup> test</p> <p>6 Visual field tests</p>	<p style="background-color: #e0f2f1; text-align: center; font-weight: bold;">NO PROGRESSION</p> <p>Large slope</p> <p>Considerable fluctuation</p> <p style="font-weight: bold;">Series declared stable because of fluctuation</p> <p>More test data is needed</p>
<p style="text-align: center;"><b>MD Mean defect</b></p> <p style="text-align: right; color: red; font-weight: bold;">10 Tests</p> <p style="text-align: center;">Slope 0.7 dB/year</p>	<p>Significant worsening at <math>p &lt; 1\%</math></p> <p>Slope 0.7 dB/year</p> <p>Test data close to trend line</p> <p>10 Visual field tests</p>	<p style="background-color: #ffe0b2; text-align: center; font-weight: bold;">WORSENING</p> <p>Overall consistent results</p> <p style="font-weight: bold;">Progressing series</p> <p>Sufficient number of tests</p>

SERIES OF VISUAL FIELDS

Defect location & depth?

Tests 1-6
All tests

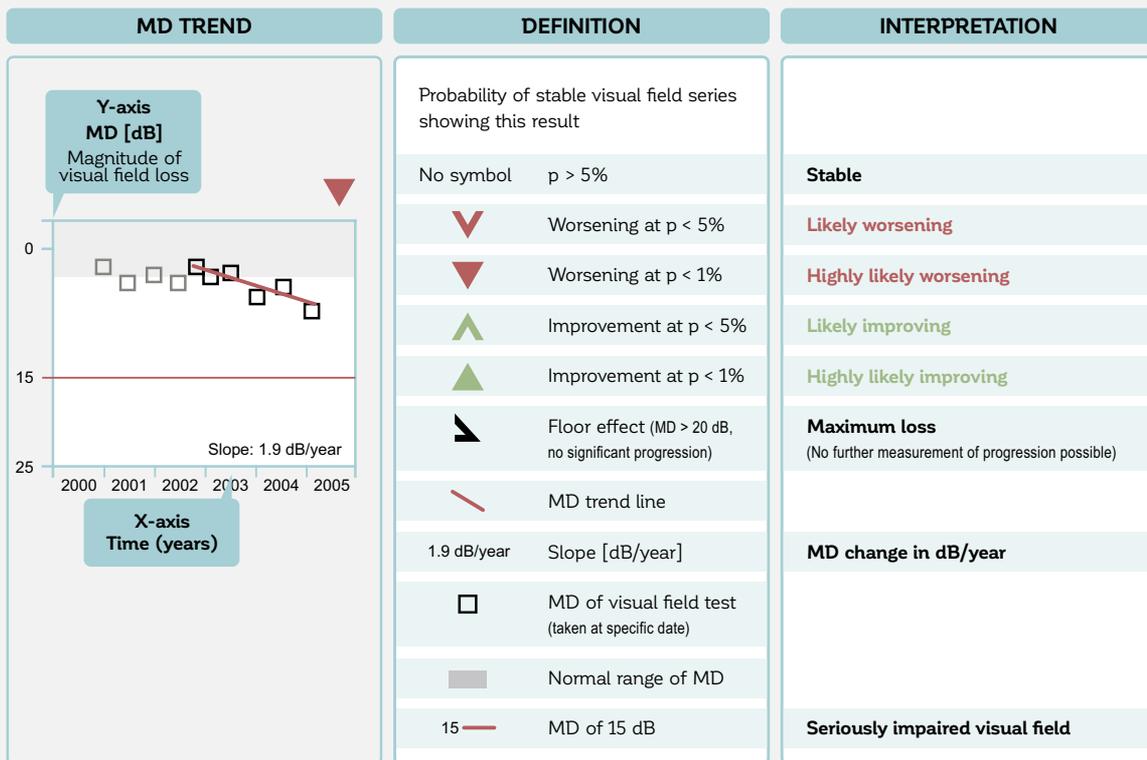
The number of visual field tests significantly influences whether a visual field series is considered stable or not. More visual fields are required when the slope is shallow or when fluctuation is large. In this example, due to fluctuation in tests 3 and 4, the visual field series doesn't show significant change after the initial 6 tests (top) even though the slope of 0.9 dB/year is relatively large. Change is only detected by the trend analysis upon inclusion of more tests (bottom).

## MD TREND ANALYSIS

Interpretation of MD Trend Analysis in clinical practice is a fast and straightforward process (if adequate visual fields are selected, which is described in more detail later in this chapter). The decision about whether a visual field series is stable, significantly worsening or significantly

improving can be made solely by looking at the red downward (significant worsening) or the green upward (significant improvement) arrows displayed. To assess rate of change, the slope is numerically displayed as change in dB/year at the bottom of the graph (FIG 9-6).

**MD TREND ANALYSIS – INTERPRETATION AID**



**FIGURE 9-6** MD Trend Analysis allows for a quick identification of worsening (red downward arrow) or improvement (green upward arrow) of a visual field series. In addition, it displays the rate of change (slope in dB/year) and shows the trend graphic including slope and individual test points to graphically assess severity of visual field loss, rate of progression, test interval, amount of fluctuation and number of tests included in the analysis.

While the detailed graphical presentation of the trend line and the test data is not necessary for deciding about the presence and rate of MD change, it provides valuable information. It allows for a quick assessment of disease severity as well as rate of disease progression. The lower the level of the curve, the more the disease has progressed and the steeper the curve, the more rapid the change.

The graph also allows for a quick determination of the frequency of the visual field tests performed. In addition, it allows one to see at a glance if there is a significant outlier, which calls for more careful evaluation to make sure that this visual field is reliable and whether it should be included in the analysis. For more information, consult the next section in this chapter on adequate selection of visual field tests.

Visual fields included in the analysis are marked in a different color which supports the visual field selection process. Lastly, different symbols are used for each perimeter model to draw attention to a possible perimeter model-related bias. This can for example occur when a patient is tested for the first time on a new perimeter model and shows a strong learning effect. For more information on transitioning from one perimeter model to another, please refer to Chapter 12.

Further orientation is provided by a gray band at the top which indicates the normal range of MD (i.e., the 95% confidence interval) and a red line at 15 dB which represents seriously impaired visual fields. The graph stops at 25 dB because in many countries, an MD of 20 to 25 dB is considered legal blindness.

## INTERPRETATION OF MD TREND ANALYSIS

MD Trend Analysis provides information about the presence and rate of progression as well as the magnitude of the sensitivity loss (i.e., magnitude of MD) of a patient. However, this data is not sufficient to make a clinical decision as these factors have a very different meaning depending on their relation to each other as well as the patient's age and life expectancy.

For example, an MD of 3 dB in a patient progressing at a rate of 0.4 dB/year has a very different meaning in a 50-year-old patient compared to an 80-year-old patient. Assuming a life expectancy of 90 years for both patients and projecting the current slope linearly into the future,

at the end of their respective lifespan, the 80-year-old patient would have an MD of 7 dB whereas the 50-year-old patient would have an MD of 19 dB. However, if this same 80-year-old patient showed a progression rate of 2 dB per year, at age 90 this patient would have an MD of 23 dB, which represents near total visual field loss.

It therefore goes without saying that these factors as well as a patient's lifestyle, adherence to and persistence with medications, other clinical issues and the practitioner's overall clinical assessment have to be taken into account to make a clinical decision.

## SELECTION OF ADEQUATE VISUAL FIELDS FOR ANALYSIS

### *IMPORTANCE OF SELECTING ADEQUATE VISUAL FIELD TESTS FOR ANALYSIS*

A trend analysis is only clinically meaningful if adequate visual fields are selected for analysis. To facilitate the selection process, the EyeSuite Progression Analysis allows examiners to choose the visual fields to be included in the analysis with a simple click. Visual fields

included in the progression analysis should be reliable, be part of a relevant time period, and be tested using the same test parameters. Each of these requirements is described in this section.

### *EXCLUSION OF UNTRUSTWORTHY VISUAL FIELD TESTS*

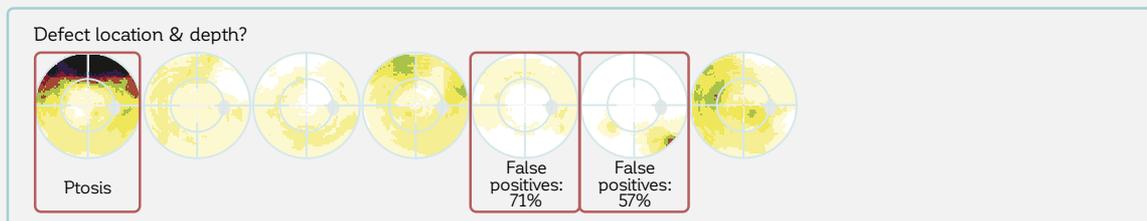
It is important that only trustworthy visual fields, reliable and free of artifacts, be included in the analysis. Untrustworthy visual fields increase the amount of

fluctuation in a visual field series and may change the outcome of visual field trend analysis as illustrated in **FIG 9-7**.

### IMPORTANCE OF EXCLUSION OF UNTRUSTWORTHY VISUAL FIELD TESTS

TREND ANALYSIS	DESCRIPTION	INTERPRETATION
<p>MD Mean defect</p> <p>High false positives</p> <p>Artifact</p> <p>Slope -0.6 dB/year</p>	<p>Filled green upward arrow (Improvement at <math>p &lt; 1\%</math>)</p> <p>Slope - 0.6 dB/year</p> <p>Unreliable visual fields included</p>	<p><b>IMPROVING</b></p> <p>Considerable fluctuation</p>
<p>MD Mean defect</p> <p>High false positives</p> <p>Artifact</p> <p>Slope 0.0 dB/year</p>	<p>No symbol</p> <p>Slope 0.0 dB/year</p> <p>1<sup>st</sup> test with ptosis artifact excluded</p>	<p><b>STABLE</b></p> <p>Considerable fluctuation</p>
<p>MD Mean defect</p> <p>High false positives</p> <p>Artifact</p> <p>Slope 0.9 dB/year</p>	<p>Filled red downward arrow (Worsening at <math>p &lt; 1\%</math>)</p> <p>Slope 0.9 dB/year</p> <p>1<sup>st</sup> test with ptosis artifact and 5<sup>th</sup> &amp; 6<sup>th</sup> test with high false positive rates excluded</p>	<p><b>WORSENING</b></p> <p>Consistent results</p>

### SERIES OF VISUAL FIELDS



**FIGURE 9-7** Visual field tests that are not trustworthy can significantly alter the trend analysis result as the example above illustrates. In this example, the first test is not trustworthy due to a ptosis lid artifact and tests five and six are unreliable due to high false positive rates. If all seven visual field tests are included in the analysis, the series seems to be improving (top), if the lid artifact is excluded (middle), the series appears to be stable and if all three untrustworthy visual fields are excluded from analysis, a significant visual field worsening becomes apparent (bottom).

### ADEQUATE TIME PERIOD FOR ANALYSIS

When choosing a time period for visual field progression analysis, it is important to keep in mind that changes in treatment as well as surgical interventions can significantly change both visual field severity and progression rates. For example, a patient with both cataract and glaucoma typically shows a significant improvement of the MD after cataract surgery. This improvement makes it challenging to assess glaucomatous progression rates after surgery, if pre-surgery visual field data are included in the progression analysis. In those cases only post-surgery data should be analyzed.

Another example is the situation in which a switch to more aggressive glaucoma treatment is made. This switch can change the rate of progression. In that situation, it would be much harder to detect the change in rate if pre-treatment data are included. However, it should be noted that the impact of the switch in treatment on rate of progression may only be assessed once a sufficient number of visual field tests become available after the switch. Thus the new rate cannot be assessed immediately following the change in treatment.

### COMPARABLE TEST PARAMETERS

All visual fields included in a given progression analysis must have the same test parameters in order to obtain meaningful information about visual field progression. Therefore, the EyeSuite Progression Analysis offers the trend calculations only on visual fields tests that have been done with the same test pattern and stimulus and background characteristics. However, although ideally

only one type of test strategy is used, the EyeSuite Progression Analysis allows inclusion of visual field results obtained using different quantitative testing strategies. The rationale for this is that even though the levels of accuracy between the TOP and the other strategies slightly differ, these effects are minimized at the level of the global indices.<sup>9,10</sup>

## DISTINCTION BETWEEN LOCAL AND DIFFUSE CHANGE

### IMPORTANCE OF DISTINCTION BETWEEN LOCAL AND DIFFUSE CHANGE

When both local and diffuse defects are present, it is not only desirable to know whether there is change but also whether the detected change is local or diffuse. This is important because local and diffuse change can be caused by different clinical situations that may call for different types of intervention (see **TABLE 8-1** on the etiology of local and diffuse loss). Because MD is affected

by both local and diffuse change, it is impossible to determine the nature of the change by looking at MD alone.

For example, a patient may have both a local defect due to glaucoma and a diffuse defect due to a cataract. If the MD is worsening in this patient, it is essential for a clinician to know whether the cataract, the glaucoma or

both are worsening. Examples of the presence of both local and diffuse change are presented in **FIG 9-9**.

In addition, the distinction between local and diffuse change is not only helpful in the presence of both a local and diffuse pathology, it is also very useful in all situa-

tions in which MD is not sufficiently sensitive to detect subtle local changes. This can for example be the case if there is subtle local glaucomatous change, but the visual field series also shows increased diffuse fluctuation. An example of this is given in **FIG 9-10**.

## USE OF DIFFUSE DEFECT (DD) INDEX TO IDENTIFY DIFFUSE CHANGE

To determine whether there is diffuse visual field change independent from the presence or absence of local change, Octopus perimeters use the global index DD. This index represents the magnitude of the diffuse defect and is calculated from the Defect Curve. For more information on its design and definition see **BOX 7C**.

The DD Trend Analysis uses comparable definitions as the MD Trend Analysis but displays DD values on the Y-axis instead of MD values and thus allows assessment

of diffuse change. No symbol is displayed if there is no diffuse change, significant diffuse worsening is indicated by red downward arrows and significant diffuse improvement is shown by green upward arrows, similarly to that described for the MD slope.

Four typical situations (stable, local progression, diffuse progression, local and diffuse progression) and the respective behavior of the DD Trend Analysis are shown in **FIG 9-8**.

### TYPICAL BEHAVIOR OF GLOBAL TREND ANALYSES FROM EARLY TO MODERATE DISEASE

	MD	sLV	DD	LD
<b>Stable</b>				
<b>Diffuse progression</b>	▼		▼	
<b>Local progression</b>	▼	▼		▼
<b>Diffuse &amp; local progression</b>	▼	▼	▼	▼

**FIGURE 9-8** This figure illustrates the typical behavior of the four Global Trend Analyses in potentially worsening visual field series from early to moderate disease. A quick visual inspection of the four global indices provides a straightforward assessment of whether a visual field series is worsening (MD worsening) and of whether the change is caused by diffuse worsening (MD and DD worsening), local worsening (MD, LD, and sLV worsening) or both diffuse and local worsening (MD, DD, LD and sLV worsening). Note that in more advanced disease (e.g., MD > 20 dB), with most visual field locations showing some degree of sensitivity loss, MD and also DD shows worsening while LD and sLV show improvement.

## USE OF LOCAL DEFECT (LD) INDEX TO IDENTIFY LOCAL CHANGE

To determine whether there is local visual field change independent from the presence or absence of diffuse change, Octopus perimeters use the global index LD. This index represents the magnitude of the local defect and is calculated from the Defect Curve. For more information on its design and definition see **BOX 7D**.

The LD Trend Analysis uses comparable definitions as the MD Trend Analysis but displays LD values on the Y-axis instead of MD values and thus allows assessment

of localized change. No symbol is displayed if there is no local change, red downward arrows indicate significant local worsening and significant local improvement is shown by green upward arrows, similarly to that described for the MD slope.

The typical behavior of the LD Trend Analysis in progressing from early to moderate disease (e.g., worsening glaucoma) is shown in **FIG 9-8**.

## USE OF SQUARE ROOT OF LOSS VARIANCE (sLV) TO IDENTIFY LOCAL CHANGE

While the combined evaluation of the DD and LD Trend Analysis is sufficient to distinguish between local and diffuse change, some users are more familiar with the square root of Loss Variance (sLV) index. Octopus perimeters therefore also provide a trend graphic of the index sLV as an alternative to using the DD and LD Trend Analysis. This allows clinicians to choose the analysis they prefer to assess progression.

The sLV global index provides a measure for the inhomogeneity of the visual field. If a visual field is normal, shows a diffuse defect or shows severe pathology (e.g., MD > 20 dB), it is very homogeneous and sLV is low. On the other hand, if a visual field shows one or more local defects, it is more inhomogeneous and sLV is larger. sLV therefore increases if a local defect is increasing, and it remains stable if a diffuse defect is increasing. While this provides comparable information in a situation in which there is only local or only diffuse change, it becomes

challenging to understand the visual field change in case of simultaneous local and diffuse change. For more information on the design and definition of sLV see **FIG 7-21** and **TABLE 7-1**. For more information on its clinical interpretation, see **FIG 8-27**.

The sLV Trend Analysis uses comparable definitions as the MD Trend Analysis but displays sLV values on the Y-axis instead of MD values and thus allows distinction between homogeneous and inhomogeneous change. No symbol is displayed if there is no change; increasing inhomogeneity is indicated by red downward arrows and increasing homogeneity is shown by green upward arrows, similarly to that described for the MD Trend Analysis.

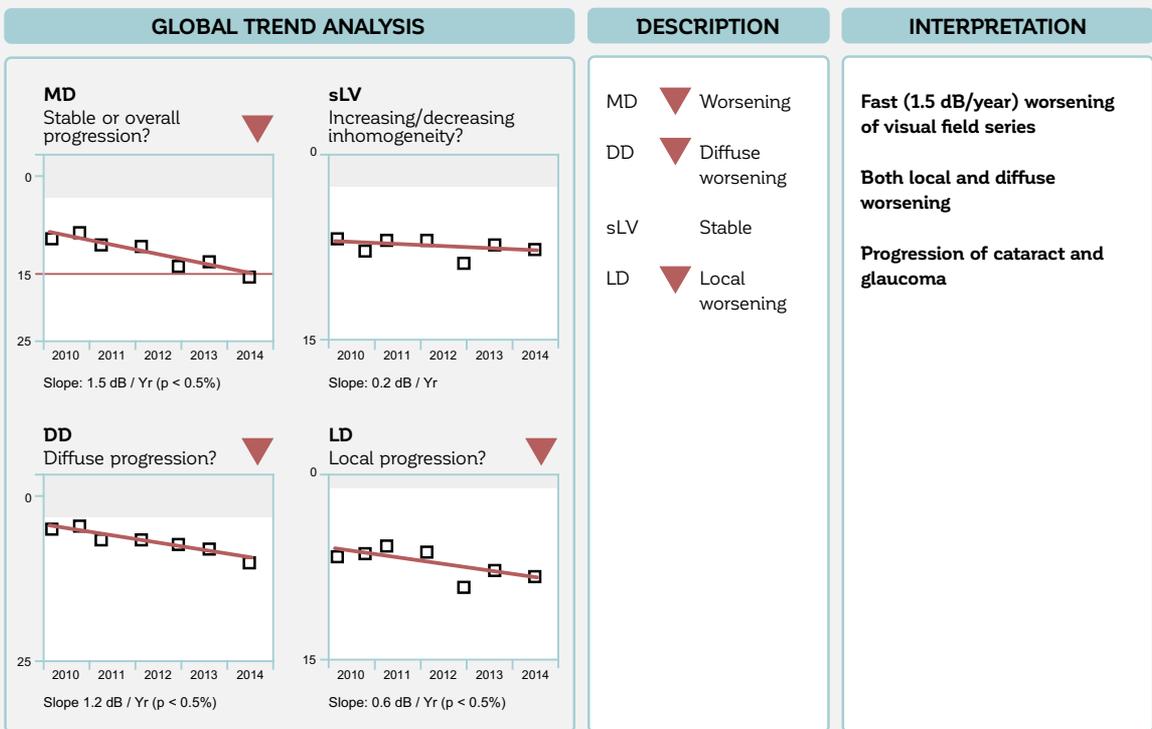
The typical behavior of the sLV Trend Analysis in progressing from early to moderate disease (e.g., worsening glaucoma) is shown in **FIG 9-8**.

## CLINICAL INTERPRETATION OF GLOBAL TREND ANALYSES

In clinical practice it is helpful to jointly consider the information from the four indices presented in the Global Trend Analysis. It is useful to assess the symbols marking significant change first to get a quick overview

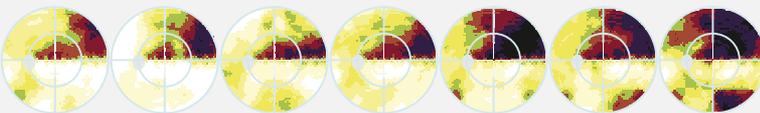
of a patient's series of visual fields. Further analysis of the individual graphs can then be performed given the clinical situation. Two clinical examples are shown in FIG 9-9 and 9-10.

### CASE EXAMPLE 1: PATIENT WITH BOTH PROGRESSING CATARACT AND GLAUCOMA



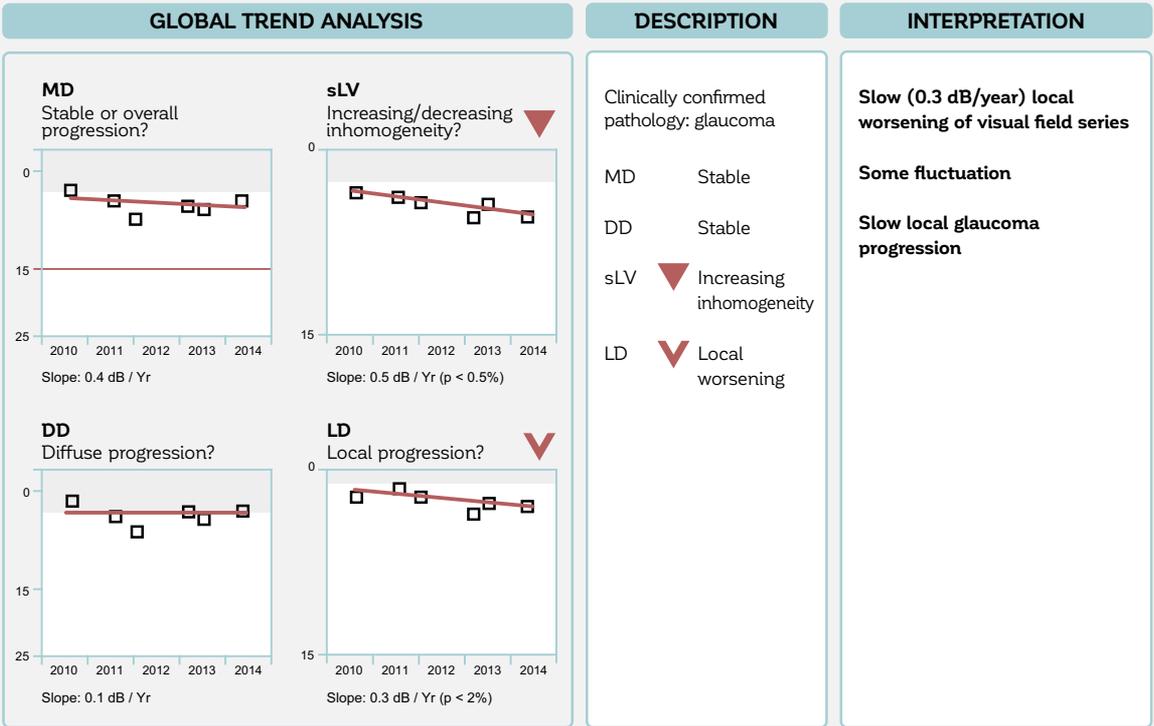
### SERIES OF VISUAL FIELDS

Defect location & depth?

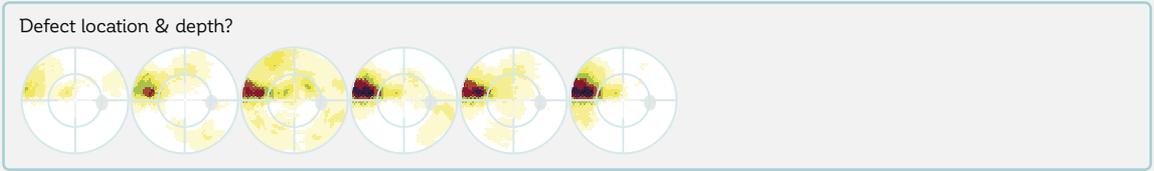


**FIGURE 9-9** This figure illustrates the usefulness of looking at the four global indices in combination. In this example, a patient has both confirmed glaucoma and cataract. While the visual field shows overall significant worsening (MD worsening at  $p < 0.5\%$ ), the MD Trend Analysis does not show which disease is progressing. An analysis of the Diffuse (DD) and Local (LD) Trend Analyses shows both significant local and diffuse progression, suggesting that both glaucoma and the cataract are progressing.

**CASE EXAMPLE 2: SUBTLE LOCAL GLAUCOMATOUS CHANGE AND MAINLY DIFFUSE FLUCTUATION**



**SERIES OF VISUAL FIELDS**



**FIGURE 9-10** This glaucoma patient shows a marked nasal step and some diffuse visual field loss in visual fields 3 and 4 in the series of Grayscale (Comparisons) representation. Looking solely at MD change, the visual field series appears to be stable (no symbol). Nevertheless, the MD Trend Analysis also shows an outlier on the 3rd test, which is also present in the DD Trend Analysis suggesting this is caused by diffuse fluctuation. Assessment of the DD Trend Analysis (no change), sLV Trend Analysis (significant worsening at p < 1%) and LD Trend Analysis (significant worsening at p < 5%) reveals no diffuse change but significant local change. In conclusion, in this situation MD is too affected by diffuse fluctuation to show the significant but local worsening of the nasal step defect. Thus, the additional assessment of local and diffuse change in this situation is more sensitive in detecting subtle local change than the assessment of only the MD Trend Analysis.

# CLUSTER TREND AND CORRECTED CLUSTER TREND ANALYSIS

## IMPORTANCE OF ASSESSING CLUSTER PROGRESSION IN GLAUCOMA

Typical glaucomatous defects caused by localized retinal nerve fiber damage, as well as some visual field defects caused by optic nerve damage, consist of a cluster of adjacent defective visual field locations (**FIG 5-1**) that correspond to the path followed by the retinal nerve fiber bundles in the retina (see step 5 in Chapter 8). Localized visual field progression therefore typically occurs in a cluster of visual field locations.

However, if localized glaucomatous progression is small and there is additional fluctuation, the global index MD may not be sensitive enough to detect that subtle cluster change because MD is an average of the sensitivity loss of the whole visual field. While in some instances looking at local change using the LD or sLV indices can lead to the detection of such change, spatial information about where the change occurs is missing.

For example, to determine whether there is a corresponding structural change in glaucoma to confirm a suspected glaucomatous change, it is helpful to know in which area of the visual field the change is happening. In addition, in a constricted glaucomatous visual field with many visual field locations showing absolute defects (i.e., sensitivity thresholds of 0 dB), progression in the remaining central visual field of a patient is of key importance for quality of life but may not be apparent from the MD Trend Analysis, due to its relative insensitivity in detecting localized change.

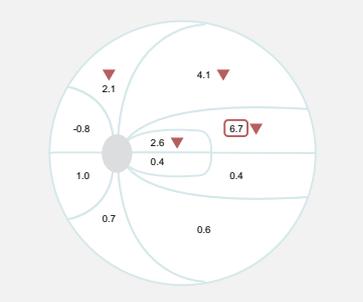
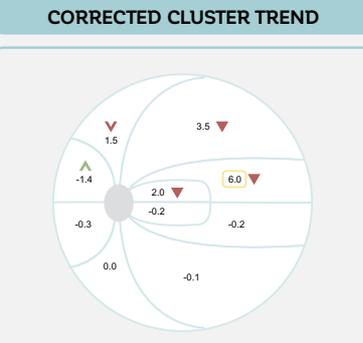
It is thus helpful to assess Cluster MD progression in addition to the global indices to detect subtle localized visual field change in glaucoma as well as to receive additional spatial information about where the change is happening. This is the purpose of both the Cluster and Corrected Cluster Trend Analysis.

## CLUSTER AND CORRECTED CLUSTER TREND ANALYSIS

Cluster Trend Analysis (CTA) is a trend analysis based on the single field Cluster Analysis whose design and definitions have already been explained in **FIG 7-12** and **FIG 7-13** and **BOX 7B** and whose clinical interpretation and usefulness have already been shown in **FIG 8-20** and **FIG 8-21** and **BOX 8B**. The Corrected Cluster Trend Analysis (CCTA) is very similar to CTA, but is based on the Corrected Cluster Analysis (see **FIG 7-20**) which eliminates the influence of diffuse defect.

Both types of Cluster Trend Analysis employ the same statistical analysis also used in the global MD Trend Analysis and use comparable symbols to indicate significance of change. However, instead of looking for significant MD change over time, they are looking for significant Cluster or Corrected Cluster Mean Defect (MD) change over time.

**CLUSTER TREND AND CORRECTED CLUSTER TREND – INTERPRETATION AID**

CLUSTER TREND	DEFINITION	INTERPRETATION
	<p>Probability of stable visual field series showing this result</p> <p>No symbol    <math>p &gt; 5\%</math></p> <p>    Worsening at <math>p &lt; 5\%</math></p> <p>    Worsening at <math>p &lt; 1\%</math></p> <p>    Improvement at <math>p &lt; 5\%</math></p> <p>    Improvement at <math>p &lt; 1\%</math></p> <p>    Floor effect (Cluster MD &gt; 20 dB, no significant progression)</p> <p>    Cluster MD Slope [dB/year]</p> <p>    Corrected Cluster MD Slope [dB/year]</p>	<p><b>Stable</b></p> <p><b>Likely worsening cluster</b></p> <p><b>Highly likely worsening cluster</b></p> <p><b>Likely improving cluster</b></p> <p><b>Highly likely improving cluster</b></p> <p><b>Maximum cluster loss</b> (No further measurement of progression possible in this cluster)</p> <p><b>Cluster MD change in dB/year</b></p> <p><b>Corrected Cluster MD change in dB/year</b></p>
<p><b>CORRECTED CLUSTER TREND</b></p> 		

**FIGURE 9-11** The Cluster Trend representations display 10 visual field clusters that spatially correlate with retinal nerve fiber bundles. In each cluster, a Cluster MD change in dB/year is indicated. Significant Cluster MD worsening is marked with a red downward arrow, whereas significant Cluster MD improvement is marked with green upward arrows. Stable clusters do not have a symbol and clusters which show a floor effect are marked with a black symbol.

CTA and CCTA also use the red downward arrows and green upward arrows to show significant cluster worsening or improvement. However, the graphical display is different from the MD Trend Analysis. The individual Cluster MDs are not shown in a two-dimensional trend graph. Instead, both the Cluster MD change in dB/year and a symbol indicating the significance of this change are displayed in each of the 10 clusters as shown in **FIG 9-11**.

Similar to the interpretation of Cluster Analysis, some caution is essential in the clinical interpretation of CTA and CCTA. This is because one random cluster showing a p value smaller than 5% is expected to occur even in stable visual fields. Thus, a significant cluster defect is much

more clinically meaningful if it is spatially correlated with another meaningful cluster defect or if it correlates with a significant structural change.

Similar to Cluster Analysis (see **BOX 8B**), CTA has been shown to be highly sensitive in detecting subtle, early glaucomatous change and has been shown to be more sensitive in detecting change than MD Trend Analysis and local event analysis<sup>11-13</sup> (not available as a statistical tool in the EyeSuite Progression Analysis).

These findings can be explained with the same rationale used to explain why Cluster Analysis is highly sensitive in detecting early glaucomatous defects. Because glaucomatous change is mostly local, the averaging used to de-

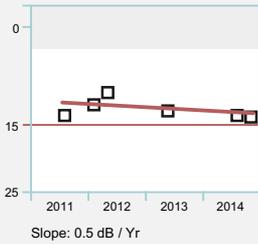
rive the MD global index reduces the chances of detecting early localized change (FIG 9-12 and 9-13). On the other hand, single point event analysis is too influenced by fluctuation to detect significant change early.

**ILLUSTRATION OF THE USEFULNESS OF CLUSTER TREND ANALYSIS**

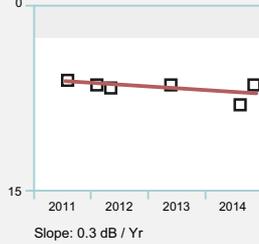
**EYESUITE PROGRESSION ANALYSIS**

**GLOBAL TREND ANALYSIS**

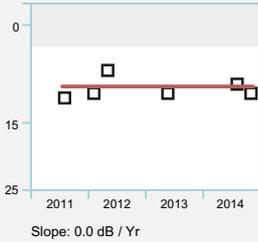
**MD**  
Stable or overall progression?



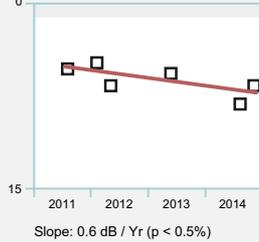
**sLV**  
Increasing/decreasing inhomogeneity?



**DD**  
Diffuse progression?

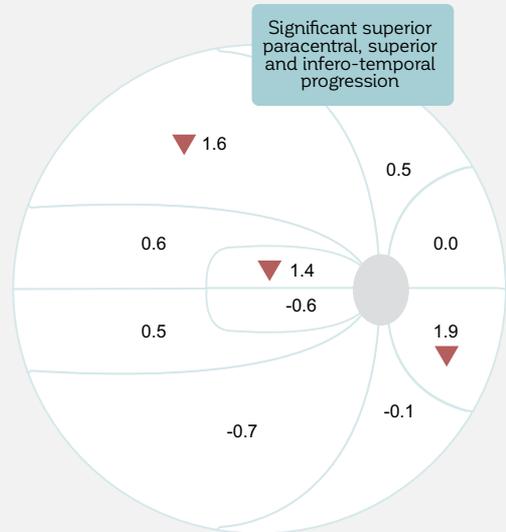


**LD**  
Local progression? ▼



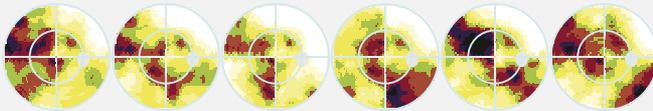
**CLUSTER TREND ANALYSIS**

**CLUSTER TREND**  
Cluster MD progression?



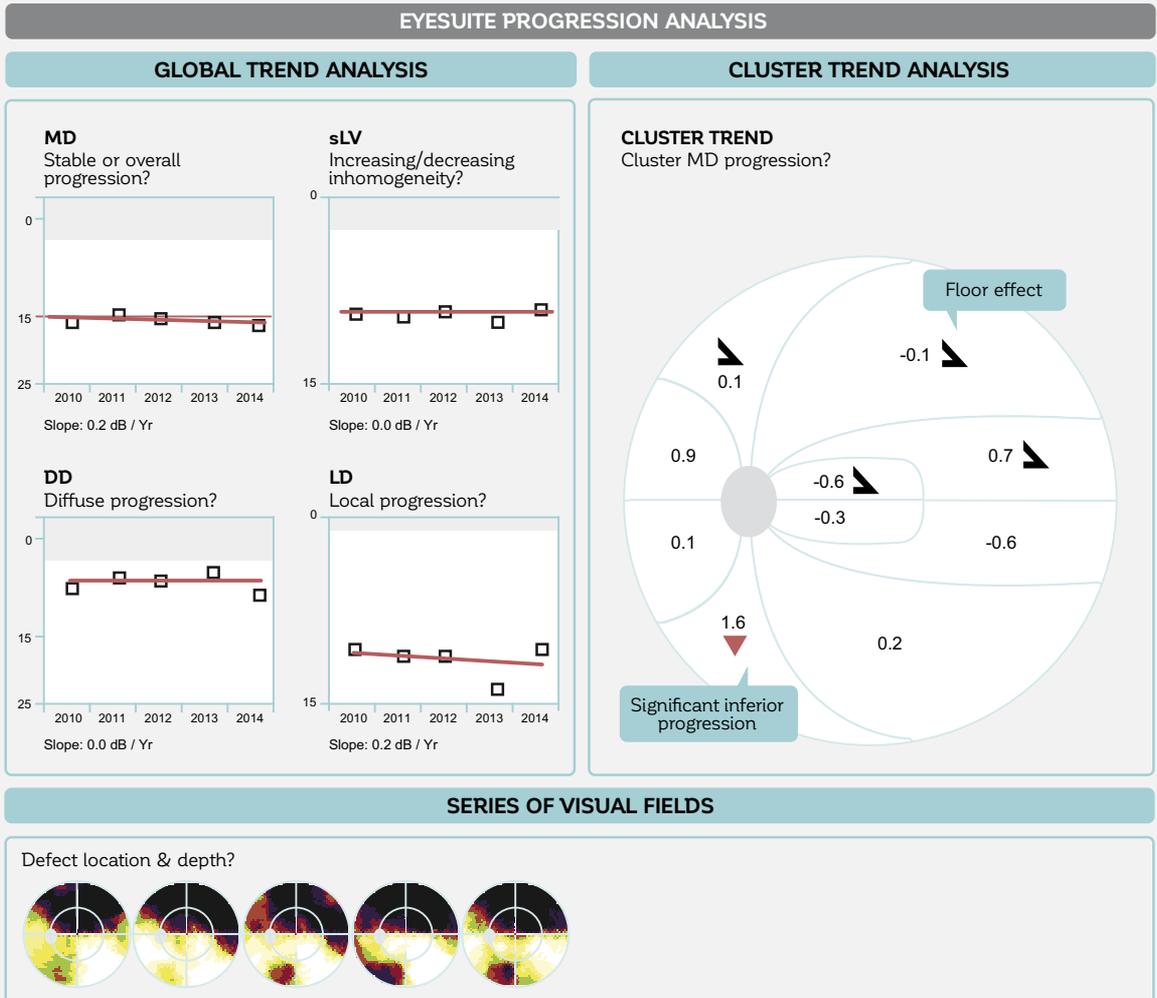
**SERIES OF VISUAL FIELDS**

Defect location & depth?



**FIGURE 9-12** The usefulness of Cluster Trend Analysis (CTA) in a case which shows a considerable amount of fluctuation is visible in the data. This visual field series of a glaucoma patient appears to be stable (no symbol indicating change) on the global index MD, but shows local worsening on the LD index. Using CTA, significant worsening (red downward arrow) is apparent in the superior paracentral, superior and infero-temporal clusters indicating clear local worsening. In this situation, CTA is more sensitive in detecting progression than MD and provides additional information about the location of progression compared to the LD index.

**ILLUSTRATION OF THE USEFULNESS OF CLUSTER TREND ANALYSIS IN ADVANCED DISEASE**



**FIGURE 9-13** This example presents the visual fields of a glaucoma patient with a severe superior altitudinal defect and no remaining sensitivity in most of the upper visual field (floor effect, no further progression can be detected). All four global indices are stable with no symbol indicating change. However, using the Cluster Trend Analysis, significant localized worsening (red downward arrow) is apparent in the inferior cluster. In such advanced situations, Cluster Trend Analysis can assist in the detection of progression in areas with remaining sensitivity, which is important for the management of the patient.

# POLAR TREND ANALYSIS

## IMPORTANCE OF ESTABLISHING A RELATIONSHIP BETWEEN STRUCTURAL AND FUNCTIONAL PROGRESSION

In eyes with early glaucomatous damage or only subtle progression, detection of pathological changes is challenging. Therefore, it is often useful to consider both functional and structural change (i.e., neuroretinal rim tissue loss; decrease of retinal nerve fiber layer thickness.

Because visual field damage is often detected in a representation of a retinal location while structural damage is evident at the optic disc, there is a need to use a representation that links the structural to the functional visual field progression. This is the purpose of Polar Trend Analysis.

## USE OF POLAR TREND ANALYSIS TO ASSIST IN THE DETECTION OF GLAUCOMATOUS STRUCTURAL PROGRESSION

Polar Trend Analysis is based on Polar Analysis, whose design and definitions have already been shown in [FIG 7-14](#) and [7-15](#) and whose clinical interpretation and usefulness have been presented in [FIG 8-23](#) and [8-24](#).

bundles arrive at the margin of the disc. It does so by employing the same trend analysis approach also used in the global MD Trend Analysis (see [FIG 9-3](#) and [9-5](#) and [BOX 9A](#)), but applies it to sensitivity loss at each test location (pointwise trend analysis). For more information on the design of Polar Trend Analysis, refer to [BOX 9B](#).

It graphically represents change at each visual field test location where the corresponding retinal nerve fiber

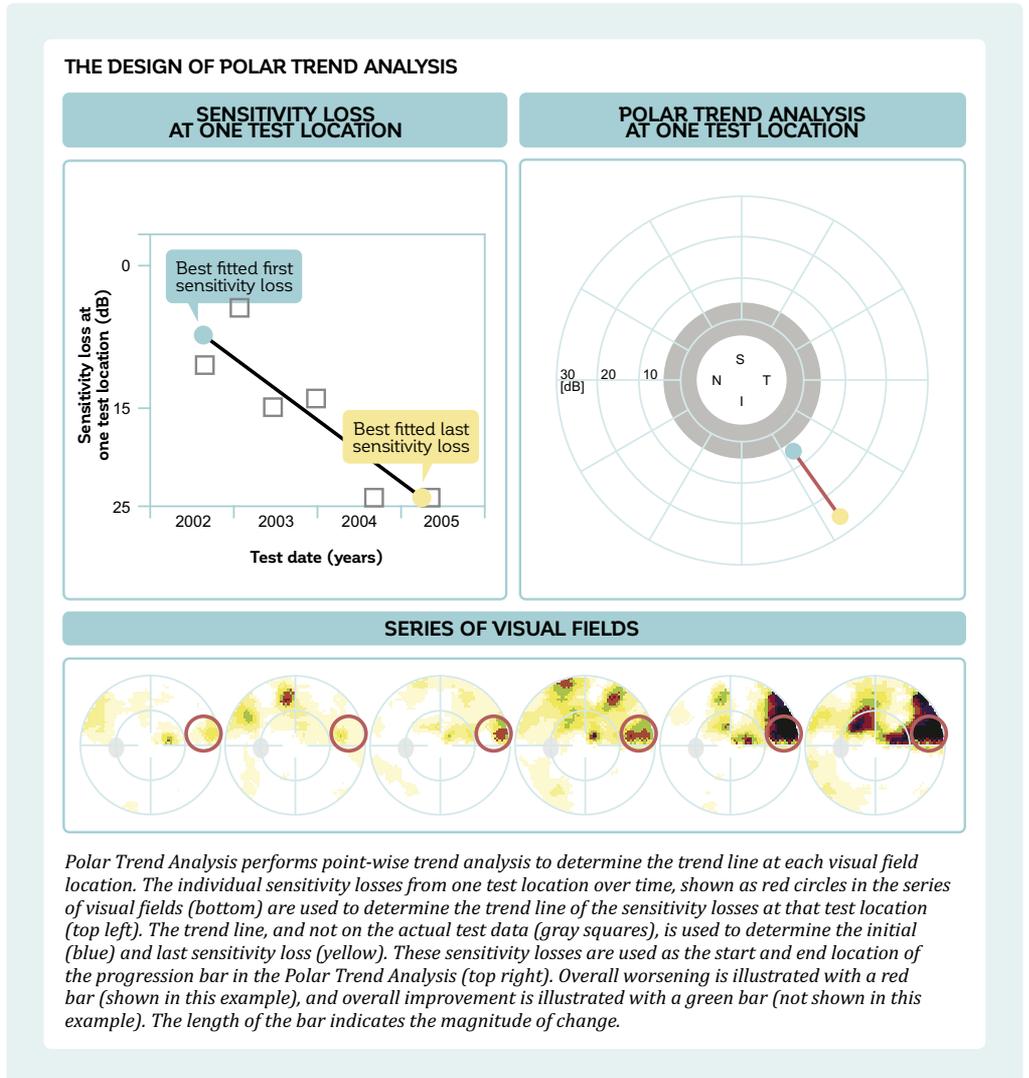
### THE DESIGN OF POLAR TREND ANALYSIS

Polar Trend Analysis performs pointwise trend analysis on sensitivity loss data to determine the trend line but not the significance of the slope for each visual field location individually. This is illustrated in the graphic in this box, which uses the example of one superior nasal test location circled in red in the Grayscale representation.

However, the graphical display of Polar Trend Analysis is fundamentally different from the other representations discussed previously. Instead of using the slope to determine a rate of change, the trend line is used to determine a best fitted sensitivity loss for the first (blue point in the graphic in this box) and the last (yellow point) of the visual field tests. It should be noted that these two data points are based on the trend line at the respective test dates, not on the individual visual field test result at a given test date.

These two fitted sensitivity loss values are then marked in the same Polar grid also used for Polar Analysis and connected by a straight line at the position where the corresponding nerve fiber bundles of the test location arrive at the margin of the disc. If there is worsening between that first and last fitted sensitivity loss, then the bar is drawn in red, while it is drawn in green if there is improvement.

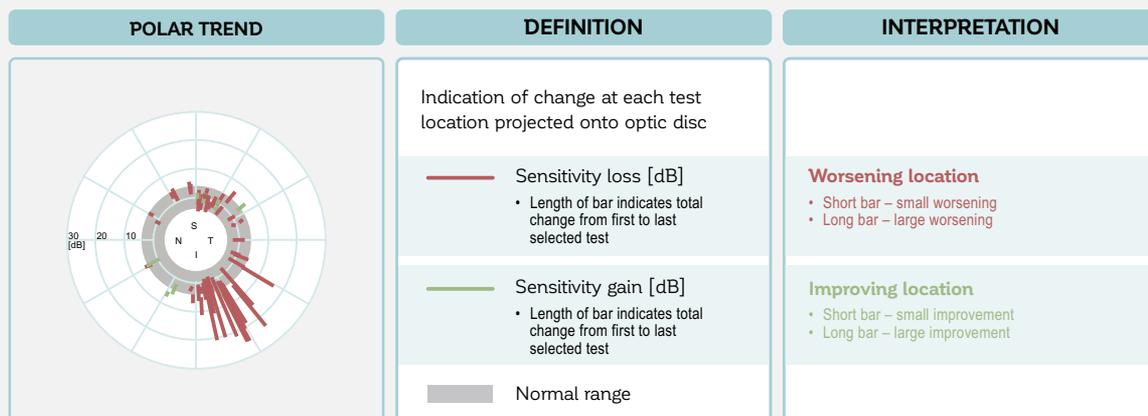
### BOX 9B



Progression (worsening) is represented by a red bar, the length of which corresponds to the best-fitted change in the sensitivity loss in dB. Improvement is similarly represented using a green bar. Though the quantity of

change is not given numerically, the approximate change of each defect can be identified on the graph in dB. A gray band in the center indicates approximate normal ranges for those bars (FIG 9-14).

## POLAR TREND ANALYSIS – INTERPRETATION AID



**FIGURE 9-14** Polar Trend Analysis representation projects local progression per test location onto the optic disc to allow for easy linking with structural results. Red bars indicate worsening while green bars indicate improvement. The starting and end location point (i.e. the length) of each bar is based on the loss indicated by the local trend line between the first and the last examination.

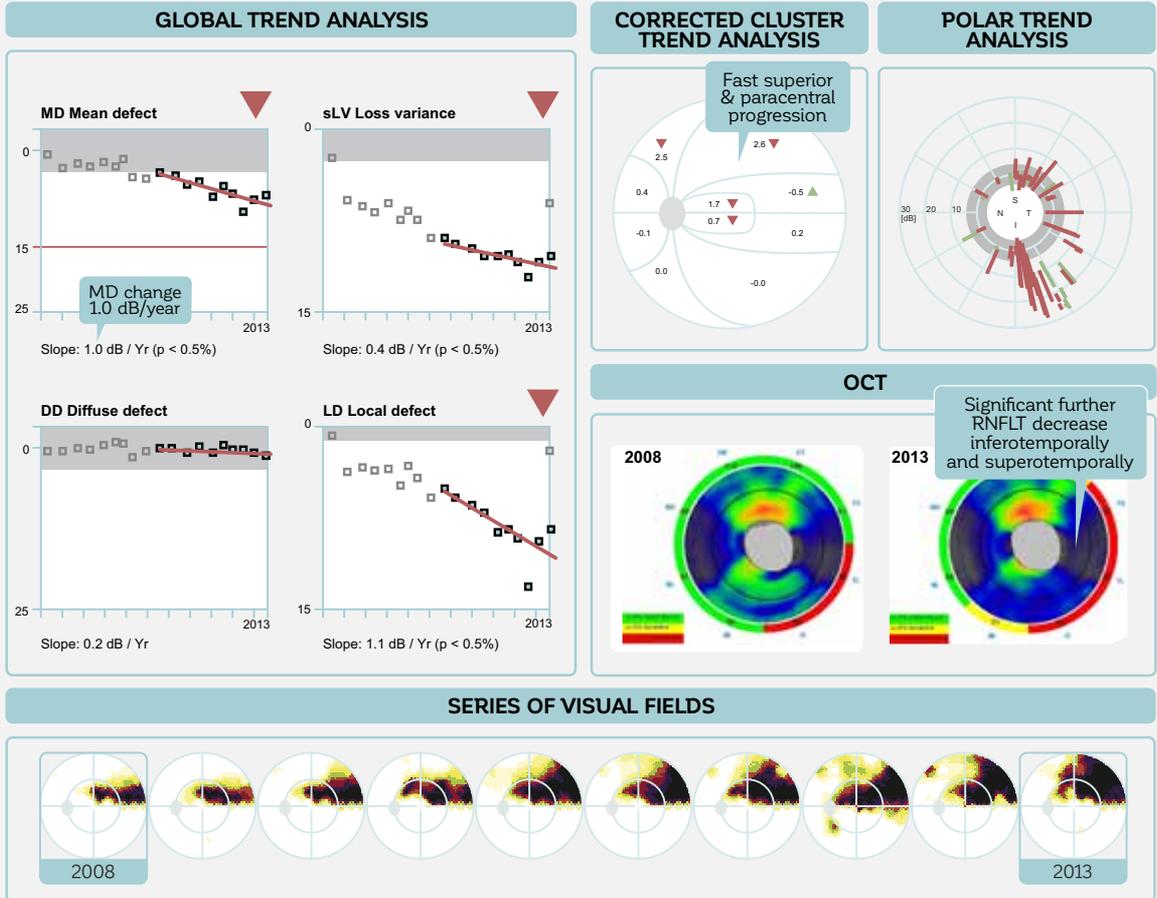
Clinical interpretation of Polar Trend Analysis is straightforward and based solely on the graphical representation. The longer the bar, the more absolute change has occurred during the time period of interest and the further away the bar is located from the center, the more damage was already present at a given test location at the time of the first test.

If there are many red bars indicating worsening clustered at one optic disc location, this indicates a visual field worsening at that position. One can determine whether a corresponding structural change at that same position is present. Defect progression on the Polar Trend Analysis report can be considered as a warning message for localized visual field progression, which may draw the clinicians' attention to the spatially corresponding

potential structural progression. However, it is important to note, no rates of progression or significance of progression are provided by Polar Trend Analysis. For an exact evaluation of these parameters, one can refer to Cluster Trend and Corrected Cluster Trend Analyses. It is important to remember that those representations are oriented as visual fields and not as structural data. This means that related defects will be positioned at the location flipped vertically across the horizontal midline.

Polar Trend Analysis has been shown to correlate well with structural progression data<sup>14</sup> and is therefore a very useful and quick tool for assistance with the combined evaluation of both structural and functional progression. A clinical case is illustrated in **FIG 9-15**.

**ILLUSTRATION OF THE USEFULNESS OF POLAR TREND ANALYSIS**



**FIGURE 9-15** This glaucoma patient shows significant local visual field worsening (MD, LD and sLV worsening at p < 1%) over a period of 5 years starting from the superior paracentral and superior nasal step areas and expanding to the inferior paracentral area, while deepening at the original defect locations (significant corrected cluster worsening in these areas). Polar Trend Analysis displays strong supero- and infero-temporal worsening. Looking at the change on the OCT retinal nerve fiber layer thickness between 2008 and 2013 (supero- and infero-temporal structural progression), there is a clear spatial relationship between structural and functional change, thus confirming that these changes stem from glaucoma.

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13. Gardiner SK, Mansberger SL, Demirel S. Detection of functional change using Cluster Trend Analysis in glaucoma. *Invest Ophthalmol Vis Sci*. 2017;58:BI0180-BI0190.
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## CHAPTER 10

# NON-CONVENTIONAL PERIMETRY

## INTRODUCTION

Static Standard Automated Perimetry (SAP, alternatively called white-on-white perimetry), which uses a white Goldmann size III stimulus presented on a white background, is by far the most commonly used type of perimetric test today. It is the standard of care to detect and follow glaucoma. The white stimulus stimulates nearly all types of retinal ganglion cells and as a result the test has a large dynamic range. Nevertheless, it would be desirable to have a more sensitive test than SAP for early detection of irreversible vision loss in diseases such as glaucoma.

Furthermore, the following shortcomings are associated with SAP using a size III stimulus: 1) there is large

variability in patient responses in areas of significant vision impairment or low vision and 2) there is a marked floor effect in areas of significant vision impairment or low vision.

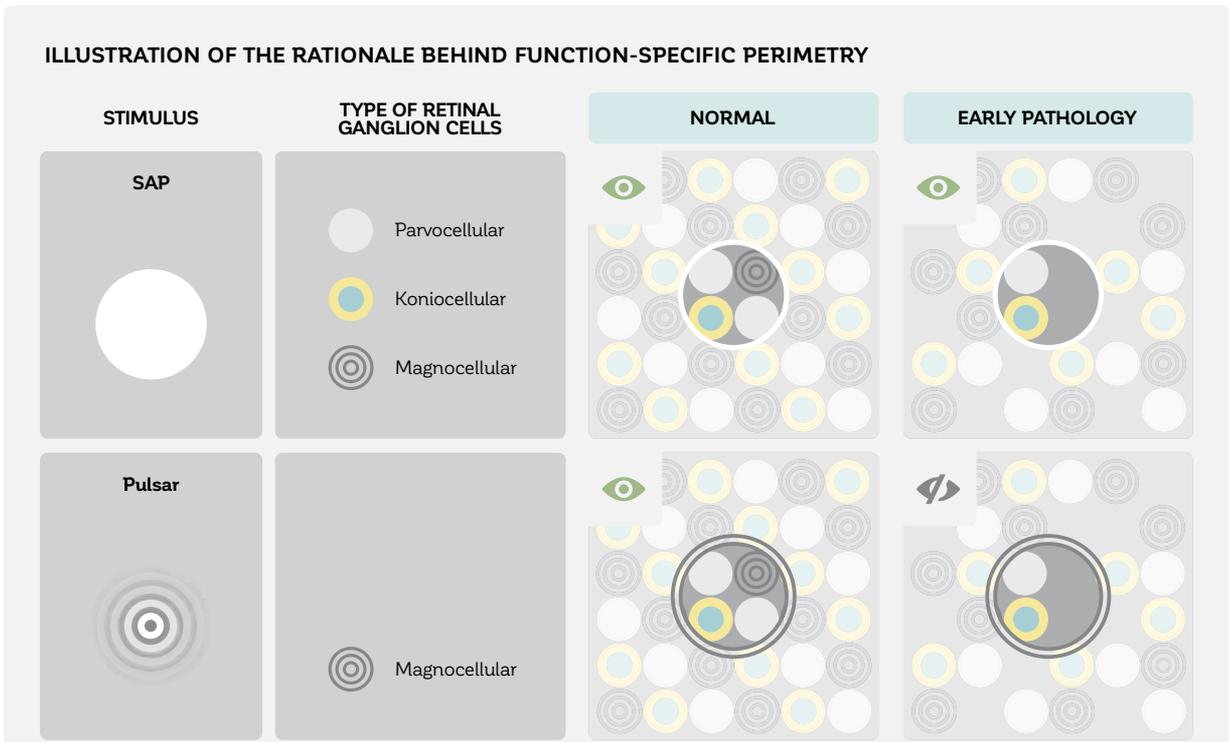
Other forms of perimetry have been developed to allow for earlier detection and to overcome the shortcomings of SAP. Non-conventional perimetry includes function-specific perimetric tests that use stimuli which target specific pathways and visual functions (e.g., flicker) and also white-on-white perimetry performed with the larger size V stimulus, which provides a useful alternative for testing in areas of vision impairment or low vision.

# FUNCTION-SPECIFIC PERIMETRY

## RATIONALE FOR USING FUNCTION-SPECIFIC PERIMETRY

Different Octopus perimeter models offer different types of function-specific stimuli. Pulsar perimetry uses a flickering stimulus with concentric rings changing in both spatial resolution and contrast that resembles a bullseye. Flicker perimetry uses a white flickering stimulus presented on a white background. Short-Wavelength Automated Perimetry (SWAP - alternatively called blue-on-yellow perimetry) uses a blue (short wavelength) stimulus presented on a yellow background. Similar to SAP, all these tests are based on functional decline due to retinal ganglion cell loss in glaucoma.

While the stimuli used in SWAP, Flicker perimetry and Pulsar perimetry differ substantially from each other, the same rationale was used to develop them. These tests are designed to overcome the redundancy of the visual system by selectively stimulating a subset of retinal cells and as a result get a more sensitive response to early changes (FIG 10-1). This rationale is based on the hypothesis that different types of retinal ganglion cells process different visual functions, but nearly all retinal ganglion cells can detect the white stimulus used in SAP. While some cells are adversely affected by pathology such as glaucoma,



**FIGURE 10-1** Function-specific perimetry has been developed to reduce the redundancy within the visual system with the goal of detecting visual field loss earlier. The idea is based on the hypothesis that white light universally stimulates nearly all retinal ganglion cell types. The loss of a few retinal cells should therefore be easily compensated by the remaining cells, as the example with the SAP stimulus (top) illustrates. The white stimulus stimulates many retinal cells and even when several are dysfunctional, the white stimulus (white circle) is still seen. In function-specific perimetry, only one cell type is predominantly stimulated. In the example with the Pulsar stimulus (bottom), there is no remaining functional magnocellular cell that can be stimulated by the Pulsar stimulus. As a result, the stimulus is not seen.

other neighboring cells may still detect the SAP stimulus. This presumably makes the SAP test less sensitive to early visual field loss. To give a simple analogy, it is as though one person out of the 20 who promised to help you move calls in sick on moving day. The other 19 helpers can effectively carry on the task and the impact of the one missing person is not felt too strongly.

In contrast, function-specific perimetry targets only a subset of retinal ganglion cells. It is assumed that if a few cells in this subset are adversely affected by

pathology such as glaucoma, there are a smaller number of cells that are able to detect the function-specific stimulus, making the test more sensitive to early visual field loss. Using the previous analogy, this would translate into having one person out of only two cancel on moving day. There is only one person to help with the move and the task becomes much more difficult.

The function-specific stimuli currently available have all been developed for early glaucoma detection, but have also been used for other diseases.

## USE OF FUNCTION-SPECIFIC PERIMETRY IN CLINICAL PRACTICE

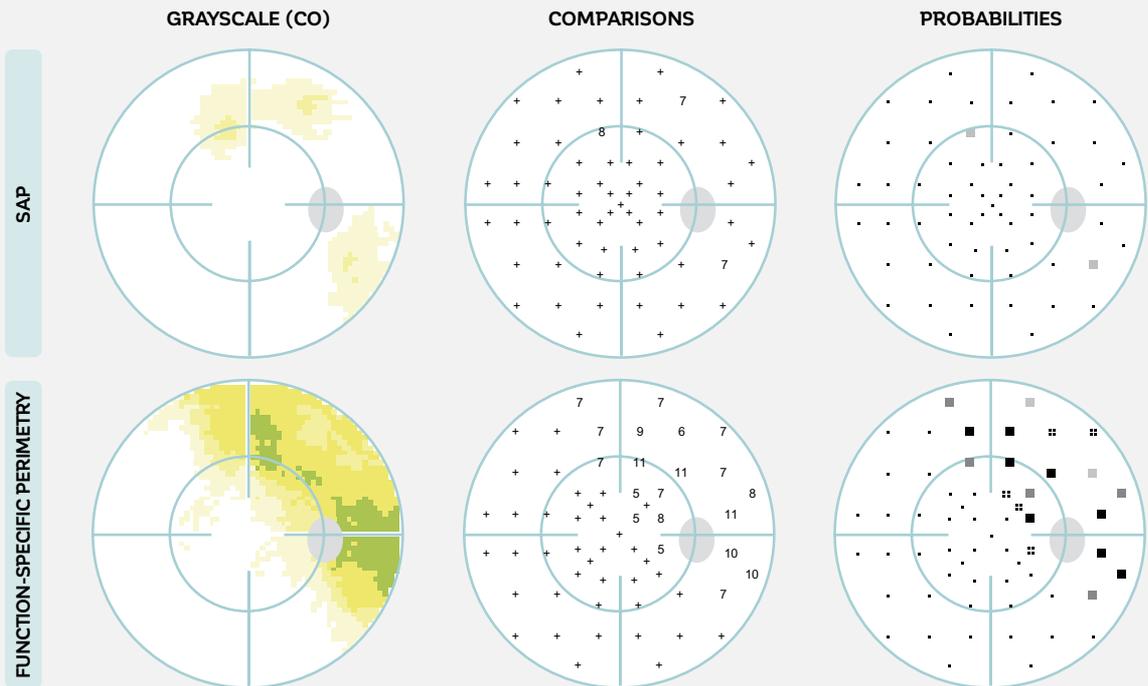
While many studies have reported that function-specific perimetry detects glaucomatous vision loss earlier than SAP,<sup>1,2</sup> other studies have found no such effect.<sup>4,5</sup> As a result, experts have not yet reached a consensus on whether function-specific perimetry provides added value in comparison to SAP.

When making a decision about whether or not to use function-specific perimetry, it is essential to keep in mind that the quantitative results cannot be directly compared with white-on-white perimetry. While SAP is the recommended standard, one may choose either SAP or one of the function-specific perimetry tests as a default test for disease detection. If time allows, one might choose to perform an additional test, particularly in situations of uncertainty (i.e., to confirm suspected but unconfirmed visual field loss as shown in the example in **FIG 10-2**).

While there are distinct normative databases for each function-specific stimulus as well as for SAP, it is essential to consider that function-specific perimetry has a smaller dynamic range than SAP. Therefore, while normal subjects may show comparable responses on all tests, patients with more advanced disease are likely to show visual field defects that appear more severe on function-specific perimetry due to the smaller dynamic range.

Consequently, function-specific perimetry cannot be used through all disease stages. If there is advanced disease, one should use SAP. If function-specific perimetry is chosen as a default for disease detection, switching to SAP is recommended for follow-up at some point. In order to avoid a lack of historic reference data, it may be best to switch to SAP early in the follow-up process.

### EXAMPLE OF SAP AND FUNCTION-SPECIFIC PERIMETRY IN THE SAME EYE



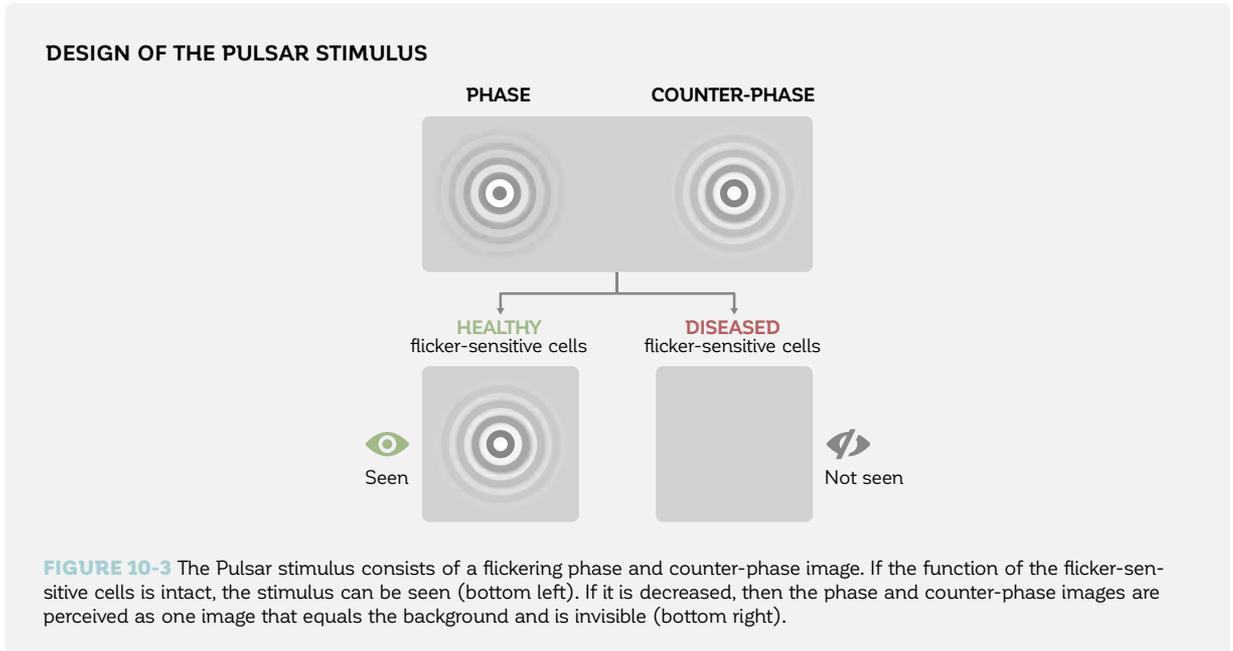
**FIGURE 10-2** The same patient with an early glaucomatous defect is tested twice, once with the SAP test (top) and once with the function-specific Pulsar stimulus (bottom). While SAP does not show a statistically significant defect in this patient, there is a clear defect visible when using function-specific Pulsar perimetry. Note that the locations with  $p < 5\%$  for SAP are within the area in which the defect is present for function-specific perimetry.

## PULSAR PERIMETRY

The Pulsar stimulus is a function-specific stimulus that tests both flicker sensitivity and contrast sensitivity. It has been developed specifically for early glaucoma detection and has been shown to be both sensitive and specific in the detection of early glaucoma.<sup>1-3</sup> It is a very patient-friendly perimetric test.

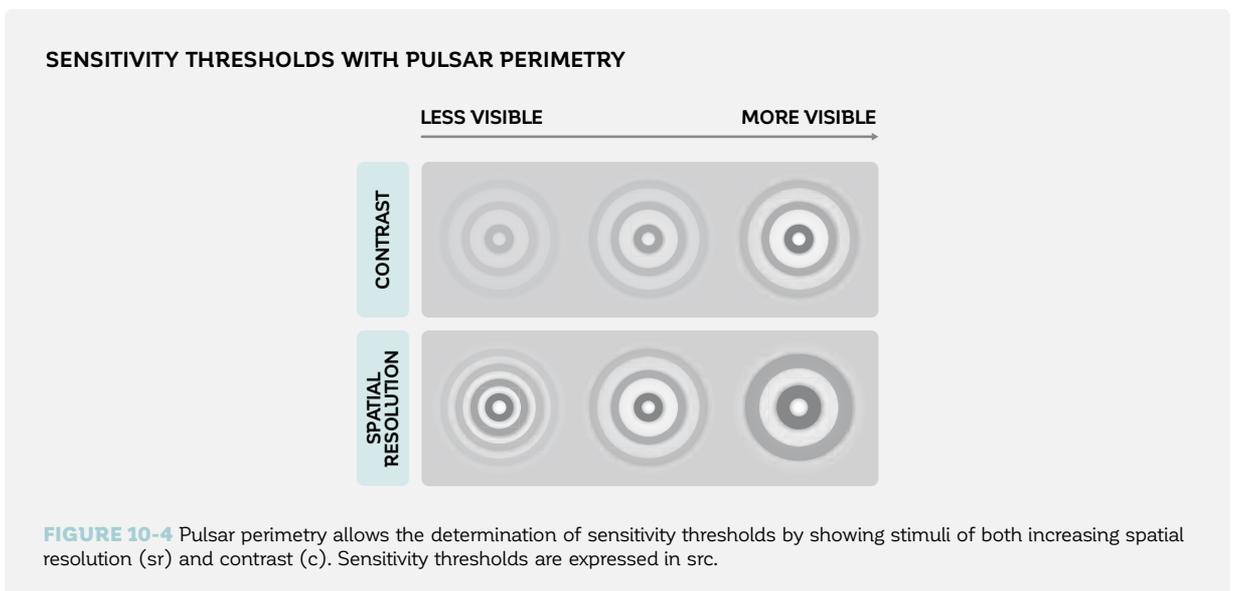
The stimulus used in Pulsar perimetry consists of a ring pattern with a diameter of  $5^\circ$  of visual angle, which is more than 10 times larger in radius and 100 times larger in area than the white size III stimulus used in SAP. The Pulsar stimulus consists of phase and counter-phase images. This means that light rings on the phase image are displayed as dark rings on the counter-phase image. The

two images alternate at a frequency of 10 Hz over 500 ms. If flicker sensitivity is reduced, the visual system cannot detect the change between the phase and counter-phase images. As a result, the phase and counter-phase images are perceived as a single image. Because the average intensity of the rings of the phase and counter-phase images are equal to the mean intensity of the background, the Pulsar stimulus blends with the background and is not visible anymore (FIG 10-3). However, if flicker-sensitivity is not affected, the visual system distinguishes between the phase and counter-phase images and the Pulsar stimulus is perceived like a pulsating ring pattern, similar to the ripple pattern generated if a water drop enters a smooth water surface.<sup>1</sup>



The Pulsar test uses a very patient-friendly stimulus. It is easy to instruct the patients on how to perform the test (seen or not seen) and patients have more confidence about seeing the stimulus both because of its large size and perceived motion. As a result, Pulsar perimetry has low test-retest variability and a minimal learning effect.<sup>6,7</sup> These features make it very suitable for screening purposes.

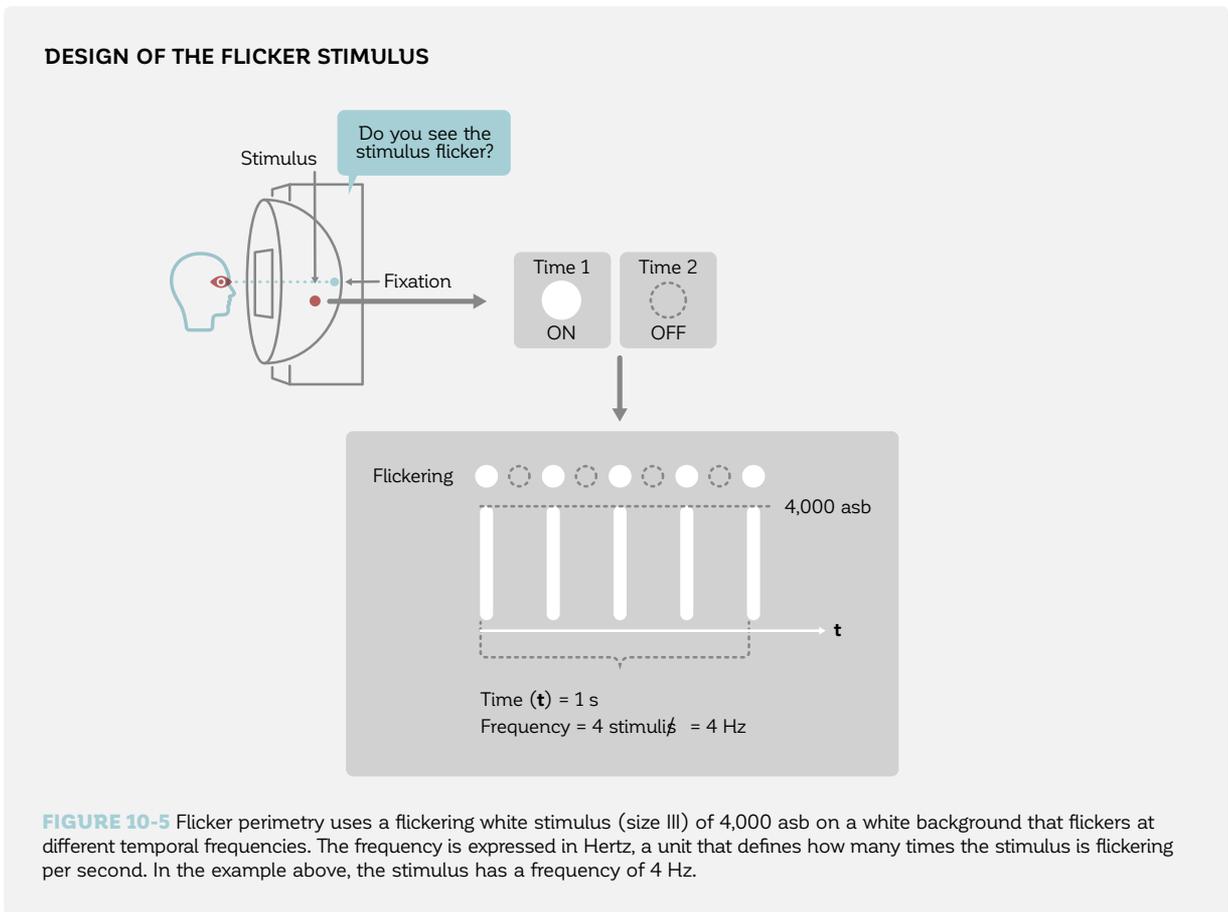
In addition, sensitivity thresholds can also be determined. Pulsar perimetry employs its own unit scale, the src scale, consisting of 36 distinct steps, with increased spatial resolution (sr) and contrast (c) with each step (**FIG 10-4**). The results of this threshold test are then displayed as any SAP result and all the visual field representations presented in Chapters 7-9 are available. Pulsar perimetry uses all representations available for SAP.



# FLICKER PERIMETRY

Flicker perimetry is similar to Pulsar perimetry in that it stimulates flicker sensitive cells and has been created for early glaucoma detection. However, the stimulus design is fundamentally different from that of Pulsar perimetry. Flicker perimetry determines the critical fusion frequency (CFF), or in other words, the frequency at which the flicker appears to fuse into continuous steady light. In this test, a white stimulus of Goldmann size III with a stimulus intensity of 4,000 asb (i.e., the most intense

stimulus that the perimeter can display) flickers over a period of 1 second and the patient is instructed to press the response button only when the stimulus seems to flicker (FIG 10-5). The flicker frequency ranges from very fast (approximately 50 cycles per second) to slow (i.e., 1-5 cycles per second). The CFF represents the sensitivity threshold of Flicker perimetry (FIG 10-6) and is expressed in Hertz (Hz).



**FIGURE 10-5** Flicker perimetry uses a flickering white stimulus (size III) of 4,000 asb on a white background that flickers at different temporal frequencies. The frequency is expressed in Hertz, a unit that defines how many times the stimulus is flickering per second. In the example above, the stimulus has a frequency of 4 Hz.

Flicker perimetry was shown to be both sensitive and specific in the detection of early glaucoma.<sup>8-10</sup> One of its major additional advantages is that sensitivity thresholds

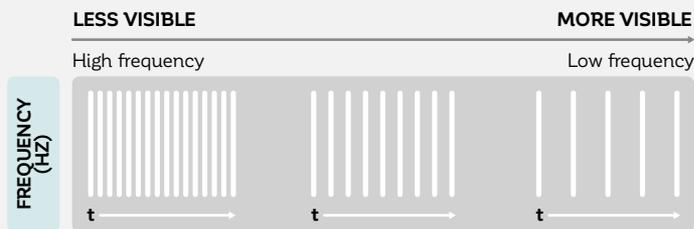
are minimally influenced by media opacities stemming from pathologies such as cataracts or refractive errors, for example.<sup>10,11</sup>

Flicker perimetry is more demanding of patients compared to Pulsar perimetry, because they must pay attention to both the presence of a stimulus and whether it is flickering or not. Thus, careful patient instruction and observation are even more essential in flicker perimetry than in other perimetry forms. Its use is therefore recom-

mended only for patients who perform very well on perimetry. In these patients, it is a useful perimetric test.

**BOX 10A** provides practical guidance on how to best perform flicker perimetry.

### SENSITIVITY THRESHOLDS WITH FLICKER PERIMETRY



**FIGURE 10-6** In flicker perimetry, stimuli flicker from high frequencies (50Hz, flicker is more difficult to see) to low frequencies (1-5 Hz, flicker is easier to see) to determine the Critical Fusion Frequency (i.e., the frequency in Hertz (Hz) at which a flickering stimulus appears to fuse into continuous steady light). The CFF defines the sensitivity threshold at a given location.

### HOW TO PERFORM RELIABLE FLICKER PERIMETRY

Most points highlighted in Chapter 3 on how to run a reliable visual field test also apply to flicker perimetry. However, there are some specific points to which particular attention should be given.

First, patient instructions need to be slightly adapted and should include a description of a flickering stimulus. An example referring to old television sets or to a candle in the wind might prove helpful. It might also be useful to describe that the test examines one's ability to recognize when lights go on and off when they are switched rapidly. It also needs to be stressed that all stimuli are visible for a full second, but that the patient should only respond when a flickering motion is perceived and not upon the mere presence of a stimulus. It might be worth starting with a practice test to make sure that the patient understands the task.

It is also recommended that the examiner pays very close attention to fixation losses, because patients are more likely to search for stimuli in flicker perimetry than in other forms of perimetry because of its inherent challenges.

### BOX 10A

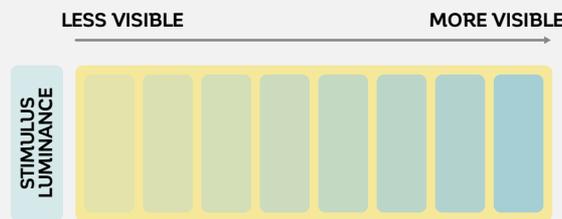
## SHORT WAVELENGTH AUTOMATED PERIMETRY (SWAP)

Short Wavelength Automated Perimetry (SWAP) is commonly referred to as blue-on-yellow perimetry, because it displays a large blue (short wavelength) stimulus of Goldmann size V on a bright yellow background with a luminance of 315 asb ( $100 \text{ cd/m}^2$ ).<sup>12</sup> The patient is asked to respond whenever a blue stimulus is visible.

SWAP is designed to elicit a response from the blue sensitive pathway (S-cones for “short” wavelength cones and the koniocellular cells in the lateral geniculate body that

receive input from blue-sensitive retinal ganglion cells) while the intense yellow background is used to suppress (i.e., adapt or fatigue) the relative sensitivity of both the green (M-cones for “middle” wavelength cones) and the red cones (L-cones for “long” wavelength cones). Sensitivity thresholds are determined by increasing the luminance (i.e., light intensity) of the blue stimuli from less visible to more visible and are expressed in dB (FIG 10-7). Nevertheless, the numerical dB values are not directly comparable to those obtained with SAP.

### DESIGN OF SHORT WAVELENGTH AUTOMATED PERIMETRY (SWAP)



**FIGURE 10-7** SWAP allows the determination of sensitivity thresholds by showing blue stimuli of increasing light intensity on an intense yellow background. Sensitivity thresholds are expressed in dB but are not directly comparable to results from SAP.

Like other types of function-specific perimetry, SWAP has also been shown to be useful for early glaucoma detection.<sup>13,14</sup> Unlike flicker perimetry, it is influenced by media opacities and blur.<sup>15</sup>

The task of performing SWAP is easy to understand for the patients (seen or unseen). Nevertheless, this test is challenging for patients because the intensity of the yellow background makes it difficult to perceive the blue stimuli. This results in increased test-retest variability.<sup>16,17</sup> In

addition, the patient’s eye needs to adapt to the very intense background for several minutes before starting the test in order to avoid false results. This light adaptation is time-consuming and makes SWAP an overall longer test to perform than SAP.

However, given a patient who is able to perform the test reliably, SWAP is a useful perimetric test. **BOX 10B** provides practical guidance on how to best administer a SWAP test.

**HOW TO ADMINISTER A RELIABLE SWAP TEST****BOX 10B**

Most points highlighted in Chapter 3 on how to run a reliable visual field test also apply to SWAP perimetry. However, particular attention needs to be given to some specific points.

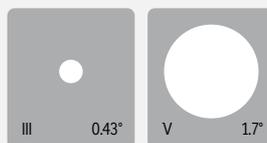
For SWAP, allow the patient's eye to adapt to the very intense background for several minutes before starting the test in order to avoid untrustworthy results. Patients should be instructed to press the response button when they see a blue light presented anywhere in the bowl. The examiner should let the patient know that the color of the stimulus may appear to be slightly different from blue, as some patients report seeing the stimulus as bluish or purplish.

SWAP is a more challenging test to perform than SAP. The examiner should closely monitor the patients as they are taking the test, to identify any need to rest. Particular attention should also be paid to reliability indices to ensure that patients are performing the test to the best of their ability. It is often helpful to provide a brief demonstration test to familiarize the patient with the test procedure.

## STIMULUS V FOR PATIENTS WITH LOW VISION

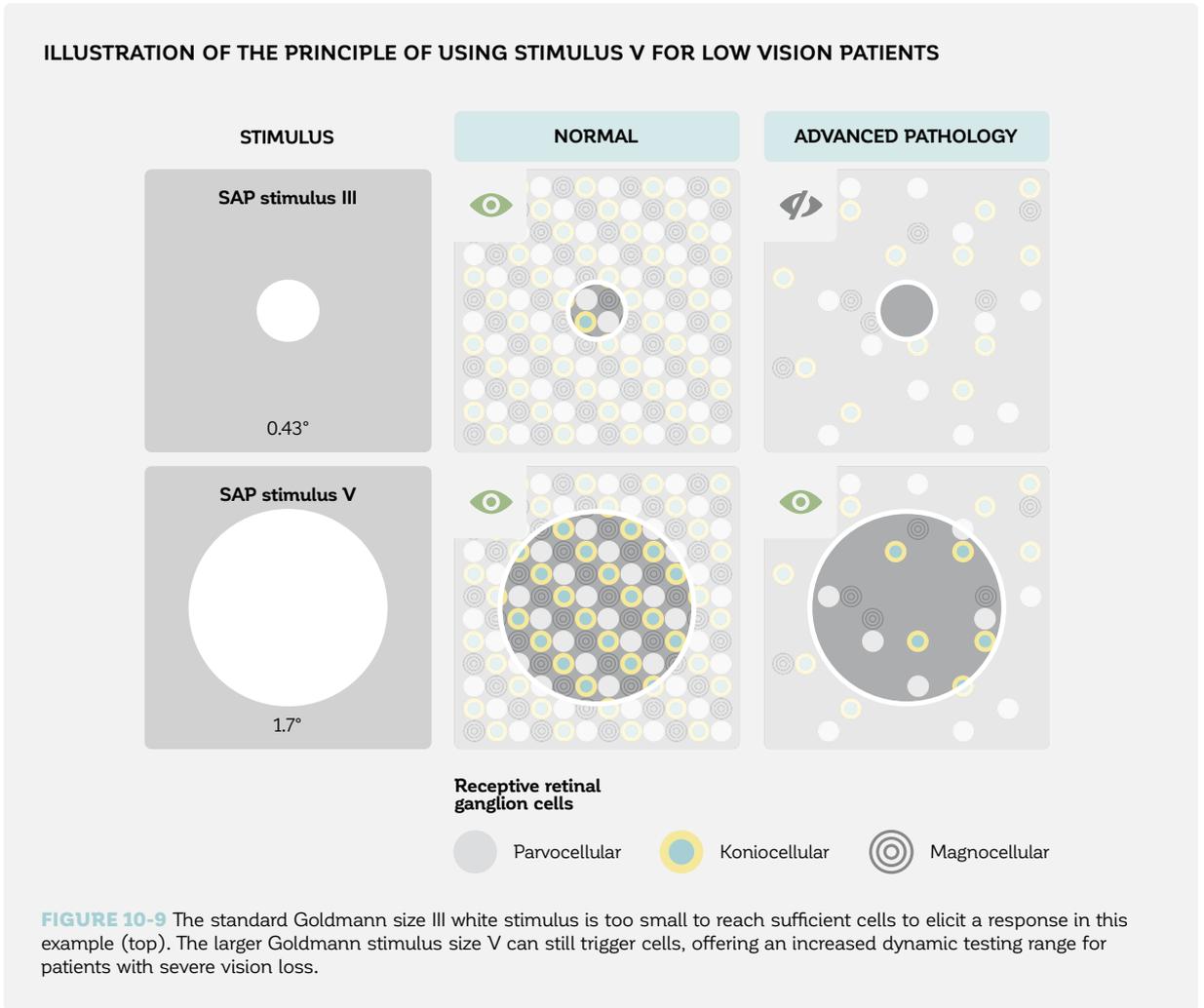
There is a limit to the visibility of the standard size III white perimetric stimulus in patients with significantly impaired sensitivity. This is because there are no longer enough intact cells to elicit a response to a stimulus even though the patient has some vision remaining (FIG 10-9). In order to overcome this floor effect and to increase the

dynamic range in regions of poor vision, the Goldmann stimulus V can be used. When this stimulus, which is 16 times larger in area than the size III stimulus (FIG 10-8), is displayed for a longer period of time (i.e., 200 ms), it provides a useful alternative perimetric stimulus for patients with severe visual field loss.

**GOLDMANN STIMULUS SIZE III VS V FOR LOW VISION**

**FIGURE 10-8** The Goldmann stimulus size V used for patients with severe vision loss is 16 times larger in area than the standard Goldmann size III. Both are displayed with the same intensities on the same white background, but due to its greater size, the size V stimulus is more visible for low-vision patients than the size III.

Because the larger stimulus V reaches more intact cells, longer can,<sup>18</sup> as illustrated in the example shown in it can elicit a response when the smaller stimulus III no **FIG 10-9.**



In addition to the increased dynamic range, the larger and thus more visible stimulus size V has also been shown to have significantly lower test-retest variability compared to stimulus size III.<sup>19-22</sup> This is thought to be due to a larger stimulus being easier to see, which is essential in low-vision patients who struggle much more with perimetric testing than patients with normal visual fields.

Besides using stimulus size V for low-vision patients, use of the low-vision strategy, which starts with the most

intense stimulus available (as illustrated in FIG 6-3), is also recommended. This approach saves valuable testing time and is easier for patients to complete. For more information on the low-vision strategy, see Chapter 6.

Because stimulus sizes III and V are not directly comparable, switching to stimulus V is only recommended for patients for whom testing with stimulus III no longer renders useful clinical results, either due to the floor effect or the large variability of stimulus III.

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# CHAPTER 11

## KINETIC PERIMETRY

### WHAT IS KINETIC PERIMETRY?

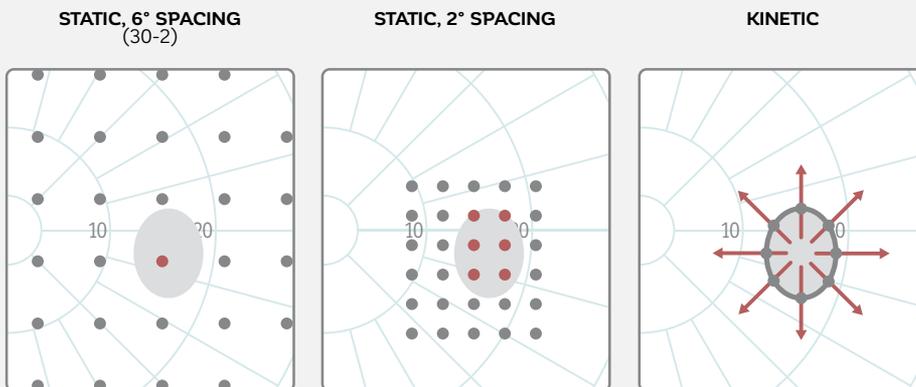
#### LIMITATIONS OF STATIC PERIMETRY

##### LOW SPATIAL RESOLUTION

Static perimetry is currently the most commonly used type of perimetry. With static perimetry, sensitivity thresholds are determined at a specified number of test locations. These thresholds are then compared to the sensitivity thresholds of normal controls of the same age as the patient. Small changes in sensitivity can be detected with high accuracy. Because this is essential for detecting glaucoma and monitoring its progression, static perimetry is well suited for glaucoma care and management.

The major drawback of static perimetry is that the most common static test patterns have low spatial resolution. Because testing the entire visual field with a densely spaced test grid would be very time-consuming, only a representative sampling of potential visual field locations is tested. As a result, static perimetry provides very limited information about small-sized scotomas such as the blind spot, as shown in **FIG 11-1**. Additionally, defining the boundaries of scotomas can also be compromised by the low spatial resolution of static perimetry.

#### LOW SPATIAL RESOLUTION WITH STATIC PERIMETRY

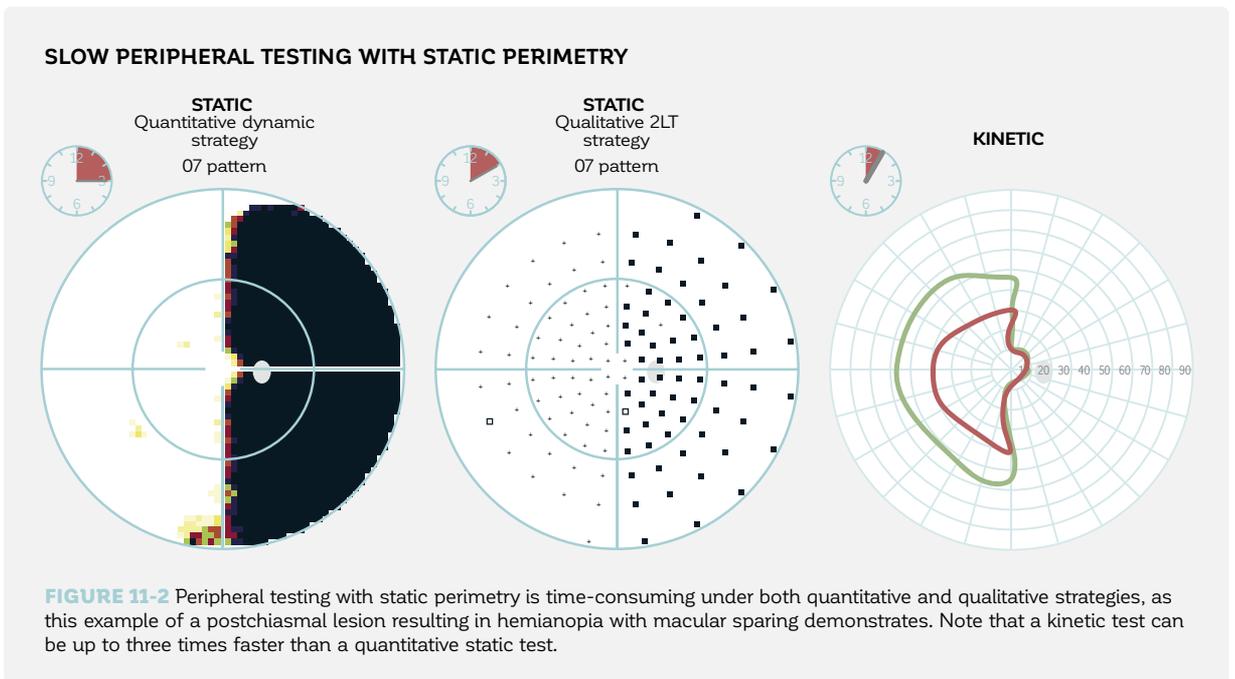


**FIGURE 11-1** Static perimetry has relatively low spatial resolution as demonstrated in this example in which the blind spot is tested. Using a 30-2 pattern with 6° spacing, only one or two locations are tested within the blind spot, providing no details about its size. Using a customized test pattern with 2° spacing provides higher, but not optimal resolution, while increasing test duration. Kinetic perimetry in this situation provides much higher spatial resolution with similar or lower test duration.

### SLOW PERIPHERAL TESTING

Static perimetric testing is typically limited to the central 30° visual field because this is the most crucial area of visual function and the region in which most early and moderate glaucomatous scotomas occur. When static perimetry is performed in the periphery, it is often used in a qualitative way such as in legal documentation or visual disability tests (e.g., visual field driving examinations,

FIG 5-13) or with widely spaced test grids such as in the G-Periphery pattern (FIG 5-6) for glaucoma to save test time. More detailed full threshold tests like the 07 pattern (FIG 5-11) require considerable test time and are too long for some patients to complete reliably. In addition, their accuracy is still limited due to the large extent of the peripheral visual field as illustrated in FIG 11-2.



## DESCRIPTION OF KINETIC PERIMETRY

Kinetic perimetry is an alternative method to static perimetry. Its major advantages are that it provides higher spatial resolution, is faster for peripheral testing and involves greater interaction between the examiner and the patient. It has the same goal as static perimetry, in

that it is used to map a patient's hill of vision in order to identify regions of normal and abnormal sensitivity to light. However, the procedure used to achieve this goal is fundamentally different.

### MOVING STIMULI ALONG VECTORS

With kinetic perimetry, sensitivity thresholds are determined by moving stimuli of various sizes and light intensities from a region of non-seeing to a region of seeing. The trajectory of the stimulus is called a vector.

As in static perimetry, the patient is asked to press the response button once the stimulus is seen. The specific

visual field location at which that response occurs has a sensitivity threshold equal to the specific light intensity used along the vector. The process continues so that all regions of the visual field are evaluated with this light intensity and stimulus size. This procedure is then repeated with stimuli of different intensities and size so that a map of visual field sensitivity can be generated (FIG 11-3).

### ISOPTERS

When a sufficiently large number of vectors are tested throughout the visual field with the same stimulus, the response points of each vector can be connected to form a boundary of equal sensitivity. This boundary is called an isopter and is comparable to the contour line on a topographical map. If a person has normal vision, then all points inside the isopter are areas of seeing and all points outside the isopter are areas of non-seeing for a given

light intensity. In pathological situations this does not always apply because within the isopters there may be smaller areas of non-seeing (scotomas) that will be discussed in the next section. Several isopters can be drawn by varying the size and intensity of the stimuli from more visible (larger and more intense) to less visible (smaller and dimmer) targets.

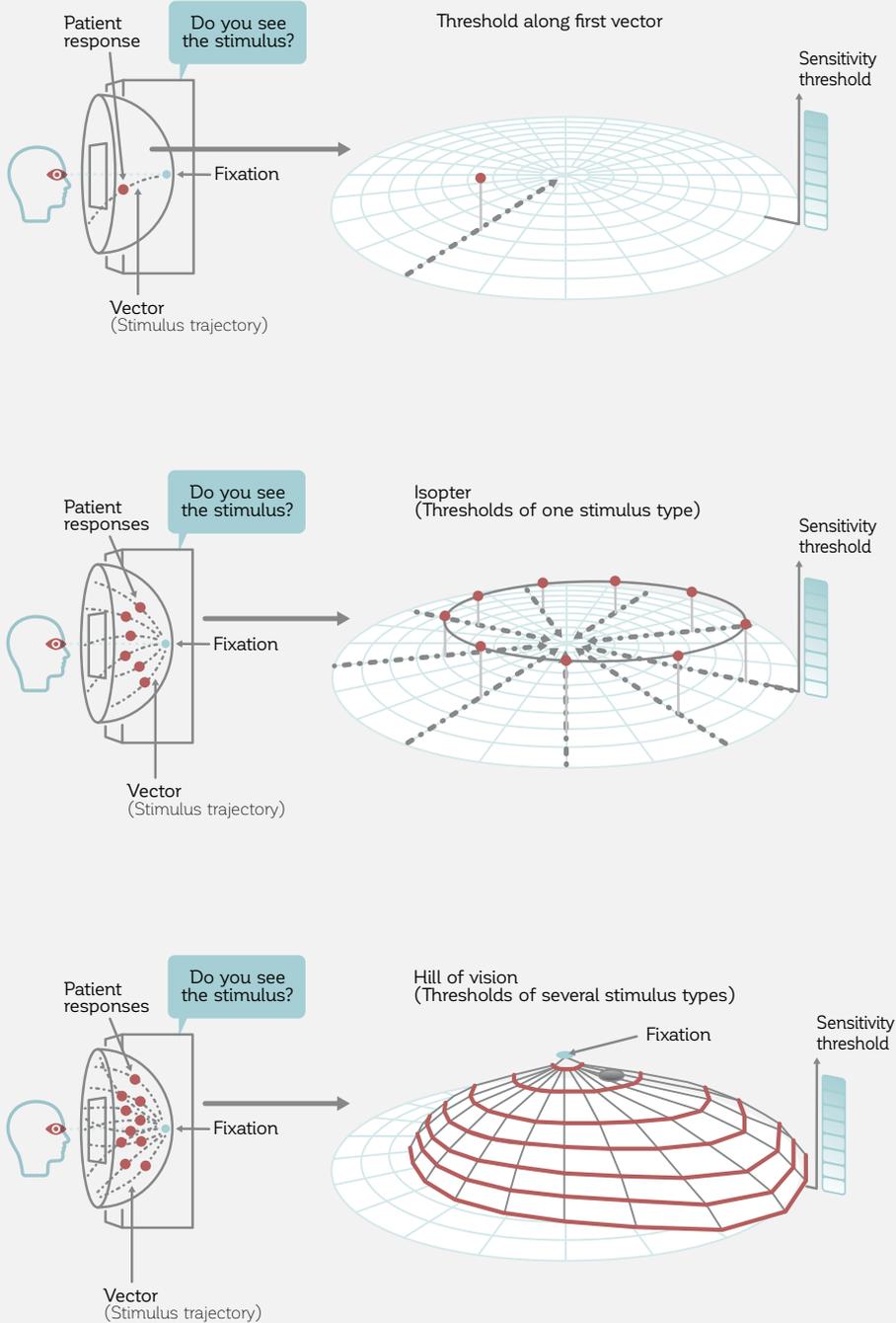
### SCOTOMAS

Not all locations within a given isopter are areas of seeing. There may also be areas of non-seeing (i.e., scotomas). Using the analogy of the hill, these areas of non-seeing are like lakes or local depressions on the hill of vision, which are not identifiable using the procedure described above. Instead, static points of the same intensity as the outer isopter already drawn have to be evaluated at different locations inside the isopter to locate scotomas. These

evaluations are called spot checks. Once located, radial vectors can be drawn moving again from the area of non-seeing (here the location of the center of the scotoma) towards an area of seeing (i.e., outwards).

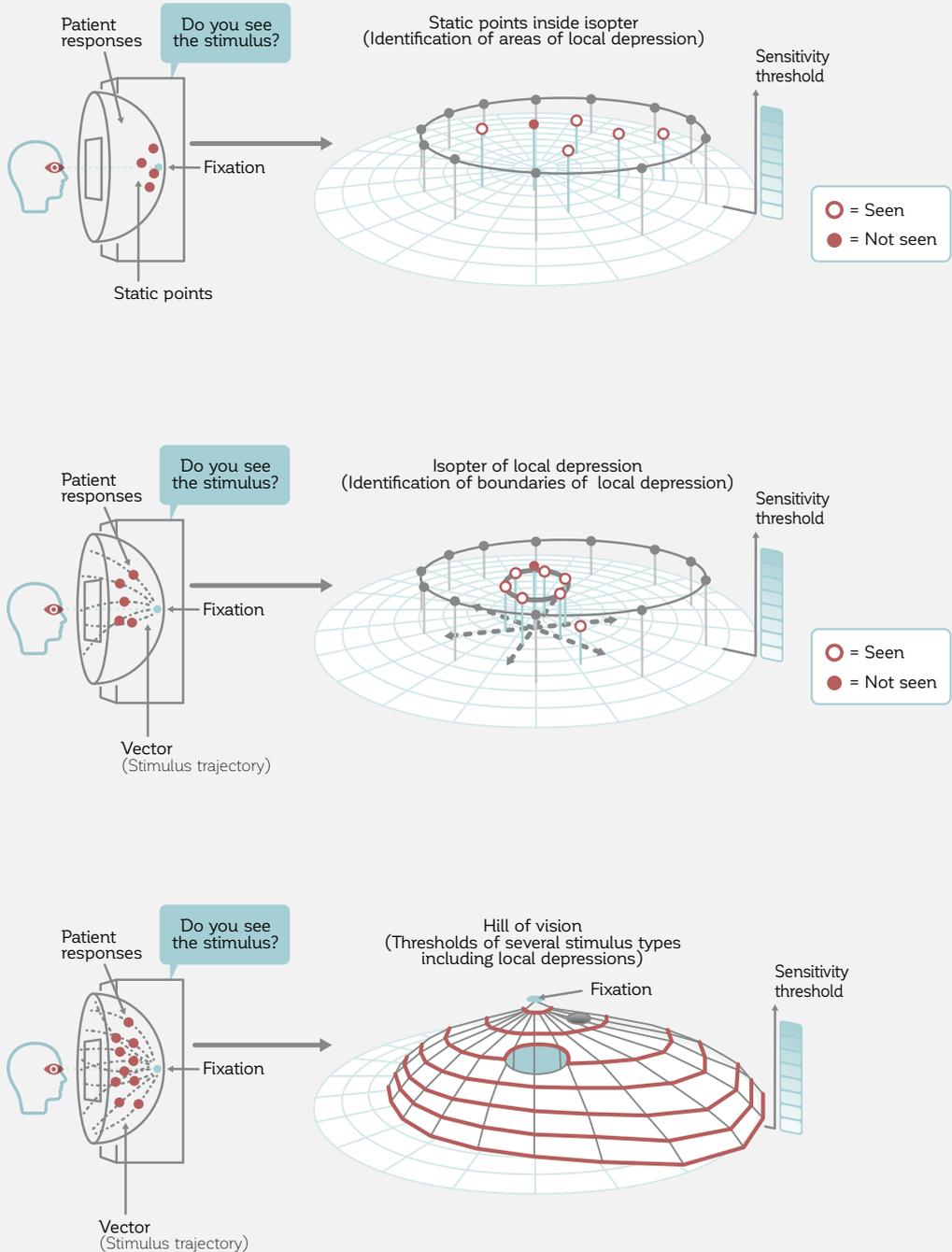
Using this approach and combining all isopters and scotomas, the hill of vision can be drawn as illustrated in FIG 11-4.

### KINETIC TESTING METHODOLOGY



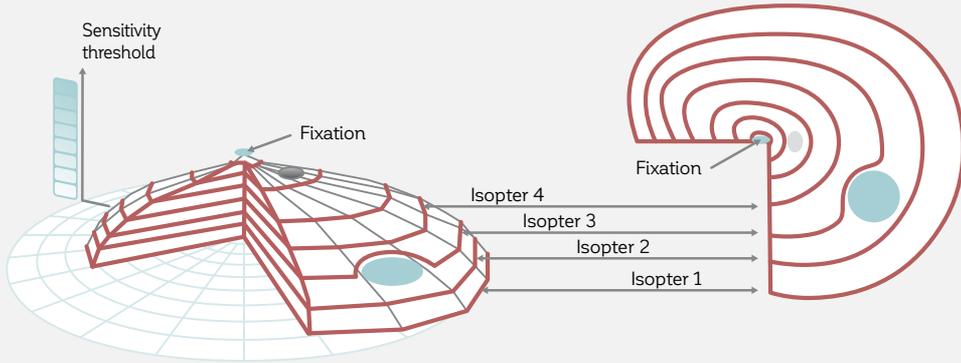
**FIGURE 11-3** In kinetic perimetry, sensitivity thresholds are determined by moving a stimulus of fixed intensity and size along a vector from an area of non-seeing to an area of seeing (top). In a normal visual field, the area of non-seeing to seeing is typically in the direction from the periphery towards fixation. The hill of vision can be drawn by connecting several thresholds of equal sensitivity (middle) thus forming an isopter and by drawing several isopters (bottom). An isopter can be thought of as a contour line of the hill of vision.

**IDENTIFICATION OF LOCAL SCOTOMAS WITH KINETIC PERIMETRY**



**FIGURE 11-4** Static points (spot checks) are used to identify areas of local depression. Once identified, radial vectors originating from the location of the local depression allow drawing the isopter representing the boundary of the local depression. The hill of vision can be drawn by connecting several thresholds of equal sensitivity thus forming an isopter and by drawing several isopters.

**HILL OF VISION AS A TOPOGRAPHICAL MAP**



**FIGURE 11-5** Kinetic results are displayed similarly to a topographical map. Lines of equal stimulus intensity and size are called isopters and are used to display the hill of vision in a two-dimensional map, similar to contour lines on a topographical map. Localized areas of non-seeing, such as that shown by the filled light blue circle, represent scotomas or areas of non-seeing for that target.

**THE HILL OF VISION AS A TOPOGRAPHICAL MAP**

Kinetic results are displayed as a topographical map. Similar to contour lines on a topographical map, isopters are used to display the hill of vision with its outline, its crevices, ridges and even local depressions as shown in **FIG 11-5**. In this manner the three-dimensional hill of vision can be represented in a two-dimensional drawing.

The procedure used to create the topographical map of

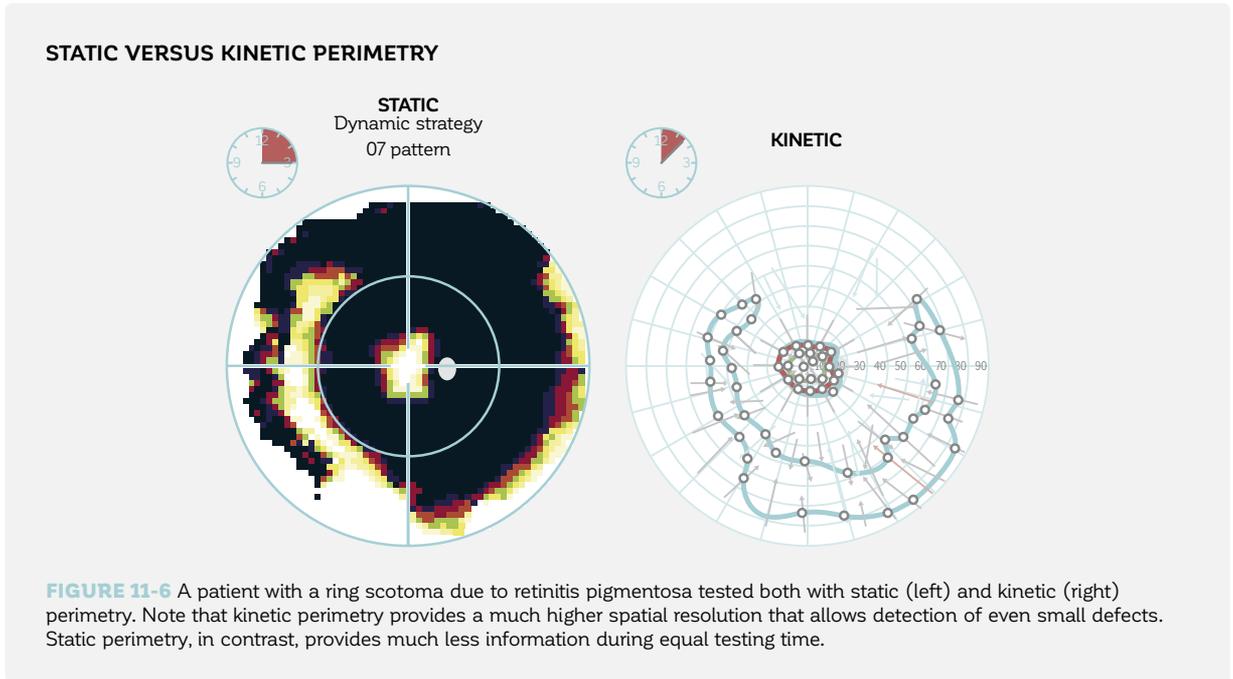
the hill of vision largely depends on its expected shape (i.e., the pattern of a specific pathology). In addition to the outline of the hill of vision, crevices, ridges and local depressions have to be identified individually, and the slope of sensitivity transitions should be noted. Because of this, kinetic perimetry today is not fully automated and requires an interaction between the examiner and the patient.

# WHY PERFORM KINETIC PERIMETRY?

## BENEFITS OF KINETIC PERIMETRY

In contrast to static perimetry, in which thresholds are carefully determined at a number of pre-determined locations (assessing a wide range of light intensities to determine thresholds at each location), kinetic perimetry searches for the location at which a given light intensity

will be at threshold (scanning through a large area and identifying a specific location). This leads to a number of very distinct advantages of kinetic perimetry over static perimetry.



### HIGH SPATIAL RESOLUTION

Kinetic perimetry is better at defining the pattern and shape of visual field loss than static perimetry, as illustrated in **FIG 11-6**. Because the patient can report seeing the stimulus at any location along the entire trajectory of a vector, many possible response locations can be mapped with a small number of vectors and the sequence of kinetic scanning can be different for each eye rather than using the same test pattern for all tests. This is especially beneficial if one is interested in identifying sharp-edged scotomas or steep isopter boundaries such as the deficits

present in quadrantanopia and hemianopia<sup>1</sup> or a constricted visual field in end-stage glaucoma.<sup>2</sup> It is also very beneficial if small scotomas need to be mapped reliably, such as the blind spot or a scotoma due to a retinal hemorrhage.

However, while stimulus intensities may be varied, typically only a small number of light intensities are used, making it challenging to detect small threshold changes throughout the hill of vision.

### FAST PERIPHERAL TESTING

Kinetic perimetry is a very efficient method of evaluating the periphery (beyond 30 degrees of eccentricity), because a large area can be covered in a relatively short time due to the moving stimuli,<sup>3</sup> as shown in **FIG 11-6**.

Several neurological and retinal diseases affect the peripheral visual field earlier or more significantly than the

central visual field; thus kinetic perimetry has many advantages for these conditions.<sup>1,2,4-6</sup>

Driving ability testing, legal blindness examinations or ptosis testing<sup>3,7</sup> also require peripheral visual field evaluation. Thus, in some countries (e.g., Germany), kinetic perimetry is a legally accepted method to perform these tests.

### **EASIER FOR PATIENTS**

Kinetic perimetry is highly flexible and interactive, and hence can be adjusted to the reliability and capabilities of the patient. Additionally, a moving stimulus is easier to see than a non-moving stimulus.<sup>8</sup> Because of these

factors, kinetic perimetry is often used for low vision patients<sup>4,5</sup> or patients who experience challenges in performing perimetry, including children.<sup>9</sup>

## **LIMITATIONS OF KINETIC PERIMETRY**

### **REQUIRES HIGH SKILL OF THE EXAMINER**

Even though kinetic perimetry is highly versatile, one of its drawbacks is that it cannot be fully automated for all clinical situations, as the shape and height of an individual hill of vision depends on pathology. Thus, kinetic perimetry requires much more interaction between the examiner and patient than static perimetry.

Conceptually, the difference between static and kinetic perimetry is similar to the difference between checkers and chess. Static perimetry uses a pattern of visual field locations (placed along either a Cartesian coordinate grid or a polar coordinate system) that are fixed for each test, and uses the same strategy to determine the sensitivity threshold for an increment of light on the uniform background. It is similar to checkers in that the procedure is essentially the same for each eye tested, which limits the amount of information one can obtain. Kinetic perimetry,

on the other hand, is a heuristic procedure that is highly interactive between the patient and the examiner. Every stimulus manipulation by the examiner affects how the patient will respond, and these responses will in turn influence the next maneuver of the examiner. In this sense, kinetic perimetry is similar to chess in that it incorporates a flexible and adaptive strategy.

Being able to correctly map all possible clinical situations requires great skill. Depending on prior knowledge, it may take a training period of three months or more for the examiner to become fully familiar and comfortable with the test procedure in any situation. In this view, it is a very challenging procedure to implement on an automated device. With a skilled and experienced examiner, however, it is possible to obtain the highest quality information concerning the peripheral visual field.

### **VARIABILITY AMONG EXAMINERS**

There is no consensus or standard method of conducting kinetic perimetry, making it more challenging to compare results from one clinical center with the findings from another than it is with static perimetry. And even

within one clinical center, the quality and efficiency of kinetic perimetry can vary considerably from one examiner to the next.

COMPARISON BETWEEN STATIC AND KINETIC PERIMETRY		TABLE 11-1
	STATIC	KINETIC
<b>LOCATIONS</b>	Fixed number of pre-determined locations	Individually adjustable moving targets
<b>AUTOMATION</b>	Fully automated	Semiautomated, needs involvement of examiner
<b>SPATIAL RESOLUTION</b>	Low	High
<b>ACCURACY OF VISUAL SENSITIVITY THRESHOLDS</b>	Higher	Lower
<b>WHAT IT IS BEST AT DETECTING</b>	Small changes in sensitivity  Changes in central 30°	Small changes in spatial extent (e.g., sharp-edged scotomas)  Changes in periphery  Remaining vision in advanced disease  Defects in children
<b>COMMON USES</b>	Glaucoma  Macular diseases  Visual ability testing	Neuro-ophthalmological conditions  Peripheral retinal diseases  Low vision  Children

**CHALLENGING IDENTIFICATION OF SMALL SENSITIVITY CHANGES AND DIFFUSE LOSS**

While kinetic perimetry is better at identifying the patterns and shapes of visual loss compared to static perimetry, small sensitivity changes<sup>2,6</sup> and widespread or diffuse

loss are more difficult to identify with kinetic perimetry. A direct comparison between static and kinetic perimetry is provided in **TABLE 11-1**.

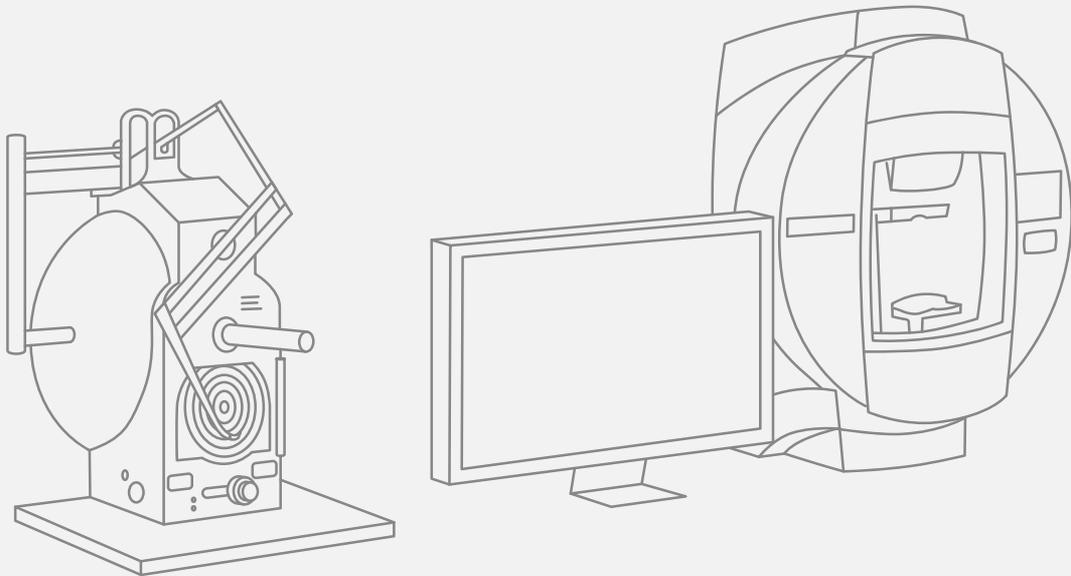
# HOW TO PERFORM KINETIC PERIMETRY

## THE GOLDMANN PERIMETER: KINETIC VISUAL FIELD TESTING

Quantitative kinetic perimetry was developed in 1946 by Hans Goldmann and Haag-Streit<sup>10</sup> and was the standard of visual field testing prior to the invention of the first automated perimeter, the Octopus 201, in 1974.<sup>11,12</sup>

Because of the flexible and adaptive properties of kinetic perimetry, the manual Goldmann perimeter (FIG 11-7) is still widely used and remains the reference for kinetic perimetry today.

**THE GOLDMANN PERIMETER AND ITS SUCCESSOR, THE OCTOPUS 900**



**FIGURE 11-7** The Octopus perimeters (right) retain all the characteristics of the manual Goldmann perimeter (left).

To allow for continuity, the Octopus kinetic perimeter retains all the characteristics of the manual Goldmann perimeter including the same flexible and adaptive properties. It has been shown to be fully comparable to a manual Goldmann perimeter.<sup>13-17</sup> In addition, it provides standardized test conditions and semiautomation of kinetic perimetry to optimize clinical workflow and increase consistency of results among examiners and centers.

**TABLE 11-2** summarizes the major differences and similarities between Octopus and Goldmann kinetic perimetries.

It is helpful to keep the legacy of manual Goldmann perimetry in mind because many definitions and uses stem from the time when the Goldmann perimeter was invented, and they are easier to understand when one is familiar with the manual Goldmann perimeter.

COMPARISON BETWEEN OCTOPUS KINETIC PERIMETRY AND GOLDMANN KINETIC PERIMETRY

TABLE 11-2

	OCTOPUS KINETIC PERIMETRY	GOLDMANN KINETIC PERIMETRY
<b>METHODOLOGY</b>	Computer controlled stimulus presentation	Manual stimulus presentation
<b>DESIGN</b>	Goldmann bowl (radius = 30cm) Background illumination 31.4 asb (10 cd/m <sup>2</sup> )	Goldmann bowl (radius = 30cm) Background illumination 31.4 asb (10 cd/m <sup>2</sup> )
<b>STIMULUS TYPES</b>	Goldmann sizes I to V Intensities 1a to 4e	Goldmann sizes 0 to V Intensities 1a to 4e
<b>STIMULUS SPEED</b>	Fixed (1 – 10°/s) Manually guided	Manually guided
<b>VECTOR TYPES</b>	Guided vector Free-hand vector Static points	Straight Curvilinear Static points
<b>INDIVIDUALIZATION &amp; AUTOMATION</b>	Full individualization Automation with added individualization Full automation	Full individualization
<b>ADDITIONAL FEATURES</b>	Reaction time compensation Normal isopter ranges	

## KEY DECISIONS IN KINETIC PERIMETRY

As with static perimetry, a number of key questions need to be asked before starting a kinetic test and the answers will largely determine the results that one is able to achieve. These questions are similar to those asked for static perimetry, but are answered differently. These questions are:

- Which **stimulus type** should be used?
  - Which **stimulus size**?
  - Which **stimulus intensity**?
  - Which **stimulus speed**?
- Which **testing methodology** should be used?
  - What is the **trajectory of the vector**?
- Can some of the testing be **automated**?

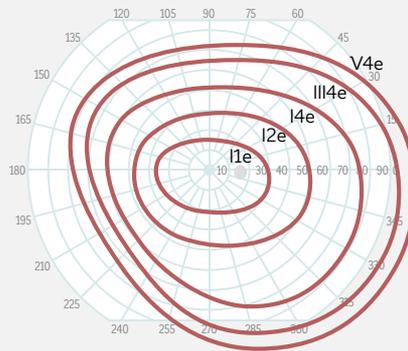
## STIMULUS TYPES

Similarly to the questions asked in static perimetry, the first question about stimulus type in kinetic perimetry has no clearly right or wrong answer. One can define standard testing methodologies for certain situations and follow them through for each patient.

In order to scan a patient's entire hill of vision, one needs more and less visible stimuli to be able to identify different

isopters and scotomas. Stimuli can be made more visible by changing the stimulus size or intensity or by varying both together. For a normal visual field, the most visible stimuli lead to the largest isopters and the least visible stimuli lead to the smallest isopters. In **FIG 11-8**, common stimuli are shown that allow a thorough assessment of the full visual field.

### NORMAL ISOPTERS FOR DIFFERENT STIMULUS TYPES



**FIGURE 11-8** By using stimuli of different size and intensity, the hill of vision of a person with normal vision can be drawn. The III4e stimulus is larger and more intense and leads to a larger isopter than the smaller and dimmer I1e stimulus.

### STIMULUS SIZE

Octopus kinetic perimetry uses five distinct stimulus sizes, Goldmann I to V, with Goldmann I being the smallest and each subsequent size being four times larger in area than the previous one as shown in **TABLE 11-3**. The sizes and naming scheme stem from the convention used by the manual Goldmann perimeter and were kept exactly the same to provide direct continuity.

While there is no standardized procedure for kinetic perimetry, and stimulus selection depends on the examiner and the patient, Goldmann sizes I to V at the highest intensity are commonly used to test the far and intermediate peripheral visual field. Goldmann sizes I and II combined with lower intensities are then used for the highly sensitive central area because the isopters of the

larger stimuli III to V are detected outside of the central visual field in people with normal vision. Goldmann size I is also often used to map small or shallow scotomas that require high spatial resolution (e.g., the blind spot). Although size 0 is available on the Goldmann perimeter, it has not been included on the Octopus perimeter. This is because the size 0 stimulus is difficult to perceive through the optics of the eye, which can lead to unreliable and artefactual test results. The size 0 stimulus also has a limited dynamic range.

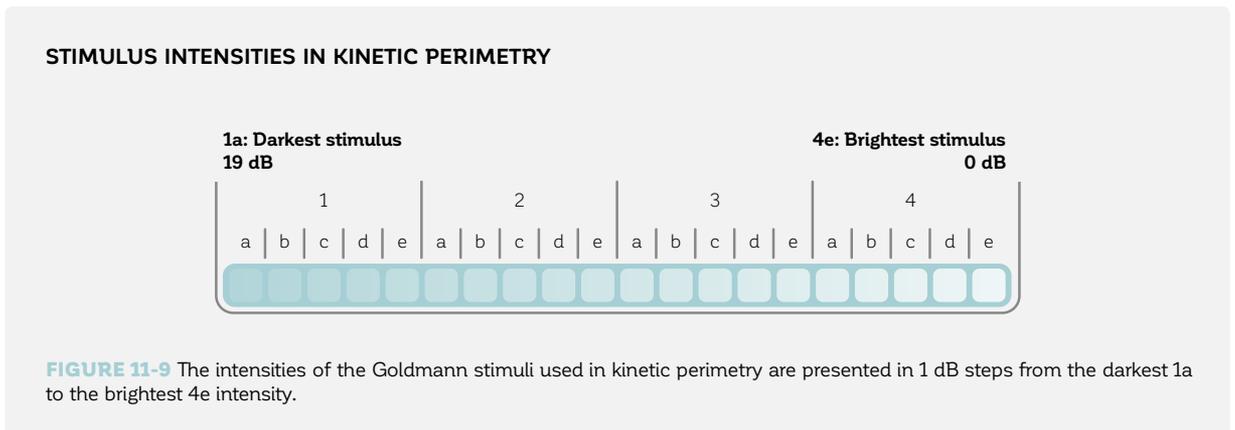
Goldmann V is the largest and most visible stimulus and is often used for low vision patients who cannot see smaller stimuli.

GOLDMANN STIMULUS SIZES I TO V			TABLE 11-3
SIZE	DIAMETER	AREA [MM <sup>2</sup> ]	RECOMMENDED FOR
V		64	Low vision (end stage disease) Far periphery (determination of anatomical visual field borders)
IV		16	
III		4	Periphery Standard for static testing
II		1	
I		0.25	Peripheral and central testing Small area and high resolution (e.g., blind spot, small or shallow scotomas)

**STIMULUS INTENSITY**

Stimulus intensities in Octopus kinetic perimetry range from 1a to 4e, with 1a being the dimmest and 4e being the brightest. A total of 20 distinct stimulus intensities are available, as shown in FIG 11-9. The naming convention

for stimulus intensity stems from the manual Goldmann perimeter (BOX 11A). Because this scale is the accepted standard in kinetic perimetry, it is also incorporated into Octopus kinetic perimetry.



**FIGURE 11-9** The intensities of the Goldmann stimuli used in kinetic perimetry are presented in 1 dB steps from the darkest 1a to the brightest 4e intensity.

As a rule, higher intensity stimuli such as the 4e are used for peripheral testing and dimmer stimuli such as the 1e are used for central testing. Using stimuli with very similar intensities adds little diagnostic information because their isopters are very close to each other and would clutter the picture and represent a generally poor trade-off between test duration and information gained. Thus, stimuli with several dB differences in intensity (3 to 5

dB) are usually chosen. When mapping absolute defects (i.e., areas of blindness), none of the stimuli are visible to the patient. Then, the brightest 4e stimulus can be selected, as it is the easiest for the patient to see and possibly respond to at the borders of the defect. When there is a wide separation between contour lines (isopters or scotomas), intermediate stimulus intensities can be selected to test the region between the isopters.

#### BOX 11A

#### THE ORIGIN OF THE STIMULUS INTENSITY SCALE

The manual Goldmann perimeter only contains one bright light source. In order to generate dimmer stimuli, filters are placed in front of the light source, making the stimulus dimmer.

There are two sets of filters. Filters a, b, c, d and e dim the stimulus by 1 dB, and filters 1, 2, 3 and 4 dim it by 5 dB. In combination, 20 different stimuli can be produced, with the brightest, 4e, representing a maximum stimulus brightness of 1,000 asb (315 cd/m<sup>2</sup>).

#### STIMULUS SPEED

Each stimulus for Octopus kinetic perimetry moves at a constant speed to allow for reproducible results. The stimulus speed should be selected to optimize the trade-off between accuracy and test duration. While the influence of patient reaction time is smaller for a slower stimulus, the longer testing time can result in fatigue. In such cases, using a stimulus that moves faster leads to more reproducible results.

As a rule, stimulus velocities of 3–5°/s have been shown to optimize the trade-offs among accuracy, reliability and efficiency<sup>13,18</sup> and are recommended as a standard setting. For small scotomas such as the blind spot, slower stimuli of 2–3°/s are recommended as the clinically relevant spatial changes are small and are more accurately mapped with a slower stimulus.

## GENERAL TESTING METHODOLOGIES

Finding the adequate testing methodology for any patient is a process that requires an experienced examiner who can adapt to the patient's responses. Consulting a textbook focusing specifically on kinetic perimetry<sup>19-21</sup> is recommended for guidance. In addition, obtaining in-

struction and advice from a colleague highly experienced in performing this procedure is highly recommended.

The next sections will illustrate key concepts of kinetic perimetry as a starting point for beginners, but are insufficient to attain high proficiency in kinetic perimetry.

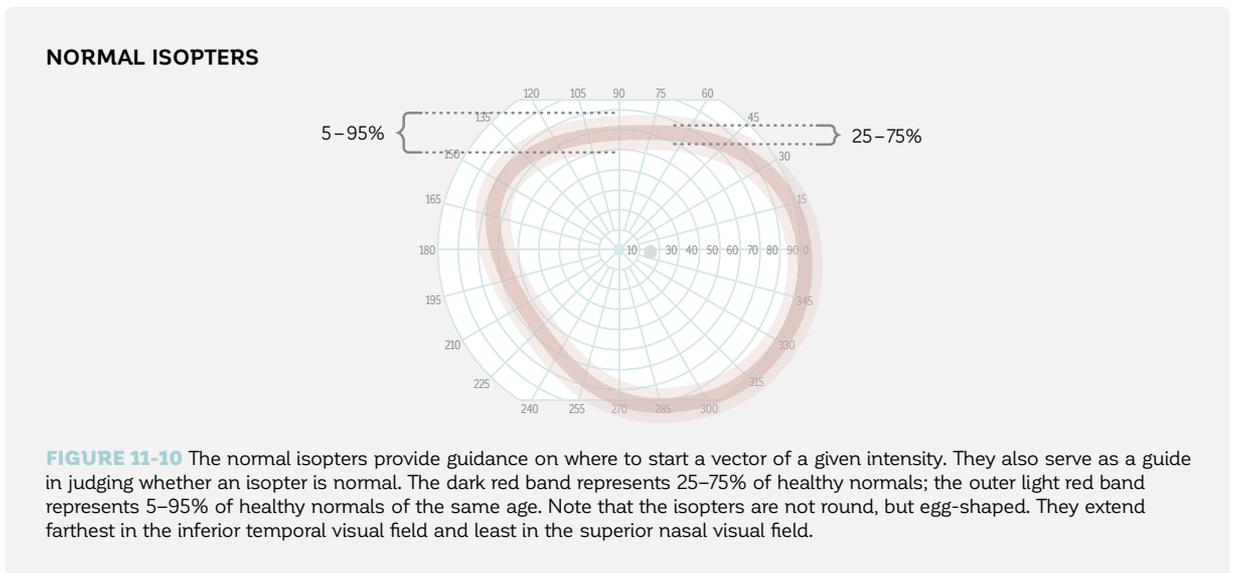
### IDENTIFICATION OF NORMAL ISOPTER LOCATION AND SHAPE

For each stimulus size and intensity, Octopus kinetic perimetry automatically provides the age-matched normal isopter location as a reference. The inner dark central band represents 25–75% of age-matched normals; the outer light band denotes 5–95% of age-matched healthy normals, as shown in **FIG 11-10**.

These zones support at-a-glance identification of deviations from normal and are especially helpful in interpreting central visual field defects and generalized diffuse or widespread loss. As the hill of vision is rather flat from the mid-periphery to the macula, those isopter locations are significantly influenced by age and only comparison

to age-matched normative data will allow correct interpretation of the results. As the hill of vision is rather steep towards the far periphery, large age-related sensitivity changes have only a small influence on isopter location.<sup>21-23</sup>

In practical terms, the normal isopter location provides guidance on where to start placing vectors. Placing vectors far outside of a normal isopter would only waste time, as the patient cannot see the stimuli in these areas. Conversely, starting too near the anticipated location of detection can make the patient unprepared to respond and can produce untrustworthy results.



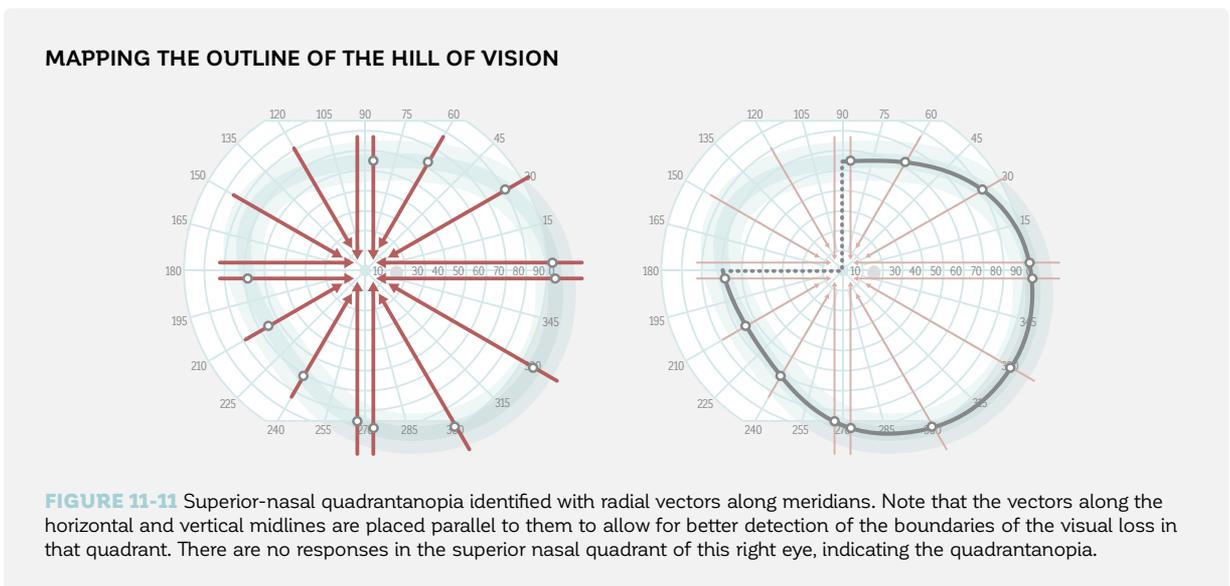
### MAPPING THE OUTLINE OF THE HILL OF VISION

The overall outline of the hill of vision provides valuable information about a patient's visual field because deviations from normal isopter shapes indicate abnormal visual fields. Thus, mapping the outline of the hill of vision is usually the first step in kinetic perimetric testing. To map the outline of the hill of vision, stimuli are moved from the peripheral end of the normal band towards the center (fixation) along a given radial meridian. By repeating this procedure with different stimulus types, the outline of the hill of vision can be drawn in detail, as shown in

**FIG 11-11.**

This procedure is a fast and easy way to identify quadrantanopia and hemianopia, as the isopter will dip in the

affected area of the visual field. As a general rule, stimuli should not move directly along the horizontal or vertical meridians, because inconsistent results will be obtained. This is because the boundaries of quadrantanopia and hemianopia are typically positioned along the horizontal and vertical meridians and a stimulus moving along these meridians cannot map them clearly. Glaucomatous deficits along the nasal horizontal meridian (e.g., nasal steps and arcuate scotomas) represent another example where the stimulus should not be moved along the horizontal meridian. Thus, for these conditions, the radial vectors are best placed with an offset of a few degrees and possibly parallel to the horizontal and vertical meridians.



### DETAILING THE BOUNDARIES OF AN ISOPTER

As with any contour or topographic map, the hill of vision may have crevices or depressions, which represent relative or absolute scotomas. As shown in **FIG 11-11**, these defects may not be identified with standard vectors moving from the periphery to the center. This is where customized individual assessment is needed. The examiner has to identify where there is a lack of normal response,

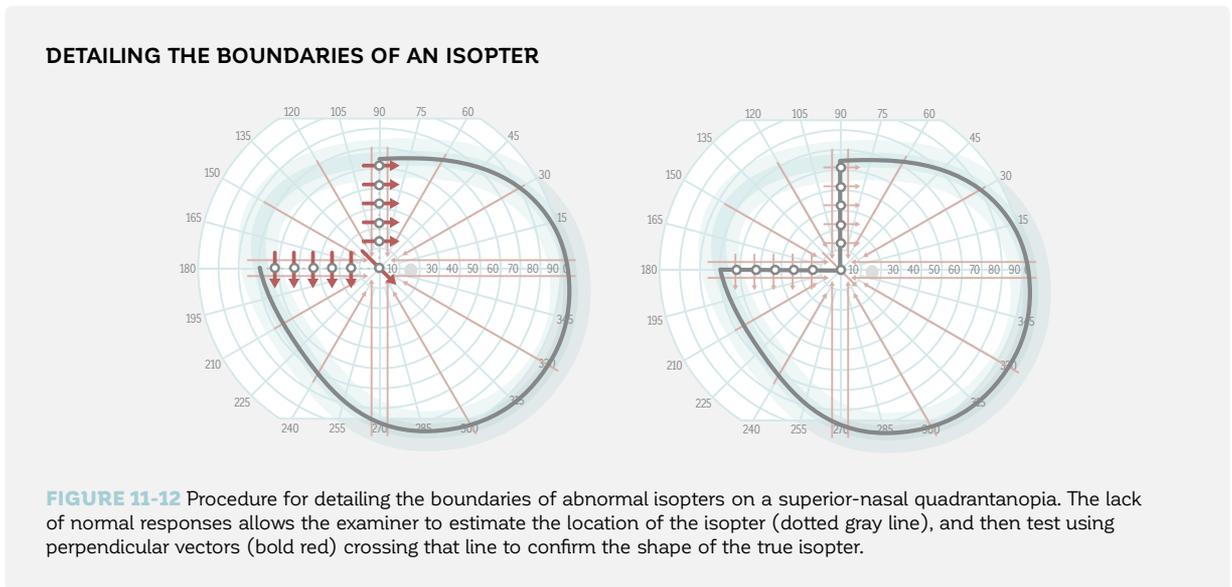
which either manifests as inconsistent with adjacent vectors or outside of the expected normal sensitivity, which requires further investigation.

Conceptually, the process is always the same. When alerted to a potential abnormal isopter shape, the operator should estimate where the isopter is likely to be. To verify

that this isopter is correct, additional vectors are drawn perpendicular to the anticipated boundary of the isopter, as shown in **FIG 11-12**. The perpendicular vectors optimize the likelihood that the hill of vision will be met “head-on”, which will reduce variability and provide more clinically meaningful information. Before initiating this process, it is important to recheck the abnormal isopter shape

to confirm that it is outside of the normal expected responses.

If the patient response is as expected on the imagined isopter, the isopter shape is confirmed and can be drawn. If not, the procedure has to be repeated, taking into account the new information until the isopter location is confirmed.



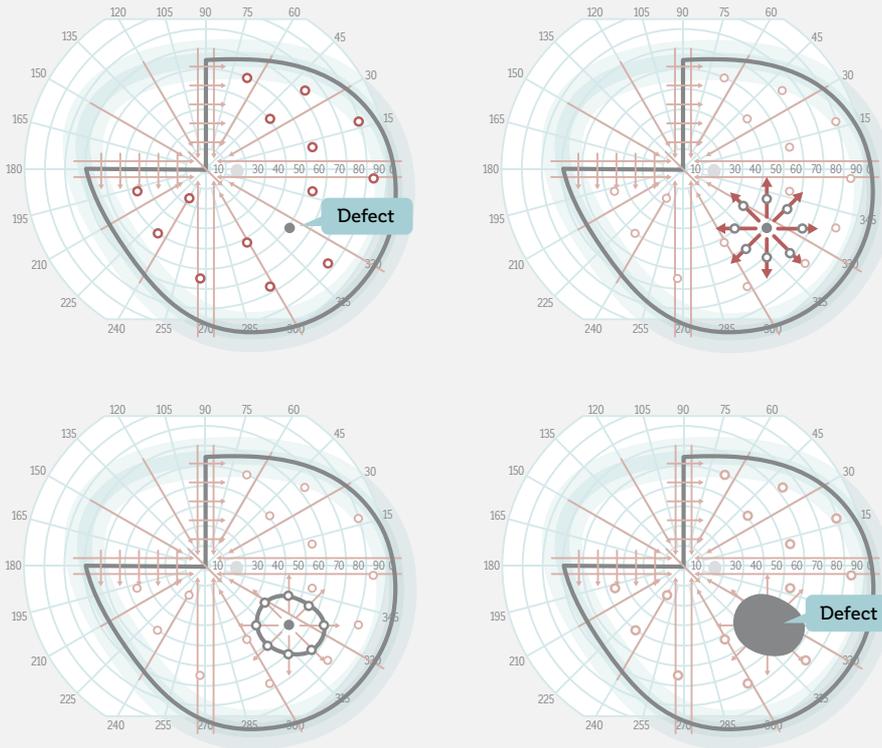
### IDENTIFICATION OF ISOLATED SCOTOMAS

While the procedure shown in **FIG 11-12** allows identification of the outline of the hill of vision, it usually misses isolated absolute defects or local depressions located inside of an isopter or between isopters. In keeping with the analogy of a hill, isolated defects can be thought of as lakes or depressions of different shapes and depths. In order to identify these defects, spot-checking inside the hill of vision must be performed. Spot-checking quickly examines locations between isopters using static points of the same size and intensity as the outer isopter, to find

possible areas of sensitivity loss (areas of non-seeing or scotomas). This allows for quick identification of scotomas as shown in **FIG 11-13**.

If areas of defects are identified, their boundaries can be mapped by moving radial stimuli from inside of the defects from the center towards its edges. This procedure can be repeated with stimuli of different visibility to define the slope and depth of the defect.

### IDENTIFICATION OF ISOLATED SCOTOMAS



**FIGURE 11-13** By placing a static point of the same intensity inside of an isopter or between isopters (spot checking, red circles), one can identify local defects that would otherwise be missed (no response, gray circle). Using radial vectors (bold red lines) from the center of the area of non-seeing (from the inside) to the area of seeing (to the outside) allows drawing the boundaries (gray bold line) of the defect in detail. For ease of reading, the defect should be filled with the appropriate color.

### MAPPING THE HILL OF VISION USING SEVERAL STIMULUS TYPES

By repeating the procedures described in the previous sections using different stimulus types with different sizes and intensities, several isopters can be drawn to characterize the patient's entire hill of vision. There are many tips and tricks to make this procedure efficient. A few of them are presented here.

When drawing a second isopter, placing the vectors of the second isopter with a radial offset to the ones used in the first isopter is recommended, as seen in **FIG 11-14**. In other words, the vectors used to determine the second isopter should be placed at different locations than those used to determine the first isopter. This increases the chance of

identifying an unnatural isopter shape without having to use extra vectors.

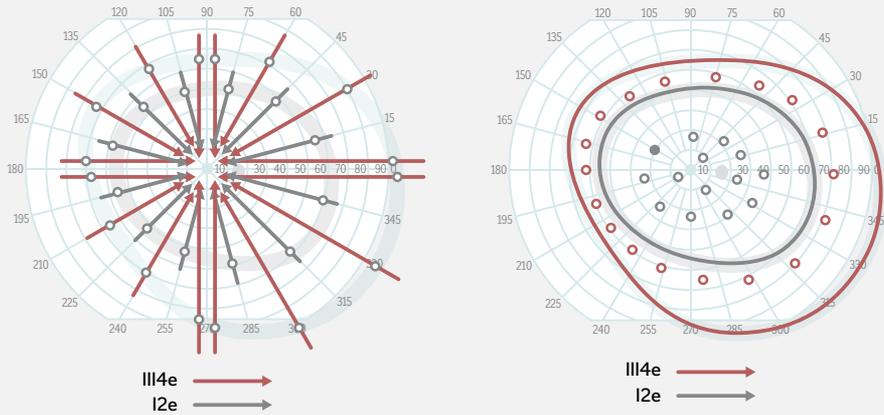
When spot checking to identify local areas of depression, the size and intensity of the outer isopter should be used between the outer and the inner isopters (**FIG 11-14**). Then, only the size and intensity of the inner isopter should be used farther towards the center.

It is also important to remember that there may be more than one isopter for the same stimulus size and intensity. There may be a region of detecting the target in the far periphery, with an area of non-seeing closer to fixation,

followed by a second area that can detect the target. This can occur in some cases of retinal disease, moderate to advanced glaucoma, and neurologic disorders affecting

the visual pathways. Because of this, it is important to make good use of spot checking and evaluate the entire visual field.

**PLACEMENT OF VECTORS AND STATIC POINTS USING DIFFERENT STIMULUS TYPES**

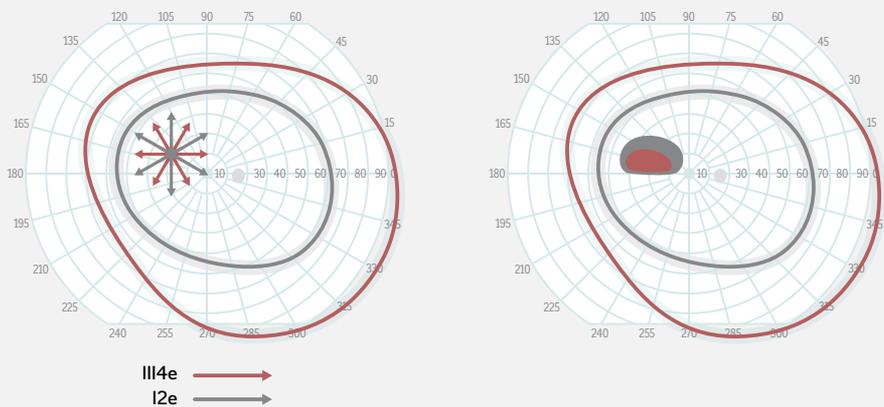


**FIGURE 11-14** Vectors of different stimulus sizes and intensities are best placed with an offset to increase the chance of identification of abnormal isopter shapes. When placing static points between two isopters, always use the intensity of the more visible outer isopter.

Local scotomas can be absolute defects with sharp-edged boundaries such as the blind spot or relative defects with a gentle slope on the edge of the defect as in glaucoma. To distinguish between the two, more than one stimulus is needed to characterize a local scotoma as can be seen in

**FIG 11-15.** For easy interpretation, these local depressions are typically filled with color to indicate that the corresponding stimulus cannot be seen within that visual field area.

**DISTINCTION BETWEEN ABSOLUTE AND RELATIVE SCOTOMAS**



**FIGURE 11-15** More than one isopter is needed to distinguish between absolute and relative scotomas. This example shows a nasal step for a glaucoma patient.

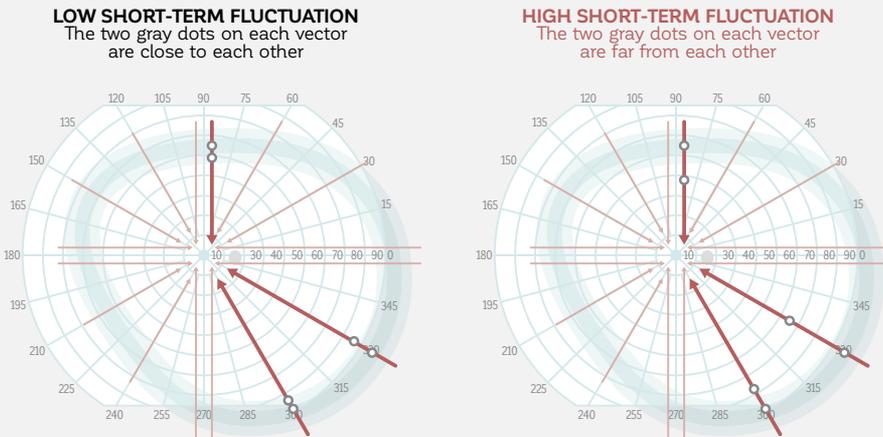
### CHECKING FOR VISUAL FIELD RELIABILITY

Like static visual field testing, kinetic perimetry has a patient-related subjective component and the reliability of the results largely depends on good patient cooperation and minimizing variability due to learning or fatigue effects.<sup>22,24,25</sup> Therefore, it is also essential to check for patient reliability in kinetic perimetry. While static perimetry uses global indices such as false positive and false negative catch trials and short-term fluctuation, kinetic perimetry employs other methodologies to test for similar reliability indicators.

To assess short-term fluctuation, it is worth duplicating

certain vectors to check for consistency of responses, as shown in **FIG 11-16**. To do this, two vectors should be placed as close together as possible (or repeated) and then compared for consistency. If the responses are reliable, the two patient responses should be very close together, as shown in the figure below to the left which means there is low test-retest variability. If they are separated, as in the example below to the right, it indicates an unreliable result with high test-retest variability. This procedure provides a good indicator for the quality of the results. Similarly, spot checking can be repeated at various locations to assess response consistency.

#### CHECKING FOR SHORT-TERM FLUCTUATION

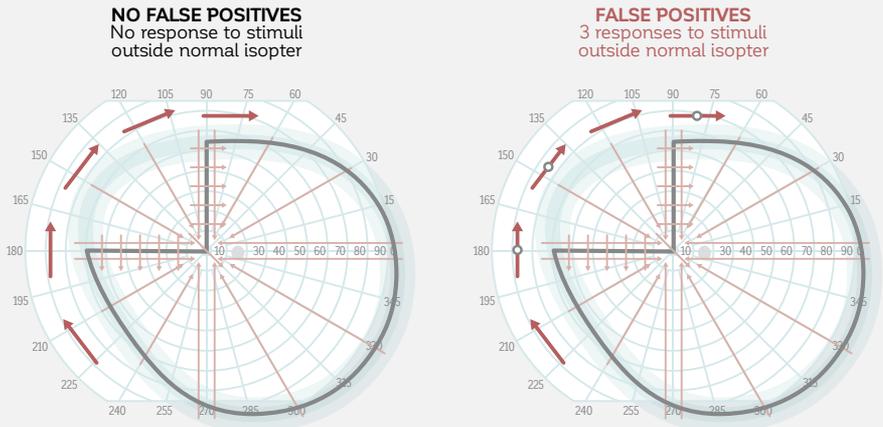


**FIGURE 11-16** By repeating some vectors, short-term fluctuation and thus test-retest variability can be assessed. If the responses are close together (left), it indicates good patient cooperation, good repeatability and high reliability. If the responses largely differ (right), it indicates an unreliable visual field.

In legal driving and blindness examinations performed with kinetic perimetry, it is worth checking for false answers to identify patients who may simulate responses or a lack of response (functional changes or visual measures that are non-physiologic and non-pathologic). This can produce visual field results that are either better or worse than the actual visual field sensitivity profile. As in static perimetry, it is possible to check for both false

positive and false negative answers even though the procedure is different. Checking for false positive answers can be easily done by presenting stimuli outside of the normal isopter area (**FIG 11-17**). By definition, the patient is not supposed to see these stimuli. If there are many positive responses, this is a strong indicator of a patient who is malingering.

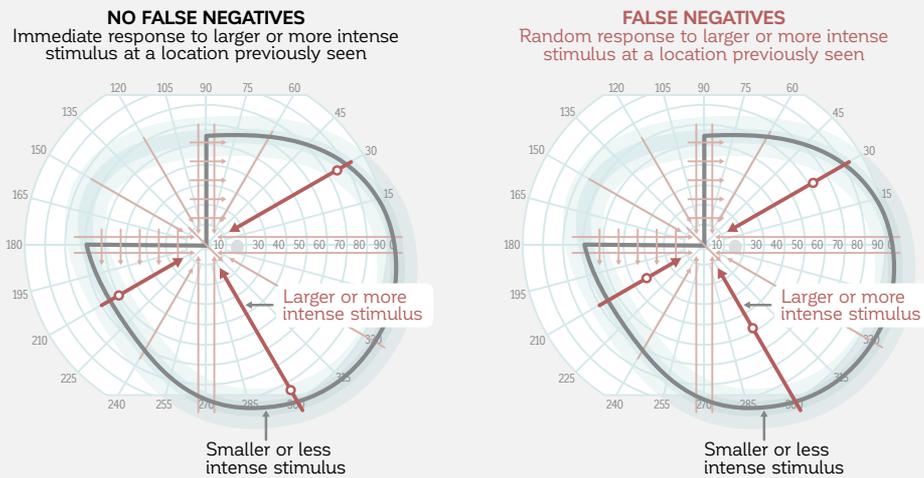
**CHECKING FOR FALSE POSITIVES**



**FIGURE 11-17** Checking for false positive responses can be done by placing vectors or static points outside of a normal isopter. If a patient responds, then these are false positives, as the patient cannot see them.

To detect false negative answers one places a more intense or larger stimulus at a location where the stimulus was previously detected. This stimulus should be easy for the patient to observe (FIG 11-18). Failure to see a more intense or larger stimulus than the one that was detected at threshold is considered to be a false negative response.

**CHECKING FOR FALSE NEGATIVES**

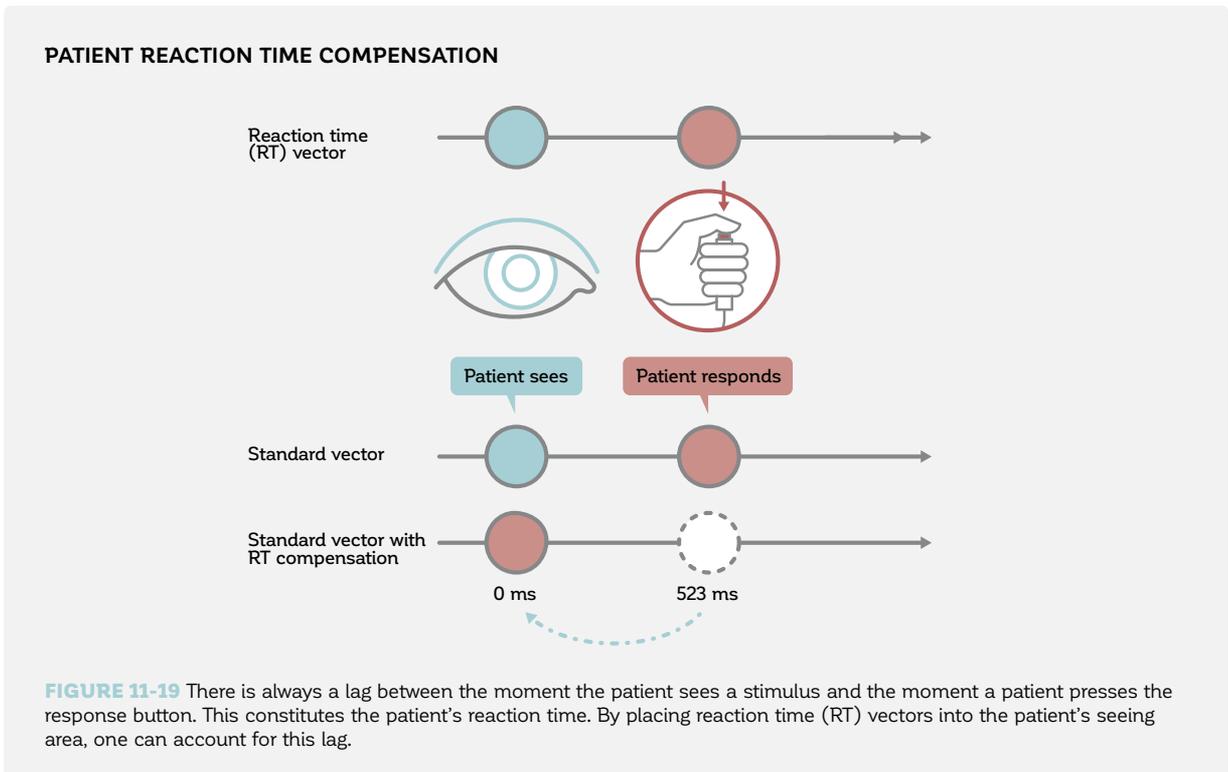


**FIGURE 11-18** Checking for false negative responses can be done by placing larger or more intense vectors or static points at a location where a smaller or less intense stimulus was previously detected. If a patient does not respond, then these are false negatives, as the patient should be able to see them.

### PATIENT REACTION TIME COMPENSATION

Patient reaction time influences the size of an isopter as the patient's response is produced some time after the stimulus is actually seen.<sup>22,23,26</sup> This also adds significant variability to the test procedure.<sup>24</sup> If a patient's responses were always instantaneous, outlines of the hill of vision would be larger and isolated defects would be smaller than they appear on the printout. This makes the interpretation of results challenging, especially in patients with long or inconsistent reaction times.

For this reason, Octopus kinetic perimetry offers the possibility of adjusting for patient reaction time by measuring its magnitude in the patient's intact visual field and applying a reaction time correction for it, as illustrated in **FIG 11-19**. In order to do so, the examiner should choose a reaction time vector of the same stimulus type as the isopter and place it into the patient's seeing area. The patient should be able to see the stimulus immediately as it is presented. Thus, the time between stimulus presentation and when the patient presses the response button represents the patient's reaction time.

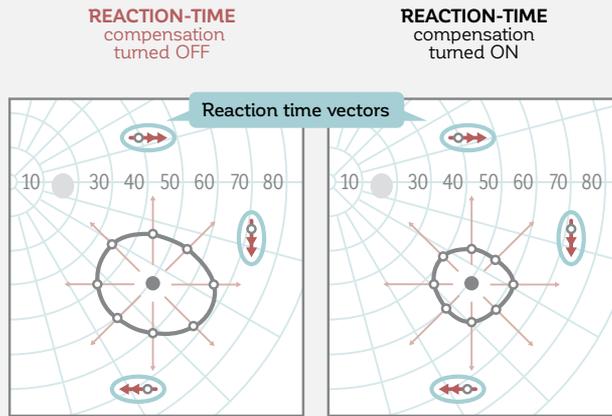


**FIGURE 11-19** There is always a lag between the moment the patient sees a stimulus and the moment a patient presses the response button. This constitutes the patient's reaction time. By placing reaction time (RT) vectors into the patient's seeing area, one can account for this lag.

For a precise measurement of patient reaction time, using the average reaction time obtained from two or three different vectors for each stimulus type is recommended,

placing the reaction time vectors close to the corresponding isopter. **FIG 11-20** provides an example of the clinical usefulness of reaction time compensation.

**EXAMPLE OF THE CLINICAL USEFULNESS OF REACTION TIME COMPENSATION**



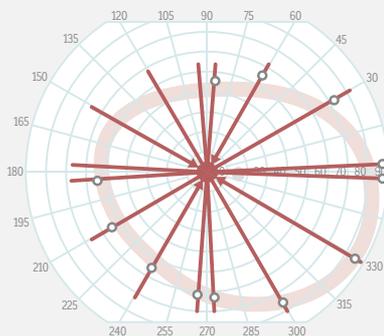
**FIGURE 11-20** Without reaction time compensation, local depressions look uncharacteristically large (left). By using reaction time vectors (bold red, double arrows) to determine the patient’s reaction time and by turning reaction time compensation on (right), the patient’s adjusted defect size is revealed.

**STEP-BY-STEP EXAMPLE OF KINETIC PERIMETRY**

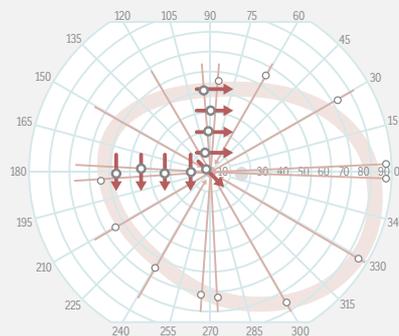
A real-life example of a complete kinetic test as performed in clinical practices is provided in **FIG 11-21**.

**STEP-BY-STEP EXAMPLE OF A KINETIC TEST WITH SEVERAL ISOPTERS (STEPS 1-2)**

1. Mapping outline of hill of vision  
14e, 5°/s



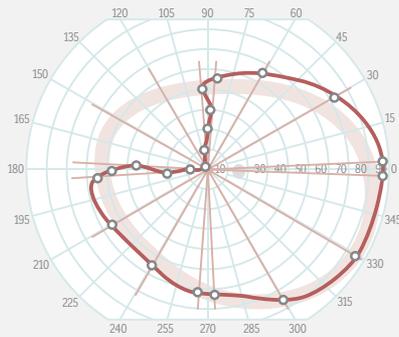
2. Detailing boundaries of isopter  
14e, 5°/s



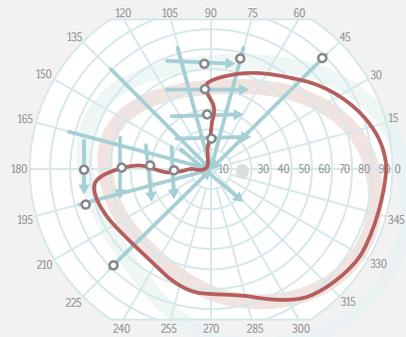
**FIGURE 11-21** This example above shows a full kinetic perimetric test of a quadrantanopia with 4 isopters (shown here in blue, red, gray and green), static points and reaction time compensation. Checks for consistent results and false positives are not shown in this example.

### STEP-BY-STEP EXAMPLE OF A KINETIC TEST WITH SEVERAL ISOPTERS (STEPS 3-8)

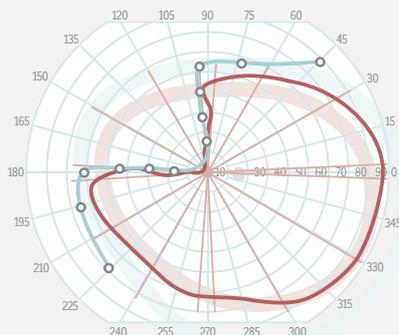
3. Drawing isopter  
 $I4e, 5^\circ/s$



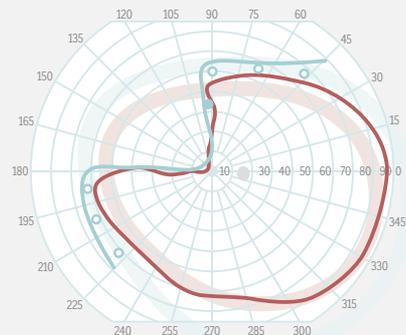
4. Mapping the next outline of hill of vision & detailing boundaries of isopter in abnormal response region  
 $V4e, 5^\circ/s$



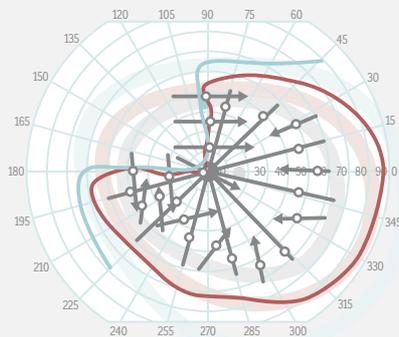
5. Drawing isopter  
 $V4e, 5^\circ/s$



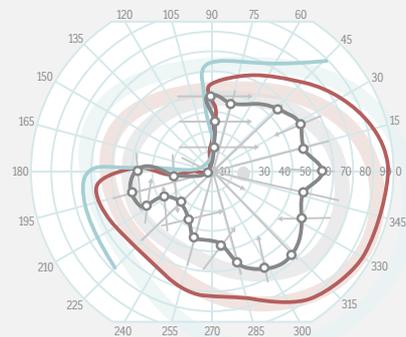
6. Spot-checking between isopters  
Use stimulus type from outer isopter  
 $V4e, 0^\circ/s$



7. Mapping the next outline of hill of vision & detailing boundaries of isopter  
 $I2e, 5^\circ/s$

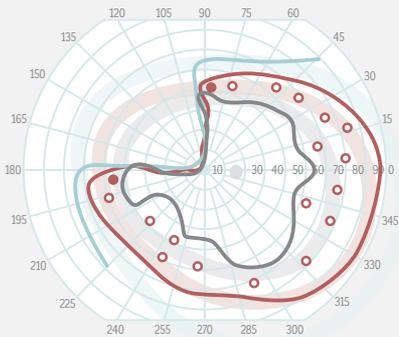


8. Drawing isopter  
 $I2e, 5^\circ/s$

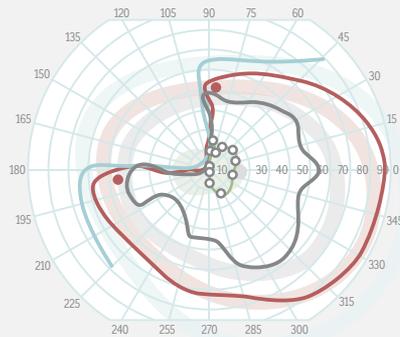


**STEP-BY-STEP EXAMPLE OF A KINETIC TEST WITH SEVERAL ISOPTERS (STEPS 9-14)**

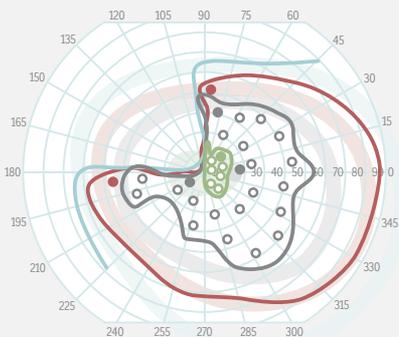
**9. Spot-checking between isopters**  
Use stimulus type  
 $I4e, 0^\circ/s$



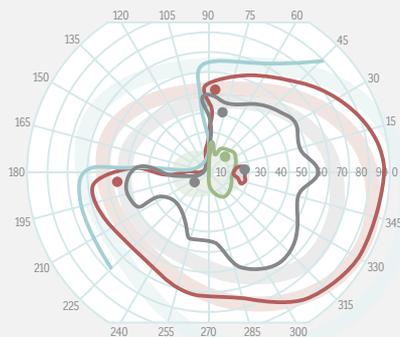
**10. Mapping the next outline of hill of vision & detailing boundaries & drawing isopter**  
 $I1e, 2^\circ/s$



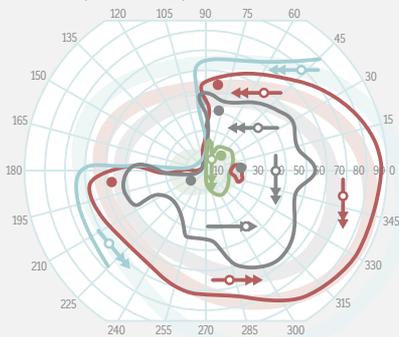
**11. Spot-checking between isopters**  
Use stimulus type from outer isopter  
 $I2e, 0^\circ/s, I1e, 0^\circ/s$



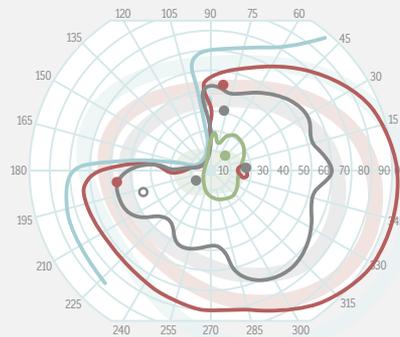
**12. Mapping of isolated defect (blind spot)**  
 $I4e, 2^\circ/s$



**13. Draw reaction time vectors in visible area**  
RT vectors, same intensity, size and speed as respective standard vector



**14. Reaction-time compensation**  
RT on



# AUTOMATION OF KINETIC PERIMETRY

## MANUAL KINETIC PERIMETRY – FULL FLEXIBILITY

In manual kinetic perimetry, the operator draws each vector individually for each patient. This procedure, which is used on manual Goldmann perimeters, is fully implemented on the Octopus perimeters. Therefore, a Goldmann manual perimetric test can be performed on the Octopus perimeter. The example presented above illustrates the flexibility of manual kinetic perimetry.

Manual kinetic perimetry is still widely used today because it allows full flexibility to adapt to any patient sit-

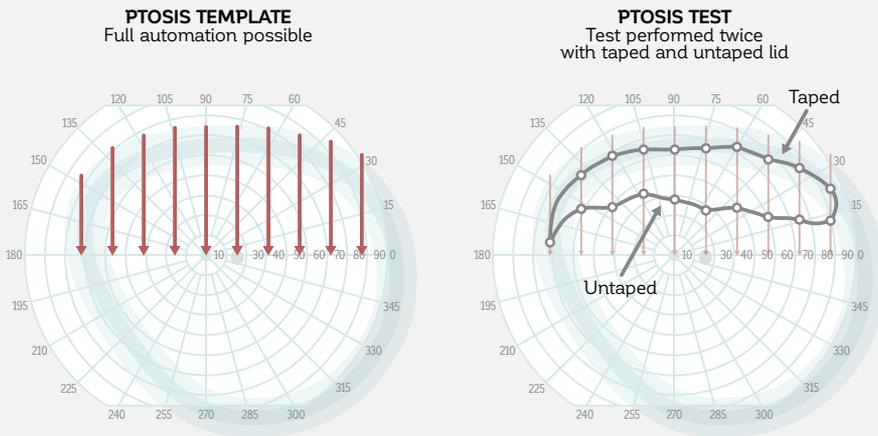
uation. A drawback of manual kinetic perimetry is the lack of consensus for a standard way to conduct it. As a result, there is limited comparability between the results obtained from different examiners and clinics. Another drawback is that manual kinetic perimetry requires intensive training and there is a certain operator bias. Simpler procedures are therefore desirable for more consistent and effective clinical workflows.

## AUTOMATED KINETIC PERIMETRY– STANDARDIZATION

While kinetic perimetry testing often needs to be individualized, there are certain indications where the expected

responses are already known. An example is visual field testing for ptosis, as illustrated in **FIG 11-22**.

### EXAMPLE OF FULLY AUTOMATED KINETIC PERIMETRY TO TEST FOR PTOSIS



**FIGURE 11-22** In ptosis testing, one is trying to identify the exact position of the lid, which always curves upwards from the nasal to temporal side. Therefore, a standardized testing procedure of a few vertical vectors is all that is needed and a very visible and adequately fast III4e to V4e at 3–5°/s is a good stimulus choice. This procedure can be fully automated and performed both on taped and untaped lids.

For any such indication with a clearly known defect pattern, Octopus kinetic perimetry allows storage of fully automated templates that can, once programmed, be run in the same way as Standard Automated Perimetry by simply pressing the start button. Only the isopters remain to be drawn manually.

Full automation not only standardizes kinetic testing and makes it much more comparable across examiners and clinics, it also makes the procedure as easy to learn and perform as static perimetry. As there is currently no consensus on how a certain indication should be tested, each clinic can define the automated templates according to its current testing methodologies.

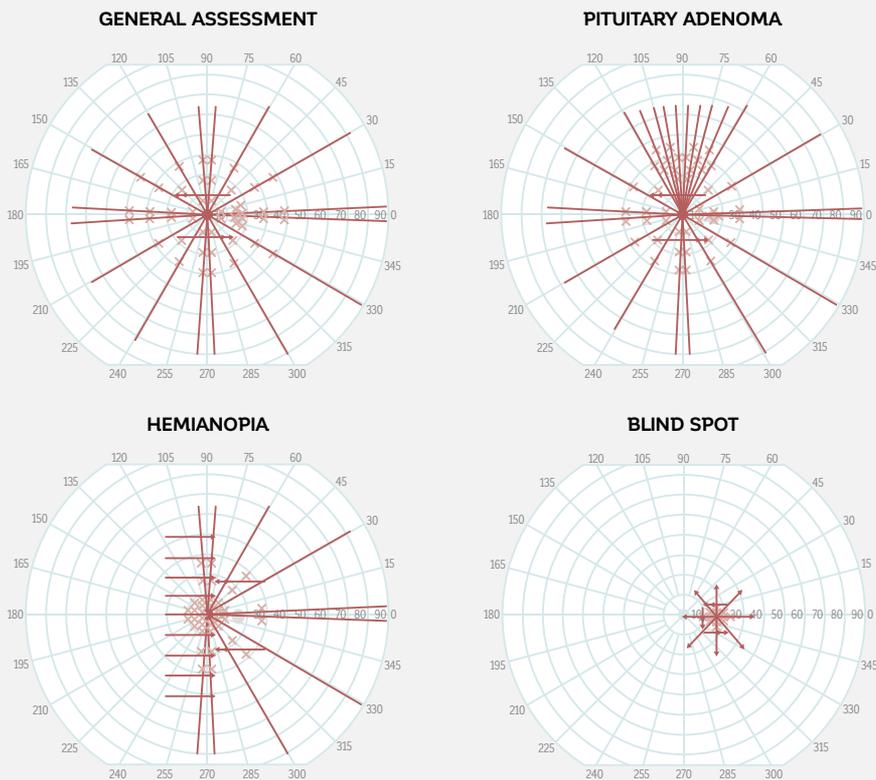
### SEMI-AUTOMATED KINETIC PERIMETRY – STANDARDIZATION AND FULL FLEXIBILITY

Semiautomated kinetic perimetry offers the benefits of both automated and manual kinetic perimetry with much less of their respective shortcomings, and is a part of Octopus kinetic perimetry.

In semiautomated kinetic perimetry, the examination is started using a given predefined template in an automated

mode. In contrast to automated kinetic perimetry, vectors can be individually added, but responses can also be repeated or deleted if the examiner deems it necessary. Because of the full flexibility offered by semiautomated kinetic perimetry, it can provide results that are as precise as manual kinetic perimetry while greatly improving the standardization within a clinic, as all examiners use

#### EXAMPLE OF CUSTOMIZED TEMPLATES FOR NEURO-OPHTHALMIC CONDITIONS



**FIGURE 11-23** Kinetic templates allow testing standardization, as the same methodology is always used. Full flexibility of adaptation to a patient's specific situation is also enabled. Above are four examples of templates regularly used in a neuro-ophthalmic clinic.<sup>25-27</sup> For simplicity, only one stimulus type is displayed, but templates with more than one stimulus type are also possible.

the same underlying technique and only make adaptations if the patient requires it. This greatly improves consistency among examiners and facilitates clinical result interpretation.

Many different templates can be created for the most commonly occurring indications, based on each clinic's

needs. **FIG 11-23** shows a number of templates that can be used in a neuro-ophthalmic clinic. These templates are not considered the only possible templates for such conditions, but rather examples of performing effective kinetic perimetry in these situations.

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## CHAPTER 12

# TRANSITIONING TO A DIFFERENT PERIMETER MODEL

## INTRODUCTION

At the end of the life span of a perimeter or in order to benefit from technologies only available on a different perimeter model or brand, transitioning to a new perimeter with distinct characteristics may be necessary. Due to differences in the design and test parameters between perimeter models, the measured sensitivity thresholds are not directly comparable. As a result, the variability introduced by a transition must be acknowledged and addressed.

Octopus perimeters offer several features that make it possible to transition smoothly between perimeter models, regardless of whether the transition is from one Octopus model to another Octopus model or from a Humphrey Field Analyzer (HFA) to any Octopus model. These features minimize, to a large extent, the impact of the different parameters used in the various perimeter models and are systematically presented in this chapter.

An explanation of why different sensitivity thresholds

are obtained on different perimeter models is first presented. Then, this chapter highlights that while sensitivity thresholds are not directly comparable between different models, sensitivity losses (i.e., deviations from normal sensitivity thresholds) are comparable to a large extent because of the use of device-specific normative databases. This chapter also provides practical guidance on how to minimize patient-related fluctuation that may arise during the transition and subside as patients become familiar with the new device.

In addition, when transitioning from an HFA to an Octopus perimeter, it is important to recognize that each perimeter uses its own, sometimes proprietary, test parameters and result displays. As a result, the transition may appear challenging. Practical recommendations for the selection of test patterns and strategies are presented to facilitate the transition. Furthermore, information is provided on how to interpret the perimetric result after the transition from an HFA to an Octopus perimeter.

# GENERAL ASPECTS OF TRANSITIONING

## MEASURED SENSITIVITY THRESHOLDS CANNOT BE COMPARED ACROSS DIFFERENT PERIMETER MODELS

Since different perimeter models vary in design and sometimes use different test parameters, patients may perceive perimetric stimuli differently. As a result, the measured sensitivity thresholds can vary<sup>1</sup> and measured sensitivity thresholds cannot be directly compared. **BOX 12A** presents an overview of major causes of variability between different Octopus perimeter models as well as the HFA perimeter and Octopus perimeter models.

### BOX 12A

#### MAJOR DIFFERENCES BETWEEN VARIOUS OCTOPUS PERIMETER MODELS

Since the various Octopus perimeter models vary in design and sometimes use different test parameters, measured sensitivity thresholds also vary.<sup>1</sup>

Firstly, design differences can lead to a different perception of perimetric stimuli. For example, there are two fundamentally different designs used in recent Octopus perimeter models. Cupola perimeters (e.g., Octopus 101 and 900) allow for testing of the full field (e.g., 90° radius) and use a moving projector to present the perimetric stimuli onto the whitish surface of a cupola. On the other hand, screen-based perimeters (e.g., Octopus 600) allow for testing of the central field only (e.g., 30° radius) and generate the stimulus on a computer display. Because of the different stimulus presentation technologies used, patients may perceive stimuli differently.

In addition, the full field cupola perimeters are open and thus need to operate under dim room lighting conditions to avoid stray light influencing the result, whereas screen-based perimeters are closed, not influenced by stray light and thus can be operated under daylight conditions. Further, while the mechanical projector of the cupola perimeters makes some noise upon stimulus presentation, screen-based perimeters are silent during stimulus presentations. As a result, even if completely identical test conditions are used (i.e., same stimulus size, same stimulus luminance and same background luminance), patients may respond differently. They can be influenced by these differences and, as a result, determined sensitivity thresholds may vary.

Secondly, different test parameters may also lead to different perimetric results. For this reason, all recent Octopus models (e.g., Octopus 900, Octopus 600, Octopus 300 and Octopus 123) use the same fixed test parameters, which are described in Box 4A. An exception is the Octopus 101, which uses a background luminance of 4 asb (instead of 31.4 asb), operating under mesopic illumination (i.e., midway between daylight and night vision) instead of photopic illumination (i.e., daylight vision), which may influence the perception of the perimetric stimulus. To reduce this bias when transitioning from an Octopus 101 to an Octopus 900, the Octopus 900 can be optionally operated using a background luminance of 4 asb.

#### MAJOR DIFFERENCES BETWEEN THE HFA PERIMETER AND OCTOPUS PERIMETER MODELS

As already explained in the section above, design differences between the HFA perimeter (which is a cupola perimeter) and other Octopus perimeter models may lead to different perception of perimetric stimuli even if the same test conditions were used.

However, the HFA perimeter and the various Octopus perimeter models also use different fixed test parameters. The most marked difference between the determined sensitivity thresholds of an HFA perimeter and recent Octopus perimeter models (e.g., Octopus 900, 600, 300 and 123) stems from the different maximum stimulus luminances used (4,000 asb in Octopus perimeters compared to 10,000

asb in HFA perimeters). This difference leads to an offset of 4 dB in the default decibel scale used to display sensitivity thresholds. This is due to the fact that both instruments take the maximum stimulus luminance as the origin of their dB scale (0 dB), as explained in **BOX 2A**. A stimulus of 1,000 asb intensity therefore corresponds to a sensitivity threshold of 10 dB on an HFA II perimeter and to 6 dB on an Octopus 900 perimeter.

## DEVICE-SPECIFIC NORMATIVE DATABASES ALLOW COMPARISON OF SENSITIVITY LOSSES BETWEEN DEVICES

### *SENSITIVITY LOSSES CAN BE COMPARED BETWEEN DIFFERENT OCTOPUS PERIMETER MODELS*

Whenever an Octopus perimeter model is developed, data are collected from people with healthy eyes and of different ages on that model in order to develop a normative database for it (see **BOX 2B** for more detail on normative databases). As a result, each Octopus model has its respective normative database. Furthermore, all Octopus models contain the normative databases of all other models in order to allow for smooth transitions between models. When transitioning from one Octopus model to another, the existing data of one device can be imported into the other device and the data compared to the appropriate normative database. For example, when the visual field tests taken on a given Octopus model (e.g.,

an Octopus 300) are imported into another model (e.g., Octopus 900), the user can be sure that the imported sensitivity thresholds are compared with the Octopus 300 device-specific normative database to calculate the sensitivity losses.

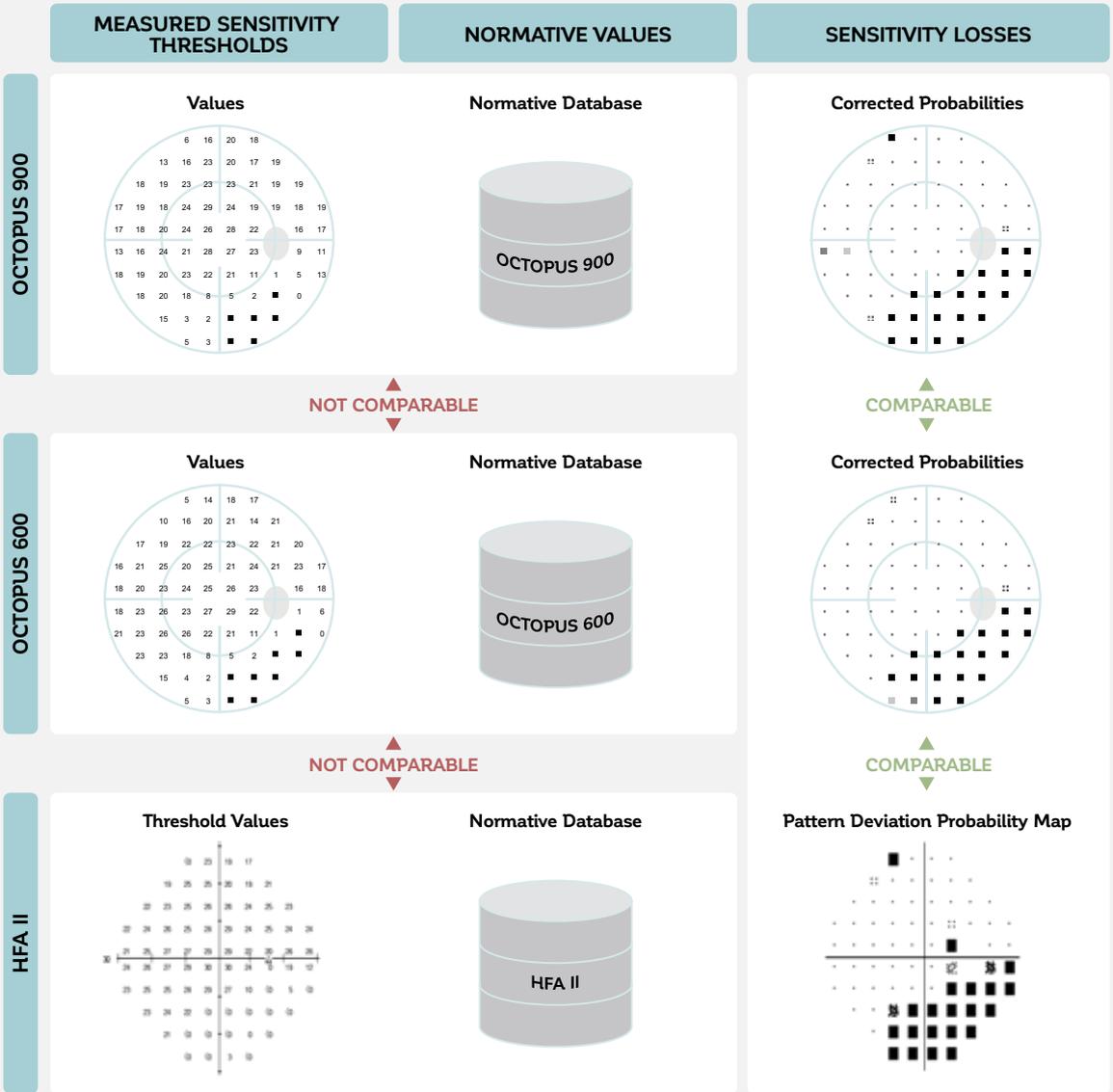
Using device-specific normative databases largely eliminates device-specific differences in sensitivity losses. As a result, sensitivity losses and all related representations, with the exception of the Values and Grayscale (Values), are largely comparable across perimeter models as shown in **FIG 12-1**.

### *SENSITIVITY LOSSES CAN BE COMPARED BETWEEN HFA PERIMETERS AND DIFFERENT OCTOPUS PERIMETER MODELS*

HFA perimeters use an HFA-specific normative database to calculate the sensitivity losses presented in the Total Deviation representation, while each Octopus model uses its own normative database. As a result, the use of these device-specific normative databases largely eliminates any model-related bias between perimetric results when looking at sensitivity losses. For example, while the

measured sensitivity thresholds of an HFA II and an Octopus 900 show an offset of 4 dB as explained in **BOX 12A**, the respective normative databases show the same offset, and as a result the sensitivity losses are comparable. This means that all representations with the exception of the Values and Grayscale (Values) representations are comparable.<sup>2,3</sup>

**SENSITIVITY LOSSES BETWEEN DIFFERENT DEVICES ARE LARGELY COMPARABLE**



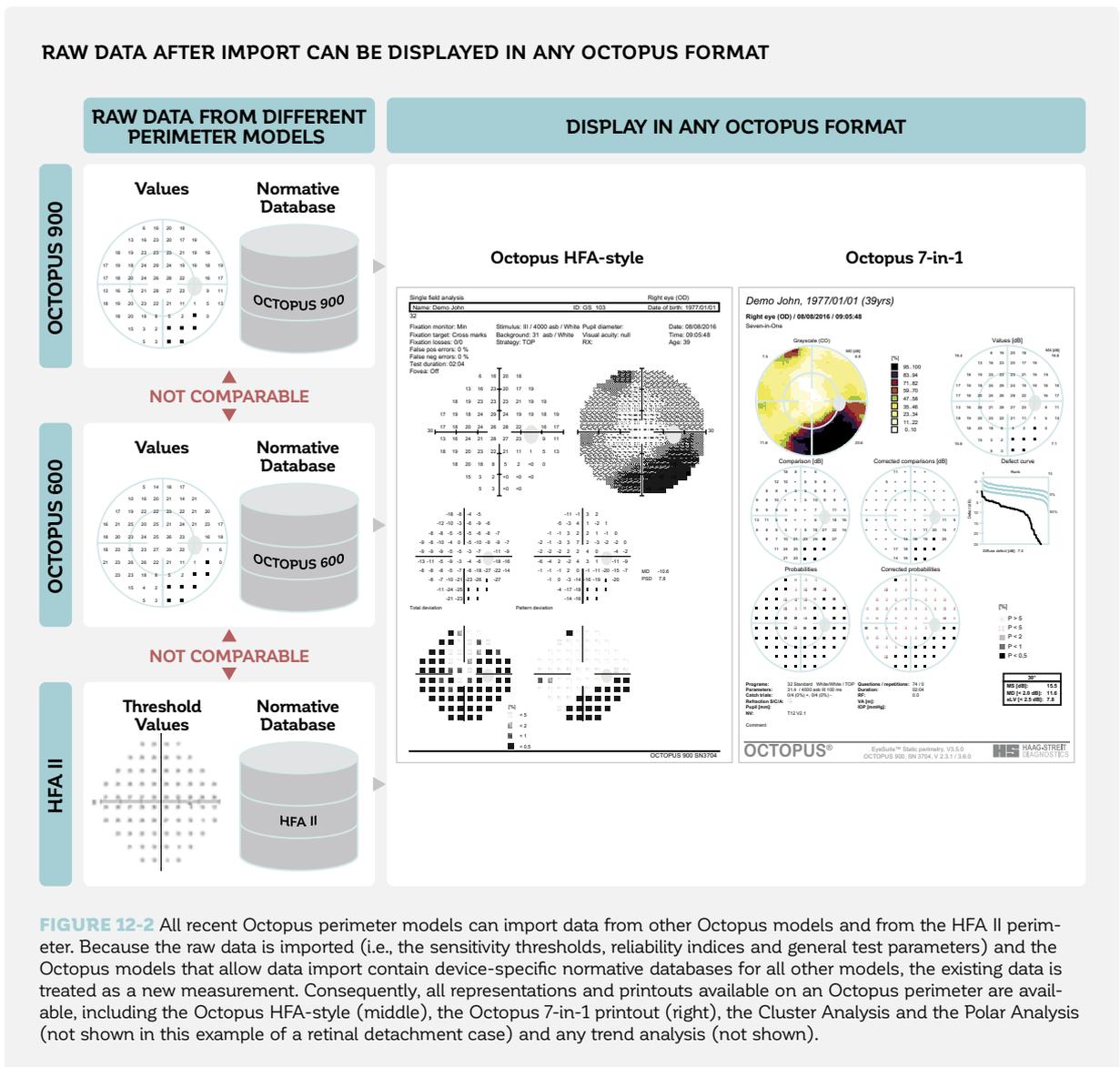
**FIGURE 12-1** This example illustrates the benefits of using device-specific normative databases (i.e., an individual normative database for each device). In this example, sensitivity thresholds of a patient with retinal detachment were determined on an Octopus 900, Octopus 600 and on an HFA II perimeter on the same day (left). These sensitivity thresholds cannot be compared to each other due to the different characteristics of the three perimeter models. However, because distinct normative databases are used for the Octopus 900, Octopus 600 and the HFA II perimeter (middle), the sensitivity losses are comparable. Sensitivity losses are calculated as the deviation of the measured sensitivity thresholds of each model from its respective normative database and are the basis of most visual field representations such as the Corrected Probabilities or Pattern Deviation Probability Map shown in this figure. Note that comparability applies to all representations with the exception of the Values and Grayscale (Values) representations.

# IMPORT OF EXISTING DATA TO ENSURE CONTINUITY

## IMPORT OF EXISTING DATA FROM ONE OCTOPUS PERIMETER MODEL TO ANOTHER

As presented in Chapter 9, a series of visual field tests over time is necessary to adequately assess visual field progression in diseases such as glaucoma. When transitioning from one perimeter to another, it is therefore essential to be able to use a patient's existing visual field

data. All current Octopus perimeter models therefore allow for the import of electronically stored visual field results from the Octopus models 500, 101, 123, 300, 900 and 600. Data can be transferred either in a single session or on a continuous basis if the other perimeter is still in use.



To ensure a seamless transition, Octopus perimeters import the measured sensitivity thresholds, reliability indices and general test parameters, including information as to which perimeter model the data is coming from. The imported measured sensitivity thresholds are then compared to the relevant normative database as described in the previous section (e.g., if importing existing data from an Octopus 300 into an Octopus 900, the measured sensitivity thresholds are compared to the Octopus 300 normative database). Because all Octopus representations are calculated from the measured sensitivity thresholds (see [FIG 7-1](#)), by comparing them to device-specific normative databases, the new device

can treat the existing data like any new measurement and display it in exactly the same format as shown in [FIG 12-2](#). Potential differences in definitions of representations and indices used are thus eliminated and progression of visual field data can be assessed as shown in [FIG 12-3](#). In addition, this approach offers the advantage that data taken years ago can be viewed with the latest analysis tools (e.g., Cluster Trend Analysis).

For full transparency, the device from which a measurement stems is clearly marked on each visual field test and assigned a distinct symbol in the global trend analysis.

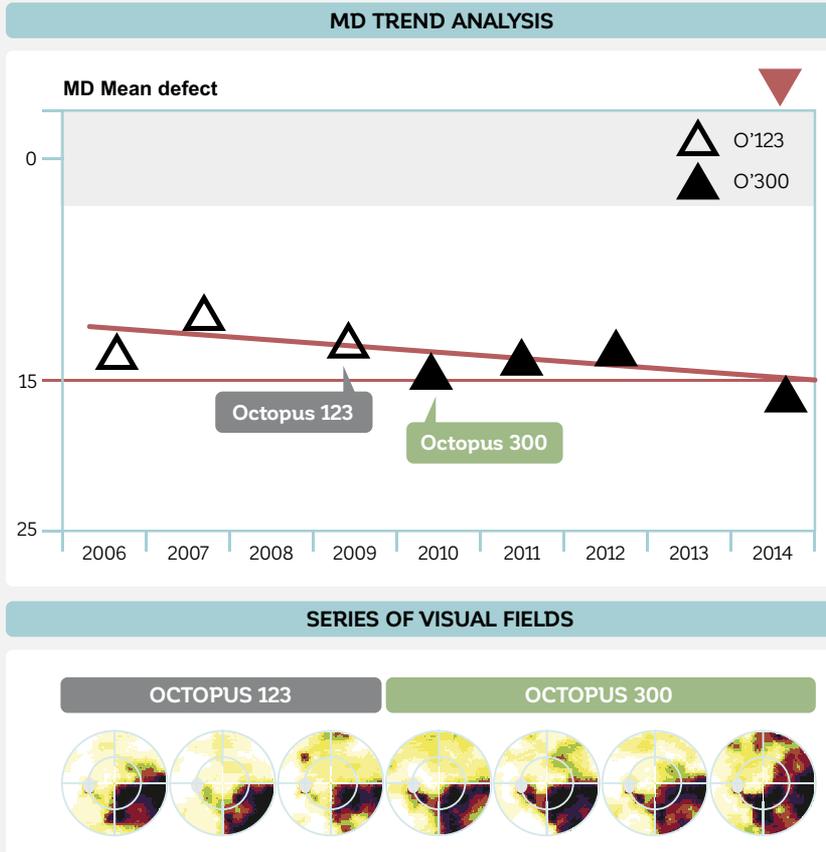
#### IMPORT OF EXISTING DATA FROM AN HFA TO AN OCTOPUS PERIMETER

To ensure that existing data collected on an HFA can be used after a transition to an Octopus perimeter, all recent Octopus perimeter models allow import of electronically stored data from an HFA II. This includes the sensitivity thresholds, general test parameters, perimeter model from which the data stems (HFA II), as well as reliability indices. To largely eliminate the influence of any device-related differences at the level of sensitivity losses, each Octopus perimeter also contains a normative database for the HFA II perimeter. The sensitivity losses (i.e., Total Deviation on the HFA-style printout and the Comparisons on the Octopus-style printout) of the HFA data are then calculated from the imported sensitivity

thresholds and the HFA normative database, thus largely eliminating device-specific differences. Because raw data (i.e., sensitivity thresholds) are imported, the Octopus perimeter can treat the existing data like any new measurement and display it in exactly the same format as shown in [FIG 12-2](#).

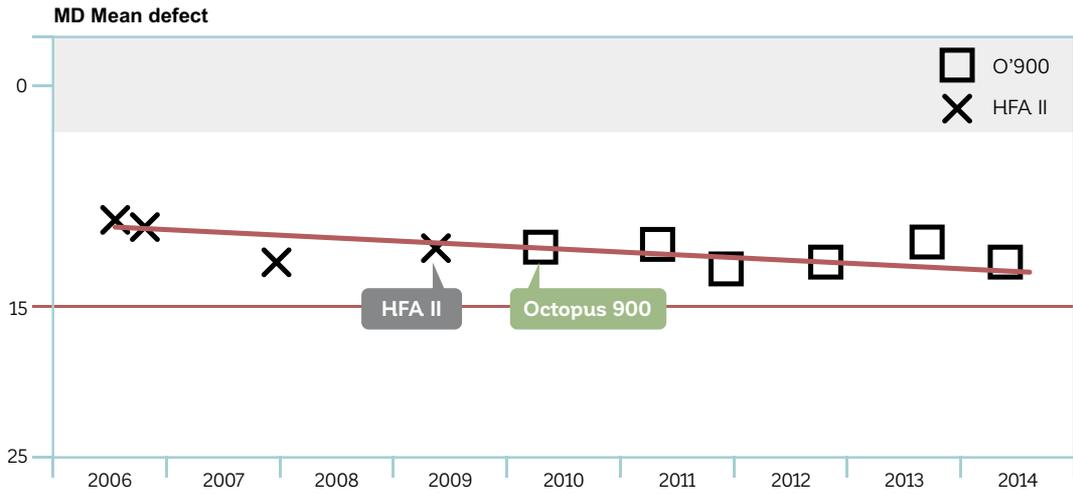
To assess visual field progression, it is important to be able to use the existing HFA data imported into an Octopus perimeter and the new measurements in the same trend analysis. This is possible as long as comparable test parameters (i.e., same stimulus type, same test pattern) are used. [FIG 12-4](#) provides an example.

**OCTOPUS PERIMETERS CAN JOINTLY DISPLAY DATA FROM ANY OCTOPUS PERIMETER IN A TREND ANALYSIS**

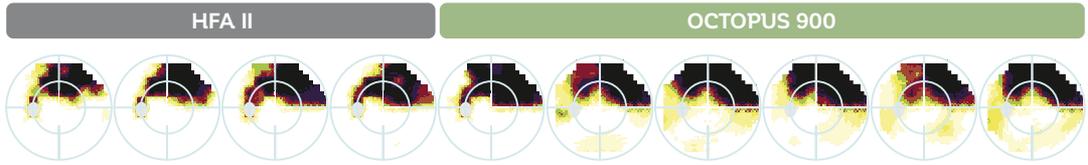


**FIGURE 12-3** All Octopus perimeters allow import of existing patient data to ensure data continuity. The measured sensitivity thresholds are imported and compared to the appropriate device-specific normative database. The data can then be displayed in any Octopus format. In the example above, a glaucoma patient with an inferior arcuate defect has been tested on an Octopus 123 perimeter (unfilled triangle) from 2006 to 2009 using Standard Automated Perimetry (SAP) with a G test pattern. In 2010, the clinic transitioned to an Octopus 300 (filled triangle) and continued testing the patient with the same test parameters. The data of both devices can be used in the same Global Trend Analysis to monitor progression. Note that this patient shows typical levels of fluctuation both before and after the transition.

OCTOPUS PERIMETERS CAN JOINTLY DISPLAY HFA AND OCTOPUS DATA IN A TREND ANALYSIS



SERIES OF VISUAL FIELDS



**FIGURE 12-4** In this example, a glaucoma patient with a superior arcuate defect has been tested on an HFA II perimeter from 2006 to 2009 using SAP with a 24-2 test pattern. In 2010, the clinic transitioned to an Octopus 900 and continued testing the patient with the same test parameters. The HFA II data can be imported into the Octopus 900 perimeter and the data of both devices can be used in the same Global Trend Analysis because of the device-specific normative databases used by the Octopus perimeters.

## MANAGING PATIENT-RELATED FLUCTUATION

As described in the sections above, Octopus perimeters offer several features that minimize the impact of the transition between different perimeter models. Nevertheless, one may still observe differences in some but not all patients after switching devices.

This can be explained in part by the fact that patient-related fluctuation is always present in perimetry and should therefore also be expected during the transition from one perimeter to another. During the transition, patient-related fluctuation can be associated with the transition itself or it may be independent of it. Chapter 3 provides many practical tips on how to minimize patient-related fluctuation. The transition between perimeter models itself may increase the amount of patient-related fluctuation in some but not all patients. Because the design and working conditions of different perimeter models vary, some patients may show learning effects during the initial tests on the new device (for more information on learning effects, see [FIG 3-12](#)). To minimize the impact of

learning effects, it is thus good practice for technicians to take some examinations with the new device themselves and to make sure to include noticeable differences in the patient instructions. Furthermore, running a practice test with a patient on a new device is also helpful.

In addition to learning effects, some patients may show personal preferences for one perimeter model over the other. For example, while cupola perimeters such as the Octopus 900 or the HFA II need to be operated under dim room light conditions, closed 30° perimeters like the Octopus 600 or 300 may also be operated at daylight levels. Different ambient light conditions may influence the patient's performance during the perimetric test, with dim light conditions enhancing concentration in some, while making others sleepy and less alert. While personal preferences cannot be eliminated, typically the impact on the visual field test results is within expected levels of fluctuation.

# SPECIFIC ASPECTS RELATED TO TRANSITIONING FROM THE HUMPHREY FIELD ANALYZER

## SELECTION OF TEST PARAMETERS

As shown in [FIG 12-1](#) and [12-4](#), visual field tests taken on either the HFA or the Octopus perimeter result in comparable test results that can be used equally well for clinical decision-making.<sup>2-6</sup> However, because both perimeter brands use their own test patterns and strategies to perform visual field testing, one may not intuitively know which ones to choose on an Octopus perimeter after a transition from an HFA perimeter.

[TABLE 12-1](#) provides an overview of the most common choices of Octopus test patterns and strategies following a transition from an HFA perimeter. More detailed information on all available Octopus test patterns is presented in Chapter 5 and more details on the available test strategies are presented in Chapter 6.

**COMMON CHOICES OF TEST PATTERNS AND STRATEGIES IN HFA AND OCTOPUS PERIMETERS**

**TABLE 12-1**

	TEST PATTERN		TEST STRATEGY	
	HFA	OCTOPUS	HFA	OCTOPUS
<b>30°</b> (Glaucoma/General)	24-2, 30-2	24-2, 30-2, G	SITA Fast	TOP
	24-2, 30-2	24-2, 30-2, G	SITA Standard	Dynamic
<b>10°</b> (Macula, constricted field, hydroxy-chloroquine retinopathy)	10-2	10-2, M	SITA Fast	TOP
	10-2	10-2, M	SITA Standard	Dynamic
<b>FULL FIELD</b> (Threshold)	60-4	07	SITA Standard	Dynamic
<b>FULL FIELD</b> (Screening)	81FF, 120FF, 135 FF	07	3-zone	2LT
<b>DRIVING ABILITY</b>	Esterman test	Esterman test		

While EyeSuite Progression Analysis (see Chapter 9) can be performed on tests that use different test strategies, it requires the same test pattern and the same overall test conditions to be used for all tests included in the visual field series. If progression analyses are needed when transitioning from an HFA perimeter to an Octopus perimeter, it is thus best to select the same test pattern used

in the patient’s existing visual field tests. For this reason, Octopus perimeters provide the most commonly used HFA test patterns, namely the 24-2, 30-2 (FIG 5-4) and 10-2 (FIG 5-10). If any other HFA pattern not available on an Octopus perimeter is needed, it is possible to create that test pattern using the Custom Test function available on some Octopus models.

## INTERPRETATION OF A SINGLE VISUAL FIELD

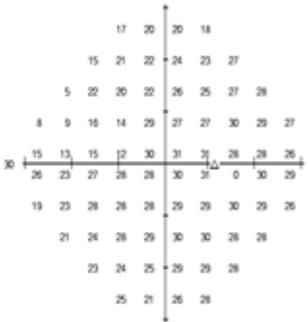
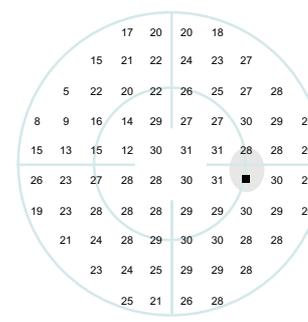
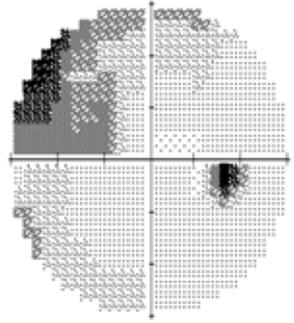
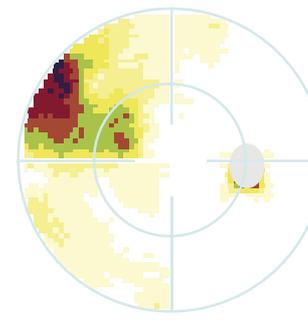
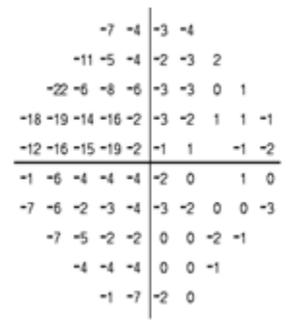
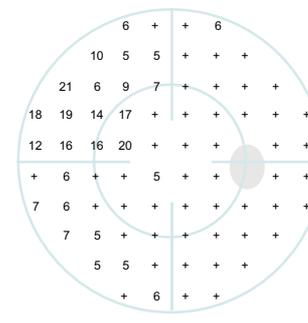
Both Octopus and HFA perimeters have developed their own brand-specific visual field representations. While the underlying reasoning and definitions are comparable, they have different names, a different graphical style and the formulas used in their calculation can vary.<sup>7,8</sup>

To facilitate the transition from an HFA to an Octopus perimeter with minimal training in visual field interpretation, all Octopus perimeters offer an HFA mode. In this mode, an HFA-style printout is available in which the single field representations and indices are named and calculated based on the definitions used in the original HFA printout. FIG 12-2 shows that any visual field test taken or

imported on an Octopus perimeter can be displayed using both the Octopus-style as well as the HFA-style printout.

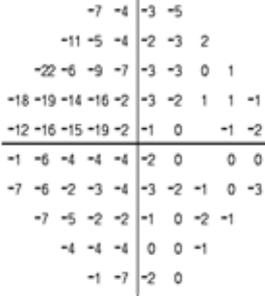
HFA and corresponding Octopus representations are very similar. Once the Octopus-specific terminology of each representation becomes familiar, those familiar with the HFA terminology can easily interpret the results. FIG 12-5 presents a side-by-side comparison of all available HFA and Octopus representations and also highlights differences relevant for clinical interpretation. Guidance on how to transition from the Glaucoma Hemifield Test (GHT) to the Defect Curve is provided in BOX 12B.

**SIMILARITIES AND DIFFERENCES BETWEEN HFA AND CORRESPONDING OCTOPUS REPRESENTATIONS**

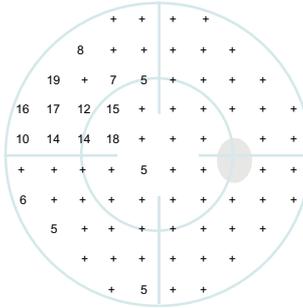
HFA REPRESENTATION	CORRESPONDING OCTOPUS REPRESENTATION	COMMENTS
<p><b>THRESHOLD VALUES</b></p> 	<p><b>VALUES</b></p> 	<p>Both perimeters display the measured sensitivity thresholds.</p> <p>Octopus perimeters display absolute defects (i.e., sensitivity thresholds 0 dB) with a “■” sign (see FIG 7-2 and 7-3).</p>
<p><b>GRAYSCALE</b></p> 	<p><b>GRAYSCALE (COMPARISONS)</b></p> 	<p>Both perimeters use an interpolated graphical map to assess magnitude and shape of defects.</p> <p>The HFA Grayscale is based on sensitivity thresholds (Threshold Values) in dB, thus it is influenced by both patient-age and eccentricity of test location.</p> <p>The Octopus Grayscale (Comparisons) is based on sensitivity loss in %, thus its interpretation is independent of patient-age and eccentricity of test locations (see FIG 7-7 and 8-18).</p>
<p><b>TOTAL DEVIATION NUMERICAL MAP</b></p> 	<p><b>COMPARISONS</b></p> 	<p>Both perimeters display sensitivity loss (i.e., deviation from age-corrected normal values), but they use opposite signs.</p> <p>Octopus perimeters display sensitivity loss &lt; 5 dB with a “+” sign (see FIG 7-6 and 8-18).</p>

**FIGURE 12-5** Side-by-side comparison of the HFA Single Field Analysis and the Octopus 7-in-1 printout of the same visual field test that was taken on an HFA II perimeter and then imported into an Octopus perimeter. Many representations in the two printouts are based on the same principles, but use different names. It should be noted that while differences between the results of the two perimeters are present, they are typically very small and do not alter the clinical interpretation of the case. Small differences in the definitions used between the perimeters are highlighted in the comment column.

**PATTERN DEVIATION NUMERICAL MAP**



**CORRECTED COMPARISONS**

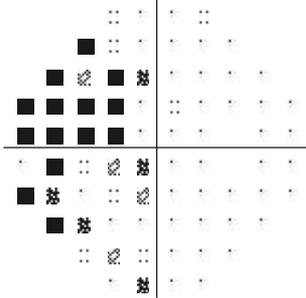


Both perimeters display local sensitivity loss (i.e., deviation from age-corrected normal values with a correction applied to eliminate any influence of diffuse loss).

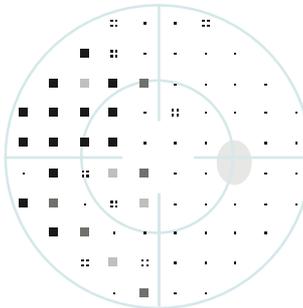
Octopus and HFA perimeters use opposite signs.

Octopus perimeters display local sensitivity loss < 5 dB with a “+” sign (see FIG 7-16, 7-17 and 8-18).

**TOTAL DEVIATION PROBABILITY MAP**



**PROBABILITIES**

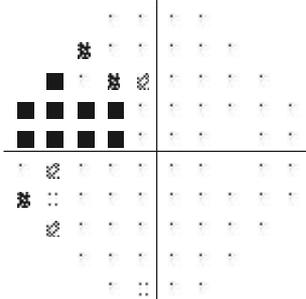


Octopus and HFA perimeters show the same levels of probabilities using similar symbols.

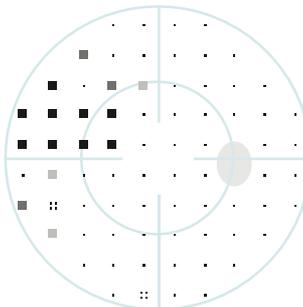
Octopus perimeters use the following symbols (see FIG 7-10, 8-14 and 8-15).

- p > 5%
- ▣ p < 5%
- ▤ p < 2%
- ▥ p < 1%
- p < 0.5 %

**PATTERN DEVIATION PROBABILITY MAP**



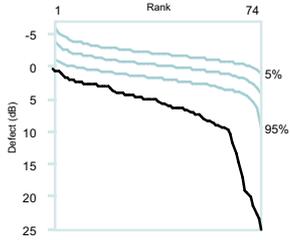
**CORRECTED PROBABILITIES**



Octopus and HFA perimeters show the same levels of probabilities using similar symbols.

Octopus perimeters use the following symbols (see FIG 7-19, 8-14 and 8-15).

- p > 5%
- ▣ p < 5%
- ▤ p < 2%
- ▥ p < 1%
- p < 0.5 %

<p><b>MD</b> <b>MEAN DEVIATION</b></p> <p>-4.66 dB</p>	<p><b>MD</b> <b>MEAN DEFECT</b></p> <p>4.4 dB</p>	<p>HFA and Octopus perimeters use opposite signs.</p> <p>HFA perimeters put extra weight on central visual field locations.</p> <p>Octopus perimeters weigh each location equally,<sup>7,8</sup> as the standard G pattern has higher density of central test locations (see <a href="#">TABLE 7-1</a> and <a href="#">FIG 8-26</a>).</p>
<p><b>PSD</b> <b>PATTERN STANDARD DEVIATION</b></p> <p>6.11 dB</p>	<p><b>sLV</b> <b>SQUARE ROOT OF LOSS VARIANCE</b></p> <p>5.3 dB</p>	<p>HFA perimeters put extra weight on central visual field locations.</p> <p>Octopus perimeters weigh each location equally, as the standard G pattern has higher density of central test locations (see <a href="#">TABLE 7-1</a> and <a href="#">FIG 8-27</a>).</p>
<p><b>GHT</b> <b>GLAUCOMA HEMIFIELD TEST</b></p> <p>Outside normal limits</p>	<p><b>DEFECT CURVE</b></p> 	<p>Both GHT and Defect Curve provide information on the overall status of the visual field, though the methods differ.</p> <p>For more details, see <a href="#">BOX 12B</a>.</p>
<p><b>VFI</b> <b>VISUAL FIELD INDEX</b></p> <p>90%</p>	<p><b>MD</b> <b>MEAN DEFECT</b></p> <p>4.4 dB</p>	<p>Both VFI and MD are measures of the overall visual field loss, and give comparable results in patients with MD values larger than <math>\pm 5</math> dB.</p> <p>VFI is expressed as a percentage of normal function, ranges from 100% to 0 % and is not influenced by diffuse visual field loss.</p> <p>MD is expressed in dB, ranges from 0 up to 25 dB and is affected by diffuse visual field loss but is also more sensitive in detecting early visual field loss.<sup>9</sup></p>
<p><b>FALSE POS ERRORS</b></p> <p>12%</p>	<p><b>FALSE POSITIVE ANSWERS</b></p> <p>1/8 (12%) +</p>	<p>Both HFA and Octopus perimeters display the percentage of false positive errors (see <a href="#">FIG 7-22</a>).</p> <p>Octopus perimeters additionally present the absolute numbers of false positive answers and the total number of positive catch trials.</p>

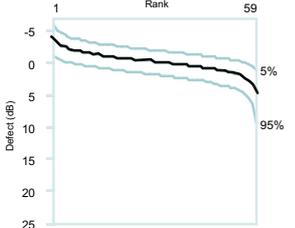
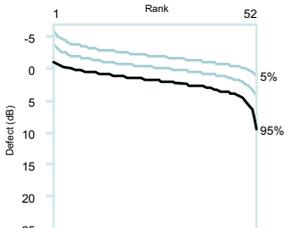
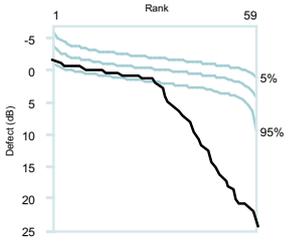
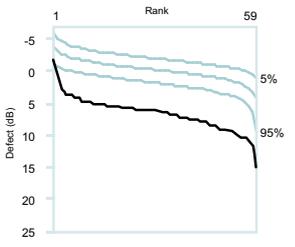
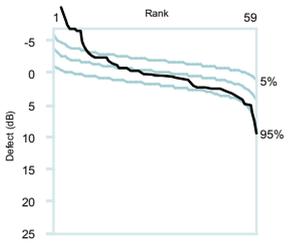
<p><b>FALSE NEG ERRORS</b></p> <p>12%</p>	<p><b>FALSE NEGATIVE ANSWERS</b></p> <p>1/8 (12%) -</p>	<p>Both HFA and Octopus perimeters display the percentage of false negative errors (see <a href="#">FIG 7-23</a>).</p> <p>Octopus perimeters additionally present the absolute numbers of false negative answers and the total number of negative catch trials.</p>
<p><b>FIXATION LOSSES</b></p> <p>0/12</p>	<p><b>NOT AVAILABLE</b></p>	<p>HFA perimeters use the Heijl-Krakau method to determine the percentage of fixation losses.</p> <p>Octopus perimeters prevent fixation losses by using Fixation Control, in which the test is interrupted when adequate fixation is not maintained (see <a href="#">FIG 3-11</a>).</p>
<p><b>GAZE TRACKER</b></p> 	<p><b>NOT AVAILABLE</b></p>	<p>HFA perimeters record eye movements using the gaze tracker.</p> <p>Octopus perimeters prevent fixation losses by using Fixation Control, in which the test is interrupted when adequate fixation is not maintained (see <a href="#">FIG 3-11</a>).</p>

**BOX 12B**

**RELATIONSHIP BETWEEN THE GLAUCOMA HEMIFIELD TEST (GHT) AND THE DEFECT CURVE**

The Glaucoma Hemifield Test (GHT) is an intuitive text-based index that provides information about the overall status of the visual field and classifies the visual field results as “Within normal limits”, “Borderline”, “Outside normal limits”, “General reduction of sensitivity” and “Abnormally high sensitivity”. Its design is based on the asymmetry of sensitivity thresholds for the superior and inferior arcuate nerve fiber bundle regions. It therefore determines statistically significant differences between two corresponding visual field clusters divided by the horizontal midline.

In Octopus perimeters, the Defect Curve is used to determine overall visual field status. And while it is based on different principles, it provides similar information about whether visual fields are normal or whether local or diffuse defects are present. The table below summarizes some rules of thumb on how to read the Defect Curve to obtain information that is comparable to the GHT. For more details on the Defect Curve, refer to [FIG 7-11](#) and [8-10](#).

GHT	DEFECT CURVE	DEFECT CURVE INTERPRETATION
<p><b>WITHIN NORMAL LIMITS</b></p>		<p><b>NORMAL</b></p> <p>Defect Curve within normal band</p>
<p><b>BORDERLINE</b></p>		<p><b>BORDERLINE</b></p> <p>Defect Curve along/slightly below normal band</p> <p>OR</p> <p>Defect Curve within normal band, but with characteristic drop on the right (not shown)</p>
<p><b>OUTSIDE NORMAL LIMITS</b></p>		<p><b>LOCAL DEFECT</b></p> <p>Drop of Defect Curve on the right</p>
<p><b>GENERAL REDUCTION OF SENSITIVITY</b></p>		<p><b>DIFFUSE DEFECT</b></p> <p>Parallel downward shift of Defect Curve</p>
<p><b>ABNORMALLY HIGH SENSITIVITY</b></p>		<p><b>TRIGGER-HAPPY</b></p> <p>Steep rise of Defect Curve on the left</p>

## INTERPRETATION OF VISUAL FIELD PROGRESSION

Both HFA and Octopus perimeters offer methods for assessing visual field progression. **FIG 12-6** presents a side-by-side comparison of all available HFA and Octopus progression analyses and also highlights differences relevant for clinical interpretation. For more detailed information on EyeSuite Progression Analysis, refer to Chapter 9.

To judge whether a visual field series is stable or progressing, both HFA and Octopus perimeters use a trend analysis approach and determine both significance of

change and the rate of change. In addition, both HFA and Octopus perimeters provide tools to determine whether there is local progression beyond what is apparent in the MD trend analysis and where the change happens. The Octopus also offers a method for identifying diffuse progression independently. Furthermore, to facilitate the combined evaluation of structural and functional progression in glaucoma, Octopus perimeters offer a trend procedure, the Polar Trend Analysis, which facilitates finding a relationship between structural and functional losses.

### OVERVIEW OF PROGRESSION TOOLS AVAILABLE ON HFA AND OCTOPUS PERIMETERS

	HFA REPRESENTATION	OCTOPUS REPRESENTATION	COMMENTS
	<p><b>GUIDED PROGRESSION ANALYSIS (GPA)</b></p>	<p><b>EYESUITE PROGRESSION ANALYSIS</b></p>	<p>GPA uses both trend analysis and point-wise event analysis, which requires two reliable baseline tests.</p> <p>EyeSuite Progression Analysis uses trend analysis.</p>
<b>OVERALL PROGRESSION</b>	<p><b>GPA TREND ANALYSIS</b></p> <p>Rate of progression: <math>-2.6 \pm 1.8\%</math> (95% confidence) Slope significant at <math>P &lt; 5\%</math></p>	<p><b>MD TREND ANALYSIS</b></p> <p>Slope: 0.5 dB / Yr (<math>p &lt; 0.5\%</math>)</p>	<p>Both perimeters use trend analysis to determine significance and rate of change.</p> <p>HFA uses the Visual Field Index (VFI), which typically ranges from 100% to 0%. Significant change is shown in text.</p> <p>Octopus uses the Mean Defect (MD), which typically ranges from 0 to 25 dB. Significant worsening is shown with red downward arrows (see <b>FIG 9-6</b>).</p>

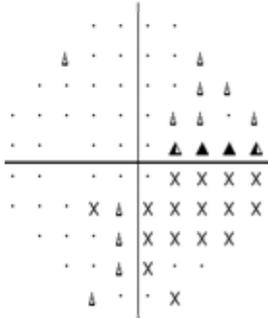
**FIGURE 12-6** Side-by-side comparison of the HFA and the Octopus progression analyses of the same visual field series that was taken on an HFA II perimeter and then imported into an Octopus perimeter. Some analyses identify similar aspects of progression, such as whether there is progression and where localized progression occurs, but use a different approach. Further, the Octopus perimeter offers analyses for identifying diffuse progression and providing guidance on where to look for structural progression. Differences in the methods used between the perimeters are presented in the comment column.

**GPA EVENT ANALYSIS**

**Deviation from Baseline**

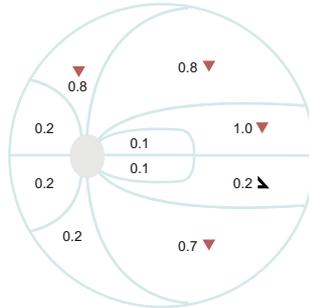
	1	-3	-4	-10						
	-9	0	-7	-3	-1	-9				
	-1	8	-5	-2	0	2	-15	-11		
	3	-2	-4	-3	-1	6	-11	-10	-5	-13
	-1	-2	-1	4	5	-18	-10	-18	-19	
0	-3		8	1	-12	-6	11	-9	2	
-1	2	0	-13	-21	-14	4	6	4	0	
	1	2	1	-20	-7	10	6	-6		
		0	1	-22	-4	-1	2			
			-11	-5	-3	4				

**Progression Analysis**

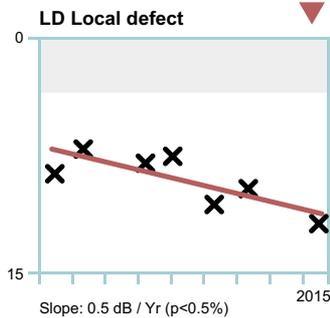


**POSSIBLE PROGRESSION**

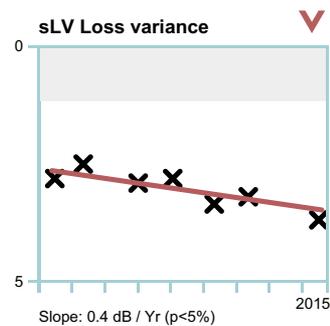
**(CORRECTED) CLUSTER TREND ANALYSIS**



**LD TREND ANALYSIS**



**sLV TREND ANALYSIS**



HFA uses point-wise event analysis to assess local progression and requires two trustworthy baseline tests. GPA Alert displays likelihood of progression as text.

Octopus uses trend analysis to determine significance and rate of change of the variables (see FIG 9-8)

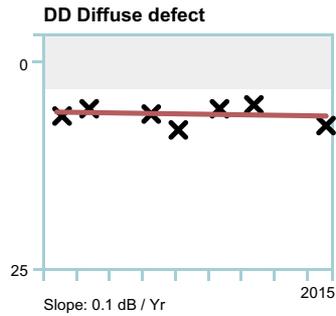
- (Corrected) Cluster MD (average defects of 10 clusters following RNFL distribution on the retina, see FIG 9-11)
- LD (Local Defect, see BOX 7D)
- sLV (Octopus equivalent of PSD, see FIG 8-27)

Trend analysis is relatively robust to outliers. Furthermore, individual visual fields can be easily excluded from the trend analysis in the Octopus perimeter by simply clicking on a given test.

## DIFFUSE PROGRESSION

NOT AVAILABLE

## DD TREND ANALYSIS

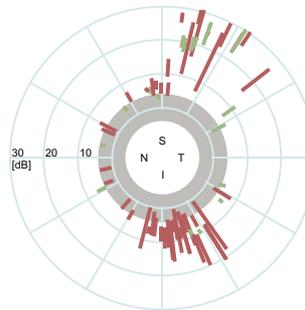


Octopus uses trend analysis to determine significance and rate of change of the variable DD (Diffuse Defect, see [BOX 7C](#)).

## WHERE TO LOOK FOR STRUCTURAL PROGRESSION

NOT AVAILABLE

## POLAR TREND ANALYSIS



Octopus uses Polar Trend Analysis to show point-wise progression per visual field location projected onto the optic disc as guidance on where to look for structural progression (see [FIG 9-14](#)).

## REFERENCES

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7. Funkhouser A, Fankhauser F. The effects of weighting the "mean defect" visual field index according to threshold variability in the central and midperipheral visual field. *Graefes Arch Clin Exp Ophthalmol*. 1991;229:228-231.
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# CHAPTER 13

## CLINICAL CASES

### INTRODUCTION

The previous chapters of this book have systematically presented various aspects of visual field testing and interpretation. To conclude, visual field interpretation is now put into a clinical context. In this chapter, 23 clinical cases are presented that show visual fields or visual field series of patients with glaucoma, neuro-ophthalmic disorder and retinal disease. The selected cases are model cases. They present typical defect patterns of the disease rather than unusual cases and are reliable, free of artifacts and can be fully trusted.

To link visual field interpretation to the clinical situation, the visual field results are presented in addition to other

relevant clinical information. Background information on the patient's history as well as other diagnostic results such as visual acuity, IOP, fundus images, OCT scans and MRIs which are relevant for clinical decision making, are shown. In all examples, visual acuity is expressed in decimal units for uniformity, but the Octopus allows users to select different units when performing the test. In each case, key diagnostic findings leading to disease diagnosis are presented and summarized.

An overview of all available cases is presented on the next page.

## GLAUCOMA – SINGLE FIELD

1. Very early stage glaucoma  
(normal tension glaucoma)
2. Early stage glaucoma  
(normal tension glaucoma)
3. Early stage glaucoma  
(primary open-angle glaucoma)
4. Early stage glaucoma  
(with cataract)
5. Early stage glaucoma  
(normal tension glaucoma)
6. Early stage glaucoma  
(primary open-angle glaucoma)
7. Moderate glaucoma  
(normal tension glaucoma)
8. Moderate glaucoma  
(primary open-angle glaucoma)
9. Late stage glaucoma  
(normal tension glaucoma)

## GLAUCOMA – TREND

10. Early to moderate glaucoma  
(normal tension glaucoma)
11. Early to moderate glaucoma  
(primary open-angle glaucoma)
12. Early to moderate glaucoma  
(primary open-angle glaucoma)
13. Early to moderate glaucoma  
(normal tension glaucoma)
14. Early to moderate glaucoma  
(primary open-angle glaucoma)
15. End-stage glaucoma  
(exfoliative glaucoma)

## NEUROLOGICAL DISEASES

16. Cerebral infarction  
(bilateral)
17. Leber hereditary optic neuropathy  
(bilateral)
18. Bilateral optic neuritis  
(multiple sclerosis)
19. Tuberculum sellae meningioma  
(bilateral)

## RETINAL DISEASES

20. Age-related macular degeneration
21. Branch central retinal artery occlusion
22. Macular hole
23. Branch central retinal vein occlusion

**1 VERY EARLY STAGE GLAUCOMA (NORMAL TENSION GLAUCOMA)**

**PATIENT**

- 57-year-old female, no family history
- Patient reported decreased visual acuity in both eyes and discomfort in left eye

**IOP/VA corr**

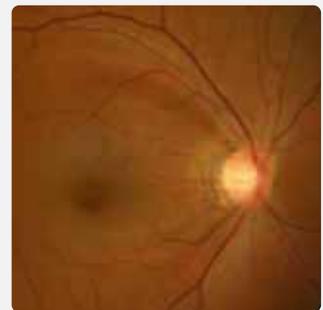
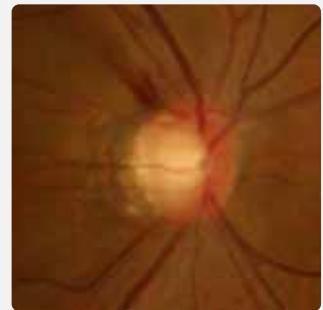
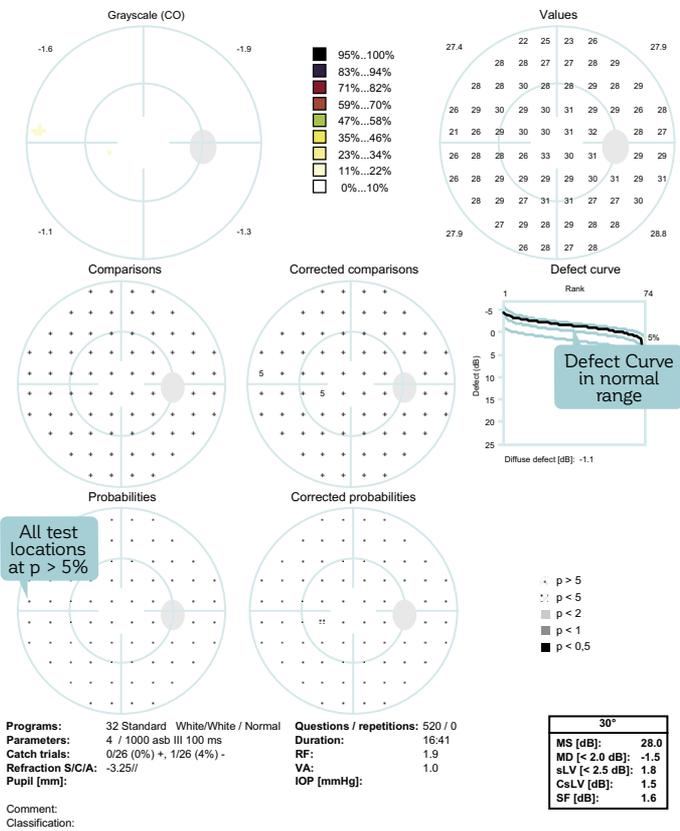
- 15 mmHg/ 1.2 - 5.25 (sph)

**FUNDUS**

- C/D = 0.9
- Rim thinning at 6 to 11 o'clock position
- Optic disc hemorrhage and narrow slit-like RNFL defect at 11 o'clock position
- Temporal alpha zone and beta zone peripapillary chorioretinal atrophy (PPA)

Demo Jane, 1947/01/01 (57yrs)

Right eye (OD) / 2004/11/18 / 12:01:27  
Seven-in-One



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EyeSuite™ Static perimetry, V2.3.0  
OCTOPUS 101

**HAAG-STREIT**  
DIAGNOSTICS

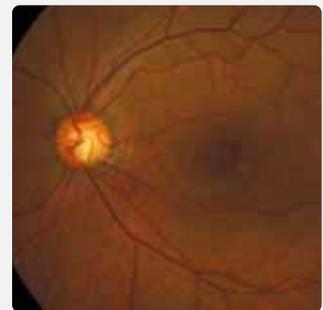
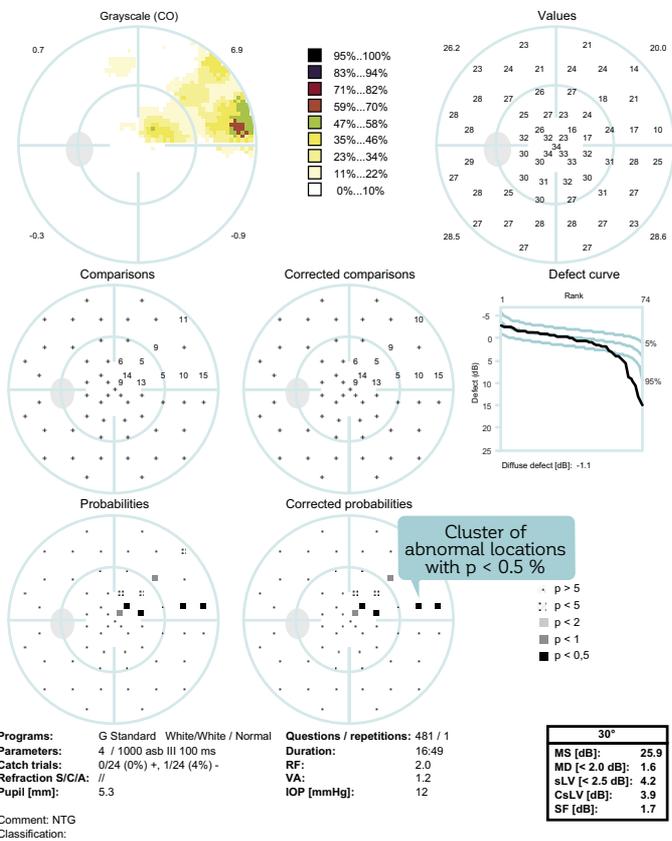
- No visual field loss
- Fundus findings show changes indicative of very early glaucoma including neuroretinal rim loss, optic disc hemorrhage, and RNFL loss

**2 EARLY STAGE GLAUCOMA (NORMAL TENSION GLAUCOMA)**

- PATIENT**
- 53-year-old female, no family history
  - Optic nerve cupping observed during unrelated emergency eye surgery
- IOP/VA corr**
- 12 mmHg/ 1.2 +0.25 (sph)
- FUNDUS**
- C/D = 0.8
  - Rim thinning and RNFL loss at 5 to 6 o'clock position

Demo Jane, 1942/01/01 (53yrs)

Left eye (OS) / 1996/06/21 / 14:24:40  
Seven-in-One



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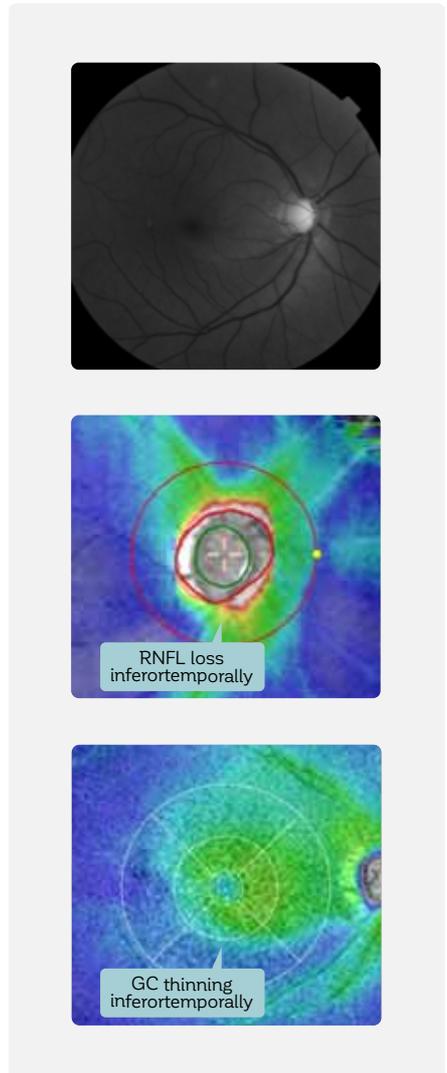
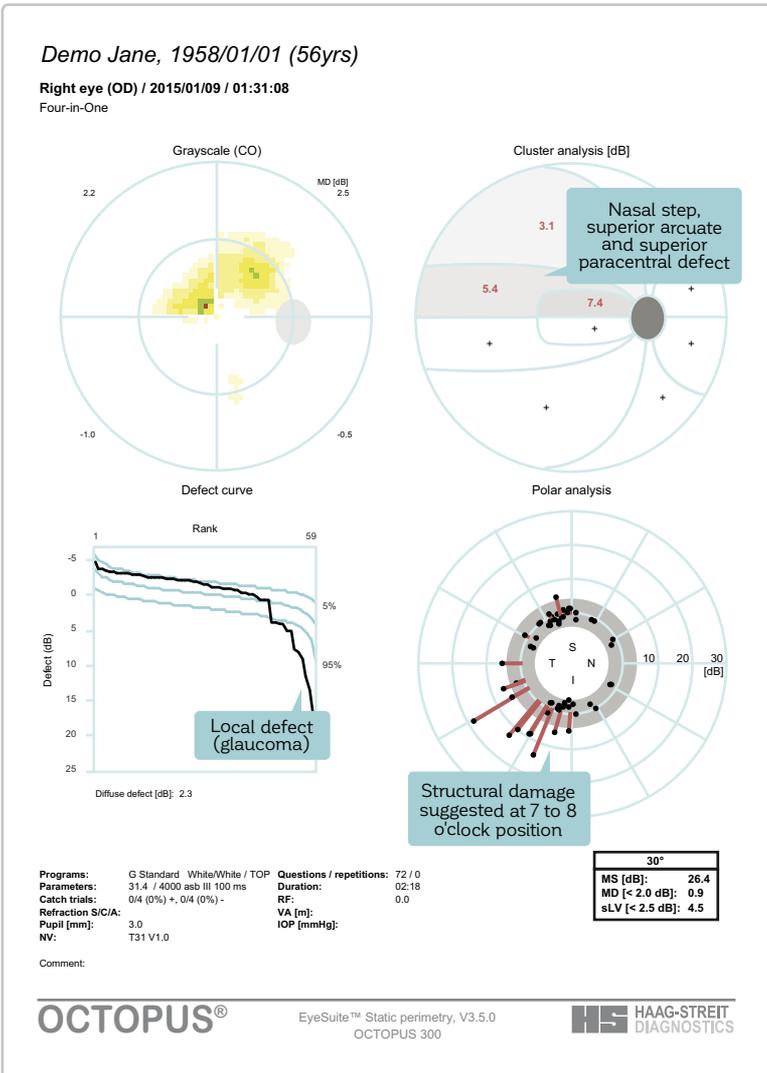
EyeSuite™ Static perimetry, V2.3.0  
OCTOPUS 101

**HS HAAG-STREIT**  
DIAGNOSTICS

- Mild superior nasal step and mild superior paracentral scotoma
- Spatial relationship between visual field loss and both rim thinning and RNFL loss in fundus photo

**3 EARLY STAGE GLAUCOMA (PRIMARY OPEN-ANGLE GLAUCOMA)**

- PATIENT**
- 56-year-old female, her brother has POAG
  - Patient visited clinic to rule out glaucoma because of her family history
- IOP/VA corr**
- 24 mmHg /1.0 -3.25 (sph)
- FUNDUS**
- Inferior RNFL defects
- OCT**
- RNFL and ganglion cell loss inferotemporally at 7 to 8 o'clock position



- Nasal step, superior arcuate and superior paracentral defect apparent in Cluster Analysis
- Spatial relationship between visual field loss (Polar Analysis suggests structural damage at 7 to 8 o'clock position) and inferotemporal structural loss (fundus photo, RNFL & GC thickness map)

#### 4 EARLY STAGE GLAUCOMA (WITH CATARACT)

##### PATIENT

- 71-year-old male, no family history
- Patient reported defective vision in both eyes over the last 6 months and glare at night while crossing roads

##### IOP/VA corr

- 24 mmHg/ 0.7 + 1.75 (sph), - 1.25 (cyl) x 80°

##### FUNDUS

- Fundus image hazy due to cataract

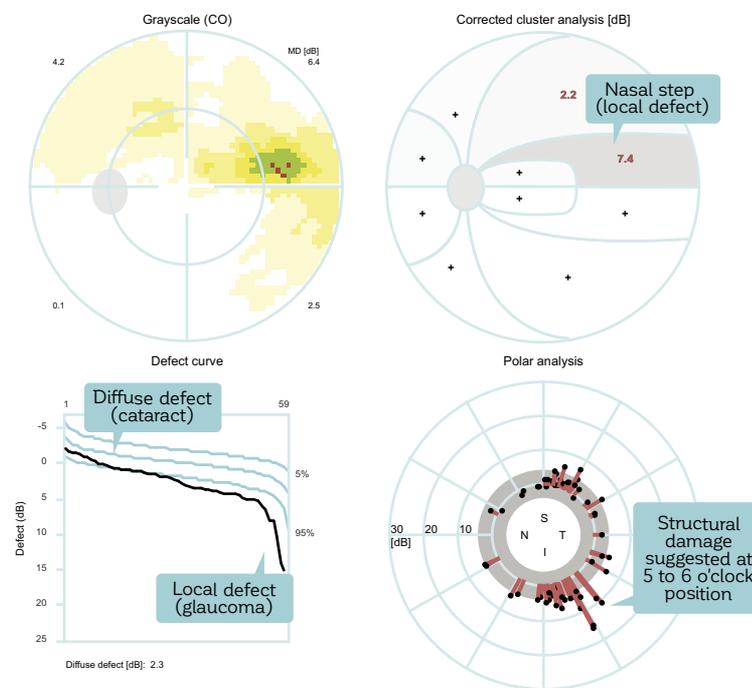
##### OCT

- RNFL loss and ganglion cell loss at 5 to 6 o'clock position

Demo John, 1944/01/01 (71yrs)

Left eye (OS) / 2015/04/29 / 14:57:18

Four-in-One



Programs: G Standard White/White / TOP Questions / repetitions: 74 / 0  
 Parameters: 31.4 / 4000 asb Ill 100 ms Duration: 02:25  
 Catch trials: 2/4 (50%) +, 0/4 (0%) - RF: 25.0  
 Refraction S/C/A: VA [m]:  
 Pupil [mm]: 3.7 IOP [mmHg]:  
 NV: T31 V1.0

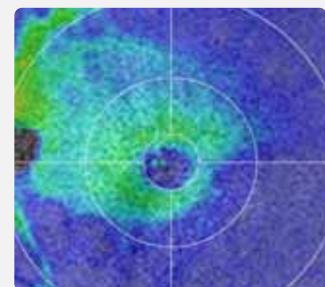
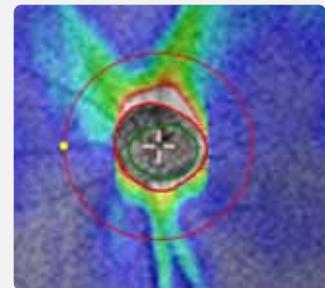
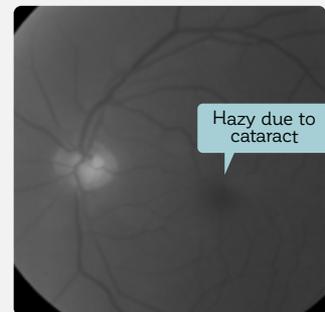
Comment:

30°	
MS [dB]:	23.0
MD [< 2.0 dB]:	3.3
sLV [< 2.5 dB]:	3.4

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OCTOPUS 300

**HS HAAG-STREIT**  
DIAGNOSTICS



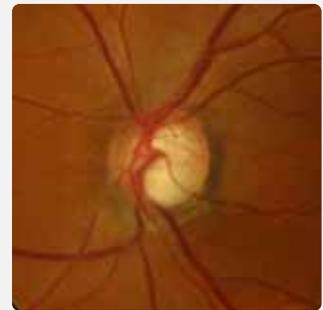
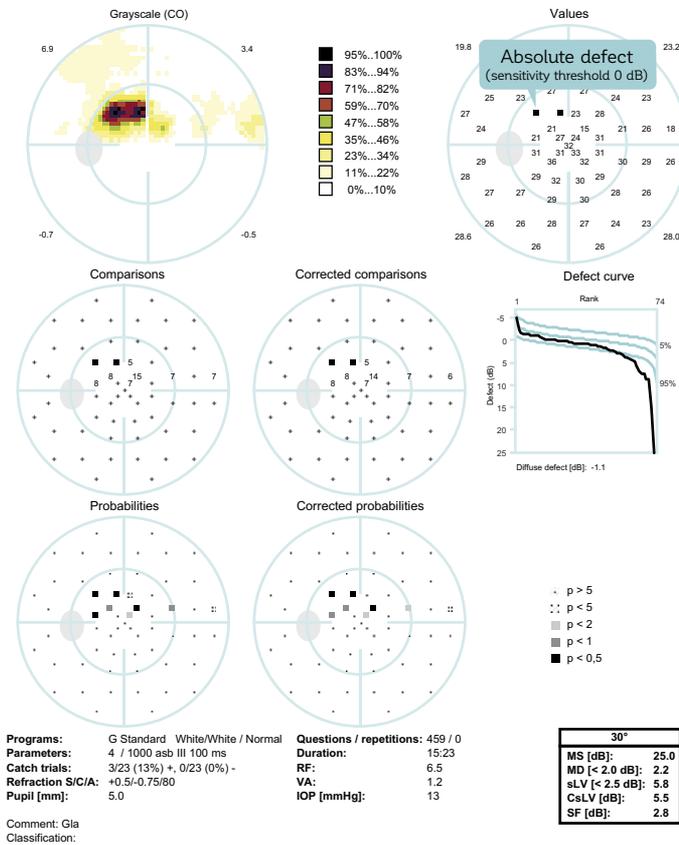
- Both diffuse defect (due to cataract) and local defect (due to glaucoma) in Defect Curve
- Corrected Cluster Analysis (removing diffuse defect) shows superior nasal step
- Spatial relationship between visual field loss (Polar Analysis suggests structural damage at 5 to 6 o'clock position) and inferotemporal structural loss (fundus photo, RNFL & GC thickness map)

**5 EARLY STAGE GLAUCOMA (NORMAL TENSION GLAUCOMA)**

- PATIENT**
- 58-year-old female, father had glaucoma
  - Optic nerve cupping detected during routine medical visit
- IOP/VA corr**
- 16 mmHg/ 1.2 - 1.0 (sph), -0.75 (cyl) x 80°
- FUNDUS**
- C/D = 0.9
  - Rim thinning and wide RNFL loss at 5 to 6 o'clock position

Demo Jane, 1944/01/01 (58yrs)

Left eye (OS) / 2003/03/14 / 16:43:49  
Seven-in-One



**OCTOPUS®**

EyeSuite™ Static perimetry, V2.3.0  
OCTOPUS 101

**HS HAAG-STREIT**  
DIAGNOSTICS

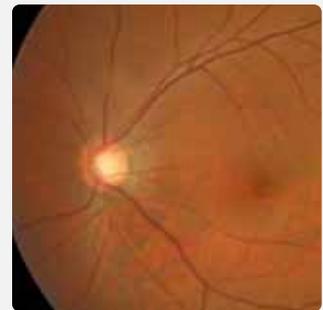
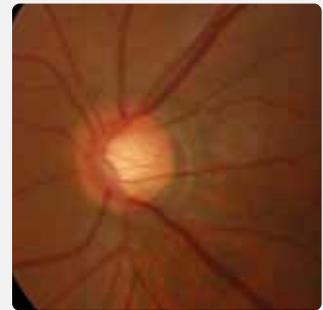
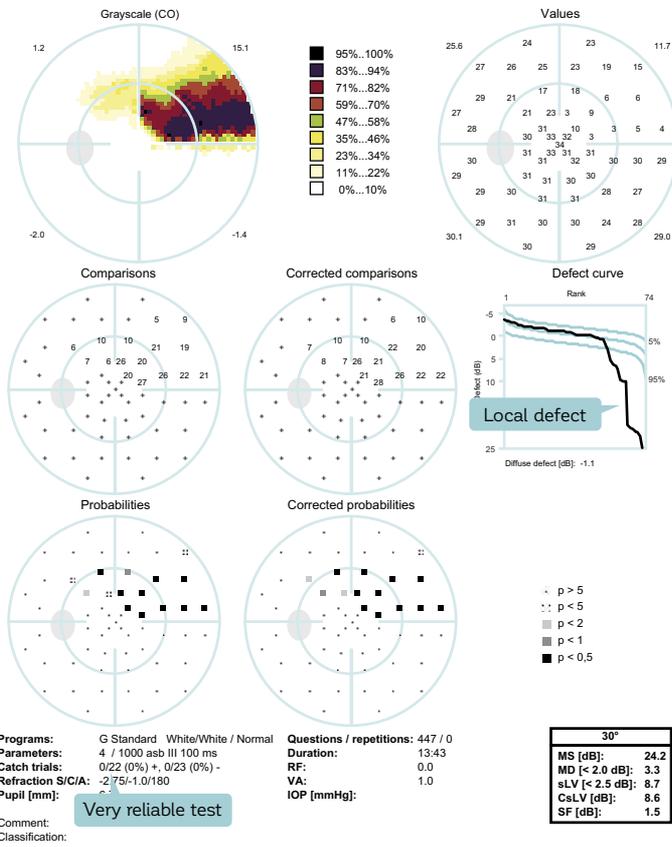
- Dense paracentral scotoma
- Spatial relationship between visual field loss and both rim thinning and RNFL loss in fundus photo

**6 EARLY STAGE GLAUCOMA (PRIMARY OPEN-ANGLE GLAUCOMA)**

- PATIENT**
- 55-year-old male, no family history
  - Patient reported decreased visual acuity and blurred vision
- IOP/VA corr**
- 23 mmHg/ 1.2 -4.25 (sph), -1.0 (cyl) x 180°
- FUNDUS**
- C/D = 0.8
  - Small disc
  - Rim thinning at 5 to 6 o'clock position

Demo John, 1951/01/01 (55yrs)

Left eye (OS) / 2007/05/11 / 10:02:54  
Seven-in-One



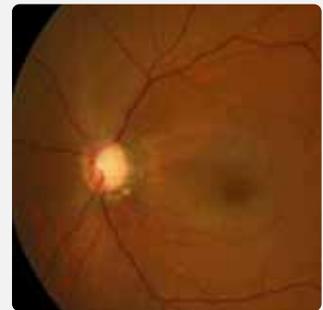
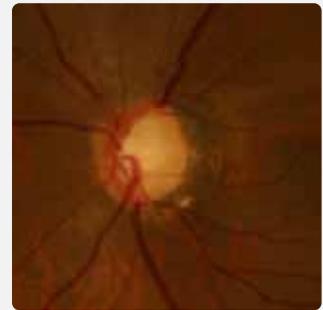
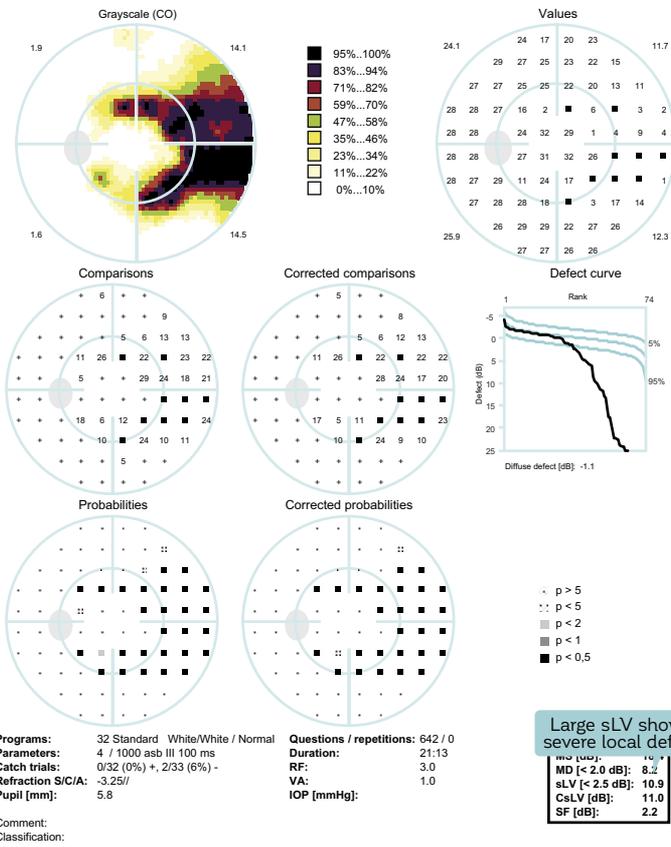
- Visual field shows superior arcuate defect
- Spatial relationship between visual field loss and rim thinning in fundus photo indicative of glaucoma

**7 MODERATE GLAUCOMA (NORMAL TENSION GLAUCOMA)**

- PATIENT**
- 57-year-old female, no family history
  - Patient reported decreased visual acuity in both eyes and discomfort in left eye
- IOP/VA corr**
- 16 mmHg/ 1.0 - 5.5 (sph)
- FUNDUS**
- C/D = 0.95
  - Rim thinning at 12 to 6 o'clock position
  - Vein angulation and bayoneting at 12 and 6 o'clock position

Demo Jane, 1947/01/01 (57yrs)

Left eye (OS) / 2004/11/18 / 12:25:31  
Seven-in-One



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**HS HAAG-STREIT DIAGNOSTICS**

- Dense partial double arcuate visual field defect
- Spatial relationship between visual field loss and both rim thinning and vein bending in fundus photo

**8 MODERATE GLAUCOMA (PRIMARY OPEN-ANGLE GLAUCOMA)**

**PATIENT**

- 52-year-old female, no family history
- Patient diagnosed with glaucoma during medical check-up

**IOP/VA corr**

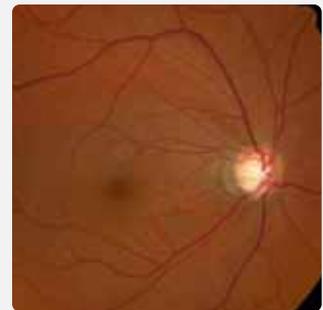
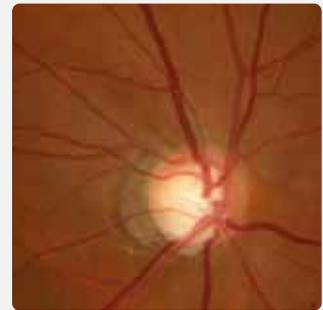
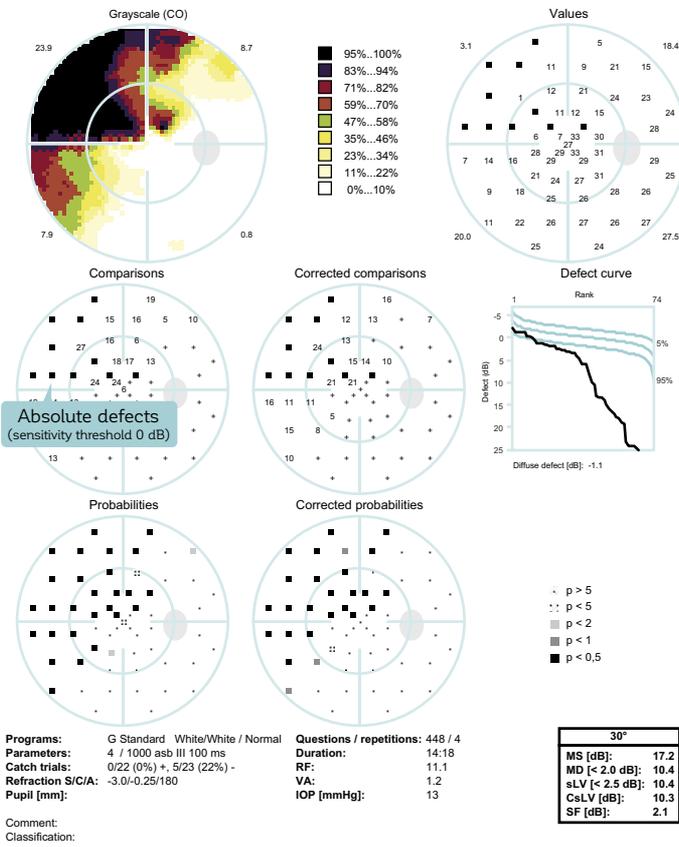
- 20 mmHg/ 1.2 -4.0 (sph), -0.25 (cyl) x 180°

**FUNDUS**

- C/D = 0.9
- Rim thinning at 6 to 8 o'clock position and notching at 11 o'clock position
- Large RNFL loss at 6 to 8 o'clock position and small RNFL loss at 11 o'clock position
- Angulation of lower vein and undermining due to optic disc cupping
- Temporal alpha zone and beta zone peripapillary chorioretinal atrophy (PPA)

Demo Jane, 1954/01/01 (52yrs)

Right eye (OD) / 2007/02/06 / 09:27:13  
Seven-in-One



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**HAAG-STREIT**  
DIAGNOSTICS

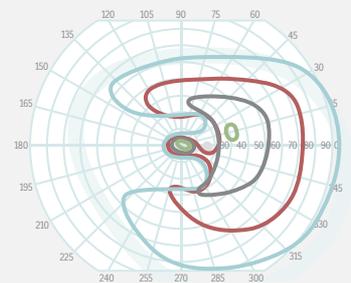
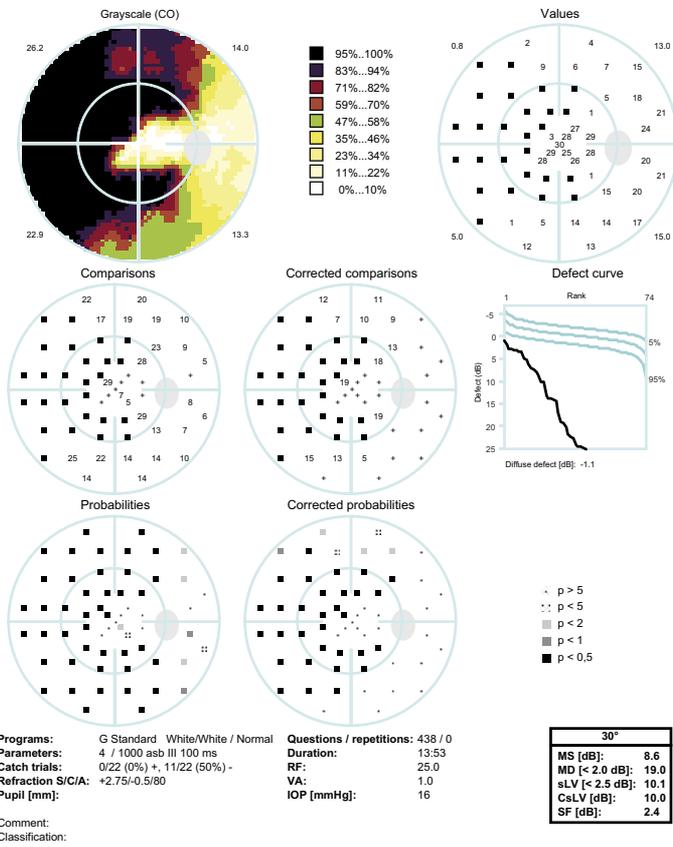
- Dense visual field loss in superior nasal quadrant with many locations showing absolute defects and little remaining sensitivity near fixation corresponding with RNFL loss at 6 to 8 o'clock position
- Mild sensitivity loss on lower nasal field relating to RNFL loss at 11 o'clock position

**9 LATE STAGE GLAUCOMA (NORMAL TENSION GLAUCOMA)**

- PATIENT**
- 52-year-old male, no family history
  - Patient reported decreased visual acuity in both eyes
- IOP/VA corr**
- 15 mmHg/ 1.2 + 1.25 (sph), -0.5 (cyl) x 80°
- FUNDUS**
- C/D = 1.0
  - Rim disappearance at 12 and 6 to 8 o'clock position
  - Narrowing of retinal artery

Demo John, 1954/01/01 (52yrs)

Right eye (OD) / 2006/11/24 / 16:24:03  
Seven-in-One



**OCTOPUS®** EyeSuite™ Static perimetry, V2.3.0 OCTOPUS 101 **HAAG-STREIT DIAGNOSTICS**

- Dense double arcuate defect with many locations showing absolute defects
- No sensitivity loss at fixation
- Kinetic perimetry shows intact temporal and central visual field
- Late stage glaucoma with preserved fixation and peripheral temporal visual field

**10 EARLY TO MODERATE GLAUCOMA (NORMAL TENSION GLAUCOMA)**

**PATIENT**

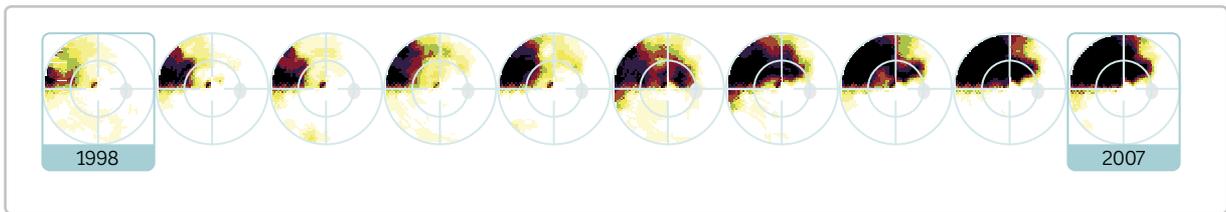
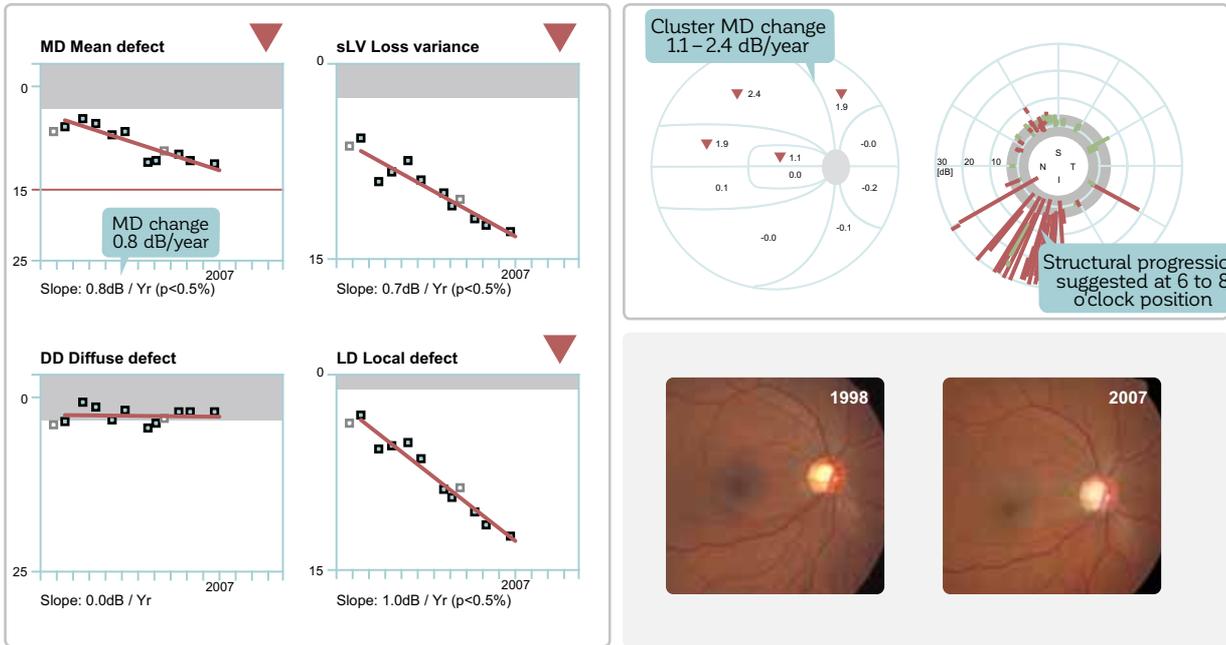
- 40-year-old male, no family history
- Glaucoma was suspected after routine medical check-up

**IOP/VA corr**

- 16 mmHg/1.2 - 2.5 (sph), - 1.5 (cyl) x 110°

**FUNDUS**

- **1998** Rim thinning RNFL loss at 7 o'clock position
- **2007** Rim thinning & RNFL loss at 6 to 8'clock position indicating progression



- Grayscale series shows expansion of superior nasal defect to a superior arcuate defect from 1998 to 2007
- Significant (p < 1%) MD worsening at 0.8 dB/year due to fast progression in affected superior clusters (Cluster MD change 1.1 to 2.4 dB/year)
- Large (up to 30 dB) progression at 6 to 8 o'clock position in Polar Trend Analysis
- Rim thinning and RNFL loss spreading from 7 o'clock position towards 6 and 8 o'clock position
- Clear relationship between fundus and visual field progression confirming glaucomatous progression

**11 EARLY TO MODERATE GLAUCOMA (PRIMARY OPEN-ANGLE GLAUCOMA)**

**PATIENT**

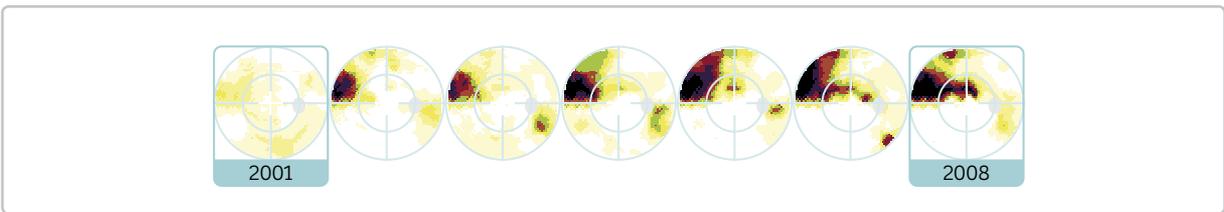
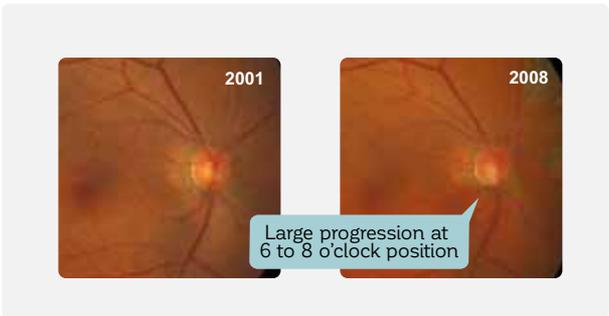
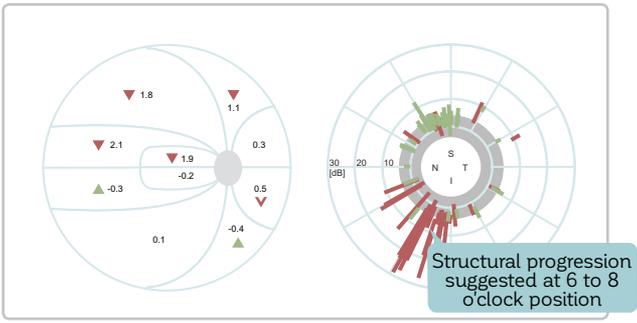
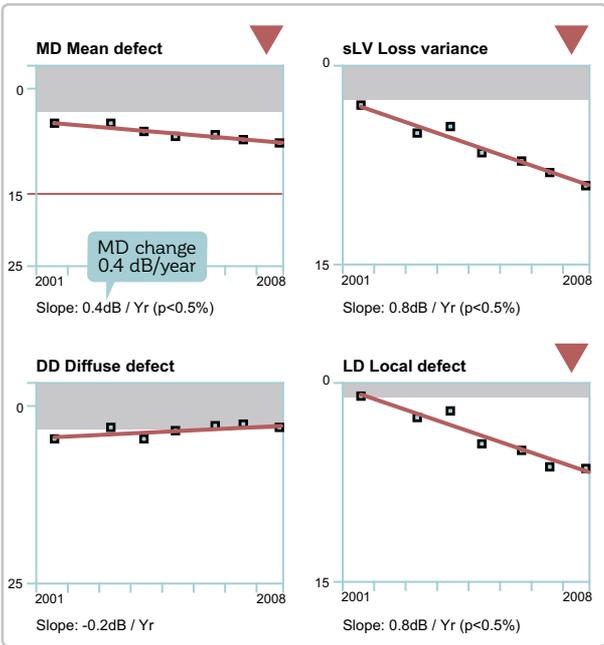
- 68-year-old female, no family history
- High IOP identified during visit initiated due to eye pain

**IOP/VA corr**

- 22 mmHg/1.5 + 0.75 (sph), -0.25 (cyl) x 10°

**FUNDUS**

- **2001** Mild, slit-like RNFL loss at 7 o'clock position. No rim thinning or notching.
- **2008** RNFL loss & additional rim thinning with undermining at 6 to 8 o'clock position indicating progression; laser scar at 1 to 3 o'clock position due to treated BRVO, which developed in 2002 during follow up



- Grayscale series shows expansion of superior nasal defect to a superior arcuate defect from 2001 to 2008 and mild inferotemporal sensitivity loss due to BRVO
- Significant (p < 1%) but slow MD worsening at 0.4 dB/year due to fast progression in affected superior clusters (Cluster MD change 1.1 to 2.1 dB/year)
- Large (up to 30 dB) progression at 6 to 8 o'clock position in Polar Trend Analysis
- Rim thinning and RNFL loss spreading from 7 o'clock position towards 6 and 8 o'clock position
- Clear relationship between fundus and visual field progression confirming glaucomatous progression

**12 EARLY TO MODERATE GLAUCOMA (PRIMARY OPEN-ANGLE GLAUCOMA)**

**PATIENT**

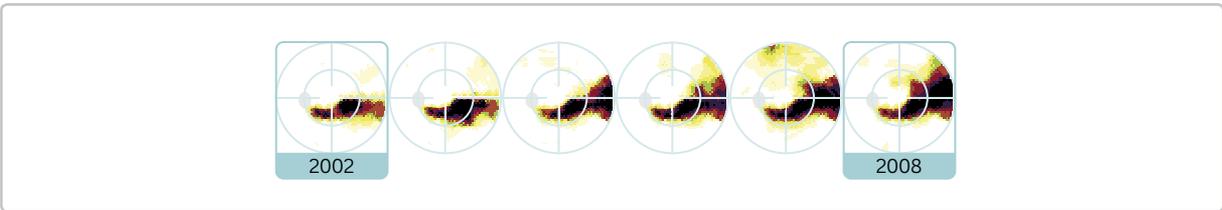
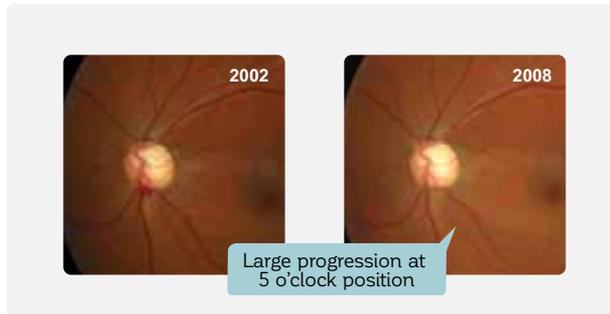
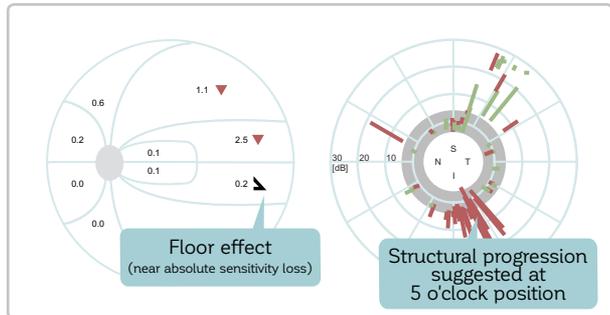
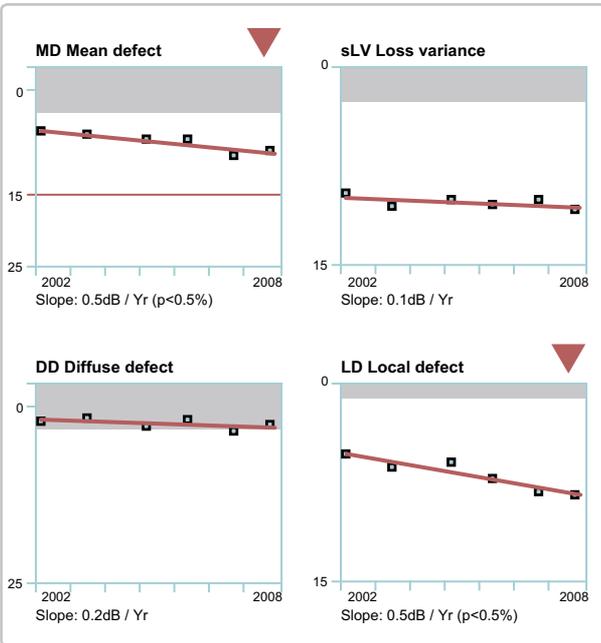
- 53-year-old male, no family history
- High IOP identified during visit related to eye pain

**IOP/VA corr**

- 25 mmHg/1.2 - 0.75 (sph), - 1.0 (cyl) x 90°

**FUNDUS**

- **2002** Rim thinning at 1 to 2 o'clock position. Rim notching at 5 o'clock position. RNFL loss at same positions. Optic disc hemorrhage at 6 o'clock position.
- **2008** Rim thinning from 1 to 6 o'clock position



- Grayscale series shows expansion of inferior arcuate defect to superior nasal side from 2002 to 2008
- Significant (p < 1%) but slow MD worsening at 0.5 dB/year due to fast progression in affected superior clusters (Cluster MD change up to 2.5 dB/year)
- Large (~28 dB) progression at 5 o'clock position in Polar Trend Analysis
- Rim thinning and RNFL loss spreading from 1 to 2 o'clock position towards 6 o'clock position
- Clear relationship between fundus and visual field progression confirming glaucomatous progression

**13 EARLY TO MODERATE GLAUCOMA (NORMAL TENSION GLAUCOMA)**

**PATIENT**

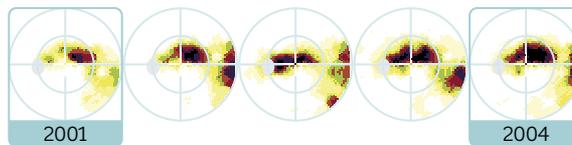
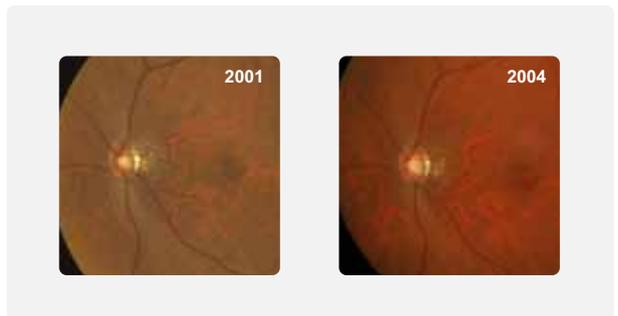
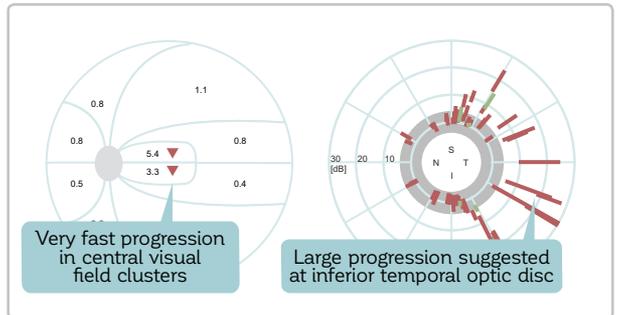
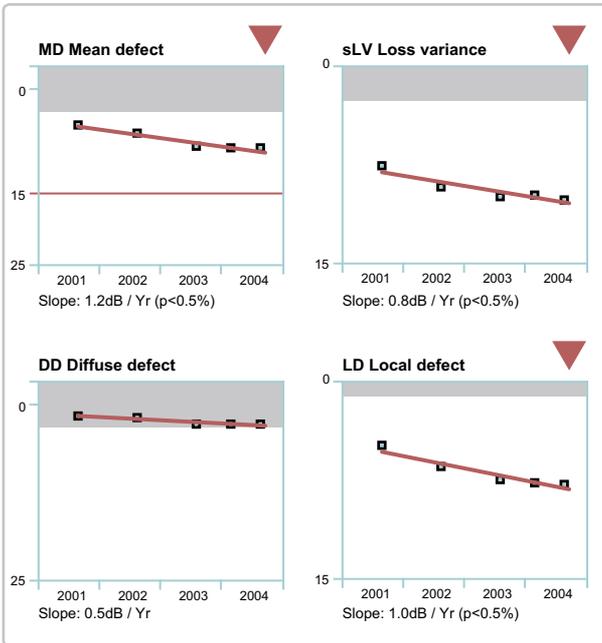
- 51-year-old male, no family history
- Patient reported a blind spot in visual field of left eye during reading and a visual field defect temporally near fixation upon fixation of distant objects

**IOP/VA corr**

- 15 mmHg/1.0 - 6.0 (sph), - 1.25 (cyl) x 160°

**FUNDUS**

- **2001** Small disc. RNFL loss (including papillomacular nerve fiber) from 2 to 5 o'clock position. Temporal alpha zone and beta zone peripapillary chorioretinal atrophy (PPA).
- **2004** Challenging to identify changes because of small disc and severe myopia



- Grayscale series shows expansion of superior paracentral defect towards fixation from 2001 to 2004
- Significant ( $p < 1\%$ ) and fast MD worsening at 1.2 dB/year due to very fast progression in affected central clusters (Cluster MD change 3.3 and 5.4 dB/year)
- Challenging to assess structural changes, but large (up to 30 dB) progression at 5 o'clock position in Polar Trend Analysis corresponding with RNFL loss in fundus image suggests glaucomatous progression
- Relationship between fundus and visual field progression confirming glaucomatous progression

**14 EARLY TO MODERATE GLAUCOMA (PRIMARY OPEN-ANGLE GLAUCOMA)**

**PATIENT**

- 74-year-old female
- Patient showed advanced disc damage at presentation
- Suboptimal IOP control under topical medication, but patient refused surgery

**IOP/VA uncorr**

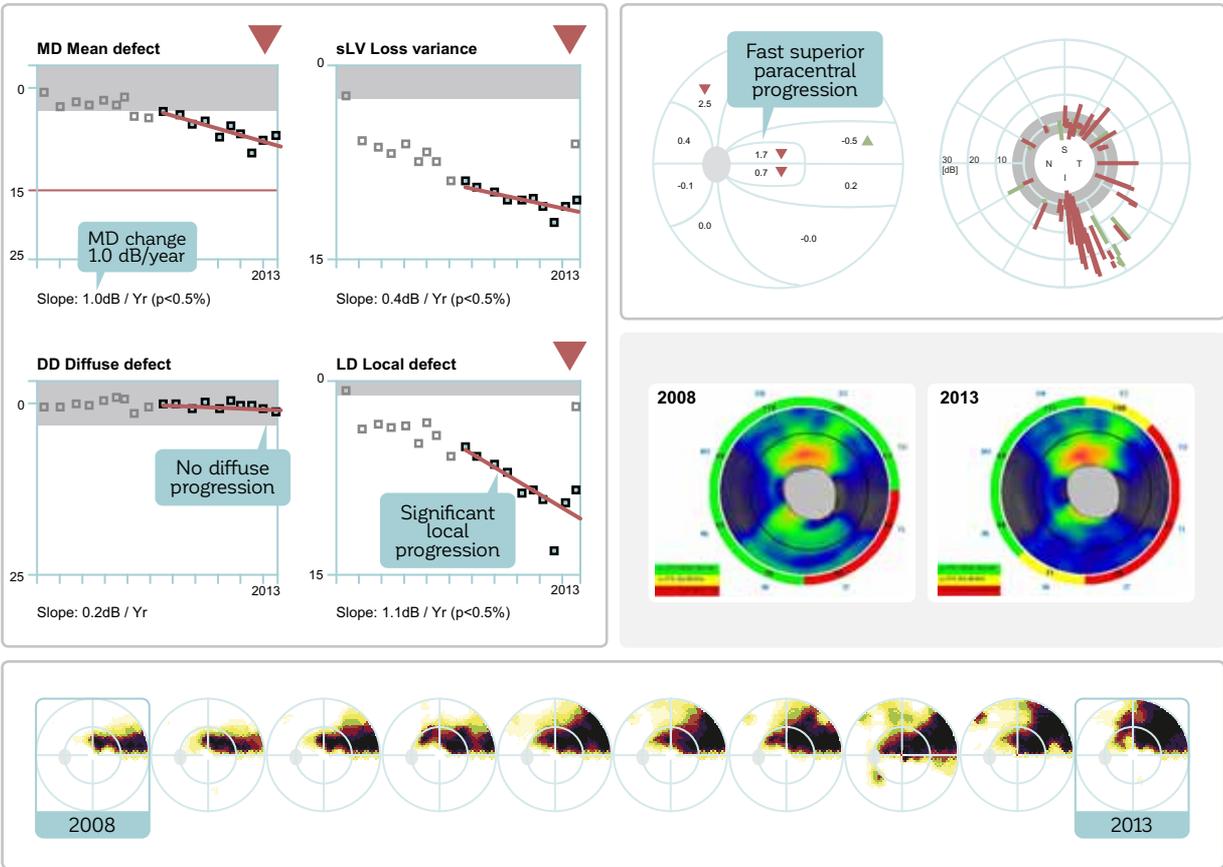
- 16–22 mmHg (28 mmHg pre-treatment)/1.0

**OCT**

- **2008** Pathologically low peripapillary RNFLT in inferotemporal sectors
- **2013** Statistically significant further RNFLT decrease both infero- and superotemporally

**FUNDUS**

- **2008** Advanced disc damage (C/D=0.95)



- Grayscale series shows progression of superior arcuate and both superior and inferior paracentral defects from 2008 to 2013
- Local progression apparent from significant ( $p < 1\%$ ) sLV increase and LD worsening due to very fast progression in superior arcuate and superior and inferior paracentral clusters (Cluster MD change up to 2.6 dB/year)
- Up to 30 dB progression at infero- and superotemporal test locations in Polar Trend Analysis spatially related to further RNFLT loss between 2008 and 2013
- Relationship between OCT and visual field progression confirming glaucomatous progression

**15** END-STAGE GLAUCOMA (EXFOLITATIVE GLAUCOMA)

**PATIENT**

- 79-year-old female
- Patient presented with end-stage glaucoma, filtration surgery was performed with no further medication during follow up
- Patient reported only minimal central visual field worsening during follow-up

**IOP/VA corr**

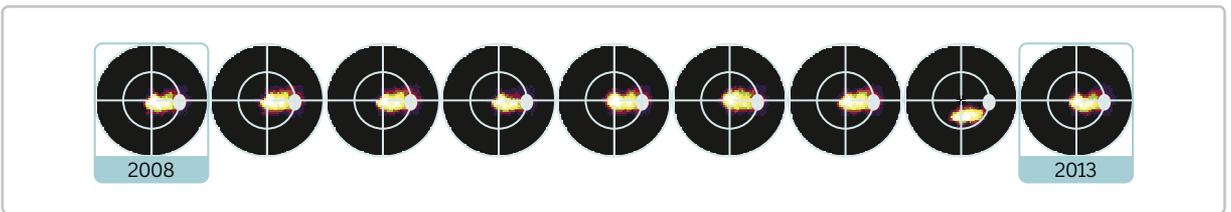
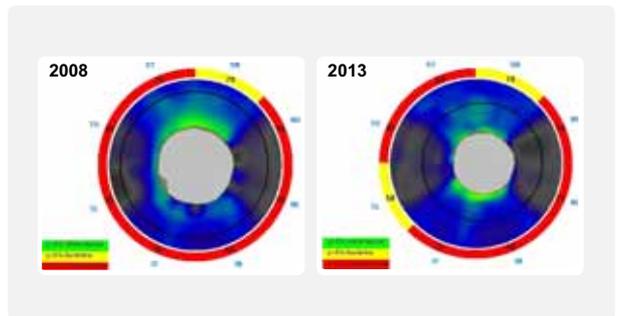
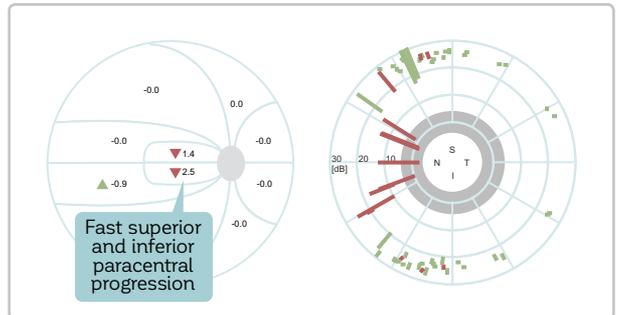
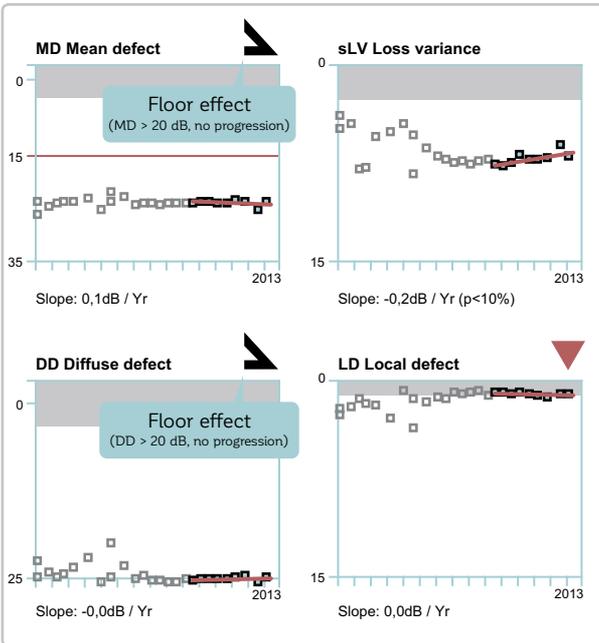
- 08–14 mmHg (43mmHg pre-treatment)/1.0 + 1.0 (sph)

**OCT**

- **2008** Severe peripapillary RNFLT loss
- **2013** No change in the average peripapillary RNFLT

**FUNDUS**

- **2008** C/D=0.99



- Grayscale series shows very dense visual field loss with little remaining sensitivity in macula
- MD appears stable, but cannot be interpreted for progression because of floor effect (exceeding perimeter’s measurement range)
- Significant (p < 1%) superior and inferior paracentral progression (Cluster MD change 1.4 and 2.5 dB/year)
- 12 to 25 dB progression at 8 to 10 o’clock position (papillomacular bundle) in Polar Trend Analysis not apparent in OCT results due to the floor effect of OCT in end-stage glaucoma
- Polar and Cluster Trend Analysis indicate late-stage glaucomatous progression

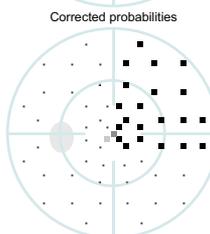
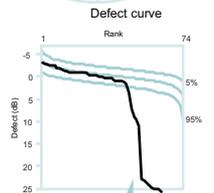
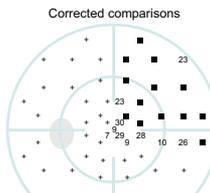
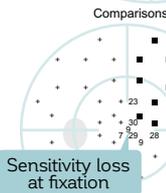
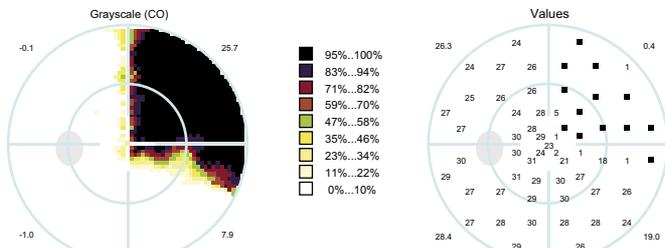
**16 CEREBRAL INFARCTION (BILATERAL)**

**PATIENT**

- 65-year-old male, no family history
- Patient experienced occipital headache and optic agnosia of name, letters, etc.
- Diagnosed with cerebral infarction in left temporal lobe
- Previous central serous chorioretinopathy in left eye

Demo John, 1933/01/01 (65yrs)

Left eye (OS) / 1999/07/12 / 11:36:23  
Seven-in-One



Vertical drop characteristic for quadrantanopia

- p > 5
- p < 5
- p < 2
- p < 1
- p < 0.5

Programs: G Standard White/White / Normal  
 Parameters: 4 / 1000 asb III 100 ms  
 Catch trials: 0/20 (0%) +, 4/21 (19%) -  
 Refraction S/C/A: +0.75/-1.5/90  
 Pupil [mm]: 6.4  
 Questions / repetitions: 409 / 2  
 Duration: 15:54  
 RF: 9.7  
 VA: 0.4  
 IOP [mmHg]: 14

30°	
MS [dB]:	18.3
MD [< 2.0 dB]:	8.4
sLV [< 2.5 dB]:	12.4
CsLV [dB]:	12.5
SF [dB]:	1.5

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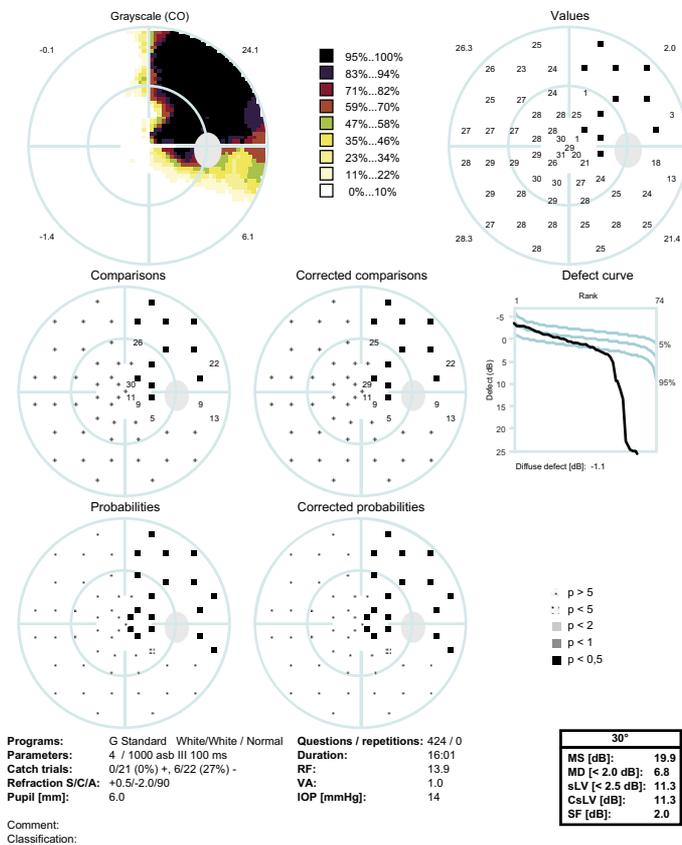
EyeSuite™ Static perimetry, V2.3.0  
OCTOPUS 101

HAAG-STREIT DIAGNOSTICS

**IOP/VA corr** • **OD** 19 mmHg/ 1.0 +0.5 (sph), -2.0 (cyl) x 100°; **OS** 20 mmHg/ 0.4 -1.5 (cyl) x 90°  
**FUNDUS** • No abnormality

**Demo John, 1933/01/01 (65yrs)**

**Right eye (OD) / 1999/07/12 / 11:00:42**  
 Seven-in-One



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EyeSuite™ Static perimetry, V2.3.0  
 OCTOPUS 101

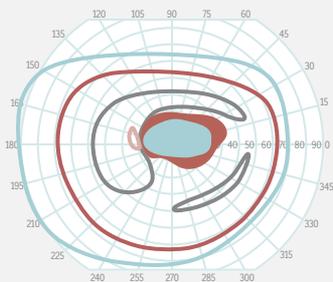
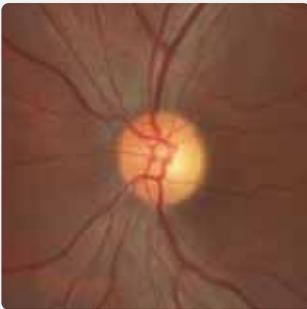
**HS HAAG-STREIT**  
 DIAGNOSTICS

- Superior homonymous quadrantanopia sparing fixation on right side of vertical meridian due to cerebral infarction in left temporal lobe
- Significant sensitivity loss at fixation in left eye due to previous central serous chorioretinopathy with decrease in visual acuity (0.4)

**17** LEBER HEREDITARY OPTIC NEUROPATHY (BILATERAL)

**PATIENT**

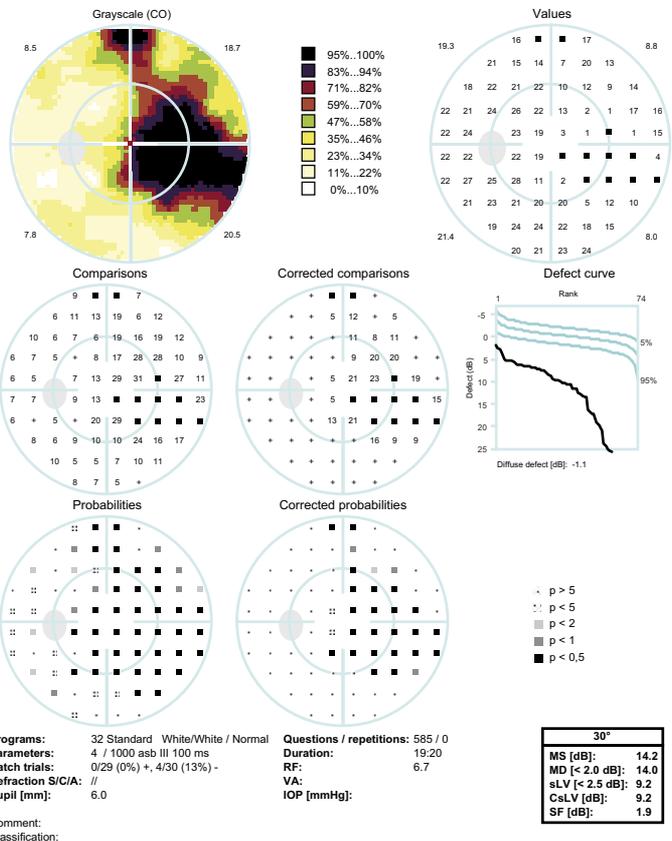
- 31-year-old male, no family history
- Patient reported decreased visual acuity in right eye
- Patient diagnosed with central serous chorioretinopathy and retinal hemorrhage
- After referral, patient diagnosed with optic neuropathy based on MRI findings
- Patient diagnosed with Leber hereditary optic neuropathy based on maternal mitochondrial DNA test



- V4e →
- I4e →
- I3e →
- I3a →

Demo John, 1973/01/01 (31yrs)

Left eye (OS) / 2004/10/21 / 12:51:41  
Seven-in-One



Programs: 32 Standard White/White / Normal  
 Parameters: 4 / 1000 asb III 100 ms  
 Catch trials: 0/29 (0%) +, 4/30 (13%) -  
 Refraction S/C/A: //  
 Pupil [mm]: 6.0

Questions / repetitions: 585 / 0  
 Durations: 19:20  
 RF: 6.7  
 VA:  
 IOP [mmHg]:

Comment:  
 Classification:

30°	
MS [dB]:	14.2
MD [< 2.5 dB]:	14.0
sLV [< 2.5 dB]:	9.2
CsLV [dB]:	9.2
SF [dB]:	1.9

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OCTOPUS 101

HAAG-STREIT  
DIAGNOSTICS

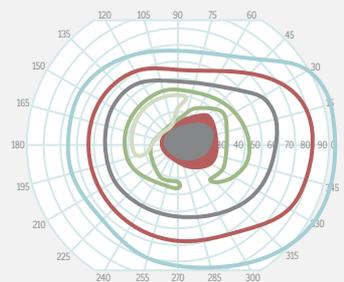
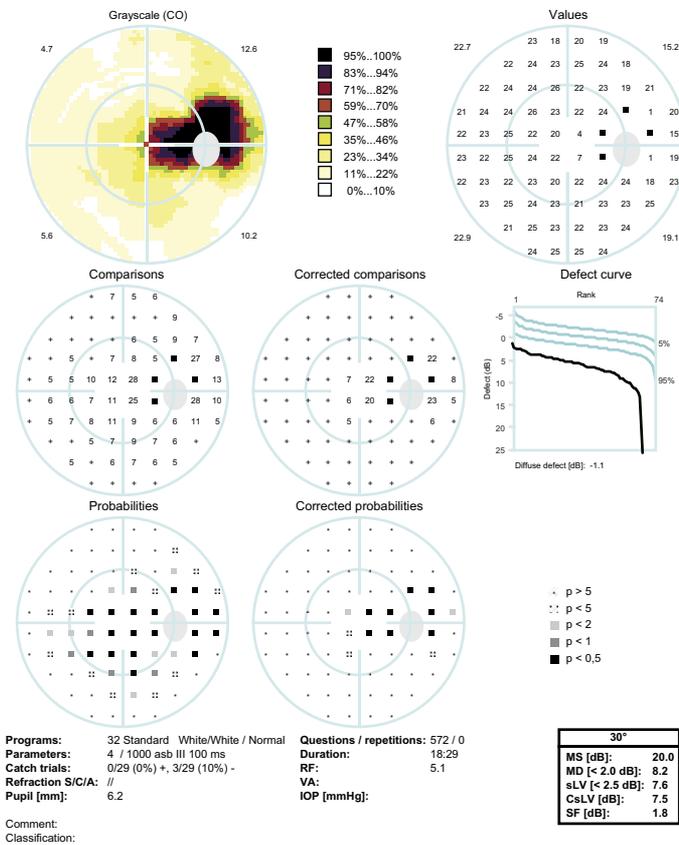
**IOP/VA corr** • OD 10 mmHg/ 10 cm, finger counting; OS 10 mmHg/ 30 cm, hand motion

**FUNDUS** • Pale optic discs in both eyes

**CENTRAL CFF** • OD 32 Hz; OS 42 Hz

**Demo John, 1973/01/01 (31yrs)**

Right eye (OD) / 2004/10/21 / 13:17:49  
Seven-in-One



- V4e →
- I4e →
- I3e →
- I3c →
- I2e →

**OCTOPUS®**

EyeSuite™ Static perimetry, V2.3.0  
OCTOPUS 101

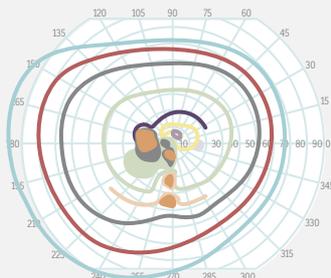
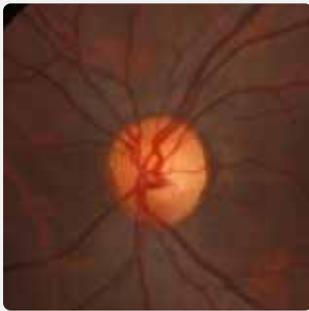
**HS HAAG-STREIT**  
DIAGNOSTICS

- Dense sensitivity loss in center of both eyes
- Additional inferior nasal visual field loss from 20 to 50°
- Asymmetrical visual field defect, central and peripheral scotomas more severe in left eye

**18 BILATERAL OPTIC NEURITIS (MULTIPLE SCLEROSIS)**

**PATIENT**

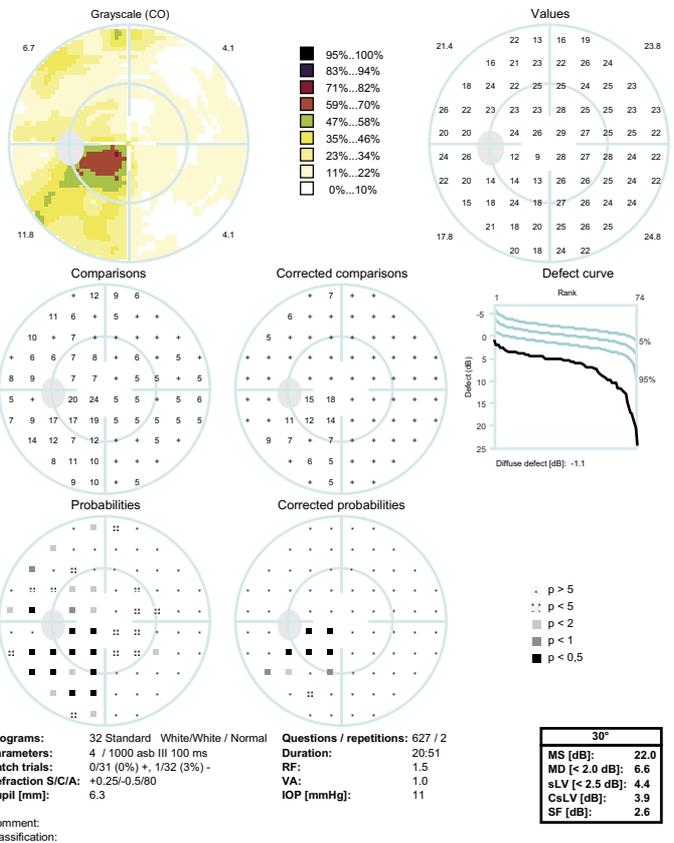
- 25-year-old female, no family history
- Patient reported difficulty in seeing for two weeks



- V4e →
- I4e →
- I3e →
- I3b →
- I2e →
- I2b →
- I1e →

*Demo Jane, 1975/01/01 (25yrs)*

Left eye (OS) / 2001/11/30 / 14:19:18  
Seven-in-One



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OCTOPUS 101

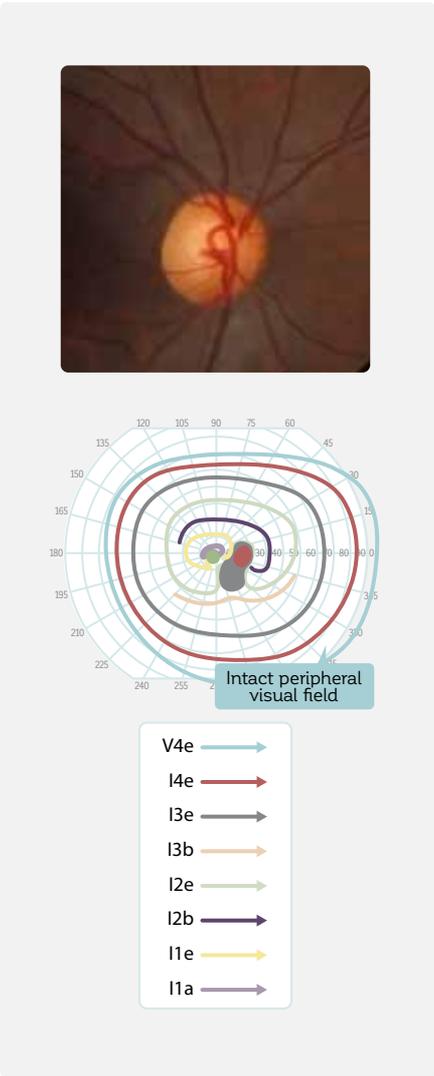
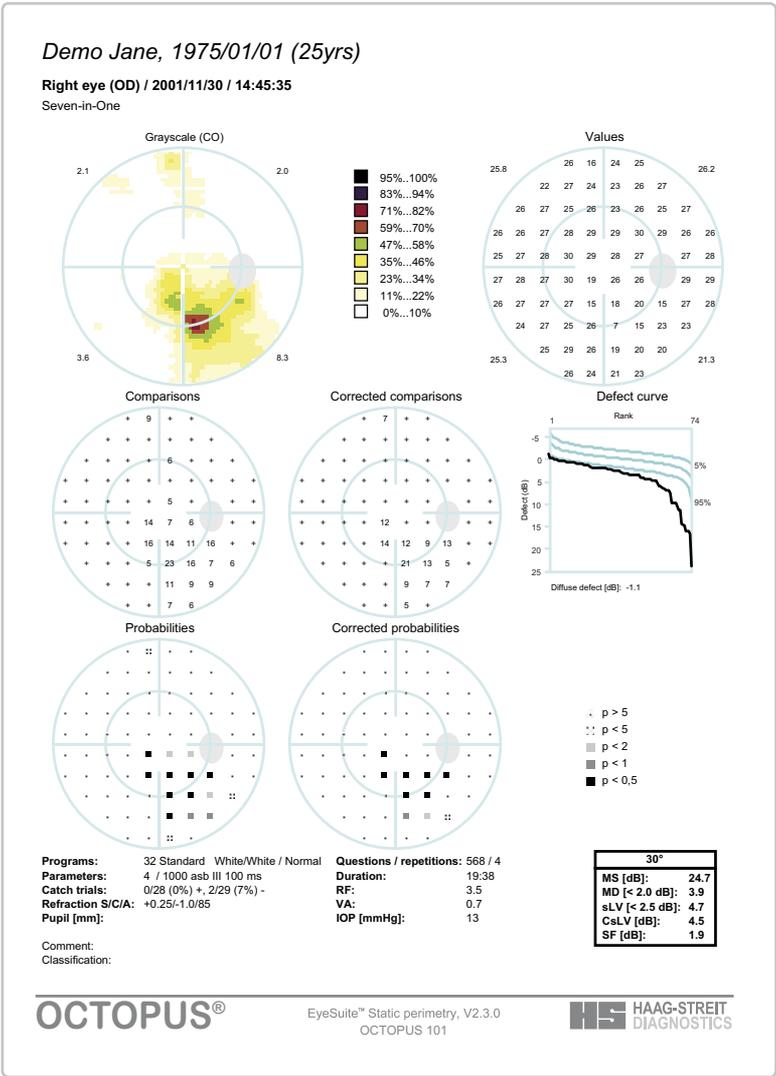
**HAAG-STREIT**  
DIAGNOSTICS

**IOP/VA corr** • **OD** 13 mmHg/ 0.7 +0.25 (sph), -1.0 (cyl) x 85°  
**OS** 11mmHg/ 1.0 +0.25 (sph), -0.5 (cyl) x 80°

**FUNDUS** • No abnormality

**CFF** • **OD** 34 Hz; **OS** 44 Hz

**MRI** • Demyelinated plaque at optic chiasm

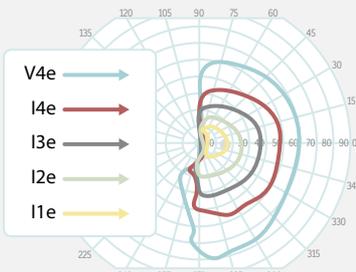
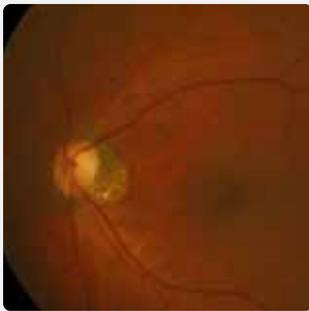


- Sensitivity loss on lower temporal side of vertical meridian in both eyes (i.e., mild bitemporal hemianopia)
- MRI shows demyelinated plaque, thus bitemporal hemianopia is attributed to multiple sclerosis at optic chiasm

**19 TUBERCULUM SELLAE MENINGIOMA (BILATERAL)**

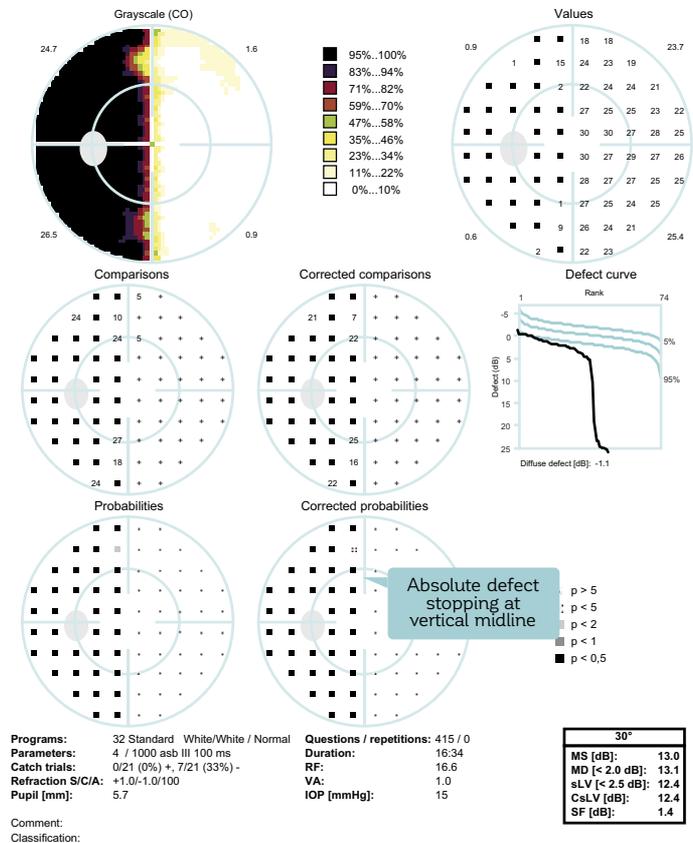
**PATIENT**

- 64-year-old male, no family history
- Patient reported difficulty in reading books and newspaper



Demo John, 1941/01/01 (64yrs)

Left eye (OS) / 2005/10/12 / 12:52:19  
Seven-in-One

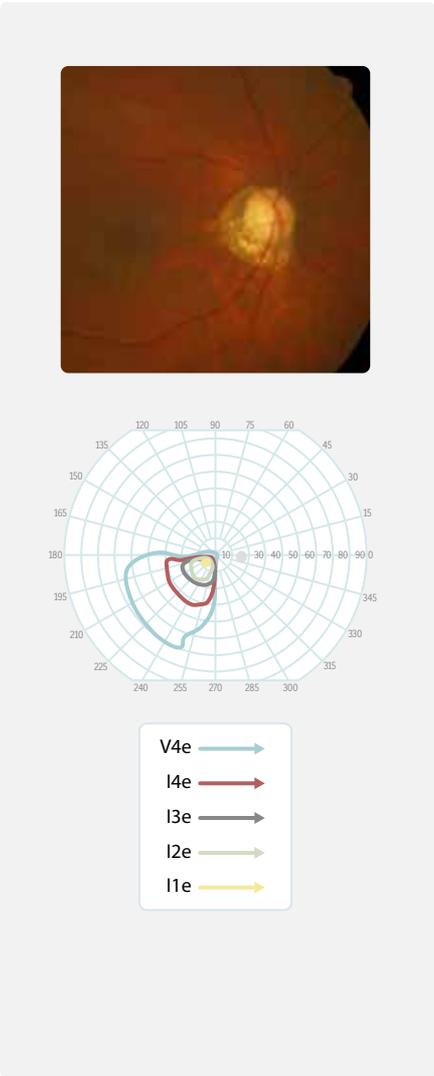
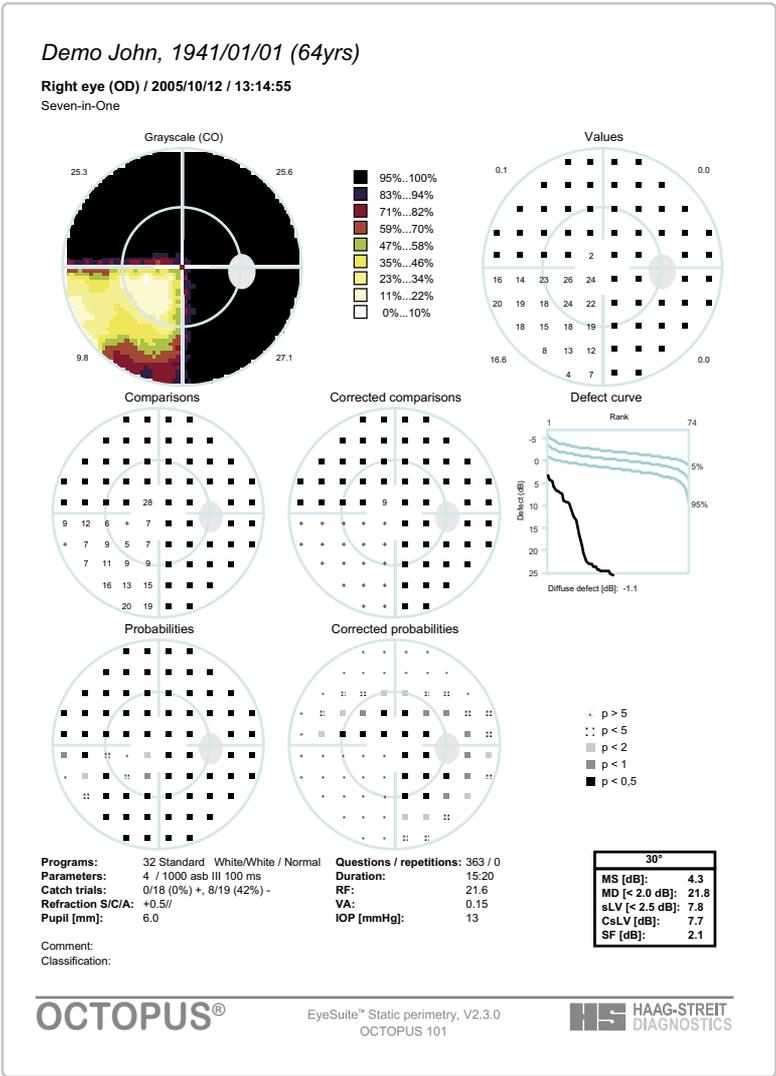


OCTOPUS®

EyeSuite™ Static perimetry, V2.3.0  
OCTOPUS 101

HAAG-STREIT  
DIAGNOSTICS

- IOP/VA corr**
  - **OD** 12 mmHg/0.15 - 2.0 (sph)
  - **OS** 13 mmHg/1.2 - 1.5 (sph), -1.0 (cyl) x 100°
- FUNDUS**
  - Pale optic disc with slight cupping
  - Slight bending of blood vessels
- CFF**
  - **OD** 25 Hz; **OS** 40 Hz
- MRI**
  - Meningioma in tuberculum sellae



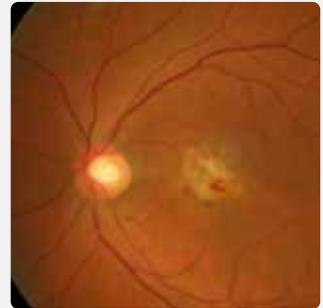
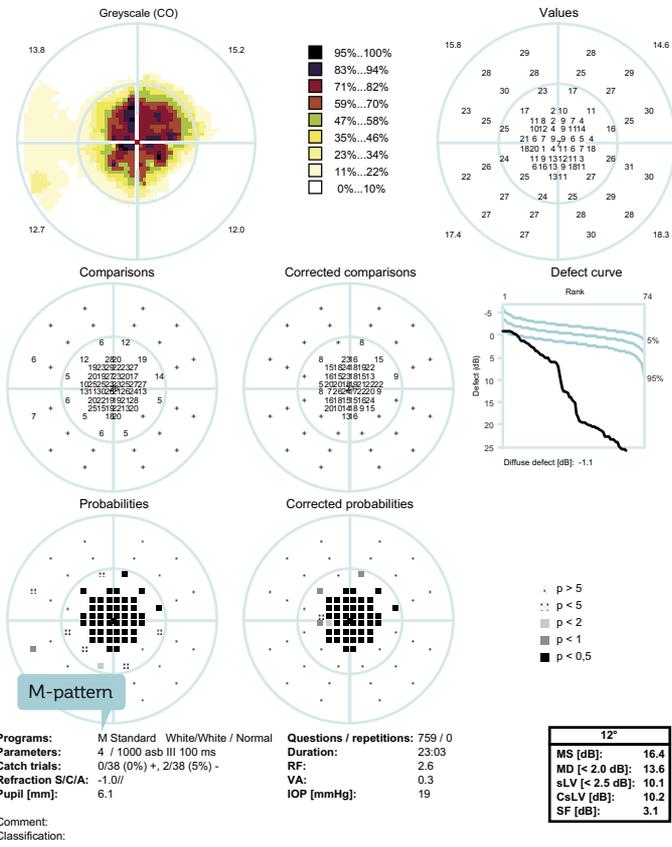
- Complete sensitivity loss (heteronymous hemianopia) temporally of vertical meridian
- Additional absolute defect in superior nasal quadrant of right eye

**20** AGE-RELATED MACULAR DEGENERATION

- PATIENT**
- 64-year-old male, no family history
  - Patient reported decreased visual acuity in left eye
- IOP/VA corr**
- 13 mmHg/ 0.2 – 1.75 (sph), – 0.75 (cyl) x 80°
- FUNDUS**
- Exudative age-related macular degeneration in macula area

Demo John, 1942/01/01 (64yrs)

Left eye (OS) / 2006/09/28 / 14:38:48  
Seven-in-One



- M-pattern (10°) used for a high resolution of the macula
- Dense visual field loss within central 5° of macula, no visual field loss from 6° to 10°

**21 BRANCH CENTRAL RETINAL ARTERY OCCLUSION**

**PATIENT**

- 51-year-old female, no family history
- Patient reported sudden loss of vision in superior visual field of left eye

**IOP/VA corr**

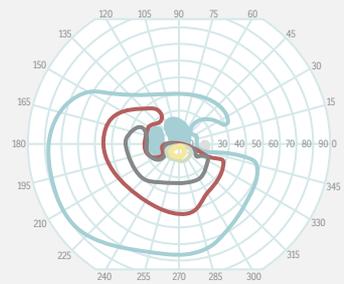
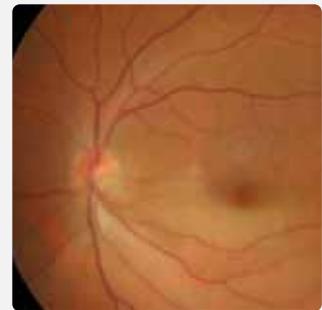
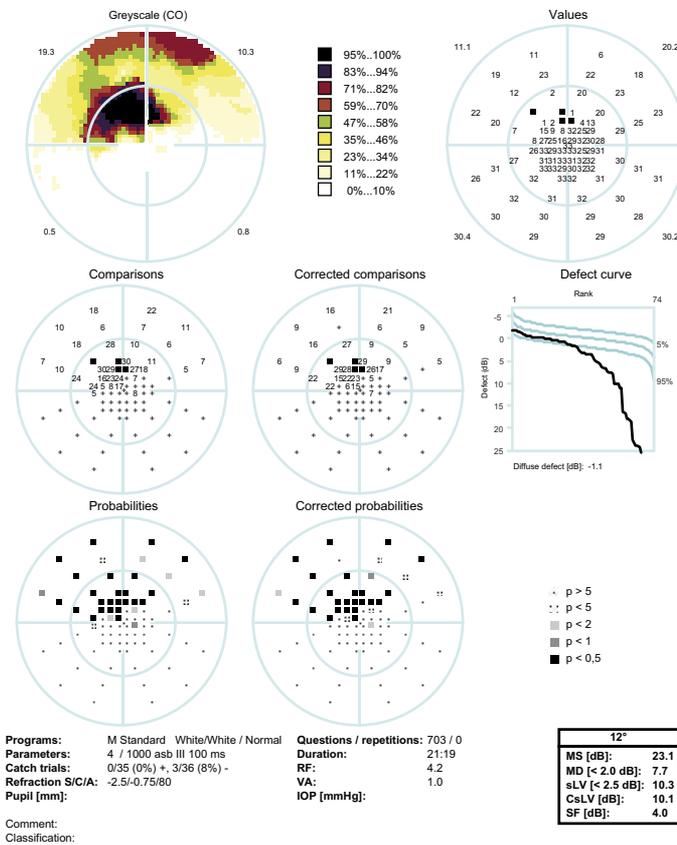
- 14 mmHg/ 1.0 –4.0 (sph), +0.75 (cyl) x 80°

**FUNDUS**

- Ischemia-induced retinal edema in area of blood vessels caused by occlusion of the downward branch of the central retinal artery

Demo Jane, 1956/01/01 (51yrs)

Left eye (OS) / 2007/05/16 / 11:37:22  
Seven-in-One



- V4e
- I4e
- I3e
- I2e
- I1e

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OCTOPUS 101

**HS HAAG-STREIT**  
DIAGNOSTICS

- M-pattern (10°) used for a high resolution of the macula
- Dense to absolute visual field loss in superior visual field corresponding with ischemic region of downward retinal artery
- Fixation is spared, corrected visual acuity of 1.0 is maintained
- Kinetic perimetry shows absolute defect outside 10° nasally

**22** MACULAR HOLE

**PATIENT**

- 67-year-old female, no family history
- Patient reported distorted vision in right eye

**IOP/VA corr**

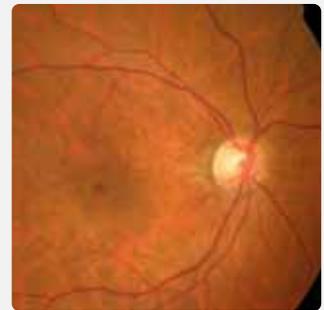
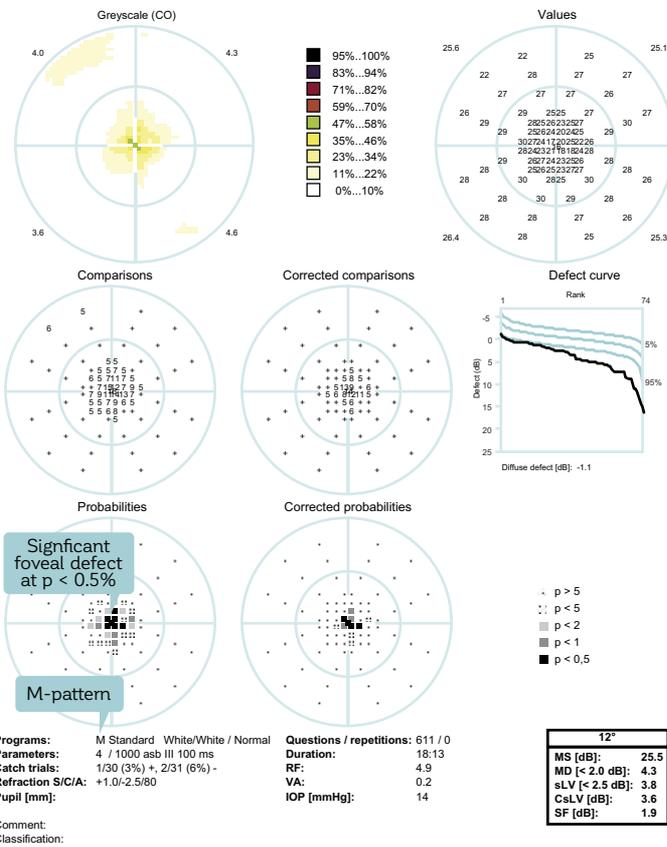
- 12 mmHg/ 0.2 - 1.5 (sph), -2.5 (cyl) x 80°

**FUNDUS**

- Macular hole with fluid cuff in surrounding region

Demo Jane, 1939/01/01 (67yrs)

Right eye (OD) / 2006/07/31 / 13:23:40  
Seven-in-One



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OCTOPUS 101

**HS HAAG-STREIT**  
DIAGNOSTICS

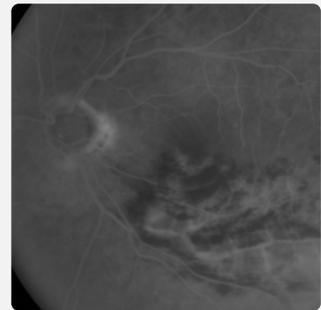
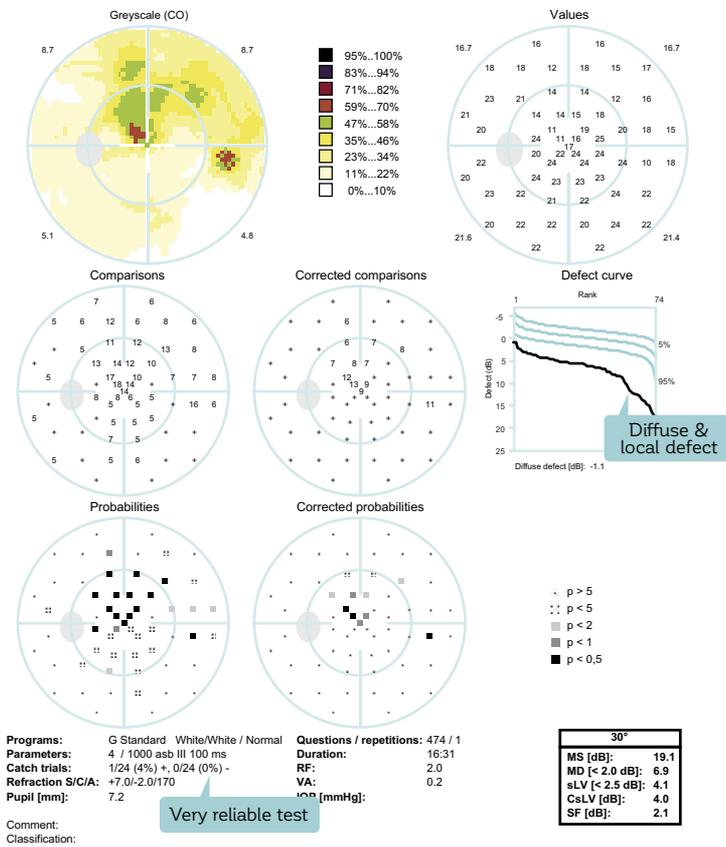
- M-pattern (10°) used for a high resolution of the macula
- Significant visual field loss in the central fovea leading to decreased visual acuity (0.2) due to macular hole

**23 BRANCH CENTRAL RETINAL VEIN OCCLUSION**

- PATIENT**
- 76-year-old male, no family history
  - Patient reported decreased visual acuity in left eye, blurred and double vision
- IOP/VA corr**
- 10 mmHg/ 0.2 + 3.75 (sph), - 2.0 (cyl) x 170°
- FUNDUS**
- Retinal hemorrhage and soft exudate along RNFL in lower retinal arcade

Demo John, 1928/01/01 (76yrs)

Left eye (OS) / 2004/03/24 / 15:44:51  
Seven-in-One



- Sensitivity loss in superior visual field corresponding with inferior retinal hemorrhage
- Diffuse visual field defect associated with poor visual acuity (0.2)
- Significant local visual field loss in superior paracentral area due to macular edema

**OCTOPUS®**

EyeSuite™ Static perimetry, V2.3.0  
OCTOPUS 101

**HS HAAG-STREIT DIAGNOSTICS**

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# VISUAL FIELD INTERPRETATION EXAMPLES

NORMAL

BORDERLINE

EARLY TO MODERATE

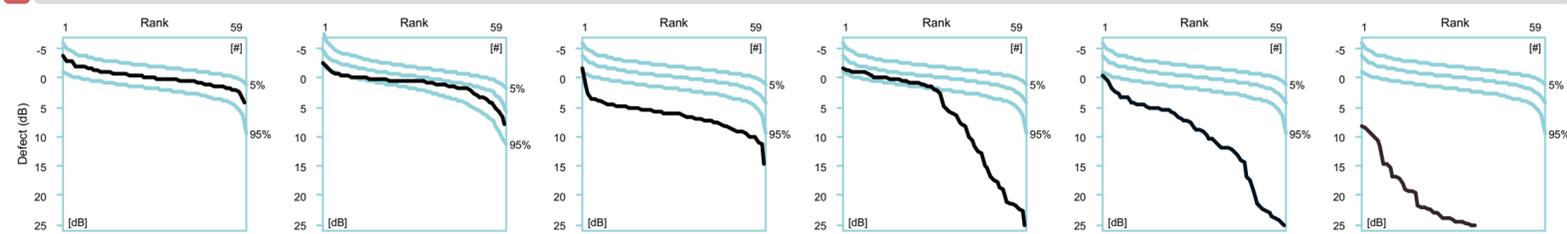
ADVANCED

Diffuse defect

Local defect

Local & diffuse defect

1 Correct patient & examination parameters? 1  
 2 Reliable, free of artifacts & trustworthy? 2  
 3 Diffuse loss? 3



DEFECT CURVE

DEFECT CURVE

DD

0.1 dB

1.3 dB

6.2 dB

1.3 dB

5.9 dB

19.3 dB

DD

LD

0.2 dB

0.2 dB

0.6 dB

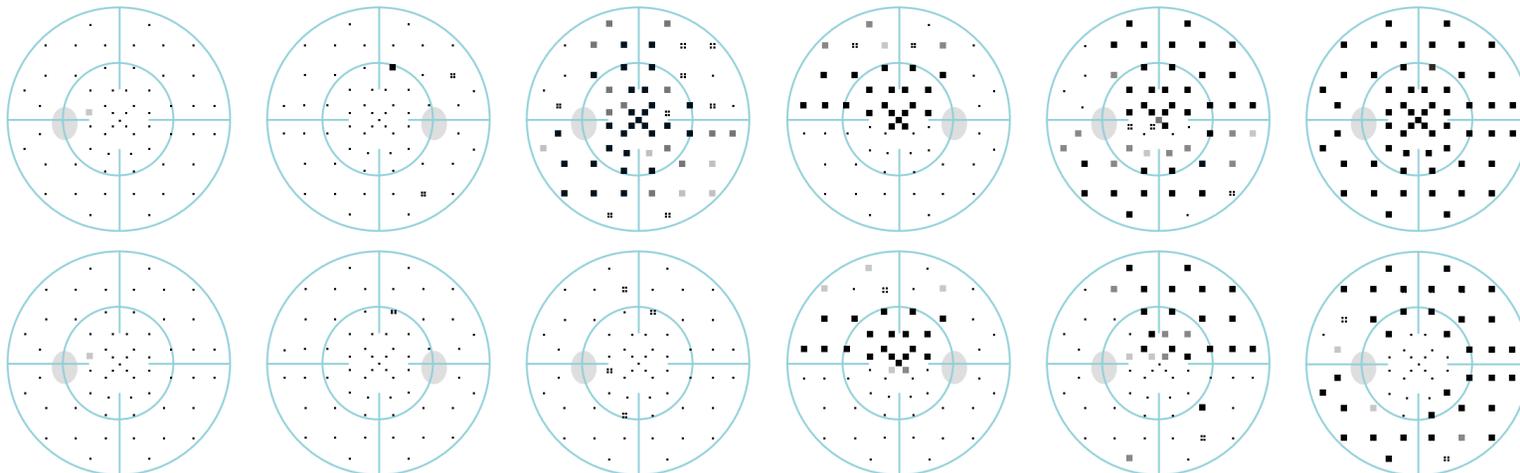
7.0 dB

6.1 dB

4.7 dB

LD

4 Significant local loss? 4



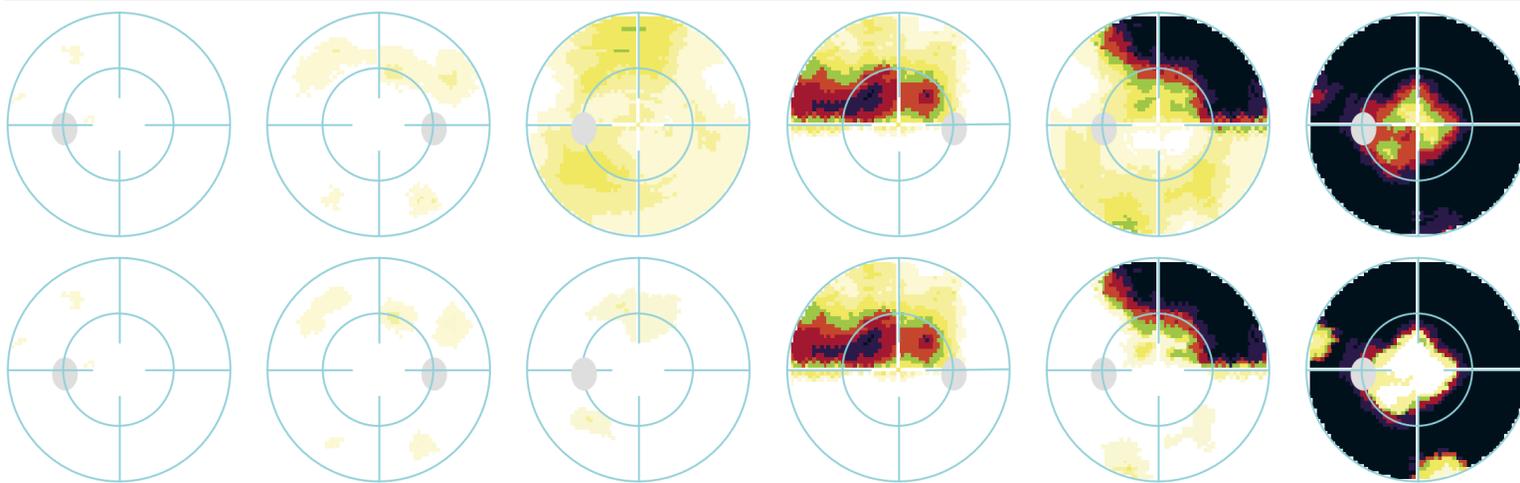
PROBABILITIES

PROBABILITIES

CORRECTED PROBABILITIES

CORRECTED PROBABILITIES

5 Assess shape & depth of defect. 5



GRAYSCALE (COMPARISONS)

GRAYSCALE (COMPARISONS)

CORRECTED GRAYSCALE (CO)

CORRECTED GRAYSCALE (CO)

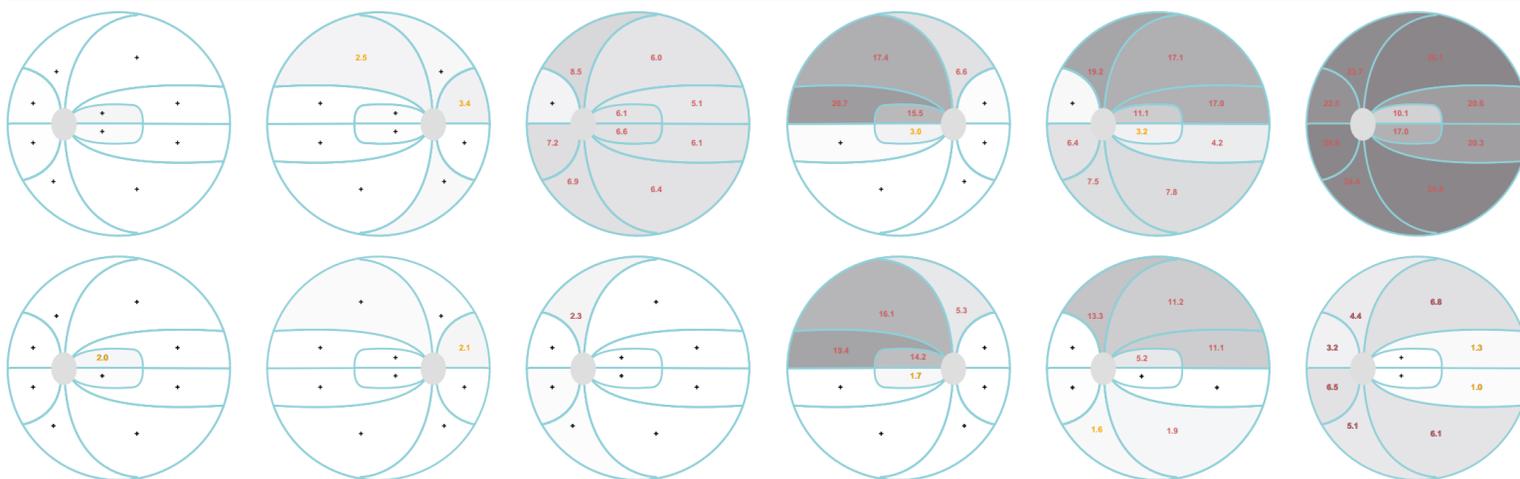
COMPARISONS

COMPARISONS

CORRECTED COMPARISONS

CORRECTED COMPARISONS

6 For glaucoma: Significant cluster defects? 6



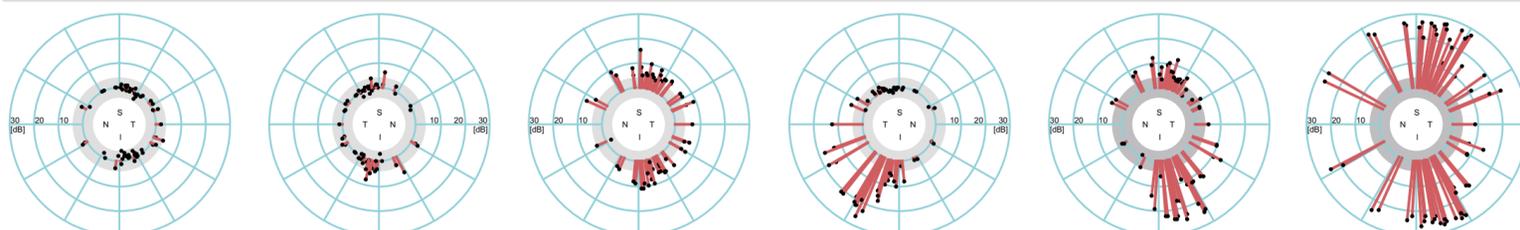
CLUSTER ANALYSIS

CLUSTER ANALYSIS

CORRECTED CLUSTER ANALYSIS

CORRECTED CLUSTER ANALYSIS

7 For glaucoma: Where to look for structural defects. 7



POLAR ANALYSIS

POLAR ANALYSIS

8 Severity? 8

-0.2 dB

1.0 dB

6.3 dB

6.5 dB

10.1 dB

21.7 dB

MD

1.5 dB

1.9 dB

2.5 dB

8.3 dB

7.2 dB

5.6 dB

sLV