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

**NORMAL**  
**BORDERLINE**  
**EARLY TO MODERATE**

<table>
<thead>
<tr>
<th></th>
<th>Correct patient &amp; examination parameters?</th>
<th>Reliable, free of artifacts and trustworthy?</th>
<th>Diffuse loss?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DEFECT CURVE**

<table>
<thead>
<tr>
<th>NORMAL</th>
<th>BORDERLINE</th>
<th>EARLY TO MODERATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 dB</td>
<td>1.3 dB</td>
<td>6.2 dB</td>
</tr>
</tbody>
</table>

**DD**

<table>
<thead>
<tr>
<th>NORMAL</th>
<th>BORDERLINE</th>
<th>EARLY TO MODERATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2 dB</td>
<td>0.2 dB</td>
<td>0.6 dB</td>
</tr>
</tbody>
</table>

**LD**

**PROBABILITIES**

**CORRECTED PROBABILITIES**

**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).
Correct patient & examination parameters? 1
Reliable, free of artifacts and trustworthy? 2
Diffuse loss? 3

Local defect
Local & diffuse defect

EARLY TO MODERATE

ADVANCED

1.3 dB 5.9 dB 19.3 dB
7.0 dB 6.1 dB 4.7 dB

Significant local loss? 4
### EXAMPLES OF SIX TYPICAL VISUAL FIELDS (CONTINUED)

<table>
<thead>
<tr>
<th>NORMAL</th>
<th>BORDERLINE</th>
<th>EARLY TO MODERATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Diffuse defect</td>
</tr>
</tbody>
</table>

5. Assess shape & depth of defect.

- **NORMAL**
- **BORDERLINE**
- **EARLY TO MODERATE**

---

**GRAYSCALE (COMPARISONS)**

- **CORRECTED GRAYSCALE (CO)**
- **COMPARISONS**
- **CORRECTED COMPARISONS**

---

**Assess shape & depth of defect.**
Assess shape & depth of defect.
EXAMPLES OF SIX TYPICAL VISUAL FIELDS (CONTINUED)

<table>
<thead>
<tr>
<th>NORMAL</th>
<th>BORDERLINE</th>
<th>EARLY TO MODERATE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Diffuse defect</td>
</tr>
</tbody>
</table>

For glaucoma: Significant cluster defects?

CLUSTER ANALYSIS

6

For glaucoma: Where to look for structural defects.

CORRECTED CLUSTER ANALYSIS

7

POLAR ANALYSIS

8

Severity?

<table>
<thead>
<tr>
<th>MD</th>
<th>Borderline</th>
<th>Early to Moderate</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.2 dB</td>
<td>1.0 dB</td>
<td>6.3 dB</td>
</tr>
<tr>
<td>1.5 dB</td>
<td>1.9 dB</td>
<td>2.5 dB</td>
</tr>
</tbody>
</table>
For glaucoma: Significant cluster defects?

Local defect

Local & diffuse defect

For glaucoma: Where to look for structural defects.

Severity?

<table>
<thead>
<tr>
<th></th>
<th>MD</th>
<th>SLV</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.5 dB</td>
<td>10.1 dB</td>
<td>21.7 dB</td>
</tr>
<tr>
<td>8.3 dB</td>
<td>7.2 dB</td>
<td>5.6 dB</td>
</tr>
</tbody>
</table>
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.

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

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.
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.

OVERVIEW OF PATIENT AND EXAMINATION PARAMETERS

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

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

Programs: G Standard White/White / Normal
Parameters: 4 / 1000 asb III 100 ms
Catch trials: 1/18 (6%) +, 1/18 (6%) -
Refraction S/C/A: VA [m]:
Pupil [mm]: 5.6
NV: T21 V2.1
Comment: Good fixation

Questions / repetitions: 356 / 23
Duration: 15.32
RF: 5.5
VA [m]: IOP [mmHg]:

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

STEP 2 – ASSESS WHETHER THE VISUAL FIELD CAN BE TRUSTED

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
Step-by-step interpretation of a visual field

UNTRUSTWORTHY VISUAL FIELD TESTS CAN SHOW SIGNIFICANT DEFECTS

<table>
<thead>
<tr>
<th>1st test</th>
<th>2nd test</th>
<th>3rd test</th>
<th>4th test</th>
<th>5th test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable normal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1st test</th>
<th>2nd test</th>
<th>3rd test</th>
<th>4th test</th>
<th>5th test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less reliable normal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1st test</th>
<th>2nd test</th>
<th>3rd test</th>
<th>4th test</th>
<th>5th test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal who experiences difficulties with perimetry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1st test</th>
<th>2nd test</th>
<th>3rd test</th>
<th>4th test</th>
<th>5th test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal with learning effects (tests 1 to 3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1st test</th>
<th>2nd test</th>
<th>3rd test</th>
<th>4th test</th>
<th>5th test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal with artifactual defects (here: lens rim artifact on 1st, 2nd and 4th test)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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.

**Figure 8-6** shows the impact of unreliable visual field tests, inconsistent patient behavior and set-up errors on the visual 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%, the results are marked in orange color. This means they should be 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%3, 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 GTOP 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.
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 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%.\(^2\) 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.\(^8\) 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.

**FIGURE 8-8** The example above shows the impact of a high rate of false negative answers on the visual field. The field on the left is unreliable because the patient did not respond to stimuli that should have been seen. As a result, the visual field appears worse than the true status of the patient’s visual field, which is shown on the right.

**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 **FIGURE 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.\(^9\) 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.²

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

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>
<thead>
<tr>
<th>Diffuse (Widespread) Defect</th>
<th>Examples of Pathologies</th>
<th>Examples of Untrustworthy Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Lens opacity (e.g., cataract)</td>
<td>- Incorrect refraction</td>
<td>- Lens rim artifact</td>
</tr>
<tr>
<td>- Cornea opacity (e.g., Fuchs dystrophy)</td>
<td>- Incorrect patient age</td>
<td>- Lid artifact</td>
</tr>
<tr>
<td>- Dense vitreous opacity</td>
<td>- Small pupil size</td>
<td></td>
</tr>
<tr>
<td>- Any advanced pathology resulting in severe visual field loss (e.g., advanced glaucoma)</td>
<td>- Learning effect</td>
<td></td>
</tr>
</tbody>
</table>

**Local Defect**

- Glaucoma
- Age-related macular degeneration
- Hemianopia
- Quadrantanopia
- Vitreous opacity

- Incorrect refraction
- Incorrect patient age
- Small pupil size
- Learning effect
- Fixation loss
- Fatigue

### Defect Curve

The Defect Curve is a graphical representation that provides a summary of the visual field and distinguishes between local and diffuse defects. 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

NORMAL
Defect Curve within normal band

BORDERLINE
Limited diagnostic value

DIFFUSE DEFECT
Parallel downward shift of Defect Curve

LOCAL DEFECT
Drop of Defect Curve on the right

LOCAL & DIFFUSE DEFECT
Parallel downward shift on the left and drop on the right

ADVANCED
Limited diagnostic value

TRIGGER-HAPPY
Steep rise of Defect Curve on the left

HEMISPHERE DEFECTS
Vertical drop of Defect Curve in the center

QUADRANT DEFECTS
Vertical drop of Defect Curve towards the right

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.

**EXAMPLE OF THE CLINICAL USEFULNESS OF THE DEFECT CURVE**

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 typically 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

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.

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. 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

<table>
<thead>
<tr>
<th>GRAYSCALE (Comparisons)</th>
<th>PROBABILITIES</th>
<th>DESCRIPTION</th>
<th>INTERPRETATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Grayscale Image" /></td>
<td>Number of locations at p &lt; 5%: 2, p &lt; 2%: 2, p &lt; 1%: 1</td>
<td>Random distribution of likely abnormal locations</td>
<td>Likely normal</td>
</tr>
<tr>
<td><img src="image2.png" alt="Grayscale Image" /></td>
<td>Number of locations at p &lt; 5%: 2</td>
<td>Two adjacent likely abnormal test locations, no cluster</td>
<td>Likely normal</td>
</tr>
<tr>
<td><img src="image3.png" alt="Grayscale Image" /></td>
<td>Number of locations at p &lt; 5%: 2, p &lt; 2%: 1, p &lt; 1%: 1, p &lt; 0.5%: 2</td>
<td>Five likely abnormal locations clustered in an inferior partial arcuate defect pattern, one likely abnormal location at random position</td>
<td>Likely abnormal, Investigate further</td>
</tr>
<tr>
<td><img src="image4.png" alt="Grayscale Image" /></td>
<td>Number of locations at p &lt; 5%: 7, p &lt; 2%: 3, p &lt; 0.5%: 1</td>
<td>Six likely abnormal locations clustered in a superior partial arcuate defect pattern, three likely abnormal locations clustered in an inferior, paracentral defect pattern</td>
<td>Likely abnormal, Investigate further</td>
</tr>
</tbody>
</table>

**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.

**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 1st 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.

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.
The Grayscale of Comparisons and 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.

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

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 FIGURE 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.

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.
CLUSTER ANALYSIS AND CORRECTED CLUSTER ANALYSIS – INTERPRETATION AID

**FIGURE 8-20** The Cluster Analysis representations group defects into ten clusters according to the paths followed by the nerve fiber bundles in the retina. Highly likely normal clusters (p > 5%) are marked with a “+” symbol, and likely abnormal Cluster Mean defects are displayed in normal font (p < 5%) or bold font (p < 1%). The Corrected Cluster Analysis representation is similar, but eliminates diffuse visual field loss and solely considers local loss.

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.\(^ {13-15}\) This is due to the fact that the clustering and averaging procedure significantly reduces the influence of normal fluctuation.\(^ {16}\) This is further explained in **BOX 8B**.

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

Cluster Analysis has been shown to be more sensitive to detect subtle glaucomatous change\(^ {13-15}\) 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.
ILLUSTRATION OF THE CLINICAL USEFULNESS OF CLUSTER ANALYSIS

This example highlights the high sensitivity of Cluster Analysis for the detection of subtle glaucomatous visual field defects. When looking at the sensitivity loss of the individual test locations (left) in the superior arcuate cluster (red shading), only one location is marked as abnormal in the Probabilities representation (center). However, most locations are slightly, but not significantly elevated, which results in a significantly abnormal (p < 1%) Cluster MD in 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.

ILLUSTRATION OF THE HIGH SENSITIVITY OF CLUSTER ANALYSIS TO DETECT GLAUCOMA

FIGURE 8-21 Example of a borderline visual field. By just looking at the Grayscale of Comparisons (left) and Probabilities (middle) representations, one may interpret this visual field as likely to be normal, as there is no pattern of contiguous abnormal locations. However, examination of the Cluster Analysis (right) shows a small, but significant superior arcuate defect pattern, which calls for further investigation.
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, 14-15 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 particularly 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).

Glaucmatous 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.
Chapter 8 | Clinical interpretation of a visual field

**ANATOMICAL RELATIONSHIP BETWEEN STRUCTURAL AND FUNCTIONAL RESULTS**

Glaucomaticous 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**

**VISUAL FIELD ORIENTATION**

**STRUCTURAL ORIENTATION**

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.17
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 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

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. 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. 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.
ILLUSTRATION OF THE USEFULNESS OF MD

<table>
<thead>
<tr>
<th>NORMAL</th>
<th>SUSPECT</th>
<th>EARLY TO MODERATE</th>
<th>ADVANCED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Diffuse defect</td>
<td>Local defect</td>
</tr>
<tr>
<td>MD = -0.2 dB</td>
<td>1 dB</td>
<td>6.3 dB</td>
<td>6.5 dB</td>
</tr>
</tbody>
</table>

FIGURE 8-26 The Mean Defect (MD) summarizes the severity of visual field loss in one number, for comparison with other patients and to quickly communicate the severity of visual field loss. The examples above show different visual fields with increasingly severe visual field loss.

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**

**COMPARISONS**

**MD 6.3 dB**

sLV 2.5 dB

**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\textsuperscript{12,19,20} 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.
REFERENCES