Automated Perimetry
Visual Field Digest
Fifth Edition, 2004

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To all our friends who helped us establish OCTOPUS as the premium name in perimetry.
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**PURPOSE OF THIS TEXTBOOK**

This publication is addressed to medical staff and clinicians so that they may gain insight into the concepts of OCTOPUS perimetry. It can also serve as a reference book for users.

An overview is presented on the basic principles - as far as they are practical and useful in daily routine - followed by a summary of the examination programs, the reporting of data, and a guide to the interpretation of visual fields. Finally, a discussion on specific hardware and software details is provided.

The Visual Field Digest is structured in a format to facilitate its reading – whether for studying the contents in depth or to assist the reader in obtaining a quick overview of the important issues.

*It is important that visual field testing is combined with other diagnostic examinations.*

Important details are framed in red to make it easy to follow the subject and keep track of the contents.

*If the results of the perimetry are critical for guiding therapy, a normal full threshold strategy may be beneficial. Shorter tests can be used if the visual field is one of several examinations that will be used for diagnosis and treatment.*

Key issues are highlighted in a green frame to signal a “take home message.”

*60-year-old insulin dependent diabetic has non-proliferative diabetic retinopathy in the right eye.*

Visual acuity was 20/60. This visual field was done before argon laser photo-coagulation. It shows a moderately dense generalized depression with several areas of localized defect.

Clinical cases are highlighted in a yellow frame.
1 **Automated Perimetry - Introduction**

Perimetry, the evaluation of the visual field, is an important diagnostic test, particularly in glaucoma, but also for diagnosing and monitoring the progression of many other eye diseases. In routine perimetry, computer supported static perimetry, as it was introduced in 1975 by Fankhauser, proved to be more practical compared to the traditional manual Goldmann method. However in special situations such as in neuroophthalmology, it is important to have information about the peripheral visual field, and so, in end stage glaucoma and in cases with patients who have difficulty collaborating with an automatic test, computer-assisted (semi-automatic) kinetic testing continues to play an important role in testing the visual field.
1.1 Perimetry - Evaluation of the Visual Field

Perimetry, the evaluation of the visual field, is an important diagnostic test in ophthalmology, not only for managing glaucoma using static perimetry in the central 30° visual field, but also for diagnosing and monitoring the progression of many other eye diseases.

Although the visual field examination is mostly used in conjunction with other clinical findings, such as intraocular pressure, and the assessment of structural changes at the optic nerve head and the retina, perimetry remains an indispensable test documenting visual function. After all, patients are not concerned about pressure or appearance of their discs but they are worried about maintaining vision.

Before the introduction of computer-supported perimetry, visual fields were performed manually. This was basically achieved by working with pointers on a wall panel, called the Bjerrum or Tangent Screen, or by using the Goldmann Cupola Perimeter for more precise results. However, the manual method is a rather demanding procedure where the results are largely influenced by the skills and the experience of the examiner – as noted by Professor Hans Goldmann himself:

“Finally, I would like to mention that perimetry, and in particular kinetic perimetry, is an art. If one lets several young assistants examine...”
the same patient, as we did, one will be astonished, even shocked, about the difference in the results. It needs a long period of training till the results of two clinicians are comparable. For this reason the same examiner should always make the glaucoma fields.”

It is clear that in normal routine such a demand cannot easily be met unless the computer becomes the examiner and standard test conditions are followed. The need for an automated perimeter became evident.

### 1.2 Automating Perimetry - a Historical Excursion

Although Mariotte discovered the blind spot in 1668, clinical campimetry, using a white piece of paper, started with Graefe in 1856. Important further steps were made by Bjerrum in 1889, who drew his first screen on the back of his door, and by Groenouw who introduced isopters in 1893 as the connection of points with the same differential light sensitivity. The Bjerrum screen remained the popular standard in the USA, here called the Tangent Screen, for nearly 100 years.

The first cupola perimeter was designed by Goldmann in 1945, and even today his manual kinetic perimetry method is seldom omitted in

---

*Groenouw introduced isopters in 1893 as the connection of points with the same differential light sensitivity.*

---

*Figure 1-2: Pflüger perimeter (1898) by Haag-Streit pictured in front of a backdrop of the city of Berne - Switzerland*
Automated perimetry also came out of the school of Goldmann in Berne, Switzerland. In 1972, Fankhauser, et al, developed the principles and concepts of automated perimetry.\(^1\)

Fankhauser was the mastermind behind the first automated OCTOPUS perimeter (1975).

Figure 1-3: Franz Fankhauser and the prototype of his computer supported perimeter - as it was used for determining the basis of today’s automated perimetry.

In his thesis, Spahr investigated the threshold determination technique and worked on basic aspects of automated perimetry.\(^2\) At the same time, Bebie started his cooperation with contributions in his papers concerning Strategies, Accuracy and Fluctuations \(^3\) and until today, he remained closely connected with the latest developments in perimetry.
Through the years, other physicists (Funkhouser, Häberlin) and psychologists (Hirsbrunner) assisted with developing more updated and sophisticated software, required by ongoing hardware improvements. It also became clear that statistical methods have an enormous impact on the evaluation of perimetric results. In particular the behavior of pathology, as a function of time, had to be cast in statistical and mathematical forms.

While not all of these approaches, though important, could be transferred into clinical practice due to their complexity, Flammer introduced the examination program G1 (1985) which combined a new set of test locations corresponding to the topography of the retina with the concept of using visual field indices.4,38 These examination programs (see Examination Programs, Chapter 5) have so far resisted the erosion of time. At the same time, Bebie, et al, suggested the use of the Cumulative defect curve (see Section 7.1.6) as a printout assessing the characteristics and depth of the visual field defects.5

Funkhouser, et al, showed that the rate of information gain in the 30° field decreased with the number of test locations, i.e., the first locations tested contributed to the final total information content more than the ones tested towards the end.6 The results of these studies initiated the design of examination programs with stages (see Section 3.3.1). These programs were the first quantitative thresholding test programs with an option to stop after the completion of either one of the stages, allowing the test duration to be shortened without much loss of information in most cases.

Recent progress in the definition of faster test strategies (see Methods for Determining the d.l. sensitivity, Chapter 3) was contributed by Weber who developed the Dynamic strategy7 and by Gonzalez de la Rosa with his “Tendency Oriented Perimetry” strategy (TOP).16 The TOP method is based in part on an algorithm of repetitive extrapolation of local visual field data, alone or in groups, while the Dynamic strategy steers the staircase algorithm, according to the steepness of the Frequency-of-seeing curve, i.e., in relation to the depth of the local depression. Both algorithms allow examination time to be reduced considerably (to a test duration of 2 to 6 minutes) although occasionally with some loss of information.
In the early nineties, new perimetric methods were initiated in support of the detection of early visual field loss. In this respect, studies with Blue-on-Yellow perimetry showed that the onset of glaucoma could be determined earlier. However, the extreme light conditions dictated in this method make it harder for the patient to perform reliably. Another drawback is that the blue stimulus cannot be discerned properly in the presence of even the slightest opacification in the optical path (see Special Diagnostic Methods, Chapter 4).

With the same objectives in mind, the Flicker Perimetry method was introduced by Matsumoto using an experimental software program in connection with an OCTOPUS perimeter under remote control.\(^9\) Clinical studies testing the CFF (critical fusion frequency) sensitivity demonstrated that Flicker Perimetry has characteristics similar to Blue-on-Yellow perimetry with respect to early detection of visual field loss but with an important difference: the CFF values are very robust against blur and optical media opacification (see Special Diagnostic Methods, Chapter 4).

Figure 1-4: The latest generation of OCTOPUS perimeters, the 300 Series, combines standard White-on-White, Blue-on-Yellow and Flicker perimetry.
Later, Bebie proposed an interesting software program (PeriSim) for the purpose of simulating perimetry examinations under realistic conditions. With this educational tool, using different test parameters and patient characteristics with predetermined visual fields, several examination strategies and behavioral patterns of a patient can be combined and analyzed on a standard PC. The results of such combinations are then compared to what the user thought, based on his intuition and skill.

Recently, Schiefer and Pätzold designed a software program that automated the “traditional” Goldmann kinetic perimetry, combining the advantages of the kinetic method with modern computer techniques.

Finally, respect needs to be paid to the INTERZEAG staff (today HAAG STREIT) who designed and constructed six generations of perimeters. Without their dedication and untiring efforts there would hardly be such an important progress in the perimeter techniques presently in use in the clinical routine of thousands of eye care providers worldwide.

1.3 Computer Assisted Perimetry

1.3.1 Automated perimetry - a subjective test
Although the computer can take over many tasks of the examiner in precisely following a predetermined process of presenting light stimuli at well defined locations, “automatic perimetry” is merely a computer assisted examination (and not a fully automatic test) because the results depend on the patient’s collaboration and the accuracy of the answers to the question of whether or not a light stimulus was perceived. Therefore, automatic perimetry remains a subjective test and for this reason it is important to always realize that the visual field data is only as reliable as the ability of the patient to perform the examination.

1.3.2 Threshold of Differential Light Sensitivity (d.l. sensitivity)
In perimetry, the differential light sensitivity (d.l. sensitivity) is measured in different locations of the retina in order to detect deviations (defects) from the values obtained from a population of normal eyes. An eye disease can cause uniform or localized depressions (or both) in the visual field. The purpose of the perimetric examination is to detect these de-
pressions at an early stage and to follow the results over time to assist the eye care provider with the treatment of the patient. At this point, it is useful to remember that in perimetry, reference is made to the *differential light sensitivity of the retina* in several ways such as the terms:

- differential light sensitivity (d.l. sensitivity)
- threshold value
- retinal sensitivity
- visual field
- hill of vision

### 1.3.3 Static or kinetic perimetry

It is evident that in glaucoma management most perimetry is done using static perimetry in the central 30° visual field. Therefore this publication deals mainly with subjects relating to static perimetry. However, in special situations – such as in neuro-ophthalmology, where it is also important to have information about the peripheral visual field, in end stage glaucoma and in other cases, e.g., with patients who have difficulty collaborating with an automatic test – computer-assisted (semi-automatic) kinetic testing continues to play an essential role in diagnosing the visual field.
2  **THE VISUAL FIELD - BASIC NOTIONS**

The area seen by the steady fixating eye defines the visual field. During the perimetric examination, the differential light sensitivity (d.l. sensitivity) is determined in different locations of the retina, under predetermined standard test conditions, in order to detect deviations from the normal values. The patient’s threshold is defined as the stimulus luminance, which is perceived with a probability of 50% as described by the frequency-of-seeing curve (FOSC) as a function of stimulus luminance.

In clinical practice, thresholds are not expressed in physical luminance values (asb or cd/m²), but rather in the decibel (dB) scale.

For a strict definition of the d.l. sensitivity and to allow comparison of data between examinations, the test conditions, like stimulus size, background luminance, exposure time and color, need to be fixed.

The difference in height between the normal hill of vision and a depressed field corresponds to the local loss of sensitivity. The normal visual field is derived from a large number of examinations obtained in multicentric visual field studies.
2.1 On the Limits of Visual Detection

The general idea of visual perception is an exciting subject. Perimetry deals with elementary aspects of the performance of the human visual system, more precisely, with the patient’s ability to perceive the faintest optical stimuli against a uniform background under controlled experimental conditions. The individual thresholds may turn out to be within normal range or they may deviate from these values and indicate a pathological state of the system. Visual perception is a very complex process and there is a wealth of functions which could be examined. Even when the primary goal of investigation is confined to the threshold stimulus luminance, there are numerous aspects that should be taken into consideration. For example:

- The absolute threshold is the threshold illuminance for the eye from a point source at zero background luminance of given wavelength, the threshold being defined by 50% probability of detection. (The absolute threshold is of basic importance for the visual system but is rarely used in clinical practice.)
- The contrast sensitivity as a function of spatial frequency and mean luminance of a grating stimulus.
- The threshold luminance of a stimulus of given size and duration on a background of given luminance (differential light sensitivity, in short: d.l. sensitivity). This is the function examined in static perimetry – the objective of this publication.

Some general remarks are necessary before going into the details of static perimetry.

For a strict definition of the d.l. sensitivity, certain parameters (test conditions), like stimulus size, background luminance, exposure time, and color, need to be defined. The standard OCTOPUS examination conditions will be covered in detail in Section 2.9. The parameters are:

- background luminance: 1.27 or 10 cd/m² (see Section 2.9.1)
- background color: white (yellow, in Blue-on-Yellow perimetry)
- stimulus size: 0.43° (diameter), corresponding to Goldmann size III (see Section 2.9.2)
- stimulus color: white (blue, in Blue-on-Yellow perimetry)
- exposure: 100 ms (see Section 2.9.3).
Explaining the threshold is difficult. There is no strict line separating visible from invisible stimuli. Rather, the probability of perceiving a stimulus increases gradually with increasing stimulus luminance. More details are explained in Section 2.3.

Flicker perimetry constitutes a completely different approach: here, the local flicker fusion frequency may be determined at different locations within the visual field. Flicker perimetry is covered in Section 4.3.

2.2 Static Perimetry

The area seen by a steady fixating eye defines the visual field. Normally, in clinical testing, one eye is tested at a time (monocular test) whereby the other eye is occluded. During the examination, the d.l. sensitivity is determined at different locations of the retina in order to detect deviations from the normal values. In perimetry, the standard test programs typically include 60 - 80 test locations. The thresholds depend on the locations in the visual field and depressions in d.l. sensitivity are related to specific areas.

An eye disease can cause uniform and/or localized loss of the d.l. sensitivity in the visual field. The purpose of the perimetric examination is to detect these depressions at an early stage and to follow the results over time to assist the eye care provider with the plan of treatment of the patient.

2.3 Threshold of Differential Light Sensitivity: Frequency-of-Seeing Curve

The threshold of d.l. sensitivity at a certain location is defined as follows: with increasing luminance of the test stimulus at a given test location, there is a gradual change from “unseen” to “seen.” More precisely, the probability of a patient perceiving the stimulus changes gradually from 0 to 100%. The patient’s threshold of d.l. sensitivity at that test location, and under the given test conditions (background luminance, stimulus size, etc.), is defined as the stimulus luminance, which is perceived with a probability of 50%. Static perimetry aims at determining this threshold luminance by means of a few test stimuli. Typically some of them are perceived, while others are not seen. The accuracy of a patient’s threshold depends on the number of stimuli presented at a given test location.
It is important to note that the patient’s response to a given stimulus is of statistical nature: for a given stimulus luminance, there is a *probability* of perceiving the stimulus. The frequency-of-seeing curve (FOSC) describes this probability as a function of stimulus luminance. A reasonably accurate determination of the FOSC (for a given patient, test location and examination conditions) would require a large number of stimuli.

The FOSC is typically rather steep with a narrow band of variability for “normal” threshold sensitivities but the curve flattens in areas where the d.l. sensitivities are depressed (demonstrated at the right side), resulting also in more uncertain threshold values.

Note: The definition of the threshold implies that even the highly sensitive eye cannot see all of the stimuli. Patients should be aware of this before they become concerned about their condition.

### 2.4 The Extent of the Visual Field

The full visual field extends from 60° nasal to slightly over 90° temporal and from 60° superior to 70° inferior eccentricities. The full field for the
right eye is shown in Figure 2-2 (see also Figure 9-2). The peripheral visual field (beyond the central 30° area) is approximately five times larger in area than the central field – and it would require a rather long testing time to cover the whole field. Fortunately, the central 30° field takes up 83% of the visual cortex and practically all of the pathological abnormalities can be found within the central area. This means that the much larger peripheral field needs to be examined only in rare and special cases.

2.5 The Hill of Vision

The hill of vision is a 3-dimensional representation of the retinal sensitivities. In Figure 2-3, the x-y-plane represents location in the visual field. The ordinate (z-axis) displays the normal threshold stimulus luminance under the examination conditions given in Section 2.9. In clinical practice, thresholds are not expressed in physical luminance values (asb or cd/m²), but rather in the decibel (dB) scale, shown here (see also the corresponding vertical scales in Figure 2-5).
The hill of vision does not serve a useful purpose in the quantification and follow-up of visual field defects. But it is an excellent, easily-understood way to explain a patient's situation. Figure 2-3 shows a normal hill of vision with a depressed pathological field underneath. The difference in height corresponds to the local loss of sensitivity.

2.6 The Normal Visual Field

It would be very difficult to interpret individual visual results without having a reference at hand, representing the visual field of a “normal” observer of the corresponding age group. The so-called normal visual field (of the respective age group) is derived from a large number of examinations obtained in multicentric visual field studies. This data is stored in the software and can be displayed together with the individual results.

The normal value is defined as the local mean d.l. sensitivity found in a normal population (for a given test location, under standard test condition as listed in Section 2.9 and for the respective age group). The annual decrease of the d.l. sensitivity amounts to 0.065 dB per year, beginning at the age of 20. It must be kept in mind that the local d.l. sensitivity – even
within a population fulfilling strict inclusion criteria — is subject to inter-
individual variations: local values (within the same age group) are within
a bandwidth of about ± 2 dB for 90% of the population (as seen in the
Cumulative defect curve, Section 7.1.6). This variance is relatively con-
stant over the central field area, which makes it easy to compare results
even if other test locations contained in another examination program —
such as a macula program or a custom test — are tested.

In the following diagram, two typical hills of vision are shown — one for a
20-year old and the other for a 70-year-old person.11

![Figure 2-4: Typical hills of vision for a 20-year-old (left) and a
70-year old (right).](image)

Note: Distinct normal values are available for Blue-on-Yellow and for
Flicker perimetry (see Special Diagnostic Methods, Chapter 4).

2.7 Static Perimetry:
Determining the Shape of the Hill of Vision

In static perimetry, the determination of the individual visual field (hill of
vision) is controlled by sophisticated computer algorithms. Typically, an
examination program aimed at quantitative threshold determination needs
to observe the following principles:

1) A threshold determination must be performed at a fixed set of test
locations.
2) At a given test location, seen and unseen stimuli are both required in order to set upper and lower limits to the individual threshold. If a first stimulus at a certain test location is perceived, the program will display dimmer stimuli at a later time during the examination. Usually, the step sizes change in luminance by a factor of 2.5 (4 dB, see Section 3.2) or, by a factor of 1.6 (2 dB) in subsequent stages of the examination. With an unseen first stimulus, the program will proceed in the opposite direction. More details will be given in Section 3.2.

3) The efficiency of the examination procedure depends on the optimal choice of the first stimuli at different test locations. This may be accomplished by making use of preliminary results at adjacent test locations.

4) All stimuli are presented at random while the computer keeps track of the stimulus luminances, test locations and the corresponding answers of the patient. Static perimetry is the most accurate and reliable method for testing the central visual field where the hill of vision is practically flat.

2.8 The Measuring Range and Scale of Sensitivities in Decibels

Under standard examination conditions (like those given in Section 2.9), thresholds might be expressed in physical stimulus luminance units (cd\textpercm \textsuperscript{2} or asb). In order to manage the wide range of possible results, and in view of the psychophysical laws, it is advisable to express thresholds on a logarithmic scale. Figure 2-5 shows the relationship between the physical threshold luminance scale (cd\textpercm \textsuperscript{2} or asb, $1 \text{ cd/m}^2 = 3.14 \text{ asb}$) and, at the left side, the logarithmic decibel (dB) scale for the OCTOPUS 101 perimeter. Here, the origin of the decibel scale (0 dB) is set at a stimulus luminance of 1000 asb ($314 \text{ cd/m}^2$). Central normal values are about 35 dB for observers of 20 years of age. A change of 10 dB (or 20 dB) corresponds to one (two) log unit change of stimulus luminance which amounts to a factor of 10 ($10^2$).

A change of 10 dB corresponds to one log unit change of stimulus luminance which amounts to a factor of 10.
Figure 2-5. In the OCTOPUS 300, both the maximum stimulus luminance and the background are brighter than the OCTOPUS 101. However, normal values expressed in decibels happen to be about the same in both instruments (OCTOPUS 300 and 101) – in fact, given the background, the maximum stimulus luminance was adjusted to yield the same normal values when expressed in decibels.

The Humphrey 700 perimeter is operated with the same background luminance as the OCTOPUS 300 but with higher maximum stimulus luminance. As a consequence of this, and also because of other differences in specifications (see Figure 2-6), the normal values expressed in the dB scale of this instrument are higher by about 3-4 dB compared to the OCTOPUS perimeters, which must be kept in mind when comparing the measured sensitivities from different instruments.

Perimeter models / types

<table>
<thead>
<tr>
<th>Retinal sensitivity</th>
<th>Stimulus light Luminance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decibels (dB)</td>
<td>Apostilb (asb)</td>
</tr>
<tr>
<td>Central normal</td>
<td></td>
</tr>
<tr>
<td>sensitivity for</td>
<td></td>
</tr>
<tr>
<td>20-year old person</td>
<td></td>
</tr>
<tr>
<td>40 dB</td>
<td>0.1 asb 0.48 asb 1 asb</td>
</tr>
<tr>
<td>35 dB</td>
<td>- 38 dB</td>
</tr>
<tr>
<td>30</td>
<td>1.0 4.8 10</td>
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<td>20</td>
<td>10 48 100</td>
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<tr>
<td>10</td>
<td>100 480 1000</td>
</tr>
<tr>
<td>0</td>
<td>1000 4800 10000</td>
</tr>
</tbody>
</table>

Perimeter models / types | OCTOPUS 101/300 | HFA700

*Figure 2-5: The measuring scale of the d.l. sensitivity in dB with the corresponding stimulus luminance in apostilb (asb).*

**Note:** When comparing results from different types of perimeters, the local loss values (defects) have the same meaning. A 6 dB defect, for example, always means that the individual threshold luminance is increased by 0.6 log units (a factor of 4 in threshold luminance) compared to the local normal threshold.
The maximum stimulus luminance of an instrument is not a very important design parameter. However, in order to avoid stray light effects, it must not be too large. Otherwise, the patient may respond YES to a stimulus in an absolute scotoma because the light was reflected to another location with higher sensitivity. On the other hand, all perimeters mentioned allow for an increase of the normal threshold luminance by at least three orders of magnitude, which means that losses can be followed down to extremely low residuary sensitivities.

### 2.9 Standard Test Conditions

The results of a perimetric test depend on a set of test conditions which are fixed for the standard examination programs in order to make sure the data is consistent from one visit to the other so that the results can be analyzed over time. With the custom test programs, the standard conditions are flexible and can be changed for special applications in scientific studies.

The results of a perimetric test depend on a set of test conditions which are fixed for the standard examination programs in order to make sure the data is consistent from one visit to the other so that the results can be analyzed over time. With the custom test programs, the standard conditions are flexible and can be changed for special applications in scientific studies.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>OCTOPUS 101</th>
<th>OCTOPUS 300</th>
<th>HFA 700</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowl type</td>
<td>Spherical bowl</td>
<td>Direct projection</td>
<td>A-spherical bowl 18-30 cm</td>
</tr>
<tr>
<td>Background - Luminance</td>
<td>4 asb (1.27 cd/m²)</td>
<td>31.4 asb (10 cd/m²)</td>
<td>31.5 asb (10 cd/m²)</td>
</tr>
<tr>
<td>Stimulus - Size</td>
<td>Goldmann I - V 100 ms</td>
<td>Goldmann III, V 100 ms</td>
<td>Goldmann I - V 200 ms</td>
</tr>
<tr>
<td>- Duration</td>
<td>1’000 asb</td>
<td>4’800 asb</td>
<td>10’000 asb</td>
</tr>
<tr>
<td>- Luminance for 0 dB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measuring range</td>
<td>0 - 40 dB</td>
<td>0 - 40 dB</td>
<td>0 - 40 dB</td>
</tr>
<tr>
<td>Test strategies</td>
<td>4-2-1 dB bracketing Dynamic strategy TOP</td>
<td>4-2-1 dB bracketing Dynamic strategy TOP</td>
<td>4-2 dB bracketing SITA Normal SITA Fast</td>
</tr>
<tr>
<td>Normal values</td>
<td>Age correction per year of age</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2-6: Basic perimeter parameters and test conditions.**

To avoid false results by stray light effects, the maximum stimulus luminance must not be too large.

With the custom test programs, the standard conditions are flexible and can be changed for special applications in scientific studies.
2.9.1 Background luminance

In most perimeters, the background illumination is in the mesopic range between 1 and 100 asb. The shape of the hill of vision depends on the background luminance (see Figure 2-7).\textsuperscript{13}

Goldmann chose a background of 10 cd/m\textsuperscript{2} (31.4 asb) for the manual kinetic perimeter. Originally, all OCTOPUS perimeters operated at 1.27 cd/m\textsuperscript{2} (4 asb) background. However, because the perimeters having a direct projection system (OCTOPUS 300 / 1-2-3) can be used in normal environmental light conditions (there is no cupola and no disturbances from ambient light) it was helpful to raise the background illumination to 31.4 asb to shorten the adaptation time.

Note: When selecting the Goldmann kinetic perimetry method (see Special Perimetry Methods, Chapter 4), the background luminance of the OCTOPUS 101 is switched automatically from 4 to 31.5 asb in agreement with the Goldmann standard of manual kinetic perimetry.

2.9.2 The standard Goldmann III stimulus size

Today, almost all work in automated perimetry is done with the Goldmann III stimulus size (diameter: 0.432\textdegree) and all normal values are related to this stimulus size. Original Goldmann sizes range from size 0 to size V (see Figure 2-8), each step corresponding to a factor of 2 in diameter or a
factor of 4 in area. In the beginning, it was thought that for detecting the smallest scotomas, a Goldmann I size target would be required (diameter: 0.108°). However, as shown in Figure 2-8, the Goldmann III size target is already a small stimulus relative to the blind spot and certainly not too large to find tiny defects.

Today, practically all work in automated perimetry is done with the Goldmann III stimulus.

Figure 2-8: This greyscale image (from an OCTOPUS examination) shows the blind spot and six standard Goldmann stimulus sizes. The Goldmann stimulus size III, most frequently used in perimetry, is projected across the disc area.

In Low Vision programs, the Goldmann V stimulus size is applied.

The Goldmann I size target is sometimes used when plotting the extent of the blind spot with isopter I4e in kinetic perimetry. However, with the use of smaller stimuli, the effect of a refractive error becomes more critical and that makes it very important to administer the correct trial lens (see Section 6.4.7 in Testing the Visual Field, Chapter 6).

In the OCTOPUS “Low Vision” programs (see Examination Programs, Chapter 5) the Goldmann V stimulus size is applied.
2.9.3 Stimulus exposure time

In the OCTOPUS perimeters, the stimulus exposure time is fixed at 100 ms for the standard examination programs. This value is sufficiently high to reach complete temporal summation of the stimulus luminance. On the other hand, this exposure time is below the reaction time of the fixation reflex, which could cause erroneous results when the stimulus is presented longer.

As an exception, in the OCTOPUS “Low Vision” programs (see Examination Programs, Chapter 5), a 200 ms stimulus exposure time is used in combination with the Goldmann size V stimulus size.

2.9.4 Stimulus interval

When the patient responds by pressing the button, indicating that a stimulus has been seen, the next stimulus can be presented quickly thereafter. However, when the patient does not respond, the program has to wait for a certain time to account for the patient’s reaction time before the answer can be interpreted as NO and the next stimulus can be projected. The OCTOPUS programs permit the use of an adaptive stimulus presentation interval. The perimeter keeps track of the average reaction time of the patient in order to proceed most effectively, i.e., speeds up or slows down stimulus presentation. In situations where the patient feels uncomfortable with the (shorter) intervals, the stimulus presentation time can be set within a range of between 1.5 and 4 seconds.
2.10 Special Perimetric Methods

In the present section, the most commonly used automated perimetric methods in clinical practice are highlighted, namely the static White-on-White perimetry. Other methods encountered are:

- Kinetic perimetry
- Blue-on-Yellow perimetry
- Flicker perimetry

2.10.1 Kinetic perimetry

Basically, there are two ways to measure the hill of vision – the kinetic perimetry and static perimetry methods.

With the static method, the stimulus luminance is varied “up and down” as explained earlier in this chapter.

With the traditional Goldmann perimeter, a stimulus (a light spot) is moved slowly from the periphery toward the point of fixation (see Figure 2-10). Because the eye is much more sensitive in the central area, compared to the periphery, the stimulus cannot be seen in the beginning. But at some point, as the stimulus comes closer to the center, the light becomes visible. This location is marked on the chart and becomes one of the data points forming an “isopter” – the connecting line of all locations with the same sensitivity.

2.10.2 Other perimetric methods

For more detailed information on Kinetic, Blue-on-Yellow and Flicker perimetry see Special Diagnostic Methods, Chapter 4.
3 Methods for Determining the Differential Light Sensitivity

The duration of an examination depends on the number of test locations tested, the strategy used and, of course not to forget, on the reaction time of the patient.

Up to a certain point, the accuracy of the results is higher with strategies using the normal threshold bracketing strategy. However, when the test duration gets longer, the effects of 'fatigue' play an increasing negative role.

If the results of the perimetry are critical for guiding therapy, a normal full threshold strategy may be beneficial. Shorter tests can be used if the visual field is one of several examinations that will be used for diagnosis and treatment.

With staging, the patient performs the most critical part of the visual field testing in the very beginning of the examination, when collaboration is still good.
3.1 Measurement Strategies

The method to determine the d.l. sensitivity is called “test strategy” and the OCTOPUS perimeters offer a choice of test strategies to meet different prognostic and diagnostic situations, like screening patients, early detection of visual field loss and to follow pathological fields over time. The strategies to be covered in this Chapter are the Normal test strategy, the Dynamic test strategy and Tendency oriented perimetry (TOP) strategy.

In order to gain insight and appreciate the concepts of these different test methods, it is helpful to start with reviewing the standard test strategy (referred to as the “Normal test strategy”) as it was introduced with the first automated perimeters.

3.2 Normal Test Strategy

The Normal test strategy uses a technique where the stimulus luminance is varied up and down in steps (the procedure is called staircasing or bracketing) to find the luminance value (threshold) that is perceived by the patient, with a probability of 50% (see Threshold of Differential Light Sensitivity, Section 2.3). The examination program presents a series of brighter or dimmer stimuli at all test locations in a random order while the computer keeps track of the YES and NO (seen or missed) responses to steer the course of the test.

At any test location, testing starts from a stimulus luminance level which is derived from preliminary results obtained within the same examination at adjacent test locations. The local threshold is then first determined in 4 dB stimulus luminance steps and then, more accurately, in 2 dB steps. To gain time, the examination starts with a full determination of the d.l. sensitivity in four “anchor” points located near the center of each quadrant (see Figure 3-1) to establish the approximate level of the visual field prior to testing further locations starting from these levels.

3.2.1 Testing four primary (anchor) points

Testing starts in the four primary points at the age-corrected normal value minus 4 decibels (NV - 4 dB, see example in Figure 3-2) followed by a 6 dB increase in stimulus luminance when the patient does not respond to the first stimulus. Thereafter, the process continues with brighter spots

A 4 dB step corresponds to an increase by a factor of 2.5 of the stimulus luminance.
in steps of 8 dB in order to quickly approach the (depressed) sensitivity level until the patient perceives the stimulus and has pressed the button for a YES. After this first crossing of the threshold, the bracketing procedure is reversed making the stimulus luminance dimmer in steps of 4 dB. Subsequently, after a NO (second crossing), the stimulus luminance is increased again in 2 dB steps (third crossing). Finally, a 1 dB adjustment is applied opposite in direction to the last 2 dB step in order to obtain the d.l. sensitivity.

Figure 3-1: Position of the four (primary) anchor points.

The four primary points are determined with three crossings of the threshold.

Figure 3-2: Simplified diagram of the determination of the four primary points.
3.2.2 Testing further locations
After the determination of the d.l. sensitivity in the four primary points, the starting levels of the surrounding locations are calculated from the results obtained at the anchor points and from the local slope of the hill of vision in this area (rather than starting each time from the normal values for every location).

From this point, the staircasing procedure continues in 4-2-1 dB steps to test other locations. Further starting levels are calculated in each case from the medium values reached in three neighboring points.

3.2.3 Determining the threshold with the Normal strategy
Starting at the levels as described above, the Normal test strategy employs a double crossing (up and down) bracketing method with steps of 4-2-1 dB to determine the threshold of the d.l. sensitivity with a nominal accuracy of ±1 dB (see Figure 3-4).
All questions, at the test points defined by the examination program, are presented in a random order while the computer keeps track of the stimulus intensities, test locations and the corresponding answers of the patient.
The results of this test algorithm determines the d.l. sensitivity below the normal age-corrected values (depressed sensitivities) as well as above the normal values (see Figure 3-5). Therefore, the Normal strategy is capable of detecting shallow pathological depressions in eyes that are super sensitive (these shallow defects are usually undetected with other test methods). With approximately five questions per location on aver-
age, the examination may take as long as 12 to 18 minutes per eye, depending on the number of test locations, the degree of pathology and the fitness of the patient.

**The Normal test strategy employs a double crossing bracketing method with steps of 4-2-1 dB to determine the threshold with a nominal accuracy of ±1 dB.**

![Figure 3-4: Schematic diagram of the normal 4-2-1 dB bracketing strategy for thresholds.](image)

**Due to 'fatigue' effects, the d.l. sensitivities decrease with long test duration.**

![Figure 3-5: Schematic diagram of the bracketing process for thresholds above normal sensitivity.](image)

**3.2.4 Fatigue effects due to a long test duration**

Threshold testing is a demanding examination where patients typically make more mistakes toward the end of the test, due to ‘fatigue’ (see Section 6.4.14). That is because an examination with 60 test locations using the Normal test strategy may take as long as 12 to 18 minutes.

Note: The fatigue effect, referred to in this book as ‘fatigue,’ consists of two components: the patient’s physical fatigue and the fatigue...
caused by increased “strain” upon the visual system during a long examination.

To help alleviate this problem, OCTOPUS perimeters offer several techniques to increase test efficiency by shortening testing time thereby improving the reliability of the results by minimizing errors caused by the effects of ‘fatigue.’ These strategies are discussed in the following sections.

- Staging technique
- Dynamic strategy
- Tendency oriented perimetry (TOP) strategy

3.3 OCTOPUS Programs with Staging

In a typical (single pass) perimetric test program (see Figure 3-6) the final result of a perimetric examination becomes available only after the last question is answered by the patient. In extreme cases, this can take as long as 20 minutes of testing. If the patient is not in a position to follow such a long procedure and the test must be interrupted prematurely, all the data is lost and no result is obtained. This critical problem is solved by the implementation of test stages in the OCTOPUS examination programs.

3.3.1 The principle of test stages

Following this concept, the examination programs are run in modular steps – a sequence of diagnostically relevant stages – where in each stage a predefined subset of the test locations is measured (following the 4-2 dB steps) and the results conserved as if it were an independent examination.

After every breakpoint (stage) the test can be restarted, continued, or the test can be saved for printout.

Duration of a single stage examination

Figure 3-6: Diagram of the staging concept.
An important benefit with staging is that priority can be allocated to the test locations that are most critical and relevant in relation to the underlying disease. In other words, the essential part of the visual field testing is done in the very beginning of the examination – when the patient is still in a relatively good condition. As a result, important information is gained very quickly in only a fraction of the examination time (see Figure 3-7).

With staging, the patient performs the most critical part of the visual field testing in the very beginning of the examination - when collaboration is still good.

![Figure 3-7: Information about the visual field is gained very quickly during the first stages of the examination.](image)

This means that the test duration can be much shorter than with previous tests\textsuperscript{14} and many examinations can be finished sooner. In particular, this is the case when fields are severely depressed or when the field appears to be completely normal. In those situations, the examination can be concluded after two or three stages.

The OCTOPUS perimeters have a smart Defect level indicator with a real time display of the momentary status of visual field allowing the operator to judge clearly between “normal,” “borderline” and “depressed” fields, each of which facilitates making such decisions during the examination.
3.3.2 The use of test phases

After concluding a number of stages in the first phase, the second phase (or further test phases, see Figure 3-8) offers the possibility to extend the examination in different directions:

- Skip further testing in the center and continue in the periphery or other specific areas as requested.
- Return to the same test locations and repeat quantitative testing (in a short procedure starting from previous data) to obtain information on short term fluctuation.
- Quantify relative defects after a qualitative test procedure in phase one (see Qualitative Test, Section 3.7).

**With staging, testing time can be adapted to the patient’s situation and condition.**

![Examination procedure and options](image)

**Figure 3-8: The staging concept offers several possibilities to extend the examination according to the intermediate results.**

3.3.3 Benefits of the stage- and phase concepts

The staging and phasing concept is a unique feature of the OCTOPUS perimeters. It allows the design of different diagnostic test programs related to a specific pathology and increases the efficiency and clinical value by:

- Adapting testing time to the patient’s situation and condition.
- Making the test shorter and losing only marginal information.
- Setting priorities on diagnostically relevant areas.
• Extending the test area if required.
• Continue testing after the patient takes a break.

3.3.4 Comparing a 2-stage with a 4-stage examination
As mentioned, the diagnostic programs using the stage concept obtain most of the information within a short period of time. Typically, approximately 80% of the result is available at halfway in a normal (single pass) examination procedure (Figure 3-7).

In comparison, the display (Figure 3-9) on the left represents the result of a shortened examination of 2 stages (32 test locations) and on the right, a complete examination of 4 stages with 59 test locations.

3.4 Dynamic Test Strategy
With the Dynamic test strategy, the step sizes adapt to the slope of the FOSC (see Figure 3-10). With increasing depth of a defect, the stimulus luminance step size increases from 2 dB (near the normal values) to 10 dB (toward the most depressed levels). The final measured value is calculated as the mean between the two last stimuli.

For additional reduction of examination time, the threshold is crossed only once.

The procedure allows retesting all locations in a second phase.

The benefit of the Dynamic strategy is approximately 40-50% reduction in testing time in situations where fields show severe depression, and approximately 30-40% in areas of normal sensitivity.
Combined with the staging concept, the timesaving effect of both methods can be cumulative. Then the Dynamic strategy can minimize examination time to only a few minutes for a threshold test depending on the number of locations tested.

The accuracy obtained with the Dynamic strategy is comparable to the Normal (4-2-1 dB) threshold strategy in the range bordering normal sensitivity (where it is important). The precision decreases towards the lower sensitivity levels. But the ratio of benefit (accuracy) versus cost (time) remains largely in favor of the Dynamic strategy. This means that in the time usually needed for a qualitative screening exam, quantitative results become available in values, greyscale, Bebie curve and indices for a follow-up analysis (see printout in Figure 3-11).

3.5 Tendency Oriented Perimetry (TOP)

Tendency oriented perimetry (TOP) presents the maximum in fast threshold testing by reducing the examination time by nearly 80% to just over two minutes.

The TOP algorithm is a systematic method which takes into account that the threshold values of neighboring locations are correlated. Because the method is purely systematic and not related to specific pathological
patterns, TOP is not limited to a specific disease and can also be applied in combination with other perimetric methods such as Flicker or Blue-on-Yellow perimetry.

### 3.5.1 Basic principles

The anatomical and topographical interdependence of visual field defects establishes a “tendency” between the thresholds of neighboring zones.

The TOP method takes advantage of this relationship by using every patient’s answer in two ways: First, to test the threshold of the d.i. sensitivity in the test location where the stimulus is presented (conventional “vertical bracketing” method), and second to assess the thresholds of neighboring points by interpolation. This means that instead of questioning each individual test point 4-6 times, the threshold in every loca-

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**Figure 3-11: Comparing the results, a 5:7 minute Dynamic test (left) and a 9:32 minute Normal strategy test (on the right).**

The TOP method takes advantage of the correlation between the thresholds of neighboring zones.
Determination of the Differential Light Sensitivity

The examination is adjusted five times with only one question per location – once by a direct question and four times by the results from questions in neighboring locations.

To achieve this, TOP divides the field test locations in a network of four evenly intermingled grids (see Figure 3-12). These four grids are examined separately one after the other and the locations of the other three matrices are adjusted to obtain new values by interpolation.

The examination starts at half the normal value (NV), i.e., start value in dB is 8/16 NV.

Thereafter, testing proceeds with bracketing as shown, applying steps in relation to the patient’s age-corrected normal value, i.e., 4/16, 3/16, 2/16 and finally a step of 1/16 NV in either direction to determine the actual threshold of d.l. sensitivity.

A multicentric study carried out in six leading institutions in the USA, Europe and Asia showed an excellent correlation between the visual field indices obtained with TOP and the Normal strategy.

The evaluation of 122 eyes in a multicentric study carried out in six leading institutions in the USA, Europe and Asia showed an excellent correlation between the MD (0.96) and LV (0.94) visual field indices (see Figure 3-13). The visual field indices are explained in Section 7.2.
In an assessment based on the greyscales, TOP receives an outstanding grade. The field at left (Figure 3-14) was obtained in close to 12 minutes while the result at right took less than 3 minutes.

Because abrupt edges are slightly “rounded” with TOP, there is a tendency to give shallower scotomas than those measured with other test strategies. This particularity is due to the spread of answers over adjacent test locations, which effectively reduces the spatial resolution.

**Figure 3-13: Correlation between visual field indices obtained from the Normal strategy and from TOP.**
Left: $MD (r = 0.96)$, right: $sLV (r = 0.94)$.

**Figure 3-14: The same field with Normal strategy (left) compared to an examination with TOP (right).**

*With TOP, there is a tendency to obtain shallower scotomas compared to those measured with other test strategies.*
3.6 Rising Amplitude Perimetry (RAMP) Strategy

The Rising Amplitude Perimetry (RAMP) Strategy is a potential OCTOPUS strategy that is presently under investigation in clinical trials. Basically, the concept is that at each location a stimulus with a steady rising luminance is presented (see diagram in Figure 3-15), starting from very dim (invisible) to a visibly bright stimulus. The luminance that is perceived by the patient corresponds with the threshold at that particular test point. Therefore, just one ramp stimulus per location is all that is needed to accomplish the examination.

![Figure 3-15: Principle of the RAMP stimulus.](image)

Obviously, the reaction time of the patient plays a role in the outcome (just as with kinetic perimetry) and therefore, a few stimuli are added to measure the reaction time of the patient in order to calculate the correct threshold values.

3.7 Qualitative 2-Level (3-Zone) Test

With the introduction of faster full threshold test methods, the original qualitative screening strategy became practically obsolete. However, for the purpose of completeness, the description of the qualitative 2-Level Test is as follows:

The 2-Level Test (2-LT) typically uses a maximum of two questions (stimuli) per test location and provides a simple qualitative assessment.
of the field in three categories – normal, relative defect and absolute defect. Testing starts with the presentation of stimuli with an intensity of 4 dB below the threshold (see Figure 3-16). When the patient sees these targets, the points are validated as “normal.”

The 2-Level Test typically uses a maximum of two stimuli per test location and provides a simple qualitative assessment of the field.

![Figure 3-16: The qualitative 2-Level or 3-Zone test strategy.](image)

Should the patient not respond, a new stimulus is shown at the same test location with the brightest intensity. If this stimulus is seen, the location is tagged with “relative defect.” But when patient does not respond to the maximum stimulus, the result will be an “absolute defect.”

In case of doubt, the qualitative test procedure can be supplemented with the quantification of missed points (relative defects) and with a further check on the absolute defects to see if they are truly absolute.

The OCTOPUS also allows the retesting of the sensitivities which were declared as “normal” – to find out if there are any early signs of depression in areas of normal sensitivity. See also the criteria for screening examinations (see *Testing the Visual Field*, Chapter 6).

### 3.8 Qualitative 1-Level (2-Zone) Test

The Qualitative 1-Level Test (1-LT) is used exclusively for the legal visual function test Program BG according to the specifications of the German Ophthalmology Society – DOG (see Section 5-15).

With this strategy, only one supra-threshold stimulus (NV-6 dB) is presented and the results (seen or missed) are recorded in a “+” mark respectively as a filled square symbol.
3.9 Test Strategies in Comparison

Figure 3-17 presents a comparison in minutes of the average test duration for the most commonly used test strategies today.

![Figure 3-17: Comparison in minutes of the average test duration of the most common test strategies (OCTOPUS strategies in red).]
4 Special Diagnostic Methods

Standard W-W perimetry is the method of choice for following visual fields over time and for following disease. But studies have shown that for the early detection of visual field loss in glaucoma, the use of temporally modulated stimuli (such as a flicker stimulus) or testing the field with blue stimuli on a bright yellow background, is more sensitive than standard W-W static perimetry.
In comparison with W-W and B-Y perimetry, Flicker perimetry (CFF) is much less influenced by media opacities and blur.
Kinetic perimetry is a valuable diagnostic method in neuro-ophthalmology and in advanced glaucoma, as well as in situations where it is difficult to obtain reliable results with automated perimetry. It can zoom in on a specific field area to examine the finest details and "normalize" the isopters by measuring the patient's reaction time.
mfERG and mfVEP are objective electrophysiological methods to investigate the central 40 degrees of the visual field. The method is based on local bioelectrical signals arising from small retinal areas stimulated with a hexagonal stimulus. Applications of mfERG and mfVEP are: Visible or invisible retinal dystrophies at the posterior pole, unexplained central or paracentral visual loss with normal fundus appearance and neuro-ophthalmological problems, such as glaucoma.
**4.1 The Use of Special Perimetry Methods**

In special situations, the standard White-on-White perimetry ($W \leq W$) needs to be complemented with other perimetry methods to obtain conclusive results.

### 4.1.1 Glaucoma

In the course of diagnosing and following patients with glaucoma, it is advantageous to use different diagnostic methods over the course of the disease (see Figure 4-1). Any one single method cannot provide complete answers during the progression of the disease from the onset to its final stage.

Several studies have shown, that for the early detection of visual field loss in glaucoma, the use of temporally modulated stimuli (such as a flicker stimulus) or testing the field with blue stimuli on a bright yellow background, is more sensitive than standard W-W static perimetry. On the other hand, for following visual fields over time, standard W-W perimetry is the method of choice in managing the disease. Finally, in end stage glaucoma, it may be more efficient to test islands of remaining d.l. sensitivity with Goldmann kinetic perimetry rather than with automatic static perimetry.

### 4.1.2 Early loss of ganglion cells

Schematically, the process of seeing can be represented by a system where the rod and cone receptors pass visual signals onto a series of

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**Figure 4-1: Detection and following the progression of glaucoma.**

*Standard W-W perimetry is the method of choice for following visual fields over time and for managing the disease.*
It seems to be useful to address specific cells separately in order to detect functional loss in the beginning stage of the disease.

ganglion cells specifically sensitive to differing light stimulations. The theory is that in glaucoma certain types of ganglion cells may lose their function before others do. Therefore, it seems to be useful to address specific cells separately in order to detect functional loss in the beginning stage of the disease.

Approximately 80% of the ganglion cells are parvocellular “P” type cells, sensitive to color and contrast; 5% are koniocellular “K” cells, responsive to blue-yellow opponents; and 15% magnocellular “M” (My) cells that react to temporally modulated stimuli.

Following this theory, a special diagnostic method can be optimized for testing the functioning of a particular cell type. Presently, the following methods are available to serve this purpose:

- K cell system: Blue-on-Yellow perimetry (B-Y)
- M cell system: Critical-fusion-frequency (CFF) perimetry and frequency doubling technique (FDT)
- P cell system: Hi pass resolution perimetry (HRP)

### 4.2 Blue-on-Yellow Perimetry

Blue-on-Yellow Perimetry (B-Y) can detect early visual field loss before a reduction in d.l. sensitivity is shown with standard W-W perimetry. The principle of B-Y perimetry is to measure the sensitivity of the blue sensitive cones (in contrast with a yellow background).

As shown in Figure 4-2, B-Y perimetry is designed to isolate the blue sensitive cones (S-cones for “short” wave cones) from the green (M-cones for “middle” wave cones) and red (L-cones for “long” wave cones) by suppressing the relative sensitivity of the M- and L-cones with a very bright yellow background. The brighter the background, the more pronounced this isolation is. For practical purposes the background intensity is standardized on 315 asb (equivalent to 100 cd/m²).\(^{18}\)

After applying a yellow background, the S-cones become more sensitive to the M- and L-cones and yield a measuring range of approximately 18 dB (blue arrow in diagram at right) for determining the “isolated” blue S-cone sensitivity.

### 4.2.1 Discussion

Although under ideal conditions B-Y perimetry is shown to be a sensitive test for early glaucoma detection, there are also some practical re-
After applying a yellow background, the S-cones become more sensitive to the M- and L-cones and yield a measuring range of approximately 18 dB.

In B-Y perimetry, opacifications of the optical media, such as cataracts, have an important filter effect.

Restrictions and limitations for this method in clinical applications.

- As explained further in this chapter, opacifications of the optical media such as cataracts, have an important filter effect, disturbing the measurement. This has an influence on the results and makes the test less reliable.
- The frequency-of-seeing curve (FOSC) for B-Y perimetry is relatively flat causing an increase in the variability of the threshold. Therefore, the data is sometimes not very meaningful.
- The bright yellow background is very intense and the blue stimuli are hard to perceive. As a result, the test is rather strenuous and more difficult for the patients, compared to standard perimetry.
- The test duration (after several minutes adaptation) is relatively long.
- There is a considerable learning curve.

Figure 4-2: After suppression of the M- and L-cones (red in diagram) by applying a bright yellow background, the S-cones are isolated to yield a measuring range of approximately 18 dB (blue arrow) for determining the S-cone sensitivity.
4.3 **Flicker Perimetry**

With Flicker perimetry, the critical fusion frequency (CFF) is measured locally at different locations in the visual field. Several clinical studies over the past ten years have demonstrated the value of CFF perimetry in glaucoma and have shown that this method is more sensitive than standard W-W perimetry in the early detection of this disease.

### 4.3.1 CFF measurement

The method determines the Critical Fusion Frequency (CFF) in Hertz (Hz) instead of the d.l. sensitivity in decibels (dB).

Figure 4-3 shows the CFF values in relation to stimulus frequency and contrast (stimulus luminance) describing the borderline where a flickering stimulus (below the curve) fuses into a continuous light (above the curve). However, in Flicker perimetry, the contrast remains fixed at its highest value and therefore, the stimulus follows the dotted red line.

The patient must answer the question whether the stimulus is flickering or seen as a continuous light. During the test, the flicker frequency is varied in steps, depending on the strategy selected, from slow (1-5 Hz) to very fast (towards 50 Hz) and the patient must answer the question whether the stimulus is flickering or is seen as a continuous light. This question is more difficult than answering whether one sees or does not see a light. For this reason, the stimulus duration is one second in order to allow for sufficient decision.
4.3.2 Superior sensitivity for early detection

In Figure 4-4, the CFF values are noted on a scale of 0-50 Hz on the abscissa while the standard perimetry values are recorded on the ordinate scale of 0-40 dB. The curve was established with 82 glaucoma patients who performed both tests – a CFF and an examination with standard W-W perimetry.

The diagram shows that in the beginning of the disease (at the right side of the graph) a small decrease in d.l. sensitivity in dB corresponds with an important loss in Hz. The CFF method is more efficient in the early stages of visual field loss – confirmed also by the data in Figure 4-5.

On the other hand, an important reduction in sensitivity on the low end of the dB scale results in only a marginal change in Hz – i.e., Flicker perimetry is not a suitable method in the end stage of the disease.

Note: B-Y perimetry follows a similar curve. However, an important characteristic of CFF perimetry is that this method is practically insensitive to opacifications in the optical path (see Section 4.3.5).
4.3.3 Experimental test strategies

For use in combination with CFF perimetry, two new test strategies are under investigation.

- The 4-Zone test strategy (Figure 4-6) uses up to a maximum of three stimuli at the upper borderlines of the probability zones yielding results labeled as Normal, Relative Defect (P < 5%), Relative Defect (P < 1%) and Absolute Defect (5 Hz).

- Another experimental strategy in CFF perimetry is a modified “Normal” bracketing strategy using 10 and 5 Hz steps and one threshold crossing.

4.3.4 Central critical fusion frequency (CCFF)

The Central-critical-fusion-frequency (CCFF) test is a quick screening test taking less than 30 seconds to determine the CFF value in the central location of the visual field. The result of the CCFF test can be used as an indicator of an abnormality of some kind needing further investigation.
In comparison with W-W and B-Y perimetry, Flicker perimetry (CFF) is influenced much less by media opacities and blur.

4.3.5 Influence of media opacities and blur

In comparison with W-W perimetry and early detection methods such as Blue-on-Yellow perimetry (B-Y), Flicker perimetry (CFF) is influenced much less by media opacities and blur.\textsuperscript{22, 23}

The curves have been established with corrected vision of:
- ≈ 0.8
- 0.5 - 0.8
- £ 0.5

Figure 4-7: An important characteristic of CFF perimetry is that this method, unlike Blue-on-Yellow perimetry and FDT, is practically insensitive to opacifications in the optical path.\textsuperscript{22, 23}
4.4 Goldmann Kinetic Perimetry

Although static perimetry is used in the majority of applications, kinetic perimetry is still an indispensable diagnostic method in a number of clinical situations where the periphery needs to be tested or where automated static perimetry reaches its limits.

This is particularly the case in patients with dramatic visual field defects, such as in advanced glaucoma, anterior ischemic optic neuropathy (AION), chiasmal lesion, and post geniculate damage, as well as in situations where it is difficult to obtain reliable results (elderly patients, children, etc.) with automated perimetry. Also, in legal visual function testing, formal (official) certificates are mostly based on kinetic visual fields.

It is generally understood that kinetic perimetry is superior to static perimetry for examining the peripheral field and it is the only method that can accurately plot the extent of focal scotomas – such as the blind spot. However, Goldmann perimetry is considered a rather difficult technique and, to a great extent, the results depend on the ability and skill of the examiner. In addition, there are no means for storing, quantifying and comparing kinetic fields.

These shortcomings are now resolved with the introduction of the OCTOPUS 101 Goldmann Kinetic Perimetry (GKP) software module.
4.4.1 The OCTOPUS 101 GKP module

Basically, the GKP module does all that the Goldmann perimeter can do, and more (see “Desktop” Figure 4-9). The GKP technique:

- Uses a 90° field spherical cupola perimeter combining automatic (W-W and B-Y) static and manual kinetic perimetry.
- Allows easy operation by manually tracing selected isopters on an interactive pen display instead of a standard monitor (a practical option) with patient eye fixation control.
- Employs the same Goldmann standard stimulus sizes and familiar filter settings, including the presentation of static stimuli.
- The path followed by the kinetic stimulus, called “Vector” (starting point, direction and distance) is easily controlled by pointing the cursor.

Figure 4-9: Desktop of the OCTOPUS 101 GKP module (see also Figure 11-7 for more details).
Visual Field Digest

- Can be used in manual, semi-automated and automated modes.
- Measures patient’s reaction time and adjusts the isopters to obtain comparable results.
- Zooms in on a specific field area, such as the blind spot, to examine the finest details.

Figure 4-10: The zoom function allows one to examine and accurately quantify scotomas such as the blind spot.

Figure 4-11: Printout of a static field with I4e and I2e isopters.

After importation of a standard static perimetry field, combines the static results with the kinetic isopters in one printout.

Measures patient’s reaction time and adjusts the isopters to obtain comparable results.

Zooms in on a specific field area to examine the finest details – such as the blind spot.
Can repeat the same procedure automatically after finishing a manually guided kinetic examination.

Figure 4-12:

40-year-old male with AION

- Draws isopters in colors and calculates the isopter area in deg² to allow analysis of change (visual field evolution).
- Imports previous tested static (central) visual fields that can be completed with kinetic isopters in the periphery.
- Displays age-corrected normal isopter values (established by the University in Tübingen) serving as an orientation to start the testing.
- Displays and prints two fields (OS and OD) on one page.
- Can underlay previous kinetic examinations to either continue an interrupted exam or to compare with a finished result.
- Is prepared to be upgraded with the “Fundus oriented perimetry” software module.
- Includes the feature for repeating (reproducing) the same procedure automatically after finishing a manually guided kinetic examination.
- Offers the possibility for creating user examinations for automatic kinetic testing.
4.5 Multifocal Electroretinogram (mfERG) and Multifocal Visual Evoked Potentials (mfVEP)

mfERG and mfVEP are objective electrophysiological methods to investigate the central 40 degrees of the visual field. mfERG is based on local bioelectrical signals arising from small retinal areas stimulated with hexagonal stimuli. The signals are collected by a non-invasive electrode device at the eye. A mapping of the retinal sensitivity is established by analyzing amplitudes, latencies and shapes in order to estimate local function. mfVEP on the other hand is measured, just as the conventional VEP, at the occipital region over the visual cortex. A so-called dartboard stimulus is used. The obtained signals representing cortical activity are more complex than mfERG signals due to the anatomy of the fissura calcarina. Work on mfVEP is not as far along as mfERG research but the clinical results are very promising. A combination of mfERG and mfVEP may differentiate between a retinal lesion (of the macular area) and a lesion of the optic nerve (ganglion cells and subsequent visual pathways). In localized retinal disease, localized abnormalities of mfVEP signals may be more significant than the corresponding mfERG signals. The objective localized bioelectrical dysfunctions are eventually accompanied by local visual field defects obtained with automated static perimetry.
Figure 4-14:

Four cases with a localized paramacular retinal lesion:
In case J.E., the lesion is ophthalmoscopically visible. In the other three cases H.D., L.M. and V.Th, the retinal lesions are invisible. Probable defect locations in the macular M2 OCTOPUS program are marked as black dots. The mfERG was performed with 103 Hexagons. The black hexagons mark locations with a rather mild retinal damage. The color-coded mfERG plots show the difference in Standard Deviations from a normal group (damage probability). The mfVEP differential plots (difference between affected and unaffected eye) are shown at the bottom: The disturbed mfVEP signals are enhanced: they correspond to the locations of the visual field- and mfERG- damage. The mfVEP damage is more evident than the mfERG damage.

Applications of mfERG and mfVEP are:
- Visible or invisible retinal dystrophies at the posterior pole
- Unexplained central or paracentral visual loss with normal fundus appearance
- Neuro-ophthalmological problems such as glaucoma, other optic neuropathies or even homonymous hemianopia.
5 OCTOPUS EXAMINATION PROGRAMS

What constitutes an examination procedure? There are several methods and ways to test the visual field. Basically, there are three elements of choice that need to be determined, depending on the underlying pathology and status of the patient.

- Which locations need to be tested (test program)
- Which strategy do we select
- What method of perimetry is indicated

The following table provides an overview of those elements.

<table>
<thead>
<tr>
<th>Examination Procedure</th>
<th>Test program such as</th>
<th>Test strategy such as</th>
<th>Perimetry method such as</th>
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</thead>
<tbody>
<tr>
<td>Program G1X, G2</td>
<td>Normal strategy</td>
<td>White / white</td>
<td></td>
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<tr>
<td>Program 32</td>
<td>Dynamic strategy</td>
<td>Flicker perimetry</td>
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<tr>
<td>Program M2</td>
<td>TOP strategy</td>
<td>B/Y perimetry</td>
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<tr>
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<td>Kinetic perimetry</td>
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This chapter details the specifications of the standard examination programs.
5.1 Elements of the Examination Programs

5.1.1 Test locations

For the selection of the test locations, there are specific requirements for different diseases – glaucoma, macula degeneration, diabetes or a neurological problem, for example. The OCTOPUS programs offer specific diagnostic patterns that are individually defined for most of the common pathological conditions.

To demonstrate this idea, Figure 5-1 shows the 59 test locations used in the G1 and G2 glaucoma programs (described later in this chapter) next to the 76 test locations implemented in the original (1975) glaucoma program 32.

The G1/G2 test locations correspond closely with the topography of the retina - in particular with areas of concern in glaucoma. Program 32 with a regular grid pattern with 6° spacing is less efficient for glaucoma.

![Figure 5-1: Two sample printouts showing the test location patterns of the examination programs G1/G2 and program 32.](image)

The G1/G2 test locations are positioned to correspond more closely with the topography of the retina – in particular with areas of concern in glaucoma. The grid accentuates the nasal step and has a higher resolution (up to 2.8°) in the paracentral area. In comparison, the program 32 has a regular grid pattern with 6° spacing between the test locations, making this program less efficient for glaucoma.

5.1.2 Test strategies

The criteria for selecting one test strategy or the other are related to the pathology, the condition of the patient and the patient’s ability to perform the test.
The following is an overview with the abbreviations and a short explanation of the strategies listed in this chapter (for details see *Methods for Determining the Differential Light Sensitivity*, Chapter 3).

**NS** Normal strategy – is the standard in perimetry. Because of the time needed for the 4-2-1dB bracketing procedure with two threshold crossings, the test duration is typically 10-15 minutes per eye.

The Normal strategy is indicated for detecting early and shallow defects with younger patients who are in a sufficiently good condition to reliably answer the questions till the end of a long program.

**LVS** Low vision strategy – presents a 4-2-1 dB bracketing test method starting with its brightest stimuli and stepping up from 0 dB thus reducing the time to reach the thresholds in the end stage of an eye disease.

**DS** Dynamic strategy – stands for a test procedure with varying step sizes and one threshold crossing. The steps are small in the region of normal sensitivity and become larger toward locations where the field is depressed. As a result, the test duration can be reduced by a factor of two.

The Dynamic strategy is useful for early detection of visual field loss and in cases where focal defects can be expected.

**TOP** Tendency oriented perimetry – takes advantage of the fact that the d.l. sensitivity of the retina is interrelated rather than having an individual (isolated) value. During the test, every answer at a particular point is also taken into account in the adjustments of the neighboring locations.

With TOP, a full threshold examination takes just over two minutes. This is a practical routine test method for following patients with depressed fields, for children, and for elderly persons who are not capable of finishing a longer examination.

**2-LT** Two-level-testing – is a qualitative rather than a quantitative screening test. The results give only a rough indication of the status of the visual field in terms of “normal,” “relative” or “absolute” defect.
1-LT One-level-test – is only used in special legal testing procedures. The qualitative results are expressed as “normal” or “not normal.”

5.1.3 Program characteristics

Staging concept
Most OCTOPUS programs provide the flexibility for examining the field in stages and phases (see Section 3.3). The idea is to test critical points first (when the patient can still answer the questions reliably) and test the areas that are only “nice to have” at the end (when the patient may get tired).

Further testing
With the staging concept, the test can be finished earlier, as soon as the intermediate results are sufficiently accurate. But if more information is needed, the procedure can be continued by:

a) Testing other locations
b) Changing to another test strategy (after a screening test), or
c) Repeating the test procedure

5.1.4 Special perimetry methods

Blue-on-Yellow perimetry
Both OCTOPUS models 101 and 311 can perform Blue-on-Yellow (B-Y) perimetry. B-Y perimetry can be selected using different programs (test point locations) and test strategies.

OCTOPUS 101 Goldmann Kinetic Perimetry (GKP)
Goldmann Kinetic Perimetry (GKP) is an option for the OCTOPUS 101. This method allows performing true 90° full field Goldmann perimetry. The isopter graphs can be combined with static perimetry fields.

Flicker perimetry
The OCTOPUS 300 Series is capable of performing Flicker perimetry. This method is particularly sensitive in the early stages of the disease. In addition, a cataract does not interfere with the measurement because, to a great extent, opaque media remain “transparent” for the flicker stimulus.
5.2 Normal values

5.2.1 Standard White-on-White perimetry

Age and coordinate-corrected normal values were established in an international multicentric study (* the investigators are listed in the footnote on this page). This normal data, valid only for a particular set of standard test conditions of stimulus size and color, stimulus duration and background illumination, is the basis for the calculation of statistical data such as Comparison, the Cumulative defect curve and the Global visual field indices.

The age correction is 0.065 dB per year from 20 years of age onward.

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</tr>
<tr>
<td>-24°</td>
<td>22</td>
<td>25</td>
<td>27</td>
<td>28</td>
<td>29</td>
<td>29</td>
<td>28</td>
<td>27</td>
</tr>
<tr>
<td>-30°</td>
<td>18</td>
<td>24</td>
<td>25</td>
<td>27</td>
<td>28</td>
<td>28</td>
<td>27</td>
<td>27</td>
</tr>
</tbody>
</table>

5.3 Program Overview

Static perimetry

<table>
<thead>
<tr>
<th>Program</th>
<th>Application</th>
<th>OCTOPUS 101</th>
<th>OCTOPUS 300</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1/G2</td>
<td>Glaucoma and general use</td>
<td>+</td>
<td>+</td>
<td>30 / 60°</td>
</tr>
<tr>
<td>32</td>
<td>General purpose</td>
<td>+</td>
<td>+</td>
<td>30°</td>
</tr>
<tr>
<td>M1/M2</td>
<td>Macula examination (0.7°)</td>
<td>+</td>
<td>+</td>
<td>4° - 10° - 26°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td></td>
<td>60°</td>
</tr>
<tr>
<td>08</td>
<td>Macula examination (2°)</td>
<td>+</td>
<td>CT **</td>
<td>10°</td>
</tr>
<tr>
<td>N1</td>
<td>Neurological testing</td>
<td>+</td>
<td></td>
<td>4° - 26° - 70°</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td>CT **</td>
<td>Blind spot</td>
</tr>
<tr>
<td>D1</td>
<td>Diabetes examination</td>
<td>+</td>
<td></td>
<td>26° - 55°</td>
</tr>
<tr>
<td>LVC</td>
<td>Central low vision test</td>
<td>+</td>
<td>CT **</td>
<td>30°</td>
</tr>
<tr>
<td>LVP</td>
<td>Peripheral low vision test</td>
<td>+</td>
<td></td>
<td>90°</td>
</tr>
<tr>
<td>ST</td>
<td>Central and full field screening</td>
<td>+</td>
<td>+</td>
<td>30° - 60°</td>
</tr>
<tr>
<td>07</td>
<td>Central and full field screening</td>
<td>+</td>
<td></td>
<td>30° - 80°</td>
</tr>
<tr>
<td>BT</td>
<td>Blepharoptosis test</td>
<td>+</td>
<td></td>
<td>50° nasal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td></td>
<td>82° temporal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>+</td>
<td></td>
<td>60° superior</td>
</tr>
<tr>
<td>CT</td>
<td>User designed test programs</td>
<td>+</td>
<td></td>
<td>90°</td>
</tr>
<tr>
<td>ET</td>
<td>Esterman test</td>
<td>+</td>
<td></td>
<td>80°</td>
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<tr>
<td>BG</td>
<td>Legal blindness test (GER)</td>
<td>+</td>
<td></td>
<td>50°</td>
</tr>
<tr>
<td>FG</td>
<td>Driver’s license test (GER)</td>
<td>+</td>
<td></td>
<td>80°</td>
</tr>
</tbody>
</table>

Kinetic perimetry

| GKP     | Goldmann kinetic perimetry            | +           |             | 10° - 30° - 90°|

Special perimetry methods

| Blue-on-Yellow perimetry | + | + | 30° - 60° - 90° |
| Flicker perimetry        | + |   | 30°           |

** User defined, Custom test programs (CT)

Figure 5-3: OCTOPUS examination programs – an overview.
5.4 Program G1/G2 - Glaucoma Examination

The examination programs G1 (OCTOPUS 300) and G2 (OCTOPUS 101) are the same within the 30° field (59 test locations). On the OCTOPUS 101, Program G2 is supplemented by 14 peripheral test locations in the 30°-60° area. The test locations are given in Figure 5-4. Although both programs are quite useful as a general-purpose threshold program, the test point pattern is specifically designed for glaucoma – special attention is paid to the para-central test locations (in the macula area, the resolution is 2.8° compared to 6° in program 32) and to the nasal step.

For the examination of the central 30° field, the strategies NS, DS and TOP are available (see Section 5.1.2). All of them allow for a quantification of local defects and of diffuse damage.

The course of the examination is organized in phases as follows:

Phase #1: The first examination of the 30° field with up to 59 test locations (Figure 5-4b) in one to four stages using either one of the three strategies: NS, DS or TOP (see Methods for Determining the Differential Light Sensitivity, Chapter 3).

With the strategies NS and DS, the most important locations are tested first. The result obtained after the first two stages is therefore sufficiently accurate most of the time. This is a valid break point for considering the option to terminate the examination at this point (see staging concept, Section 3.3). The procedure to test two stages may take approximately four minutes (with DS) to seven minutes (NS) of testing time. If more information should be required, mostly in borderline situations with patients who are in a good enough condition to reliably sustain a longer testing time, one can proceed with the option to examine the remaining 27 central locations in stages #3 and #4.

Phase #2: This option offers the possibility to repeat the examination of the locations tested in phase #1 with the same strategy (note the difference between the programs G1 and G2, Section 5.4.1 and 5.4.2). This procedure is followed when information about the Short term fluctuation (the visual field index SF, see Section 7.2) is requested.

Phase #3: After completing phase #1 (or #2), the 14 peripheral test locations (see Figure 5-4a) can be tested with the OCTOPUS 101 using the qualitative 2-LT strategy (see Section 3.7).

Phase #4: In case any relative or absolute defects show up in the periphery, the peripheral locations can be retested in this phase, using a threshold strategy (NS or DS), to quantify those defects.

5.4.1 Program G1

In case the determination of the global indices Short-Term Fluctuation (SF) and Corrected Loss Variance (CLV) is requested, we need to finish all four stages before we can continue with phase 2 in order to obtain a double measurement.

5.4.2 Program G2

With program G2 the values for SF and CLV can be calculated earlier, after repeating only the stages #1 and #2 in the second phase.
### Program G1/G2 characteristics

<table>
<thead>
<tr>
<th></th>
<th>OCTOPUS 101</th>
<th>OCTOPUS 300 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
<td>59 points from 0 - 30°</td>
<td>59 points from 0 - 30°</td>
</tr>
<tr>
<td></td>
<td>14 points from 30 – 60°</td>
<td></td>
</tr>
<tr>
<td>Strategy</td>
<td>NS, DS or TOP (Phase 1,2)</td>
<td>NS, DS or TOP (Phase 1,2)</td>
</tr>
<tr>
<td></td>
<td>2-LT, NS (Phase 3,4)</td>
<td></td>
</tr>
<tr>
<td>Stimulus size</td>
<td>Goldmann III</td>
<td>Goldmann III</td>
</tr>
<tr>
<td>Stimulus duration</td>
<td>100 ms</td>
<td>100 ms</td>
</tr>
<tr>
<td>Background</td>
<td>4 asb</td>
<td>31.4 asb</td>
</tr>
<tr>
<td># Test phases</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

### Further testing

- **Phase 2**: Retest threshold values for SF calculation.
- **Phase 3, 4**: Screening periphery (3), quantify defects in the periphery (4)

![Program G2 all test locations](image1)

![Program G1/G2, ST central test locations](image2)

*Figure 5-4 a/b: Examination programs G1 / G2 and ST test point locations (OD).*

  a) Program G2 (OCTOPUS 101), central and peripheral test locations.
  
  b) Central test locations program G1/G2.
5.5 Program 32 - General (Threshold) Examination

Program 32 is the classical “off axis” central program that was introduced with the first OCTOPUS perimeters in 1975. In the design, it was thought that the test duration should not be longer than a maximum of 25 minutes (including ten double determinations). This means that the maximum number of test locations is 76 (spaced in an equidistant grid pattern with 6° resolution).

The original program 32 established a value for the short-term fluctuation with a double determination in 10 fixed selected locations. This was called the “Root Mean Square” or RMS value. With the current OCTOPUS perimeters, short-term fluctuation can be assessed by testing all locations a second time in phase 2 of the examination. Due to the wide spacing of the locations (not related to the retinal topography or any specific pathology), it was soon realized that with this pattern, program 32 could not be an ideal program for glaucoma. Therefore, the more effective glaucoma programs G1 and G2 were introduced.

However, in the meantime, thousands of visual fields were tested with the OCTOPUS program 32, and the Humphrey program 30-2 (which is practically identical to program 32) is still used extensively. For these reasons, program 32 remains an option when used in follow-up examinations to allow a direct comparison of the results with a statistical analysis program.

Program 32 characteristics

<table>
<thead>
<tr>
<th>OCTOPUS 101</th>
<th>OCTOPUS 300 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
<td>76 points from 0 – 30°</td>
</tr>
<tr>
<td>Strategy</td>
<td>NS, DS or TOP (phase 1)</td>
</tr>
<tr>
<td>Stimulus size</td>
<td>Goldmann III</td>
</tr>
<tr>
<td>Stimulus duration</td>
<td>100 ms</td>
</tr>
<tr>
<td>Background</td>
<td>4 asb</td>
</tr>
<tr>
<td>Test phases</td>
<td>2</td>
</tr>
</tbody>
</table>

Further testing

| Phase 2 | Retest threshold values for SF calculation | Retest threshold values for SF calculation |
5.6 Program 08 - Macula Program

The examination program C08 covers the central 10° visual field with a total of 56 test locations in an equidistant grid pattern with a spacing of 2°.

Program C08 characteristics

<table>
<thead>
<tr>
<th>OCTOPUS 101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
</tr>
<tr>
<td>Strategy</td>
</tr>
<tr>
<td>Stimulus size</td>
</tr>
<tr>
<td>Stimulus duration</td>
</tr>
<tr>
<td>Background</td>
</tr>
<tr>
<td>Test phases</td>
</tr>
</tbody>
</table>

Further testing

Phase 2 Retest threshold values for SF calculation

Figure 5-5: The test locations in a 6° test grid of examination program 32 (left). Examination program 08 test point locations with 2° spacing (right).
5.7 Program M2X/M2 - Macula Examination

The OCTOPUS M2 programs (program M2X for the OCTOPUS model 1-2-3) were designed for the detection and follow-up of central or para-central visual field defects in patients with neurological disorders or with macular or peri-macular diseases.

The M2 program starts with examining 45 test locations in two stages in the central 4° area, which results in a resolution of 0.7° in the macula (the diameter of the Goldmann stimulus size III is 0.43°). Then, in two further stages, the examination can be completed with 36 additional points between 4° and 9.5° eccentricity. This is the highest concentration of test locations in any available examination program.

As an option, the central locations can be tested a second time with a 2-1 dB strategy, starting from the previous values, to obtain data on short-term fluctuation. If “peripheral” information is required, testing can be continued an additional 38 locations between 9.5° and 26° followed by another 14 locations between 30° and 60°. All these points are tested first using the qualitative 2-LT strategy, with an option to retest relative defects using the NS strategy.

Figure 5-6: Examination program M1 / M2 test point locations (OD) in three groups between 0° – 4°, 4° – 9.5° and 9.5° – 26°.
### Program M1/M2 characteristics

<table>
<thead>
<tr>
<th></th>
<th>OCTOPUS 101</th>
<th>OCTOPUS 300 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
<td>45 points from 0 – 4°</td>
<td>45 points from 0 – 4°</td>
</tr>
<tr>
<td></td>
<td>36 points from 4 - 9.5°</td>
<td>36 points from 4 - 9.5°</td>
</tr>
<tr>
<td></td>
<td>38 points from 9.5 – 26°</td>
<td>38 points from 9.5 – 26°</td>
</tr>
<tr>
<td></td>
<td>14 points from 26 – 56°</td>
<td></td>
</tr>
<tr>
<td>Strategy</td>
<td>NS, DS or TOP (phase 1)</td>
<td>NS, DS or TOP (phase 1)</td>
</tr>
<tr>
<td></td>
<td>2-LT, NS (Further testing)</td>
<td>2-LT, NS (Further testing)</td>
</tr>
<tr>
<td>Stimulus size</td>
<td>Goldmann III</td>
<td>Goldmann III</td>
</tr>
<tr>
<td>Stimulus duration</td>
<td>100 ms</td>
<td>100 ms</td>
</tr>
<tr>
<td>Background</td>
<td>4 asb</td>
<td>31.4 asb</td>
</tr>
<tr>
<td># Test phases</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

### Further testing

<table>
<thead>
<tr>
<th>Phase</th>
<th>Description</th>
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<tbody>
<tr>
<td>Phase 2</td>
<td>Retest threshold values for SF calculation</td>
</tr>
<tr>
<td>Phase 3, 4</td>
<td>Screening 9.5 – 26° (3)</td>
</tr>
<tr>
<td></td>
<td>Quantify defects 9.5 – 26° (4)</td>
</tr>
<tr>
<td>Phase 5, 6</td>
<td>Screening (5) and quantify defects in periphery (6)</td>
</tr>
</tbody>
</table>
5.8  **Program N1 - Neurological Test**

The Neuro-Ophthalmological Program N1 offers a perimetric procedure for the evaluation of the visual field in patients with neuro-ophthalmological defects. Program N1 is basically a multistep examination program using special test point patterns for the central 30° field, the peripheral field and for the centro-macular and blind spot areas. The test locations are selected to take into account possible field rotation due to extraocular muscle imbalance and to avoid artifacts resulting from hemianopia or hemineglect.

The examination procedure starts with screening 54 locations (phase #1) in the central 30° field. From this point on, different routes may be followed:

- go to phase #2, retest the “relative defects” of phase #1 using NS
  with the possibility to continue with phase #3; retest the “normal” locations of phase #1 using NS
- go to phase #4, test 4° foveal area using NS
- go to phase #6, screening of the blind spot using 2-LT
- go to phase #7, screening in the periphery using 2-LT
- to end the examination

All these details look rather complex. However, routine comes with practice. Also, we must keep in mind that the patient can do the different stages and/or phases in different sessions, if necessary, even on different days.

A completed N1 examination cannot be printed out in one single format because the results from the different phases vary widely in spatial extent. The diagrams (Figure 5-7 and Figure 5-8) show how the test locations are arranged. Moreover, to appreciate the details, a separate printout for the different areas is more useful.
Program N1 characteristics

<table>
<thead>
<tr>
<th>OCTOPUS 101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
</tr>
<tr>
<td>Strategy</td>
</tr>
<tr>
<td>Stimulus size</td>
</tr>
<tr>
<td>Stimulus duration</td>
</tr>
<tr>
<td>Background</td>
</tr>
<tr>
<td>Test phases</td>
</tr>
</tbody>
</table>

Further testing

Phase 2 - 9: Quantify defects and normals between 4 – 26° (2, 3), quantify and retest 0 – 4° area (4, 5), blind spot mapping (6), screening periphery (7) and quantify peripheral defects and normals (8, 9)

Figure 5-7: Examination program N1 test point locations (OD). Qualitative and quantitative testing can be performed in different field areas in stages #1 to #9. Here, the locations for the central 30° and 70° visual field are shown.

Figure 5-8: Examination program N1 macular and blind spot test point locations (OD).
5.9 **Program D1 - Diabetes Examination**

Patients with diabetes may also develop defects in the peripheral field. Therefore, after routine testing of the central area, it is sometimes useful to check the $30^\circ - 60^\circ$ field. For this purpose, Program D1 was designed with a larger concentration of test locations (42 points) in the periphery compared to the central area (16 points).

**Program D1 characteristics**

**OCTOPUS 101**

<table>
<thead>
<tr>
<th>Test locations</th>
<th>16 points from $0 - 26^\circ$, 42 from $26 - 52^\circ$</th>
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</thead>
<tbody>
<tr>
<td>Strategy</td>
<td>NS, DS</td>
</tr>
<tr>
<td>Stimulus size</td>
<td>Goldmann III</td>
</tr>
<tr>
<td>Stimulus duration</td>
<td>100 ms</td>
</tr>
<tr>
<td>Background</td>
<td>4 asb</td>
</tr>
<tr>
<td>Test phases</td>
<td>4</td>
</tr>
</tbody>
</table>

**Further testing**

Phase 2 Retest threshold values in central area for SF

Phase 3, 4 Test peripheral locations (3), retest threshold values for SF (4)

*Figure 5-9: Diabetes examination program D1 test point locations (OD).*
5.10 Program BT - Blepharoptosis Test

The Blepharoptosis test is a special examination to determine the degree of disability with increasing blepharo-
chalasis. In this case, the upper lid covers the upper portion of the pupil with the eye open. This can result in
a large area of absolute scotoma with adjoining relative defects toward the center.

Program BT characteristics

<table>
<thead>
<tr>
<th>OCTOPUS 101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
</tr>
<tr>
<td>Strategy</td>
</tr>
<tr>
<td>Stimulus size</td>
</tr>
<tr>
<td>Stimulus duration</td>
</tr>
<tr>
<td>Background</td>
</tr>
<tr>
<td>Test phases</td>
</tr>
</tbody>
</table>

Figure 5-10: Blepharoptosis test program BT test point locations.
5.11 Program LVC and LVP - Central and Peripheral Low Vision Tests

The use of the central Low Vision program serves to test how much sensitivity remains in the central foveal area (small island of vision), for example, in a case of end stage glaucoma. For this purpose, program LVC uses the same test grid as program 32, which was discussed earlier in Section 5.5. However, for this application the stages are organized in another order of priority – the central locations (stage #1 within 10°) are tested before the “peripheral” points in the stages #2 through #4. Obviously, the examination can be terminated at this stage or when the patient has lost sensitivity.

In an optimum (time efficient) procedure, OCTOPUS Low Vision programs use a special “low vision” strategy starting at 0 dB in order to arrive quickly at the expected threshold level. Also, the larger stimulus size V and stimulus duration of 200 ms are used.

The peripheral Low Vision program uses the same “low vision” test strategy. But here, the priority testing goes in stages, in a reverse direction, starting from the periphery toward the central area.

Figure 5-11: Program LVC test locations (left) and LVP test locations (right).
Program LVC characteristics

<table>
<thead>
<tr>
<th></th>
<th>OCTOPUS 101</th>
<th>OCTOPUS 300 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
<td>77 points from 0 – 30°</td>
<td>77 points from 0 – 30°</td>
</tr>
<tr>
<td>Strategy</td>
<td>LVS</td>
<td>LVS</td>
</tr>
<tr>
<td>Stimulus size</td>
<td>Goldmann V</td>
<td>Goldmann V</td>
</tr>
<tr>
<td>Stimulus duration</td>
<td>200 ms</td>
<td>200 ms</td>
</tr>
<tr>
<td>Background</td>
<td>4 asb</td>
<td>31.4 asb</td>
</tr>
<tr>
<td>Test phases</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Program LVP characteristics

<table>
<thead>
<tr>
<th></th>
<th>9 points from 0 – 30°, 66 from 30 – 87°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy</td>
<td>LVS</td>
</tr>
<tr>
<td>Stimulus size</td>
<td>Goldmann V</td>
</tr>
<tr>
<td>Stimulus duration</td>
<td>200 ms</td>
</tr>
<tr>
<td>Background</td>
<td>4 asb</td>
</tr>
<tr>
<td>Test phases</td>
<td>2</td>
</tr>
</tbody>
</table>

Further testing

Phase 2

Quantify central test locations from 0 – 30°
5.12 Program STX/ST - Glaucoma Screening Test

The STX and ST programs are used for glaucoma screening. The difference between the programs are the same as described for programs G1 and G2 with the exception that the ST programs have 26 rather than 14 peripheral test locations.

The program is organized in prioritized stages in such a way that the screening may take only 3 - 5 minutes per eye. In the following phases, we may continue with the quantification of the “relative,” and the “absolute defects” and also the results determined as “normal” can be retested. This way, a complete ST procedure can eventually provide the same quantitative result as a single-phase G2 examination.

Another application of the staging procedure consists of making a (quick) qualitative test in the central 30° area, and then to quantify the periphery. Such an exam may be useful in following peripheral defects such as that found in Retinopathia Pigmentosa.

Program ST characteristics

<table>
<thead>
<tr>
<th>OCTOPUS 101</th>
<th>OCTOPUS 300 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
<td>59 points from 0 – 30°</td>
</tr>
<tr>
<td></td>
<td>26 from 30 – 56°</td>
</tr>
<tr>
<td>Strategy</td>
<td>2-LT (phase 1)</td>
</tr>
<tr>
<td></td>
<td>2-LT, NS (further testing)</td>
</tr>
<tr>
<td>Stimulus size</td>
<td>Goldmann III</td>
</tr>
<tr>
<td>Stimulus duration</td>
<td>100 ms</td>
</tr>
<tr>
<td>Background</td>
<td>4 asb</td>
</tr>
<tr>
<td>Test phases</td>
<td>6</td>
</tr>
</tbody>
</table>

Further testing

Phase 2 - 3          Quantify “relative” defects (2) and “normals” (3) Quantify “relative” defects (2) and “normals” (3)
Phase 4 - 6          Screening periphery (4) quantify peripheral defects (5) and normals (6)

Test point locations:

Same locations as program G2 (Figure 5-4 b)
5.13 Program 07 - Screening Test (Central and Peripheral Field)

The 07 program, one of the original programs from the early days, is mainly implemented to support continuity and meet the needs of the users who regularly applied this program for training the patient before the first threshold examination. However, in the software of the current OCTOPUS models the “Restart” function is now mainly used for this purpose. Also, as demonstrated by the test grid, program 07 is also very useful in neuro-ophthalmological situations.

In program 07, the 130 test locations (within the 75° field) are initially screened. Then, as an option, all points can be retested until a complete quantitative result is reached. Of course, the stage procedure provides the means for interrupting the test, or to shorten the test duration, according to the patient’s condition.

As explained in Section 5.2, this program can be used to quantify the periphery with the threshold strategy (also with the dynamic strategy) after screening the central 30° field.

Program 07 characteristics

**OCTOPUS 101**

- **Test locations**: 48 from 0 – 30°, 82 from 30 – 75°
- **Strategy**: 2-LT, DS, NS
- **Stimulus size**: Goldmann III
- **Stimulus duration**: 100 ms
- **Background**: 4 asb
- **Test phases**: 6

**Further testing**

Phase 2 -6 Quantify defects and normals in central 30° (2, 3), screening of the periphery (4) and quantify peripheral defects and normals (5, 6)

*Figure 5-12: Program 07 test locations.*
5.14 Program ET - Binocular Esterman Test

This program is designed to test visual function on a score from 0 to 100 (%). The test is binocular and requires the patient to fixate with both eyes. Fixation control of the dominant eye is recommended.

Program ET characteristics

<table>
<thead>
<tr>
<th>OCTOPUS 101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
</tr>
<tr>
<td>Strategy</td>
</tr>
<tr>
<td>Stimulus size</td>
</tr>
<tr>
<td>Stimulus duration</td>
</tr>
<tr>
<td>Background</td>
</tr>
<tr>
<td>Test phases</td>
</tr>
</tbody>
</table>

Figure 5-13: Test locations of the binocular Esterman test.
5.15 Program BG and FG - Legal Test Examinations

According to the specifications of the German Ophthalmology Society – DOG.

5.15.1 “Blindengutachten” Program
The “Blindengutachten” program is a legal visual function test used in Germany. The requirement is to test both eyes within a 55° area and have the results documented on a single printout form.

5.15.2 “Führerscheingutachten” Program
The “Führerscheingutachten” program is a legal drivers’ license program required in Germany. The field should cover a full 90° area with a total of 105 test locations.

**OCTOPUS 101**

<table>
<thead>
<tr>
<th></th>
<th>Program BG</th>
<th>Program FG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test locations</td>
<td>68 from 0 – 50°</td>
<td>105 from 0 – 80°</td>
</tr>
<tr>
<td>Strategy</td>
<td>1-LT</td>
<td>2-LT</td>
</tr>
<tr>
<td>Stimulus size</td>
<td>Goldmann III</td>
<td>Goldmann III</td>
</tr>
<tr>
<td>Stimulus duration</td>
<td>500 ms</td>
<td>200 ms</td>
</tr>
<tr>
<td>Background</td>
<td>31.4 asb</td>
<td>31.4 asb</td>
</tr>
<tr>
<td>Test phases</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Further testing
Phase 2 1-LT second eye

**Figure 5-14: Program BG (left) and FG (right) test locations.**
5.16 Program CT - Custom Test Program (User-Defined Tests)

The custom test program allows the user to design specialized test protocols for his or her own use. To specify a custom program is a simple menu-guided procedure, which can be understood and implemented without any computer knowledge or special training.

The user-defined examination programs automatically take advantage of OCTOPUS software features such as using the normative data, a selection of test strategies, catch trial questions, etc. At the same time, test parameters other than standard can be chosen for the particular application under study.

The test parameters are:

- Test grid – linear or nonlinear
- Number of test locations from 16 to 100
- Spacing between test points (smallest spacing of 1.0°)
- Orientation (location) of the test points within the visual field
- Stimulus size and stimulus duration
- Background illumination
- Test strategies
- Use of staging

Figure 5-15: Typical setup menu for defining a custom test program. OCTOPUS 101 (left), OCTOPUS 300 (right).
### OCTOPUS Examination Programs

#### CT characteristics

<table>
<thead>
<tr>
<th></th>
<th>OCTOPUS 101</th>
<th>OCTOPUS 300 Series</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Test locations</strong></td>
<td>16 – 100 points in regular format from 4 – 90°</td>
<td>16 – 100 points in regular format from 4 – 30°</td>
</tr>
<tr>
<td><strong>Resolution / spacing</strong></td>
<td>Minimum spacing 1°</td>
<td>Minimum spacing 0.5°</td>
</tr>
<tr>
<td><strong>Examination area</strong></td>
<td>Linear or nonlinear grid in round or square shape</td>
<td>Linear or nonlinear grid in round or square shape</td>
</tr>
<tr>
<td><strong>Position of test grid</strong></td>
<td>Test point area can be freely positioned somewhere within the field (offset from center)</td>
<td>Test point area can be freely positioned somewhere within the field (offset from center)</td>
</tr>
<tr>
<td><strong>Strategy</strong></td>
<td>NS, DS, 2-LT, LVS</td>
<td>NS, DS, 2-LT, LVS</td>
</tr>
<tr>
<td><strong>Stimulus size</strong></td>
<td>Goldmann I to V</td>
<td>Goldmann III and V</td>
</tr>
<tr>
<td><strong>Stimulus duration</strong></td>
<td>100 - 500 ms</td>
<td>100 - 500 ms</td>
</tr>
<tr>
<td><strong>Background</strong></td>
<td>4, 31.4 and 314 asb</td>
<td>4, 31.4 and 314 asb</td>
</tr>
<tr>
<td><strong>Stages / Phases</strong></td>
<td>Yes / Yes</td>
<td>Yes / Yes</td>
</tr>
</tbody>
</table>

### OCTOPUS Exam Programs
6 TESTING THE VISUAL FIELD – PRACTICAL DIRECTIONS

The visual field is an examination documenting visual function. In routine perimetry, computer supported static perimetry proved to be more practical compared to the manual Goldmann method. However, in special situations such as in neuro-ophthalmology and advanced glaucoma, kinetic perimetry is still the method of choice.

It may be beneficial to invest in a longer examination (test strategy) the more the therapeutic decision is based on the perimetric results. Because the complete perimetric examination is a rather elaborate procedure, it is extremely important to make sure that time is well spent. Therefore, it “pays” to take maximum care to obtain reliable results by strictly following certain rules to avoid the most common pitfalls. It is recommended that the examination be closely supervised and to inform the patient regularly about the progression, which will encourage him/her to answer the questions properly.

The OCTOPUS control system interrupts the examination when the patient is not fixating or is closing the eye. It also signals the technician that the patient lost fixation so the situation can be corrected before unreliable answers are validated.
6.1 Basic Considerations for Testing Visual Fields

There are several good reasons for performing visual field examinations. Usually, a field is requested based on other diagnostic findings. The table in Figure 6-1 reviews a general list of indications that may justify performing a first perimetric examination.

<table>
<thead>
<tr>
<th>Situation / Test method</th>
<th>TOP or Screening</th>
<th>Quantitative Retest</th>
<th>TOP, Dynamic Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syst. hypertension</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High myopia</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unexplained low VA</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neurological conditions</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cluster of rel. defects</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>&gt; 5 rel. defects</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>IOP &gt; 21 mm Hg</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Intraocular difference</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Abnormal disc</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Pallor edema asymmetry</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>History of glaucoma</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>History of oc. hypertension</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Transient vision losses</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Once visual field defects have been documented, it is advisable to re-examine the patient regularly every 3-12 months.

6.1.1 A quick (screening) test

A quick screening test is indicated, for example, when the patient comes in with complaints of headaches or when there is a history of systemic hypertension or diabetes. Also, patients with high myopia should not delay having a (short) perimetry test.

Which strategy is recommended for the first (screening) test? With the introduction of fast quantitative methods, such as the Tendency oriented perimetry (TOP), the traditional screening test is no longer a useful option because the qualitative strategy used for screening takes even
It may be beneficial to invest in a longer examination (test strategy) if the therapeutic decision is based on the perimetric results.

Accuracy and validity of the results, which finally contribute to the direct objective of the perimeter examination, which is to maintain sight and health, must not be neglected or forgotten.

The use of only a few select test procedures is recommended.

longer than the time required to obtain quantitative results with a fast threshold strategy (see Methods for Determining the Differential Light Sensitivity, Chapter 3).

6.1.2 A more extensive examination

In other situations, when a more extensive examination is indicated from the very beginning, it may be beneficial to invest in a longer examination (test strategy) if the therapeutic decision is based on the perimetric results. A shorter test can be used if the visual field is one of several other diagnostic examinations.

6.1.3 The patient’s condition may ask for a compromise

It is important to note that a perimetric test is a subjective examination and that the results depend partly on the ability of the patient to collaborate with the examination.

In this respect, comfort and speed have a positive influence on the quality of the patient’s answers and thus on the reliability of the visual field. Besides this, patients will be thankful and will be more prepared to return for a follow-up examination.

However, the accuracy and validity of the results, which contribute to the direct objective of the perimeter examination – which is to maintain sight and health – must not be neglected or forgotten.

6.2 Selecting the Examination Program

Although a large number of different examination programs with specific test location patterns are implemented in the perimeter, the use of only a few select test procedures is recommended. This makes interpretation easier and also, in following fields over time, a statistical software program can assess whether the fields are stable or are changing. Such an analysis is not possible when the results are obtained from different examination programs.

Basically, there are two criteria which need to be combined in selecting a test procedure (see Examination Programs, Chapter 5):

• Pattern of test point locations (examination program)
• Test strategy
6.2.1 Selecting the test locations

Details of the OCTOPUS diagnostic examination programs with their particular test location patterns are explained in Chapter 5. Therefore, the criteria dictating the test location pattern for a particular examination are not developed in detail here.

In the selection of a suitable test location pattern, the question is where a possible defect can be expected and how much detail (resolution) is required.

In most clinical situations and unless no other specific examination program is requested, e.g., as that used for a macula examination, the program G1 test locations are selected. This pattern is available in the programs G1, G2, and ST.

6.3 Selecting the Test Strategy

6.3.1 Supra-threshold (qualitative) screening tests

In situations where a fast quantitative strategy is not available, a qualitative screening test provides useful results when the patient does a first examination and in cases when a quick check of the visual field is requested. If the field shows a few relative defects, these particular locations can be retested with the normal threshold strategy to verify whether they are really depressed. If confirmed, an examination with a full threshold program should be anticipated, possibly at a later date.

Screening tests still serve a purpose when many test locations need to be tested such as in Program 07 with 130 test points in the 75° field.

An examination with the TOP strategy takes just over 2 minutes for all patients. As a result, patients make fewer mistakes. Also, the effect of ‘fatigue’ is drastically reduced.

6.3.2 Threshold examination with the TOP strategy

It takes only 2-3 minutes to obtain full threshold data with the Tendency oriented perimetry (TOP) strategy, depending on the number of points tested (see Section 3.5). For this reason, TOP can effectively replace the earlier qualitative screening tests.

A major advantage of TOP is that the test duration is so short that patients make fewer mistakes. Also, the effect of ‘fatigue’ (see Section 3.2.4) is drastically reduced.

There are situations in which the visual field is not tested even if it would be “nice to have,” often because the examination takes too long or the patient is not very cooperative. In those cases, it is a benefit to be able to
perform a TOP examination and obtain full threshold information in a relatively short time. The TOP test strategy may also be selected when there is doubt whether the patient can sustain a longer threshold test because of age or a bad general condition or when the field has major defects.

Typical for TOP is that sharp edges of scotomas are slightly rounded and also the depth of a defect is more shallow (although the volume of the scotoma remains the same).

The results of a TOP examination are processed and are presented the same way as with the Normal or Dynamic threshold tests, i.e., in Grey-scale, Cumulative defect curve, Trend analysis, etc.

6.3.3 Threshold examinations using the Dynamic test strategy

In cases where smaller focal defects are expected or with younger OHT patients, the use of the Dynamic test strategy can be recommended. This is a full threshold test with maximum accuracy for (near) normal d.l. sensitivity. On the other hand, results obtained with the Dynamic test are more of an estimate when there are deeper depressions (see Section 3.4).

The data can be displayed, printed and analyzed with a statistical software package.

6.3.4 Normal threshold examination

Occasionally, more time must be invested to obtain the most complete information foregoing the shortcomings of a faster strategy. In these cases, the Normal strategy is selected but the examination for one eye may take 10 to 15 minutes on average (see Section 3.2).

It must also be understood that, due to the longer test durations, more errors can occur and 'fatigue' effects can lower the measured values.

Note: It is important here to realize that with the stage concept, the procedure follows strict priorities (all the critical points are tested in the beginning of the examination) and that approximately 80% of the information is already available at halftime. This makes it possible in many cases for time to be optimized to increase the testing efficiency.

Note: The normal test strategy is also used as the standard strategy in normal value studies to obtain best possible (reference) data on
Because the complete perimetric examination is a rather elaborate procedure, it is extremely important to make sure that the time invested is well spent. Therefore, it “pays” to take maximum care to obtain reliable results by strictly following certain rules to avoid the most common pitfalls.

There are several sources that can create artifact field defects (see also Section 9.1.1). Logically, every external obstruction that blocks the stimuli from reaching the retina affects the fields but also certain mistakes in the set-up procedure influence the results.

Note: Generally, the Cumulative defect curve (shown in Figure 6-3) is a good indicator to understand non-pathological defects discussed in the following sections.

### 6.4 How to Avoid Artifacts and Improve Field Reliability

Because the complete perimetric examination is a rather elaborate procedure, it is extremely important to make sure that the time invested is well spent. Therefore, it “pays” to take maximum care to obtain reliable results by strictly following certain rules to avoid the most common pitfalls.

#### 6.4.1 Setting up the perimeter

It is important to enter the patient data (date of birth, refraction, etc.) and the examination data (test program, strategy, etc.) ahead of time. If the time schedules are known, this data can be entered into the perimeter before a patient comes in or maybe even the day before the examination.

- Switch the unit ON and make a calibration before the patient enters.
- Apply the trial lens(es) before seating the patient (see Section 6.4.7).

#### 6.4.2 Instructing the patient, explaining the procedure

It is easier to instruct the patient before he/she is seated in front of the perimeter. The following suggestions have proven helpful:

**Please do ....

- Make sure you sit in a comfortable position.
- Maintain that position. Do not move.
- Always look straight ahead at the fixation target.
- Blink regularly to avoid discomfort. Listen to the sounds of the machine to find the interval.
- Press the button when you think you see the stimulus (depending on
the strategy used, many stimuli cannot be seen at all).

- Do not press the button when you do not see a stimulus.

**If you feel uncomfortable.....**

- You may close your eye for a moment. The test will be interrupted and will only continue after you open your eye again.
- Should you feel rushed, or have a question, keep the button pressed and ask for assistance.

### 6.4.3 False entries

A typing error in the year of birth like 1972 instead of 1927 produces wrong results. The mistake here results in a uniform artifact depression of approximately +3 dB such as shown in Figure 6-3.

### 6.4.4 Setting up the patient

After the instructions, it is extremely important to seat the patient in a comfortable position, upright on a height-adjustable chair with a back rest.

Ask the patient to press the button a few times to see if it works and apply the eye occluder, making sure the patient can blink freely.

---

*Figure 6-2: Correct positions of the patient in an OCTOPUS 300 (left) and OCTOPUS 101 (right) examination.*
6.4.5 Positioning the patient and alignment of the chin rest
The patient’s forehead should touch the headrest and the chin rest needs to be adjusted to align the eye in the center of the trial lens.
It is important that the patient’s eye is close to the trial lens to avoid a typical “ring” scotoma that can appear when the patient is positioned too far away from the correction lens holder (see case in Figure 10-22, Section 10.9).

6.4.6 Facial structure of the patient
A prominent nose, a heavy brow or long eyelashes can cause artifacts leading to misinterpretation of the visual field. If such a problem exists, turning or tilting the patient's head – without losing fixation – is recommended.
The problem of ptosis can be corrected by using tape to lift the eyelid, taking precaution to leave enough freedom to blink.

The Cumulative defect curve is a good indicator to "uncover" non-pathological defects, such as a mistake in the date of birth, a dirty contact lens, a missing or incorrect trial lens, or a small pupil.

It is important to check the refraction prior to the examination.

6.4.7 Refraction and trial lenses
Checking the refraction prior to a perimetric test is recommended because if the patient does not have a sharp image of the stimulus, the d.l. sensitivity values will be reduced accordingly and show diffuse defects (compare the case in Figure 10-21, Section 10.9).
For the selection of the proper diopter value of the trial lens (it is important to use thin rim, wire frame type lenses), it must be taken into account that with the direct projection type perimeters such as the OCTOPUS 300...
the stimulus comes optically from an “infinite” distance and requires a trial lens for far correction (normally the value taken directly from an autorefractor).

With a cupola perimeter such as the OCTOPUS 101 the stimulus is at a near distance of 42.5 cm and therefore an additional near correction according to the patient’s age needs to be used:

<table>
<thead>
<tr>
<th>Age</th>
<th>Add</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-44</td>
<td>+1.0 D</td>
</tr>
<tr>
<td>45-49</td>
<td>+1.25 D</td>
</tr>
<tr>
<td>50-54</td>
<td>+1.75 D</td>
</tr>
<tr>
<td>55 - &gt;</td>
<td>+2.0 D</td>
</tr>
</tbody>
</table>

### 6.4.8 Cylinder lenses

A cylinder correction can be discarded when the prescription is 0.25 D or less. If the cylinder is 0.5 to 0.75 D, the spherical correction can be adjusted by 0.25 D to maintain the equivalent power. If the cylinder is 1.00 D or higher an extra lens needs to be placed in the lens holder positioned closest to the eye. Important: make sure the axis is set correctly!

If no “+” cylinder lenses are available, it is possible to make a conversion from a “-” cylinder into a “+” lens, as explained in the two examples in Figure 6-5.
6.4.9 Dirty contact lens
Moderate myopic patients who leave their contact lenses in, must inspect their lenses before the test. Here again, dirty contact lenses result in artifacts (a diffuse depression will show up in the Cumulative defect curve). Generally, it is advisable for a patient with very high corrections to use a contact lens (spectacle glasses are not recommended for visual field testing).

6.4.10 Pupil size
The amount of light entering the eye is controlled by the diameter of the pupil. As an example, a change from a 7 mm to a 5 mm pupil means that only about half the same amount of light can enter the eye.
As a rule, it is understood that with 3 mm or wider pupil diameters the results will be within the range of normality. Below this value a uniform depression of the visual field can be expected in the order of 1-3 dB and as much as 3-4 dB for a 1.5 mm pupil. It must be noted that the effect can be even larger with cataract patients.
Because of this, it is extremely important to note the pupil size on the printout in order to be in a position to interpret the field properly and to allow comparison with previous results (see also Section 9.1.2).

How to convert a “+” into a “-” cylinder.

<table>
<thead>
<tr>
<th>Refraction:</th>
<th>Trial lenses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sph = + 2.25 D</td>
<td>+ 3.75 D</td>
</tr>
<tr>
<td>Cyl = + 1.5 D</td>
<td>- 1.5 D</td>
</tr>
<tr>
<td>Axis = 30°</td>
<td>120°</td>
</tr>
</tbody>
</table>
Method: Sph + Cyl = 2.25 + 1.5 = 3.75 D, use Cyl - 1.5, add 90° to Axis

<table>
<thead>
<tr>
<th>Refraction:</th>
<th>Trial lenses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sph = - 2.25 D</td>
<td>- 0.75 D</td>
</tr>
<tr>
<td>Cyl = + 1.5 D</td>
<td>- 1.5 D</td>
</tr>
<tr>
<td>Axis = 30°</td>
<td>120°</td>
</tr>
</tbody>
</table>
Method: Sph + Cyl = - 2.25 + 1.5 = - 0.75 D, use Cyl - 1.5, add 90° to Axis

Figure 6-5: Example for converting a “+D” cylinder correction into a “-D” trial lens.
6.4.11 False positive catch trials

The number of false positive answers (positive response after no stimulus was presented) is expressed as a percentage of the total positive trials. In a situation where the patient shows 20% false positive answers, the other questions are probably also answered with the same rate of error. This shows best in the Cumulative defect curve with an elevated result when compared to the bandwidth of normality. Mostly, a few locations will be recorded with a supra-sensitive and unrealistic value. Care should be exercised with a rate of false responses higher than 10-15%. This problem may appear with persons who are eager to do well or patients who are too nervous (see case Figure 10-21, Section 10.9) – or have not been instructed properly!

6.4.12 False negative catch trials

False negative answers (negative response after presentation of the brightest possible stimulus in an area where the patient showed sensitivity in prior questions) are also expressed in number and in percentage of the total questions asked. Patients with a higher than 10-15% rate of false negative responses, may need closer surveillance because they are no longer concentrating or are not in good condition.

Note: In cases of strongly depressed fields, the rate of false negative responses may be higher and, due to an elevated fluctuation, may even reach a value of 50% or more, in spite of good cooperation by the patient.

6.4.13 Learning effect

In their first test, patients often hesitate to press the button when faint stimuli, near the threshold, are seen and in follow-up examinations the sensitivity values tend to be higher. Because of this learning effect, it is recommended that, in borderline situations, a second examination be performed.

6.4.14 ‘Fatigue’ effects

A similar effect, but in the other direction, can be observed in a lengthy threshold examination – which can take as long as 10 to 20 minutes. When a patient becomes tired, his/her attention level will decrease and the answers become less reliable.
To improve the reliability of the data, the following points need to be addressed and taken into consideration:

- Because the threshold is determined with a 50% probability of seeing the stimulus (Section 2.3), several stimuli close to the thresholds are hard to see and some cannot be seen at all. For this reason, patients find the perimetric test rather difficult and it is typical to hear the comment, “Wow, very difficult! I have certainly missed many questions.” For this reason, it is particularly important to inform patients in advance about this aspect of the perimetric test.

- Patients should be instructed to press the button when they believe they have seen the stimulus rather than after they are positive they have seen the light.

- Encourage the patient to blink normally in cue with the audible signal. This way, his/her eyes will not dry out and cause discomfort.

- Threshold testing is a demanding examination where, due to ‘fatigue,’ patients make more mistakes toward the end of the test (see Section 3.2.4). As a result, the d.l. sensitivities become more depressed with longer test duration. Therefore, it makes sense to make the procedure as short as possible in order to maintain the attention of the patient and improve the reliability of the data.

### 6.5 Supervising the Examination

The main issue here is how to keep the patient motivated to collaborate well during a (long) examination.

#### 6.5.1 Test duration and progress

The test duration remains a major concern for patients and technicians alike. Fortunately, today, by using a faster strategy, testing time can be reduced by half, to 6-8 minutes with the Dynamic strategy, or even more with TOP, a strategy that shortens the examination time to just over two minutes for full threshold data (see Methods for Determining the Differential Light Sensitivity, Chapter 3).

Even when the Normal strategy is used, the test can also significantly be reduced to 6 - 9 minutes in cases where the field appears either well within normal limits or shows severe loss. This can be accomplished by observing the Defect level indicator (see Section 3.3.1) showing the sta-
The progress of the test can be monitored and it is recommended that the technician keep the patient informed of the progression to encourage him/her to answer the questions properly. Because the OCTOPUS 300 does not need dark room installation, the perimetrist can attend to other tasks and still be around to supervise the examination. On the other hand, the OCTOPUS 101 must be in a dark room (like all cupola perimeters) to avoid unreliable results caused by stray light from the environment. For this reason, the measuring unit (cupola) is separate from the control unit, which can be installed nearby in a lighted room.

6.5.2 Eye fixation control

The reliability of a visual field depends largely on the quality of the eye fixation. For this reason, the OCTOPUS perimeters are equipped with an electronic eye fixation control system. It is important to realize that controlling fixation is much more than just monitoring the eye with a video image!

While the eye monitor shows whether or not the patient is fixating, mistakes are not correctable. The OCTOPUS control system interrupts the
examination and signals the technician to correct the situation when the patient is not fixating or is closing the eye. The system also senses when the patient blinks during a stimulus presentation and repeats the same question later during the test. Basically, the eye fixation control makes sure that only those stimuli are validated when the eye is well fixated and not blinking.

6.6 Useful Guidelines to Test Visual Fields

- The examiner should take note of whether the patient was a good and active collaborator or had difficulty in following the examination.
- Enter the patient data carefully and explain the examination procedure to the patient.
- Inform the patient that not all stimuli are visible and to press the button only if they believe they have seen the stimulus light.
- Explain the importance of making an effort to stay attentive.
- Tell the patient not to be concerned about making a mistake.
- Check the patient’s refraction and select the corresponding (thin rim) trial lens(es) for near vision correction with the cupola perimeter or with the direct projection perimeter for far vision correction.
- Note the correct position of the cylinder lens axis. Remember that the lens holder is positioned inversely to the position of lenses fitted in a trial frame.
- Make sure the patient’s eye that is to be tested is wide open to avoid artifact defects.
- Apply the eye occluder in such a way that the patient feels comfortable. Instruct the patient to blink normally.
- Position the patient with the eye close to the trial lens to avoid artifact (ring) scotomas.
- Make sure the patient can see the fixation mark sharply. It is recommended that the fixation mark be adjusted to the dimmest light and the patient still sees clearly.
- Select another fixation mark if the patient has no central vision (like the ring fixation mark available with the cupola perimeter).
- Confirm that the patient has no difficulty pressing the button.
- Stay nearby during the examination and inform the patient often about the progression to encourage him/her to answer the questions properly.
7 REPORTING VISUAL FIELD DATA

Before interpreting a visual field, the charts must be carefully "read" and this information must be combined with other findings. The results from a perimetric examination are the local d.l. sensitivities and from this set of “raw data” all other statistical calculations are made and presented in tables, images and in graphics. One of these graphs, the “Cumulative defect (Bebie) curve” is useful in clearly and quickly assessing the characteristics and depth of the defects.

The global and most important characteristics of a visual field can be expressed by a few numbers (called indices), for instance, the average of all local defects, or the local variability of defects. The index MD is independent of age and includes all local defects – also the smaller ones (< 5dB) hidden behind the “+” symbol. The “Loss variance” (LV) presents the variance (or square value of the standard deviation) of the local defects. Therefore, the LV index is sensitive to irregularity and is an early indicator for localized damage.

For follow-up fields, plotting MD and LV is a powerful combination for the detection of visual field changes. The pupil size is an extremely important value in order to be sure the conditions are valid for comparison with previous data or with the normal data.
7.1 Display and Printout Formats

Before interpreting a visual field, the charts must be carefully "read" and this information must be combined with other findings.

For this purpose, it is useful to begin with an explanation of the contents of the standard tables and charts in which the data can be presented by following the elements contained in the “Seven-in-One” (see Figure 7-1).

Bear in mind that the results from a perimetric examination are limited to the values of the local d.l. sensitivities. From this set of “raw data,” all other statistical calculations are made and presented, as shown in Figure 7-1, in tables, images and in graphics. To assess the visual field and interpret the results, most clinicians review the test results in the order presented in the following sections.

7.1.1 Patient data
(Table # 1 in Figure 7-1)

First, verify that the name of the patient is correctly entered, check the date of birth and verify the patient’s age also printed on the form. See if the complete refraction data corresponds to the latest test and if the IOP value is marked (optional).

Finally, at the foot of this column under “Patient file,” the directory is listed in which the examination data is stored on the PC.

7.1.2 Examination data
(Table # 2 in Figure 7-1)

This column shows the examined eye and the pupil size at the top. The pupil size is an extremely important value in order to be sure the conditions are valid for comparison with previous data or with the normal data (see Sections 6.4.10 and 9.1.2). Other information listed is examination date, time, test duration and the actual test parameters such as, selected perimetry method, examination program and strategy.

The total number of questions and repetitions also appear here. Repetitions occur because the patient has blinked or lost fixation at the same time a stimulus was presented. If there are an elevated number of repetitions, it can be concluded that the patient was a little nervous. However, this does not influence the quality of the data because the final results are derived from the other questions asked (see case 10-23).

Continue on page # 96
The Seven-in-One report presents all elements needed to assess the visual field of a single examination. The Seven-in-One report presents all elements needed to assess the visual field of a single examination. The details of the different components on the chart are discussed in the order most clinicians follow when assessing visual fields (see numbering in Figure 7-1):

1. Patient data – information about the patient
2. Examination data – details about the examination
3. Value table – this table shows the measured values. All further statistical and graphical details are derived from this set of raw data
4. Comparison table – representing the local difference between the measured values and the normal values valid for the patient’s age
5. Greyscale graphics (in color or in b/w) – an easy overview
6. Cumulative defect (Bebie) curve – a statistical representation of the visual field defects in comparison with the normal population
7. Corrected comparison table – shows the “retinal” defects discounting any uniform depression caused by a cataract or other diffuse loss, e.g., non-pathological artifacts
8. Probability plots – statistical evaluation of the probability or significance of a defect
9. Visual field indices – condenses the visual field results in a few numbers

The printout presents the visual field of a 68-year-old glaucoma patient. The examination was done in two phases to yield a short term fluctuation (SF) of 2.7 dB. The pupil size was 4.7 mm, the test duration 13:07 minutes and there were 402 questions with 12 repetitions, showing that the patient made a few blinks. The reliability (RF = 9.8) is O.K. Careful inspection of this visual field reveals an early inferior nasal step and an arcuate scotoma. Note the three abnormal points just below the horizontal at the nasal edge. They are best highlighted on the Comparison plot which compares this 68-year-old patient’s responses to age-corrected normal values and then displays the difference. A defect is identified when there are clusters (2 or more of abnormal points) in a characteristic pattern which varies with the specific pathology.
The VA-greyscale graphics provide a first assessment of the visual field at one quick glance. The lighter the shades or colors, the higher or better is the d.l. sensitivity. The darker areas indicate depressions. Black depicts an absolute defect.

To assist in reaching a decision whether the field is reliable, the effect of the missed catch trials is combined in the „Reliability factor“ (RF) which is shown at the very end of the form below „Indices“.

The last line in table #2 reports the number of missed / presented catch trials (see Sections 6.4.11, 6.4.12 and 7.2.7). This is an important indicator for the reliability of the results of the actual examination. The percentage of missed catch trials of both categories defines the “Reliability factor” (RF) given in Table #9 together with the Visual field indices.

On average, the percentage of wrong answers should not be higher than about 15% (Reliability factor = 15). If the patient has difficulty performing the test and the value is higher than 20%, the technician should add notes about these exceptions.

7.1.3 Value (VA) table
(Table # 3 in Figure 7-1)
All information about the patient’s visual field is contained in the actual measured values of local sensitivities in decibels (dB) as shown in the Value table (VA). The other graphs, plots and images are derived from this data by calculations based on normal data and statistical methods. It is important to remember that a person’s normal d.l. sensitivity value decreases with age. Therefore, experience is needed to use the VA-table to assess the patient’s visual field.

7.1.4 Comparison (CO) table
(Table # 4 in Figure 7-1)
A much easier to interpret numerical value is presented by the difference (comparison) between the age-corrected normal data and the actual measured results. These numbers are defects if they are significantly higher than the variation (see Interpretation of Visual Field Data - Basic Considerations, Chapter 8).

It is always somewhat confusing to comprehend a large number of figures. For this reason, the CO-table is designed to use just a simple “+” symbol for normality to avoid “overloading” the graph.

7.1.5 Greyscale
(Graph # 5 in Figure 7-1)
For a quick overview, OCTOPUS created the greyscale graphics, which provide a first assessment of the visual field at one quick glance. The darker areas indicate depressions. Black depicts an absolute defect.
OCTOPUS offers two greyscale options:

Although greyscales are very popular, they cannot serve for quantifying and following visual field results.

a) The “standard” greyscale (GS) shown at left in Figure 7-2 is based on the actual measured (VA) values. This means that in the periphery, where normal d.l. sensitivity values become lower, the shading becomes darker although those values can be perfectly normal at these eccentricities and therefore should not be misjudged.

b) The second option is the greyscale of the CO values (CS) of the same field shown at right in Figure 7-2. This graph represents the deviations from the age-corrected normal value in a range of 100% for normal sensitivity, to 0% for absolute defect. This means that a normal field will be perfectly white and thus, the shaded areas depict the defect pattern(s) more clearly.

7.1.6 Cumulative defect curve (CD)

(Graph # 6 in Figure 7-1)

The CD-curve (also “Bebie curve”) shows all defects sorted in the order of increasing depth (from left to right in Figure 7-3). This presentation is useful in clearly and quickly assessing the characteristics and the depth of the defects.5

In Figure 7-4, the sorted curves are shown of two fields compared to the “zone” of normality (bandwidth of about ± 2 dB) representing the 90%
The "Cumulative defect (Bebie) curve" is useful in clearly and quickly assessing the characteristics and the depth of the defects.

In cases where a uniform depression is caused by a cataract, the Cumulative defect curve estimates the "depth" of such depression.

The examples in Figure 7-4 refer to program G1 with all four stages measured. The number "59" represents the total number of locations tested. For an examination with Program 32, the number would be “74.”

The curve on the left in Figure 7-4, which runs parallel to the "normal" zone, indicates that the field has a uniform diffuse depression. Such a result can be caused by a cataract or an artifact (see Section 6.4) but it can also be an indication of early glaucomatous damage.

Figure 7-4: Two examples of the CD-curve showing an examination with 59 test points.
The case at right in Figure 7-4, indicates that most of the field is perfectly normal but, to the right of the bend, there are a few locations with deep focal defects.

7.1.7 Deviation
(Numerical value in graph # 6 in Figure 7-1)
An estimate of the depth of the diffuse loss is derived from the CD-curve and is given numerically in a dB value as “Deviation.” This may be an estimate of diffuse loss due to a cataract. However, it may also be due to true (pathological) diffuse visual field loss.

7.1.8 Corrected comparison table
(Table # 7 in Figure 7-1)
The “Corrected comparison” table can be explained as the result of the values in the CO-table minus the “Deviation” (in Figure 7-1, the Deviation is 4.2 dB).
The Corrected CO-table depicts local defects relative to the mean diffuse depression (while the CO-table displays the local defects with respect to the age-corrected normal values) to show a much clearer picture of the true defects in d.l. sensitivity “behind” a possible cataract.

7.1.9 Probability plot
(Table # 8 in Figure 7-1)
The “Probability” plot is calculated from the comparison values in the CO-table (7.1.4) and is graphically displayed. Here, the statistical significance of the local defects is indicated as a symbol in different shades. The darker the symbol, the more significant the defect or the more likely it is that there is a real defect at this location.
The most significant values are tagged with $P < 0.5\%$ which means that less than 0.5% of the subjects (within a normal population) may show such a defect of this depth at these test locations. However, with 60 test locations the probability to find one such defect value in a perfectly normal visual field is about 30%. Care should be observed in drawing direct conclusions from isolated marks of significance.
The lowest significance has the symbol $P > 5\%$ which indicates that 5% or more of the population may have the same value – which is still considered normal at these points.
7.1.10 Corrected probability plot
(Table #8 in Figure 7-1)
The “Corrected probability” graph shows the significance of the corrected comparison values explained in the same way as for the Probability plot. This graphical presentation makes the localized defects, such as the typical nerve fiber bundle defect in this example, more visible.

7.2 Visual field indices
(Table #9 in Figure 7-1)
All perimetric examination programs primarily determine local d.l. sensitivity (or local defects). This kind of information is important for the detection and the localization of deviations from a normal visual field. The global and most important characteristics of a visual field can be expressed by a few numbers (called indices), which are the average of all local defects, or the local variability of defects. Based on the work of Flammer, the first visual field indices were introduced in the OCTOPUS perimeters in 1985.

![Table of visual field indices](image)

*Figure 7-5: Table of visual field indices.*

By reducing a large amount of data into a few key numbers, the visual field indices are of great help in the assessment of visual fields and for keeping a record of them over time. Compare the convenience of using the Dow Jones Index to follow the quotation of shares at the stock exchange.

The visual field indices are more precise because the inaccuracy and scattering of the local results are reduced by averaging the results over all the test locations (for details see Interpretaion of Visual Field Data - Basic Considerations, Chapter 8).
7.2.1 Definition of the visual field indices
The following explanation of the mathematical definition of the visual field indices is offered for the interested reader – although making use of an index does not require understanding all the details. However, it is useful to keep in mind:

- Visual field indices characterize the visual field as a whole, without reference to the location of the defects.
- Visual field indices are more precise because the results are averaged over the test locations. Fluctuations are reduced by the square root of the number of the test locations – typically, a factor of 8.
- Visual field indices can easily be handled and plotted in order to visualize the main characteristics of a visual field as a function of time.
- For each visual field index, there is a known normal range; deviations indicate possible pathological features of the visual field under consideration.

7.2.2 Mean sensitivity – MS
(Table #9 in Figure 7-1)
The first index is the average of all measured values of d.l. sensitivity in dB - called the “Mean sensitivity” (MS).

\[ MS = \frac{1}{N} \sum_{k=1}^{N} x_k \]

The measured local sensitivities \(x_k\) provide the basic information for all displays and evaluations (\(x_1 \ldots x_{59}\) in program G1, G1X or G2, for example). The comparison with the local normal value \(n_k\) (corrected for the patient’s age) is provided by the so-called local defect value \(d_k\) defined by the difference \(d_k = n_k - x_k\). \(n_k\) is taken from the current normal data base (see Section 5.2).

Like the local normal values, the normal MS depends on the patient’s age, and therefore, a unique normal range of MS does not exist.
7.2.3 Mean defect – MD

(Table #9 in Figure 7-1)

A comparison of the MS with normal data is very helpful. This information is provided by the “Mean defect” (MD) index, which is simply the average of all local defects as shown in the comparison plot.

\[ MD = \frac{1}{N} \sum_{k=1}^{N} d_k \]

Note that all local defects are taken into account, including the small ones hidden behind the plus-symbol. MD is independent of age. By definition of the local normal values, the average normal MD is zero. About 90% of normal visual fields have an MD in the range of −2 … +2. Statistically speaking, an MD value of 2.3, for example, indicates that the case is borderline and needs reexamination. MD is the most important index related to global damage. A trend in visual field change can be analyzed best by following MD changes (see Sections 7.4 and 8.5).

7.2.4 Loss variance – LV

(Table #9 in Figure 7-1)

In mathematical terms, the “Loss variance” (LV) is nothing but the variance (or square value of the standard deviation) of the local defects (CO). Therefore, the LV index is sensitive to irregularity and is an early indicator for localized damage.

\[ LV = \frac{1}{N-1} \sum_{k=1}^{N} (n_k - x_k - MD)^2 \]

For example, an elevated LV (a value over 6 dB²) in combination with a normal MD (between −2 and +2 dB) tells us that the field has one or more localized defects probably exceeding the normal variability of local defects. Moderate defects at a few test locations may considerably increase LV without driving MD out of its normal range. For follow-up fields, plotting MD and LV is a powerful combination for the detection of visual field changes (see Sections 7.4 and 8.5).

Because the LV value in dB² increases drastically with the progression of the disease, the square root of LV (sLV) is a more practical index and used instead of LV in following fields over time.
7.2.5 Short term fluctuation – SF
(Table # 9 in Figure 7-1)
For an even more accurate diagnosis, in borderline situations, the patient is tested twice in one session to obtain the “Short term fluctuation” (SF) index.

At a given test location, the results of repeated threshold determinations (taken within the same session) represent a distribution with a standard deviation s. SF is an estimate of s (averaged over all test locations of the visual field under consideration).

Although SF can be used as a separate indicator for pathology (SF varies from 1.5 dB for normal to 2.5 dB and higher for patients with disturbed visual fields), the SF value is used to judge the reliability of local results as well as to determine the index CLV (see below).

7.2.6 Corrected loss variance – CLV
(Table # 9 in Figure 7-1)
When the SF is elevated, the value for LV (see 7.2.4) will be affected accordingly. With the “Corrected loss variance” (CLV) an index is created for localized loss independent of SF.

Basically, the CLV index corrects for the variance by subtracting the square of SF from LV which results in an even more sensitive value than LV for the detection of early local defects. For 90% of the normal population, CLV is below 2.5 dB².

7.2.7 Reliability factor – RF
(Table # 9 in Figure 7-1)
The “Reliability factor” (RF) indicates the patient’s cooperation. This value is calculated from the positive and negative catch trial questions – the sum of the false positive answers and false negative answers, divided by the total number of catch trial questions. The RF value should normally not be higher than 15%. A "grade" of 0 is excellent.

7.3 Printout Reports
There are several formats for printing data. Most often used is the “Seven-in-One” format available for the central field area or an overview for the whole field. Further options include large Greyscales and Numerical tables.
7.3.1 Seven-in-One report
(The Seven-in-One report was discussed in detail in Figure 7-1)

7.3.2 Combination report
A central or full field combination printout contains the essential information in numbers and in a fixed graphical format.
- Value and Comparison table
- Greyscale of values
- Cumulative defect (Bebie) curve
- Visual field indices

7.3.3 Large graphics
The large graphics, whether a greyscale or a value table, are useful in presentations and discussions with patients. The printing is initiated directly from the display by clicking on the printer icon.

With the OCTOPUS 300, the Combination Report allows for a free selection of four images and positioning them in any order on the form.

<table>
<thead>
<tr>
<th>Printout formats</th>
<th>OCTOPUS 101</th>
<th>OCTOPUS 300 (direct printout)</th>
<th>OCTOPUS 300 (PeriTrend)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seven-in-One</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Combination of 4 tables</td>
<td>+</td>
<td>+ (free selection)</td>
<td>+</td>
</tr>
<tr>
<td>Two-on-One</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Series of six examinations</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Trend analysis MD, sLV</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Delta report Series / Change</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Large VA table</td>
<td>+</td>
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<tr>
<td>Large CO table</td>
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</tr>
<tr>
<td>VA Greyscale</td>
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<tr>
<td>CO Greyscale</td>
<td>+</td>
<td>+</td>
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<tr>
<td>CO Greyscale with CO values</td>
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<td>+</td>
<td>-</td>
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<tr>
<td>Bebie (Defect) curve</td>
<td>+</td>
<td>-</td>
<td>+</td>
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<tr>
<td>Global indices</td>
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<td>-</td>
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<tr>
<td>Isopters (GKP option)</td>
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</tbody>
</table>

*Figure 7-6: Overview of the various OCTOPUS printout formats.*
The OCTOPUS 300 can be programmed in any local language as long as there is a Microsoft Windows version in that language.

7.3.4 Two-on-One report

The “Two-on-One” report on the OCTOPUS 300 prints two examinations of the same patient on one page for ease of comparison (see Figure 7-7). The option is available to show the results for the left and right eye (OS and OD) or to select and print two fields of the same eye.

The software of the OCTOPUS 300 can be programmed in any local language – as long as there is a Microsoft Windows version in that language. The sample here shows a report in Greek.

Figure 7-7: Sample of a “Two-on-One” printout in Greek language (available on the OCTOPUS 300).
7.4 PeriTrend PC Software

The PeriTrend software, installed with a Microsoft Windows environment, provides the means to import / store / manage / display and print examination data from all OCTOPUS perimeter models. It combines the results in one station and when this station is part of a network, the visual fields can be displayed on several other monitors in different locations.

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Figure 7-8: Single field display and printout formats with PeriTrend.
Greyscale of values with general test data (top).
Greyscale of comparison with Cumulative defect curve and visual field indices.
Figure 7-9: Multiple field displays and printout formats with PeriTrend. 
(Top left) Fields can be reviewed in “Sequence” one-by-one by “turning pages.” (Top right) Different images of fields in “Series,” here a series of CO greyscales. (Middle left) Analysis of field progression in “Trend.” (Bottom right) Comparison of two groups of fields in “Delta” mode.
8 INTERPRETING VISUAL FIELD DATA - BASIC CONSIDERATIONS

We have to ask ourselves a number of questions when interpreting the results of visual field examinations.

• Is the visual field normal?
• Did the visual field change significantly between two examinations?
• Is there a global trend in a series of fields?
• Are there significant local changes in a series of examinations?

The interpretation of visual fields is a demanding task. The main difficulties stem from the variability of visual field results and from the overlap of normal and pathological visual fields.

Except for dramatic visual field changes from one examination to the next, there is only a small possibility of detecting a moderate trend with a low number of examinations. Reliable examinations are a prerequisite for early detection of significant trends.

In the subsequent Section, the variability of the test results is addressed. The criteria to analyze a significant deviation from the normal value or the minimum deviation needed to have a significant trend in a series of visual fields are also reviewed.
8.1 The Variability of Visual Fields

It is well known that the patient’s thresholds fluctuate at a given test location. They will not exactly reproduce in repeated examinations, be it in minutes or days or months (see Figure 8-1).

There are two independent reasons for threshold fluctuations:

- The patient’s answer to the same stimulus at the same test location may be seen or not seen.
- There are (reversible) physiological fluctuations with time, over days, weeks or months.

For this reason, it is often difficult to decide whether a visual field has undergone a ‘true’ change over time.

8.2 Thresholds and their fluctuations

The individual local threshold is the luminance perceived with a probability of 50%. Expressed in decibels, it is called the local d.l. sensitivity. As explained in chapter 2 (*The Visual Field - Basic Notions*), the threshold is not a sharp borderline between seen and unseen stimuli; rather, the probability of seeing a stimulus increases gradually with increasing target luminance. This is expressed by the Frequency-of-seeing curve (FOSC, explained in Figure 8-2), describing the probability of the patient’s reaction to stimuli with various luminances.
This curve can be established from the answers of a subject when a great number of stimuli of different luminances are presented repeatedly at the same test location. The threshold – in a strict sense – is defined as the luminance which is perceived with a probability of 50%. However, in a real test, with only a few stimuli spent per test location, the threshold can only be estimated and a repeat examination will typically not reproduce the same result.

On the left, the graph shows a relatively steep FOSC from a normal subject. Increasing the probability of perceiving the stimulus from 16% to 84% requires a stimulus luminance increase of approximately 4 dB. In areas of depressed sensitivity, the curve (on the right) becomes wider and the corresponding range is considerably larger – up to 10 dB in heavily disturbed visual fields. In view of these facts, one can expect that threshold results in disturbed visual field areas are less stable, or, in other words, fluctuations (on the level of measured sensitivities) are more pronounced there.

8.2.1 Short term fluctuation – SF

As mentioned in Chapter 7 (Reporting Visual Field Data), the patient’s short-term fluctuation (SF) stands for the variability of the local results.
observed when the same threshold is determined repeatedly within the same session (or within about an hour). SF is the standard deviation of the distribution of results obtained at the same test location within the same session (actually, SF is the mean of the local standard deviations). Obviously, SF depends on both the width of the FOSC (see previous section) and on the threshold determination method. A more elaborate method will yield more stable results. With the Normal examination strategy and in normal visual fields, SF is about 1.5 dB. In disturbed visual fields, it may be considerably larger – 2.5 dB or even more.

8.2.2 Long term fluctuation – LF

The d.l. sensitivity by itself (even when determined precisely by means of the 50% “seen” probability) is not a constant value: there are (reversible) physiological fluctuations with time, over days, weeks or months – to some extent even in normal visual fields, but especially in disturbed visual fields. This phenomenon gives rise to an increase of the local fluctuations, not so much in normal visual fields, but rather in pathological fields. In fact, reversible fluctuations of glaucomatous fields are quite common.

With time, reversible physiological fluctuations increase the local fluctuations – and more so in pathological fields.

Figure 8-3: Reversible fluctuations of glaucomatous fields are quite common.

8.3 Comparison with Normal Sensitivity

The measured local sensitivity values constitute the raw data obtained from the examination. Without local normal values, corrected for the patient’s age, it would be very difficult to determine the extent and depth of depressions.

The OCTOPUS age-corrected normal values – built into the software of each instrument – were determined from a large sample of several hundred normal eyes of all age groups between 20 and 70 years (see Exam-
...nation Programs, Chapter 5). The local normal value (at a given test location and for a given age) is the mean of the results observed in this study.

Unless there are obvious gross defects, decisions as to whether a visual field is normal or not may be difficult for two reasons: the measurements are subject to fluctuations (see previous sections), and in addition, there is overlap of normal and pathological visual fields. As mentioned above, the indices are not influenced much by the local inaccuracies of the measurement process. Typically, normal visual fields have a very stable MD: when determined many times in repeat exams, MD fluctuates with a standard deviation of about 0.3 dB with traditional examination strategies (Normal and Dynamic strategy), and slightly more with the TOP strategy. In glaucomatous visual fields, MD may fluctuate with standard deviations of 1.2 dB or even more.

8.3.1 Local deviations from normal sensitivity

The deviations from the normal values, termed the local defect values, are listed in the table of Comparisons (7.1.4). So to not overload the picture, local ‘defect’ values up to 4 dB are replaced by a “+” sign. Usually, such ‘defect’ values are not significantly indicative of local scotomas (Figure 8-4).

Local results are much less stable than the indices – the significance of local deviations from normal is readily overestimated. This statement can

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**Figure 8-4:** Probably a normal field (left) and a clearly pathological field (right).
be illustrated by the following estimation based on a value of SF = 1.5 dB, typical for normal visual fields. Assuming normally distributed results of repeat exams at each test location, local errors exceeding 2·SF = 3 dB will show up in about 5% of the test locations (3 test locations in program G1 with a total of 59 test locations, for example). If the mean sensitivity is at the lower end of the normal range (MD = 2 dB), some local defects exceeding 4 dB (and as high as 5 or 6 dB in single test locations) will readily be observed, even though the visual field is normal.

Each row below shows the four largest defects in an examination of 59 test locations, assuming a visual field with SF = 1.8 dB and MD = 1.5 dB. (5 independent simulations).

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Figure 8-5: Local nonsignificant defects can be present.

8.4 Assessment of Visual Field Change with Time

Again, the assessment of visual field change with time is a demanding task. In the beginning, the issue may be to compare two fields and later, a possible change from a series of fields – possibly taken at intervals of several months – has to be analyzed.

8.4.1 Comparing two fields: local changes

From our discussion of fluctuations in previous sections, it does not come as a surprise that it is very difficult to assess significant local changes from one examination to the next. In fact, single local changes are often overestimated. Note that the standard deviation of the local differences between two fields (SF times the square root of 2) easily leads to a maximum apparent local change of the order of 8 dB in typical situations (see highlighted row in Figure 8-5), even for almost normal visual fields. Obviously, the situation is different when these changes are grouped in a cluster of adjacent test locations.
8.4.2 Significant Trend: Minimum Change per Interval

Given a time series of MD values from visual field examinations of the same eye, the regression line can be calculated. Both software programs presented at the end of this chapter can accomplish this task, and furthermore, they test for a significant trend. The situation is depicted in Figure 8-6.

The t-test of the regression coefficient evaluates whether the regression coefficient (slope of the regression line) deviates significantly from zero. Here, this mathematical background is used in order to discuss the minimum change of MD per interval required for the trend to be significant. The result shows a dramatic dependence on the number of examinations (or, dependence on time elapsed since the first examination, for given time interval between consecutive examinations).

Let N denote the number of examinations, assumed to be made at fairly regular time intervals Δt between consecutive examinations. Let σ stand for the mean deviation (rms) of the MD values from the (ideal) regression line. For glaucomatous visual fields, σ is about 1 dB, or slightly more. The table in Figure 8-7 describes the minimum change ΔMD_{min} along the regression line from the first to the last examination in order for the trend to be statistically significant on a level of 10% (two-tailed). The next column gives the minimum change per interval, ΔMD_{min} / (N-1).
For the trend to be significant, the required change of MD from one examination to the next decreases dramatically with an increasing number of examinations (see last column). On the other hand, there is only a small chance of detecting a moderate trend with a low number of examinations. A mean change of 1 dB per interval, for example, requires 5 exams to be made – a requirement which is probably systematically underestimated in practice.

The numerical values for $\Delta MD_{\text{min}}$ given above rely on the assumption $\sigma = 1$ dB, which, admittedly, is a typical value for stable glaucomatous fields. Since $\Delta MD_{\text{min}}$ is proportional to $\sigma$, it is desirable to keep $\sigma$ as small as possible. In view of the fact that unreliable examinations will increase the fluctuations $\sigma$ around the regression line, reliable examinations are a prerequisite for early detection of significant trends. However, $\sigma$ cannot be driven below the long term fluctuation of the mean sensitivity, whose origin is physiological in nature, and which is of the order of 0.5 dB for normal visual fields and about 1.2 dB for stable glaucomatous visual fields.

The numerical values for $\Delta MD_{\text{min}}$ given in Figure 8-7 are derived from the formula:

$$\Delta MD_{\text{min}} = t_{N-2} \times \sqrt{12} \times \frac{\sqrt{N-1}}{\sqrt{N(N+1)}} \times \sigma$$
8.5 Global visual field indices

Evidently, the point-to-point comparison of fields is a tedious process. Fortunately, the global indices are at our disposal and are of help in evaluating change (see Reporting Visual Field Data, Chapter 7). Remember, the indices are derived from an average over all test locations. Thus, local fluctuations are damped, the indices are more stable, and represent a more reliable basis for assessing visual field change with time.

The global indices used routinely are:

- MD : mean defect
- LV: loss variance (or sLV, the square root of LV)

Remember that MD and MS (mean sensitivity) carry the same information; however, MD does not depend on the patient’s age and is therefore more practical to use. Although not always available, SF provides interesting additional information.

In normal visual fields, typical fluctuations of MD have a standard deviation of about 0.5 dB. This means that a change of MD exceeding 1.4 dB (= 2 · 0.5 · 2) in either direction occurs in 5% of compared pairs of examinations.

The table in Figure 8-8 describes the typical index changes found in a population of stable glaucomatous visual fields (selection criterion: no

<table>
<thead>
<tr>
<th>Change of MD in stable glaucomatous visual fields (in dB):</th>
<th>percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>interval: up to 1 year</td>
<td>-2</td>
</tr>
<tr>
<td>interval: 2...3 years</td>
<td>-2.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Change of sLV in stable glaucoma visual fields (in dB):</th>
</tr>
</thead>
<tbody>
<tr>
<td>percentile</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>interval: up to 3 years</td>
</tr>
</tbody>
</table>

Figure 8-8: Distribution of index changes found in a population of stable glaucomatous visual fields.
significant visual field change over a period of three years). The upper half of the table refers to MD and the lower half to sLV. Out of a series of about 8 exams per patient (taken at intervals of 6 months), all pairs of exams with arbitrary time interval from 6 months up to three years were compared intra-individually. The examinations were made with the Normal strategy. From the MD table it can be concluded, for example, that 20% of the pair comparisons with a time interval of up to one year show a (reversible) MD change exceeding 1.5 dB in either direction. In other words, an MD change observed in a glaucomatous visual field of about 1.5 dB may be indicative of a true change, but the statistical significance is low (p < 0.2).

8.6 Follow-up Assessment of Trends

There are very simple ways to follow fields without the need of math or computer. For example, the single printouts can be spread over a table and ‘eyeball’ the results to assess a possible trend, similar to comparing Goldmann fields. This is, however, neither a very practical, nor an accurate method.

This simple “Follow-up Form” allows following visual field changes without computer techniques.

Figure 8-9: OCTOPUS Follow-up Form allows following visual field changes without computer techniques.
8.6.1 OCTOPUS Follow-up form
A convenient way to follow visual fields without using a PC is to mark the index values for MD and sLV manually on a conveniently prepared Follow-up form such as shown in Figure 8-9. After a number of examinations, the curves, thus obtained, do readily establish the picture of the progression (or stability) of the visual field results.
An additional advantage of using such a chart is that both eyes can be followed on one document.

8.6.2 Glaucoma staging system
The Glaucoma Staging System designed by Brusini presents a more advanced format to manually plot the visual field indices mean defect (MD) and the variance (LV or CLV) on a coordinate diagram. At the same time, the fields are classified in diagnostic stages related to the progression of the disease. The diagram (see Figure 8-10) also depicts generalized, localized and mixed defects.

**The Glaucoma Staging System**
- A manual plot of the visual field indices on a coordinate diagram. At the same time, the fields are classified in diagnostic stages related to the progress of the disease.

**Figure 8-10: Glaucoma Staging Diagram by Brusini**

8.7 PeriTrend Statistical Software
PeriTrend is a user-friendly software package to store, display, print and analyze the visual field results on a PC. The data can be imported from all OCTOPUS perimeter models.
8.7.1 Series display and print

With the “Series” program, a selected number of examinations are presented much in the same way as by arranging single printouts on the table. For the printout in Figure 8-11, three examinations were selected for comparison.

The “Series” printout presents a selection of visual fields in the same way as by arranging the charts on the table.

Figure 8-11: PeriTrend “Series” report.
8.7.2 Trend display and print

Another option is to use the “Trend” function. This program calculates the regression curves of MD and sLV for either display or print (see Figure 8-12). To signal significant field changes, the curves are color-coded in red for when the fields become more depressed and green for an improvement of the fields. The lines are blue when the trend is not significant or the fields are stable.

![Figure 8-12: Trend analysis of up to six selected examinations.](image)

8.8 PeriData Statistical Software

PeriData is a statistical software package, designed by Weber (PeriData GmbH), with numerous functions and printout formats for studying and analyzing visual fields in applications which go beyond the routine. It also provides the means for importing data from other makes of perimeters such as the Humphrey Field Analyzer or the Frisén Ring Perimeter. Consult the product brochure for complete and more detailed information than can be provided here.

8.8.1 PeriData trend analysis

The most important application of the PeriData software is the analysis of change – the Trend Analysis.
This module calculates a separate regression line for every measured location of a selection of examinations. The minimum is three fields and the maximum is 30 fields. It provides a point-to-point (local) comparison as well as a global (visual field indices) comparison of change.

8.8.2 PeriData GATT graphics

The results of the regression analysis lead into a greyscale representation of change called GATT analysis \(^{36}\) for “Global Analysis of Topographical Trends.” The graphics show different patterns with horizontal stripes for negative trends, vertical lines indicating areas of improvements and checkerboard patterns for areas without significant change.

*The horizontal patterns indicate a negative trend and any vertical stripes represent the areas of improvements.*

*Figure 8-13: Graphics of the PeriData “Global Analysis of Topographical Trends” (GATT)\(^{36}\)*
9 ANALYZING VISUAL FIELDS

For the evaluation of visual fields, observance of the following steps is recommended:

• Evaluate the reliability of the results and estimate if there are any effects not related to the disease under consideration.
• Decide if the field is normal or pathological
• Compare the results with prior examination(s)

In the previous chapters 6, 7 and 8, the more “technical” principles influencing the quality of the visual fields and the statistical rules that need to be considered in the determination of pathological loss of sensitivity were presented.

In this Chapter the clinical aspects of assessing visual field defects are reviewed.
9.1 Analyzing Visual Fields

The first steps to take in analyzing a visual field printout are the recognition of characteristic defects on the basis of their size, shape and location. Unfortunately, to find a correlation between a certain eye disease with a particular pattern of visual field defects is in many cases not a straightforward and easy process. There are certain field defects where the corresponding lesion can be observed directly on the fundus image (diabetic retinopathy is a good example). With other diseases, such as with glaucoma, this may prove more difficult. On the other hand, most neurological cases, where the damage is hidden “behind” the eye, show typical visual field defects enabling identification and localization of the lesion in the visual pathway from the optic disc to the visual cortex.

Finally, it must be taken into consideration that disturbances in front of the retina can affect the transmission of the light stimulus – and bring about “pseudo” defects in the visual field.

9.1.1 Avoiding artifacts

Ideally, the effects of any potential obstruction in front of the eye need to be ruled out first.

• Observe the physiognomy (facial structure) of the patient. A prominent nose, a heavy brow or long eyelashes can cause artifacts leading to misinterpretation of the visual field. If such a problem exists, it is recommended to turn or tilt the patient’s head to the side out of the central field.

• A droopy lid (ptosis) is another possible cause for interference. This problem can be corrected by using tape to lift the eyelid (being careful to leave enough freedom to blink).

• As explained in Chapter 6, it is important to use the correct (narrow rim) correction lense(s) and that the patient is positioned correctly and aligned in front of the trial lens holder in order to avoid artifact defects that can be misleading in the interpretation of a visual field. For a patient with very high corrections, it is suggested to use a contact lens (spectacle glasses are not recommended for visual field testing).
9.1.2 Accounting for pre-retinal defects

- The optical clarity of the cornea, crystalline lens, and vitreous are important in the evaluation of visual fields. Opacities such as cataracts and hemorrhages will cause absorption and diffuse scattering of light across the retina. Therefore, these “pre-retinal” structures can be responsible for a diffuse or localized depression of the visual field. A thorough slit lamp examination, through a dilated pupil, will alert the practitioner to the existence of any media opacities which may interfere with the visual field.

- In addition, a small pupil diameter reduces the threshold values in various ways and therefore, patients with less than 3 mm pupils, as measured in a dim room illumination, should be dilated before the perimetry examination. Even so, by comparing a series of fields, it is important that the pupil size is nearly the same for all examinations. For comparing fields performed with different pupil sizes, this table converts the value of the mean defect (MD) for a smaller or larger pupil.

<table>
<thead>
<tr>
<th>Pupil Diameter</th>
<th>MD 1 mm</th>
<th>MD 2 mm</th>
<th>MD 3 mm</th>
<th>MD 4 mm</th>
<th>MD 5 mm</th>
<th>MD 6 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mm</td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 mm</td>
<td>2.4</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 mm</td>
<td>2.8</td>
<td>1.6</td>
<td>0.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 mm</td>
<td>3.2</td>
<td>2.0</td>
<td>1.2</td>
<td>0.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 mm</td>
<td>3.6</td>
<td>2.4</td>
<td>1.6</td>
<td>0.8</td>
<td>0.4</td>
<td></td>
</tr>
</tbody>
</table>

*Figure 9-1: MD conversion table.*

Example: A change in pupil size from 3 to 2 mm from one examination to the next corresponds to a reduction in MD of 0.8 dB.

9.2 Anatomy of the Visual Pathway

The visual pathway begins with the photoreceptors (rods and cones) which lie in the outer layer of the retina. Information is passed from the photoreceptors through several retinal cell layers to the ganglion cells. Axons from the retinal ganglion cells then begin their course across the inner surface of the retina as the retinal nerve fiber layer. The ganglion cell axons (i.e. the nerve fiber layer) exit the eye through the optic disc or blind spot (see Figure 9-2).
Figure 9-2: Axial view of the nasal and temporal sides of the retina, the corresponding visual fields and the visual pathways (labels 1 - 6 see text).
At this point, it can be shown that the blind spot of the right eye, which is located at the nasal side of the retina, is projected onto the temporal side of the visual field. This means also that the visual field topographically corresponds to the mirror image on the retina.

From the optic disc, the axons continue their path to join with the axons from the fellow eye at the optic chiasm. Here, the information from the retina is “sorted out” to separate the right hemifields (blue in Figure 9-2) from the left hemifields (red). Specifically, axons from the nasal side cross over at the optic chiasm – whereas the temporal axons do not cross. Uncrossed temporal and crossed nasal fiber axons then follow the optic tract until they eventually terminate and synapse at the lateral geniculate body (LGB). Geniculate fibers leaving the LGB travel further to the occipital lobe and the visual cortex.

A lesion anywhere along the length of this visual pathway is likely to produce a characteristic visual field defect in terms of its shape and location based on the anatomical organization.

A brief overview of some of the classical field defects is provided below.

9.2.1 The retina and choroid

The first observation is that the density of the ganglion cells varies from the center to the periphery. Approximately 2/3 of the cells are concentrated in the 30° area (900,000 in the center and 500,000 in the remaining periphery). Therefore, if receptor cells lose sensitivity, the resulting defect areas or scotomas can be very small and deep in the center, typical for toxic amblyopia, but larger in size toward the periphery. Sensitivity loss can occur as a diffuse depression or as localized defects.

The nerve fiber bundles (Figure 9-3) can lose their function because of increased intraocular pressure, reduced vascular supply or naturally due to aging (the estimation goes from 5,000 to 10,000 ganglion cells per year). These defects can show the typical “bundle” like arcuate scotomas, often connected to the optic disc.

Focal lesions to the choroid and photoreceptors will produce distinct field defects. They cause defects which do not respect the vertical or horizontal midline. Recall that lesions to the superior retina will be projected to the inferior visual field and inferior lesions to the superior visual field. Examples of these types of defects include lesions from: focal
chorioretinal inflammations, pigmentary maculopathies, laser photocoagulation, age-related macular degeneration and several others. Retinal vascular pathology may also give rise to characteristic field defects.

Figure 9-3: Orientation of the optic nerve fiber bundles (OD). The macula area is approximately 4° and the blind spot 5° wide.

The nerve fiber loss can take several closer or wider (arcuate) shapes between the disc and the nasal area.

Figure 9-4: Typical visual field loss in glaucoma is the “nasal step” related to the nerve fiber bundle path. The nerve fiber loss can take several closer or wider (arcuate) shapes between the disc and the nasal area.
9.2.2 The optic nerve head

The optic nerve head is the origin of a wide variety of visual field defects. The shape and location of these defects is determined by the anatomy of the retinal nerve fiber layer. Glaucoma is one of the most common causes of retinal nerve fiber bundle defects. Briefly, the specific types of visual field defects in automated perimetry which characterize early glaucoma include nasal steps, arcuate or Bjerrum scotomas and paracentral scotomas. Constriction of the central field and a small central island may be all that remains of the field in advanced glaucoma. Other conditions, which can cause nerve fiber bundle defects, include arteritic and non-arteritic ischemic optic neuropathy, thyroid optic neuropathy and disc edema (papilledema). There are also several congenital anomalies of the nerve, which may produce field defects: colobomas, tilted disc syndrome, optic pits and hypoplastic nerves.

9.2.3 The optic nerve

Lesions affecting the optic nerve behind the nerve head are classified as retrobulbar (intraorbital), intracanalicular or intracranial, depending upon the exact location. These lesions are ophthalmoscopically undetectable. Optic neuritis is a relatively common cause of acute visual field loss. In this inflammatory disease, macular fibers are preferentially affected, leading to a central scotoma (involving fixation) and often reduce Snellen acuity. A centrocecal scotoma may be seen with the field defect involving both fixation and the blind spot. An arcuate nerve fiber bundle defect or a generalized depression may also be observed. Anterior ischemic optic neuropathy will often present in an elderly patient with an acute loss of vision and a dense, central scotoma.

Figure 9-5: (refer to lesion location #1 in Figure 9-2)

Optic neuritis leads to unilateral central (sometimes also peripheral) visual field loss.
Compressive lesions may be distributed anywhere along the intraorbital portion and may lead to a wide variety of visual field defects. Examples of defects from compressive lesions include nerve fiber bundle defects, generalized depressions, and central scotomas breaking through to the peripheral field. Toxic and nutritional optic neuropathies will cause central and centrocecal scotomas.

There are several congenital abnormalities of the optic nerve head or optic nerve, which will produce visual field defects. Congenital optic pits are known to cause both arcuate and centrocecal scotomas. Optic nerve head drusen (hyaloid bodies) can cause a variety of field defects including arcuate scotomas, nasal steps, paracentral scotomas and an enlarged blind spot. In patients with drusen of the optic disc, the differential diagnosis could include disc edema and glaucoma, based upon ophthalmologic signs and visual field results. In general, the field abnormalities are stable, although cases with progression have been reported. Optic nerve hypoplasia has a wide spectrum of alterations. In severe cases, a generalized depression with dense localized scotomas in association with reduced vision may be observed. In the tilted disc syndrome, a superior temporal scotoma which crosses the vertical midline may be detected.

Overall, the optic nerve and optic nerve head give rise to an impressive variety of nonclassical visual field defects. While many of these conditions are potentially progressive and vision threatening, they are not ophthalmoscopically observable although they can be made visible by imaging techniques. Automated perimetry plays an important role in their diagnosis and management.

9.2.4 The chiasm

Visual field defects that originate from lesions to the optic chiasm are well recognized by the characteristic bitemporal hemianopia. In this condition, axonal fibers from each eye begin to run together, thus allowing a single lesion to cause a visual field defect in both eyes. There are three important anatomic relationships:

- nasal retinal fibers cross through the body of the chiasm
- the inferonasal retinal fibers course anteriorally into the contralateral nerve
• lower retinal fibers project through the chiasm to lie laterally in the tracts

![Diagram showing lower retinal fibers]

*Figure 9-6: (refer to lesion location #2 in Figure 9-2)*

*Losing peripheral vision on both sides (bitemporal hemianopia) can be caused by a pituitary tumor.*

Characteristics of bitemporal hemianopia from pituitary adenomas and other lesions respecting the vertical midline are progression from superior to inferior hemifield and often a lack of congruity between the right and left eyes.

A second classical chiasmal lesion is a junctional scotoma. With this visual field defect, there is a central scotoma in one eye and a superior temporal hemianopia or quadrantanopia in the fellow eye. The lesion for this defect is localized to the right or left anterior chiasm where the optic nerve enters. The central scotoma is on the ipsilateral side of the lesion.

### 9.2.5 Postchiasmal

The postchiasmal visual pathway consists of the optic tract, lateral geniculate nucleus, optic radiations and ultimately, the visual cortex. The hallmark of postchiasmal visual field defects is a homonymous hemianopsia.

Lesions along the pathway will produce contralateral field defects in both eyes, which will respect the vertical midline. The congruity (similarity) of the scotoma in each eye will be greatest with lesions further back along the pathway.

![Diagram showing postchiasmal visual field]

*Figure 9-7: (refer to lesion location #3 in Figure 9-2)*

*Loss of the left hemifield in both eyes.*
Lesions affecting the optic tracts and LGB are rare and will present with a variety of noncongruous hemianopia. Compressive masses or tumors within the temporal lobe optic radiations result in a homonymous superior quadrantanopsia or homonymous hemianopsia, which is denser superiorly than inferiorly. This classical field defect is produced by damage to fibers within Meyer’s loop. The scotoma is often wedge-shaped and is thus termed a “pie in the sky.” Congruity is often observed with these field defects.

For the temporal lobe, the optic radiations continue on into the parietal lobe with further organization and rotation of the optic fibers. Classical parietal lobe lesions produce an inferior homonymous quadrantanopsia. As these defects may also be wedge-shaped they may be labeled “pie in the floor,” although homonymous hemianopsias are also noted. The etiology behind these lesions includes both cerebrovascular accidents and tumors. Patients with parietal and temporal lobe lesions often have a variety of associated neurological symptoms, which should be appropriately evaluated.

The end point for fibers, which originated within the LGB is the occipital lobe and visual cortex. Due to the high degree of organization of corresponding retinal fibers from each eye, any single lesion is likely to
produce a highly congruous field defect in both eyes. The complete architecture of the visual cortex will not be reviewed. However, the visual field characteristics of lesions within this location include macular sparing, extreme congruity, and macular splitting. Vascular disease, strokes and trauma are the most common causes of visual field defects originating from the occipital cortex. In some cases, because of their small, focal nature, the patient may be unaware of the visual field defect.

In summary, postchiasmal defects are an important sign of neurological disease. Homonymous hemianopic defects are often noted prior to visual field examination on the basis of the patient’s history or presenting symptoms. Automated perimetry can serve as a vital adjunct to diagnosis and localization of the offending lesion. Both screening and threshold programs may be utilized to identify and outline the extent of the scotoma and its impact on the patient’s visual functioning.

9.3 Useful Guidelines for Detecting Abnormality

- When the first visual field meets the criteria of a “reliable” test (see Chapter 7), this field can be accepted when the field is normal. However, when the field is abnormal, a second or third examination should be performed to assess the base line.
- A reliable and valid field may be considered abnormal:
  - with one location having a nasal step difference of >10 dB
  - with two neighboring but non-edge defects of >10 dB anywhere in the field
- Repeat the test when there are three neighboring non-edge deviations >5 dB to confirm the findings.
• The Global visual field indices are more robust against the variability of single test locations. In borderline situations where the MD value is still within its tolerance range of -2 to +2 dB, be suspicious when LV is over 7 dB$^2$ or sLV > 2.7 dB.

• The Probability plots can assist in indicating the likelihood that a deviation represents a real defect.

• The Cumulative defect curve provides a general idea about the deviation of the field from normal. It shows the bandwidth of normality and indicates a uniform depression (parallel to the band of normality) and any focal defects by a steep drop at the right side of the curve.

• When the Cumulative defect curve shows a small uniform loss (this is not visible in the CO table) the cause may be: cataract, a small pupil, incorrect date of birth, incorrect trial lens, dirty contact lens – but also the onset of a true defect.

• Note the “Deviation” value underneath the Cumulative defect curve. This value represents the uniform depression of the field in dB and is the difference between the CO values and the Corrected CO values. Because OCTOPUS makes all calculations with one decimal place, there might be small rounding differences.

• In the Corrected probability plot the focal defects in the field become visible after subtraction of the uniform deviation.

• Observe or verify asymmetry between both eyes.

• Observe typical defect patterns (see Chapter 10).
10 Pathology and Visual Fields

Perimetry is used extensively in the diagnosis and follow-up of many eye diseases, particularly glaucoma. Unlike assessing possible glaucomatous damage by examining the structural changes of the disc and nerve fiber cells, perimetry measures the functional vision loss.

In this chapter, the visual fields of several clinical cases, including examinations with children, are discussed.

In order to have an idea about the available display and printout options, the results are presented in different formats.
Perimetry is used in the diagnosis and follow-up of several eye diseases, such as in:

- Glaucoma
- Diseases of the retina
- Neurological diseases

### 10.1 Glaucoma

The term “glaucoma” covers a wide range of diseases. Unfortunately, the word is not always universally used in the same sense. Sometimes glaucoma is defined as a group of conditions having an elevated intraocular pressure (IOP) in common. Other publications define glaucoma as those cases where there is damage to the optic nerve and a loss of visual function.

In clinical routine, it has proven useful to apply the term glaucoma to all patients having increased intraocular pressure (with or without glaucomatous damage), as well as to all patients suffering from glaucomatous damage (with or without a high IOP).

In glaucoma, the nerve cells and nerve fibers progressively die. As a consequence, the connection between the eye and brain, so crucial for vision, is gradually severed. In the early stages of the disease, when the first nerve cells and their “extensions” are dying, visual function often remains surprisingly intact. As the condition progresses, increasingly severe defects arise in the patient’s vision. Though the patient is often still unaware of these defects, they can be detected by testing the visual field. The fact that visual field loss can be severe even with 20/20 vision is one of the problems with glaucoma. Under certain circumstances, a glaucoma patient with severe visual field defects might be able to read even the smallest print without difficulty or read a road sign far away.

With glaucomatous damage, there are two phenomenological aspects: one is of structural nature and the other functional.

#### 10.1.1 Structural damage in glaucoma

The structural aspect describes the visible changes at the nerve fiber layer and the optic nerve head, and specifically for glaucoma, this is cupping or excavation.
The development of this damage is a very slow process that can take years or even decades. In the area of the excavation, the blood vessels may bend sharply backwards (“bayoneting”) as they cross the excavation margin. Local constriction of the blood vessels (vasoconstriction) may occur as well as small hemorrhages at the rim of the optic disc, or there may be peripapillary atrophy of the choroid. This is a sign of tissue loss around the disc. Photoreceptors and pigment epithelial cells in the part of the retina that borders on the papilla are threatened.

10.1.2 Functional loss in glaucoma

As would be expected when nerve fibers die, the patient experiences a decrease in visual function. But what is surprising is that such a large number of axons can disappear before the ensuing visual defect is noticed.

Defects in the visual field are the most common functional loss. Most scotomata go unnoticed by the patient. Just as someone with normal vision is not aware of his blind spot, a glaucoma patient discovers his scotomata either late in the disease course or not at all. Once again, it must be stressed that visual acuity sometimes remains normal even in cases with advanced visual field losses.

In the following sections several case reports of glaucomatous visual fields are presented.

10.2 The role of perimetry in glaucoma

Unlike assessing possible glaucomatous damage by examining the structural changes of the disc and nerve fiber cells, perimetry measures the functional vision loss.38
Usually, the visual field is studied together with the IOP, biomicroscopy, fundus photography and other methods of analyzing the optic disc, to arrive at a conclusive diagnosis of the patient’s ophthalmic situation. If the results of the perimetry are critical for guiding therapy, a normal full threshold strategy may be beneficial. Shorter tests can be used if the visual field is one of several examinations that will be used for diagnosis and treatment. Therefore, a reliable test accurately done with a fast strategy may provide better results than a longer test affected by a patient’s physical fatigue and the fatigue caused by increased “strain” upon the visual system during a long examination.

As it is very rare in glaucoma that changes in the differential light sensitivity (d.l. sensitivity) commence only in the periphery (without any sign of loss in the central field), the visual field examinations should be focused on the central 30° area.

In the management of glaucoma, the analysis of visual field progression is a major task and therefore, it is most important that the field examination is done rigorously to minimize any variability of the results. As discussed in Chapter 5, there are different perimetry methods used in the detection and evaluation of glaucomatous visual field loss.

### 10.3 White-on-White Perimetry

In clinical routine, standard White-on-White (W-W) perimetry is most commonly used to determine the d.l. sensitivity, whereby visual field defects can be observed in many different forms and shapes.

#### 10.3.1 The nerve fiber bundle defect

A typical visual field loss in glaucoma is related to the nerve fiber bundle path. There are several patterns of defects that can be observed. The superior and inferior nerve fibers run from the nasal periphery and from either side of the horizontal meridian to opposite poles of the disc. In glaucoma, it can be observed frequently that either the superior or inferior side becomes affected before the other, giving rise to contrasting sensitivity values across the horizontal meridian – the so called “nasal step” (Figures 10-2 and 10-3).
Figure 10-2:

42-year-old female with primary open-angle glaucoma.

- The visual field (OD) shows an arcuate loss in the superior area.
- PeriTrend “Comparison” display.

Figure 10-3:

66-year-old female with normal tension glaucoma.

- The OCTOPUS 123 examination was performed with the TOP strategy. Test duration 2:24 min.
- The visual field (OD) shows a superior nasal step with an arcuate scotoma.
- The results are presented in a “Central Combination” format.
10.3.2 Other visual field areas of concern in glaucoma

Other critical areas of concern in glaucoma are the paracentral area, which is best examined with a macula program (Examination Programs, Chapter 5), and blind spot enlargement, preferably determined by using kinetic perimetry (Special Perimetry Methods, Chapter 4).

Unfortunately, there are also other nonspecific defects that make it difficult to assess whether the visual field loss is due to glaucoma or some other disease. Therefore, the visual field needs to be studied together with the IOP, biomicroscopy, fundus photography and other methods of analyzing the optic disc, to arrive at a conclusive diagnosis of the patient’s ophthalmic situation.

10.3.3 Diffuse and focal field defects

The visual field can show focal defects (scotomata), a diffuse depression (although such a loss is rarely uniform) or a combination of both as can be seen by the Bebie curve in the example shown in Figure 10-4.

Figure 10-4: 35-year-old female patient diagnosed with glaucoma.

- The field of the left eye (top) has a uniform depression. The Bebie Curve runs parallel but clearly below the 5% population limit.
- The right eye (below) has a diffuse loss as well but in addition, the steep drop on the right-hand side of the defect curve indicates that there is also a deeper focal defect.
10.3.4 Perimetry and optic nerve cupping

The combination of perimetry, i.e., the assessment of visual function and the structural evaluation of the optic nerve head by an HRT Laser Scanning Tomograph, is useful in establishing the diagnosis (Figure 10-5). However, both tests are not always in agreement and do not always provide good correlation. It may happen that perimetry shows an abnormality with a normal looking disc and there are cases where the opposite may be observed (Figure 10-6).

Therefore, it is important that the different structural and functional diagnostic methods be combined to arrive at conclusive results.

Figure 10-5:

79-year-old patient with asymmetric glaucoma.
• Good correspondance between optic nerve head (OS) and perimetry.

Figure 10-6:

83-year-old patient with chronic open-angle glaucoma.
• No correspondance between optic nerve head and perimetry.

10.3.5 Perimetry in the case of terminal optic nerve cupping

In the final stages of the disease, terminal optic nerve cupping no longer provides useful information and perimetry remains the method of choice to follow the patient (Figure 10-7).
60-year-old patient diagnosed 19 years ago with glaucoma.
- Large optic disc (OD) excavation with scarce residual tissue.
- The visual field still allows follow-up of the patient when the optic disc has already reached a very advanced stage.

10.4 Flicker Perimetry

Flicker perimetry, the determination of the “critical fusion frequency” (CFF) seems to be more sensitive in the early stages of the disease and has the advantage of being minimally affected by blur or opacification of the optical media (Special Diagnostic Methods, Chapter 4).
In Figure 10-9, a case is shown comparing the standard W-W with the corresponding CFF perimetry fields before and after cataract surgery. The test strategy used in these cases is a modified “normal” bracketing strategy with 10 Hz and 5 Hz steps.

Figure 10-9:

62-year-old female patient, diagnosed POAG and cataract (OS).

Before surgery:
- The W-W visual field (upper left) shows a dense uniform depression caused by the opacification of the cataract (slit lamp image).
- The CFF perimetry field depicts clearly the glaucomatous defect “behind” the cataract.

After surgery (images below):
- Both perimetry tests (W-W and CFF) confirm the visual field loss caused by POAG.
10.5 Blue-on-Yellow Perimetry

It has been shown that Blue-on-Yellow perimetry is a more sensitive method compared to standard White-on-White perimetry for detecting early changes in visual function in glaucoma (see also Special Methods, Chapter 4).

**Figure 10-10:**

55-year-old female glaucoma suspect (OD).

- There is a clinically evident excavation of the optic disc.
- Perimetry: Examined with TOP W-W (left) and TOP B-Y (right). W-W field, MD and LV indices appear normal. B-Y field shows two clusters with reduced sensitivity and a nasal step. Interestingly enough, the overall B-Y results are still within the 5% and 95% normality boundaries. Since B-Y perimetry shows large intersubject variability, cluster analysis becomes more important for detecting early changes.
- HRT-II Analysis: Disc area 2,079 mm², Cup/disc area ratio 0.48, Cup shape measurement -0.080 (abnormal). Moorfields regression analysis: 3 nasal sectors are “Borderline”.

![Blue-on-Yellow Perimetry Diagram](image)
46-year-old female, with normal tension glaucoma (OS).

- IOP was 16 mm Hg, and a clinically assessed optic disc excavation of 0.5. Significant drop of blood pressure during the night (average of 88 / 53 mm Hg).

- Perimetry: Examined with W-W and B-Y perimetry, using the dynamic strategy. In W-W (left), LV is borderline, in B-Y (right), both MD and LV are borderline. The shape of the defect curve shows marginal signs of abnormality and no significant changes are seen in the W-W comparison plot, while the B-Y test clearly shows 3 affected areas in the comparison table and CO plot (bottom right), a good example of how B-Y can provide additional information for judging a case uncertainly diagnosed from W-W perimetry.

- HRT-II Analysis: Disc area 2,205mm², Cup/disc area ratio 0.484, Cup shape measurement -0.086 (slightly abnormal).
10.6 Neurological Fields

Patients with a neurological dysfunction often have difficulty performing visual fields. For this reason, the test needs to be adapted to the particular condition of the patient. In some cases, an automated static perimetry examination cannot be achieved successfully at all. In such a situation, the Goldmann kinetic perimetry method is the only way to obtain relevant visual field data.

10.6.1 The static field

It is advisable to start with a simple program, like a qualitative test, and then build up information with further examinations (in additional stages and/or sessions). The OCTOPUS Neurological program N1 allows to follow these steps one after the other within the same program.

10.6.2 Defect Characteristics

The neurological defects are typical when complete segments have absolute defects or when we see a general constriction.

The area of the blind spot provides important information of any vascular defects and also the area close to the center must be tested as optic nerve defects tend to originate at fixation.

Note: Arcuate scotomas, usually seen in glaucoma, can also be caused by certain neurological diseases.
63-year-old female with pituitary adenoma.
- Magnetic resonance image depicts tumor (circle).
- Perimetry (program 32 with TOP strategy) shows bitemporal defect.

10.7 The Goldmann kinetic field

It is often easier and faster to do a kinetic examination with the OCTOPUS Goldmann Kinetic Perimetry (GKP) module (see Special Methods, Chapter 5). This method allows interaction with the patient to adjust the test procedure to his or her particular needs.

In neuroophthalmology the peripheral visual field is particularly important and these areas cannot be reached easily with static perimetry.

Sharp borders are typically tested by moving a kinetic stimulus towards the horizontal and vertical meridians at right angles in order to find and determine possible defects that approach but do not cross the axis.

Kinetic fields are indicated when large defects with steep borders are expected, but also in situations of reduced cooperation and inability to perform an automatic perimetric test.
Figure 10-14:

64-year-old male with upper right homonymous quadranopsia.
Stato-kinetic visual fields by an OCTOPUS 101 with GKP option.

Figure 10-15:

40-year-old male with anterior ischemic optic neuropathy (OD).
Stato-kinetic visual fields by an OCTOPUS 101 with GKP option.

10.8 Diseases of the Retina

Retinal defects ignore the borderlines defined by the horizontal or vertical meridians. They usually correspond directly with the fundus image as seen through the ophthalmoscope.
10.8.1 Retinitis pigmentosa
Retinitis pigmentosa starts often with a ring scotoma that progresses to the periphery as well as toward the center.

![Figure 10-16: 34-year-old patient with retinitis pigmentosa (OD). Display in CO-greyscale.](image)

10.8.2 Diabetic retinopathy
Threshold perimetry is generally not part of the evaluation of diabetic patients. It can, however, give a better understanding of the patient’s visual function.

![Figure 10-17: 60-year-old insulin dependent diabetic has non-proliferative diabetic retinopathy in the right eye.](image)
10.8.3 Macular diseases
Central field defects in the macula need to be analyzed by a macula test program where the spacing of the test locations is very narrow.
The OCTOPUS M1/M2 examination program has a total of 45 test points within the central 4° area resulting in a foveal resolution of 0.7°.
Defects associated to age-related macular degeneration vary from small spotty depressions in the central field to larger absolute defects in later stages.
Toxic substances such as Chloroquine may cause visual impairment, often with a narrow central ring scotoma of around 3° (bull’s eye).

Figure 10-18:
70-year-old patient with age-related macular degeneration (AMD).
• The examination was carried out with Program M1 in two stages.
  First, 45 test locations in the 4° foveal area followed by 36 points in the area between 4° and 10°.
• Presentation in PeriData display.

Figure 10-19:
61-year-old patient with AMD, visual field loss and metamorphosia.
• Pigment epithelium “window effect” in fluorescence angiography.
• Macular perimetry allows functional evaluation (TOP strategy, program M2, test duration 2:32 min).
10.9 Pediatric Visual Fields

Most children succumb to fatigue and boredom during an automated static perimetry (ASP) full threshold testing session, which may last 12 to 18 minutes per eye. Therefore, ASP has not yet been widely used for diagnostic visual field testing in children.

A recent study has shown that practically all 6- through 12-year-old normal children are able to complete an ASP examination using the Tendency oriented perimetry (TOP) strategy, which reduces test time to 2 to 3.5 minutes per eye. Based on this finding, TOP was performed on a number of children with abnormalities of the eye(s) or optic nerve(s) of various etiologies. The results from this group of patients fell into two broad categories.

First, children with retinal abnormalities such as coloboma, staphyloma, or choroidal ruptures could map a visual field defect consistent with the anatomic defect with a good degree of reproducibility and accuracy (i.e. consistent with the predicted visual field defect based on the retinal anatomy). These lesions have well defined boundaries between markedly abnormal, and nearly – or fully-normal retina.

Second, children with more diffuse problems such as optic nerve atrophy, macular pigmentary disturbance, or macular hypoplasia showed non-specific generalized depressions. Of this second group, children with one sound eye could provide their own normal base line reference, which was of help in preventing a false-positive interpretation based on poor test performance.

We have observed that patients with one normal eye are best tested in the order: normal-abnormal-abnormal-normal. If the final test on the normal eye is significantly depressed, this indicates that a fatigue effect has developed which may also affect the accuracy of the second test on the abnormal eye.

It is important to recall that, at the present time, there are no normal values for individuals under 20 implemented in the perimeter. Any interpretation based on the normal values for adults may be inaccurate. In adults, the assumption is made that normal values decrease with age starting from the age of 20. However, this trend cannot be extrapolated from young adults into the pediatric population because two factors...
influence the outcome of ASP in children: 1] retinal and cortical maturity which may truly affect the threshold values, and 2] poor performance due to inattention which will artificially increase the threshold values.

A recently completed study measured the visual field of 142 normal children between 6 and 13 years of age using TOP. A high degree of variability was found within the 6-year-old age group and these results were removed from subsequent analysis. Statistical analysis of the 119 remaining 7- through 12-year-old children showed that no age adjustment to the MS value was required (i.e., the value for 20-year-old subjects was not statistically different from that of the pediatric cohort).

The following guidelines (Section 10.10) outline the considerations we found useful for the interpretation of visual fields in children. Performing ASP twice in each eye is possible with TOP perimetry because the test is much shorter than a standard bracketing strategy and has the advantage of identifying the learning and fatigue effects during the same session, although sometimes an additional learning effect can be observed in later sessions.

**10.10 Useful Guidelines for Performing and Interpreting Visual Fields in Children**

- Test both eyes twice and choose the best (least depressed) field of each eye for interpretation.
- False-positive borderline fields will improve with learning; true-positive borderline fields will remain abnormal and show better mapping of defects.
- The field indices (MD, LV) and the Bebie curve are depressed substantially with poor performance.
- Shifting or “dancing” scotomas are usually not real, but may be seen more often in children with conditions expected to cause generalized central depression, and may be a reflection of erratic fixation.
- Borderline or moderately abnormal fields that do not correlate with the clinical picture should be repeated during a separate session before interpretation.
- With children, the false-positive rate is usually higher than the false-negative rate.
• Some children (and adults) perform poorly on visual field testing and the value of the test will be limited under any circumstances.
• These recommendations apply only to neurologically normal children without intellectual delay.
Figure 10-20:

9-year-old boy with normal fields.

The results of this young boy are typical for a “missed” start of the examination.

- In the first test (top), a large area of reduced sensitivity was due to his missing stimuli at the beginning of the examination. In the TOP strategy the first responses are used to find areas of low sensitivity. If 3 stimuli are missed in the initial stage of the examination, they will be automatically repeated. If 4 or more stimuli are missed in this stage of the examination, the result will be affected as seen here.

- The second examination (right) shows a normal field with no clustering of relative defects.
9-year-old girl with normal fields.
This 9-year-old girl provides a good example of a learning effect and of refractive error:

- **The first examination (OD)** at the top shows a slight diffuse reduction of the d.l. sensitivity as can be observed by the parallel drop in the Bebie curve. It was done without refractive correction and results in an MD of 2.4 (although showing “trigger happy” behavior with an RF = 28.6% purely from false positives).

- **The second examination (OD)** below, this time corrected for refraction and with the experience of the first examination, shows an absolutely normal result.
Figure 10-22:

6-year-old girl with normal fields.
This case shows the effect of a wrong position (distance of the eye from the trial lens holder).

- First test (OS) at the top. Younger children need special attention to position during the perimetric test. Even with pediatric chairs children tend to relax and back away during the examination, leading to pseudo scotomas as in the rim scotoma shown here.
- Readjustment before the second examination and close observation during the 3-minute test resulted in a perfectly normal field shown at right.
7-year-old boy with normal fields.
This 7-year-old boy shows the effect of excessive blinking as is often seen with children.

- 17 repetitions within 90 stimuli means that about 20% of stimuli had to be repeated due to blinks of the subject during presentation of the stimuli. With the fixation control turned ON – which is the default setting – stimuli that may not have been perceived due to blinking are repeated automatically.

- Without repetitions, these “unseen” stimuli would lead to a false result. Simulation shows that with 20% negatives the reduction in sensitivity is on the order of 3 to 5 dB using the TOP strategy.

- In this case, because of the OCTOPUS eye fixation control, the outcome is still good, regardless of the frequent blinking.

- At the top, the PeriTrend CO-greyscale display with the examination data. Below, the same examination in VA-greyscale with the Bebie curve and Indices.
Figure 10-24:*

8-year-old boy with peripapillary staphylomas.

- Vision was 20/125 and 20/40. ASP of the right eye showed a dense superior hemifield defect that was reproducible and corresponded with the anatomic location of the staphyloma. The left eye showed moderate to marked diffuse depression with peripheral defects that were variable, possibly due to shifting fixation.

- Left eye, left figures; right eye, right figures. The results of the first two tests are shown in the center figures, and those of the second two tests are in the bottom figures.

- Note the reproducible superior scotoma OD and diffuse depression OS. The deterioration in the second field OS (the fourth test) suggests fatigue or loss of concentration.

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**Figure 10-25:**

11 year-old boy with blunt trauma.

An 11-year-old boy had a blunt trauma OD with a hyphema.

- Vision recovered to 20/20. There was a choroidal rupture with overlying intraretinal hemorrhage superotemporally to the optic disc. After the resolution of the hemorrhage and the hyphema, ASP suggested a moderate and reproducible scotoma in the inferonasal quadrant comprising the peripheral 20-30 degrees, corresponding well in anatomic location to the choroidal rupture.

- OS at left, OD right. Reproducible infero-nasal scotoma OD, anatomically consistent with supero-temporal choroidal ruptures.
11 THE OCTOPUS PERIMETERS

The line of OCTOPUS perimeters consist of two different models, designed for their particular application in eye clinics.

The OCTOPUS 101 is a 90° field cupola perimeter combining automated White/White, Blue/Yellow, Static- and manual / semi-automated Goldmann Kinetic perimetry. The measurement unit, usually installed in a dark room, is controlled by a standard personal computer operated under Microsoft Windows.

The OCTOPUS 300 is a perimeter to test the central 30° visual field. It is a direct projection perimeter that does not need to be installed in a dark room for that reason.

Both perimeter models can transmit the visual field data to a central PC and be integrated in a local or remote network.
11.1 **Cupola Perimeter OCTOPUS 101**

The OCTOPUS 101 is a 90° field cupola perimeter with the combination of automated White/White, Blue/Yellow, Static and manual / semi-automated Goldmann Kinetic perimetry.

For obtaining accurate data and convenience for the medical staff, the measuring and control units are separated. This way, both units can be installed in different rooms (or separated by a curtain) which represents the perfect setup to assure the most reliable results because the patient remains undisturbed from movements, sounds and light changes in the environment.

The measurement unit is controlled by a standard personal computer with the Microsoft Windows operating system. In a standard configura-
tion, the system can store virtually an unlimited number of patients / examinations in different directories. As an external printer, a (color) ink jet or a laser printer using normal paper is connected.

The measurement unit or “bowl” contains such modules as lamp housing, stimulus projector, CCD eye camera, power supply and electronics. It is also equipped with all the controls needed to set up the patient remotely from the PC.

Once the examination is started, the bowl runs the test by itself unaffected by the PC controller.

11.1.1 The measuring unit

Test parameters
For its diagnostic test programs, the instrument employs the same standard test parameters as with earlier OCTOPUS cupola perimeters:

- Goldmann size III stimulus size
- 4 asb background illumination
- 100 ms stimulus duration time

However, these parameters can be freely selected with the definition of the custom test programs.

- Stimulus size I through V, with a free definition for a custom size stimulus.
- Test strategies: 2-LT (3-zone) screening, normal threshold and low vision strategy, TOP and dynamic strategy.
- Background illumination: 4, 31.4 asb and 314 asb for the B/Y settings.

System components
The stimulus projection system is capable of reaching any location in the full 90° visual field with a maximum resolution (spacing) of 0.5°.

An accurate and stable background illumination is provided by using an optical system rather than by regulating the light source.

A separate projector is provided for three fixation target patterns:

- Single point
- Cross marks
- 6° circle

For stimulus light attenuation, the OCTOPUS 101 uses a precision opti-
cal wedge in conjunction with a (completely silent) magnetic type shutter. Since the experience shows that patients do better when they hear a functional sound – making it easier to blink regularly – an audible alert can be set up to signal the patient that a stimulus can be expected. However, without the alert signal, the operation is completely silent.

Note: d.l. sensitivity values typically reach higher values when:

- patients hear the alert
- patients are instructed to press the button when they think they might have seen the stimulus rather than answering when they are sure

The CCD is an infrared sensitive camera. This arrangement allows perimetric testing in absolute dark background conditions (which may be required later for other perimetry methods such as pupil perimetry) while still being able to monitor and control fixation.

Another state-of-the-art feature is the use of a Flash EPROM. Such a hardware chip can be (re)programmed from the external PC which makes it possible to upgrade the measuring unit software by diskette rather than by exchanging hardware components such as EPROM boards.

**No loss of data after loss of power**

Once the test is started, the measurement unit can continue and finish till the end of the phase independently of the control unit. Also, the test results stay in the measurement unit memory till a successful transmission of data has taken place. Therefore, when either unit loses power, the last examination (or part thereof) remains in storage and can be retrieved for continuation or printout after the power is reestablished.

**Patient positioning**

Patient positioning is made easy with the adjustment of the motorized headrest by using the buttons on the Patient set-up panel on the measuring unit. This panel, which can be mounted on either side of the cupola for left / right installation in the room, also shows the eye on an LCD display for correct alignment. Later, during the examination, this alignment can be remotely readjusted during the test from the PC. There is no need to be near the patient and disturb the procedure if fixation needs to be corrected.
Both the headrest and the trial lens holder have position sensors to alert
the operator when the tested eye does not correspond to the selected
eye and when the lens holder needs to be removed for a peripheral field
test.

11.1.2 The control unit

Hardware
A standard PC is used as the controller for the measuring unit. As men-
tioned, this unit is a standard PC connected to a VGA or LCD monitor or
an interactive pen display and a commercial printer.

For the video display of the eye on the screen, in either a smaller or larger
image, the video camera connects through a USB cable/port with the PC.
A hard disk can hold virtually any number of examinations (100,000 and
more). However, the more examinations that are stored in one directory,
the slower the response time is going to be. Ledgering separate patient
files is recommended for quick retrieval, for instance, having <A>, <B>,
etc. files in alphabetical order of the patients. Or in another form of iden-
tification such as <Glaucoma>, <Macula>, etc. If patient volume is high,
such as in clinics, a CD writer is recommended for backing up the data in
the directories and files on a regular basis.

The Windows™ environment does not normally need a long introdjec-
tion to learn to use it. The operation is conveniently and simply organ-
ized in four main menus.

OCTOPUS 101 menus

In the main screen, below left, all patient / examinations are stored and
listed under „Patient file,” in alphabetical order (it is also possible to sort
the according to ID numbers).

The easiest way to find a patient/examination is to click on the binoculars
icon (or go to “edit” and “search”) and type in some of the first charac-
ters of a name, PeriTrend will then search for the patient in all files and
directories on the hard disk.

The total number of patient examinations in the file is listed at right at the
bottom of the menu.

The “Examination buffer” is a temporary file for examinations that are
not completely finished (or interrupted). Also the data pertaining to pa-
The OCTOPUS Perimeters

Patients that are waiting for an examination can already be entered and listed here.
The “Selected patient” menu at right provides the page where the data for a new patient is entered and the selections of the examination program and test parameters are made.
Below is an area for selecting the examination programs and custom tests. The selection can be individually defined in the setup program to only show those examination programs which are regularly used and hide those that are not used frequently.
The correct pupil size is automatically entered during the examination. This input is essential for interpreting the data.
After all data has been completed we save the information in the buffer for later, or directly start a static or kinetic (GKP option) examination and enter into the “Examination control” screen.

The examination control window is “open” during the test procedure. A defect level indicator and the indices are updated after every question and answer, rendering an on-line assessment of the visual field. This information can assist us in determining the duration of the examination.
Normally, the eye image is displayed in the upper left corner of the screen (as shown here). At the same time the intermediate test data in dB can be followed. If fixation needs to be corrected the PC arrows serve as a remote control for the headrest.

Figure 11-2: The OCTOPUS 101 “Main menu” and the “Selected patient” windows.
If the patient must be supervised and monitored from a distance, a larger eye image can be displayed filling the whole screen area where the test data were shown before (see Figure 6-6).

**11.1.3 Displaying results**

By using the icons on the tool bar we quickly access different display and print options. The “Standard display” shows the VA- or CO-Values or Greyscales, the Bebie curve and the Global indices. The graphics can be zoomed in to show details.

*Figure 11-3: The “Examination” window makes it easy to follow the examination on a PC monitor - even when the patient is performing the test in another room.*

*Figure 11-4: Quick access to a particular display mode.*
Figure 11-5: Display of a single field in CO-greyscales: A normal visual field (left) and a case of diabetes (right).

From top right down to left:
- Sequence display
- Series display
- Trend analysis
- Delta format

Figure 11-6: Display of multiple fields in different formats.
11.1.4 Import data from other sources (perimeters)

An important feature of the OCTOPUS 101 software is the option to connect one or several other perimeters to the same computer in order to combine, manage and analyze the perimetric results at one PC station. This also offers the possibility to display and look at the visual fields at another workstation, which is connected in a network.

11.1.5 Blue-on-Yellow (B-Y) perimetry

The OCTOPUS 101 can be set up for B-Y perimetry (see Special Methods) with standardized test parameters for

- Blue stimulus, peaking at 440 nm with 35 nm bandwidth
- Yellow background, 315 asb
- Age-corrected normal values for B-Y perimetry

With these specifications, the system reaches a perfect isolation of the blue cones resulting in a dynamic range between 18 dB at the fovea and 12 dB at 20° eccentricity.

Note: B/Y perimetry is useful for the early detection of glaucoma with younger patients.

11.1.6 Goldmann Kinetic Perimetry (GKP Option)

With the GKP software option (see also Special Methods, Chapter 5), the OCTOPUS 101 can fully replace the manual Goldmann perimeter and even combine the static field data with kinetic isopters to obtain a complete picture of the total 90° visual field.

The main GKP characteristics are:

- Offers a full 90° field spherical cupola perimeter combining automatic static and manual kinetic perimetry
- Allows easy operation by manually tracing selected isopters on an interactive pen display
- Employs the same Goldmann standard stimulus sizes and familiar filter settings including the presentation of static stimuli
- Draws and identifies isopters in colors
- Displays age-corrected normal isopter values serving as an orientation to start the testing.
The OCTOPUS Perimeters

- Calculates the isopter volume in degrees to allow analysis of change
- Zooms in on a specific field area to examine the finest details – such as the blind spot
- Upon selection, displays and prints two fields (OS and OD) on one page
- Measures patient’s reaction time and adjusts the isopters to obtain comparable results
- Can overlay previous kinetic examinations to either continue an interrupted exam or to compare with a finished result
- Can repeat the same procedure automatically after finishing a manual kinetic examination
- Offers the possibility of creating user examinations for automatic kinetic testing
- Upgradable to Fundus Oriented Perimetry and Scotoma Oriented Perimetry (SCOPE)

Figure 11-7: The Goldmann kinetic perimetry (GKP) “desk top.”
11.2 Direct Projection Perimeter OCTOPUS 300

The OCTOPUS 300 perimeters consist of two different configurations.

The OCTOPUS 301 perimeter
The OCTOPUS 301 is the basic model that can be upgraded with several software options such as:
- Automatic eye fixation tracking
- Flicker perimetry
- User-defined test programs

The OCTOPUS 311 perimeter
In addition to all of the above, the standard version of the OCTOPUS 311 includes:
- B-Y perimetry

Figure 11-8: The OCTOPUS 300 perimeter system.
11.2.1 Direct Projection System

The OCTOPUS 300 is a direct projection perimeter and does not make use of the traditional perimetric bowl or cupola. Instead of looking at the reflected light spots, the stimuli are projected directly onto the patient’s retina together with the surrounding light, and the fixation target. Also the CCD camera is aligned in the same optical path.

Although the patient sees no difference between this direct projection system and a bowl perimeter, the dimensions of the instrument can be drastically reduced which allows a construction similar to an auto refractor. This makes the OCTOPUS 300 a user friendly perimeter for technician and patient alike.

Because there is no bowl, stray light from the surroundings cannot disturb the measurements. Therefore, the OCTOPUS 300 does not need dark room installation and the subject can do a test in the normal light conditions of an examination room.

Moreover, the optics of the direct projection perimeter are designed to project the stimuli from an infinitely distant source. This way, near correction trial lenses or the presbyopic addition are not needed.

Figure 11-9: Because of the direct projection optical system, there is no bowl and stray light from the surroundings can not disturb the measurements.
11.2.2 Revolving optical unit
Another innovation of the OCTOPUS 300 is that the optical unit is motorized to be positioned up, down and sideways by rotation. This makes it possible for the perimeter to follow eye fixation automatically without moving and disturbing the patient.

11.2.3 Control elements
The functions of the perimeter are controlled by the touch of a pen on the LCD screen or simply by using a common cotton swab.
After the patient data has been entered the perimeter is ready for starting the examination.

Eye fixation control
In the examination menu, the optical alignment with the pupil center is achieved by pressing the respective directional arrows.
One of the most important factors in obtaining a reliable visual field is the ability of the patient to maintain fixation. Although monitoring the eye with a video image is the way most perimeters try to ensure proper fixation, OCTOPUS takes it a step further – the fixation remains fully under control making certain that the examination is only active when the eye is correctly centered.
Once fixation is secured, you may encourage the patient to blink regularly to feel more comfortable and focus on giving correct answers.

The moment the eye is not centered within a tolerance range, the perimeter will pause and signal the staff to adjust for fixation. This is accomplished by quickly and easily pressing a button. Eye fixation is thus under permanent control – unlike systems that only monitor the eye position without intervention.

As an option, the OCTOPUS 300 offers an Eye Tracking feature to track the position and automatically follow the patient’s eye movements. Since the optical unit moves and NOT the chin rest, the patient’s attention and collaboration is not interrupted, thus yielding more reliable results.
11.2.4 Printing the results

The visual fields can be printed directly in several formats from the OCTOPUS 300 in black/white or in color on a HP ink jet printer through a standard USB connection.

A particularly interesting printout mode of the OCTOPUS 300 is the Two-on-One format that allows the printing of two visual fields such as left and right eye on one page.

Other than that, the choice of printout reports is the same as with the other OCTOPUS models (see Reporting Visual Field Data, Chapter 7).

Menus and printed reports in local language

The OCTOPUS 300 menus can be set up to “speak” the local language - as long as there is a Windows version of it. Once this language is prepared and downloaded, the printout forms will also appear in the foreign language.

11.2.5 Data transmission

As an alternative, the visual field data can be transmitted to a PC to store, manage, display, analyze and print results. For this purpose the OCTOPUS 300 includes a data transmission function. The condition for this feature is that a suitable personal computer is connected through a RS 232 serial cable and that the PeriTrend software and Windows is installed on the PC.

After transmission of the examination results, the data is stored in a Patient file (normally sorted by name and in the chronological order of the examinations).

11.2.6 LAN interface

The optional LAN interface board with a standard Ethernet connection provides the means for integrating the OCTOPUS 300 in a local or remote network. A typical application is that the patient data can be entered at the reception desk in advance for an efficient usage of the perimeter.

Also, visual fields can be accessed, reviewed and printed at other locations.
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