PERIMETRY

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INTRODUCTION

This chapter includes a review of:

- The visual field – an introduction
- Introduction
- Instrumentation
- Examining set-up
- Recording: printout and data analysis
- Graphic representation
- Threshold tests
- Statpac analysis
    - Single test analysis
    - Summary of global indices graphic representation
    - The glaucoma hemifield test
    - Change analysis
    - Overview
    - Statpac II (update software of Statpac I)

AUTOMATED PERIMETRY

INTRODUCTION

Automated perimetry is now the standard procedure for visual field testing. Automated perimetry moves visual field testing from the previous manual and relatively imprecise procedures relying heavily on operator technique, to quick, accurate and computerized exam that yield standardized and reproducible results. Automation offers a significant number of advantages over manual perimetry (Table 5.6). Although some disadvantages are also created, the benefits of automated perimetry far outweigh the drawbacks. The automated perimeter should be considered as essential to primary eye care practice.

Advantages	Disadvantages
Ease of use	Initial cost
Easy data collection	Time consuming
Sensitivity	Difficult testing procedure
Accuracy	Complex interpretation
Reproducibility of standard testing set-up	
Quantifiable results	
Statistical analysis	
Flexibility	
Data storage (computer)	

Table 5.6: *Comparison of advantages and disadvantages of automated perimetry*

A number of automated perimeters are available on the market. All offer their own special features that may appear appealing to different practitioners and the automated visual field chosen is ultimately a matter of personal preference. The components that are common but variable between the different automated visual field testers are listed below (Table 5.7). Although the variability presents an important advantage in automated perimetry, it also presents the disadvantage of not permitting the direct comparison of results obtained with different systems. For example, a decibel on one machine does not equal a decibel on another (see table 5.3 on page 13).

Targets Size Colour Position/intervals Brightness range Type (projected or Light Emitting Diodes) Presentation time **Backgrounds** Standard brightness Range of brightness Colour **Testing strategies** Static Kinetic Screening Threshold Patterns Limits **Head Position Monitors** Head Tracking Vertex monitor	**Fixation Monitors** Telescopic device (manual) Video camera and TV monitor Heijl-Krakau technique Eye movement tracking devices **Computers** Built-in or peripheral Software Data storage Data manipulation Statistical analysis Database **Printouts** Graytones Numeric Depth defect Overviews Profiles 3-D maps Statistical data

Table 5.7: *Components of various automated visual field testers*

Probably the most commonly used automated perimeter, one which many consider the standard of care, is the Humphrey Visual Field Analyzer (HVF) (Fig. 5.34). The interpretation of automated perimetry will be covered extensively using the HVF principles, characteristics and terminology as a basis. Most other visual field testers use features and methods that are very similar to those of the HVF. A solid understanding of the HVF should provide, with a few adjustments, the necessary background to understand most automated perimeters available commercially.

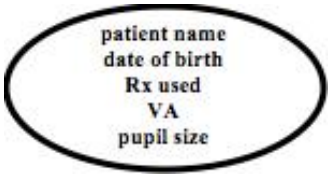
INSTRUMENTATION

Figure 5.34: *Humphrey visual field analyzer*

EXAMINING SET-UP

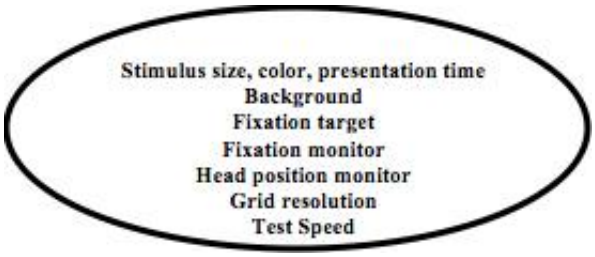
HVF should be performed in a quiet dark room where the only the perimeter's illumination is perceptible. The HVF takes several minutes to auto-calibrate each time it is turned on. Once ready the patient information, test parameters and test protocol must be adequately entered. Correctly setting up the instrument is crucial to run a proper automated visual field. The set-up must be verified each time to insure that what is performed is exactly what is desired.

1. Patient Information



The patient information is important both for information retrieval and for data analysis. Incorrect entry may result in misinterpretation of the final visual field result. The information to enter is: patient name, date of birth, Rx used, VA and pupil size. Particular care must be taken to enter the date of birth correctly since the statistical analysis involved in automated perimetry is based on patient's age. The pupil size is important to insure that future tests are performed under similar pupillary conditions or to account for any variation in the results that may be due to differences in pupil size from one exam to the other.

2. Test Parameters



The test parameters on automated visual field afford a wide flexibility.

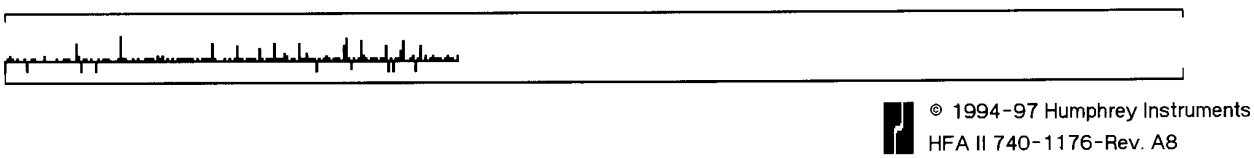
The stimulus size is usually fixed to the standard Goldmann size III (0.43°), but it can be adjusted to match the Goldmann visual field stimuli (I to V). Unlike the Goldmann visual field, in automated perimetry the size of the stimulus is kept constant and intensity is varied to obtain stimuli of different visibility. The stimulus is usually white, but coloured spot can also be presented and changed to red or blue to allow colour perimetry. The stimulus presentation time is fixed at 200 msec. Unlike other parameters, the presentation time is fixed and cannot be altered. The 200 msec. fulfills the criteria of being beyond the critical period but below the latency of voluntary eye movements.

The background intensity and colour can also be varied but a white background of intensity 31.5 apostilb is usually the standard setting for the HVF.

The fixation target is usually a central illuminated fixed spot. The HVF also includes two fixation diamonds of different sizes located just below the central target. The diamonds can be used for patients with low VA or central scotoma, fixation being set on the apparent center of the diamond. The diamond is also used to establish the foveal threshold.

Fixation monitoring can be done in several ways. The manual method may still be used in some instruments with the use of telescopes or closed circuit TV monitors, but it is rather cumbersome, requiring that the examiner subjectively and constantly supervise fixation. Contrast sensor devices that are sensitive to eye (pupil) movements may also be used. Using these methods, the computer can be programmed to disregard the tested point when an eye movement is registered. This approach is precise, but very costly.

In automated perimetry, the Heijl-Krakau method is usually used. A test spot is occasionally projected in the blind spot and the number of times that the patient responds to this test spot indicates the number of fixation losses. The Heijl-Krakau method is practically the standard approach used in automated perimeters. HVF also uses a gaze monitoring system to record the position of the eye during stimulus presentations. The results are graphed as shown below.



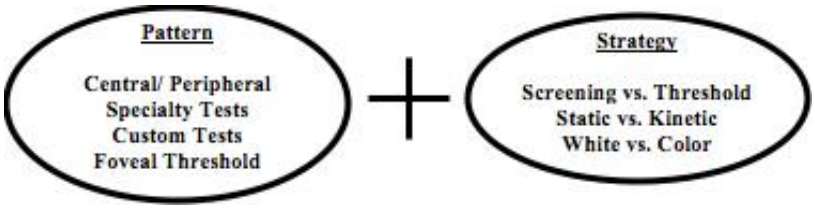
Upward markings indicate that the eye deviated from fixation at the time of stimulus presentation; the higher the line, the higher the deviation. Downward marks indicate that the gaze system could not locate the patient's gaze (small marks) or that the patient blinked (large marks). The clinical usefulness of this system is questionable.

Head Position Monitoring may be performed with the Head Tracking and Vertex Monitor options. Head Tracking helps maintain proper patient alignment during the testing by keeping the patient's eye centered behind the trial lens. During the test, the Head tracking device monitors the eye position relative to the fixation light and makes small increment adjustments (0.3mm) to position the head rest back to its initial position. The Vertex Monitor controls the patients distance from the trial lens. If the head moves 7mm or more away from the trial lens, the HVF beeps and displays a message to that effect. The test continues but the examiner can halt the testing and reposition the patient.

Grid resolution refers to the spacing of the tested points on an automated perimeter. The resolution on the most common HVF central tests (e.g. 24-2, 30-2) is 6 degrees and on common peripheral tests (30/60-1, 30/60-2) it is 12 degrees. However, merging functions which combines different test into a single printout can provide a higher resolution impression. For example merging a 24-1 with a 24-2 creates grid density of 4.2 degrees. Custom patterns can further reduce the grid resolution to as close as 1 degree. Other VF instruments may use different grid resolutions or allow for it to be varied as needed.

The test speed can also be varied to allow a slower stimulus presentation for patients that may need it. The standard setting is "fast" and rarely does it need to be changed. However, some visual field programs, like the HVF SITA, adjust test speed according to patient normative data (faster for younger patients) and individual responses (faster patient responses speed up the test and vice versa). The strategy reduces overall test time and fatigue with able patients but also slows down the pace when patient performance or response time is reduced.

3. Test Protocol



A wide variety of **protocols** is permitted by automated perimetry (Table 5.8 and 5.9). Each method has its own advantages and clinical applications that may be worth considering in some circumstances. The choice of protocol will depend on the patient, the clinical condition under investigation and the examiner's preference. The number of truly useful clinical patterns and strategies can really be narrowed down to just a few. One must aim to constantly use the same testing protocol (at least for a given patient) to allow comparisons upon retest.One must bear in mind, however, be it for particular clinical situation or research purposes, that a gamut of potentially useful testing possibilities is available with automated perimetry.

Pattern

Central, peripheral, full field and a number of custom and specialty tests can be performed with automated perimetry. Ideally a comprehensive full field threshold test would be performed every time on every patient. However, full field testing requires a substantial amount of time and effort that makes it a practically impossible test to administer to anyone! Therefore visual field testing is usually limited to either the central or peripheral areas of the visual field.

Most visual field anomalies occur in the central 30 degrees of the visual field. Peripheral testing is therefore less valuable clinically except when indicated in specific clinical cases (e.g. patients with a stroke). The central 30 degrees is the most clinically useful area to test and is still considered the standard test area. However many clinicians opt for the central 24 degree pattern which provides almost the same clinical information but saves a significant amount of testing time. Given the same testing strategy for example, the 24-2 tests 22 fewer points than the 30-2 (75 test points) and should be at least 22/75 faster; practically it is about 40 percent faster. An automated threshold visual field test is difficult to undertake for many patients including young healthy subjects. Increased testing time will make the test strenuous and reduce reliability. Any amount of time saved will therefore be of benefit to both patient and clinician. Furthermore, reducing the tested area from 30° to 24° may reduce anatomical artifacts (e.g. lid interaction) that often affect the edges of the tested area.

Custom and specialty tests such as the Armaly, Nasal Step, Macula, Superior, Neurological **and** Easterman patterns are also available. Except for the Easterman, these patterns concentrate on particular areas that may be more likely involved in certain conditions. The Armaly and Nasal Step patterns are aimed to test areas commonly affected in glaucoma. The Macula pattern is aimed at increasing the test resolution for macular defects. The Superior pattern tests for superior hemifield defects. Neurological patterns concentrate on the horizontal and vertical meridians which are most diagnostic for neurological diseases. The Easterman pattern, listed as a disability screening test, incorporates a single intensity stimulus to test the field monocularly (100 points) or binocularly (120 points); the result yield **functional disability** in a straight percentage score (%).

Notwithstanding the above, the central 24-2 pattern (or 30-2) provides the most widely used approach even for specialty testing since it can quite reliably investigate the same areas and in most cases uncover the same abnormalities. Note that the “-2” notation (24-2 vs. 24-1) simply denotes that the visual field is tested on each side of the horizontal and vertical meridians rather than directly on the meridians. Testing on each side allows easier identification of defects that respect the meridians, such as nasal steps or hemianopias.

The foveal threshold can also be tested during a visual field test to provide additional information about the central sensitivity. Since it is not standard procedure, the foveal threshold option must be chosen each time a visual field is performed. The threshold is established at the beginning of the test while the patient fixates the center of the fixation diamond.

	Test Pattern	Visual Field Tested	# of Points	Average Last Time (min.)	Application	Strategy	Printout
	Central 30° tests					All screening tests are possible in:	All screening tests can be printed in:
	Central 40 point	30°	40	2-4	Gen.		
	Central 64 point	30°	64	3-5	Gen., G, N		
	Central 76 point	30°	76	3-5	Gen., G, N	Threshold related	Threshold related
	Central 80 point	30°	80	3-5	Gen., G, N	Three- zones	Three- zones
						Quantify defect	Quantify defect
S	**Peripheral tests**					Single Intensity	Single Intensity
C	Peripheral 68 point	30°to 60°	68	5-6	Gen., G, N, R		
R	Full field 81 point	55°	81	6-7	Gen., G, N, R		
	Full field 120 point	55°	120	6-8	Gen., G, N, R		
E	Full field 135 point	87° T	135		Gen., G, N, R		
E	Full field 246 point	55°	246	14-15	Gen., G, N, R		
N	**Specialty tests**						
I	Armaly central	30°	84	5-6	G		
N	Armaly full field	50°	98	7-8	G		
	Nasal step	50°	14	2-3	G		
G	Easterman Monocular	75°T/60° N	100		Functional Disability		
	Easterman Binocular	150° Bi-T	120		Functional Disability		
	Superior 36	60° S	36		Superior Field Defect		
	Superior 64	60° S	64		Superior Field Defect		
	Custom tests						
	Any pattern: alone, in arc or profile as individual points, clusters or grid positioned using x-y coordinates to a possible grid resolution of 1°.						

Figure 5.8: *Screening protocols permitted in automated perimetry*

Test Pattern	Visual Field Tested	# of Points	Average Last Time	Application	Strategy	Printout
Central 30° tests						
Central 24-1*	24°	56	10-12	Gen., G		Num, DD, GS, P
Central 24-2	24°	54	10-12	Gen., G, N		Num, DD, GS, P
Central 30-1*	30°	71	12-15	Gen., G, N, R	All threshold tests	Num, DD, GS, P
Central 30-2	30°	76	12-15	Gen., G, N, R	are possible in:	Num, DD, GS, P
Peripheral tests					FastPac	
Peripheral 30/60-1*	30°to 60°	63	12-15	G, R	Full threshold (FT)	Num, DD, GS
Peripheral 30/60-2*	30°to 60°	68	12-15	G, R	Fast threshold	Num, DD, GS
Peripheral 60-4	30°to 60°				FT from prior data	Num, DD
Nasal Step	50°	14	2-3	G		Num, DD
Temporal crescent*	75°	37	3-4	N, R, advanced G	except custom tests	
					only Full threshold	
Specialty tests						
Neurological 20	20°	16	5-6	N	SITA only with	Num, DD
Neurological 50	50°	22	8-9	N	30-2, 24-2, 10-2, 60-4	Num, DD
Central 10-2	10°	68	10-12	Macular, N, advanced G		Num, DD, GS
Macula	4°	16	8-10	Macular, advanced G		Num, DD
Custom tests						
Any pattern: alone, in arc or profile as individual points, clusters or grid positioned using x-y coordinates to a possible grid resolution of 1°.						

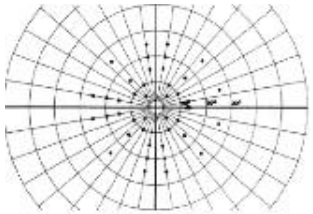
Table 5.8: *Threshold protocols permitted in automated perimetry*

Gen = general G = glaucoma N = neuro R = retina Num = numeric DD = defect depth GS = gray scale P = profile

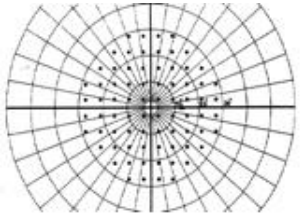
**** Not available in all systems***

Screening Tests Pattern (adapted from the HVF analyser primer book)

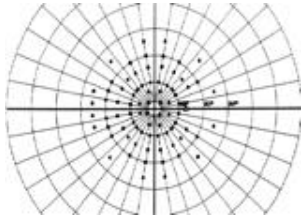
Central Tests



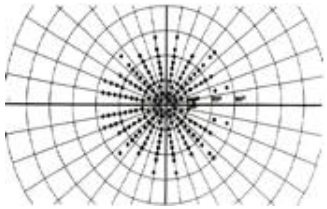
Central 40-points



Central 76-points

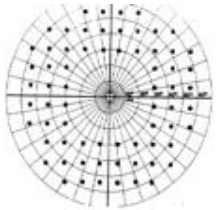


Central 80-points

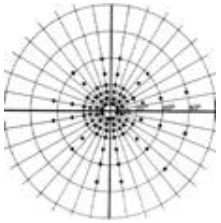


Central 166-points

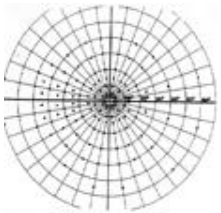
Peripheral Tests



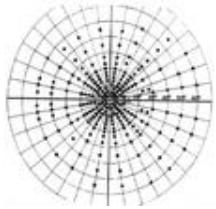
Peripheral 68-points (30-60)



Full Field 81-points

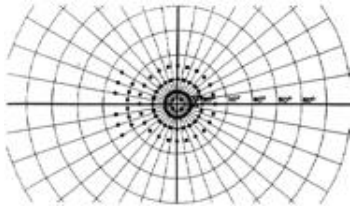


Full Field 120-points

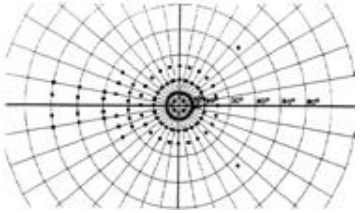


Full Field 246-points

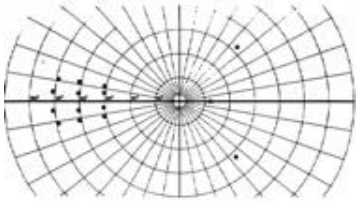
Specialty Tests



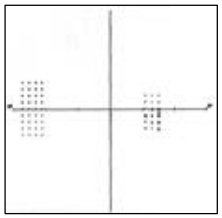
Armaly central



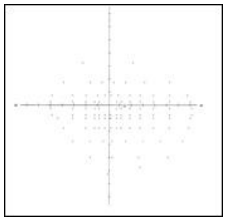
Armaly full-field



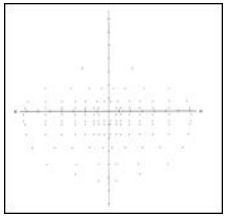
Nasal Step



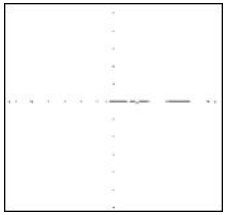
Custom



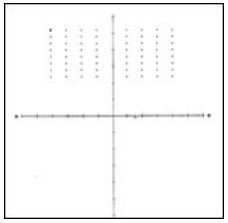
Easterman Monocular



Easterman Binocular



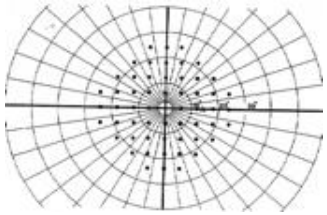
Superior 36



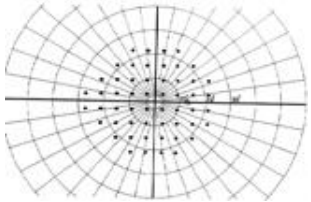
Superior 64

Threshold Tests Pattern (adapted from the HVF analyser primer book)

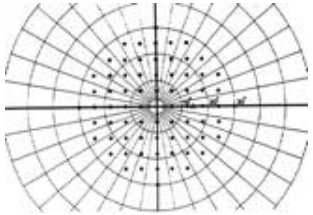
Central Tests



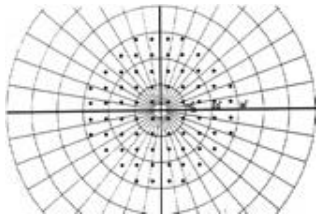
Central 24-1



Central 24-2

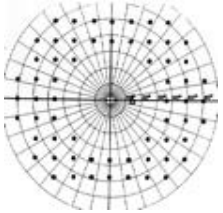


Central 30-1

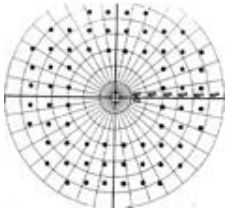


Central 30-2

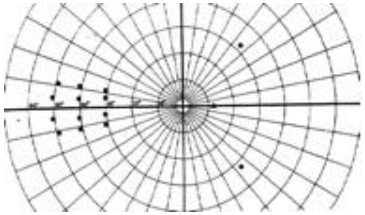
Peripheral Tests



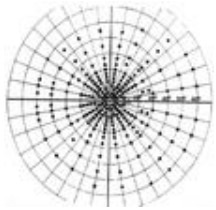
Peripheral 30/60-1



Peripheral 30/60-2Nasal Step

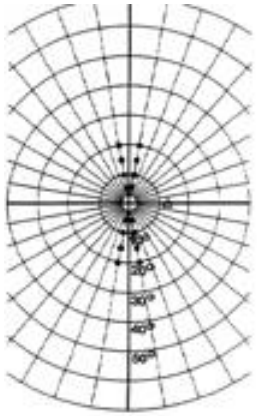


Nasal Step

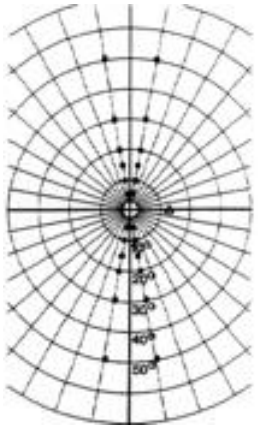


Temporal Crescent

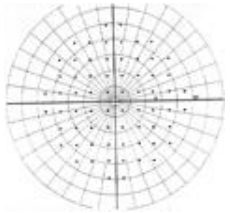
Specialty Tests



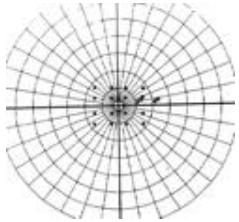
Neurological 20



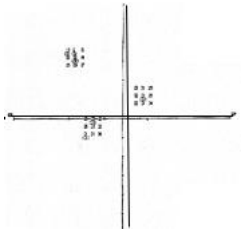
Neurological 50



Central 10



Macula



Custom

4. Strategy

Screening vs. Threshold

Screening visual field generally involves the use of suprathreshold stimuli to qualitatively survey the visual field (Fig. 5.35). Traditional screening tests generally use a predetermined single intensity stimulus to investigate the whole visual field. This method is the simplest and quickest, but obviously yields only absolute or very deep defects. With the methods available today, it should probably be avoided clinically.

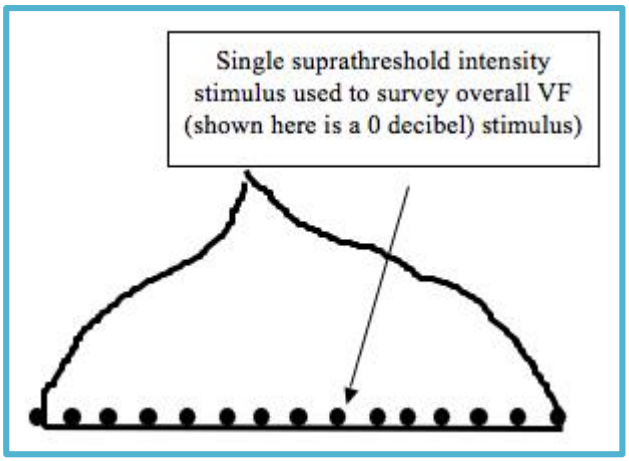


Figure 5.35: *Screening visual field*

Screening tests that are **age-related** or **threshold-related** are more reliable than single intensity suprathreshold screening tests, since they usually use stimuli that are 6 dB brighter than the expected values for the patient (Fig. 5.36). Age-related strategies establish the testing stimuli from the expected (or mean) hill of vision for a given age group.

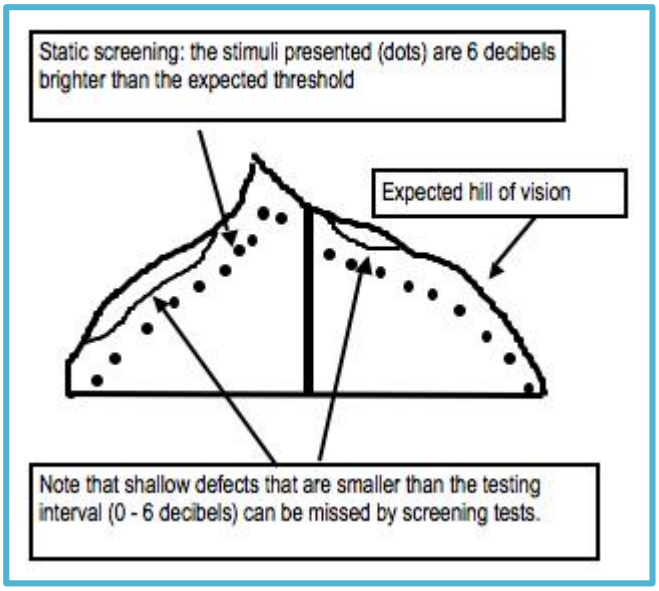


Figure 5.36: *Static screening test*

Age	Theoretical central reference level (dB)
<40	36
40-45	35
46-50	34
51-55	33
56-60	32
61-75	32

Table 5.8: *Theoretical central reference level in relation with age of the patient in threshold-related screening*

Threshold-related strategies establish the testing level from the patient's actual threshold at a given reference point. The HVF uses a threshold-related screening approach. The expected visual field is estimated from 4 primary seeds points located at x=9°, y=9° in each quadrant. The threshold value of the 4 primary seed points is determined at the beginning of the visual field test. The second most sensitive point value is then used to calculate the expected height of the hill of vision used as a reference level for the subsequent screening test (Fig. 5.37).

The threshold-related method is a little more precise since it corrects for individual variations (e.g. cataracts, pupil size…) which are "pooled" and averaged in an age-matched visual field. However, visual field defects that are small and shallow (< 6dB) may still go unnoticed in either of these approaches.

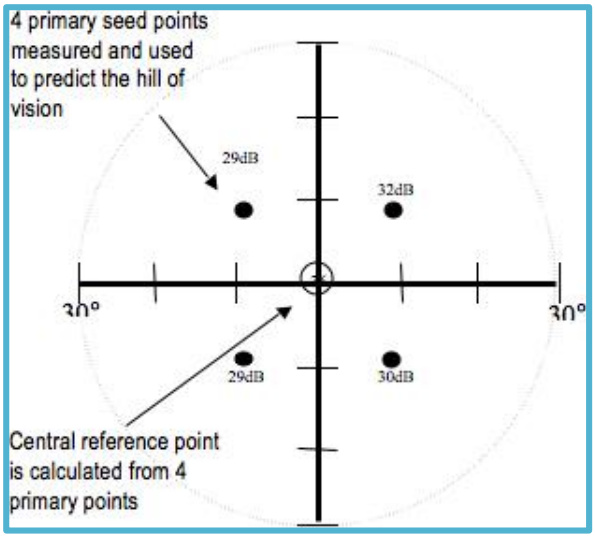


Figure 5.37: *Determining the expected height of the hill of vision in static screening test (threshold-related)*

The HVF offers 3 different threshold-related screening strategies:

(i) The **threshold-related screening** is a standard screening test that records tested points as seen or not seen. The screening is done at 6dB brighter than the expected threshold, and points missed twice at that level are recorded as defects.

(ii) The **three-zone screening** test records tested points as seen, relative defects or absolute defects. Screening is done at 6dB brighter than the expected threshold. Points missed twice are retested at 10 000 apostilb; if seen they are noted as relative defect, if missed again, they recorded as absolute defect.

(iii) The **quantify defect screening** test provides more precise information. Screening is done at 6 dB brighter than the expected threshold. Points missed twice are threshold tested and the depth value of the defect relative to the expected threshold is noted.

The main advantage of screening visual field tests is speed, since in most cases very little time (2-5 minutes) is required to perform the tests. They may prove useful in cases where patients are unable to take threshold tests. They may also have clinical value in cases where the expected visual field defects are deep and gross qualification is sufficient.

Whenever possible, however, clinical use of screening visual field should be avoided. The tests are unreliable and somewhat dangerous since shallow and small visual field defects can be missed. They also present the additional disadvantage in that criteria for abnormal screening tests are necessary for their adequate interpretation. These can be rather cumbersome or difficult to observe and still not full proof. An example of an established criteria (Comer *et al.;*1988) for failing a (HVF central 30°, 76 point) screening visual field is:

- 2 or more adjacent points missed and repeated misses on retest
- 2 or more misses within the central 20° of fixation and repeated misses on retest
- a central reference level of 26 dB or less on threshold phase.

In addition, screening test results do not provide sufficient quantifiable data to be statistically analyzed or compared to normal visual field results. Statistical analysis is an essential component to visual field analysis without which results can be misleading and yield errors of interpretation. Finally, with the existing fast threshold testing methods, the time saved using screening strategies is not clinically useful, thus essentially removing that edge from screening tests.

Threshold involves a point by point sensitivity determination over the full visual field each point being tested individually. Although more time consuming and difficult, threshold visual field tests afford much more precision and data analysis capacity and provides the most definitive method of visual field assessment. In automated perimetry**,** full-threshold visual field testing is probably the standard strategy to adopt.

The HVF offers several threshold testing strategies:

(i) The **Standard Full-Threshold Strategy** uses a 4-2 dB double staircase strategy based on the starting value of 2 dB brighter than the subjects predicted threshold obtained from the four primary seed points. Threshold is taken to be the last seen stimulus after 2 threshold crossings.

(ii) The **Full Threshold from Prior Data** begins testing at 2dB brighter than the thresholds established in a previous visual field and follows the same bracketing strategy as the standard full-threshold strategy. This theoretically saves time since a reference hill of vision very close to threshold is already available and used throughout the test.

(iii) The **Fast Threshold Strategy** also begins from stored values but instead of re-establishing thresholds, this strategy tests the whole field at 2dB brighter than the stored values from a previous threshold visual field. Only the missed points are fully thresholded. The fast threshold strategy is practically a screening test since it uses a threshold-related stimulus 2dB brighter than the hill of vision. However, the actual hill of vision is used as a reference level instead of a “predicted” one. The method saves time since only deteriorated points are retested, but points that may be improving are not documented this way.

(iv) The **FASTPAC** is a full-threshold strategy that uses a different bracketing algorithm to reduce testing time (fig. 5.38). FASTPAC uses a 3dB step size instead of the 2dB step used in full threshold testing to determine threshold. One half the points are tested from a starting value of 1 dB brighter than expected, the other half from a starting point of 2dB dimmer. The threshold value is taken to be the **last seen stimulus after a single crossing** where the stimulus goes from being seen to non-seen or vice-versa. Threshold values that differ from the expected threshold by more than 4dB are re-tested, but the step of 3dB remains constant.

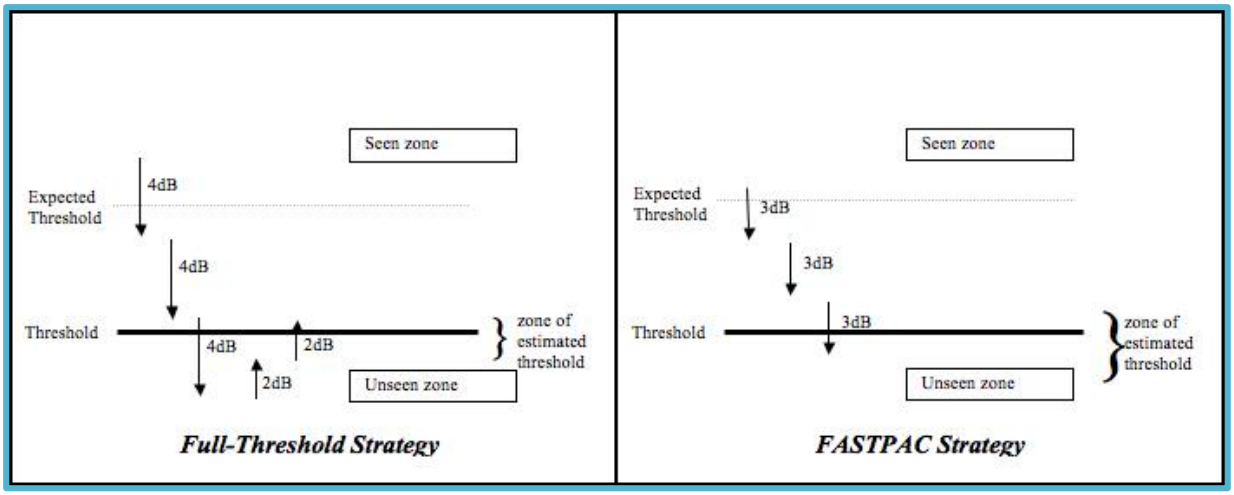


Figure 5.38: *Static screening test*

With Fastpac, a reasonably reliable threshold visual field can be performed with approximately 40% less required time, which is about 5min per eye. The time reduction is a significant advantage for the patient since it reduces fatigue, increases acceptability and facilitates cooperation. In fact, Fastpac may even increase reliability by allowing a threshold test in approximately the same amount of time as a screening test thus increasing patient compliance. Unfortunately, it may do so at the expense of other reliability and statistical indicators.

Fastpac is therefore a viable alternative to screening and fast threshold tests since it offers more information within similar time frames. It is frequently used as a first test in patients with suspected visual field loss since it produces clinically useful information while teaching patients how to perform more reliably subsequent tests. However, clinical decisions should probably not be based on Fastpac visual fields unless other clinical information supports the obtained result.

(v) **The SITA (Swedish Interactive Thresholding Algorithm)** is the most recent threshold strategy released for the HVF. SITA may reduce testing time by as much as 40% and maintain the same reliability as a full-threshold strategy. Two strategies exist: the SITA Standard which is designed to provide the same information of Standard Full-Threshold visual field and the SITA Fast which is designed to cut the test time of the Fastpac strategy.

In comparison to previous algorithms, SITA is more “active” in that it continuously adjusts its strategy based on the patient’s responses during a test. The test program tailors its approach according to the tested individual (both normative and individual data) allowing the test to run more efficiently.

First SITA considers known factors such as age, normative data and detailed characteristics of abnormal and normal tests to determine the stimuli to present. It thus starts with stimuli at each point that are already very near threshold, avoiding the long, inefficient process of gradually brightening or dimming the stimulus while searching for threshold.

Second, SITA “intelligently” uses the information contained in the patient’s responses to a given stimuli to efficiently determine the brightness of the next presented stimulus both at the tested point and at the next one. That means that SITA continuously uses the answers provided by the patient to modify its algorithm (strategy) as the test progresses. The SITA algorithm, therefore, is not fixed: it is “written” as the test runs using the answers given by the patient to most efficiently determine the threshold of each point.

In the same vein, SITA tailors its testing pace to each individual. In a threshold test, less than half the stimuli will be seen. Thus, the perimeter must decide how long to wait after a stimulus presentation before presenting another. The test must allow a reasonable amount of time between presentations, but waiting too long will unnecessarily prolong testing time, fatigue the patient and increase inaccuracy. SITA uses special techniques to measure the patient’s response time. SITA then adjusts its pace to closely match the patient’s response time, thus minimizing time lost between presentations.

SITA also uses an “information index” which is continuously calculated from the patient’s responses during the test to determine when to stop. The Standard Full Threshold strategy uses a fixed end-point and determines threshold after 2 threshold crossings. The “information index” provides data regarding the consistency of a given result in comparison to others. SITA is thus told to spend less time at locations where answers are in good agreement with one another and to test further where results are unsure.

At the end of the exam, SITA looks at the complete pattern of patient responses assessing it globally for factors such as response time and answer consistency. Unlike other strategies which use the last crossing of each point as the determined threshold value, SITA considers all the responses obtained for each tested point, which provide important reliability clues, to recalculate and refine the obtained measurements.

Kinetic vs. Static in Automated Perimetry.

The HVF allows both kinetic and static visual field testing. As discussed previously, static testing is more advantageous than kinetic testing since it allows more precision and more data analysis versatility. In fact, the relative ease of performing static perimetry on automated perimetry is one of its greatest advantages. Little information is currently available as to the additive value of kinetic isopters as an adjunct to central static testing. Kinetic perimetry is, however available and one should consider its use when clinically appropriate (e.g. patient unable to perform static testing, to establish visual field limits for driving, etc.). Nevertheless, the method of choice for HVF testing remains static perimetry.

White vs. Colour Perimetry

White is the standard stimulus used for perimetry. Colour perimetry is however possible with automated perimetry. Although controversial and not clinically widespread, colour perimetry has some clinical uses. The Red Automated Perimetry (RAP) and Short Wave Automated Perimetry (SWAP) tests are currently the most useful clinical options with the HVF.

Red automated perimetry (RAP) makes use of a red stimulus to test for central toxic maculopathies due to certain medications (e.g. chloroquine toxicity). A central 10° threshold test using red perimetry is believed to be more sensitive at detecting early loss in central sensitivity.

Short Wavelength Automated Perimetry (SWAP) may be valuable in detecting very early glaucomatous visual field loss and in predicting progressive glaucomatous damage. SWAP uses a size V blue stimulus (530nm) on yellow background (440nm), colours very carefully chosen to isolate the blue cone system as much as possible. Based on clinical studies, blue on yellow deficits may precede white on white visual field losses by several years. The main issue with SWAP remains the difficulty most patients have in performing the test.

Patient set-up / procedure (Fig. 5.39)

- Using full aperture thin rim trial lenses, insert Rx and near add (30 cm distance)
- Place Rx lenses as close to the eye as possible without touching the lashes
- To reduce fatigue in prolonged testing, it is better to be generous on the addition
- For astigmatic Rx < 1.00 DC the equivalent sphere is sufficient
- Use Rx and Add for central 30° ; remove for peripheral test
- Consider contact lens for Rx > +/- 10.00 D
- The HVF can calculate the required add if needed but it is not error free; one must double check its calculation
- Clean head and chin rests using alcohol swabs
- Comfortably position the patient in the instrument
- Adequately adjust chair and instrument height
- Instruct patient clearly on fixation target, response button and responses expected

- Patch non-tested eye; always test OD or better eye first
- Position patient's head on chin and forehead rest
- Use the head alignment level to center the pupil precisely with the reference point on the screen's eye video monitor
- Measure the pupil size; dilate if < 3mm
- Compensate physical obstruction if necessary
- (e.g. tape lid, tilt head for big nose)
- Provide strong encouragement notes
- Perform a demonstration run if necessary
- Run the test continuously monitoring fixation and adjusting centration
- Save on disc
- Print results
- Add pertinent comments to printout.

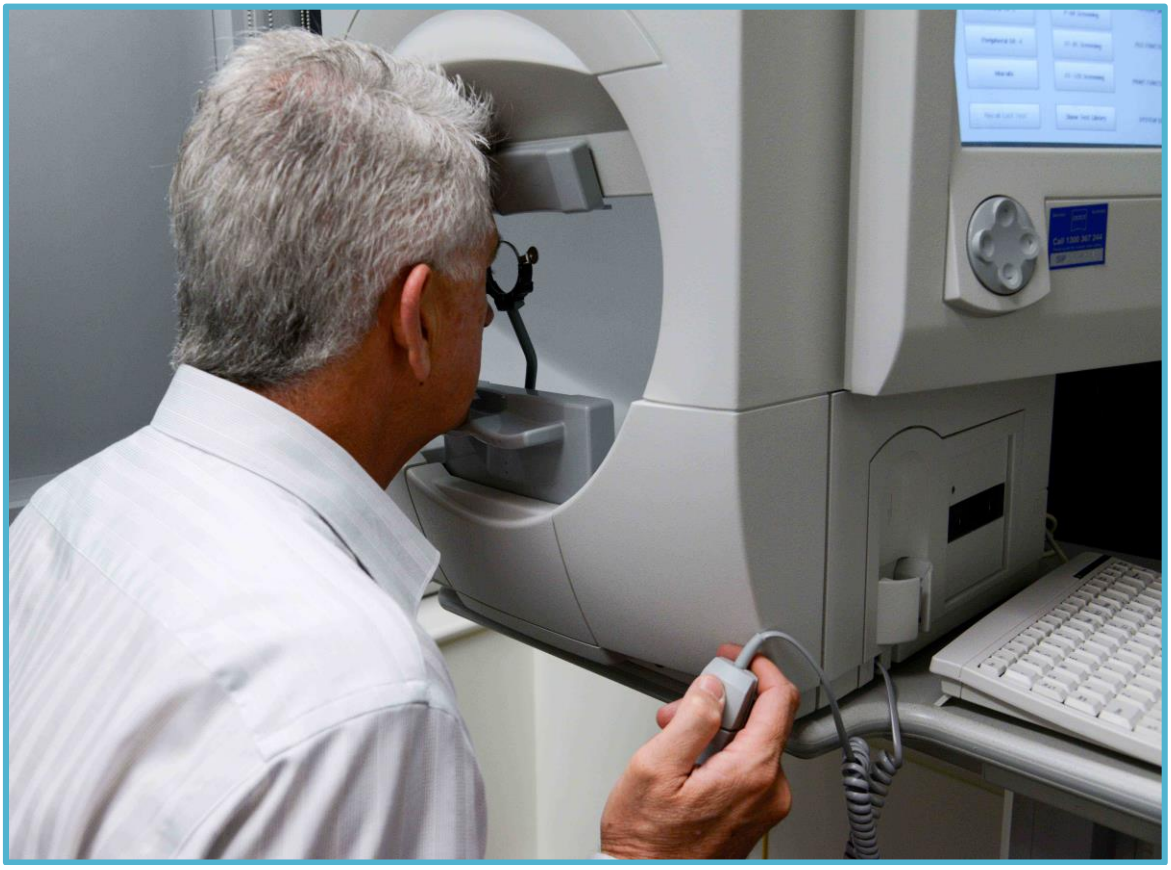


Figure 5.39: *Automated static screening test with HVF*

Tips

- Insist to patient on the importance of remaining as still as possible during the test
- Encourage the patient to take breaks, if mental or physical fatigue affects their concentration or positioning in the perimeter; instruct the patient to hold the response button in if they need a break
- Pause the instrument yourself if in the midst of the test, the patient appears tired, restless or moves excessively. Allow a break, reposition the patient and resume testing
- Constantly monitor the alignment of the eye during the test and make adjustments as needed to re-center the pupil. Adjustments can be made without stopping the test
- Do not pursue a test that appears unreliable from its very beginning. Stop the test, re-instruct the patient and re-start
- If the pupil is dilated or dilating during the visual field test, provide the full +3.25D add to compensate for the induced cycloplegia even on young patients
- Avoid the most common errors made in performing the HVF (Table 5.9).

- Poor patient alignment
- Poor patient instruction
- Poor encouragement notes
- Bad Rx especially Add!
- Bad vertex distance of Rx
- Examining wrong eye!
- Leaving the patient unattended during exam
- Running an initially poorly reliable field

Table 5.9: *Common error in performing HVF*

RECORDING: PRINTOUT AND DATA ANALYSIS

Most automated perimeters use printers either within the instrument or on the side to hard copy the results. The HVF printout involves a number of different printing and data manipulation options (Fig. 5.40). Understanding the printout format and the specific data analysis involved in automated visual field is crucial to their interpretation. The printout can be broken down in 4 parts:

1. Test Information

The first part of the printout includes the general patient information, test parameters and test protocol. Before proceeding with the analysis of a visual field printout, the test information should always be reviewed to ensure that the correct information was entered and obtained.

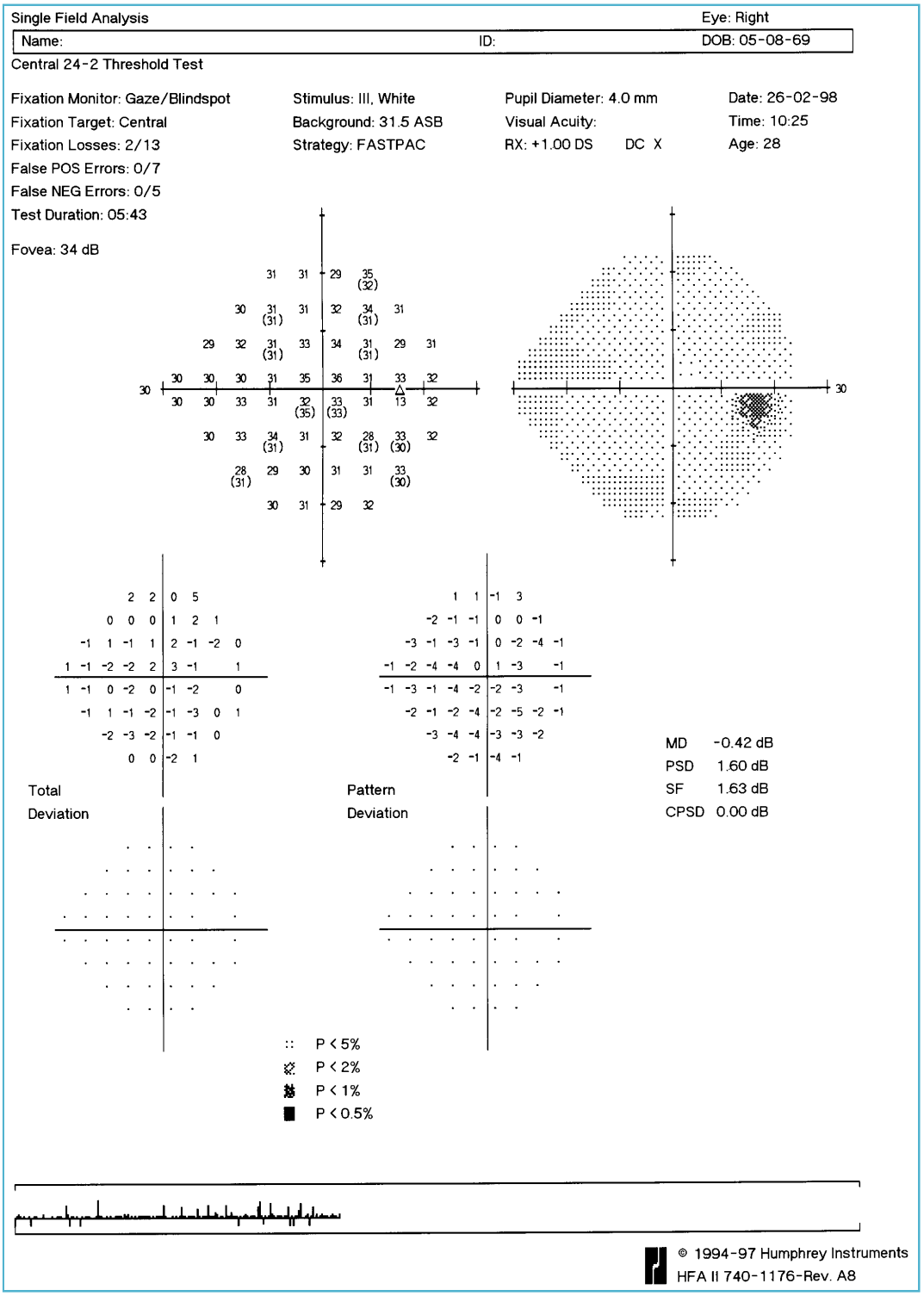
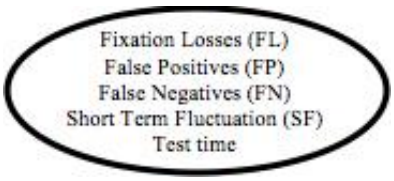


Figure 5.40: *HVF printout*

2. Reliability indices



The **reliability indices** indicate the extent at which a visual field result can be reliably interpreted. Questionable results render visual field interpretation practically unfeasible (but not always impossible!). A certain amount of "normal" error that does not significantly affect the results is generally permitted in automated perimetry. In certain cases, however, obviously unreliable results can still yield valuable and useful clinical information.

Fixation losses (FL) indicate the patient's ability to maintain fixation. The HVF uses the Heijl-Krakau method and randomly spot checks in the blind spot to test fixation. The number of times that the patient responds to a stimulus presented in the blind spot are counted as fixation losses. If FL are greater than 20%, the computer flags the visual field as being unreliable and crosses appear next to the FL number.

False positive errors (FP) give an indication of the patient's ability to respond truly to the visual stimulus. In a false positive error, the patient clicks as if a stimulus had been perceived but either it was sub-threshold or not presented. Some patients misunderstand the instructions, respond rythmically, are anxious, "trigger happy" or base their response on the HVF noises rather than to the actual visual stimulus. The HVF will occasionally not present any stimulus but still make the sound of projection to test for the patient's false responses. If the number of FP is greater than 33%, they are flagged by the computer.

False negative errors (FN) are an indication of the patient's level of attention. In a false negative error, the patient does not click even if a stimulus is perceptible (according to already established thresholds). The HVF occasionally presents very bright stimuli in areas where normal sensitivity has already been established. Inattentive or fatigued patients will not always respond to these stimuli and the HVF will flag the FN if they exceed 33%. An interesting point to remember about FN is that a high FN rate **may indicate diseases**. Some sick areas of the retina may require more time to recover from the bleaching effect of the first time that they are tested. Upon retest, the stimulus may not actually be seen, but the HVF interprets it as a FN.

The **test time** may be regarded as an additional indicator of visual field reliability. Lengthy subjective tests such as automated visual field render the procedure less reliable because of fatigue and loss of patient cooperation. In the HVF, test times that exceed 15-20 minutes for 1 eye should be regarded a little more suspiciously with regard to their reliability.

The **short term fluctuation (SF)** is an indication of the intra-test variability. Ten centrally located points are tested twice to measure the difference in response between the first and second test. As in any psychophysical test, a certain level of fluctuation in the obtained value is normal and expected. A higher than expected SF indicates unreliable patient responses. The HVF will flag SF that exceed age-matched normal values. It is noteworthy that like the FN, a high SF **may also indicate pathology**. If an area is diseased, it may respond well the first time that it is tested but not respond as well upon retest due to the bleaching effect and the decreased re-adaptive ability of the sick retina. The HVF interprets this as abnormal SF.

GRAPHIC REPRESENTATION

The visual field results can be represented graphically in a number of ways depending on the type of visual field performed.

Screening tests

In HVF screening tests, the visual field are graphically presented according to the test strategy used.

In **threshold-related schemes,** the points tested are shown as seen using an "○" or defective using a "v" (Fig 5.41).

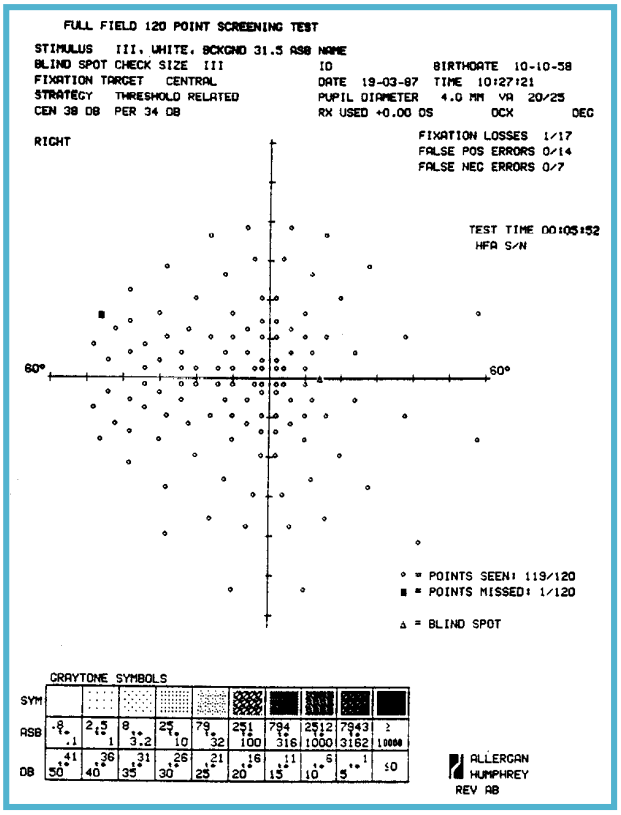


Figure 5.41: *Threshold related scheme*

In the **three-zone scheme** the same symbols are used but a “7” is used in addition to denote a relative defect (Fig. 5.42).

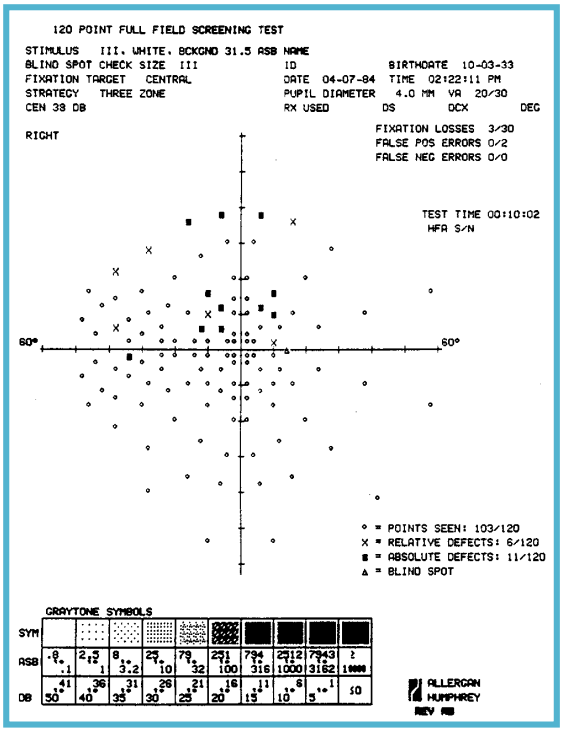


Figure 5.42: *Three-zone scheme*

In the **quantify defect scheme,** a value is given that represents the depth of the defect from the expected value (Fig. 5.43).

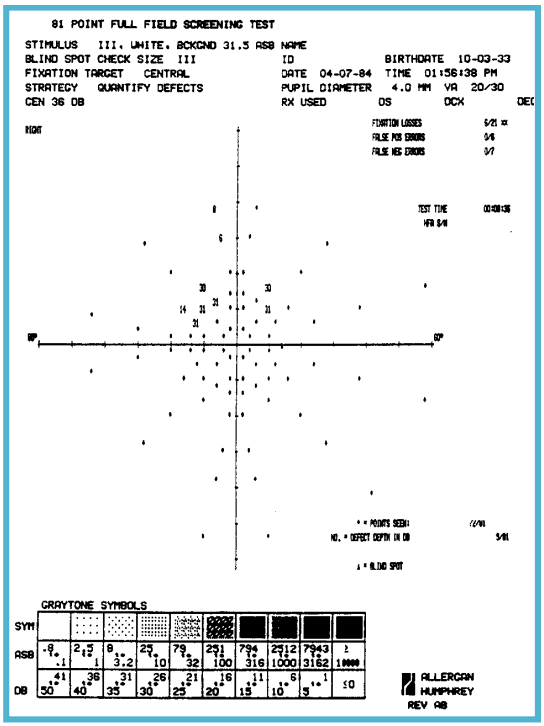


Figure 5.43: *Quantify defect scheme*

THRESHOLD TESTS

Threshold visual field can be represented using **numeric, graytone or profile** formats (Fig. 5.44).

The **numeric plot** grid is a simple graphical representation of the actual sensitivity (threshold) of the tested retinal point in decibel. Values that depart from the expected value by more than 5dB are retested automatically to insure that the departure is not simply a mistake in the patient's response. The re-test value is presented in brackets below the first. If a Fast-Threshold Strategy is used, the numeric plot will show the reference level in brackets below each tested point. The Fast-Threshold tests each point at 2dB above the reference level which is in fact the result of an earlier test.

The **threshold graytone** is a graphic representation that uses different shades of gray to represent different levels of retinal sensitivities. The HVF reorganizes the numeric dB scale into 10 gray scale steps of 5 dB each. The darker grays are used to indicate the lower dB values, hence the less sensitive areas. The graytone graph yields a gross overview of the visual field. Be aware that it is not compared to age-matched expected values and it may be dangerous towards visual field interpretations. Furthermore, in the grayscale, the interval between tested points intervals is interpolated and truly misrepresents what the actual visual field may be in those areas.

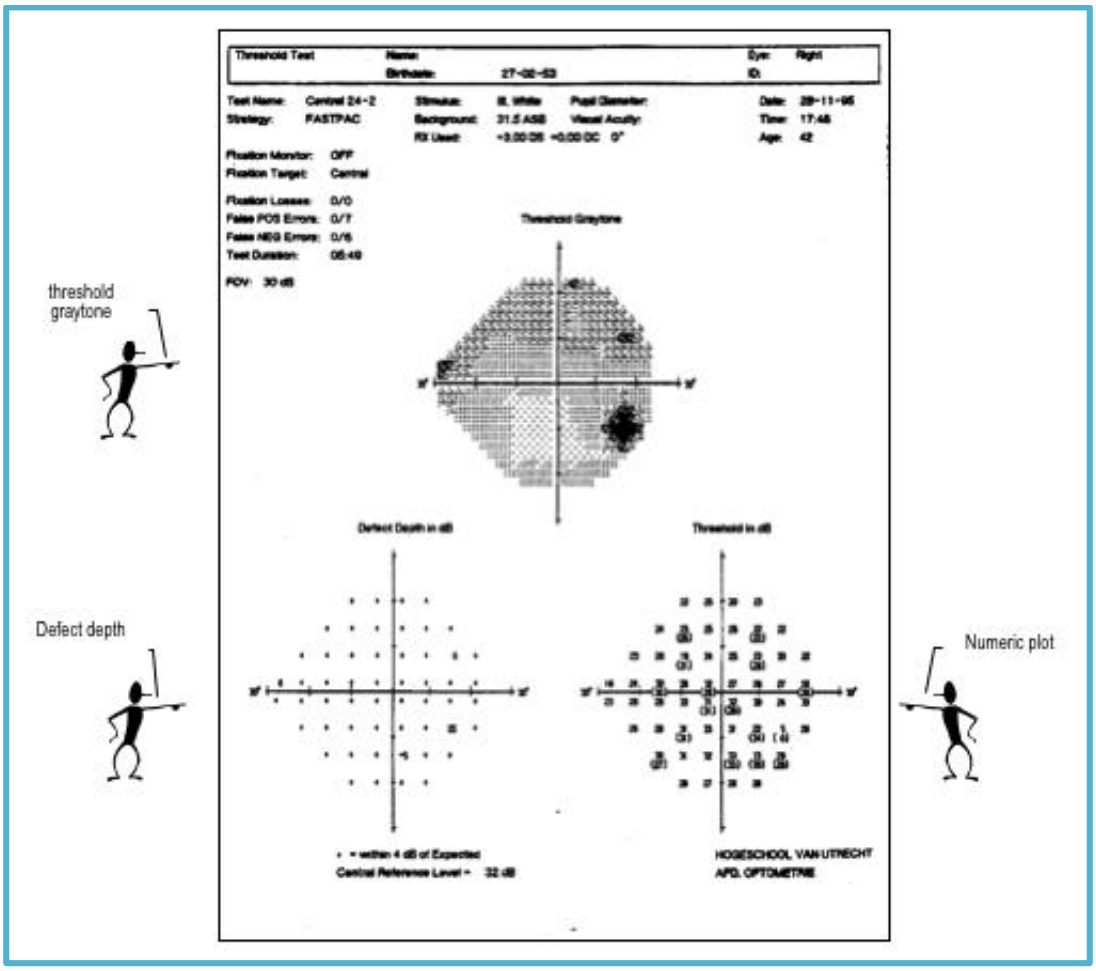


Figure 5.44: *Representation of the threshold tests*

Finally, the threshold **profile** format is a “section” outline of the hill of vision through any chosen meridian (fig. 5.45).

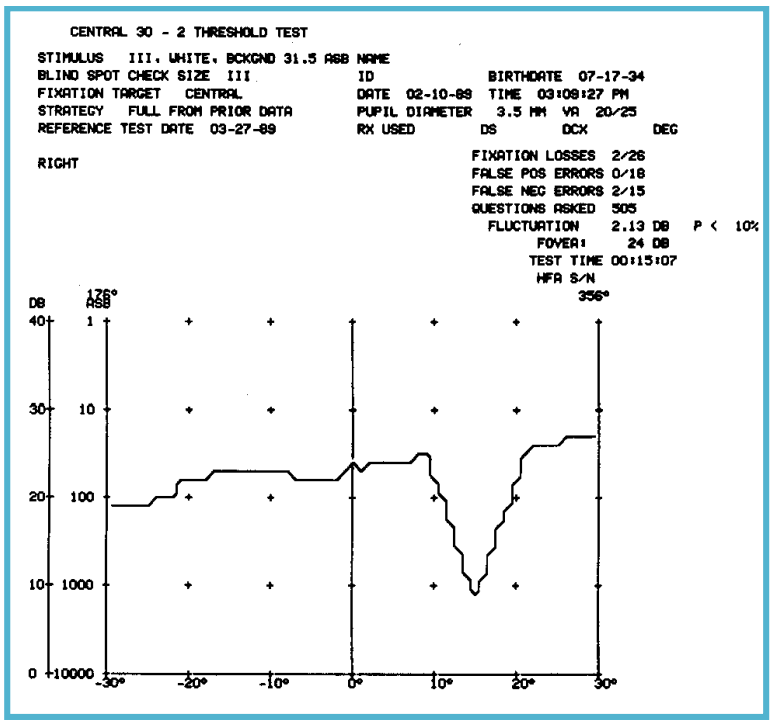


Figure 5.45: *Threshold profile format*

An example of the numeric plot in a Fast Threshold strategy (fig. 5.46). The circles indicate that the stimulus at 2dB brighter than the reference level in bracket is seen.

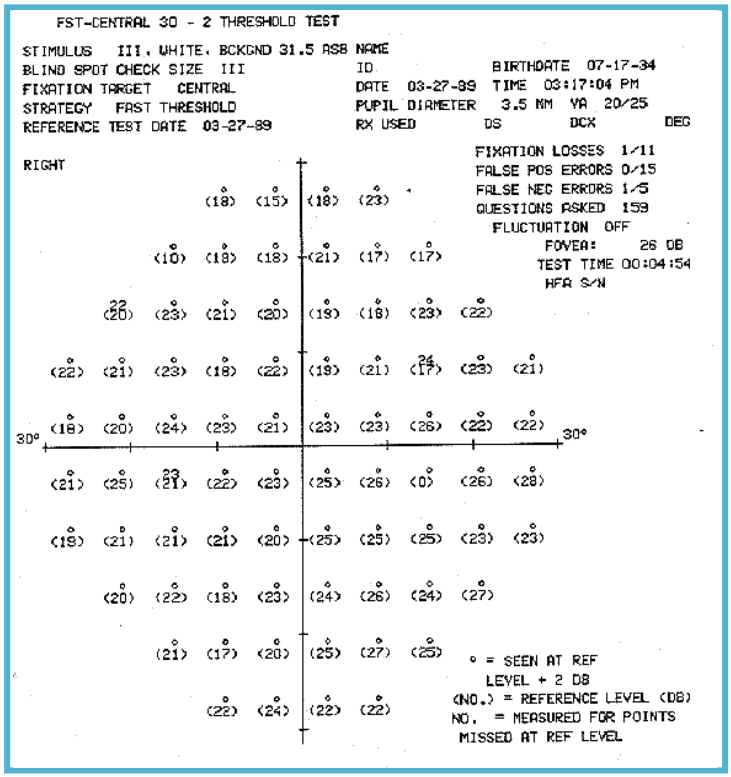


Figure 5.46: *Numeric plot in a fast threshold strategy*

Threshold visual field results can also be presented using simple data manipulation schemes such as **Average and Compare.**

Average calculates the mean of up to 5 visual field results onto a single graph and presents in graytone, defect depth or dB values (Fig. 5.47).

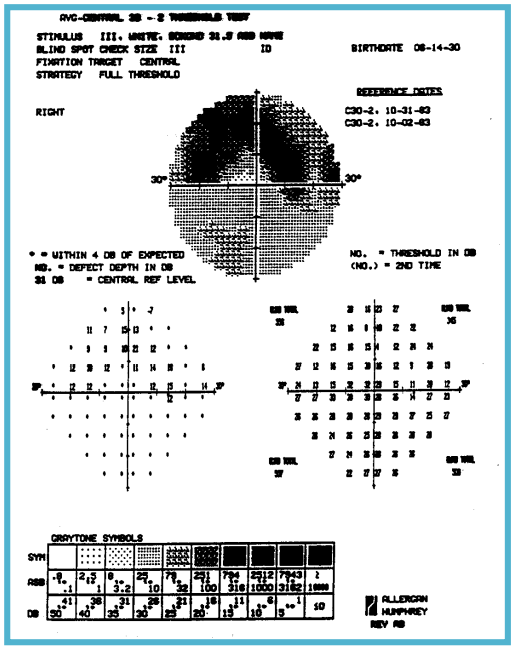


Figure 5.47: *Average threshold visual field*

Compare calculates the numerical difference between the last visual field and the new field for a quantitative measure of change is sensitivity.

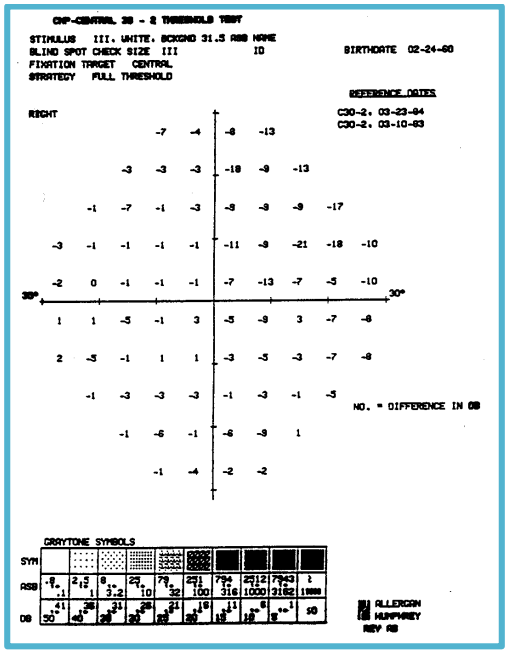


Figure 5.48: *Compare threshold visual field*

(Fields drawn from Humphrey Field Analyzer Capabilities & Applications, Allergan Humphrey, 1989).

STATPAC ANALYSIS

The range of visual field responses in the normal population is very extensive and the amount of data obtained in automated perimetry is quite vast. In addition, a precise psychophysical method such as automated perimetry can be coated with testing artifacts (e.g. fluctuations, media scatter, etc.). Differentiation of normal from abnormal results and interpretation of automated visual field therefore becomes a very complex process and nearly impossible without the use of statistical analysis.

Statpac is a statistical package that is provided with the HVF to analyze visual field results. Statpac includes a database of reliable visual field results that serves as the basis for comparison. The database was obtained empirically from a large number of experienced normal individuals of different age groups. Statpac establishes the point by point numerical difference between the measured visual field results and the **age-matched normal** results**.** Unwanted information is also mathematically filtered out to make truly suspicious areas more obvious.

Numerical differences, however, are not sufficient since one can never say with 100% certainty that a given result is normal or abnormal. In some instances, an apparently abnormal result (e.g. a foveal threshold of 20dB in a 20 year old person) can be found in completely normal individuals, just like a normal person can be 2.5 meter tall. The probability of that occurrence is very low but not impossible. Given the range of normal results, only the likelihood or probability of finding the given result in the normal population can be established.

Statpac uses the database and statistical manipulation to determine a **probability match** for each numerical result obtained in the visual field. **Probability matches indicate the statistical likelihood that the obtained value at a given point is found in the age-matched normal population**. HVF probability matches are denoted by “p” values of ½, 1, 2, 5 and 10%. For example, p<5% indicates that the threshold obtained is a possible normal occurrence in less than 5% of the normal population of the same age as the patient. Obviously, the lower the p-value, the higher the chance that a given result is abnormal. One must remember, however, that it is never possible to affirm with 100% certainty that a given result is abnormal, because everything is possible!

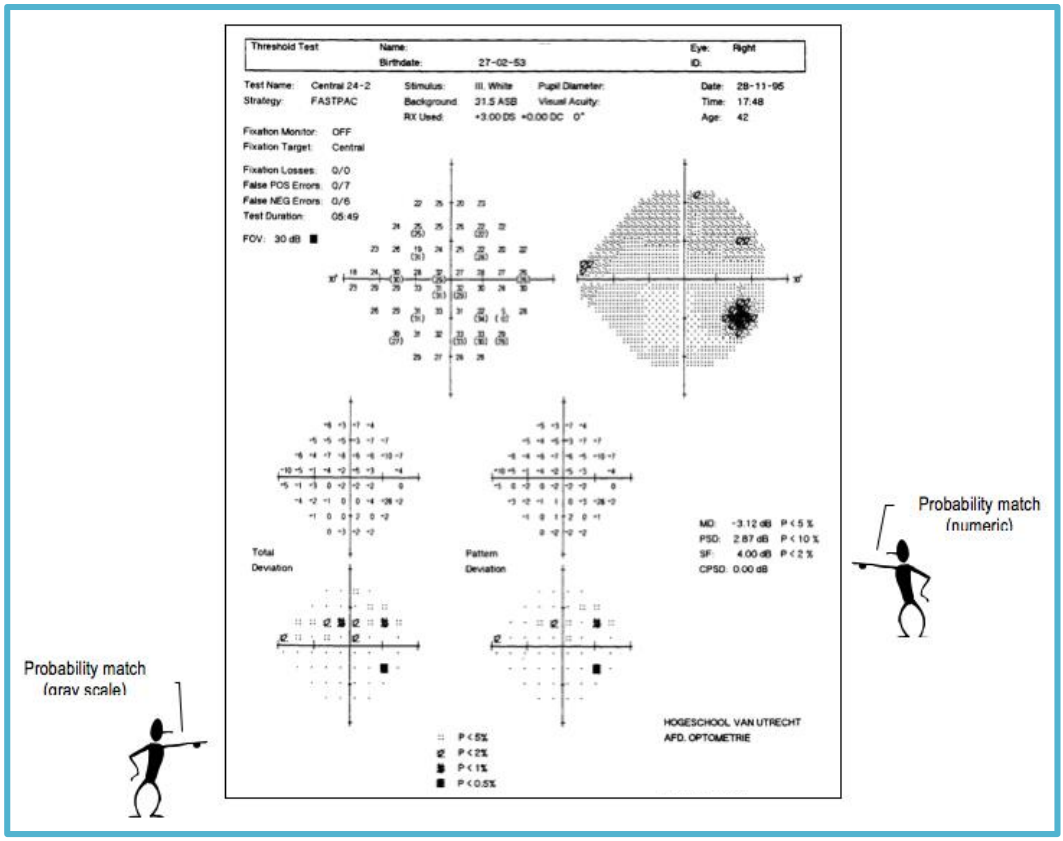


Figure 5.49: *Statpac printout*

In assessing Statpac results, one must bear in mind that statistics are far from representing the perfect science and Statpac is not free of errors. If all statistical parameters (no p-values are given) produced by Statpac are within normal range, chances are the visual field is normal. The opposite is not true. Due to the high number of artifacts related to automated perimetry, statistical parameters often appear abnormal in the presence of normal patients with normal visual field.

Probability matches can be graphed using a gray scale format. Dark shades of gray indicate a lower probability match, therefore darker spots are most likely abnormal**. Do not confuse the probability match gray scale with the graytone printout**. In the graytone printout, dark areas indicate low sensitivity areas: the darker the area, the less sensitive ("blinder") the area. In the probability match graph, darker spots simply indicate lower probability of occurrence - they do not indicate non-seeing areas!

Statpac can investigate and present the results in a number of clinically useful manners either numerical or graphical (Table5.10). An additional and noteworthy advantage of Statpac is the compilation of visual field results that allows quantifiable change analysis to be made over time.

Statpac I	• Single Test Analysis Foveal Threshold Total Deviation Plot Pattern Deviation Plot Global Indices Glaucoma Hemifield Test • Change Analysis Box Plot Summary of Global Indices Linear Regression Analysis of MD • Overview Global view of up to 16 tests on 1 page
Statpac II	• Glaucoma change probability analysis • Modified Linear Regression analysis of MD

Table 5.10: *Uses of Statpac results*

Note: Statpac II is an update of the original Statpac I version.

SINGLE TEST ANALYSIS

The single test analysis involves statistical investigations of the data obtained within a single visual field test. The analysis provides 5 useful numerical or graphical formats (Fig. 5.50):

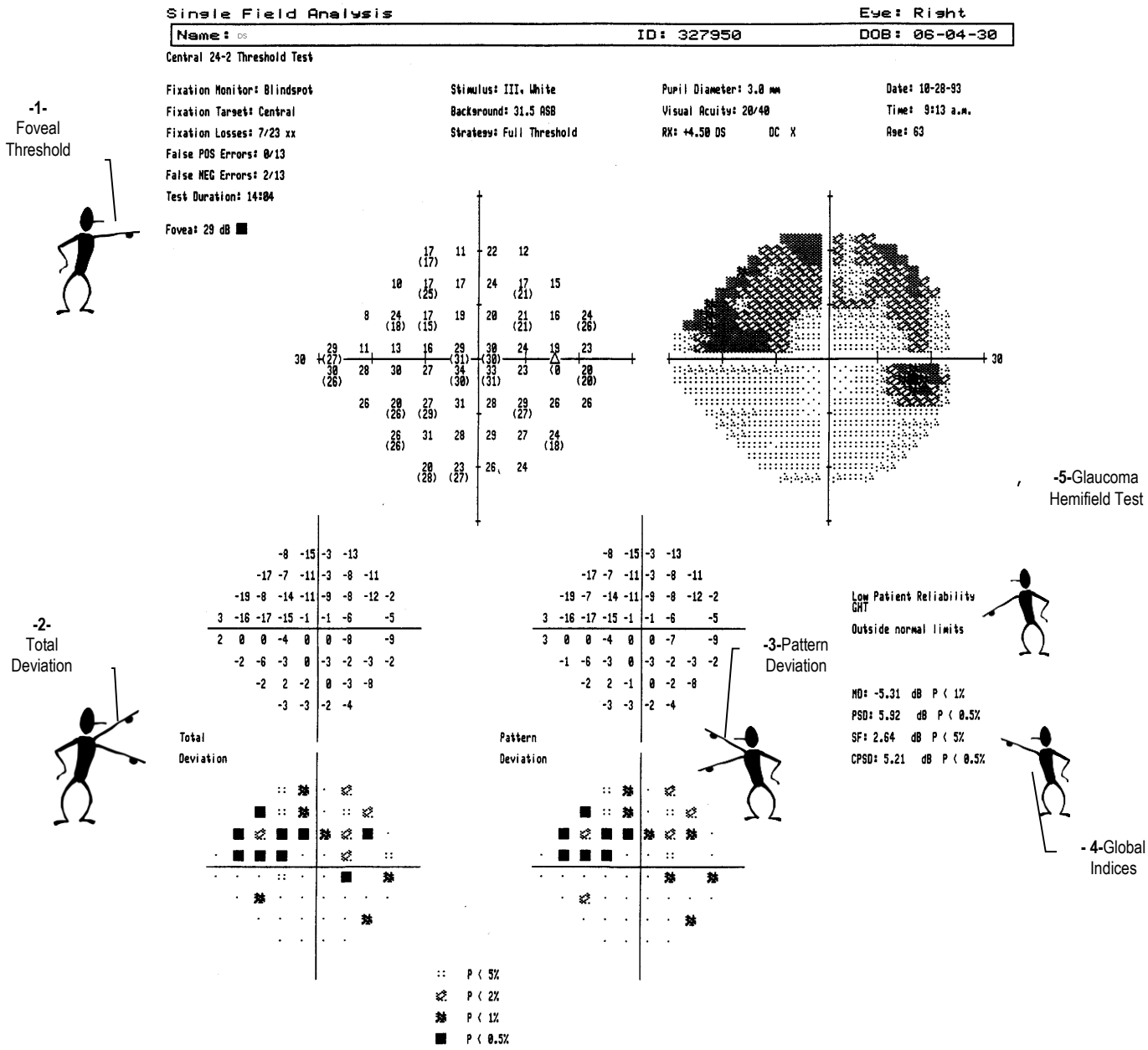


Figure 5.50: *Standard HVF threshold printout*

1. The **Foveal Threshold** obtained at the beginning of each visual field is compared to the values in the age-matched normal individuals. The foveal threshold will have an assigned probability match if it falls outside the normative range.
2. The **Total Deviation Plot** is a numeric **defect depth and probability plot** of the obtained visual field in comparison to the **age-matched normal population results**. The graphical representation indicates global deviations (defect depth) of the results from normal patients found in the database (expected norms). Deviations (scotoma, depressions) are plotted in a numerical graph indicating the difference between the obtained value and the expected value. The probability plot represents graphically the probability that the obtained threshold value for a given point is found in the normal population. Refer to Fig. 5.51.

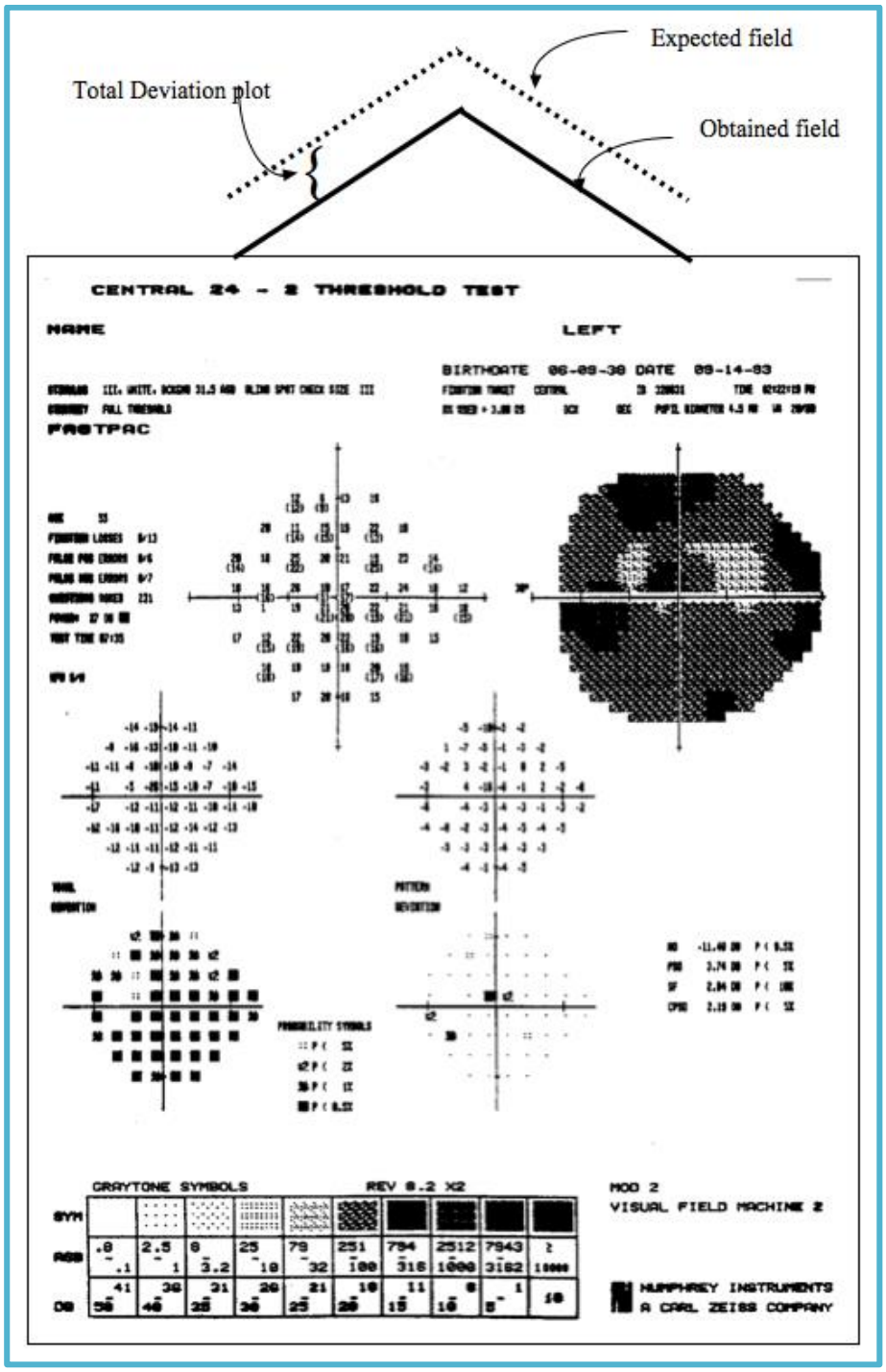


Figure 5.51: *The total deviation shows a typical VF with general reduction in sensitivity with respect to expected results in age-match normal individuals*

3. The **Pattern Deviation Plot** is a statistical representation that adjusts the "general height" of the hill of vision obtained for an overall decrease or increase in sensitivity. Focal defects can be "buried" within generalized defect and not show up on the Total Deviation Plot. If the hill of vision is reduced overall by a statistically significant value (e.g. p< 0.5%), a deeper scotoma along the visual field will not reduce the p-value even more. The apparent total deviation will remain the same and the focal defect will not be manifest. A clinical example of this is a glaucomatous defect in a patient with significant cataracts! Refer to Fig. 5.52.

4. The Pattern Deviation Plot removes or filters out a **common denominator** (common factor) found within each field point tested. By eliminating a homogeneous component of the field, deeper, more localized deviations will surface on the graph. A numeric plot is then used to indicate the actual difference of the tested point from the expected level. A probability plot denotes the statistical distribution of the noted difference within the normal population. It follows that if no general reduction or increase in sensitivity is noted, the total deviation and Pattern Deviation Plot will be identical. Clusters of 2 or more points together on the PD graph should be considered as suspicious if they are repeatable on separate tests.

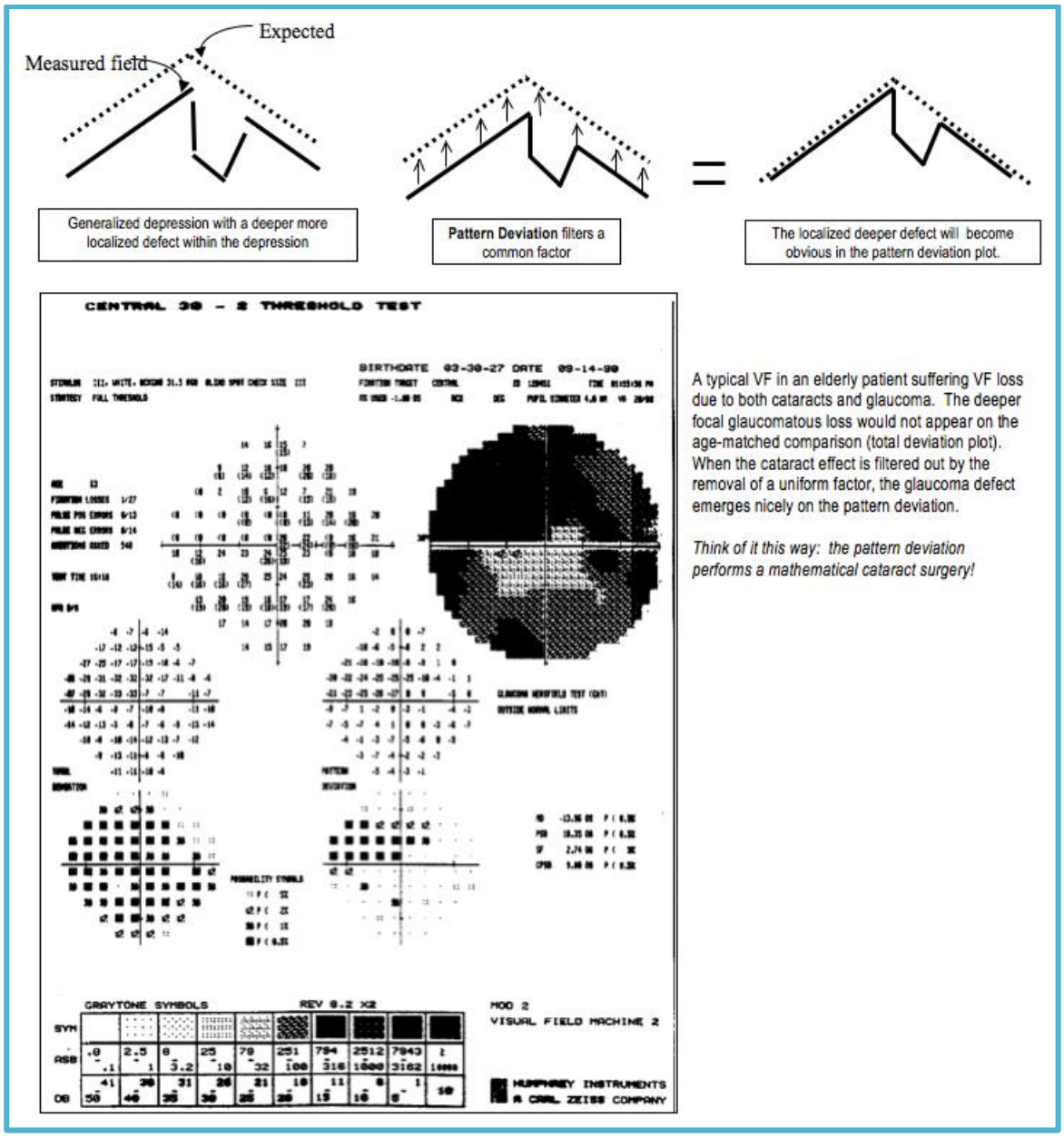


Figure 5.52: *A typical VF in an elderly patient suffering VF loss due to both cataracts and glaucoma*

5. The **Global Indices** are overall numeric representation the obtained visual field results. Similar to Total and Pattern Deviation Plots, they allow quantification and separation of diffuse damage from local scotoma. The indices however provide additional information that allow differentiation of true defects from 'noise' and facilitate the follow-up of visual field especially when the field defect deepens without visibly enlarging. The actual formula used to calculate indicators in automated perimetry is complex and beyond the scope of this reading. The concepts can however be demonstrated using a simplified numerical scheme that assumes that the hill of vision is flat and contains 10 points (see examples below)

The **Mean Deviation (MD)** represents numerically the difference in average height of the hill of vision (mean sensitivity value) from its expected value. One can think of the MD as being the global numeric representation of the Total Deviation Plot. The sensitivity values obtained over the whole field are averaged and compared to age-matched normal values. Like any average value, the MD is not affected so much by small focal numerical deviations (focal scotoma!) unless they are extreme (deep scotoma!). The MD is an indicator of the size of visual field defects and is most affected by diffuse damage such as general depressions and large or deep scotoma. Refer to Fig. 5.53.

situation # 1 : *small non-significant fluctuations along field*

expected field:	30 30 30 30 30 30 30 30 30 30	mean sensitivity = 30 dB
obtained field:	30 32 28 30 30 32 34 26 26 30	mean sensitivity = 30 dB
		MD = 0 dB

situation # 2: *overall general field depression*

expected field:	30 30 30 30 30 30 30 30 30 30	mean sensitivity = 30 dB
obtained field:	28 26 26 24 26 26 26 28 30 28	mean sensitivity = 27 dB
		MD = - 3 dB

situation # 3: *small but deep defect along field*

expected field:	30 30 30 30 30 30 30 30 30 30	mean sensitivity = 30 dB
obtained field:	30 30 16 16 30 30 30 30 30 30	mean sensitivity = 27 dB
		MD = - 3 dB

Figure 5.53: *Calculation of mean deviation*

The Pattern Standard Deviation (PSD) is a representation of the uniformity (smoothness) of the hill of vision. The PSD, as the name denotes, is a measure of the standard deviation of the obtained threshold values from the expected values. It represents the variability or irregularities along the hill of vision. Contrary to the MD, large field depressions will not affect the PSD dramatically. Numeric variations from focal scotoma and response fluctuations which render the visual field uneven will affect it most. The PSD can therefore be thought of as a global numeric representation of the Pattern Deviation Plot. This can also be shown numerically using the 10 point flat hill of vision scheme (Fig. 5.54):

situation # 1 (small non-significant fluctuations along field)

expected field: 30 30 30 30 30 30 30 30 30 30 — mean sensitivity = 30 dB

obtained field: 30 32 28 30 30 34 34 26 26 30 — mean sensitivity = 30 dB

$$PSD = [\sum (\text{point value - mean value})^2 / \#\text{ points}]^{1/2}$$
$$= [(0+4+4+0+0+16+16+16+16+0)/10]^{1/2} = 2.68$$

MD = 0 dB
PSD = 2.68

situation # 2 (overall general field depression + small non-significant fluctuations along field)

expected field: 30 30 30 30 30 30 30 30 30 30 — mean sensitivity = 30 dB

obtained field: 24 26 22 24 24 28 28 20 20 24 — mean sensitivity = 24 dB

$$PSD = [\sum (\text{point value - mean value})^2 / \#\text{ points}]^{1/2}$$
$$= [(1+1+1+9+1+1+1+1+9+1)/10]^{1/2} = 2.68$$

MD = - 6 dB
PSD = 2.68

situation # 3 (small but deep defect along field)

expected field: 30 30 30 30 30 30 30 30 30 30 — mean sensitivity = 30 dB

obtained field: 30 30 16 16 30 30 30 30 30 30 — mean sensitivity = 27 dB

$$PSD = [\sum (\text{point value - mean value})^2 / \#\text{ points}]^{1/2}$$
$$=[(9+9+121+121+9+9+9+9+9+9)/10]^{1/2} = 5.6$$

MD = - 3 dB
PSD = 5.6

Figure 5.54: *Calculation of pattern standard deviation*

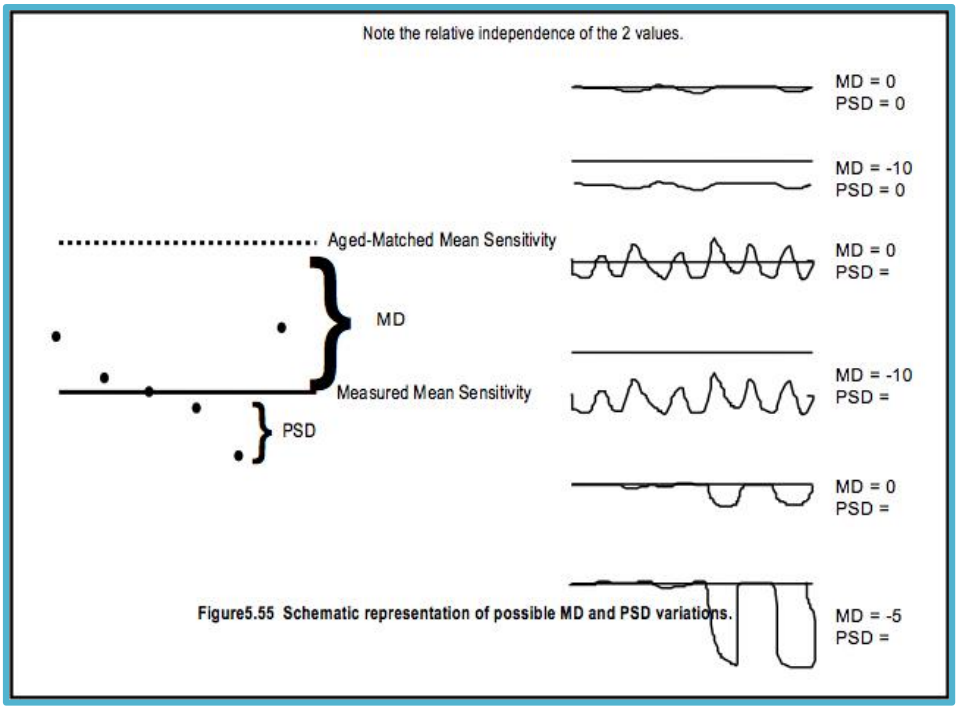


Figure 5.55: *Schematic representation of possible MD and PSD variations*

A VF with generalized or diffuse loss secondary to cataracts (Fig. 5.56). Notice how significantly the MD is affected (p< 0.5%).

The PSD is also affected but less significantly than the MD (p<5%). The small defect noted in the pattern deviation may be caused by the non-uniformity of the cataract. This results in deeper loss of sensitivity at certain points across the field and hence affect the PSD.

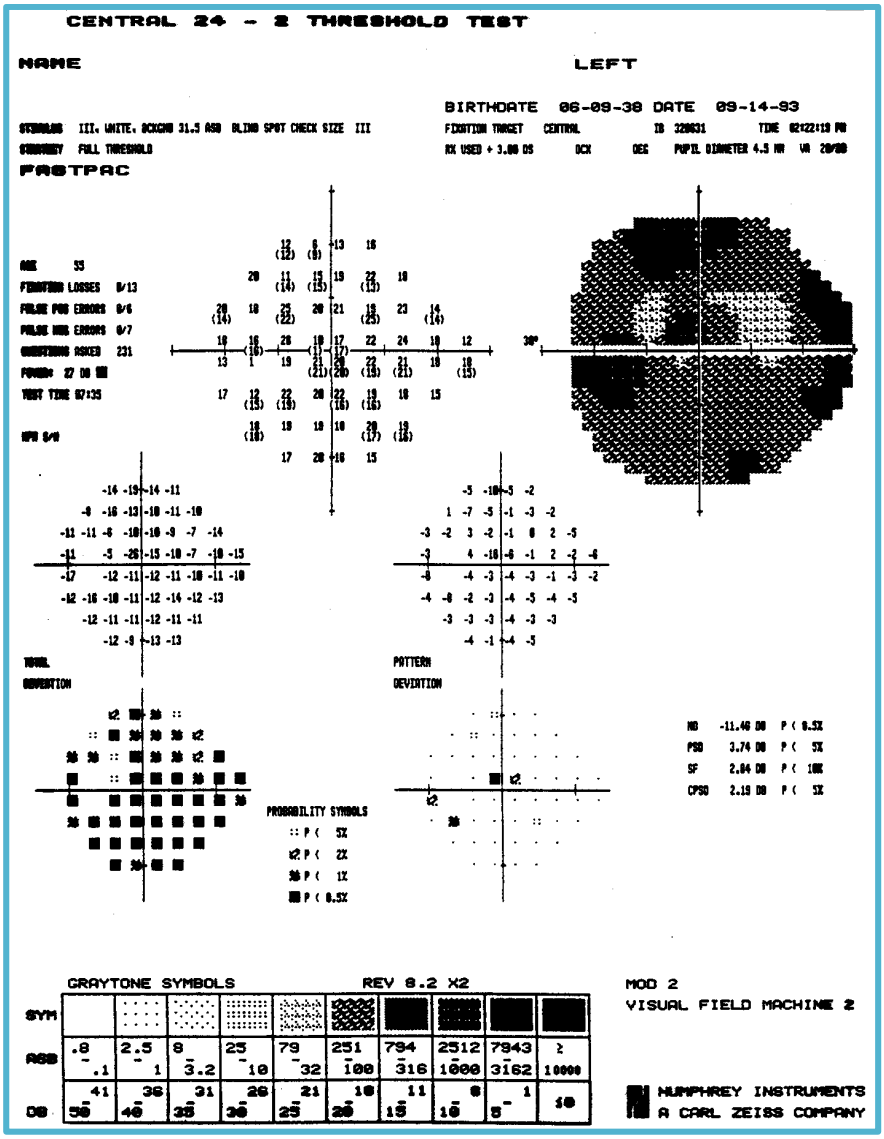


Figure 5.56: *A VF with generalized or diffuse loss secondary to cataracts*

Below is a VF with a very deep local defect (Fig. 5.57). The PSD is markedly affected by the defect causing a pronounced “irregularity” in the field.

The MD is also affected because the defect is very deep, but it is only minimally affected (-2.72 dB p<10%).

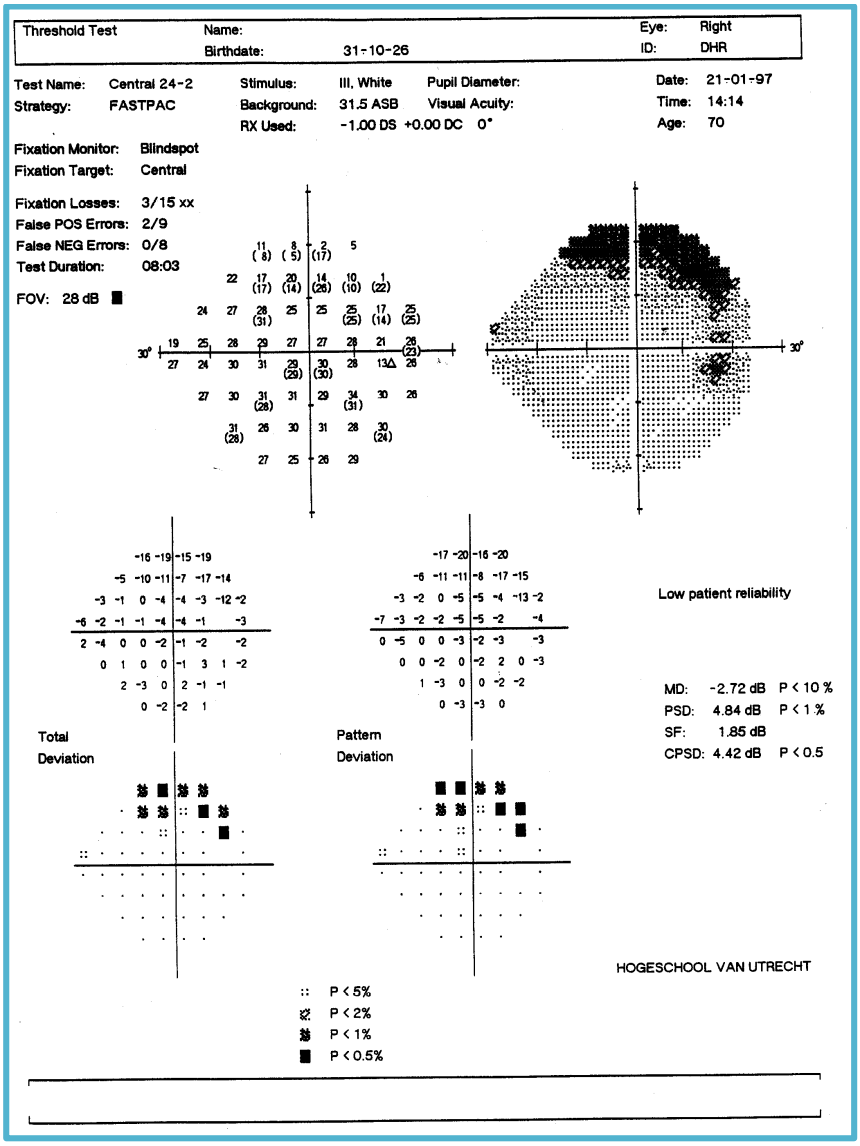


Figure 5.57: *A VF with a very deep local defect*

The **Short Term Fluctuation (SF)** is a measure of the intratest variability. A specific point tested twice may not yield the exact same dB value even if it is tested within a small interval. In the HVF, the SF is calculated by testing 10 specific points 2 times and averaging the differences obtained. A high SF usually indicates unreliable responses, but it can also denote an early disease process, as discussed previously.

The **Corrected Pattern Standard Deviation** (CPSD) is the PSD corrected for the SF. SF fluctuations can make the field appear very irregular. High intratest variability will adversely affect the numerical uniformity of the hill of vision and hence mathematically increase the PSD. The CPSD can be considered in principle as the PSD minus the deviation caused by the SF. If the SF is small, the CPSD and PSD will be very similar. If the SF is high, the CPSD will usually be significantly smaller than the PSD. The CPSD is a more reliable indicator of the smoothness of the field. Just like the PSD, it will be most affected by small scotoma.

With the increasing use of the SITA strategy, newer automated perimeter have ceased to include SF and CPSD.

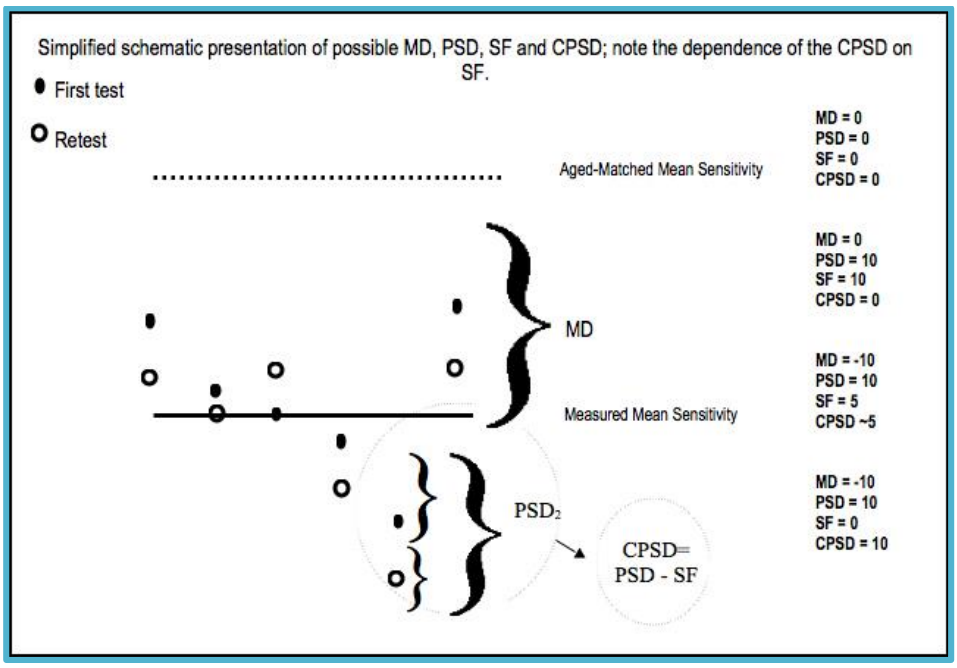


Figure 5.58: *Simplified schematic presentation of possible MD, PSD, SF and CPSD*

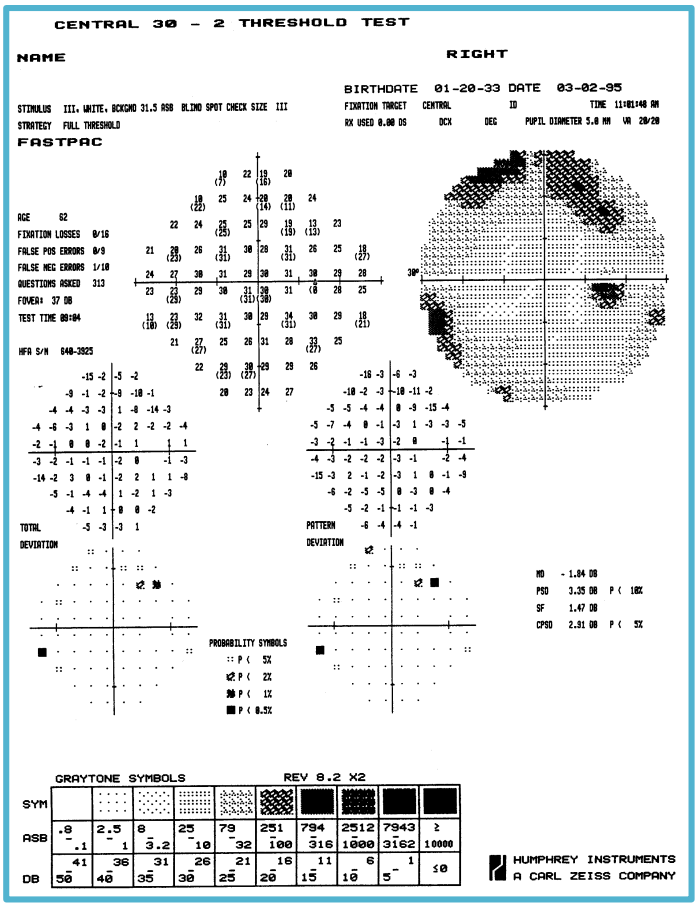


Figure 5.59: *The small VF defect may be true. The SF only partially accounts for it and the CPSD is significantly affected (p<5%)*

SUMMARY OF GLOBAL INDICES GRAPHIC REPRESENTATION

	Indicative of:	Sensitive to:
MD	Height of the hill of visionwith respect to age-matched normals	Diffuse damage Progression of advanced stages Deep local scotoma
PSD	Smoothness of hill of vision Uniformity of visual field loss	Small scotoma Fluctuation
SF	Response variability	Unreliable patient Early disease
CPSD	Smoothness of hill of vision Uniformity of visual field loss	Small scotoma

Table 5.11: *Summary of global indices*

Based on the above explanations, the most important global indices are probably the MD and CPSD. By looking at these 2 values, it is possible to predict the nature of the visual field defect even without looking at the graphical representation. However, CPSD and SF are not useful when using SITA software and these indices have been removed from newer machines that use SITA.

		Most probable **visual field result:**
MD CPSD	Normal Normal	Visual field is probably normal
MD CPSD	≠ Normal Normal	Most probably a pure generalized defect is present
MD CPSD	Normal ≠ Normal	Most probably a small purely localized defect is present
MD CPSD	≠ Normal ≠ Normal	Most probably a large defect with a localized component Or artifacts are present

Table 5.12: *Summary of global indices*

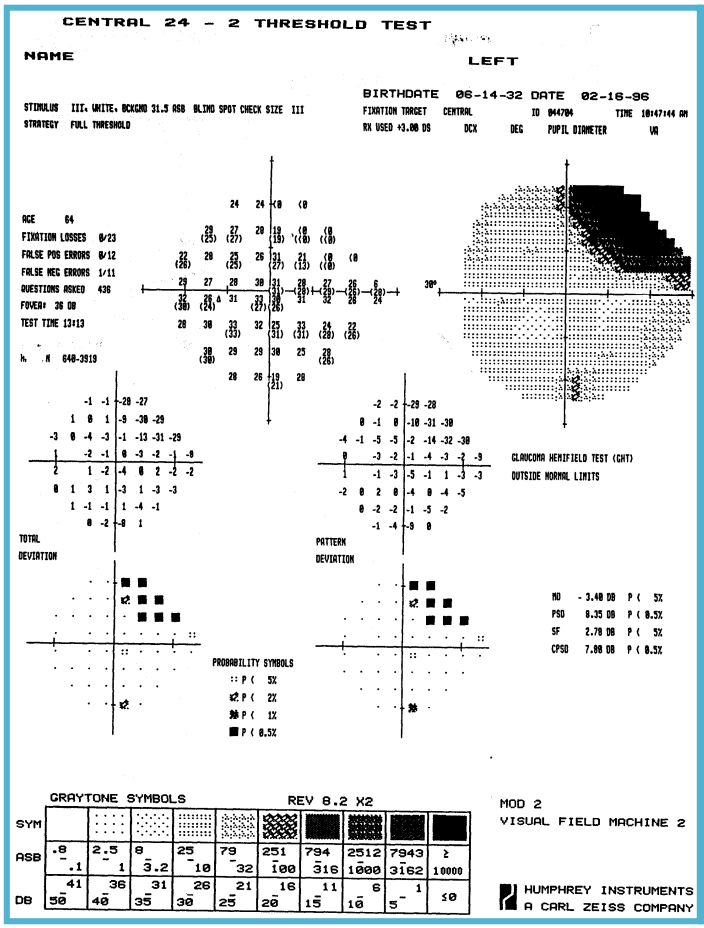


Figure 5.60: *A true focal VF defect*
The CPSD is significantly affected while the MD isn't.

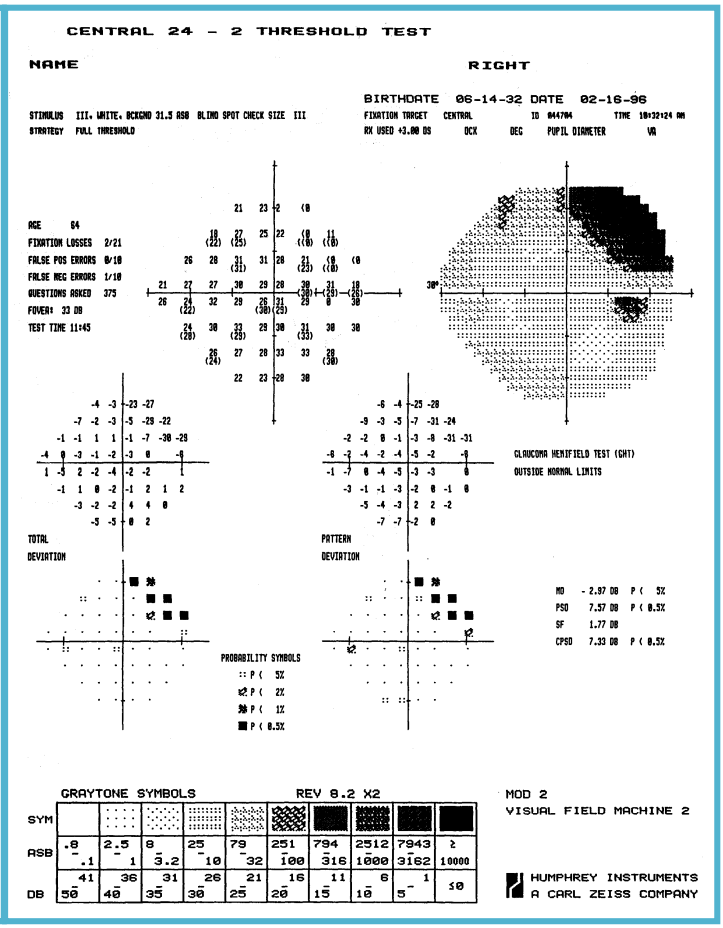


Figure 5.61: *The right eye of the VF on the left*
Notice how the CPSD is slightly altered by the SF. The SF in this case may be increased because of the presence of disease.

THE GLAUCOMA HEMIFIELD TEST

The **Glaucoma Hemifield test (GHT)** is based on the anatomy of the nerve fiber layer (NFL). The GHT evaluates 5 zones in the superior field and compares these zones to their mirror image zones in the inferior field. Primarily intended to facilitate the observation of asymmetric defects between superior and inferior hemifields, it also indicates diffuse visual field loss and abnormally high sensitivities.

The point-by-point results are based on Statpac pattern deviation maps rather than on threshold numerical values (note: there is some uncertainty as to whether the pattern deviation or pattern standard deviation is used). The analysis shows the significance of deviations from normal age-matched values corrected for overall sensitivity. The GHT enhances the detection of early defects that may be more visible in one hemifield in comparison to the other. Five possible results can be obtained from the GHT.

- Within normal limits → no significant difference between sup. and inf. fields
- Borderline → significant difference (p< 3%)
- Outside normal limits → significant difference (p< 1%)
- General reduction of sensitivity → overall depression (p<0.5%) - no hemifield difference
- Abnormally high sensitivity → abnormally high sensitivity (p< 0.5%)

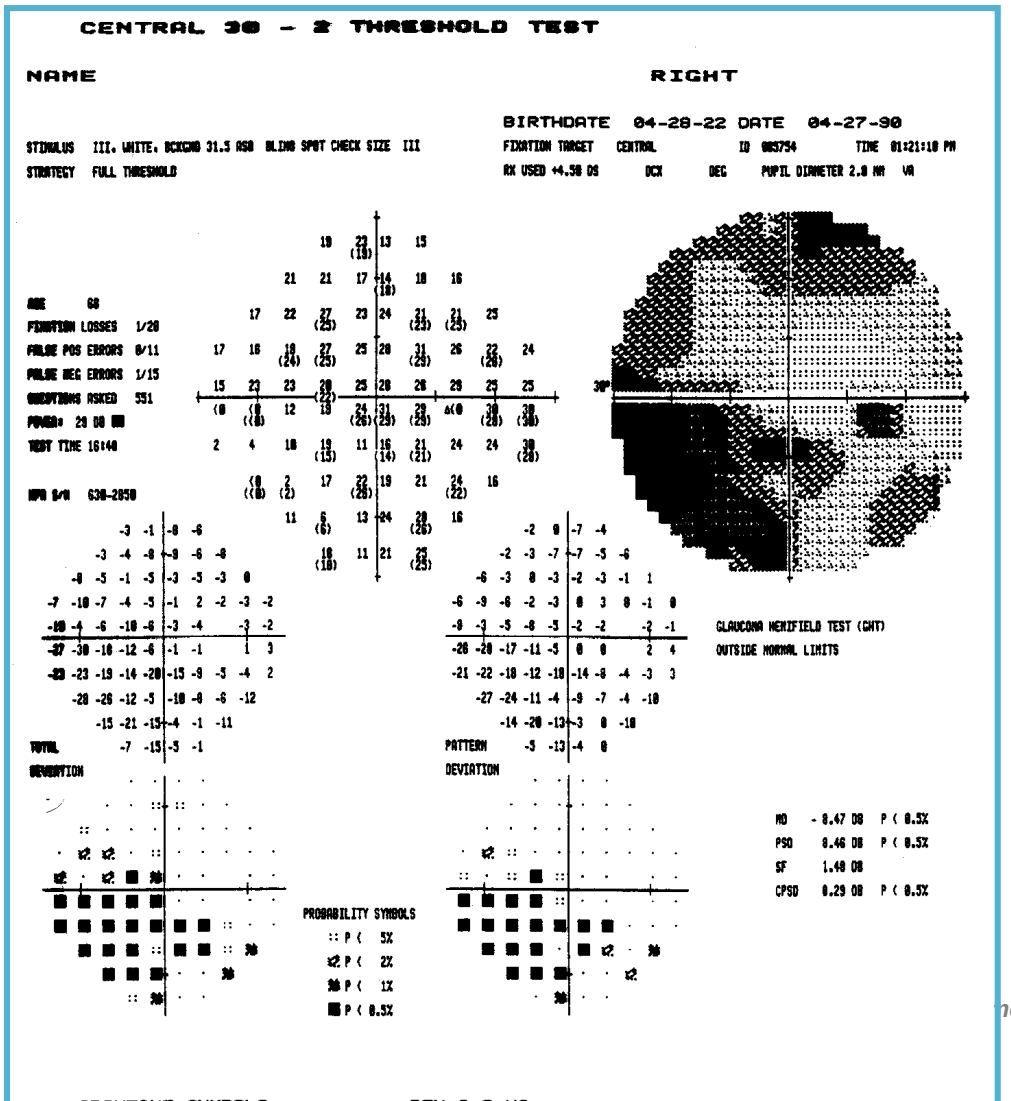

CENTRAL 30 - 2 THRESHOLD TEST
NAME
RIGHT
BIRTHDATE 04-28-22 DATE 04-27-90
STIMULUS III, WHITE, BCKGND 31.5 ASB BLIND SPOT CHECK SIZE III
STRATEGY FULL THRESHOLD
FIXATION TARGET CENTRAL
ID 085754
TIME 01:21:10 PM
RX USED +4.50 DS DCX DEG PUPIL DIAMETER 2.0 MM VA
AGE 68
FIXATION LOSSES 1/20
FALSE POS ERRORS 0/11
FALSE NEG ERRORS 1/15
QUESTIONS ASKED 551
POWER: 28 DB
TEST TIME 16:40
HFA S/N 630-2850
GLAUCOMA HEMIFIELD TEST (GHT)
OUTSIDE NORMAL LIMITS
TOTAL DEVIATION
PATTERN DEVIATION
MD -8.47 DB P < 0.5%
PSD 8.46 DB P < 0.5%
SF 1.48 DB
CPSD 8.29 DB P < 0.5%
PROBABILITY SYMBOLS
:: P < 5%
P < 2%
P < 1%
P < 0.5%

Figure 5.62: *VF printout with the Glaucoma Hemifield Test*

CHANGE ANALYSIS

Statpac allows the compilation of visual field results such that quantifiable change analysis can be made over time. Statpac Change Analysis provides a statistical summary of up to 16 **serial** visual field tests. Using regression statistics, the analysis indicates the significance of field changes over time. Change analysis can be represented in several ways (Fig. 5.64).

STATPAC I (first software version of Statpac)

1. The **Box Plot** is a modified histogram that illustrates in summary the distribution of values after comparison to normals. The X-axis of the histogram indicates time while the Y-axis indicates the departure of the results from normal, "+" indicating better, "-" indicating worst. The normal distribution is shown to the left of the box plot, while the patient's distribution over time is plotted to the right. Downward shifts of the histogram indicate progression in the visual field defects. The box plot uses 5 number to show test results.

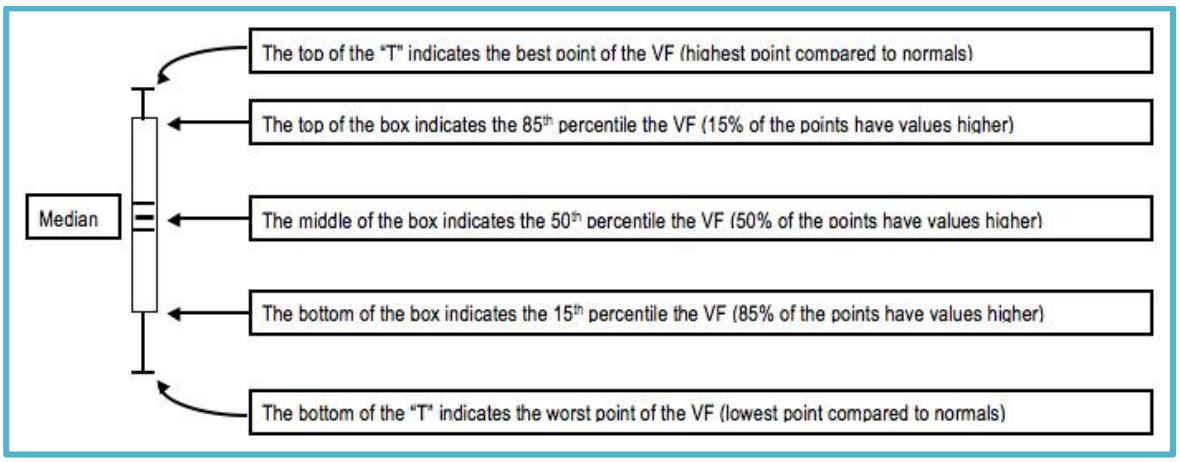


Figure 5.63: *The box plot*

Four things must be observed when analyzing the box-plot:

- The overall shape of the box (elongated vs. compact)
- Location of the median
- Top and bottom location of the "T"
- Location of box-plot in comparison to normal age-match scale on left.

General depressions will keep the shape constant but depress the whole symbol downward. Deep scotoma affecting few points will give box an approximately normal shape but lower the negative tail (worst point). Enlarging scotoma (>15% of points) will elongate the lower limits of the box.

2. The **Summary of Global Indices** uses a graphic representation to plot the global indices (MD, PSD, SF, CPSD) over time. The graph includes dotted lines indicating the p<5% and p<1% limits to facilitate interpretation.
3. The **Linear Regression Analysis of MD** is a linear plot of the MD over time. The test determines whether the slope of the MD plot, which indicates the MD change in dB/year, is statistically significant or not. A "significant" result indicates that the MD has changed in the direction of the slope. A p-value is also noted to indicate the level of confidence: the lower the p, the more likely the MD change is true. Note that a minimum of 5 serial visual field are needed for this test to be valid.

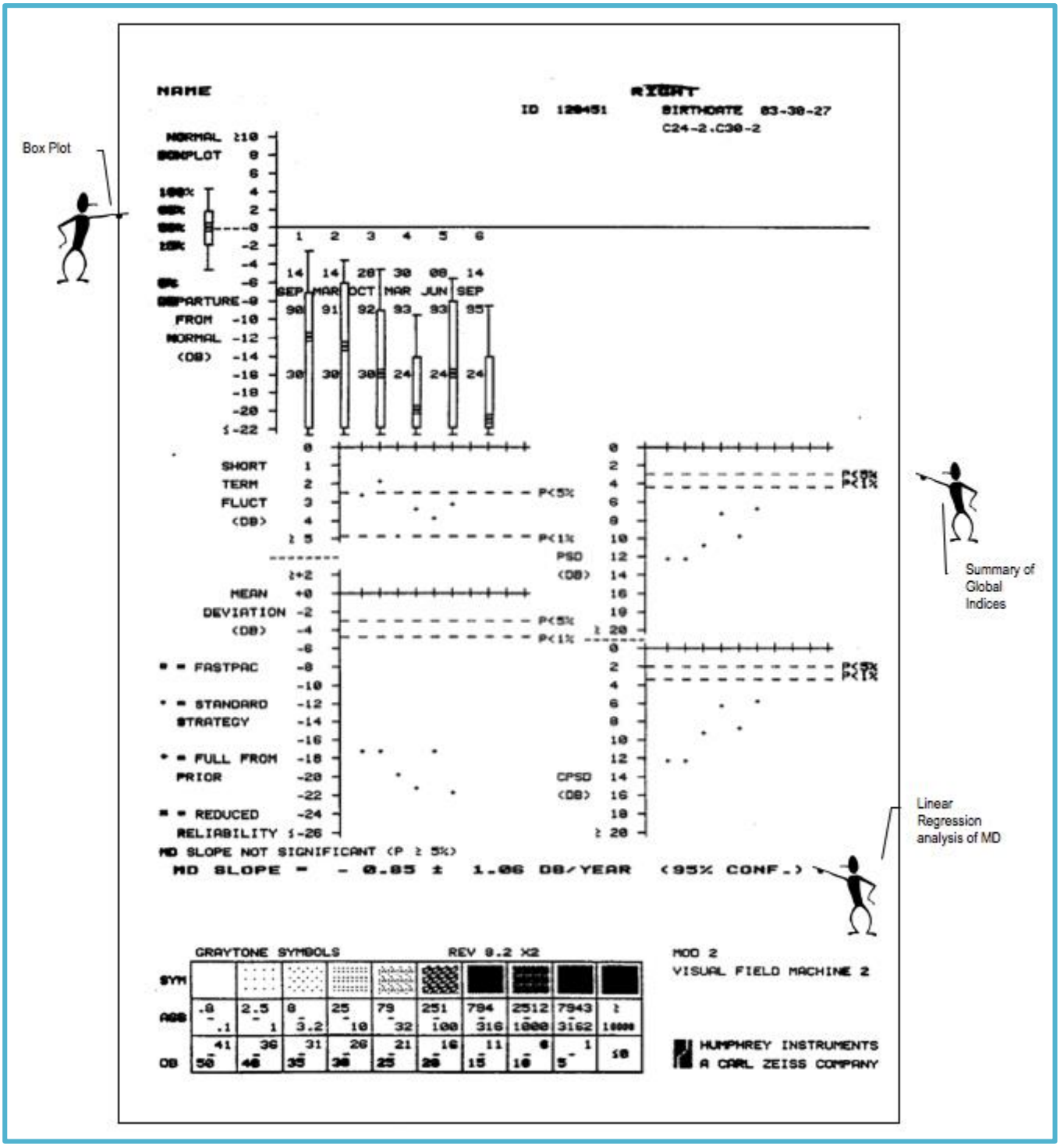


Figure 5.64: *Change Analysis Printout*

OVERVIEW

The **Overview** is a printout that simply groups a number of visual field (up to 16 tests) on the same page (Fig. 5.65). The gray scale, total deviation and Pattern Deviation Plots are plotted with the corresponding global indices. The overview allows easy visualization of the changes in the visual field.

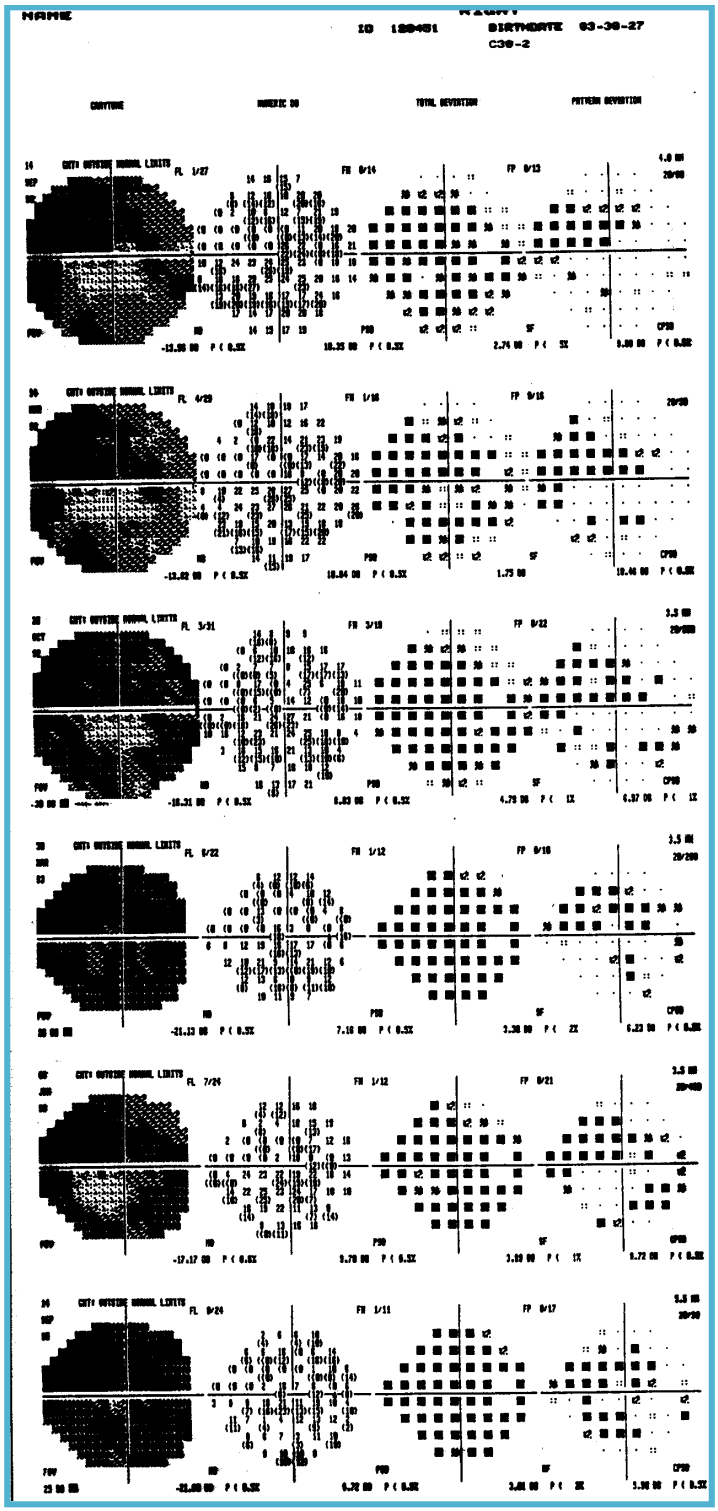


Figure 5.65: *Overview Printout*

STATPAC II (UPDATE SOFTWARE OF STATPAC I)

Glaucoma Change Probability Analysis (GSPA)

The **GSPA** is designed specifically for glaucoma patients. In glaucoma patients, there exists a greater than normal inter-test variability (random variation, long term fluctuation) that is typical of stable glaucoma patients. The GPSA attempts to separate visual field changes on glaucoma patients that are due to progression of damage from those that are due to the increased random variation. Refer to Fig. 5.66.

The GSPA shows the statistical significance of the changes in sensitivity (dB) of each visual field from a baseline visual field plot established from the average of two earlier field tests. The total deviation probability plot and MD of each visual field is analyzed and compared point-by-point to the baseline plot. A comparison of the change is then made to the expected inter-test variability to insure that the change is not due to the random variation. The expected inter-test variability is obtained from a database of visual field repeated in stable glaucoma patients.

The results are shown graphically. The display shows the gray scale, Total Deviation Plot and the difference in threshold from baseline values for a series of visual field. To the right of these, a plot represents the probability that the change at each test point is a true deterioration using symbols (note symbols may vary across machines/regions)

- o → A single, solid dot indicates a point not changing by a significant amount.
- Δ → A small open triangle identifies a degree of deterioration expected less than 5% of the time at that location in stable glaucoma patients ($p < 0.05$).
- ∆ → A half-filled triangle indicates significant deterioration at that point in two consecutive tests.
- ▲ → A solid triangle indicates significant deterioration at that point in three consecutive tests
- x → deterioration is present but significance is impossible to determine

An additional message stating that the “average mean deviation of all tests is too low” indicates that the MD is lower than –15.

Progression of glaucomatous defects will therefore be indicated by clusters of solid triangles that enlarge over time. Noteworthy is the fact that at least **6 serial visual field** are needed for the GSPA to be valid.

Modified Linear Regression Analysis of MD

The modified linear regression analysis of MD is a variation of the linear regression analysis of MD available in Statpac I. The analysis also plots the changes of MD over time to determine whether the slope is statistically significant or not. However, the newer version modifies the analysis to compensate for the presence of marked learning effects. In cases where the MD obtained in early visual field results is significantly ($p<5\%$) out of line from the trend observed in later fields, the Statpac II regression analysis discards the first test results. Similar to the Statpac I test, the significance of the **modified MD slope** is then given.

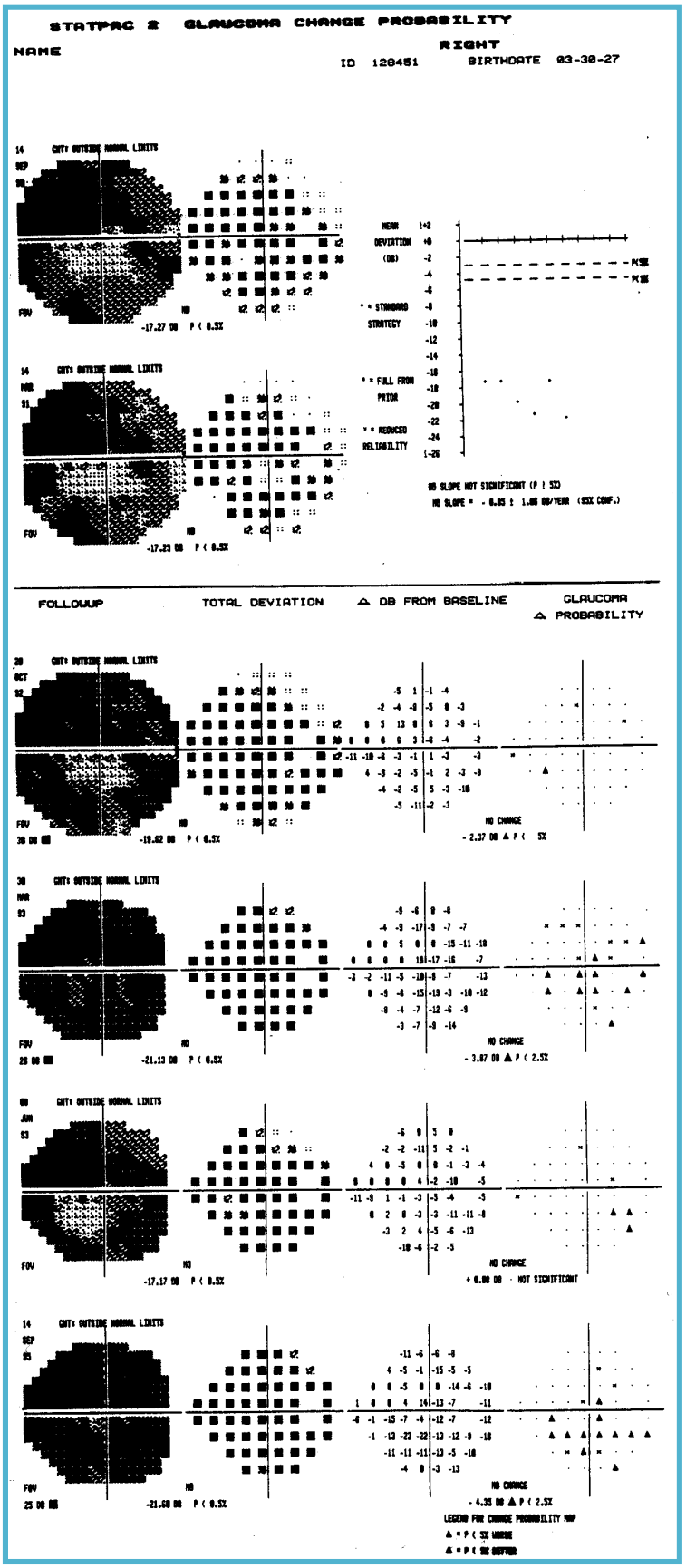


Figure 5.66: Overview Printout